CENTRIC 2013

The Sixth International Conference on Advances in Human oriented and Personalized Mechanisms, Technologies, and Services

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CENTRIC 2013 Editors

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CENTRIC 2013

Forward

The Sixth International Conference on Advances in Human-oriented and Personalized Mechanisms, Technologies, and Services (CENTRIC 2013), held on October 27 - November 1, 2013 in Venice, Italy, addressed topics on human-oriented and personalized mechanisms, technologies, and services, commonly known as I-centric.

There is a cohort of technologies that favored the so called “user-centric” services and applications. While some of them reached some maturity, others are to prove their economics (WiMax, IPTV, RFID, etc). The human-oriented and personalized technologies and services rely on a key set of features, some to be deployed, others getting more mature (personal profiles, preferences, identity, proximity, personal devices, etc.). Following, advanced applications covering human related activities benefit from personalized and human-oriented networks and services, especially preventive and personalized medicine, body networks and devices, or anticipative systems.

The conference provided a forum where researchers were able to present recent research results and new research problems and directions related to them. The conference sought contributions presenting novel result and future research in all aspects of user-centric mechanisms, technologies, and services.

Similar to the previous editions, this event continued to be very competitive in its selection process and very well perceived by the international community. As such, it attracted excellent contributions and active participation from all over the world. We were very pleased to receive a large amount of top quality contributions.

We take here the opportunity to warmly thank all the members of the CENTRIC 2013 technical program committee as well as the numerous reviewers. The creation of such a broad and high quality conference program would not have been possible without their involvement. We also kindly thank all the authors that dedicated much of their time and efforts to contribute to the CENTRIC 2013. We truly believe that thanks to all these efforts, the final conference program consists of top quality contributions.

This event could also not have been a reality without the support of many individuals, organizations and sponsors. We also gratefully thank the members of the CENTRIC 2013 organizing committee for their help in handling the logistics and for their work that is making this professional meeting a success.

We hope the CENTRIC 2013 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in personalization research. We also hope the attendees enjoyed the charm of Venice.

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MobileSage — A Prototype Based Case Study for Delivering Context-Aware, Personalized, On-Demand Help Content

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***Abstract*—We present the system design decisions for the MobileSage Prototype, a service for the on-demand delivery of multimodal help content to anyone in general and seniors in particular. Findings from user-centered research formed the system requirements, design considerations and decisions. The design of the system also includes availability, relevance, accessibility, conciseness, and comprehensiveness of multimodal content. The prototype has been evaluated in user trials with encouraging results, showing the participants' high appreciation of the system.**

***Keywords*—Mobile; smartphone; application; assistance; guidance; help on demand; personalization; adaptive; accessible; usable; multimodal; context; location aware; Ambient Assisted Living.**

I. Introduction

Our everyday lives are becoming ever more technological with an increasing number of machines and devices surrounding us. This leads to a continuously rising degree of complexity in everyday life. This can be a challenge for many – particularly elderly persons. This is why many senior citizens meet these solutions based on Information and Communication Technology (ICT), such as ticket machines and web services, with anxiety.

At the same time, modern elderly – here defined as people aged 65 and older – live longer, are healthier, more active, mobile, independent, and more demanding customers [1]. There are approximately 87 million elderly in Europe [2]. They are increasingly looking for useful, user friendly, and personalized ICT services that add value to their active and mobile life; they also desire services that can help them to stay active despite various impairments. MobileSage provides a timely approach and solution that is detailed below.

The article is organized as follows: First, we present the system architecture of MobileSage and its main components. Next, we lay out the requirements for these components and their consequences for system design and content production. We then present results from the first round of user evaluations in Norway. Finally, we conclude with next steps in the project and other lessons learned. This work's main contributions cover the thorough discussion of the needs of various user groups, the derivation of constraints for the design of the system and the production of media content, as well as results and recommendations from user trials.

II. MobileSage Overview

MobileSage stands for *S*ituated *A*daptive *G*uidance for the Mobile *E*lderly. Its aim is to give the modern elderly a smart agent that provides relevant, accessible, usable, and multimodal assistance for carrying out and solving everyday tasks and problems in the self-serve society, whenever and wherever they occur [3, 4]. Related research and solutions are discussed in [5].

A. MobileSage Components

MobileSage consists of two components: the Help-on-Demand (HoD) mobile application and the Content Management Service (CMS). Figure 1 shows the overall architecture. The system is developed in three major iterations, and the findings here are from the first iteration.

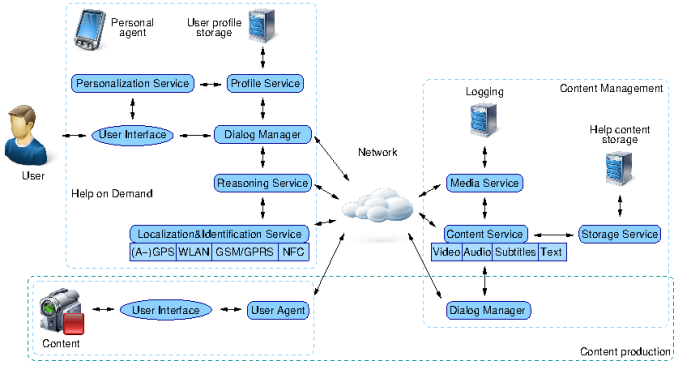

Fig. 1. System architecture and major building blocks for HoD (left) and CMS (right)

1) Help-on-Demand Service: The HoD application is the personal agent, a thick-client application running on a smartphone. It is built up in a service-oriented manner, see Figure 1. The user interacts with the Dialog Manager through the User Interface. The Dialog Manager utilizes information from the Profile Service taking care of the user profile. The user profile stores personal preferences and usage patterns. User behavior and User Interface events are logged and analyzed by the Personalization Service, upon which the user profile is readjusted.

The Dialog Manager is in contact with the Reasoning Service to help determine the user's context. Reasoning makes use

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of network services such as Media Service, Search Service, and the Content Service. The Reasoning Service gets help from the Localization Service, which can determine the user's location based on technologies like A-GPS, WLAN, GSM/GPRS, NFC, and triangulation methods.

The HoD Service requests the content from the CMS upon initiation of the user.

2) Content Management Service: The CMS is a cloud service running on a web server. Content producers interact with the service's Dialog Manager, which in turn controls the User Interface on a User Agent like a web browser. The logic for handling the multimodal content lies in the Content Manager, which has a modular design to be able to add additional modalities in a simple way. The prototype supports the modules Video (with or without captions), Image, Audio, Text, and Formatted Text (basically simplified HTML). The content is stored by the Content Service. It is also possible to refer to content located elsewhere (e.g., from other video services).

There is no limitation in the kind of content that can be facilitated. This includes manuals, usage instructions, descriptions of travel routes, and geographical points of interest. We anticipate that vendors or service providers generate most of the content. For instance, a particular vendor might provide manuals for their ticket machines, or the railway operator that runs these machines might do so. Even a municipality might be interested in producing such help content as a special service for their citizens and visitors. Other interested parties are expected to add content to the CMS to fill in the gaps left behind by vendors or service providers, as they are likely to have a direct interest in helping someone using HoD. Finally, there is nothing that prevents users of the HoD from producing and making help content available themselves.

III. User and System Requirements

The following sections address the formulation of the requirements and constraints for the system design. The primary MobileSage users are those using the HoD service. Secondary users are content producers, and tertiary are vendors or service providers.

A. Requirements for Primary Users

The derivation of the requirements of primary users is split into the gathering of the users' expectations towards the system (user needs analysis), and the collection of user requirements. The system requirements were derived from the latter.

1) User Needs Analysis: Focus group work was conducted in the three countries Norway, Romania, and Spain to find the needs of primary users [6]. The focus groups had 39 participants and represented a broad range of parameters, including age (48 to 96), gender (24 female vs. 15 male), disabilities (sensory and cognitive impairments), nationality (4 foreigners), and ICT experience and usage. Two scenarios were presented to the participants: an individual with reduced vision traveling in a foreign country where he was not proficient in the language, and an elderly lady at home trying to understand how to use an electric household appliance.

The focus groups' results show that "modern elderly persons" is a very heterogeneous group with a wide range of – sometimes contradictory – needs and wishes. This applies also to the users' familiarity with ICT in general and mobile technology, which ranges from none to professional users. However, it was possible to identify themes of what the solution should have [6]. The solution should *a*) lead to higher independence of elderly people according for the help-for-self-help principle, *b*) increase a person's mobility, and be usable for transportation and travel, including holidays and visits, *c*) be applicable in the home environment and throughout daily living, *d*) provide relevant, useful, context- and location-sensitive and multimodal assistance in an on-demand manner, *e*) be accessible, user-friendly, designed for all, possible to personalize or customize, adaptive, social, and *f*) honor privacy, security, and trust matters.

2) User Requirements: The results from the user needs analysis were collected and formulated as user requirements [7]. The roughly 50 requirements mirror the expectations of primary users regarding HoD, but were extended to be valid for the CMS as well. The user requirements served as input to the process of formulating the first draft of the system requirements for the service's two components.

3) System Requirements: The requirements for the Help on Demand and Content Management services were derived from the user requirements.

The requirements specification for HoD has over 60 requirements [8], while the CMS specification contains only 40 [9]. Both address topics such as system functionality, user interface, and input and output matters. Also included are sections on the technology choice and mockup examples regarding the services' user interfaces.

B. Requirements For Secondary and Tertiary Users

MobileSage's focus is on primary users. Secondary and tertiary users have been accounted for by formulating a set of requirements representing the needs of the transport company participating in the project. These are as follows: *a*) It should be possible to identify one or several points of interests with a unique ID. *b*) There could be multiple help topics per ID. *c*) One topic could be presented in multiple languages. *d*) The service should support content hosted elsewhere ("upload once, available everywhere"). *e*) It should be possible to edit help content in order to add locations, languages, and modalities.

IV. System design

For the HoD service, a user profile lays the ground for personalization and adaption of the service. It contains the user's settings and preferences, such as font size, emergency number, accepted media types, and additional languages. Also other parameters are stored there, including usage log. This log is the basis for system adaptation. Screenshots of the HoD are shown in Figure 2.

Both primary and tertiary users have requested that it should be possible to associate content with specific locations or points of interest. However, it should also be possible to link certain content to several locations (e.g., "how to buy a ticket" is valid for any ticket machine in the Oslo area). Moreover,

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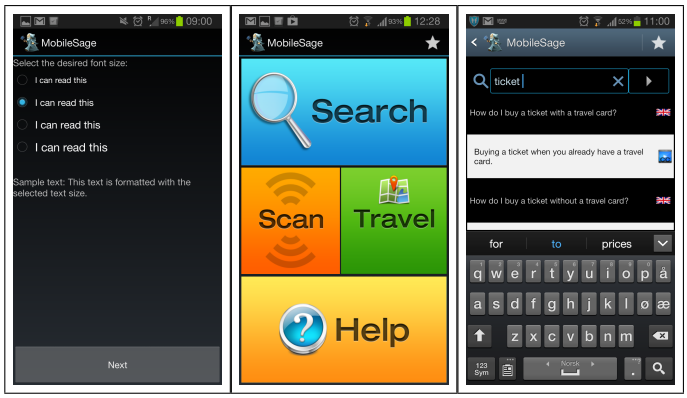

Fig. 2. Screenshots of the Help-on-Demand application: set up (left), home screen (middle), and search (right)

there are situations where several pieces of content are relevant at a single location (e.g., how to validate a ticket, arrival time of the next bus, or choosing the correct platform for departure).

These issues have been solved by the Content Item, see Figure 3. This uniquely identifiable item is a logical unit to gather content that is related to each other. Multiple locations in terms of latitude, longitude, and altitude can be linked to a single Content Item, and so can Records, each representing a particular topic. The topic itself is described by a Record's title together with a language identifier. Language translations of a topic become a new Record. To avoid topics being mixed in the result listing, the results are ordered according to language first, and alphabetically by topic. The user needs analysis recommended further to split content into several Steps or segments, and to promote segmented content, something the presented data model is capable of by combining multiple Steps into a Record. A Step has the same language as the Record it belongs to and has one of the Media Types: text, formatted text (HTML), audio, an image or animation, video, or a video with captions. Further elements are a brief Summary and an URI/URL pointing to the media itself. The URI can point to a server that is part of the CMS, but it may also point to external resources (e.g., a video on YouTube). For such external resources, the CMS effectively functions as a service holding metadata on indexed resources. This model supports multiple media types not only for the same Step but also mixing of media types per Record (i.e., several Steps) depending on which type suits a particular step best. For instance, video might be best suited to illustrate a movement, while often a still image is beneficial for highlighting a specific region of a visual.

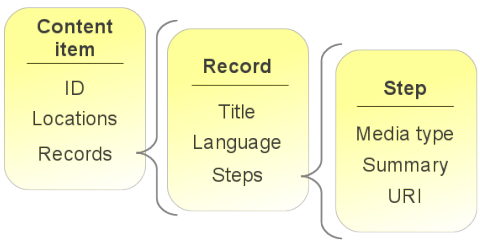

Fig. 3. Data model of the content

MobileSage is about just-in-time guidance and *on-demand* assistance. Based on suggestions from the primary-user studies, it was deemed too intrusive to let the mobile application initiate requests for help based on the location of the phone at points of interest, nearby radio fields, etc. Thus, the user indicates a wish for assistance either by scanning a QR code orNFC tag, or by sending a text phrase to the CMS. In the former case, the code or tag carries the ID of a particular Content Item, which is read by the mobile app and sent to the CMS, resulting in a list of all topics associated with that ID. Regarding the search phrase, topics are viewed as relevant regardless of the ID, accounting for both Record titles and Step summaries.

One of the challenges of MobileSage is to find *relevant* content and not to confuse the user with extraneous information [9], which helps individuals with orientation and problem solving challenges. The key to this problem is determining the user's context, in terms of (most importantly) location, time and date, user habits, and other aspects. Nearby objects are considered relevant in the CMS by calculating a proximity radius around the user's current position; only Content Items with a location within this circle are returned as results to the phone. The exact radius of the circle was based on heuristics and set to roughly 40 m.

Records are sent in "pages" to the phone, meaning that HoD tells the server how many results per request to return. This is done first of all for practical reasons, i.e., bandwidth limitation, and second because the user is likely to be interested only in the most relevant results, which are presented first. The client on the phone keeps track of the number of transmitted records and is hence able to request a particular page with results, say, page 3 with the records 21 through 30 in case of 10 allowed records per page. If the user scrolls down while being at the bottom of the results list, the client fetches more results if available.

For simplicity, any media content is offered to the HoD as a file for download through HTTP. While this works great with text-based content, the performance in terms of responsiveness of the playback on the media player is suboptimal when connected over a channel with very limited capacity, as discussed in Section VI-B because media downloads in most clients have to finish before the media is rendered on an output device. Clients that support (true) media streaming and pseudo streaming methods like HTTP Live Streaming will start rendering the output as soon as sufficient data become available. These methods require the proper setup of a streaming media server and are planned for the next iteration.

V. Content Production

This section considers the production of content for MobileSage in particular and educational and instructive content in general.

The content found should be relevant, concise, and comprehensive. However, as recent research surveys show [10–13], it is extremely difficult to develop methods which can check exactly that in a satisfactory manner. MobileSage offers a manual approach in its CMS [9]. As mentioned before, the splitting of longer content into shorter steps is encouraged. The content producer now provides the content abstraction on two

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levels: A summary of the step itself, and a title wrapping-up of the entire record (see Figure 4). The content producer must tag the content with the proper descriptors for language, and its location, if applicable.

Currently, the content must be uploaded in a format accepted by the Android OS. This applies to both the format of the content tracks, be it video, audio, or captions, and the format of the embedding media container. In future iterations, the CMS is planned to accept any format with transcoding into a proper format supported by the OS. This targets locally stored and remote content likewise.

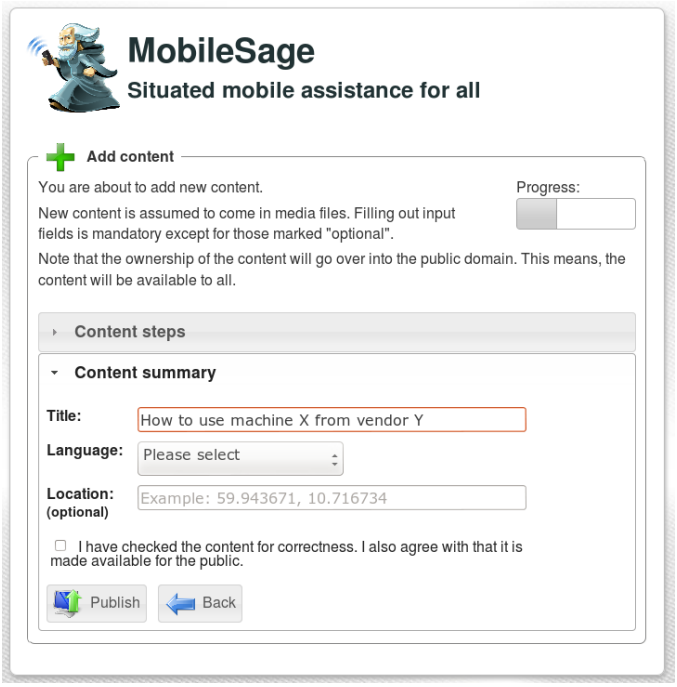

Fig. 4. Screenshot from the uploading of new content to the CMS.

While the video material could be presented at any resolution, we chose to encode video with a resolution of 480×360 pixels and a bitrate of roughly 200 Kbps @12 fps in H.264 Baseline Profile Level 2.2 format, and embedded in an MP4 transport container. The audio tracks (both stand-alone and as part of a video) had a rate of roughly 48 Kbps @22 KHz mono and were encoded in AAC format. A video containing one visual and one audio track thus had a bitrate of roughly 260 Kbps, which includes overhead data used for track muxing and the container format. The length of the content varied from approximately 10 s to 4 min, but most of the content was between 30 s and 45 s.

We used open-captioning, where a voice's transcript are printed as always visible titles on the screen, instead of composing a separate captions track. This avoided the extra work of producing a captions file and ensured that the video player always worked properly, without any user action. We chose a "slab serif" font that was originally designed for fax machines, with a size of at least 36 points. One disadvantage to this approach is that more space is taken up on the content server to store each captioned video, but as the videos were short and at a low resolution, we believe this is a minor issue.

The content is currently provided in a single quality in terms of resolution/sampling frequency and bitrate as mentioned above. Both have implications for the bandwidth necessary to transmit a given content file to the client's media player: the larger a picture (in pixels), and the higher the audio sampling frequency (in Hz), the more bandwidth will be necessary. Likewise, the higher the encoder bitrate (in bps), the more bandwidth is required. Channel capacity of the cellular link, however, is a limited resource for physical reasons. It takes time to transmit a particular amount of data over a channel, which also has an impact on the user experience. The service is thus required to respond upon user interaction within a reasonably short time span [7]. Currently, this requirement is not reflected in the system, but it is planned to honor it by measuring the duration of packet downloads at the client side (which may vary over time according to the signal strength and coverage) and include this information in the server requests, together with information about the phone's screen size. In the next development iteration, content will be provided in several resolutions or sampling frequencies, and several bitrates. Media searches at the server side can then utilize this information about the channel conditions and limit the results to media qualities that meet the bandwidth constraints. For example, a phone with a 480×800-pixel screen is connected to the network over a GSM (2G), and the bandwidth averaged over 20 s is measured to be 100 Kbps. Based on the different resolutions and bandwidth, the server decides that a 480×360-pixel will still render acceptable to good quality. Yet, the 480×360-pixel video comes in two different bitrates; one encoded at a rate of 260 Kbps, and one encoded with 130 Kbps (assuming a constant encoding bitrate). The latter is closest to (but still above) the estimated channel capacity and will be sent to the phone to minimize the service's responsiveness, together with a notification about poor channel conditions.

VI. User Evaluations

User trials were conducted in Norway, Spain, and Romania in December 2012 to evaluate the service after the first development cycle.

A. Setup

The evaluation in Norway consisted of a travel situation at a subway station in Oslo, where participants used the prototype to find help with getting to a subway station, finding a ticket machine, buying and validating a ticket, and choosing the correct platform. We created content for all of these scenarios, with a minimum of audio and video for each. All but one of the scenarios had captioned video, and some had a textual modality in addition. Each of audio, text, and video was done both in Norwegian and in English to allow users to choose an additional content language. We then created several NFC tags for each of the scenarios and used it as a way of getting the information. We also wanted to use QR-codes, but we ultimately dropped it as it was to unreliable to scan with the current version of the mobile application. We tested on two smartphones with an Android OS 4.1 and screen sizes of 480×800 and 720×1184 pixels without any discernible difference in the results.

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Eight participants were recruited for the evaluation. They were between 65 and 76 years old, and four of them had no experience with smartphones; however, they were somewhat experienced with computers. A few of them knew the location to a certain extend. A session consisted of a short introduction to the MobileSage idea, followed by a brief interview concerning their experience with mobile phones. Then, we demonstrated the application. After this, we began the tasks. One evaluator would take notes, while the other would guide the participant to make sure a task wasn't forgotten. After completing the tasks, there was a short follow-up interview about the service and the participant's experience about it.

B. Results

In the first task, the participants had to create a profile that matched their preferences for text size, language, and types of media they wanted to receive help in. The users understood the concept of several content languages, and the majority (75%) added English to their profile. The user-specific media types ranged from a single one to the entire range as detailed in Section IV, where captioned video was chosen most often. The majority (90%) of test persons checked 4–5 media types including audio, even though some participants said they would avoid wearing earbuds or headphones. Text was never requested. Choosing video and captioned video was inconsistent, hinting on a potential misunderstanding of the user concerning the meaning of "captioning". It is hence recommended to improve the description of media types or show brief examples of them. All participants but one expressed that making the profile was sufficiently easy.

The second task concerned navigation, where the participants had to get from their current location to the nearest subway station. All were able to enter the information needed, but the phone's positioning worked unreliable, sometimes placing the participant a block further south and/or facing the wrong direction. This issue sorted itself out when walking to the location.

The next task dealt with getting help at the ticket machine. Two participants were not able to finish this task due to a technical issue that caused no results to be returned from the CMS, which was corrected subsequently. All others succeeded with using NFC tags or by manually searching for information about where the ticket machine was, how to purchase a ticket, how to validate the ticket, and which platform they had to go to. Though only one was familiar with the technology, two had heard about it, and the rest were unaware of what it was, all really liked the technology and experienced it as easy to use.

A problem encountered was the effect the environment had on the signal strength in the phones. While above ground, it was possible to get video and audio without any issues, and the selected item would show up almost instantly. Yet, underground in the subway station, it became very troublesome for the phone to contact the content server. The main reason for this is that the only connections that are currently available in this particular station are so-called Edge (2G) connections. They are much slower compared to a 3G connection and also very latent. This was no big issue when retrieving, say, the results list. Participants had to wait a long time, though, if they wanted to watch a video. The audio fared a little better, but downloading would not always complete. Sometimes, the application on the phone would simply give up and it would be necessary to download the audio or video from the beginning. Most participants noted that it took a while to get the information in this case. With the continuing widespread of 2G connections in many countries, it is recommended to produce at least one version of low-resolution low-bitrate content, and to use techniques that increase the responsiveness of media players, such as media streaming, as discussed in Section IV.

No users complained about the size, resolution, quality, frame rate, or length of the video. Some participants noted that the font used for the captions indeed was sufficiently large and easy to read. There was only one instance where people commented on unclear information, where a video showed an unreadable display on a ticket machine.

All the participants felt that a help-on-demand system was something that would be useful for them. One of the participants even claimed that she was scared of using the ticket machine and always went to a store to buy her tickets, but would now she would use the ticket machine since she felt confident that she could use it based on the provided instructions. Concerning potential improvements, the most popular suggestions were a shorter response time for videos (when in the subway station) and dynamic information, such as time schedules. Those familiar with mobile applications suggested to include MobileSage's functionality in the public transport provider's current smartphone application.

VII. Conclusion and Outlook

We presented a first version of the MobileSage prototype, a service for delivery of context-aware, personalized help content in an on-demand manner. MobileSage incorporates the needs of primary, secondary, and tertiary users and has been been evaluated by primary users in user tests.

The aspects of content provision include multimodality and internationalization to take care of user personalization, multi-resolution and multi-rate for device adaptivity, and location-aware media searches for relevance. It has been shown that the system can index both internal and external media databases.

The idea of MobileSage was well received, as the participants in all focus groups and user tests viewed the service as useful. Yet, they also pointed out areas for future improvement: The concept of media types is not fully understood, in particular "captioning"/"subtitles" remains an unclear term to most users. Positioning could be improved, for instance by combining several techniques like A-GPS and WiFi triangulation. Also, users requested more information like transport schedules to be integrated into the service. The application needs further improvement in presenting results. The challenge is to find content relevant for the given context and reduce the need to search for the correct result. For example, only a single language and the "most rich" media type could be presented for a particular topic. Finally, the responsiveness in situations with limited bandwidth could be improved by using more advanced protocols and device and channel adaptivity.

Content producers need guidelines on how to produce content. While it is empowering that anyone can contribute

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content, it is important that the offered content is usable. Guidelines should include information about the length of help sections, phrasing of information, and how multimedia content should be organized. The results from the user trials can help with preparing these guidelines.

MobileSage will proceed its work with two more development iterations, combined by user evaluations, before the final version is going to be released early in 2014. In the next user trials, we are also planning to give special attention to how QR codes are accepted as compared to NFC.

ACKNOWLEDGMENTS

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Personalized Shopping Experience with NFC Smartphone Apps and Electronic Shelf Label

Project Y-Mart

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***Abstract*—Near Field Communication (NFC) capability has become a standard feature in majority of smartphones on the market today. As more users have adopted NFC enabled smartphones, systems are developed to utilize the NFC protocol for electronic payment and other convenient functions to improve personalized shopping experiences. However, most of the NFC enabled functions available today interact with shoppers at point of sale (POS) which only provide limited fraction of the rich customer benefit promised by this new technology. By integrating NFC capable smartphone applications with NFC enabled electronic shelf labels (ESL) and back-end web services, we can provide a more interactive, informed, efficient, fun and personalized shopping experience at a variety of retail environments.**

Keywords-NFC; Smartphone; RFID; Electronic Shopping Label; ESL.

I. INTRODUCTION

The retail industry has been advocating "smart shopping" for many years by adopting various technologies to enhance the shopping experience at the retail environment. The vision of smart shopping promises to provide on-the-spot production information at your fingertip such as specifications, reviews, promotions, recipes, related products, payment through the use of technologies. For example, some of the most recent attempts include the use of camera enabled smartphones and QR (Quick Response) code to provide on-the-spot information by visually scanning QR code which takes you to a website. However, the technologies have not quite lived up to the expectations and promises of the smart shopping vision.

Some of the reasons why smart shopping has not been widely adopted relate to cost and ease of use. For example, while QR code can be an excellent way to bring online content to a smartphone, the scanning process can be cumbersome and unreliable. The Electronic Shelf Labels (ESL) can potentially improve the on-the-spot interactivity with the shoppers, but the higher cost and lack of standardization hinder the wide adoption and applications. As lower cost and NFC compliant ESL become available, it could conceivably make it easier for the retailers to justify the investment if it could deliver the real smart shopping benefits to the shoppers.

Analysts have predicted that smartphones will play a bigger role in shopping [1]. As the use of NFC enabled smartphones become popular, the unique ID (UID) in each phone can become one's personal identification. This feature can further enhance and personalize the smart shopping experience by providing purchasing history, targeted promotions, loyalty rewards, and much more.

Project Y-Mart was designed and developed to leverage the latest NFC enabled smartphones and low cost ESL in conjunction with back-end web services to build a complete end-to-end prototype system. NFC enabled smartphone apps are developed on the Android and Windows Phone platform to demonstrate the working prototype. Web portal is also provided to allow retailers to manage and customize the system.

Current state of ESL systems will be reviewed in Section 2, followed by a system overview of Y-Mart in Section 3. The design detail and conclusion will be covered in Section 4 and 5, respectively.

II. RELATED RESEARCH

The increasing use of smartphone with Internet data services [2] has made augmented reality a reality in many fields of research and application [3], such as travel, library, and in some cases the retail industry. We have seen many attempts by the researchers and retail industry to enhance the shopping experience through the use of technologies, such as RFID, camera phones, QR code, smartphones, ESL and now NFC [4-8]. However, none seem to have provided a solution that the retailers are willing to implement at scale.

While NFC-based applications have come a long way and promised to enhance personal experience [9], the implementations at retail environment currently seem to be limited to electronic payment at the point of sale (POS). One of the main reasons is that the NFC enabled on-the-spot product information and smart shopping experience would require ESL to interact with the personal smartphones. The current state of the art of ESL systems are the commercial systems provided by Pricer and Store Electronic System [10-

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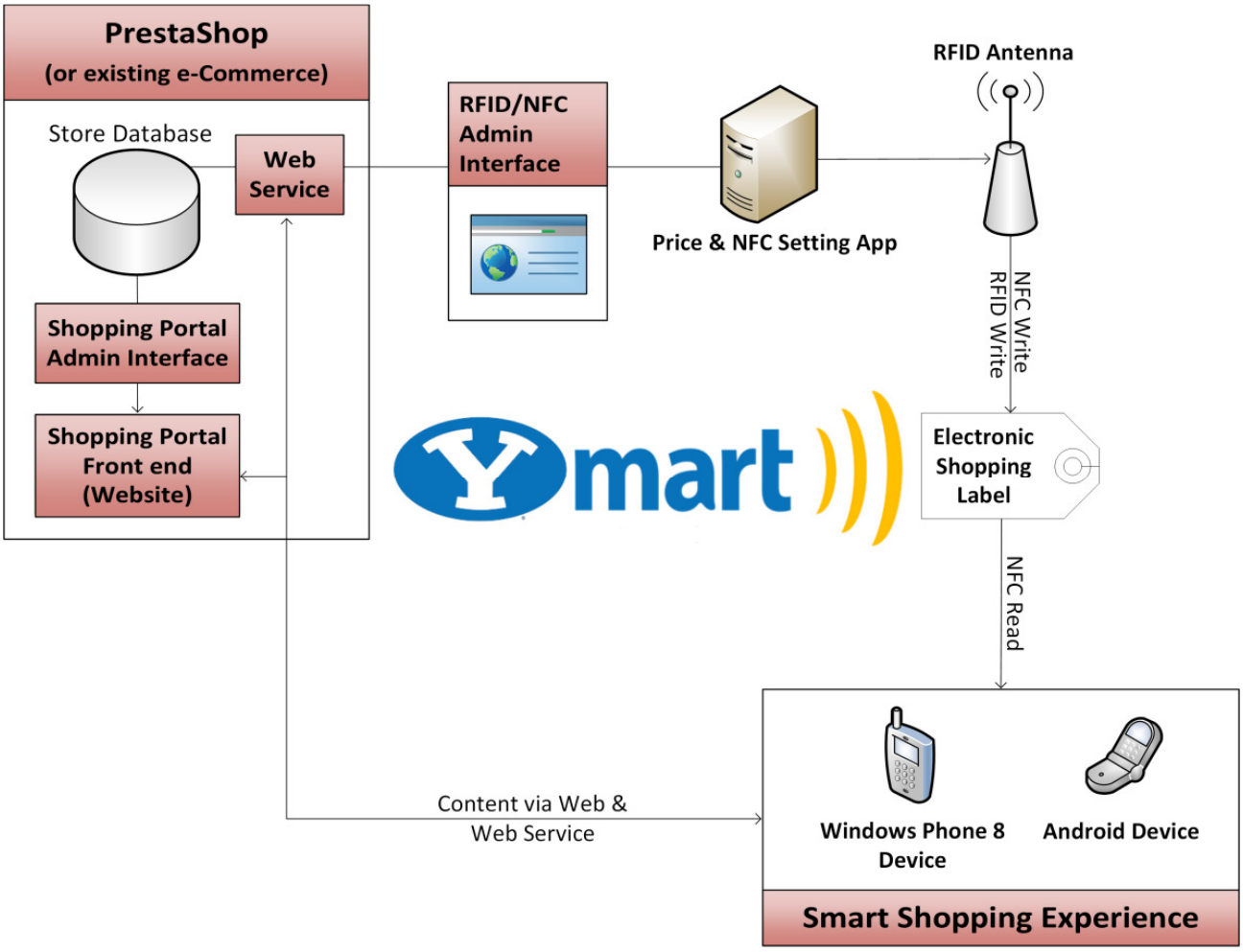

Figure 1. Y-Mart System Overview Diagram

11], which are too expansive and based on proprietary systems. While they were originally designed for store management and not for smart shopping, some have begun to advertise NFC capabilities in the new ESL products. A startup RFID/NFC vendor Jogtek Corp. has developed a new class of ESL that is low cost, battery-less, RFID ISO 15693 and NFC compliant [12]. The Y-Mart system is designed and implemented based on the Jogtek ESL and standard RFID and NFC protocols in conjunction with NFC compliant Android [13] and Windows Phone [14] mobile devices.

III. SYSTEM OVERVIEW

In order to provide end-to-end solution in this prototype, the Y-Mart system includes the following components as shown in Fig. 1.

- A back-end server with product database, smart shopping content (specification, promotion, recipe, etc.), user data (gender, age group, history, loyalty reward, etc.), RESTful web service interface, and web management portal.
- Battery-less ESLs that contain NFC ID that can be mapped to product ID or SKU and product information in either hypertext or URL. The ESLs can be programmed through RFID ISO 15963 and read through NFC protocols.
- RFID driver and antenna that programs the ESLs.
- Mobile apps that run on NFC capable smartphones and tablets including Windows Phone 8 phone, Android phone, Android tablet.

A. *Retailers' Perspective*

From the retailers' perspective, the back-end server is the heart of the system which includes:

- A typical e-commerce product database that supports all the traditional services such as inventory and pricing.

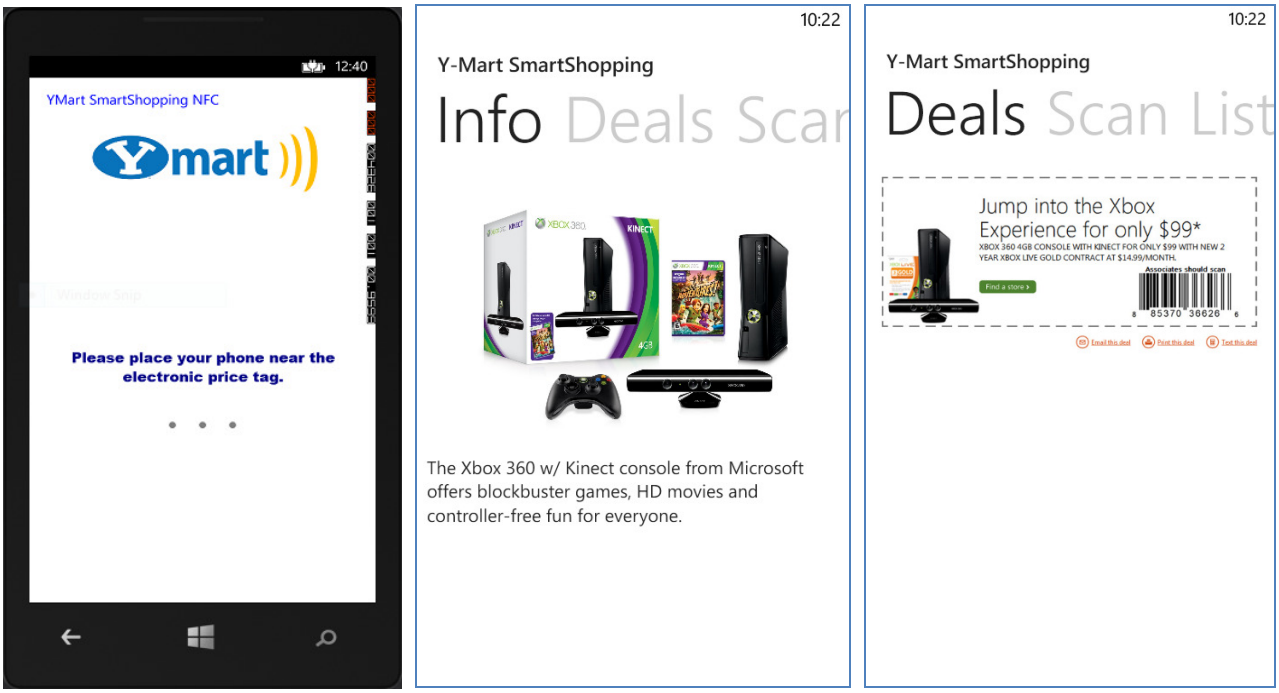

Figure 2. Screenshots of current prototype Y-Mart Windows Phone app. (Xbox and Kinect are trademarks of Microsoft Corp.)

- A user database which may track users' product queries and product purchases based on the smartphone NFC ID. For registered loyalty program customer, the database can potentially has more information, such as gender, age group, loyalty rewards, etc. The user information and/or history can be mined to provide targeted promotion, product suggestion, or advertisement through the smartphone apps.
- A smart shopping database that contains the enriched smart shopping content such as product details, (user and expert) reviews, recipes (for food), and related products. The related products can be items in a recipe, accessories for electronics or many other scenarios.
- RESTful web services that provide programming access to the data mentioned above.

Figure 3. Jogtek Battery-less ESL Prototype

B. *Shoppers' perspective*

From the shoppers' perspective, the smartphone (or tablet) app is the heart of the system that makes the shopping experience informative, personal, and fun. For the shoppers to enjoy the full benefit of personalized smart shopping, they simply need to install the apps for their smart mobile device. The apps are developed by the retailers and post on the app distribution service for the mobile platform.

The common user scenario this system intends to address is when the shopper is at the product shelves in a retail store where they would simply need to tap the smartphone on the ESL to bring up the product information on the screen; any additional information, such as review and recipes, are just a finger tap away on the smartphone. The app will also inform shoppers of relevant products that are on sale based on user's product query, history, and personal information. Fig. 2 shows examples of screenshots from the current prototype Y-Mart app for Windows Phone 8 device, where special promotion is prompted when user scanned a product item.

IV. IMPLEMENTATION

A complete end-to-end functioning prototype of the Y-Mart system was implemented for proof of concept and feasibility. Implementation details for some of the components are described below.

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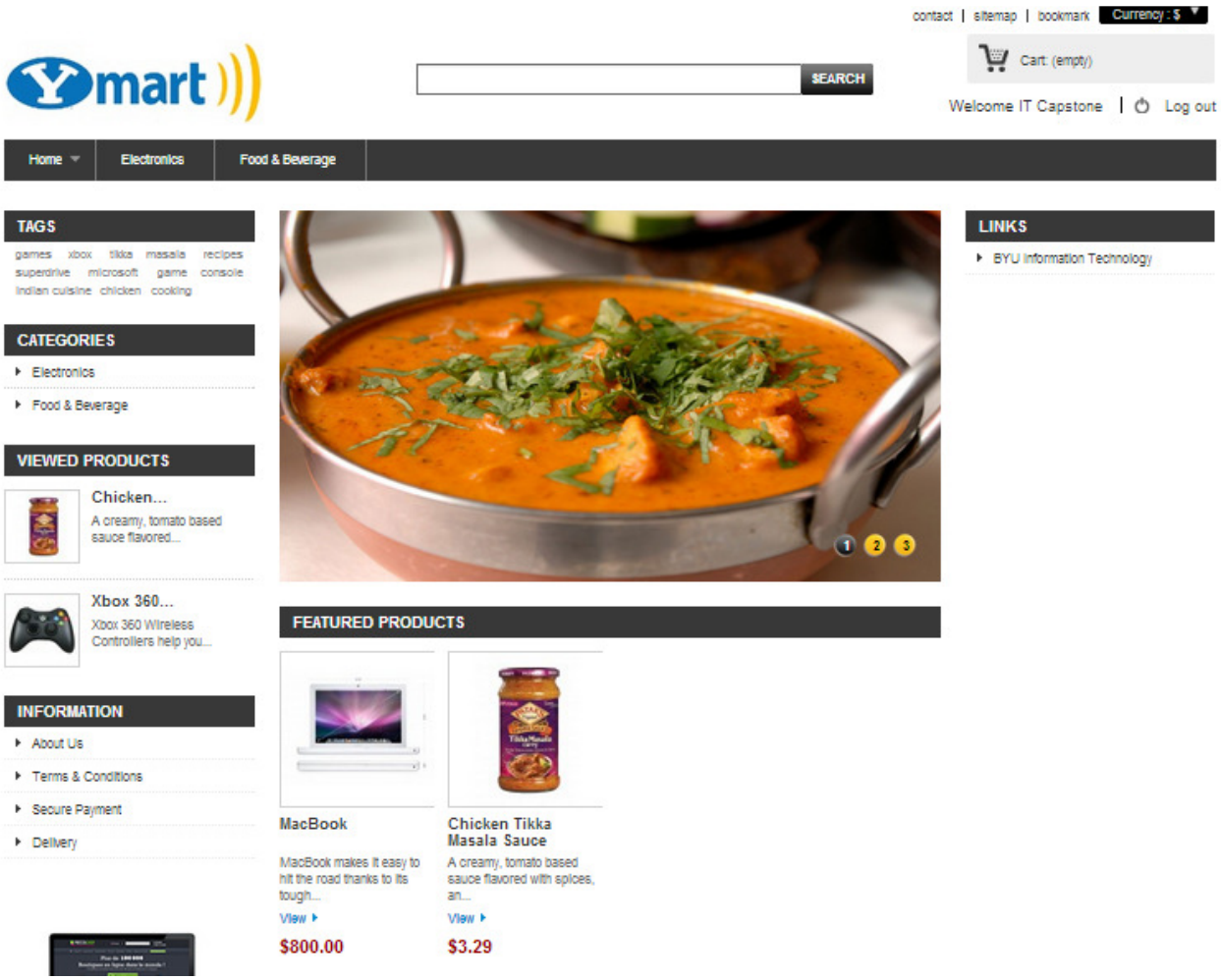

Figure 4. Y-Mart customized PrestaShop server example screenshot.

A. *ESL*

The NFC enabled ESL is the component that facilitates the personal interaction at the product shelf, for large scale retailers that have tens or hundreds of thousands SKUs in a store. The cost and manageability of store ESLs are obviously major concerns. We prototyped the system based on a battery-less, low cost ESL technology (shown in Fig. 3) that can dramatically reduce the initial capital to install the ESLs on the product shelf. One additional benefit for the retailers is that an automated ESL update process can reflect more accurately the price labels, which can potentially lead to less overhead in regulatory compliance with consumer or government agencies.

B. *Back-end server*

The Y-Mart store back-end server is developed with the open-source PrestaShop e-commerce software [15] to provide a presentation and logic layer for the smartphone app and management web portal. The PrestaShop component represents an existing store platform, which most retailers would already have. The smart shopping system would simply be an extension to the existing system. An example screenshot of the currently running Y-Mart customized PrestaShop prototype server is shown in Fig. 4, where stores can manage the additional smart shopping content.

RESTful web services were also developed as API (Application Programming Interface) for the management web portal and mobile apps to access product information, user data and smart shopping content. The web services are designed to be scalable in case of a large retail store where there could be hundreds of customer at a time.

Each UID on the NFC ESL is stored in the database and linked to a product ID (or SKU). Each UID on the NFC smartphone is also stored and linked to a user. When a customer scans an ESL for a product, the smartphone app reads the UID and calls the web services to retrieve the product information. At the same time, the mobile app will also use the UID of the NFC smartphone to retrieve the user information. The server can then use the combination of the product and user to present personalized content on the smartphone.

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C. *Price update server*

The pricing data and smart shopping content on the ESL are updated wirelessly through RFID 15693 protocol. The Y-Mart prototype consists of a small power RFID driver and antenna which is connected to a price update server via USB. The price update process will run periodically to check changes in the PrestaShop server and update the ESL through the driver.

D. *Mobile apps*

A few popular NFC capable mobile devices were chosen to develop prototype Y-Mart apps.

- Nokia Windows Phone 8 phone
- Google Nexus One Android phone
- Google Nexus 7 Android tablet

The apps use the standard NFC APIs provided by the operating systems to read the NFC tags and use the HTTP protocols to call the back-end web services. Some example screenshots are shown in Fig. 2 and Fig. 5.

V. CONCLUSION AND FUTURE WORK

The Y-Mart project successfully implemented a personalized smart shopping experience with the latest NFC technologies. While only limited usability test were conducted, the preliminary result has shown that, comparing to scanning QR code, the users can more easily and reliably interact with the ESL through their smartphone to access the rich and personalized smart shopping content right at their fingertips.

There are certainly many features that we would like to add to the system; for example, shopping list, shopping cart, integration with payment, etc. Additional tests of usability and at scale are necessary as we continue to develop. As the ESL technology continues to advance, exciting personalized smart shopping experience could be here in the near future.

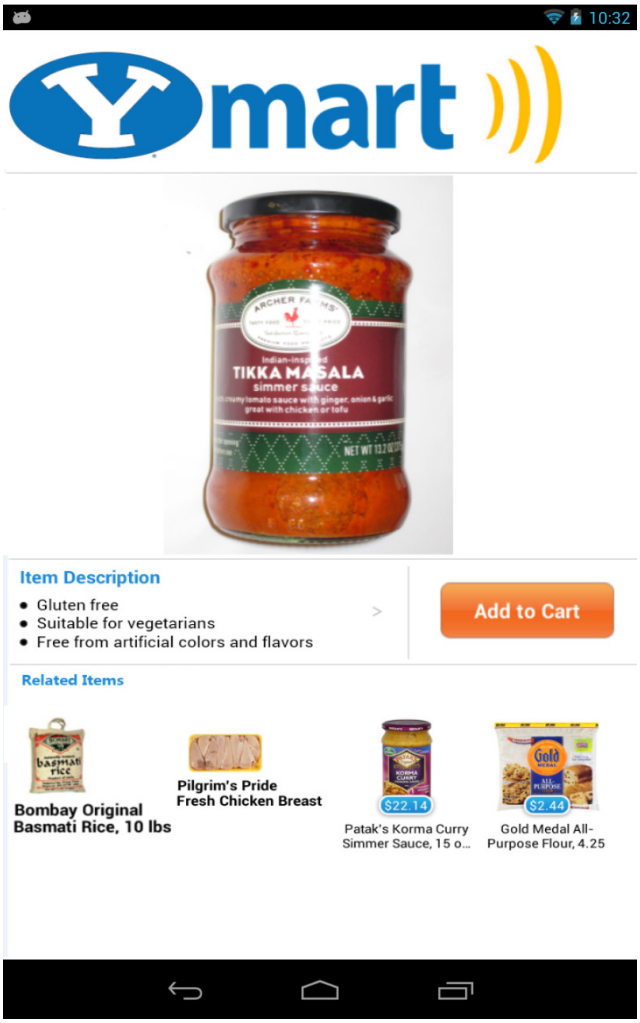

Figure 5. Example of Android app screenshot

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Student Driven Innovation: Designing University Library Services

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Abstract— **This paper addresses the question of how to engage students in design and innovation of library services. Student involvement in the design of the university library services is needed as they have distinct patterns of technology use: variety of platforms, nearly always including smart-phones and laptops, variety of social networks and often, a range of other digital tools. The involvement can take place in many different ways, e.g., participatory design projects, involvement through social media and others. In this paper, we describe our approach to innovation through student engagement in design of library services: innovation through an interaction design course and exposure to design thinking. Over a period of three years, our findings show that student projects have become increasingly original and creative. In addition, the level of engagement to produce finished products and services after taking the course has increased.**

Keywords- innovation; user-driven; design; service design; design thinking.

I. INTRODUCTION

Innovation is as old as humankind, but where and how users could influence the path of innovation has changed significantly during the last decades [1]. Already in the 19th century a possibility was open to employees as domain experts or skilled labor, to influence processes and products within a company. Two types of internal innovator types arose: the core and the peripheral innovators [2], roughly indicating those who are paid to be creative and those who sit on the periphery but through their knowledge can participate and are interested in innovation processes [3], [4]. The third category of innovators includes everyone outside the company or organization and among them, includes users of products and services. When innovators build up their competence in the field of innovation, some problematic aspects may arise. One of them is related to the concept of "sticky" innovation, see [5], implying an accumulation of innovation forces, which are difficult to share afterwards. The consequence may be that other "innovation areas or problems" arise that always need to be delegated to the same group of innovators.

Students, at all levels, are users of university libraries. Their potential as innovators within university libraries, see [3], [6] or [7] is starting to be recognized. In this paper, we describe the case of service innovation through design and design thinking. Design is increasingly viewed as an important resource [8] and consequently companies and organizations worldwide look at design as help to innovate [9], [10]. Innovation through design, combined with user participation in all phases of the design process, was chosen in order to facilitate and research the potential of a student-driven innovation in the context of the university library.

The possibility to get engaged in a design of innovative services for the library was offered through a course in interaction design. Students were free to choose their projects and for the past three years, eight projects in total were concerned with innovation in the library, engaging over 30 students in the design process as innovators.

The following question was the bases for our research: what if students, who are learning to design services and who, in addition, have the ability to develop them, and need them as users, get interested in innovation? Perhaps classical designer/user /developer gaps could be bridged?

The paper is structured as follows: we first describe the context for innovation within library services and why student driven, user centered view was chosen. In Section 3, we introduce the concept of the library living lab, describe projects related to innovation of library services and address the issue that our innovators are also developers, as well as the primary user group for the university library. Subsequently, in Section 4, we discuss findings from these projects and finally, draw conclusions and direction for the future work.

II. THE CASE OF STUDENT-DRIVEN INNOVATION IN THE LIBRARY

Libraries, in a world increasingly dominated by technology, are looking for ways to renew and re-invent themselves as service providers. The university library that we worked with was not an exception. In this case, a user centric perspective was a primary orientation of the library towards innovation and development of future services. Participatory design, user-centered design and co-design are all methods used in order to design systems, products or services that are more in tune with real user needs. These approaches also predict easier adoption of technologies designed with users for users [11].

The Library has a long history of offering services to users. These services were often based on a librarian's tacit knowledge and skills related to lending, searching for information and resource guidance. These skills, and the need for them, are now under discussion. The students are

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efficient in searching the net, a lot of resources are available online, as is some form of guidance. Thus, library users are generally much more self-sufficient. Some of the services offered by the libraries are time constrained, e.g., how long one can keep a book, some are requiring services from multiple departments or organizational groups, such as negotiation of copy rights, or loan from another library. These services are tangible. Yet, other services are intangible, such as exchange of knowledge between a librarian and a user. With the introduction of a large number of digital services over the last decade, an important shift in how services and communication with users are organized has occurred. For instance, the transition from the paper book to e-book was a complex process [12], where the library paid attention to technology adoption, but had a tendency to forget the user perspective in relation to these new digital services and e-books. Another example of an important change in services is the migration of many traditional library services to the web. The library, as a service provider, must adapt to the development and requirement of the information [13] related to user expectations and new technologies.

The university library also offers a range of services in situ, in the library building. These services are not always connected to lending out books, help from librarians with subject expertise and like. The library also provides services around facilities for users, such as rooms where they can read and work either alone or with others. The librarians could observe that the uses of these diverse library resources are changing, including the use of rooms in the building. One of the projects, described later, builds on this possibility, finding new ways of organizing the use of this space, enableing more democratic booking of rooms, as well as easier social and knowledge exchange.

In order to capture all types of changes and how they are reflect on users, the library initiated several projects, all with user in focus. The largest user group of the university library consists of students, and our approach in this project was to allow students to innovate with and for students. The innovating students were taking an interaction design course. Their home base was a computer science department, a program for design, use and interaction. These students work with technology as a design material. They also have the skills needed to make functional prototypes of their designs themselves, thus wearing developers hats to some extent as well. In contrast to education programs offered by design schools, such as product design or architecture, they do not focus primarily on the form but on the functionality of products or services that they design. The design thinking is used to map the problems space broad and open enough to foster creativity, as the students need to focus away from the very concrete, problem solving approach that they often have. This phenomenon is also a trend in the whole field of human-computer interaction (HCI) design. From the first wave of HCI often described as an era of usability testing in 80´s, through the second wave with the "human" in the center, HCI is currently in its third wave with user experience design and situated use of technology in focus [14].

In 2010, at the start of interaction design students' involvement with library services, one could say that projects had the use of innovative technology in the library as a focus. The issues they investigated were related to digital content acquisition and use of these digital resources in course settings, using e-book readers and tablets. In 2011, students found the area of translation of web-services to mobile services to be of interest, in particular discussions such as should things be broken down into a series of apps or kept whole as accustomed. In the third year, 2012, real innovation started to happen. Students looked into what their own needs are, and there was no common denominator for the three projects other that they are all concerned with designing services that benefit students directly. We next describe the context and methodological tools that were used, and provide examples of projects that interaction design students were involved in.

III. THE LIVING LAB PROJECTS

The central research concept that we have used in the present work is that of a *living lab*. We consider the Wikipedia definition [15] of a living lab to be appropriate, even though our territorial context is narrowed to university libraries: *"A living lab is a user-centred, open-innovation ecosystem,[1][2] often operating in a territorial context (e.g. city, agglomeration, region), integrating concurrent research and innovation processes[3] within a public-private-people partnership."* The citations in the definition relate to highly relevant work of von Hippel, Cheesbrough and Bilgram et al. [16]–[18].

A. 2010: Engaging with innovative technology

Being the first year when the big educational disruptor, the iPad, came out, one of the projects was concerned with its implementation as a classroom tool, how digital books would replace the paper books etc. [19], [20]. Like many others, e.g. [21], we wondered if these new devices will deliver innovation, inclusion and transformation of a range of practices, from learning to communication. The second project was concerned with a much less successful e-book reader, Boox [22]. Neither the iPad nor the Boox project reported on enthusiasm and desire to innovate by the students attending classes that used these new tools. By innovate, in this context, we mean to find novel ways to organize class materials, communication with other students from the class, schedules, to use new apps or to suggest what could be cool to have in the future. It was clear that Boox does not offer a new or added value to students. The analysis with the iPad was not as clear, but in the class in which it was applied, there was no time spent with it, apart from the time that it was used for the course or pure entertainment. In other words, student did not attempt to organize their work in new ways, make new apps or even customizations. So, this first year, the design students mostly studied the use of tablets rather than innovating themselves. In the case of Boox, attempt was made to design a better interface, but it was half-hearted: the design students considered the tablet,

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just like the class that used it, to be a rather lost cause in terms of design.

B. 2011: web to mobile – app it or not?

The next year's generation of design students seemed to be missing more services made for mobile platforms as all three project teams have chosen the theme of transferring services from the web to mobile platforms, see [23], [24], and [25].

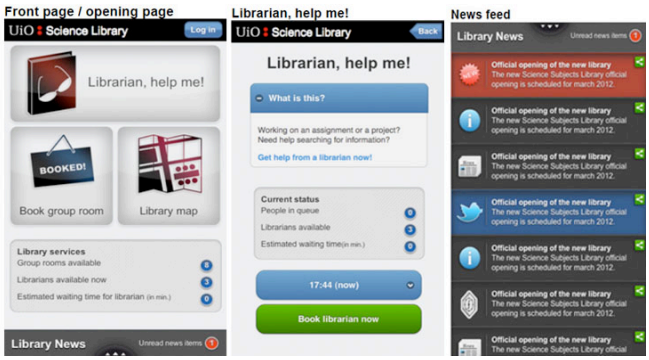

Figure 1. The students from a project [24], 2011, considering services within the library building.

The main problem that two of the project groups wrestled with were related to whether the services should be organized as they were on the net, arguing that familiarity could aid adoption, or broken into meaningful small groups and published as apps. The third group focused on the library building and what users might want to have while in the library. The group, as shown in Fig. 1, made a small selection of already existing services into an app, usable while on the premises only: get to talk to the librarian, book a room, see the map of the library and tweets, events and news feed.

C. 2012: services we did not have before!

In 2012, the library related projects excelled in terms of innovativeness and creative thinking. All three projects were different, both in terms of approach and methods used in their work.

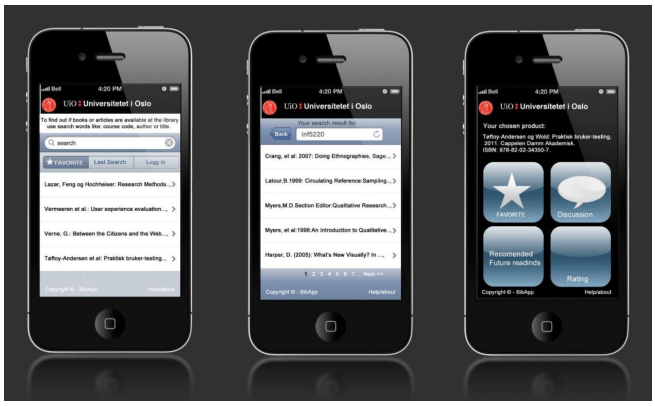

Figure 2. The students [26], 2012, implemented a syllabus search.

One of the groups, see Fig. 2, addresses a real need that students have: a much better organized curriculum literature. They used a participatory design, and did not rely on only their own perceptions, but conducted surveys, user groups and included a small group of other stakeholders in the entire design process, in the Scandinavian spirit [27]. The students paid attention to need finding at the start of the semester, and truly by understanding that need with other stakeholders, including administrators responsible for course listings, as well as BYBSYS, a library management system, currently in use by the library Another project group, see Fig. 3 and Fig. 5, was interested in physically finding a book in the library with aid of a smart phone. Librarians traditionally were in the library for this purpose. They are still there. This engagement clearly demonstrates larger and larger individuation and need for being able to complete a task through self-service. In addition, this team was going for what we call a design of techno-cools [28]. This is the kind of applications librarians would not need, but students think it is cool.

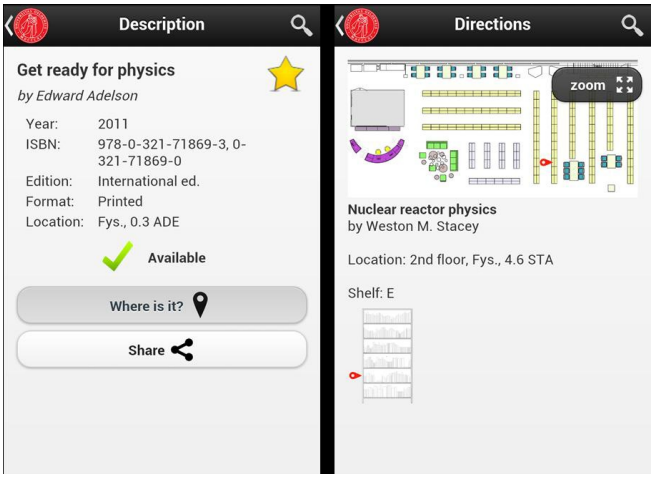

Figure 3. App for finding a book in the library, and on the shelf [29].

The last project [30], combined value-based design, focusing on producing a democratic room booking system, with a fun social spin. Their storyboard motivated the design team, see Fig. 4.

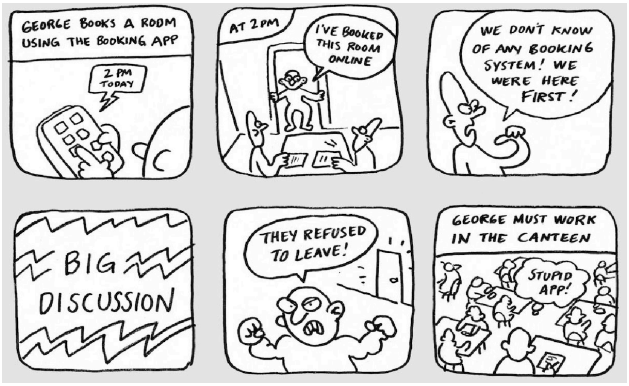

Figure 4. Motivating the democratic booking system [30].

The social spin was based on the idea that one could join interesting conversation in the rooms if there was a free seat, by following social networks and finding out what is the basis for the conversation or discussion.

The description of the projects provided here is minimal, more than be seen from the references provided. The purpose of presenting them briefly is to ground our findings from following the designers, by direct participation in their design meetings and by observing their actions during and after the course.

IV. DISCUSSION

From the library side, the support during all three years has been given in form of competence and knowledge related to services they provide, equipment, stuff, technical support, etc. During the 2012, a project team of three library employees was added. In addition, consultations with a professional user-experience consultancy company (Netlife Research) were added. The efforts invested in these projects were well worth it, according to one of the library employees and a library leadership, who were interviewed at the end of the spring semester 2013. More exciting projects are starting this fall, expanding to some new buildings. Increased resources are allocated to projects in terms of one more researcher and a high level management being involved in project leadership. Thus, through their actions, in addition to words, the library is expressing a very positive attitude towards results of student driven innovation.

Seen through students' words and actions, the library projects were very exciting. One student expressed it as follows: *"I am so happy I chose this project! At the beginning of the semester, one does not know, so many things sounded so exciting, from designing automated rescue vehicles to designing interactive games for children. This sounded almost boring, but I trusted the others in the group. In retrospect, this was the most exciting project. I learned so much."* Again, seen through actions, in 2010 no projects went any further than the final delivery in class. In 2011, there was a lot of excitement around project [24] and students were given a possibility to, as paid employees continue the work on the app until it is published. Even when the director argued for a possible huge impact of their work on the new library the interest was only moderate, they responded negatively to the offer. The primary reason was that the most active member had a full time job in addition to the studies. In 2012, two groups got the offer to continue their work, the third group did not, as technical difficulties in connecting the app to the database required involvement that was not possible to make at that point. Both groups accepted the offer and the Bookworms, [29], app is now available from the Apple app store [31] and Google Play [32]. The Minesweeper [30] is scheduled for a test run in the Science Library during the fall semester. In conclusion, actions and words of both major stakeholders confirm that the experience with student-driven innovation is positive, and adds value for both the university library and students.

In addition, further research into what are the motivating factors for a student innovator is well under way, using qualitative methods such as ethnography and in-depth interviews with participants. Some of the main factors that we have seen during the past three years are related to the clear definition of the context for design, time and finally, added value.

The context for innovation through design may have a large impact in how innovators behave. The context is an occasional property of action whose features are defined dynamically. On the other hand, context is not a form of information. Context is produced, maintained and enacted during an activity. Dourish [33] argues for a close relationship between activity and practice. For innovation, the possibility to create an arena where innovators can produce new context in which they can be creative and cooperate to achieve common results is crucial. In the examples above, the library building itself has been used as one such context, social networks are another example of a context that was used in [30]. Even from the short presentation of the projects above, it may be seen that the projects ([29], [30]) that were having such a context were the most successful ones.

Within both contexts, we as researchers are building the awareness that the library and the social networks connected to the library (Facebook, twitter and so on) are a living lab to be used by students to try their ideas, to experiment and to be creative.

The time as a factor has several dimensions. The interesting one is what we would call a digestion time. That is the time it takes to accept concepts related to design and context. A concept, for example, such as that of a living lab takes time to understand, not only cognitively, but with the whole body, as a phenomenon. After all, it is living, dynamic, experimental environment.

Time is also important in relation to co-creation through design methods involving users, such as participatory design or co-design. It takes time to shape and share design practice and space, even when designers are also users. Other students, who were not in the design course, were also involved.

Last, but not least, the time switches from Chronos (the linear time that nobody has enough of) to Kairos (the perceived time) as the engagement increases. For example, a member of the innovation team [29], also has a full time job as a physician, alongside of full time studies. Part, or even full time work, in addition to classes, is not an exceptional occurrence. People dedicated their time to the projects, as they were perceived as both valuable and cool. Thus, the time and the value are also deeply connected. The higher the perceived value, the less importance is paid to time spent.

The "added" value is interesting for us as a subjective perception of the worth of what we leave to the world, in this case the library, as a legacy. This same factor has motivated many hackers in hacker communities to achieve things believed to be impossible. The harder it is, the better. The members of both projects that are being implemented all believe that what they do has the possibility to be a success on one hand, and useful on the other. Another positive aspect of making something cool is kind of status

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among students that is achieved. One not only makes cool things, but also becomes cool him/herself.

Another finding worth mentioning is that student innovators focused on useful things rather than fun interactions. For example, they could choose to design a huge screen game, ambient art or something with near field interactions. But usefulness, at least throughout these first three years, has been important for student innovators.

V. CONCLUSIONS

In this paper, we have addresses the question of how to engage students in design and innovation of library services. Our findings show that the library living lab provides a good context for developing new ideas. The time and the added value are both important factors supporting innovation through design. In addition, we could observe a clear progress in the quality of projects from year to year, attributing this to time it takes to embody the concepts innovators work with, such as for example, the concept of the living lab. The difficulty we have observed has to do with sharing and ownership issues regarding the results of innovation.

As for the future research, we would like to take a deeper and longer look at motivation for participating in student-driven innovation. There is a volume of work on this from many perspectives, but none covers the same context, at least to the best of our knowledge. In addition, we have seen in other areas of our work that gamification has a potential to form habits. It has not been used yet, but we are looking forward to exploring what gamification can do in forming new habits for students related to library services and new ways of acting and relating to library systems.

Discussing the possible problem with innovation mentioned in the introduction around sharing and ownership of the results of the innovation and its "stickiness" is important. In our case, the transition of the ownership from innovators to the library is not entirely problem free. The reason for that is insufficient sense of ownership over these new services on the library side. It is, however, too early to draw any conclusions around this at this time. The librarians have been included in the innovation through design processes, and increased involvement is planned for the fall. This aspect will thus be considered in our future work more closely.

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The authors are indebted to all student participants and the university library employees for their involvement in, and support of the projects in diverse ways, most importantly by giving their time when needed and resources such as location for work, equipment etc. The National Library, in part, financed the project.

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Figure 5. One of the features of Bookworms App is to show the shelf that the desired book is on, see [29].

UWB Radar with Array Antennas for Human Respiration and Heartbeat Detection

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***Abstract*— Detection of human respiration and heartbeat is an essential demand in medical monitoring, healthcare vigilance, as well as in rescue activities. Radar is an important tool to detect human respiration and heartbeat. Compared to body-attached sensors, radar has the advantage of detection without contact to a subject, which is favorable in practical usage. We conducted preliminary studies on ultra-wideband (UWB) radar for detection of respiration and heartbeat by computer simulations in this paper. The main achievement of our work is the development of a UWB radar simulation system, which is designed in line with real implementation. Using the developed system, three UWB frequency bands are compared for respiration and heartbeat detection. The effects of using antenna arrays are also examined.**

Keywords- UWB radar; antenna array; respiration detection; heartbeat detection; UWB bands

I. INTRODUCTION

Detection of human respiration and heartbeat is of essential importance in medical and healthcare services. Some examples are patient's status tracking in medical triage, routine monitoring in elderly healthcare, searching of survivals under rubble of earthquake aftermath, and so on. Although respiration and heartbeat can be obtained by using body-attached sensors, detection without physical intervention to human body is much more comfort and convenient in practical usage. Radar is an important tool to detect human respiration and heartbeat without physical intervention to a subject. Researchers have been conducting studies on respiration and heartbeat detecting radars for decades. Some recent works can be found in [1-5, 8].

Doppler radar is often used for respiration and heartbeat detection [1-3]. In this case, the Doppler shift incurred by respiratory and circulatory contraction and expansion is measured by a continuous wave (CW) radar. Generally, the reflections and interference of surrounding scatters as well as interference between the respiration and heartbeat degrade the detection sensitivity. Using higher frequency is helpful to increase the detection sensitivity. L. Chioukh, et al. evaluated the effects of frequencies for 5.8 GHz, 24 GHz, and 35 GHz, and concluded that the highest sensitivity detection is achieved at the highest frequency [1].

UWB radar for human tracking had been studied by several researchers [6-7]. Moreover, many authors had conducted studies on respiration and heartbeat detection using UWB radars. In [4], a pulse generator at the transmitter and a sampler at the receiver were used to detect respiration using UWB pulses at 0.5GHz - 2.5GHz. In [5], design issues for UWB radar at 3.1-10.6 GHz with 90nm CMOS were discussed.

In this paper, we present preliminary results of UWB radars for detection of respiration and heartbeat by computer simulations. We developed a computer simulation system for UWB radar in line with real implementation. UWB bands are different in countries and regions, the developed radar simulation system mainly targets at the frequency bands that are allowed in Japan, while with the frequency band allowed in USA as comparison. Moreover, antenna array models are developed to investigate the effects of the number of antennas under the constraint of maximum total radiation limits.

The rest of the paper is organized as follows. In section II, the developed simulation system of UWB radar and the detection principle are illustrated in detail. In Section III, the simulation setting and models are described. Then, examples of simulation results and discussions are presented in section IV. A short conclusion of the paper is given in Section V.

II. SYSTEM OVERVIEW

The block diagram of the developed UWB radar system for simulation is shown in Figure 1. The clock generator generates strobe pulses with a frequency of f_{cg} for synchronization of all modules in the system. In pseudo random (PN) dither module, strobe pulses are randomized in accordance with PN M-sequence. Each strobe pulse triggers a random PN number according to the law of M-sequence. Period of M-sequence in time unit is given by

$$T_{PN} = \frac{N_{PN}}{f_{cg}} \tag{1}$$

where, N_{PN} denotes the length of the M-sequence. Each strobe pulse arrived at PN dither will be delayed by a time interval that is linearly related to the PN numbers. The maximum delay corresponds to the maximum number of M-sequence and it does not exceed the period of strobe pulse.

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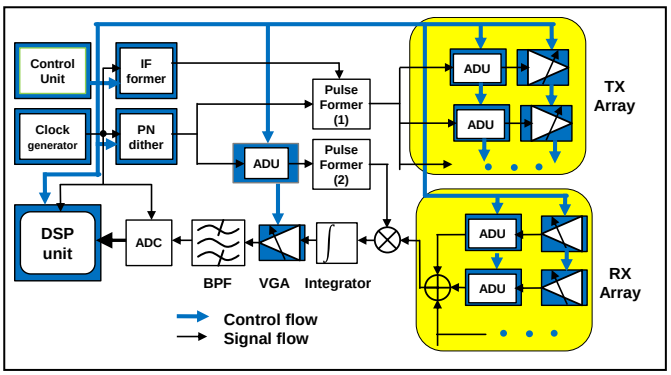


Figure 1. Block diagram of the UWB radar simulation system.

There are two main purposes to perform pulse randomization. Firstly, randomization can reduce the line spectrum components at frequencies that are multiples of clock frequency f_{cg}. Secondly, randomization makes the signal spectrum more noise-like, which is favourable for better electromagnetic compatibility and for achieving efficient usage of power spectral density. Finally, the PN dither outputs randomized pulse sequence, whose repetition period is equal to T_{PN}.

After PN dither, the randomized pulse sequence is divided into two equivalent parts. On one hand, the first part is sent to pulse former (1) to generate UWB pulse for emission. On the other hand, the second part is passed through a variable delay module and sent to pulse former (2) to generate a heterodyne signal for signal detection at the receiver. At pulse former (1), randomized pulse sequence is modulated by an IF former. The latter operates on the clock frequency f_{cg} and generates periodic square signal with a period of $2 \times T_{PN}$. Therefore, pulse former (1) is switched on during the first T_{PN} interval and outputs the randomized pulse sequence. Pulse former (1) is switched off during the second T_{PN} interval without outputs. Another role of the IF former is that it enables the use of bandpass amplifier working at intermediate frequency at receiver. That eliminates the flicker noise in the amplification of the received signals. In contrast, pulse former (2) outputs a delayed version of randomized pulse sequence continuously.

Pulse burst from pulse former (1) is sent to the transmit antenna array (TX array). At TX array, input signal is divided and fed into every element. Each element of the TX array contains an adjustable delay unit (ADU), a variable gain amplifier (VGA), and an antenna. The ADUs can be used to coordinate delays among antennas. After delay and amplification, UWB pulses are emitted towards subject. The numbers of array antennas enabled in the simulation system are 1×1, 2×2, and 4×4, respectively.

The emitted UWB signal is reflected by the subject. A sequence of reflected pulses is received by the receive antenna array (Rx array). Each element of the RX array contains an antenna, a VGA, and an ADU. ADUs are used to coordinate delays among receiving antennas. The received signals from all elements are added and fed into the mixer, where the received signal is demodulated using the heterodyne signal from pulse former (2). The output of the Mixer is passed to the integrator.

If the received signal matches with the heterodyne signal, the integrator outputs correlated signal, which strength is proportional to the amplitude of the received signal with the period of $2 \times T_{PN}$. By taking advantage of the huge bandwidth of UWB, we use a range-gated architecture with a basic sensing resolution element of dR.

$$dR = \frac{d_t \times c}{2} \quad (2)$$

where c is speed of light and d_t is the UWB pulse length measured at -10 dB level. The latter varies in accordance with frequencies and bandwidths. We can detect a number of N_{dR} resolution elements by sequentially sending N_{dR} of pulse bursts and adjusting variable delay for pulse former 2, so that each pulse burst corresponds to one out of the N_{dR} elements.

Then, the signal is amplified by VGA to compensate signal attenuation due to reflection and transmission. Finally, the signal is filtered by BPF and passed through analogue digital converter (ADC) and then fed into the digital signal processing (DSP) unit. The sampling frequency is same as the clock frequency f_{cg}.

The structure of DSP is shown in Figure 2. In amplitude detector module, the input signal is divided into in-phase and quadrature-phase components and converted into baseband signal. Square root samples of envelope of the baseband signal are calculated for each resolution element. The obtained envelope samples are sent to the bin decimation module, where decimation is performed while keeping the resulted sampling frequency large enough to recover the targeting objective.

The signal reflected from stationary objects, repeats in each sweep and presents as DC component in each resolution element. Infinite impulse response (IIR) filter of the first order is applied as Bin DC filter to remove the DC component and to output realizations of samples. In the cyclic buffer module, a number of N_{FFT} counts of realizations are stored for each of the N_{dR} resolution element.

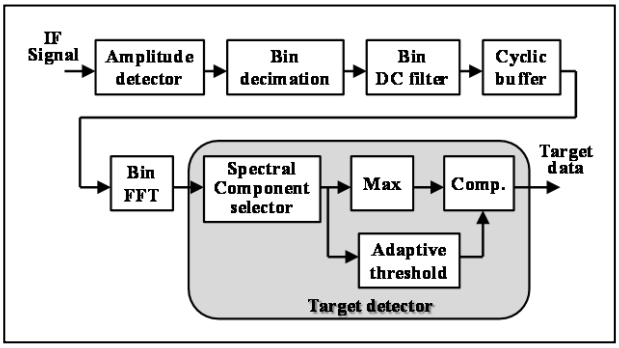


Figure 2. Structure of DSP unit.

When the buffer is full of N_{FFT} counts, a new incoming count will drive out the oldest count so that the buffer is continuously updated. Then, Bin FFT module performs sequentially moving fast Fourier transform (FFT) with pre-weighting by windowing function. A weighted realization can be written as

$$S_{bin\_win\_i}(n) = S_{bin\_i}(n) \times win(n); \quad n = 0,\ 1,\ \cdots,\ N_{FFT} - 1 \tag{3}$$

where $S_{bin\_i}(n)$ denotes the n'th realization of N_{FFT} counts for *i*th resolution element, and *win*(*n*) denotes the weighting window. Bin FFT is performed as follows.

$$\dot{S}_{bin\_FFT\_i}(k) = \sum_{n=0}^{N_{FFT}-1} S_{bin\_win\_i}(n) \cdot \exp\left(-i \cdot \frac{2\pi}{N_{FFT} - 1} \cdot n \cdot k\right); \quad k = 0,\ 1,\ \cdots,\ N_{FFT} - 1. \tag{4}$$

The resulted spectral sample is given by

$$\left|\dot{S}_{bin\_FFT\_i}(k)\right| = \sqrt{\mathrm{Re}\left(\dot{S}_{bin\_FFT\_i}(k)\right)^2 + \mathrm{Im}\left(\dot{S}_{bin\_FFT\_i}(k)\right)^2} \tag{5}$$

Finally, the resulted spectral samples are sent to target detectors. In which, corresponding spectral components of respiration and heartbeat are tuned. The maximum value is chosen from the tuned spectral components, which is compared with a threshold. If the spectral component is larger than the threshold, the corresponding subject is detected.

III. SIMULATION SETTING

In this section, we describe the assumptions and conditions that are used to carry out simulations with the developed UWB radar system. We first show the frequency bands examined, which affect the UWB pulses directly. Then, parameters related to radar as well as parameters of subject to be detected are illustrated.

A. Frequency Bands

The available UWB bands are different in countries or regions. In the developed simulation system, we mainly investigate the following three frequency bands.

(1) 3.4 - 4.8 GHz
(2) 7.25 – 10.25 GHz
(3) 3.1 -10.6 GHz

where, (1) and (2) are UWB low band and high band regulated in Japan, while (3) is UWB band regulated in USA. The reason that we select both low band and high band of Japan is that low band will be impelled to more strict regulation, although low frequency is suitable for radar in general. A UWB pulse can be expressed as

$$s(t) = A_{\max} \exp\left(-a^2 t^2\right) \sin\left(2\pi f_c t - \pi\right) \tag{6}$$

where, f_c is the center frequency of the corresponding band, a is a pulse parameter and is dependent on UWB band. A_{max} is the maximum amplitude, which is restricted by regulations and is also dependent on UWB band. For the above three UWB bands and different antenna arrays, these parameters are summarized in Table I.

TABLE I. PULES PARAMETERS RELATED TO UWB BANDS

Parameter		3.4-4.8GHz	7.25-10.25GHz	3.1-10.6GHz
Central frequency f_c (GHz)		4,1	8,75	6,85
Pulse parameter a		1,210e9	2,592e9	9,903e9
Maximum amplitude A_{max} (v)	1×1	2,164	4,638	17,718
	2×2	1.531	3.280	12.529
	4×4	1.082	2.319	8.859

The detected frequencies at the target detector are calculated as follows.

$$f = i \cdot \Delta f = i \cdot \frac{f_{s\_bin}}{N_{FFT}} \tag{7}$$

where, i denotes the number of spectral components, Δf denotes the frequency resolution of FFT. f_{s_bin} is the sampling frequency, which is given by

$$f_{s\_bin} = \frac{f_{cg}}{2 \times T_{PN} \times N_{dR} \times N_{decim}} \tag{8}$$

where, Ndecim denotes the performed decimation number. All other parameters of the UWB radar used in the simulations are summarized in Table II.

TABLE II. PARAMETERS USED IN THE SIMULATION

Parameter	Value
PRF	1 MHz
ADC quantization	12 bits
Length of PN sequence (N_{PN})	31
weighting window	Hanning/Hamming/Blackman
Number of resolution elements (N_{dR})	128
FFT dimension (N_{FFT})	1024
Decimation number (N_{decim})	6

B. Detection Setting

As shown in Figure 3, the radar is located at the ceiling of a room. In our simulation system, omni antennas are assumed. When 2×2 or 4×4 antenna array are used, the neighbour antennas are separated by a distance of $\lambda/2$, where λ is the wave length at the center frequency of the UWB band. The body skin vibration caused by respiration

and heartbeat is combination of respiration signal *RP(t)* and heartbeat signal *HB(t)*. Suppose that the radar is put in a position right above the subject as shown in Figure 3, the skin vibration caused by respiration and heartbeat will only on Z axis and can be represented as follows.

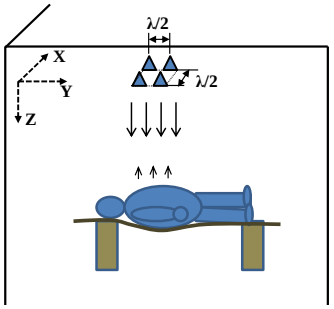


Figure 3. Detection Setting.

$$z(t) = z_0 + A_{RP}\sin(2\pi F_{RP}t + \varphi_{RP}) + A_{HB}\sin(2\pi F_{HB}t + \varphi_{HB}) \quad (9)$$

where, A_{RP} and A_{HB} are the amplitudes, F_{RP} and F_{HB} are the frequencies, φ_{RP} and φ_{HB} are the phases, respectively for respiration and heartbeat signals. Z_0 is the distance between the subject and antenna. The values of amplitudes, frequencies, and phases for respiration and heartbeat used in simulation are summarized in Table III.

We adopt point target model in the simulation. The amount of collected reflected power P_r at the receiver antenna is calculated as

$$P_r = \frac{\sigma G_t G_r \lambda^2 P_t}{(4\pi)^3 r^4} \quad (10)$$

where σ denotes radar cross section. The related reflection area of the target is assigned with values of 20 cm^2 for respiration and 3 cm^2 for heart beat respectively. The antenna gain G_t and G_r are both set to 0 dBi and the transmit power P_t is decided by the allowed UWB power spectrum density (PSD) and bandwidth. The wave length λ is calculated at the center frequency of a given UWB band. Furthermore, thermal noise is assumed with a one-sided power spectral density N_0.

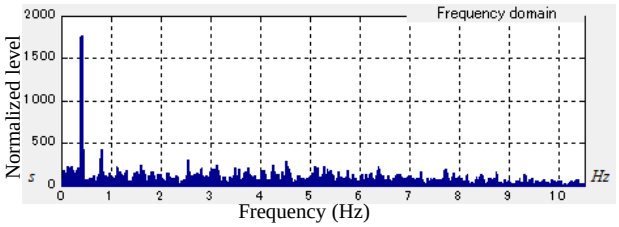
TABLE III. PARAMETERS OF RESPIRATION AND HEARTBEAT.

Parameter	Value
F_{RP}	0.4 Hz
F_{HB}	1.2 Hz
A_{RP}	5mm
A_{HB}	0.5mm
φ_{RP}	0
φ_{HB}	0

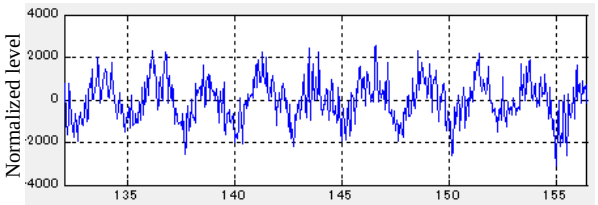
IV. SIMULATION RESULTS AND DISCUSSION

In the following, we show some examples of the computer simulation results. Our main concern is put on the examination on the three UWB bands as well as the examination on numbers of antennas. In the developed simulation system, GUI is installed so that one can intuitively observe the detection of a subject. Graphics in both frequency domain and time domain are shown simultaneously through GUI.

Examples of respiration and heartbeat detections on GUI are given in Figures 4 and 5 respectively. In Figure 4, an example of respiration detection using 3.4-4.8 GHz band and with 2×2 antenna array is shown. It can be seen that the respiration frequency is clearly detected at 0.4 Hz, although a small component appears at the two-time harmonic in the

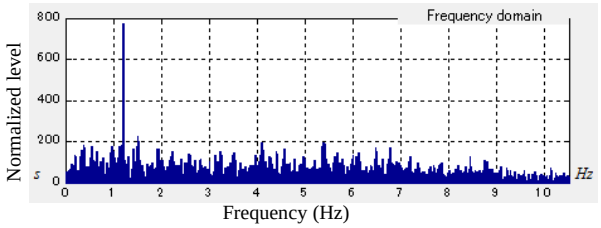


(a) Frequency domain signal

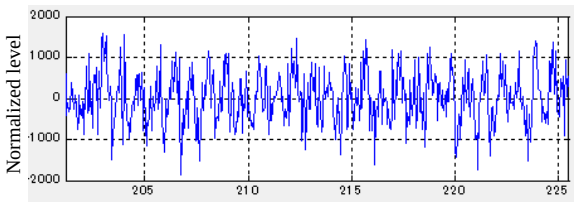


(b) Time domain waveform

Figure 4. Example of respiration detection using 3.4-4.8 GHz.



(a) Frequency domain signal



(b) Time domain waveform

Figure 5. Example of heartbeat detection using 7.25-10.25 GHz.

frequency domain. In the time domain, the period of the respiration can be clearly recognized, which is about 2.5s. An example of heartbeat detection using 7.25-10.25 GHz band and with 4×4 antenna array is shown in Figure 5. The heartbeat is detected at 1.2 Hz in frequency domain and the period of heartbeat obtained in time domain is about 0.83s.

In Figure 6, required gains of the VGA that is located after the integrator are obtained. The detection target is respiration and the distance between the subject and radar antenna is fixed at 3m. For comparison convenience, the results are normalized to that of the 1×1 antenna case on 3.1-10.6 GHz band. Evaluation and comparison among the three frequency bands as well as the three patterns of array antennas are made.

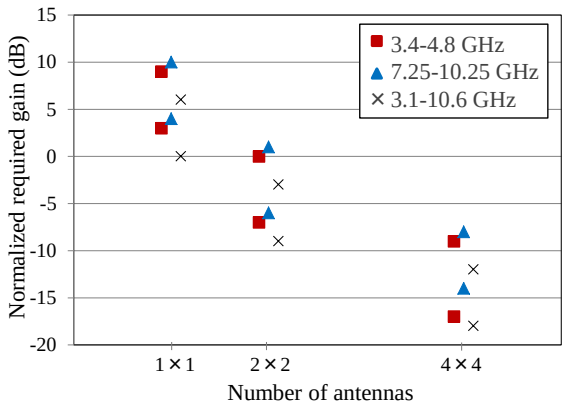


Figure 6. Required gains for respiration detection at a distance of 3m.

It can be seen that for all three frequency bands, increasing the number of antenna can steadily reduce the required VGA gains. Compared to 1×1 antenna, 2×2 array saves 9-10 dB gains, while 4×4 array further saves another 9-10 dB gains compared to 2×2 array. For each case of antenna array, we give two results which correspond to two detection status. The results show that 3.4-4.8 GHz band and 7.25-10.25 GHz band present similar detection ability. In comparison, 3.1-10.6 GHz band can save 3-4 dB gains than the other twos. The reason that 3.4-4.8 GHz band and 7.25-10.25 GHz band give similar results can be explained as follows. On one hand, the center frequency of 3.4-4.8 GHz band is slightly less than half of that of 7.25-10.25 GHz band. On the other hand, 7.25-10.25 GHz band has a slightly larger bandwidth than double that of 3.4-4.8 GHz band. The merit provided by the low center frequency is waived by the merit of large bandwidth.

Next, we investigate the maximum distance for heartbeat detection for the three UWB bands. To make fair comparisons, in each frequency band and for each antenna combination we increase the maximum VGA gains as large as possible until ADC clipping occurs. The obtained results are summarized in Figure 7. It can be seen that when 3.4-4.8 GHz band and 7.25-10.25 GHz band are used, there is not big difference on maximum distance. However, when 3.1-10.6 GHz band is used, the detecting distance is increased. Moreover, increasing the number of antennas results in large detecting distance. In Figure 7, using 3.1-10.6 GHz band with 4 × 4 array, the heartbeat can be detected from a distance of 3.4 m.

Finally, using heartbeat detection as an example, the relation of detecting distance with required gain are depicted in Figure 8. All three UWB band are investigated with 4×4 array and 2×2 array, respectively. The results for 2×2 array are shown with blank symbols while the results for 4×4 are shown with filled symbols. It can be seen that for each combination among the three UWB bands and two types of antenna arrays, the required gain almost linearly increases with detecting distance. The inclinations of increase for all cases are very similar. Except for a single point at 1m, 3.1-10.6 GHz band needs less gain than the other two bands. It is also obvious that 4×4 array presents constant gain against 2×2 array. The gain is around 8-11dB. This number also coincides with the result of respiration detection given in Figure 6, in which the gain obtained by 4×4 array over that of 2×2 array is 9-10 dB. Thus, it is an effective way to increase the radar detectability by increasing antennas.

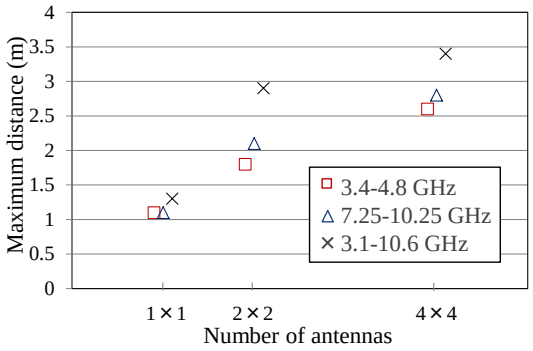


Figure 7. Maximum distance for heartbeat detection

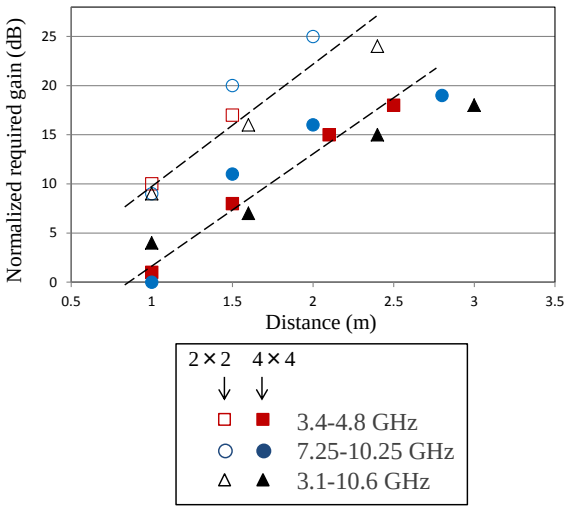


Figure 8. Relation of detecting distance with required gain.

V. CONCLUSION

We conducted preliminary studies on UWB radar with antenna arrays for detection of human respiration and heartbeat. A computer simulation radar system is developed in line with the structure and processing of real radar systems. We also installed a GUI so that the detection of respiration and heartbeat can be shown intuitively.

As our goal is to develop a UWB radar system within the scope of regulation in Japan, the regulated UWB low band, 3.4-4.8 GHz, and UWB high band, 7.25-10.25 GHz, of Japan are investigated. The regulated USA UWB band, 3.1-10.6 GHz is presented as a comparison. Three types of antenna combinations, 1×1, 2×2, and 4×4, are also investigated. The simulation results show that UWB low band and UWB high band of Japan present identical detection performance. Both of them are a little deteriorated by the 3.1-10.6 GHz band. However, if the subject is under rubble, 3.4-4.8 GHz band should be superior because it can go through rubble more easily than the latter. Our results show that increasing antenna is an effective way to enhance detection ability.

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Applying Augmented Reality to Tourism Pamphlet and its Evaluation

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***Abstract*—Various studies have been undertaken to adapt Augmented Reality (AR) technology for use in real application. We see AR as being suitable for creating an enjoyable tourism pamphlet for users. In this study, we developed an AR tourism pamphlet and compared three types of different pamphlet (AR with map, AR-only and map-only). The results show that the combination of a map and AR performed better the traditional map pamphlet. By conducting an experiment where we measured the participants' brain activities, we confirmed that the burden on spatial cognizance and working memory, as well as throughout the rest of the brain, was reduced with the map-and-AR combination. We also confirmed that the combination drew interest far more than the map-only pamphlet. We believe this shows that the proposed pamphlet is overall a more natural form of information and, when compared with a traditional pamphlet, has the potential to be more enjoyable and less stressful for users.**

***Keywords*—Augmented Reality; Tourism; Pamphlet; Brain Activity; NIRStation**

I. INTRODUCTION

A. Background

Augmented Reality (AR) technology has gained attention in recent years. AR is defined as an extended (or heightened) sense of realism. As its name implies, the technology is designed to extend (or intensify) the real world [1]. More specifically, it can show us a world containing a greater amount of content by layering digital information over the real world as seen through a computer or smartphone screen.

AR is divided into several categories [2]. First is marker-type AR, defined by a marker image that, when seen through the camera attached to a Personal Computer (PC) or similar device, interacts with the image to display digital data. In contrast, there is also marker-less-type AR, which detects specific shapes and colors in the camera image to display digital data without a marker. Both marker-type and marker-less-type AR use image recognition technology. There is also location-information-type AR, which uses the Global Positioning System (GPS) and sensors present in smartphones and similar devices to determine the specifics of the user's location in displaying digital information.

AR allows worlds that previously only existed in comics and animation to be actualized, a concept that excites us with its amusement and charm. Kobayashi [2] states that "Media like television, movies, comics and games are not used solely for the purposes of entertainment. Pleasure is, of course, a huge factor in these media, but it is possible to use that pleasure to our advantage to produce the experience of 'being educated while being entertained' (Edutainment) [3]. This point also applies to the new medium of AR." With this principle in mind, we conducted research with the expectation that the excitement experienced by users using AR would also be effective for a tourism pamphlet.

B. Past research

There have been various research works on the practical use of AR.

Kondo [4] states that one of the merits of composite reality (roughly equivalent to AR) is the ability to expand upon traditional teaching media such as textbooks. In addition, he developed three-dimensional computer graphics (3DCG) and audio explanations of the structure of the human brain. Materials useful for teaching mathematic spatial diagrams were developed and implemented in a high-school lesson. After the lesson, 70% of the students reported that it was easier to understand the content with the composite-reality technology.

Alzua-Sorzabal et al. [5] presented a usability study of a new prototype based on AR technologies. The observation-based study revealed the possibilities and limitations of the design of the prototype on the basis of the behavior of users. Most participants agreed that the approach of using AR technologies enhanced the interactive experience with tourist content. Moreover, they positively assessed the usefulness of the prototype as a tourist information point because of its ability to provide location-based content.

Teshima and Kosugi [6] reported tests using cartography teaching materials made by the researchers. The tests demonstrated that AR 3DCG displays were effective in cartography study. It was confirmed that AR teaching materials significantly raised test scores when it came to questions about target locations and names. The researchers reasoned that AR had a great effect on the learning of important components (i.e., the place and name memorization) of cartography.

Miyosawa et al. [7] states that AR is suitable for creating an enjoyable learning experience (i.e., edutainment) for students. They developed an AR application based on the same content as conventional printed teaching material in the field of foreign-language study. The learning efficacy of the two media was assessed by comparing the results of verification tests and monitoring brain activity during the

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learning process. There were no significant differences in test results between the two media. However, it was found that the subjects' brains were more active while studying the printed teaching materials than while studying the AR teaching materials. The researchers believed that this showed that the proposed method of study is overall a more natural one and, when compared with traditional methods of study, has the potential to be less stressful for students.

Despite the above studies, there has been insufficient research and discussion on the effectiveness of AR in other fields and on whether AR is suitable for highly specific fields.

C. Objective of the Paper

A standard tourism pamphlet is an item that contains pictures and information regarding sightseeing locations. In this paper, we conduct a subjective evaluation via a questionnaire about a tour pamphlet that employs AR, in terms of the information obtained about sightseeing locations, and perform a test to observe any trends in brain activity. From these test results, we determine the compatibility of AR with tourism pamphlets.

D. Composition of the Paper

The first section covers the background to the present study, existing challenges, past research, and the objective of the paper. The second section introduces the thought put into developing the AR tourism pamphlet, and the pamphlet's contents. The third section discusses the two tests conducted using the materials prepared in the second section, and the questionnaire results. The fourth section covers in further detail the results of each test performed in the third section. In the fifth section, we analyze the results obtained in the previous section. The sixth and final section presents our conclusion and discusses future research.

II. THE TOURISM PAMPHLET

A. Development environment

1) ARToolKit

ARToolKit [8] is a C/C++ programming language library that allows support of marker-style AR applications. Originally, the process of detecting a marker in the captured image and acquiring data about the position and orientation required a fair amount of technical knowledge, but ARToolKit turns that data into a simple black box around a marker. Its primary feature is to obtain the image from the camera, detect the marker through pattern recognition, calculate the position of the marker in three-dimensional (3D) space, and display the composite 3DCG as shown in Fig. 1, allowing us to create an application where the printed marker is read through a webcam and then overlaid with 3DCG. We were able to use markers and 3DCG that we had prepared. For this study, we created a tourism pamphlet using ARToolKit.

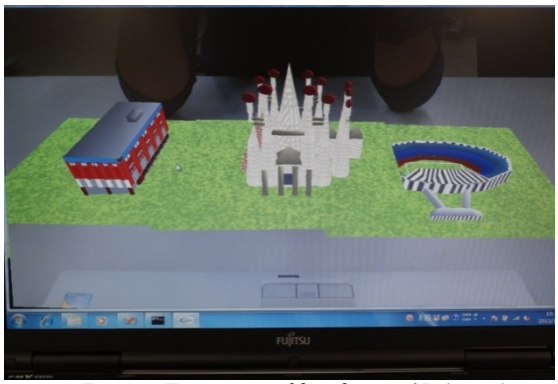

Figure 1. Tourism pamphlet adopting AR (image)

2) Metasequoia

Metasequoia [9] provides configuration materials for modeling and mapping. It is modeling software that allows 3D objects to be compiled in polygonal units. In our research, we used the free version of Metasequoia to create five 3DCG models, as seen in Fig. 2.

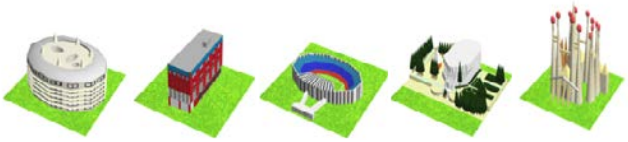

Figure 2. 3DCG objects created in Metasequoia

B. Applying AR

In our research, we developed a pamphlet that put AR to practical use. By paying attention to the pictures of sightseeing locations on the map and replacing the pictures with 3DCG, we expect that it is possible to better capture the viewer's interest.

C. Developed Tourism Pamphlet

We produced three different tourism pamphlets. Figure 3a shows the tourism pamphlet with map and AR, which provides information about sightseeing locations in Rome, Italy. Figure 3b shows the map-only tourism pamphlet, which provides information about sightseeing locations in Barcelona, Spain. Figure 3c shows the AR-only tourism pamphlet, which also provides information on attractions in Rome, Italy.

Figure 3. Pamphlets with a) map and AR, b) map only, and c) AR only

The AR-with-map and AR-only pamphlets display the prepared 3DCG over the marker on the PC screen when the marker is viewed through a webcam connected to a PC. The map-only pamphlet specifies the sightseeing location on the map with a picture alongside.

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Figure 4. Examples of the included information sheets.

The pamphlets introduced in Fig. 3 include information sheet on each location, as shown in Fig. 4.

III. EXPERIMENTS

We performed two experiments. Section 3.1 outlines the questionnaire for the first experiment using the pamphlet and information sheets. Section 3.2 details the second experiment in which brain activity was measured while the participants were given the pamphlets and informational sheets. Experiments 1 and 2 were carried out at the same time and for the same participants.

A. Experiment 1: Questionnaire Results

1) Experiment Objective

From the questionnaire results, we can examine whether the map with AR better conveys information and captures the interest of travelers than the traditional map-only pamphlet and AR-only pamphlet. The questionnaire results are used as indicators of the overall evaluation and points of possible improvement.

2) Participants

Nineteen students (20 to 24 years old) from the Tokyo University of Science, Suwa, participated in the experiment.

3) Materials

The materials used in the experiment were

a) the three tourism pamphlets (the AR+map tourism pamphlet, the map-only pamphlet, and the AR-only pamphlet),

b) the three information sheets (information corresponding to each of the three pamphlets),

c) a laptop equipped with a webcam, and

d) the questionnaire.

4) Experimental Method

Each participant took information from each pamphlet for 1 minute (i.e., a total of 3 minutes for the three pamphlets). The order of the pamphlets was changed for each participant to prevent any bias due to the order of presentation. The participants then filled out a questionnaire. We ran a training session for participants not familiar with AR.

5) Questionnaire Results

Four evaluation options were provided: “strongly agree”, “agree”, “disagree”, and “strongly disagree”. We chose four options to prevent a neutral answer. With each option respectively counting as four, three, two or one point, we used PASW Statistic (SPSS) to perform a statistical analysis. The significant variance using this software is below 5%.

Significant variations in results among pamphlets were found for the statements “It was easy to connect the name with the location”, “I was interested in the location”, “I want to visit the location”, and “I want to use the pamphlet again”.

The statements for the various pamphlets were compared using the Bonferroni method. This paper discusses only the significant variations that were observed.

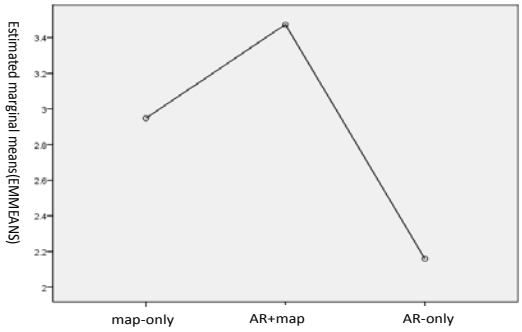

Figure 5. Was it easy to connect the name with the location?

For the statement regarding how easy it was to connect the name with the location, we observed significant variance between map-only and AR-only pamphlets and between AR+map and AR-only pamphlets. Figure 5 shows that the average ratings descended from best to worst in the order AR+map > map-only > AR-only. We can conclude from these results that the AR+map pamphlet was best able to connect the name with the location.

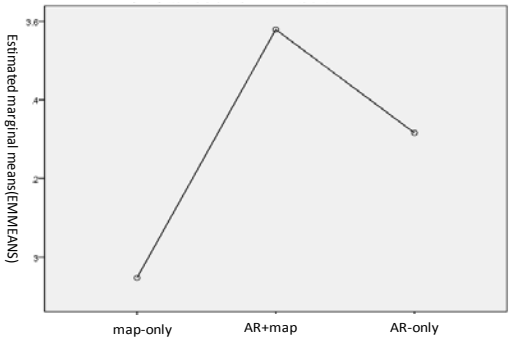

Figure 6. Were you interested in the location?

For the statement regarding interest about a location, we observed significant variance between map-only and AR+map pamphlets. Figure 6 shows that the average ratings descended from best to worst in the order AR+map > AR-only > map-only. We can conclude from these results that the AR+map pamphlet elicited the most interest in the participants.

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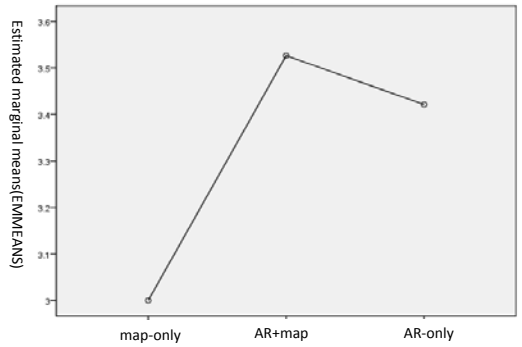

Figure 7. Did you want to visit the location?

For the statement regarding the participant's desire to visit a location, we observed significant variance between map-only and AR+map pamphlets. Figure 7 shows that the average ratings descended from best to worst in the order AR+map > AR-only > map-only. We can conclude from these results that the AR+map pamphlet elicited the most desire to visit a location.

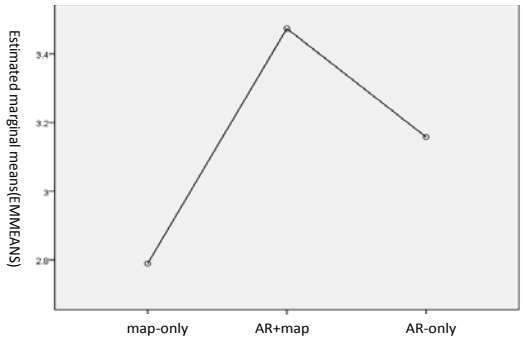

Figure 8. Do you want to use the pamphlet again?

For the statement regarding the participant's desire to use the pamphlet again, we observed significant variance between map-only and AR+map pamphlets. Figure 8 shows the average ratings descended from best to worst in the order AR+map > AR-only > map-only. We can conclude from these results that, of the three pamphlets, participants most wanted to use the AR+map pamphlet again.

By condensing these statements, we can argue several points.

(1) The statements "It was easy to connect the name with the location" and "The information about the tourist locations was easy to understand" were categorized as statements measuring ease of comprehension. In that category, the order of results was AR+map > map-only > AR-only. There is a high probability that the AR-only pamphlet received low valuations because participants were unfamiliar with managing the markers. We also postulate that the AR+map pamphlet was the most intuitive scheme in allowing participants to understand the location. We can conclude that the AR+map pamphlet was easiest to understand.

(2) The statements "I was interested in the location", "I want to visit the location" and "I want to use the pamphlet again" were classified as statements measuring interest. In that category, the order of results was AR+map > AR-only > map-only. We can conclude that the map-only pamphlet was insufficient for capturing the participants' interest as both AR+map and AR-only pamphlets received higher valuations.

B. Experiment 2: Measuring Brain Activity

1) Experiment Objective

By measuring the brain activity of participants as they take information from the AR+map, map-only and AR-only tourism pamphlets, we can investigate which parts of the brain are most active. We can also confirm which pamphlet was easiest to use through differences in brain activity of participants between each pamphlet.

2) Participants

We conducted the experiment with 19 students from the Tokyo University of Science, Suwa.

3) Materials

The materials used in the experiment were

a) the three tourism pamphlets (AR+map tourism pamphlet, the map-only pamphlet, and the AR-only pamphlet),

b) the three information sheets (information corresponding to each of the three pamphlets),

c) a laptop equipped with a webcam, and

d) a brain-activity measuring device (NIRStation, a multichannel near-infrared spectroscopy brain-activity measuring device).

As shown in Fig. 9, NIRStation measures changes in blood volume in the surface area of the cerebrum using optic fibers at the scalp to emit near-infrared light. Blood volume (oxyhemoglobin, oxy-Hb) is increased to send more oxygen to active parts of the brain. Near-infrared light enters 25–30 mm below the scalp and travels along the cerebral cortex and decays during a cycle of diffusion and absorption before returning in part to the scalp. From the light absorption levels and light path length in the oxy-Hb, we can detect changes in blood volume (indicating activity). As the equipment is non-invasive and unrestrictive for the wearer, it is possible to use the equipment in long and repeated measurements.

4) f-NIRStation Setup

As seen in Figs. 9 and 10, using the summits of the triangles formed by the eye sockets and auricles, the headgear follows the latitudes provided by the 10-20 system for brain activity between the 6ch and 11ch of the left brain, and between the 29ch and 34ch of the right brain, allowing for measurement of each channel. The number of channels in f-NIRStation was set to 44.

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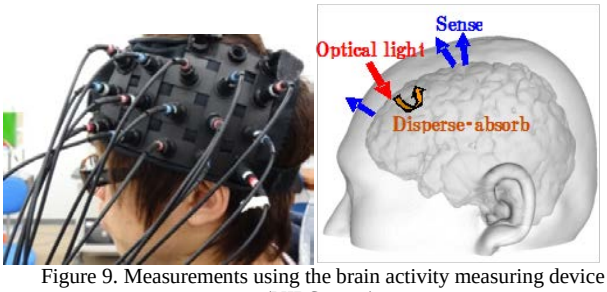

Figure 9. Measurements using the brain activity measuring device (NIRStation).

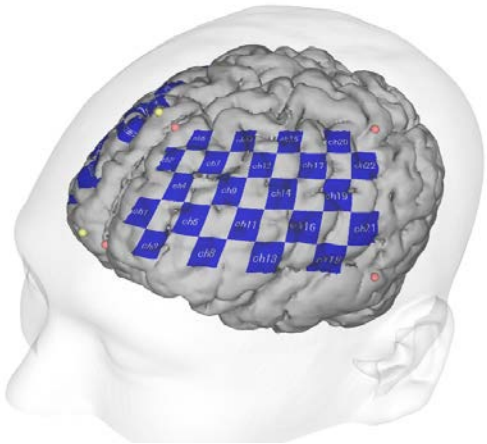

Figure 10. Corresponding brain position and channel numbers

5) Experimental Method

Brain activity was measured in the participants as they reviewed information in the tourism pamphlet for a duration of 1 minute. Before receiving the information, we established a 20-second rest (no action or thinking) period. This allowed us to determine the difference between the brain's activity during the rest period and during the task. The participants were given each pamphlet for 1 minute. The order of the pamphlets was changed for each participant to prevent order bias.

6) Process

Each participant was provided with a chart describing the process and a laptop with a Web camera for use with the AR+map pamphlet and AR-only pamphlet, with the AR application already prepared. For the map-only pamphlet, they were provided with only the pamphlet and the accompanying information sheet. Of the five sightseeing locations provided on each pamphlet, the participants were asked to select three. We had them repeat this three times for a total of nine places. We also provided information sheets about these locations.

IV. BRAIN ACTIVITY MEASUREMENT RESULTS

A. Statistical Analysis of Brain Activity Measurement Results (Average Values)

With f-NIRStation, it is possible to output the brain activity values during rest compared with the values during the task as a t-statistic. Using these t-statistics, we can perform a statistical analysis using PASW Statistic. The percentage of significant variations is within 5%. The Bonferroni method was used simultaneously for multiple comparisons.

f-NIRStation outputs data for one experiment in 44 channels for each activity. Since the experiment was performed three times, there are three instances of data for all 44 channels for each participant. Using PASW Statistic, we were able to obtain the average value of all channels of brain activity for each of the map-only, AR-only and AR+map pamphlets and search for any significant variations between the three.

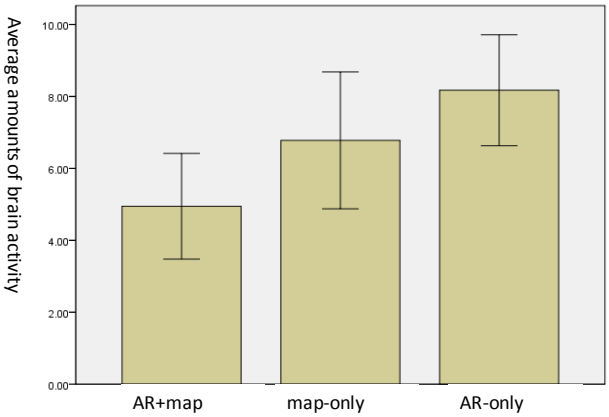

Figure 11. Differences in average brain activity between pamphlet types.

As a result, we were able to confirm significant variations between the types of pamphlet. The bar graph in Fig. 11 shows the average amounts of brain activity. The figure shows that there is significant variation in brain activity for the AR+map and AR-only pamphlets. The descending order of average brain activity is AR-only > map-only > AR+map.

When using the AR-only pamphlet, the brain activity increased. As there was no map, we conjecture that participants were required to carefully read the information sheets and to pay close attention to the sightseeing location. We can conclude that for purposes of stimulating the brain, the AR-only pamphlet is most suitable.

There was little brain activity for the AR+map pamphlet. We postulate that this is because the pamphlet can be reviewed in a passive manner. When one is passively performing an action, brain activity is less than that when one is actively performing an action. As the AR will display the sightseeing location in 3DCG, it seems that one can comprehend the pamphlet without reading the additional information. We can conclude that for the purposes of not over-stimulating the brain, the AR+map pamphlet is most suitable.

B. Considerations Regarding Brain Activity Measurement

Figure 12 displays the parts of the brain assigned to the channels of f-NIRStation, the brain activity measurement device used.

Sections 1 through 14 in Fig. 12 correspond to the following areas of the brain: ①left dorsolateral prefrontal

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cortex, ②left inferior frontal gyrus, ③left angular gyrus, ④ left superior frontal gyrus, ⑤left frontotemporal region, ⑥ left superior parietal lobule, ⑦left motor cortex, ⑧right dorsolateral prefrontal cortex, ⑨right inferior frontal gyrus, ⑩right angular gyrus,⑪right superior frontal gyrus, ⑫right frontotemporal region, ⑬right superior parietal lobule, ⑭ right motor cortex.

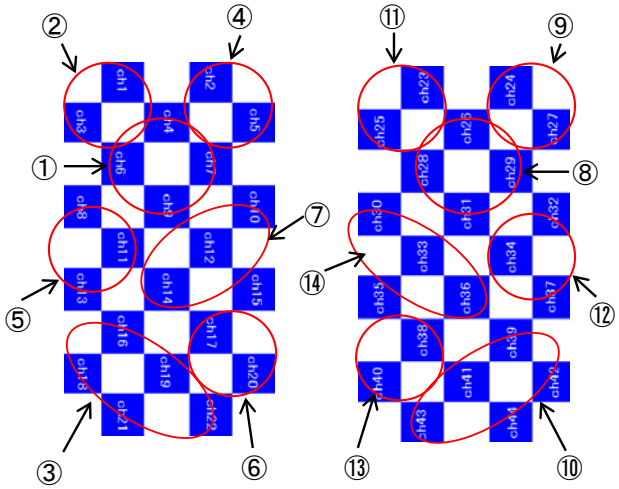

Figure 12. f-NIRStation's channels in relation to portions of the brain

Parts in which significant variance was observed are aggregated in Fig. 13. From left to right, each bar graph represents the results for the AR+map, map-only, and AR-only pamphlets. The bars display activity during the task as being in the plus-end, and at rest as being in the minus-end. The plus-ends of the graphs are proportionate to the amount of brain activity, while the minus-end is inversely proportionate.

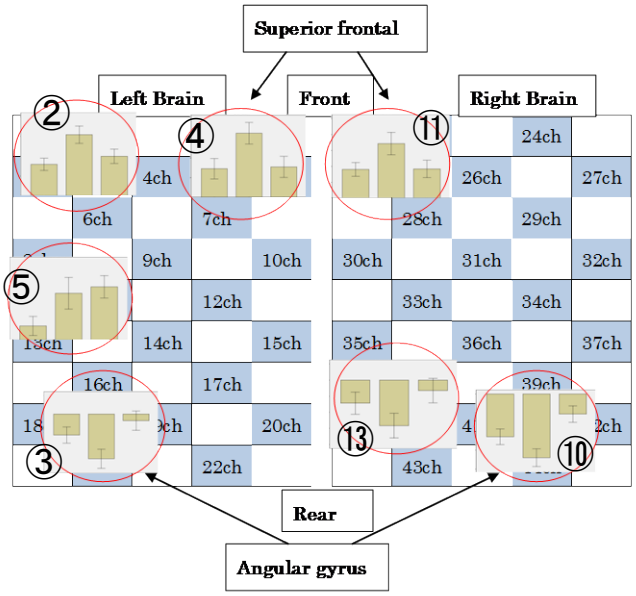

Figure 13. Areas in which significant variation was observed

As seen by looking at each part in Fig. 13, significant variances were detected in ⑩ the right angular gyrus, ⑬the right superior parietal lobule, ⑪ the right superior frontal gyrus, ③ the left angular gyrus, ② the left inferior frontal gyrus, ④ the left superior frontal gyrus, and ⑤ the left frontotemporal region; however, after employing the Bonferroni method, we discovered there were no significant variations between types of pamphlet in the right superior frontal gyrus.

1) The angular gyrus (③ and ⑩) is the parts of the brain responsible for language processing, particularly for figurative expressions and conjecturing [10]. When the parts of the brain are categorized, they are often grouped with the visual cortex. As seen in Fig. 13, the order of amount of activity descends in the order AR-only > AR with map > map-only. We postulate that with the AR-only pamphlet, the participants were able to confirm the contents of the information sheets using the 3DCG. Additionally, the AR allowed the participants to see the tourist locations before their own eyes and move around them freely. We believe it is possible that the AR gives the sensation that they are in fact in the place, rather than just viewing 3DCG on a screen. We believe it is for these reasons that the brain was more active for the AR-only pamphlet.

2) Significant variation was only detected in the right of the superior parietal lobules (⑬). The parietal lobe is the part of the brain responsible for somatic sensations related to spatial reasoning. The right parietal lobe is concerned with input. As seen in Fig. 13, the order of amount of activity in the right parietal lobe descends in the order AR-only > AR with map > map-only. This part of the brain inputs information related to deciphering the spatial image and location of the 3DCG from the AR-only pamphlet (the image appears in front of the eyes rather than one simply on top of a map). We postulate that the brain activity was low for the map-only pamphlet as one only had to read the information sheets, which required little input from the parietal lobe.

3) The left and right superior frontal gyrus (④ and ⑪) is part of the working memory [11] that deals with spatial cognizance and allows us to concentrate. As seen in Fig. 13, the order of the amount of activity in the superior frontal gyrus descends in the order map-only > AR-only > AR and map. As activity in this area was greatest for the map-only pamphlet, more concentration was required to closely read the supplied material as there was no 3DCG. We postulate that for that reason, the map-only pamphlet made the working memory more active.

4) Significant activity was detected only in the left frontotemporal region (⑤). The temporal lobe is responsible for understanding spoken language and grasping meaning and form. As seen in Fig. 13, the amount of activity descends in the order AR-only > map-only > AR and map, with the AR-only pamphlet inducing the most activity. We

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can postulate that by looking at computer graphics, our brain works harder at perceiving the form of an object. We believe that the activity was lowest for the AR+map pamphlet as the meaning and form of objects was easier to perceive and required less reasoning.

V. OVERALL CONSIDERATIONS

The objectives of this paper were to use AR with a map created by the researchers to examine any effect on interest of the observers in the field of tourism, to examine the compatibility of AR with tourism pamphlets, and to consider the effectiveness of AR with a typical tourism pamphlet.

We first performed an experiment using a questionnaire to obtain subjective opinions on the information received about sightseeing locations. It was found that ease of comprehension (based on differences in averages) descended in the order AR+map > map-only > AR-only. It is highly probable that the AR-only pamphlet had the lowest valuation because participants were unfamiliar with how to manipulate the pamphlet. It is believed that with the AR+map pamphlet, the locations of the sightseeing locations were conveyed in an intuitive manner. As such, the AR+map pamphlet was easiest to understand.

The interest in the locations (based on differences in averages) was found to descend in the order AR+map > AR-only > map-only. The map-only pamphlet failed in capturing interest when compared with the two pamphlets implementing AR.

We conducted another experiment to observe trends in brain activity and monitor any differences between the types of pamphlet. From the results, we can form the following conclusions for the combination of the map and AR.

1) In terms of spatial cognizance, combining AR with the map induced significantly less brain activity than using AR alone. We believe that this reduces stress on the brain.

2) In terms of working memory and grasping the significance/form of objects, a combination of AR and the map induced less brain activity than just one or the other alone.

3) The overall brain activity descended in the order AR-only > map-only > AR+map; this trend of brain activity applied to the whole brain.

From the above points, we see that the AR+map pamphlet created the least stress in inputting the significance and form of objects into the working memory, leading us to believe that the combination of AR and a map (when used to convey location information) is effective not just when applied to tour pamphlets.

VI. SUMMARY AND FUTURE PROSPECTS

We were able to grasp the features specific to each type of tourism pamphlet: one with a standard map, one with AR only, and one combining the map with AR.

We demonstrated that there was predominance particularly in the combination of the map and AR over the traditional map pamphlet. By conducting an experiment where we measured the participants' brain activities, we confirmed that the burden on spatial cognizance and working memory, and throughout the rest of the brain, was reduced with the map and AR combination. Additionally, we confirmed that the combination drew far more interest than the map-only pamphlet.

In previous practical studies of AR in foreign-language studies, the results for AR studies were much the same, demonstrating that AR allows for study with reduced stress. In our research, though we were able to demonstrate that combining map information and AR increased interest and reduced stress, there was much that we were unable to confirm, such as how long the information lasts in the mid-range memory.

We are also interested in the differences between AR devices, for example a PC, Smartphone and head mount display. The effectiveness of AR may depend on the device type. We are thus planning to conduct more studies in this realm of research.

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Experiential Adaptation to Provide User-Centered Web Content Personalization

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***Abstract*—Personalization of pages on the basis of each specific users' need is a key factor in navigating the Web, in particular for those users who browse under specific conditions. This paper proposes to track user's behavior and to gain his/her effective needs by means of machine learning concepts. Our goal is to provide a system which improves Web legibility and readability, customizing typographic characteristics of pages. The system lets users adapt Web pages and learns how to apply automatic personalization. This can be of great benefit both for users with reading-related disabilities and for users accessing with non-conventional devices.**

Keywords-Content Adaptation; Web Personalization; Profiling Users; Maching learning.

I. INTRODUCTION

Personalization is a key feature in providing services and content which are effective for users. Self-adaptation of Web pages is strongly overworked by Web 2.0 applications. Nevertheless, this issue is not usually exploited so as to meet specific user's needs, making the Web pages personalization (both in terms of content and shape) an interesting and unsolved challenge [8, 14, 16].

In this field, a more user-centered approach is necessary to customize Web page elements, adapting their shape with the aim of meeting each single user's needs. Such kind of approach can have a strong impact, in particular for those users with some reading-related disabilities (i.e., aging people, people with dyslexia, people with low vision, users with color blindness, etc.). Moreover, this approach can make the Web content more accessible even for those users who are equipped with devices with different capabilities (i.e., different screen sizes, different interactions systems), such as tablets, smartphones, smart TVs, etc. In these contexts, both readability and legibility are affected by Web pages characteristics [5, 12], users' abilities [4, 9] and device capabilities.

In order to make Web pages (or just some parts of them, such as paragraphs, headings, links, tables, etc.) more legible and readable to users with disabilities and to users who exploit different devices, transcoding and adaptation activities can be performed. Transcoding and adaptation have been strongly exploited in research field and they are usually driven by categorizing device capabilities and users' needs [1]. In this paper, we propose an innovative Web pages adaptation system based on the concept of experience-based transcoding, called "experiential transcoding" [2]. Comparing with more traditional forms of content transcoding and adaptation, the main advantage of experiential transcoding is that it is strongly user-centered. Furthermore, it applies techniques and mechanisms which adapt content on the basis of users' experience, by understanding and predicting it [13].

The main aim of this work is to improve Web pages legibility and readability by adapting some characteristics (such as font size, font face, luminance contrasts, and so on) according to users' preferences and needs. To reach this goal we have designed a system which lets users adapt Web documents, tracking users' behavior (on the basis of the device in use), so as to learn and model their preferences and to automatically provide the best adaptation, tailored for each user, predicting his/her needs.

In order to understand user's experience and to learn user's preferences, we have used a machine learning mechanism, the Reinforcement Learning [15] one, based on the idea of reward/punishment. Thanks to this, we can build and feed a user's profile which models his/her preferences in terms of Web page characteristics affecting his/her reading ability (both in positive and in negative ways). Thus, the Web content adaptation will be more user oriented, meeting each single user's need.

In this paper, we present the system we have designed and a prototype we have developed which can adapt HTML pages. The main advantage of our system is the deep and detailed user's profile we can gain: the system tracks the user's behavior and continuously updates his/her profile, (the more the user exploits it and the more the profile will be accurate). This lets the system take into account users' preferences and needs, even when they change. Moreover, this means that users are not categorized according their disabilities, but the system can provide Web content personalization for each single user. Without such adaptations a user's need can conflict with general best practice, or can conflict with another user's need. For instance, many people with dyslexia and other reading impairments need low contrast between text color and background color [9], while many people with low vision and many people with declining eyesight due to ageing need high contrast. On the contrary of other similar works, in which the entire content is customized according to user's preferences and needs [7, 8, 9, 11, 16], our system adapts only those elements in the Web page which present some characteristics that can affect the user's reading, without

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distorting the whole page and its layout. Currently the prototype is under a testing phase by simulating users with low vision and dyslexia. An evaluation campaign with real users will be conducted next months: this will report users' appreciation, the ease of use of the prototype, and the validity of our approach.

The remainder of the paper is organized as follows. Section 2 presents the system structure and it describes in details each system modules: the users profiling, the users' preferences learning and the adaptation ones. Section 3 shows the prototype we have developed. Finally, Section 4 concludes the paper presenting further work.

II. SYSTEM STRUCTURE

In this section, we are going to describe our system structure, which includes: the users profiling module, the users' preferences learning module and the adaptation module, as depicted in Figure 1. Each module is described in details in the following subsections.

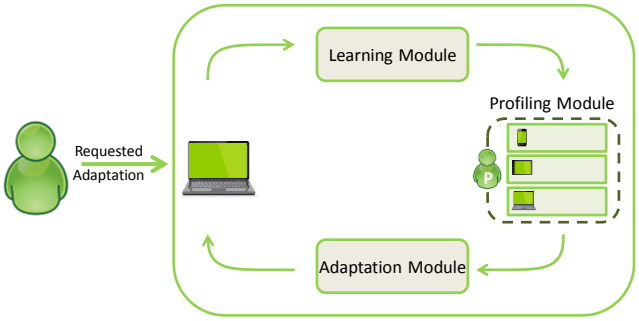

Figure 1. The whole system.

A. Users Profiling Module

Profiling users is an activity which can be useful in several contexts and applications, such as user interfaces and Web applications (i.e., recommendation system in e-commerce Web sites, personal data in social networks or in search engines filters, and so on). Data gathered in users' profiles can range from personal data to contextual conditions, from user's skills to his/her personal preferences [10]. Such data can be collected in different ways, for instance the user can explicitly declare them or they can be learnt by the system as the user exploits it.

In our system, the user profile is a collections of typographic characteristics gathered by the system (as described in the following Subsection 2.B), on the basis of adaptations (see Subsection 2.C) the user has requested in so as to improve Web content legibility and readability. Such a profile is shared among all the devices the user exploits and it takes into account different user's needs according to capabilities of the device in use (i.e., different display size, etc.).

When the user exploits the system and asks for adaptations, our system computes automatic adaptations and related reward/punishment values, tracking the user's behavior. Periodically, the system updates the user's profile, adding new characteristics, updating reward/punishment values for the already existing ones or adding new characteristic values as requested by the user.

The system provides adaptations as state changes: from the original one (let us call it A) to the adapted one (let us call it B), according to each user's request. Let us use the following formalism to indicate the state change from the original state A to the adapted state B: A→B.

Characteristics of state A (which are substituted by characteristics of state B) are the ones the user has discarded, while characteristics of state B are the ones the user has chosen. Hence, the system learns all the Web page characteristics which affect user's reading ability (both in positive and in negative ways). Obviously, the user's profile will be the more accurate the more the user asks for adaptations. As described in the following subsection, the system punishes discarded characteristics, while it rewards characteristics the user has chosen through the requested adaptations.

We have designed an xml-based profile which is structured in different parts, according to the devices the user exploits. In each of these parts, the system stores typographic characteristics (as tags) the user has preferred or the user has discarded, the related value (as the "**v**" attribute) and a number (as the "**w**" attribute). Such a number states the reward/punishment related to the adaptations asked by the user.

In fact, the "**w**" value varies according to user's behaviors and in particular:

- if "**w**" is < **0**: the user has discarded the characteristic with the related "**v**" value;
- if "**w**" is > **0**: the user has asked for the characteristic with the related "**v**" value;
- if "**w**" is = **0**: the characteristic with that "**v**" value has obtained the same quantity of rewards and punishments.

The absence of a characteristic or of a specific "**v**" value in the user's profile, means that the user has never asked for such characteristic adaptation or he/she has never discarded or chosen such a "**v**" value.

Hence, the profile is composed by a set of Web page characteristics the user has adapted and by the related values he/she has asked and discarded, grouped by the devices the user exploits. For each device, the profile stores the type, an id value, the display width and the display height (in terms of pixel). The device in use is deduced by the HTTP request and its capabilities are collected from repositories [17].

The Web page characteristics our system takes into account are related to text and to content features which can affect both legibility and readability [5, 12]. Typographic characteristics are related to fonts (i.e., face, size, style), spaces (i.e., word and letter spacing, margins, line height, alignment) and colors (i.e., background, foreground and luminance ratio) [4], while content characteristics are related to acronyms, abbreviations and foreign words or sentences.

Figure 2 shows a fragment of a user's profile, as an example. Web page characteristics are grouped by a tablet

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device. In such an example, the user has asked (among all the adaptations): Arial as font face, 18 as font size, and 1.5 as line height. In the same example, the user has discarded: Times new roman as font face, 9 as font size and 1 as line height, while he/she has used the tablet.

```
…
<device type="tablet" id="2" display_width=""
display_height="">
        …
        <font_face family="sanserif" w="5"
          v="arial"/>
        <font_face family="serif" w="-2" v="times
        new roman"/>
        <font_face family="monospace" w="-5"
        v="courier new"/>
        …
        <font_size w="8" v="18"/>
        <font_size w="-5" v="9"/>
        …
        <line_height w="5" v="1.5"/>
        <line_height w="-2" v="1"/>
        …
</device>
…
```

Figure 2. A fragment of a user's profile.

B. *Users' Preferences Learning Module*

In order to learn users' preferences, our system has been modeled by using the Reinforcement Learning concept. The learning algorithm adopted is the Q-learning algorithm [15]. Q-learning is a popular Reinforcement Learning algorithm which works by estimating the values of state-action pairs. The value *Q(s, a)* is defined to be the expected discounted sum of future payoffs obtained by taking action *a* from state *s* and following an optimal policy thereafter. Once these values have been learned, the optimal action from any state is the one with the highest Q-value. Q-learning works by successively improving its evaluations of the quality of particular actions at particular states. The system learns the Q-values as the user exploits it. Then the system uses the learnt Q-value for making better decision about possible adaptations when the user requests a Web page. Q-values can thus provide estimation of how successful that action might be. The Q-learning algorithm has been already used in several works, where systems have been design to provide customizations according to learnt users' preferences [11].

Our work focuses on directly interacting with the user to learn his/her preferences. In fact, the user contributes by helping the system which tracks the user's behavior to adaptations. In particular, the system obtains some feedbacks from the user, in the form of reward or penalty.

This problem has to be formulated as a Reinforcement Learning problem. In order to do this, we have to set up states, actions and rewards. States represents sets of Web page characteristics (font face, font size, word spacing, line height, acronyms expansion, and so on). Actions are the adaptations explicitly requested by users, the adaptations proposed by the system and the adaptations the system automatically performs. Rewards are related to user's behavior: if the user explicitly applies an adaptation or if the user accepts an adaptation the system proposes, then the reward for the chosen characteristics is +1. If the user rejects an adaptation the system automatically performs then the rewards is -1. A -1 reward is assigned also to those discarded Web page characteristics as well.

Hence the whole system works in the following way:

1. when the user opens up a Web page, the system parses its characteristics, taking into account the user's profile.
2. If there are some characteristics the user has discarded (with a negative "**w**" value, state A), then the system computes if automatically adapting such characteristics, substituting the original values with the ones the user prefers (with the highest "**w**" value, state B) or just proposing such adaptations, changing the state from A to B (A→B).
3. Then the user exploits the Web page with a specific set of characteristics (state B): font size and face, spacing, alignment, background and foreground colors, acronyms, and so on.
4. The system computes reward/penalty values tracking user's behavior, according to his/her feedbacks:
   - If the user ignores the adaptations the system has automatically performed (hence the user implicitly accepts state B characteristics), then the reward is +1. Else, if the user rejects such adaptations then the reward is -1.
   - If the user explicitly accepts the adaptations the system has proposed (characteristics in state B) then the reward is +1. Else, the reward is -1.
   - If the user applies a certain adaptation to a certain set of Web page characteristics, changing from original A state to the adapted B one (A→B) then the system assigns +1, as a reward, to the requested characteristics (in state B) and -1 to the discarded ones (in state A).
   - Unchanged characteristics in state A and in state B receive no reward.
5. Updated rewards and/or Web page characteristics adapted for the first time are stored into the user's profile.

As an example, let us take into account a user who exploits his/her PC and asks for a paragraph font size increase in a Web page, from 10 to 18 pixel. The system assigns +1 as reward to font size 18 (B state) and -1 as reward to font size 8 (A state).

After updating the user's profile, when the user opens up another page, the system parses the characteristics and finds a paragraph with font size 10. Such a characteristic is stored in the profile with a negative "**w**" value (let us consider the user's profile depicted in Figure 2). In this example, we can have the following system behavior:

- if **t < w < 0**: the system proposes to adapt such a characteristic by substituting it with the "**v**" value with the highest "**w**" (font size 18, with "**w=7**") only on the

mousehover event. The user can accept such a proposal, then the system assigns a +1 reward to font size 18 (the new "**w**" value will be 8) and a -1 reward to font size 10 (its new "**w**" value will be -5), else the system assigns a -1 reward to font size 18 (its new "**w**" value will be 6);

- if **w < t**: the system automatically adapts such a characteristic by substituting it with the characteristics with the highest "**w**" value (again font size 18, with "**w=7**"). If the user rejects such an adaptation, then the system assigns a -1 reward to font size 18 (the new "**w**" value will be 6), else the system assigns a +1 reward to font size 18 (the new "**w**" value will be 8) and a -1 reward to font size 10 (its new "**w**" value will be -5);

where **t** is a specific threshold. Such a threshold is a negative integer value which can be differently set for each characteristic. At the moment, we are conducting a testing phase to define such thresholds for the most common characteristics.

In this example, the system proposes the same adaptation even when paragraphs with smaller font size are found in the Web page. For instance, the system can propose adaptation to font size 18 even for paragraphs with font size 8. More generally, the same consideration is taken into account also for those characteristics with numeric values, such as luminance ratio, color contrasts, word and letter spacing, line height, etc. Hence, if the user has discarded a characteristic with a specific numeric value, the system learns to adapt such characteristic with worse values.

C. Adaptation Module

Content adaptation is the action of transcoding or transforming content so as to meet users' preferences and needs, even according to the device he/she is using.

In our system, we provide content adaptations with the aim of improving Web pages readability and legibility. In our system, the adaptation process is in charge locally, on the client side. The system can locally decide and employ the most appropriate adaptations, according to user's profile, which is fed on the basis of the user's behavior.

The aim of the whole work is to adapt any kind of markup document, such as LaTeX, PDF, RTF documents, etc. But currently the system works on explicit and descriptive markup documents, in particular HTML pages. Our system performs adaptations by changing tags, attributes and related values: the system injects new tags or attributes and/or it substitutes original tags or attributes value with the customized ones, changing markups.

When a user opens up a Web page, then the system parses the DOM and the related style rules, by considering those characteristics with a negative "**w**" value in the user's profile. If such characteristics are found in the page, then the system decides if automatically adapting them (if the "**w**" value is less than a threshold "**t**") or if just proposing to the user such an adaptation (if the "**w**" value is greater than "**t**"). The discarded characteristics are substituted by the "**v**" values with the highest "**w**": since the user has chosen them the most (to improve his/her reading ability), so we can assume these are his/her preferences in terms of such characteristics.

For instance, let us consider the user's profile depicted in Figure 2. If the user opens up a Web page and the system finds a paragraph written in Times New Roman (with "**w**" equal to -7), then the system proposes an adaptation from Times New Roman to Arial as font face. The system chooses Arial instead of Verdana, because Arial "**w**" value is higher than Verdana one.

A list of adaptations the system can employ is the following one:

- *Zooming font size*: the system can increase font size by a specific percentage or unit.
- *Changing font face*: the system can substitute the original font face with another one.
- *Changing font style*: the system can set a specific style (i.e., italic, underline or normal) to the text.
- *Changing spacing*: the system can change spacing-related attributes (i.e., letter spacing, word spacing, line-height, margins, paddings, etc.).
- *Changing text alignment*: the system can set users' favorite text alignment (left, right, center or justify).
- *Enhancing luminance ratio*: the system can increase the luminance ratio. The system keeps the same background color and computes a new foreground color, so as to enhance the luminance contrast ratio.
- *Changing background and/or foreground colors*: the system can set different background and/or foreground colors, according to users' choice.
- *Language translation*: the system can substitute original words and/or sentences in translated ones.
- *Acronyms expansion*: the system can substitute acronyms with their related expansions.

III. PROTOTYPE

We have designed and developed a prototype of our system which adapts HTML documents. Such a prototype has been implemented as a Firefox extension. Users can activate a contextual menu to set the preferred adaptations on an HTML page. Then the system performs such adaptations by suitably changing the HTML and/or the CSS code of the page, on the client-side. In the meanwhile, the system tracks users' behaviors with the aim of learning their preferences and then automatically applying or proposing suitable adaptations.

This prototype has been implemented as a Firefox add-on by means of Mozilla SDK [6]. Scripts have been created so as to:

- provide an ad-hoc contextual menu, letting users choose among a sub-set of available adaptations (as shown in the screenshot depicted in Figure 3): changing font face changing font size, and changing background and foreground colors.

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- Adequately modify the DOM of the HTML page, injecting new attributes or changing values for the already existing ones. In particular, the prototype can add "`style`" attributes with CSS rules to the element tag or can change the existing CSS rules values, according to the adaptations the user has requested. This way, thanks to CSS cascading feature, customized values of inline rules override the same ones eventually declared in external or internal CSSs.
- Add scripts to create and activate pop-ups: when an adaptation is just proposed to users, this is triggered on the mousehover event, by means of AJAX scripts.

Currently, the prototype has been tested on laptops (equipped with different operating systems) and on Samsung Galaxy Tab 2 devices, equipped with Firefox browser. More browsers extensions are needed and are under development (i.e., for Chrome, Internet Explorer, etc.), so as to provide a wider and more complete system.

Figure 3 shows a screenshot of a Web page with the contextual menu of the prototype we have developed: after activating such a menu, it is possible to zoom in, to zoom out, to change the font family, to change the background and foreground colors of the specific element the user has chosen (which is highlighted by means of a colored border).

Figure 4 depicts a screenshot (of the same Web page in Figure 3), when an adaptation is proposed to the user: a pop-up is activated only on the mousehover event on the element the system proposes to adapt. The user can accept or reject the proposed adaptation, providing a feedback and letting the system learn about his/her preferences.

Figure 5 shows a screenshot (of the same Web page in Figures 3 and 4), when the chosen adaptation is automatically performed. In particular, the text in the chosen element has been increased from 16px to 24px, by means of zoom in adaptation. Screenshots in Figure 3, 4 and 5 have been taken from a PC equipped with Ubuntu 13.04 and Firefox 21.0.

A synchronization mechanism is still under development: synchronization among different devices used by the same user is needed so as to let the user enjoy customized Web pages on the basis of his/her preferences and of different device capabilities. Figure 6 shows the whole system architecture. Currently, each user stores his/her profile, structured in device-related profile sections (as reported in subsection 2.A), on each device he/she is using. Updates to the user's profile are locally stored (on the device in use) and a synchronization mechanism is needed to spread such updates on the other copies of the profile. The different copies of the profile have to be periodically synchronized. All the profiles will be stored on the server side. The copy of the profile stored on the server will be used in case of new devices associated to the same user: when a new device joins the system, the user's profile will be downloaded from the server and a new profile section will be added to all the copies of the profile, via the synchronization mechanism.

Figure 3. A screenshot showing our contextual menu.

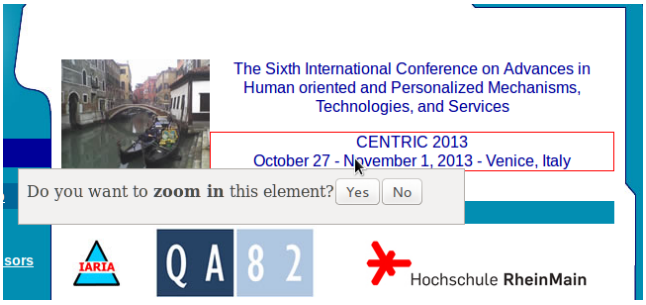

Figure 4. A screenshot showing an adaptation proposal.

Figure 5. A screenshot showing an adapted element.

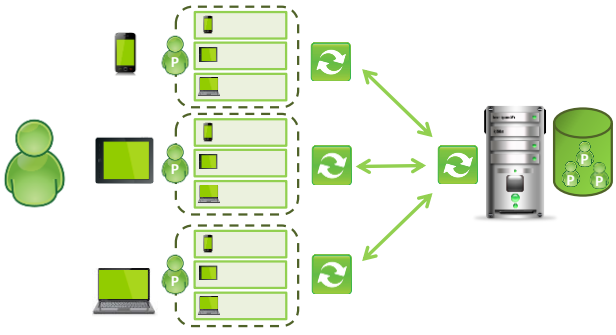

Figure 6. System Architecture.

IV. CONCLUSION AND FUTURE WORK

Our work on improving Web pages legibility and readability by means of experiential transcoding (learning user's profile by tracking his/her behavior) is still under

development, however we have presented in this paper the system we have designed and a prototype we have developed. The goal of our system is to adapt Web page characteristics (such as font size, font family, colors, luminance contrasts and so on) according to users' preferences and needs. The system we have presented lets users adapt such characteristics and tracks users' behavior with the aim of learning their preferences, so as to automatically provide the best adaptations, tailored for each single user, even on the basis of the exploited devices (PC, tablet, smartphone, smart TV, etc.).

Further work is needed to develop extensions and/or adds-on for the most commonly-used browsers (i.e., Chrome, Internet Explorer, etc.) and for other kinds of documents viewers and readers, letting the system adapt not only HTML pages, but also other markup documents (i.e., LaTeX ones). Moreover, further investigation is needed so as to adapt also PDF documents: some researches have been conducted studies on how to customize text characteristics on tagged PDF documents [3]. In order to provide a wider range of adaptable documents, these findings will be taken into account in our future work.

A system testing phase is ongoing. This is important to define suitable thresholds **t** for each document characteristic (in order to support the system in deciding when automatically adapt or just propose a specific adaptation). Finally, a user testing phase is needed and it would involve several users with different preferences and specific needs (i.e., aging people, users with low vision, users with dyslexia, users with color blindness, etc.) equipped with different devices.

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Development and Evaluation of a Rehabilitation Program using Kinect™ Motion Capture Technology

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***Abstract*—A rehabilitation program was developed and applied using the recent development of Kinect motion capture technology. We tested the use of Kinect in the rehabilitation of people with physical disabilities (the elderly in our case). The rehabilitation takes advantage of Kinect without requiring a controller and the intuitive use of Kinect through physical gestures. Evaluation of an improved program in a second test identified new ways of using Kinect in future tests and as an exercise aid for the test subjects. Survey results collected following the tests indicate that many subjects were interested in the program as a new application, and the program encouraged exercise by reminding the subjects of when they were young.**

***Keywords*—Rehabilitation Program; Motion Capture; Kinect; Elderly; Nursing**

I. INTRODUCTION

A. Background

In recent years, it has become increasingly common to use motion capture technology for the movement of characters in three-dimensional (3D) movies and video games. This technology allows for the movements of humans in real life to be read by a computer. Since these data are a reproduction of the movements of actual humans, the recorded movements are extremely real.

Motion capturing is performed by attaching sensors to joints of the human body. Receiving sensors, such as those in cameras, record signals from the attached sensors and send them to a computer to be converted into digital data. By assigning the movements of each sensor to the joints of a computer-created person, it is possible to make the computer-created person move in the same way as an actual human.

However, using motion capture technology requires a wide space for filming and much technical machinery, such as cameras and computers, and it is thus not easy to use from a financial point of view.

In 2010, the public started using Kinect™ [1]. Once the potential of Kinect, which uses motion capture technology, was identified, Kinect was modified for use on computers.

The Kinect for Windows® software development kit (SDK) was officially released as a tool for personal computer (PC) development, on the prerequisite that it was not to be used for commercial purposes. As a result, Kinect is currently being used as a motion capture technology in various research fields, e.g., research on games and video, nursing and medical care.

B. Kinect

Kinect is an interactive system that allows the control of video games without the use of a controller. It is a peripheral for the Xbox 360 released by Microsoft that allows for intuitive control using gestures and voice recognition as shown in Figure 1. The word “Kinect” is a combination of the words “Kinetics” and “Connect”.

Figure 1. Kinect Source: XBOX360 Kinect [1]

Kinect was released by Microsoft in 2010. At that time, the Nintendo Wii, which was released in 2006, had opened up a new games market with its controller that used physical motions for controls. Users then found alternative uses for the interactive game systems. One of the biggest differences between Kinect and the Wii is that Kinect does not require the player to hold a controller, and it is possible to move characters in the game simply by making physical motions. Both consoles use motion capture technology. The Wii reflects the player’s movements in the game by performing detection along three axes: pointer movement (through acceleration), changes in movement and inclination via the motion sensor built into the controller and pointer detection using infrared light. Kinect uses a number of sensors and processors and does not need to attach markers to the body. Therefore, it can reflect movements in the game by estimating and constructing indirect parts on acquired skeletal images and using these to track movements in real time.

C. Past research

Much research has been performed in the medical field employing motion capture technology that uses Kinect.

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1) Navigation support for the visually impaired

The Human-Computer Interaction group of the University of Konstanz in Germany is conducting a navigation support project for the visually impaired [2]. The project aims to provide aid for the blind as they walk down hallways, ascend and descend stairs, and open doors, using Kinect as a sensor.

This project involves scanning an environment with Augmented Reality using Kinect and then recognizing that environment. A system voice then tells the person wearing the device the distance to the next object (such as a door or staircase). By tying a device containing a vibration motor linked to the Kinect around the waist, it is possible to prevent the wearer from bumping into obstructions by physically (tactually) notifying them of danger, using vibration that becomes increasingly strong as the wearer approaches the obstruction in question.

2) NAIST Ballpool

Hiroyuki Funaya of the Doctor's Course in Information Science and Technology at the Nara Institute of Science and Technology developed an application (app) called "NAIST Ballpool" [3], taking advantage of the fact that Kinect does not require a controller or the user to own a videogame console or computer. This app provides an exercise in which Kinect is used to move a robot displayed on a screen to touch a ball. The app was used in a retirement home [4] by residents aged 80–90 years. When asked what they thought of the experience, they said it was "fun". Kinect is used to reflect physical movements on a screen, allowing the body to move freely in a virtual sense. However, the retirement home residents reported problems in implementing Kinect. First, "when using the Kinect for input-based controls, 3D input is not necessarily appropriate for two-dimensional display." For example, when Kinect is used *in lieu* of a mouse, the arms must be continuously raised to perform input commands. This activity is tiresome compared with using a mouse controller, which allows easy input using only the fingers. Second, "when using the Kinect, there is nothing for the user to touch, so there's no physical feedback." This is because physical movements are reflected on a screen and there is no sense of being in control as there is no tactile feedback.

D. Kinect for Windows SDK and the Sample Shape Game

Microsoft initially stated in the Kinect instruction manual that Kinect should not be used to control a PC itself, but they acknowledged the use of Kinect on PCs for non-business purposes, provided that the internal algorithms would not be altered and that Kinect would not be used for the manipulation of Xbox games. Microsoft officially released a beta version of "Kinect for Windows SDK" (a program development kit for running the Kinect on a PC) on June 16, 2011 [5][6].

Kinect for Windows SDK contains a "Skeletal Viewer" and "Sample Shape Game" as sample programs. These were constructed in a basic program that allowed Kinect to be used on PCs, and provided a simple experience demonstrating the abilities of Kinect.

The Skeletal Viewer allows the display of depth images and color images, recognition of two people and indirect recognition of each person. Thus, source code from the Skeletal Viewer allowed users to study the basics of how to program and use Kinect for Windows SDK.

In the Sample Shape Game, the player must touch falling objects with his/her body to score points. It also supports voice recognition, allowing the player to control the game with commands such as "Reset" and "Faster". However, to make use of the voice recognition function, a voice recognition framework must be installed.

E. Purpose and approach of this paper

The purpose of this paper is to evaluate the effectiveness of Kinect application as the rehabilitation program. Subjects in a nursing home played the Sample Shape Game program included in the Kinect for Windows SDK. We then asked which areas of the game they would like to see improved using questionnaire. Based on their request we made improved version of application and then had them play the improved version. After they experienced improved version, we asked questionnaire again to evaluate the effectiveness.

F. Composition of this paper

The first section covers the background that brought us to undertake our present study, existing challenges, past research, and the objective of the paper. The second section introduces the developed program. The third section discusses how an evaluation test was conducted. The fourth section presents the results of each test performed in the third section. The fifth section discusses observations related to the results obtained in the previous section. The sixth and final section summarizes the work and discusses future research.

II. DEVELOPED PROGRAM

A. Development environment

We installed Kinect for Windows SDK on a PC so that Kinect could be controlled using the PC. The development/implementation environment was as follows.

PC System: FMV - F8370
CPU: Intel® Core™ 2 Duo CPU T8100 (2.1 GHz)
Memory: 2.00 Gb
OS: Windows 7 Professional

Furthermore, we used Microsoft Visual C# 2010 Express as a development tool to implement improvements in the

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Sample Shape Game program used in this test. Improvements were made according to survey results collected after test 1 (described below).

B. Falling objects

The size, type and drop rates of falling objects were not originally programmed with our test subjects in mind, so we made the objects simpler and bigger and reduced the drop rate. The program was changed as follows.

```
    public void SetSize(double f)
{   baseShapeSize = f
    shapeSize = sceneRect.Height*
                    baseShapeSize / 1000.0;  }
public void SetDropRate(double f)
{   dropRate = f ;  }
```

- Changed underlined value:
  - 1000.0 → 500.0
- Increased size of falling objects
  - dropRate = f → dropRate = f/2

To simplify the objects, we changed the poly types to circular objects, such as circles and bubbles. Figure 2 shows the results of our changes.

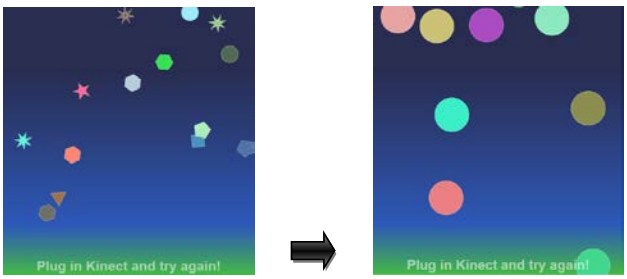

Figure 2. Screen captures from the original program (left) and the changed program (right).

C. Projecting the player on the game

Originally, the top right of the main game window displayed a tiny player image entered via the Kinect camera. We decided to make the player image the same size as the full window by overlaying the player image on the main game window. When we superimposed the Kinect camera image of the player on the game window, we encountered a problem that only the camera image was being displayed, and the game screen was not visible. Therefore, to make it look as if the player was transported into the game, we made the image from the Kinect camera semi-transparent and superimposed the camera image onto the skeletal frame-based image. The program was changed as follows.

```
<Image Name="video" Opacity="0.5"
  Margin="12,50,12,12" HorizontalAlignment="center"
  Width="504" Height="550"
  VerticalAlignment="center" />
```

By changing the opacity value from 1.0 (non-transparent) to 0.5 (semi-transparent), the player image was projected onto the game window. The semi-transparency meant that the screen images were slightly difficult to observe, but the result was adequate for our purposes.

D. Final program

The results of the changes and improvements of the program in Sections 2-B and 2-C are shown in Figure 3.

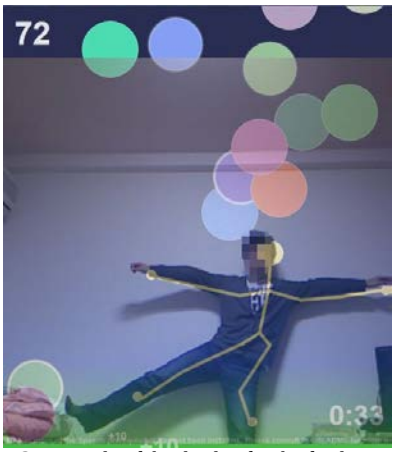

Figure 3. Example of the display for the final program.

We were, thus, able to improve the program in terms of the falling objects and the superposition of the player image from the Kinect camera onto the game screen. The improved program was used and evaluated in test 2 (described below).

III. EVALUATION

A. Test 1: Sample Shape Game experience

1) Purpose of test 1

Elderly people living in nursing homes who do not usually exercise and people who require day services were asked to participate in the test. Both the subjects and their exercise instructors played the Sample Shape Game. This formed the basis of the test. We asked the subjects and their exercise instructors for their opinions and thoughts on how the program should be improved for test 2.

2) Test subjects

Seven people receiving day services and one exercise instructor were enrolled from the Suwa Central Hospital Union Nursing Home *"Fureai no Sato"*.

3) Materials

The following materials were used.

– Kinect
– one laptop PC

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– one projector
– the Sample Shape Game.

4) Procedure

On the day of the test, people who receive day services in the nursing home facility were asked to play the Sample Shape Game for about 30 minutes. We then asked them which aspects of the program they would like to see improved.

5) Comments and Opinions of the subjects

The thoughts/opinions/requests we received from the people who experienced the game were as follows:
– The game should display the actual person as recognized by the camera, not just a skeletal frame.
– The falling objects should be more interesting (e.g., money or strawberries).
– The falling objects should be larger.
– There should be recognition of wheelchairs (which are not detected properly).
– There should be selectable levels of difficulty.
– There should be familiar music (without music, there is little desire to play).

B. Test 2: Playing the improved Sample Shape Game

1) Changes from test 1

The following changes were made to the Sample Shape Game:
– Changes were made to the falling objects.
– Changes were made to the size of the falling objects (they were made twice as large).
– Changes were made to the type of falling objects (they were changed from squares, triangles, and stars to just circles).
– The falling rate was reduced and the intervals between falling objects were increased (by a factor of 2).
– The players themselves were projected into the game by superimposing the player image captured by the Kinect camera (originally displayed in a small window at the top right of the screen).

2) Purpose of test 2

We made changes to the Sample Shape Game according to the feedback we received from test 1, and we had the subjects play the improved version and take a survey afterwards. We used the results to study the usefulness of a program using Kinect in rehabilitation.

3) Test subjects

Seven people receiving day services (different subjects from test 1) and one exercise instructor were enrolled from the Suwa Central Hospital Union Nursing Home "*Fureai no Sato*".

TABLE 1. NUMBER OF SUBJECTS THAT VISITED FOR DAY SERVICE CATEGORIZED BY AGE AND NURSING LEVEL.

Age	**Number of subjects**
70–74	1
75–79	2
80–84	5
85–89	7
90–94	3
Nursing level	**Number of subjects**
1	2
2	4
3	4
4	4
5	2
Support Required	2

On the day of the test, as shown in Table 1, 17 people came to the facility to receive day services. Seven subjects and one exercise instructor experienced the program.

4) Materials

The following materials were used:
– Kinect
– Two laptop PCs (one for connecting the Kinect, and the other for connecting speakers and playing music)
– The improved version of the Sample Shape Game produced by our group
– Two audio speakers
– One projector
– One music compact disc (the best of Bon festival dance)
– Survey forms
– Writing material

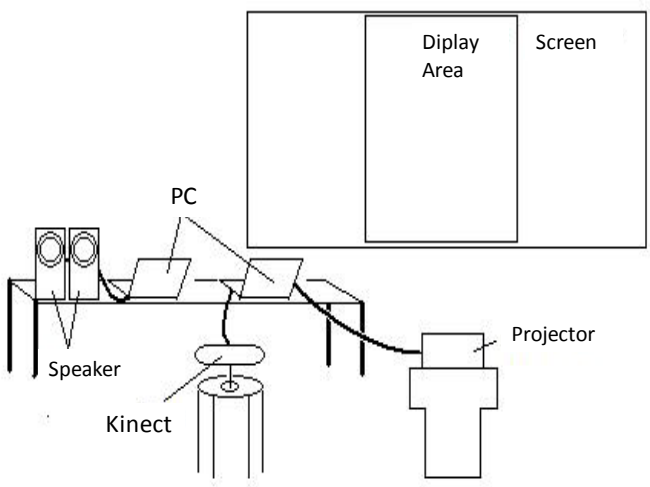

Figure 4. Configuration.

The speakers were connected to one PC to play music, and the other PC was used to connect the Kinect and the

projectors as shown in Figure 4. The projector was used to display the combination of the game screen and the image obtained from the Kinect camera on the main screen.

5) Procedure

We returned to the facility where we performed test 1 so the subjects could experience the improved Sample Shape Game. In test 2, we played music during the test, in response to the subjects' opinions in test 1. Since we used different subjects for test 2 and the testing time was restricted, we did not compare the program before and after improvements.

Figure 5. Test subjects experiencing the improved program.

Subjects used the improved program, as shown in Figure 5, and then filled out a survey, in which they were asked to provide a five-level evaluation (from "I agree" to "I disagree") in response to five statements: "The game was easy to use", "The game helps me exercise", "I want to play again", "There should be music" and "The size of the objects was appropriate".

IV. TEST RESULTS

A. Results and observations for test 1

As stated above, the thoughts/opinions/requests we received from subjects who played the game in test 1 were as follows:

– The game should display the actual person as recognized by the camera, not just a skeletal frame.
– The falling objects should be more interesting objects (e.g., money and strawberries).
– The falling objects should be larger.
– Wheelchairs should be detected properly.
– The player should be able to select the level of difficulty.
– Familiar music should be played.

Subjects wanted to see themselves projected in the game instead of a skeletal frame, suggesting the skeletal frame, which appeared inorganic, did not make them feel as if they were directly participating in the game.

Some subjects wanted more interesting objects to fall, but since the original program only contained very simple shapes such as circles and triangles, it was difficult to change the shapes into specific objects; we thus decided to use only one shape. The size of the objects was changed by adjusting some values in the program, but since this would increase the density of objects on the screen, we changed the speed and number of falling objects accordingly.

During the survey to determine which points required improvement for test 2, we encountered a problem not directly related to the program. Some subjects were wheelchair users, and they experienced problems in terms of being recognized by the game. Probable causes for this are that the game was not played within an area most suitable for using Kinect and that the armrests of the wheelchairs were mistakenly recognized as human arms.

We did not think of using music when we designed the test, but subjects suggested that music was necessary to make them want to exercise. Therefore, we decided to use traditional Japanese Bon festival music, such as "Tankō Bushi", to provide music familiar to people of the subjects' age.

B. Results and observations for test 2

Test 2 involved a survey with a five-level evaluation (from "I agree" to "I disagree") in response to five statements: "The game was easy to use", "The game helps me exercise", "I want to play again", "There should be music" and "The size of the objects was appropriate". The results are given in Table 2.

TABLE 2. SURVEY RESULTS

	Evaluation				
Item	**5**	**4**	**3**	**2**	**1**
Game was easy to use	5	1	0	1	0
Game helps me exercise	2	3	2	0	0
I want to play again	5	1	0	1	0
There should be music	7	0	0	0	0
Size of objects was appropriate	7	0	0	0	0

The results are summarized as follows.

1) The game was easy to use; mean score: 4.4

The controls were simple, as the subjects only had to move their arms and legs to score points, and the subjects were thus able to get used to the game relatively quickly. Sometimes the skeletal frame was not properly detected, resulting in the subjects not being able to control and play the game.

2) The game helps me exercise; mean score: 4.0

This statement referred to the question of whether the subjects felt the game helped them exercise. The results varied slightly, but several subjects felt that the game would be a good incentive for exercise.

3) I want to play again; mean score: 4.4

Several subjects mentioned that the game reminded them of being younger and that they would like to play again.

4) There should be music; mean score: 5.0

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We did not use music during test 1, but in response to the opinions received during test 1, we played songs the subjects were familiar with, such as Tankō Bushi and Sōran Bushi, during test 2, resulting in the subjects being more motivated in their participation.

5) The size of the objects was appropriate; mean score: 5.0

We doubled the size of the falling objects in the original program to make them easier to recognize. There did not seem to be any particular problem in recognizing the objects and there were no negative opinions.

Comprehensive evaluation of the five statements demonstrated that the game was easy to control and that it enabled the subjects to exercise by being reminded of when they were younger. It also demonstrates that playing music leads to more motivated participation and that feedback was generally positive.

When evaluating the desire to play again, it is important to take into account that the skeletal frames were not always properly detected and that the subjects might become bored with the game over long periods. We did not survey this point in the study.

The following positive and negative comments were made by the respondents outside of the five-level evaluation.

Positive points
– The game is a good incentive for exercise.
– The game reminded me of my younger self.
– The game gives me something to focus on.
– The game enabled me to move my hands again by reminding me of when I was younger.
– The game is nice in that the colors change.
– The game reminded me of when I played basketball.
– The game is good for exercise.

Negative points
– I was not used to the game, so the movements were a bit difficult.
– I did not have a good impression of the game because it did not display me properly (the skeletal frame was not properly detected).
– The game responded too slowly.
– It would have been nicer if the game moved in accordance with the music (permitting dancing).
– There should have been more variety in the falling objects.

One opinion that was particularly prevalent was that the game reminded the subjects of being younger, allowing them to move their bodies freely again. It is likely this was due to (1) increased motivation to move associated with their interest in new things (the Kinect system) and (2) music they were familiar with was being played.

Some subjects were not able to evaluate the game properly because their skeletal frame was not correctly detected. Most of these subjects were wheelchair users, implying that the problem was due to Kinect not being able to distinguish armrests from arms and therefore failing to recognize a proper skeletal frame.

V. OBSERVATIONS

The nursing home facility usually has a 45-minute recreation session in the afternoon, where the elderly exercise by participating in bread-eating contests, playing balloon volleyball in which they move their arms in fan-like motions, or playing on a Wii (Wii Sports, Wii Fit). They also perform exercises that involve balancing, stretching, getting up and walking as a pastime while waiting for other people to finish their morning baths. In contrast to the kind of rehabilitation performed at hospitals, which is aimed at recovering a person's motor functions (such as going to the bathroom alone) by practicing movements necessary for daily life, at the nursing home, rehabilitation involves the functions the person still possesses. Regarding the differences between the two kinds of rehabilitation, we received comments from the exercise instructors including "It's good that they can use their whole bodies without the use of objects" and "The movements have been made slower, so it is different from things that are made for slightly younger people, like the Wii, and it provides a more comfortable exercise for people who cannot move quickly, such as the elderly." As these comments show, the game was more playable for the elderly subjects in test 2 than those in test 1 by adjusting the rate and speed of the falling objects to be lower than those in the original program.

Next, we considered the opinions received in the survey. These opinions suggested that some of the subjects required a long time to get used to the controls, but since the movements were very simple, it did not take long to understand the game in general. Many subjects also stated that being able to remember their younger selves made them able to move their bodies again. It is likely that the music played at the time played a large part in this. Subjects stated that this program offered a new experience for the subjects, and we were able to get them interested and move their bodies actively because of this. However, this only reflects their evaluation of the program when first experiencing it. It is possible that they will be less interested with the program, if they use it numerous times. The program itself involves touching round objects that fall from above to earn points, but there is no fixed play time, and the same objects fall down (even if they change color). Therefore, there is not a lot of visual variety and subjects may become easily bored with the game when playing it repeatedly or for long periods. Regarding detection of the skeletal frame, recognition was insufficient during test 1. Several people experienced problems in having their skeletal frames detected because the distance from Kinect to the subjects had not been adjusted to the number of people present, and the test location was too bright. Also, sometimes Kinect had trouble discerning between the armrests of a wheelchair and the arms of the person in that wheelchair. However, in test 2,

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detection of the skeletal frames was improved, because we had a better understanding of the optimal distance between Kinect and the test subjects.

A comprehensive evaluation of the results from test 2 showed that most suggestions received in test 1 were properly implemented in the revised program. Thus, test 1 allowed us to improve the game so that subjects could perform reasonable exercise, and disregarding the problem of experiencing the same program continuously, the program was fresh and new and stimulated the subjects. In addition, the game was relatively easy for the subjects to understand because of the intuitive controls of Kinect.

When comparing our program using Kinect with the Wii, we suggest that Kinect is more useful for rehabilitation programs, because it is easier to perform exercise with the easy controls, and because the movements can be slowed to the subjects' requirements.

VI. FUTURE WORK

We asked the instructors who participated in test 2 what they would like to see changed in the future. The following comments were received:

– The program should change as time passes.

– It might be fun if the objects came in from the sides as well from above.

– There should be more room for competition.

– The game should stimulate the subjects to bend their bodies and stretch their arms sideways by having the objects center on the subjects at first and then gradually fall in from the sides.

VII. SUMMARY

The purpose of this study was to develop and apply a rehabilitation program using the recent development of Kinect motion capture technology. We performed tests making use of the Kinect's innate features of not requiring a controller and allowing intuitive play through physical gestures for the rehabilitation of people with physical disabilities, such as the elderly. Evaluation of the developed program in test 2 suggested new ways of using Kinect as an exercise aid for the test subjects.

Kinect was originally used for playing games and creating 3D images on PCs using motion capture technology. However, this study demonstrates that our revised program can be used with Kinect to offer rehabilitation to elderly people with physical disabilities.

Results of surveys taken after the tests indicated that many people were interested in the program and it yielded favorable impressions as a means of exercise by reminding the subjects of when they were young. In addition, playing music that the subjects were familiar with helped encourage subjects to participate.

However, some subjects could not use the program because their skeletal frames were not detected properly. This suggests it is necessary to alter the sensitivity of the skeletal frame detection program specifically for the environment used. In addition, the program should be enhanced to prevent the subjects from becoming bored during the long-term use required for rehabilitation.

Surveys results for problems with our program and suggested improvements demonstrated that Kinect can be used for rehabilitation programs. Therefore, future research should investigate the development of rehabilitation programs using Kinect. This study shows that the revised program in conjunction with Kinect was enjoyed by elderly people and it invoked their desire to exercise.

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Interface Design Techniques for Electronic Nose Sensors:A Survey

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Abstract—**Electronic nose systems comprise a more or less sophisticated hardware that is incorporated with sensors, electronics, pumps, and flow controller, where the software components ensure suitable technological hardware monitoring, data pre-processing, statistical analysis, and display of processed data. The current paper seeks to survey on interface design techniques for electronic nose sensors, with a specific focus on interface circuit design techniques for signal conditioning of electronic nose sensors. In addition, the paper classifies these circuits into two primary categories: integrated circuits and non-integrated circuits. Lastly, tables are provided to compare frequent methods used and specific application of the e-nose.**

Keywords- Electronic nose; Sensor; Interface; Circuit

I. INTRODUCTION

Electronic noses incorporate an array of chemical sensors that have varied specificities. They simultaneously respond to the volatile chemicals present in a gas sample [1]. According to recent researches, these sensors have cognitive ability based on human-computer interaction by means of sensor information processing. This makes researches related to this technology to employ a convergence of electronic, mechanical, and chemical engineering research [2]. Therefore, the entire performance of an e-nose system largely relies on the individual effectiveness and performance of its constituent features [3]. This implies that careful selection and design of frontal nose signals at the posterior of the conditioning circuit is of critical significance if optimum performance of the artificial odor sensing system is to be realized [4]. For this reason, the current research paper aims to survey the interface circuit design for signal conditioning of electronic nose systems. The paper classifies these circuits into two primary categories, which include: integrated circuits (which use very-large-scale integration (VLSI) circuits and sensors both on a chip), and non-integrated circuits (which uses discrete electronic components, such as microcontrollers, field programmable gate arrays (FPGAs), programmable logic devices (PLDs), and operational amplifiers (Op-Amps). At the end, tables are provided to compare frequent methods used and specific application of the e-nose.

The first section of this paper will discuss different types of integrated circuits as proposed by different experts. Besides, there will be a discussion on the different types of technologies employed in developing these circuits. This will provide the reader with a deeper understanding on how these circuits operate with their significance. Section two will discuss the various types of non-integrated circuits. Thereby, it will also help the reader to get a deeper meaning of these circuits. There will also be a discussion on applications of these circuits in this section using a wide range of examples. The last section of the paper will summarize the whole paper in a qualitative analysis format and will include comparison table for these methods and for the application of circuits. Also, the paper ends with a conclusion of the whole study.

II. INTEGRATED APPROACH

In the paper published by Koickal and colleagues [5], the authors have discussed extensively about VLSI circuit design and implementation of the components of an adaptive neuromorphic odor sensing chip. This integrated circuit system is composed of three systems, which include an on-chip adaptive neuromorphic olfactory model, on-chip sensor interface circuitry, and an on-chip chemosensor array. This system is fabricated on a single chip platform that utilizes the three component functional circuitry constituents. During the 2011 14th International Symposium on Olfaction and Electronic Nose, Aziz et al. [6] presented their findings, where they proposed a different VLSI model that integrates nine separate neuromorphic chips with an aim of creating a comprehensive signal conditioning circuit, which is also capable of solving extremely complex odor sensing problems. The typical circuit arrangement and functionality of the VLSI chip is shown in Fig. 1.

Furthermore, an earlier dissertation presented by Kea-Tiong [7], proposes integrated system capable of applying an interface circuit that is represented as an analogue signal that can be amplified, linearized, offset, altered and compensated for temperature by integrating multiple platform chips. In the circuit design process, the primary approach is to incorporate a power connecting source and field-effect transistors (FET) sensor arrays. This is integrated into a differential circuit used in the processing of signals accelerated from the difference between FET coated array and active FET sensor array. This allows existing common mode signal to be suppressed at the analogue signal input processing unit. At this stage, band-pass filtering is taken into consideration in removing high frequency signal interface and effects related to low frequency drift. Temperature variations introduced by

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electronics, analyze mixture and air passed over sensors are detected by a chip diode at this point [8].

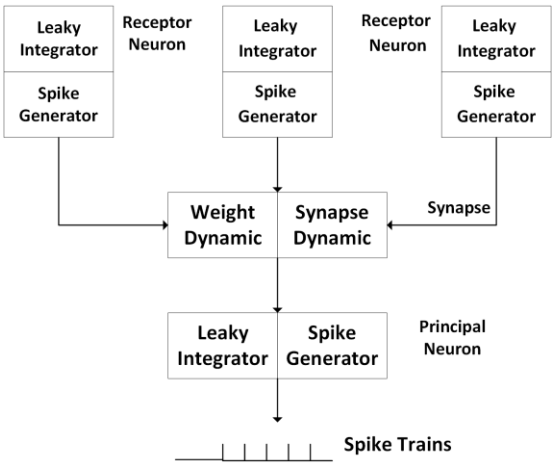

Figure 1: Typical circuit arrangement and functionality of the VLSI chip

On the other hand, the chemosensor arrays consist of diverse sensor types adjusted to react to different biochemical complexes. These heterogeneous arrays have the potential to proliferate selectivity in the artificial olfactory system recognition tasks while imitating the function of the mammalian olfactory structure [9]. The chemosensor array is used as a platform on which olfactory sensors are implemented where carbon black composites are used as a sensing material together with an incorporated signal processing circuit [10]. This sensor interface circuit, as described later, contains a cancellation dc circuit, which ameliorates the loss of measurement ranges linked to array sensors. The signal processing point is formed with spiking neuron design from the olfactory bulb architecture. In addition to this chemosensor array, an on-chip spike-time-reliant conditioning-learning circuitry is incorporated to dynamically familiarize with weights needed in the classification and detection of odors [6].

It is crucial to implement an on-chip learning program in the chemosensor array design, so as to enable the system to sense, recognize, and distinguish odors before passing them into the next sensor interface circuit [7]. Koickal et al. notes that this approach provides a compensation for the VLSI analog imperfections and enables it emulate plasticity function present in biological olfactory systems in line with the environment where the device must operate [5]. In most research works, the chemosensor arrays circuit elaborated above has been successfully fabricated and emulated in silicon [3-6].

In the neuromorphic olfactory chip, the olfactory bulb circuit is fitted with an input that has chemosensors fabricated with a 0.6 μm Austria Micro System. Through chemoresistive arrays, a chemically sensitive film is fitted to measure sensor responses as a factor of change in resistance. Additionally, carbon black coating is used as a polymer material depending on the targeted odor employed in the pattern recognition task. Operatively, the materials work by merging carbon nanospheres with an insulation rubber that provide electrical conductivity to the final resultant mixture. However, individual chemoresistant sensors across the circuit can be achieved by depositing carbon black polymers between any two sensor conductors. Gatet, Tap, and Lescure [11] denote that every sensor along the circuit is usually fitted with a baseline cancellation circuit, sensor, and a source of current. Hsieh & Tang [12] use multiplex mechanisms with an aim of giving access to individual sensing arrays without any complex circuits. Nonetheless, in integrated circuit approach, the problem is creating a sensing array that has individual outputs directly fitted to signal conditioning so that there is a continuous sensor response that is interfaced to neuronal circuits short of complex connections in achieving optimal amplification.

Once the chemosensor array is in place, the next stage is to design the sensor interface circuitry to mimic the neuromorphic model. Chible [9] recommends an active VLSI analogue input to ensure complexity and parameters of the model are quickly mapped to the VLSI environment. An undesirable characteristic associated with a heterogeneous chemosensor array is the large variation in baseline dc signals among the different sensors types in the array. Signal conditioning is aimed at performing a number of critical functions including noise cancelling, temperature compensation, offset control, amplification, linearization, multiplying array output signals, and sensor biasing [4].

According to [5], circuit building is achieved through two approaches: focusing on sensory output and designing an adaptive neuromorphic olfaction chip. First, the neuromorphic olfaction chip is realized by implementing various chip cycles. On sensory approach, the primary challenge in designing circuits is to compensate large differences in baseline sensors in the chemosensor arrays that can result in unrecoverable loss of measurement ranges. This is achieved by implementing a dc cancellation on the chip so to annul variations in baseline sensors. Second, implementation of neuromorphic model is linked to designing a circuit that has large time constraints and at the same time maintaining the neuron structure simple while occupying a limited space in the silicon area [7]. A case by Koickal et al. [5], uses simple operational transconductance amplifier-capacitor (OTA-C) structures to design on-chip learning circuit, synapses and neurons. In addition, the need for large space capacitors can be eliminated through reduction of transconductance on the OTA-C stage in the 300ms range.

III. Non-Integrated Approach

A range of different circuit designs used in non-integrated systems applies discrete electronic components, such as microcontrollers, FPGAs, PLDs and Op-Amps. First, in the Op-amp, is well designed to address a number of challenges; variance in baseline resistance, which can be fabricated easily into tens of ohms to infinity ohms when polymer based resistance sensors are used, and the Op-amp also address large coefficient in temperatures in chemosensors which can reach 10(-2) C^{o} [13]. A signal conditioning approach based on Op-amp can solve this

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problem as it is based on a principle proposed by Hatfield [14]. Hence this has the capability to remove common mode effects. The approach has been proposed previously by Dyer and Gardner [15], and also reflected in the works by Hatfield and Chueh [16], who instigated for its need to be reserved as a circuit interface in polymer sensor conductors. The circuit is formed by using two identical chemo resistors as shown in Fig. 2, where Ri is passivized with an impervious coating. In this case, the Op-amp circuit can be grouped as an innovative technique of an active divider circuit. The first Op-amp senses the current from the virtual earth and modulated by the passivized chemosensor (Ri), when it is introduced into the sensor. This offsets the baseline voltage present in the Op-amp circuit and this sensitivity can be amplified through a high gain voltage amplifier.

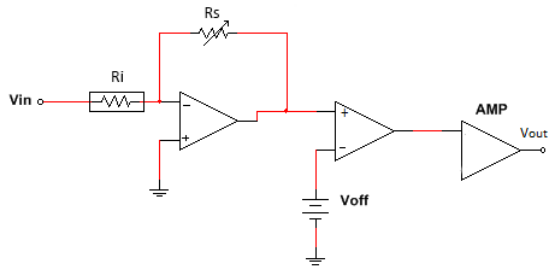

Figure 2: The ratio metric op-amp circuit

The second approach applies the FPGA implementation, where its olfactory circuit is interconnected to multiple non-integrated chipsets. The sensors employ chemo-sensor carbon black with a signal processor circuit. Various scholars, such as Sudalina and Nalini [17], who designed integrated sensor systems, have designed the circuit and technology using spike time linked neuromorphic model to mimic an e-nose system in FPGA. The circuit includes a chemical sensor with a dc cancellation and spiking neuronal network is merged to form a signal processor while the learning platform continuously weighs classification and detection [4].

Tan and Halim [18], based on data acquisition system shown in Fig. 3, have developed another non-integrated technology that runs on the FPGA platform but utilizes metal oxide technology. The technology is applied in identification of sulphate reducing bacteria that causes microbial corrosion in anaerobic environments. The sensor type is composed of an array of semiconductor metal oxides similar to one applied by Zhai et al. [19], an artificial neural network, and a data processing unit. The circuit architecture has two components: one between FPGA and the sensor, and another one between FPGA and the PC (Fig. 4). The first structure consists of the sensing oxide gas, which is designed to detect analog signal outputs so that the data can be processed at the FPGA interface, while the second component uses Quartus II software and Verilog language for learning the odor in the system. Modern approaches that have been developed are aimed at speeding or reducing the period taken to detect the presence of sulphate-reducing bacteria.

Another non-integrated system has been proposed by Tang et al. [20], where a portable e-nose system is built in printed circuit board (PCB) interface with 8 commercially available microprocessors, and a sensor array (Fig. 5.a). Through the circuit, there is a data acquisition card and a display implemented on LabVIEW program for certifying the e-nose system. It is designed to mimic an olfactory system that can test complex fruit odors including litech, banana, and lemon. The interface PCB comprises an 8-bit analog-to-digital converter (ADC), eight to one multiplexer (MUX), and an eight interface processing circuits (IPC). Eight sensors are connected to 8 interface processing units and this adapts actively to the baseline voltage circuit. The IPC operates on two modes; sensing mode and adaption mode. The principle works similar to that developed by Harun, Covington and Gardner [21], where in the adaption mode, the circuit regulates its operational point to a given baseline preset voltage while the sensing mode establishes gate voltage by using a negative loop on the odor passed across the system (Fig. 5.b).

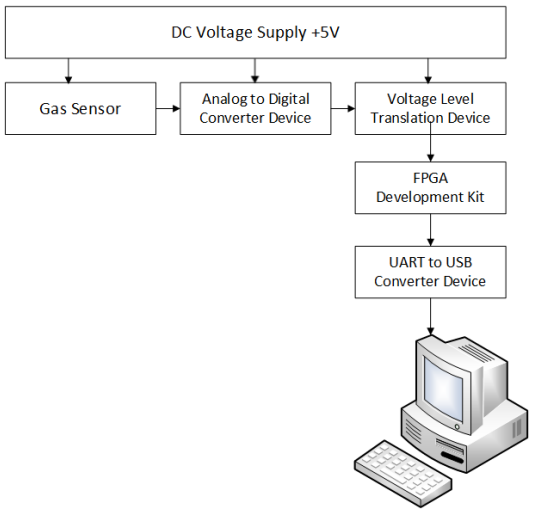

Figure 3: Data acquisition system architecture

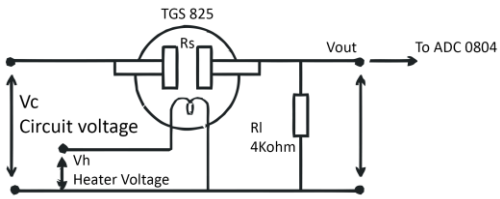

Figure 4: Signal circuit detection interface

Based on Figaro sensor system, Mamat, Samad, and Hannan [22] implemented a technology for implementing and classifying beverages. Their circuit design incorporated temperature sensors and commercially available metal oxide gas sensors. The system uses Principal Component Analysis (PCA) and Multi-Layer Perception Neural Network (MLP)

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platform and diverse sensor batches to authenticate the model's reproducibility. For the circuit to work, the system requires a simple measuring and heating model. The two are built inside and require a 40 °C, which is realized through a constant voltage supply similar to work by Peris and Gilbert [23]. Here, two voltage inputs operate at 12 V and 5 V circuits (Fig. 6.a & 6.b). Units of 5 V are needed to stabilize the inner sensor circuit unit while the 12 V circuit is required in measuring the output sensor (Fig. 6.c).

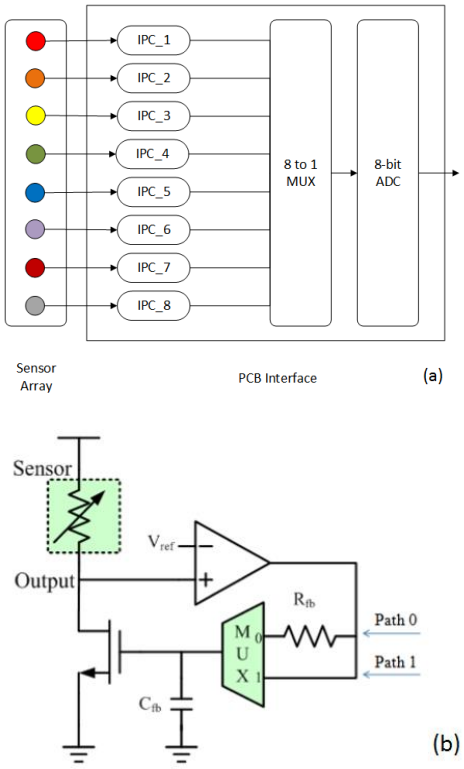

Figure 5: (a) Interface PCB, (b) Basic architecture of the processing circuit

On their part Kim, Yang, Ha, Pyo, and Chang [24] have proposed a miniaturized e-nose system developed using personal digital assistant (PDA) and 8-channel vapor detection array. The technology is based on PCB interface circuit and it is used to successfully classify and distinguish between essential oils including eucalyptus plants, lavender, and mint. The circuit is made up of manually assembled material including processing program, data acquisition, sensor chip array, and test samples. The primary element of the circuit is the 8 channel array chip whose fabrication is achieved by the carbon-black polymer, established in a substrate flexible polyimide. Inside the 8-sensor chip, there is a voltage divider system that weights large standard voltage (Fig. 7). The system is applied in sensing a wide array of fruit odors such as oranges, mangoes, and black-current.

Furthermore, Chiu, Tang, Chang, and Hsieh [25] have proposed a low power signal sensor technology based on a multi-walled nanotubes (MWNTs) circuitry interface, which is a polymer that swells reversibly upon exposure to chemicals. At low power, the sensor technology is formulated to identify 2-Butanone, chloroform, and carbon tetrachloride. The circuit chip is based on microprocessor embedded on pattern sensing algorithm, digital-analog converter, and interface circuit (Fig. 8). The adaptive interface circuitry has a sensing mode and an adaptive mode and the system works like the one proposed by Mamat, Samad, and Hannan [22] as previously discussed.

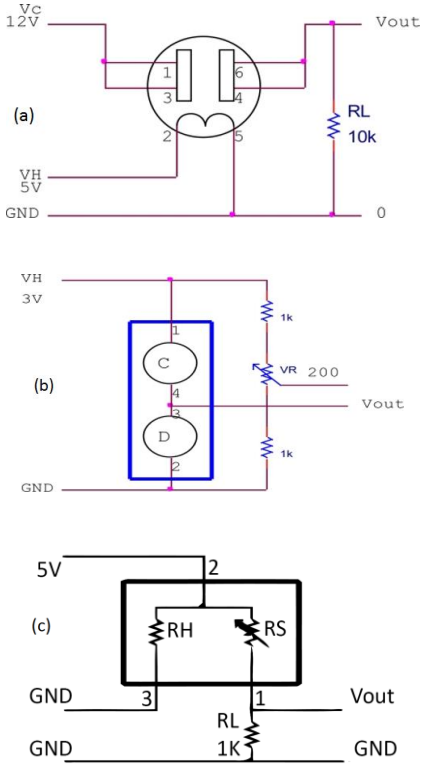

Figure 6: Interface circuits for (a) TGS8xx sensor, (b) TGS2xxx sensor, and (c) TGS6812 sensor

Another low power identifier system has been proposed by Young et al. [26] to form an intelligent wireless e-nose network (WENN) based on microcontroller interface. The interface is designed to incorporate two sections: first, there is a saturator that mixes with the target gas before releasing to the testing chamber; two, the WENN measures periodical gas entry from a thermal modulated microarray and neuronal-fuzzy network. The WENN system is designed to identify two binary gases, which are H_2S and NH_3.

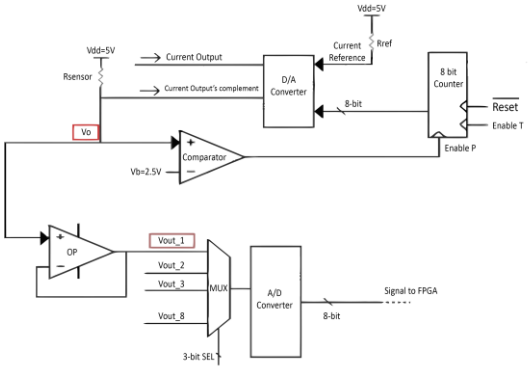

Figure 7: PDA-based E-Nose system interface circuit

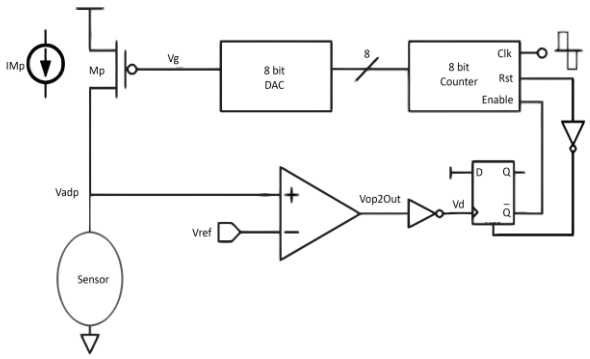

Figure 8: Adaptive interface circuit in Low power e-nose chip

In micro-electromechanical field, Stavrov et al. [27] have proposed a piezoresistive sensor technology centered on fast signal processing and parallel operation. The system is based on microcontroller circuit and mostly that of a silicon cantilever and Wheatstone bridge. The length of the cantilever is designed to avoid mechanical cross talk and to simplify resonance frequency. The system also incorporates 4 input/output (I/O) to operate by deflecting self-sensing and in supplying power. It measures a resonance spectrum in mechanical checkups applied in e-nose during the identification and characterization of various analytes. This device can be produced from manufacturing technology, basing on micro-mechanical cantilevers. In such a case, it relies on the ability to implement a parallel operation and a faster signal processing.

IV. DISCUSSION

Table I gives a comparative summary of technological sensors largely used, their applications, and their interface circuit and research references. From the above analysis, about sensor types and their application it is clear that interface circuitry is a very important factor in achieving an appropriate technology and circuit olfactory sensor sensitivity. Most sensitivity circuits used in inorganic sensors employ microcontrollers, while organic sensors are largely used in organic olfactory systems. Even if the circuit sensitivities may be elevated with amplification, this improvement may be marginal because of the baseline voltage component in the signal amplification. On circuit interface and sensitivity application best circuit performance is achieved by eliminating sensor baseline voltage.

The circuits discussed above use the simplest technique of counteracting the baseline voltage through its second potential divider. As deliberated previously, a signal conditioning circuit that has a linear productivity characteristic imparts itself to the role of odor classification and analysis. Therefore, it may seem from the analyzed circuits that the most suitable presentation, in terms of linearity and sensitivity is ratio metric op-amp and the constant current resistance interrogation circuits. The Op-amp circuit interface has a large advantage of excluding the temperature effect from the baseline output signals through the application of a passivized active sensor copies.

TABLE I: DIFFERENT TECHNOLOGICAL SENSORS, THEIR APPLICATION AND TYPE OF INTERFACE CIRCUITRY USED

Technology/Sensor type	Application	Interface Circuitry	Reference
1. Data acquisition system	Sulphate reducing bacteria	FPGA	[18]
2. Portable e-nose	Complex fruit odors e.g. lemon, banana, litech	Interface PCB (printed circuit board)	[20]
3. Figaro sensor-Measurement and Classification	Fruit sensor-black current, mango, orange	Microcontrollers PCA, and MLP	[22]
4. Miniaturized e-nose	Classification of essential oils eucalyptus, lavender, mint.	PCB	[24]
5. Low power e-nose chip	Sensing 2-butanone, chloroform, carbon tetrachloride	MWNTs	[25]
6. Intelligent wireless e-nose (WENN)	Binary gas mixtures H2s, NH3	Microcontrollers	[26]
7. Piezoresistive sensors	Micro-electro-mechanical system	Microcontroller/ Wheatstone brdge	[27]
8. Frontal-end signal	Odor sensing	Ratio-metric Op-amp	[28]
9. Analog circuit design	Odor classification and detection	Analog VLSI	[5]

It can be established that, among the signal-conditioning circuits examined, Op-amp circuits address majority of the issues that have been defined previously.

V. CONCLUSION

Individual e-nose performance relies on its performance and effectiveness and its constituent interface circuit. This survey paper has looked into various sensor technologies, their application and circuitry interfaces they use. It is clear that careful selection and design of frontal nose signals at the posterior of the conditioning circuit is of critical significance if optimum performance of the artificial odor sensing system is to be realized. However, most cases we have presented are proposals in theoretical works and studies that need to be developed further to determine their application in real-time odor sensing. Future technological aspects should address various challenges that are expected in the ultimate integration of a complete structure. This will require careful deposition of sensor material with wide diversity of chemical sensors that are needed together with screen process for every sensor, so as to ensure there is ideal chemical response recognition. Systems and circuit issues, such as the use of address event representation or spike output, layout optimization, component mismatch, and lasting weight storage also should be addressed.

Most examples for integrated circuits presented in this paper have differential circuits with ability to process signals accelerated from the difference between FET coated array

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and active FET sensor array. Thus, allowing existing common mode signal to be suppressed at the analogue signal input-processing unit. On the other hand, most non-integrated circuits presented here have temperature sensors and commercially available metal oxide gas sensors. As evidenced from this paper, non-integrated circuits are characterized by change in resistance and low power consumption. From various findings in this paper, most of these circuits rely on Principal Component Analysis and Multi-Layer Perception Neural Network platforms and have diverse sensor batches for their systems authentication. Hence, this new technology is reliable for commercial purposes.

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Study of Cochlear Implants Electrodes Stimulation Based on the Physics of the Ear for Audio Signal Integrity Improvement

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***Abstract* – Cochlear implants are neuro-stimulating devices helping severely deaf people to perceive sounds. This work proposes two models for the optimization of electrodes array stimulation in cochlear implants. The first model was developed according to wave propagation theory applied to the cochlea. The second one consisted on data processing using a Short Time Fourier Transform (STFT) in order to remedy to the first model limitations. The models were tested with an acoustic signal, which frequency belongs to the human hearing frequency range. Frequency and transient representations of the reconstructed signals were compared, emphasizing the better linearity of the STFT model.**

Keywords- cochlear implants; physics of the ear; audio signal processing

I. INTRODUCTION

As electronic technology is getting smaller, more accurate and low power, embedded processing solutions are nowadays available to encapsulate in biomedical applications. Among the disability remedy devices, cochlear implants are used to remedy partial or complete hearing loss. They allow direct stimulation of the auditory fibers with an electrodes array designed to reproduce the stimulus that would be generated by a healthy cochlea (Fig. 1).

To do so, an external part of the hearing devices is located within the outer ear and contains a microphone that captures the acoustic waves and transforms them into an electrical signal. Then, this signal is up-converted from baseband (audio signal from 20Hz to 20kHz) to the transmit frequency defined by the chosen ISM standard (13,56MHz, 433MHz, 866MHz or 2.45GHz). The corresponding receiver is located within the patient's head, close to the skull. It is composed of a demodulator, a data processing unit and a set of electrodes driven by electrical signals that will contract the cochlea and stimulate the auditory nerve [1][2].

However, the reconstructed signal is far from being the same as the original sound due to the fact that the number of electrodes is limited (around 20 depending on the type of implants) and the total contact area between the cochlea and the electrodes is small compared to the total cochlea length, resulting in signal distortion. As stated in [3] patient speech recognition is mainly influenced by the audio signal (80% of speech recognition is achieved using only auditory indications, 40% using only lip reading and 90% using both). As a consequence, signal integrity has to be preserved through cochlear implant signal processing, to allow optimal patients hearing sensation.

To improve the signal reconstruction with a limited number of electrodes, two models are compared: the first one using wave propagation theory within the cochlea and the other one using an ad hoc Fourier Transform (FT) to find the electrical stimulus of each electrode. This allows having a simple and yet accurate evaluation of the auditory nerve stimulation generated by a sound cochlea and comparing it with FT based electrodes stimulation.

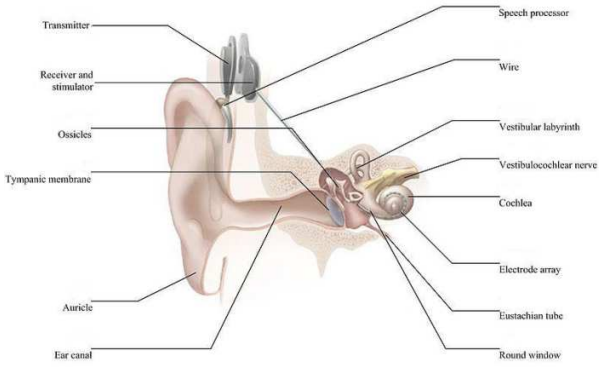

Figure 1: Ear anatomy and cochlear implant **[4]**

The second section gives an overview of the physics of the cochlea and how a cochlear implant can remedy a cochlea malfunction. In the third section, the theory of wave propagation is detailed in order to show how a sound cochlea model can be implemented. The fourth section aims to describe which frequencies are stimulated by cochlear implants. Finally, the last section gives a comparison between the signals obtained with a cochlear implant using the different electrode stimulations.

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II. COCHLEA PHYSICS

When an acoustic wave traveling inside the outer ear channel strikes the eardrum, the ossicles located inside the middle ear amplify the sound intensity. This is achieved by producing a lever effect. The last ossicle (stirrup) hits the oval window of the cochlea. The fluid (perilymph) inside the scala vestibuli of the cochlea provides support for mechanical waves propagation. The amplification provided by the ossicles aims to correct the loss of energy associated with the impedance change at the air to liquid interface [5] (Figure 2).

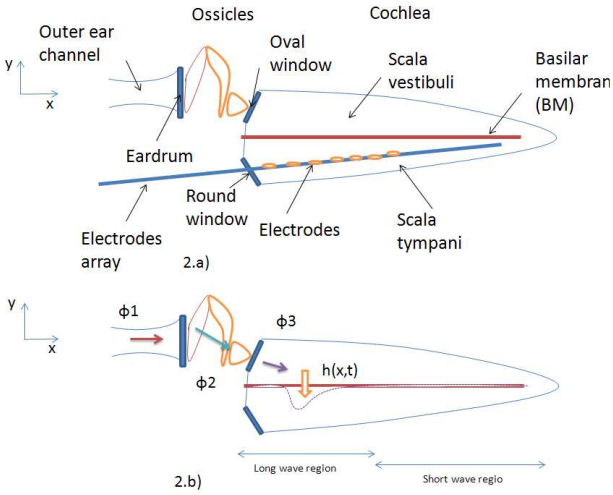

Figure 2.a) ear schematic with inclusion of the electrodes array inside the cochlea. Figure 2.b) ear schematic and the wave propagation leading to a basilar membrane height change (h(x,t))

More precisely the cochlea works by converting a wave propagating inside the perilymph into nerve a stimulation using the complex organ of Corti structure. Inside the cochlea, the Outer Hair Cells (OHC) are stimulated by a soft membrane (Basilar Membrane: BM) vibrations and release chemical messengers which excite nerve cells.

According to biophysical theories [6],[7] when a mechanical wave propagates inside the cochlea, the BM distorts to absorb the wave energy. In consequence, the height (denoted as h(x,t) in the following parts) of the BM excitement mainly depends on the sound intensity as well as the position along the x axis, which is the distance from base of the cochlea. The width, denoted as W(x), of the basilar membrane excitement around the resonance greatly depends on x as shown in the Section III. As the number of excited OHC depends on W(x) the number of auditory fibers excited is hence associated with the x variable.

If one or many functions described above are not working properly, the patient may suffer from hearing loss or deafness. In this case, a cochlear implant may substitute to the natural sound processing to provide the auditory nerve stimulation via an electrodes array sunk inside the scala tympani (Figs. 1 and 2).

The electrodes array (which is the connective link between the implant and the cochlea) is composed of a limited number of electrodes stimulated by an electric current. The electric current at proximity of the auditory fibers permits theirs direct stimulations even with nonfunctional OHC.

We chose the device CI422 with Slim Half-Band Straight Electrode manufactured by Cochlear® [8], which is composed of 22 electrodes to implement our models. Then we compare the results with a FT approach, applied to only the frequencies stimulated by the electrodes, to select the electrodes.

III. SOUND WAVE PROPAGATION AND BASILAR MEMBRANE DISPLACEMENT.

The wave propagation theory is quickly reviewed in this section for a better understanding of the biophysics of hearing and for determining the characteristics of the basilar membrane resonance in terms of amplitude and width. This theory and the computations are extracted from [9] and [10], the main results are recalled here for the reader's convenience.

A sound wave φ_1 propagating along the x axis is characterized by:

$$\varphi_1(x,t) = A_1 exp^{i(k1*x-\omega*t)} \quad (1)$$

Where A_1 is the sound amplitude, k_1 is the wave number and ω is the pulsation.

At the oval window interface, the mechanical wave is converted into a wave propagating in a viscous fluid, resulting in impedance mismatch. Therefore, the transmitted power from the mechanical wave into the liquid wave is damped by 29dB.

As demonstrated by various authors, the main function of the ossicles in the middle ear is to reduce the power loss due to the impedance mismatch therefore the wave power at the oval window interface is equal to the power of the air wave minus 3dB [11][12].

The wave propagating inside the scala vestibuli ($\varphi 3$) is expressed as:

$$\varphi 3(z,t) = \frac{A_3}{2} * [\exp(i(k * z^* - \omega * t)) + \exp(i(k * z - \omega * t)) + \exp(-i(k^* * z - \omega * t)) + \exp(-i(k^* * z^* - \omega * t))] \quad (2)$$

Where A_3 is the amplitude of the wave, $k = k_r + ik_i$ is the wave number and z the complex variable: z = x +iy.

Mathematical equations developed in [9] lead to the following relation between membrane height displacement and auditory wave:

$$\frac{\partial h(x,t)}{\partial t} = -\frac{\partial \varphi_3(x,y,t)}{\partial y} \quad (3)$$

Solving this equation permits to obtain the basilar membrane height displacement h(x,t) (spatial and transient

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shape of the basilar membrane displacement is given in Figure 3)

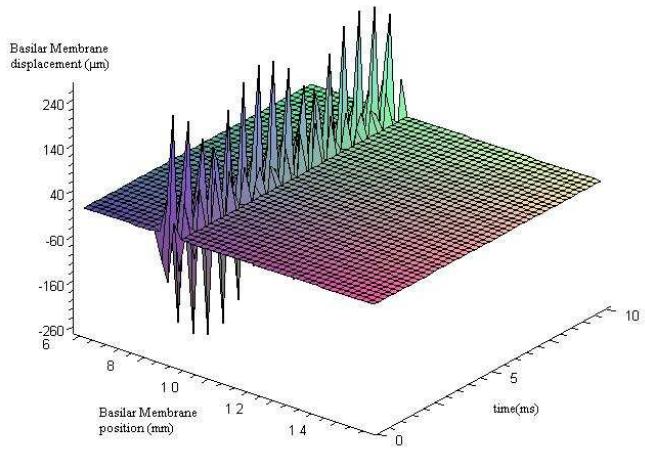

Figure 3: Basilar membrane displacement (µm) with respect of the distance from the cochlea base (x in µm) and time (ms) for a 600Hz input acoustic wave

One can observe that the BM displacement is a function of the distance from the cochlea base and the amplitude of the auditory wave. The auditory nerve stimulation is proportional to the BM displacement and this phenomenon has to be recreated artificially with electrodes stimulation.

IV. ELECTRODES ARRAY STIMULATION BASED ON THE COCHLEA PHYSICS

The width of the BM displacement greatly depends the position x as shown in Fig. 4.a, when the BM is excited by a 600Hz sound wave and by a 300Hz sound wave which make it to resonate at different places and with different widths. The detection of a BM displacement permits to obtain the width of this excitement:

$$W(t) = \int_{X_W} h(x,t)dx$$
$$with\ X_W = \{x \mid abs(h(x,t) \geq threshold\} \quad (4)$$

The basilar membrane movement compresses the organ of Corti resulting in a voltage variation in the corresponding auditory fiber. If this voltage variation is greater than a threshold voltage around 30mV for the human auditory nerve [13], the nerve fiber is excited. We implemented the mechanical model of the organ of Corti found in [14] (we simplified it by neglecting the Tectorial Membrane influence over the Reticular Lamina) and after converting the voltage threshold into the corresponding membrane height, we obtained the basilar height threshold value around 20µm.
Extraction of the width W for acoustic waves of different frequencies varying from 60Hz to 20KHz (hence resulting in different place of excitation of the BM) is shown in Fig. 4.b.

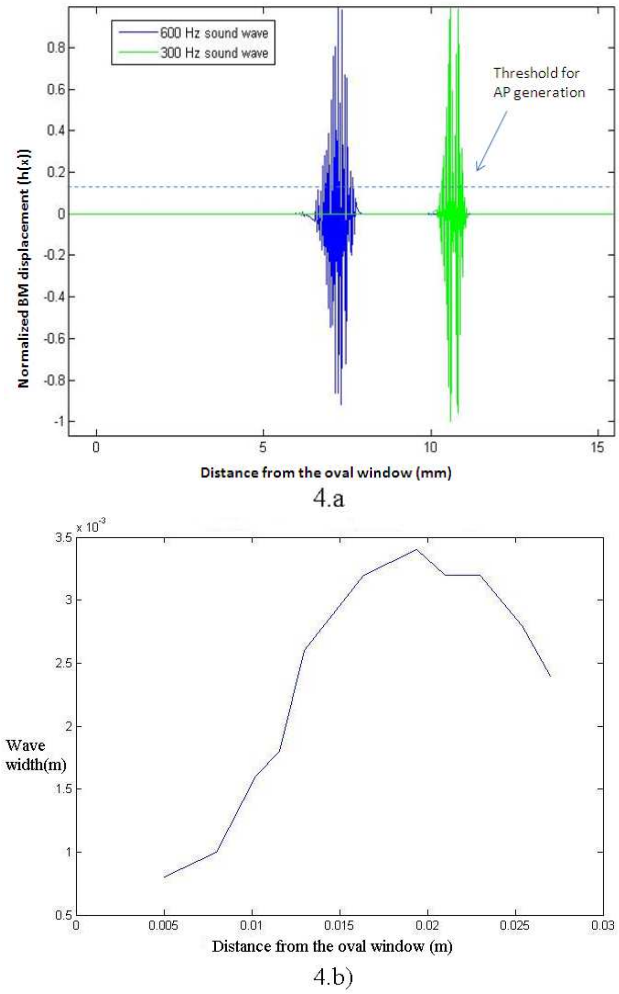

Figure 4.a: BM excitation. Figure 4.b: Width of the BM excitement.

We use CI422 device characteristics with an insertion depth of 20-25mm, a mean diameter of the electrodes around 0.35mm and a spacing between the electrodes around 0.45mm. As explained in [8], the number of nerve fibers stimulated by an electrode is a function of the power magnitude as well as the proximity of the electrodes with the BM. In fact, the electrodes array is sunk inside the scala vestibuli and due to spatial inhomogeneity of the cochlea, the distance between the electrodes and the BM may be fluctuating. For simplification purposes we supposed that the electrodes array is very close to the BM resulting in a rectangular window-like stimulation of the nerve fibers by the electrodes ($H_{implants.}$) displayed in Fig. 5.a. The selection and the power sent to the electrodes depends on the function h(x,t) as depicted in Figs. 5.b. and 5.c

The relation between the distance from the oval windows where the BM displacement is maximaland the frequency of the acoustic wave is given by the Greenwood function [15] and will be used thereafter in this paper to switch from the distance x where W(x) is maximal to the frequency of the input wave.

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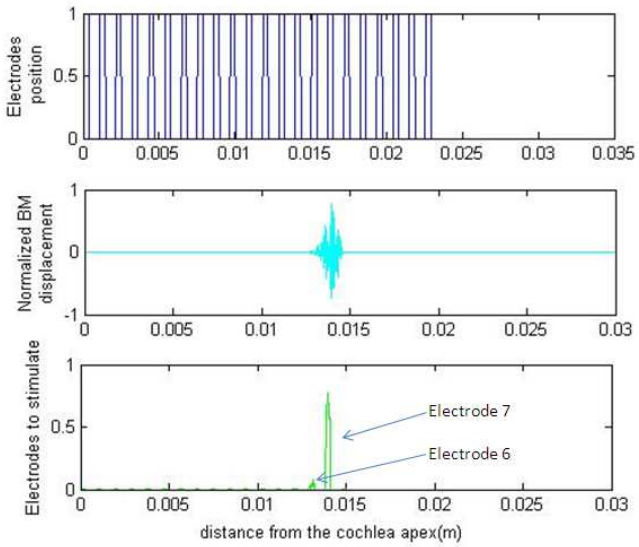

Figure 5.a: The auditory nerve fibers position stimulated by the electrodes array.
5.b: BM displacement for a 1250Hz sine wave.
5.c: Resulting electrodes stimulated by the 1250 Hz sine wave based on the BM displacement theory

As can be seen on the figure, not all the frequencies can be stimulated by the electrodes and the main limitation of this model is that the input frequency must match with the frequencies coverage by the implant, which is rarely the case for high frequencies. In consequence, an alternative model has been developed

V. COMPARAISON WITH THE FT BASED AUDITORY NERVES STIMULATION

The function $H_{implants}$ presented in Section IV selects the frequencies stimulated by the electrodes array. We chose to only compute the Fourier Transform on the frequencies which can be stimulated by the cochlear implants. Hence we obtain the following equations for the FT computation:

$$X_k = \sum_{n=0}^{N-1} x_n * e^{-\frac{i2\pi f_{central}(k)n}{N}}$$

And

$$x_n = \frac{1}{N} \sum_{f_{central}(k=0)}^{f_{central}(N-1)} X_k * e^{\frac{i2\pi f_{central}(k)n}{N}} \qquad (5)$$

Where X_k are normalized frequencies (the normalizing frequency is the sampling frequency chosen at 44KHz, similar to audio formats as .wav, .mp3, etc.) ,$f_{central}$ is the central frequency of each rectangular sub window of $H_{implants}(f)$ as one electrode can only have one voltage value and N is the number of electrodes. As the sampled audio signal contains more than N points, the sampled audio signal was cut into many windows of N samples where the previous formula was applied (Short Time Fourier Transform (STFT) [16]).

The corresponding results for a 1250 Hz sine wave stimulus is shown in Fig. 6.a.
As the frequency of 1250Hz does not match with a frequency covered by one electrode, the signal power is distributed over the frequencies covered by the electrodes, causing distortion in the reconstructed signal.

This test signal stimulates only two electrodes (in the actual physical model as presented figure 5.c) or all the electrodes (in the STFT model). Transient simulations were carried on and reconstructed signal from the STFT model was significantly less distorted than the other one (Fig. 6.c). However, when the frequency of the control signal was inside the frequency range corresponding to the electrodes position shown in Fig. 5.a, both models gave approaching results (not shown in this paper). In that case the most efficient model in terms of processing resources should be selected.

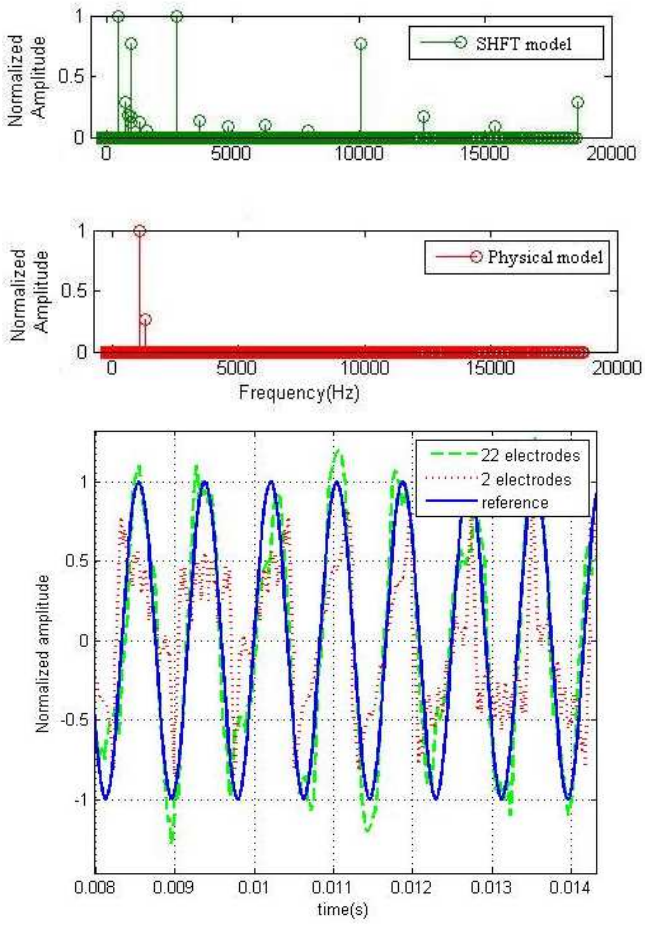

Figure 6.a: Normalized voltage sent to the electrodes for a 1250Hz input auditory wave (using the SHFT model).
6.b:Normalized voltage sent to the electrodes for a 1250Hz input auditory wave (using the BM displacement model).
6.c: Comparison between transient simulations of the reference signal, the signal reconstructed using all the electrodes and the signal reconstructed using only 2 electrodes

Testing this hypothesis may provide new insights of the hearing process. In fact if the combined models would give better results in person using cochlear implants than the algorithms implemented at present, this could mean that the brain could adapt to these new nerve stimulation. In that case our combined models, if utilized in very young patients (maximal brain plasticity and with extended learning process), could give better results than the algorithms used commercially. For instance the modification of the current algorithms to include our model is the first step, before its implementation on the cochlear implants microprocessor for real time data processing

VI. CONCLUSION

We proposed an electrodes stimulation optimization which resides on the complementary nature of physical and mathematical models, therefore, deserving further work and tests. The two models proposed in this paper (physical cochlea model and FT based model) have been compared theoretically and the corresponding results have been presented for a 1250Hz sine wave input signal. At present general knowledge in hearing processes is improving due to a large community of biomedical research, which should bring further development in the modeling of the cochlea and the mechanism of hearing. In this context the implementation of our model in upcoming cochlear implants may add hearing accuracy.

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Sightseeing Spot Communication System using Four-Frame Stories

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***Abstract*— Recently, many people introduced their personal sightseeing trips on the Internet, with the effect that some of the introduced sightseeing spots have attracted the attention of tourists. In this research, we propose a sightseeing communication system based on making and sharing a sightseeing "story". Users make a story consisting of four frames about the sightseeing by editing pictures taken at sightseeing spots. The story-creating process yields to new discoveries about the appeal of sightseeing spots, because the user will look for topics to feature in a story during their sightseeing trip. We expect that such a process will make the sightseeing more individual and creative. The produced story is also shared among other users, which we anticipate to generate interest in the sightseeing spots.**

Keywords-Sightseeing support system, Four-frame story, Tourism recommendation.

I. INTRODUCTION

A great deal of importance is placed on the tourism industry in Japan. Domestic and overseas trips are one of the main leisure activities of Japanese people. In recent years, the sightseeing style of Japanese consumers is changing. Traditionally, the package tour has been the most popular sightseeing style in Japan. The package tour is a travel product wherein the entire process including destinations, routes and time schedule, is managed by a tour company. Thus, the participants enjoy their sightseeing simply by following the instructions of a tour guide. However, another sightseeing style has come into use significantly in recent years. This is a style wherein tourists determine the process of their sightseeing themselves and enjoy their trip without using a package tour. Ishimori [1] describes this as "autonomous tourism." In addition, "Travelers Trends 2010" [2], published by the Japan Travel Bureau Foundation, calculated that the number of people who were interested in gourmet food, history, urban tourism, and strolling had increased by 10% in 2009 compared to 2007. With all these factors, it can be said that tourists are interested in various activities and want experiences of various types. Therefore, just as Ishimori points out, the sightseeing style in Japan is changing from moving efficiently along a predetermined route to freely visiting places of interest anywhere, anytime, and tourists are looking for new discoveries and chance encounters.

In planning such a personal tour, many people gather information about sightseeing spots from social media such as Facebook and Twitter, and take into account word-of-mouth information from such sites. A tourist who had a positive experience and memories uploads some stories and photos of their trip to the Internet, and other people who are planning their own tours are affected by these shared stories and photos. Since people have diversified personal preferences, the attractive factors of a sightseeing spot differ from person to person. Thus, people select information on the Internet, which matches their preferences and plan their personalized tours. Therefore, a desired recommendation system for sightseeing spots should propose not only standard destinations but also personalized destinations for each user, and lead to new discoveries about the appeal of sightseeing spots.

This paper proposes a novel sightseeing spot communication system. Our goal is to invite tourists to visit various new sightseeing spots by sharing their experiences and memories about trips with each other. As a way of sharing experiences of the sightseeing spots, we focus on the interesting part of making and reading a "story" using photos taken at the spots. That is, users make a four-frame story about their sightseeing experience by editing photos taken at sightseeing spots, and share the story using our system. The shared stories are read by other users, which we anticipate to generate interest in the introduced sightseeing spots. We consider that the processes of creating and sharing the stories will yield new discoveries about the appeal of sightseeing spots, because the user will look for topics to feature in the story during their sightseeing trip in the story-creating process, and in the sharing processes, the user will have access to the various perspectives of many other tourists.

This paper presents the results of an evaluation experiment using our prototype system. These results demonstrate the effectiveness of our system in terms of occurrence of discoveries about new appeal of sightseeing spots by creating four-frame stories, guidance to new spots by sharing stories, and the addition of narrative to sightseeing information.

In this paper, we present the related works in Section II. Sections III and IV show the outline and details of our proposed system. The evaluation results are shown in Section V, and we conclude this paper in Section VI.

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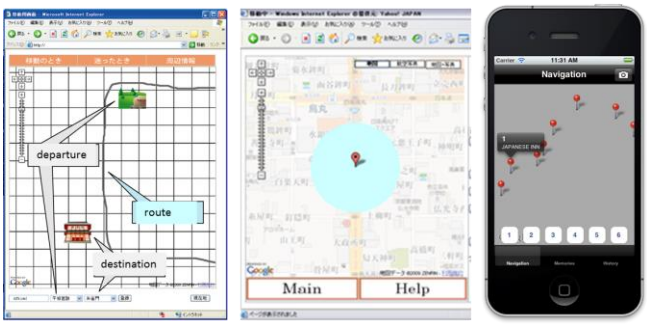
II. RELATED WORK

In this section, we introduce sightseeing navigation systems, which attempt to create opportunities for encounters, and systems for sharing edited photos.

A. Encounter-Creating Navigation Systems

Most traditional sightseeing navigation systems used by tourists during sightseeing offer the shortest route and methods of transport from a departure to a destination, and attach a high value to the efficiency of user movement. However, it can be said that the user's area of activity is limited, and opportunities for new discoveries and chance encounters that may happen during sightseeing decrease in order to realize high efficiency. Considering the sightseeing trends in Japan in recent years, such methods are not effective because tourists who demand fun and memorable sightseeing are increasing.

In order to resolve these problems, some sightseeing navigation systems, which attempt to stimulate new discoveries and chance encounters, have been proposed [3]. These systems adapt the idea of "Benefit of Inconvenience". Ichikawa, et al. proposes a system which shows a map consisting only of a rough handwritten route, some icons and the current position of the tourist (Fig. 1 (a)). In the system proposed by Tanaka et al., an electronic map hides the information related to the area immediately surrounding the tourist (Fig. 1(b)). By hiding detailed maps and routes, these systems promote interaction with the user's previously unnoticed surrounding environment, and foster new discoveries and chance encounters. As an extended system, Takagi et al. built a navigation system, which hides most of the map's information (Fig. 1(c)) [4]. In this system, only the current and destination positions, and some landmarks, are shown on the display. The landmarks are selected based on the user's preferences.



(a) (b) (c)

Figure 1. Screen images of navigation systems which promote interaction with the user's surrounding environment.

B. Edited Photo-Sharing Systems

Due to the widespread use of smartphones, in recent years some tourists use photo-sharing applications, such as LINE camera [5]. Users of these applications take photos at sightseeing spots using their cell-phone or smartphone camera, edit these photos in the application, and share the edited photos with their friends or all other users. In LINE camera, a user can edit a photo by adding text, stamps featuring characters, and decorated frames. The edited photos are shared on LINE, Facebook, and Twitter. The goal of these systems is only the sharing of photos, not the sharing of information about sightseeing spots such as their locations. Thus, they do not provide a function of navigation to sightseeing spots.

Dinh Pham Quang et al. propose a navigation support system to sightseeing spots by sharing photos with "graffiti" [6]. A tourist takes a photo at a spot, and enjoys editing the photo by adding graffiti freely. The photo with graffiti and the location data of the photo are shared on the Internet. Other users see the photo with graffiti on an electronic map. Evaluation results demonstrate that the expressing sightseeing as a narrative by adding graffiti to photos attracts other users' interest. In addition, the system implements sightseeing spot navigation function by providing location information showing the place where the photo was taken. Some evaluators said that they would look for graffiti topics during their sightseeing trip. This fact indicates that the system creates opportunities for new discoveries and chance encounters.

Dinh Pham Quang et al. use only one photo to express a story. In our study, we use more than one photo; specifically, we use a four-frame story, because we consider that higher diversity of story will realize the provision of multiple opportunities for new discoveries and chance encounters.

III. OUTLINE OF PROPOSED METHOD

This paper proposes a novel communication system by sharing four-frame stories based on photos taken at sightseeing spots. The system targets tourists who are carrying out casual sightseeing on foot. Through the action of making and sharing stories, tourists obtain opportunities for new discoveries and chance encounters.

A. Benefits of Story-Making

Cognitive actions related to creative processes occur in a chain [7]. In order to perform a creative process, a human responds sensitively to various visual features and relationships between spatial locations of objects in a space, and then creates conceptual meanings for the objects. Thus, such responses lead to a new discovery for the human.

Our proposed method compels tourists to have active interaction with their environment at sightseeing spots by taking actions to create stories. This active interaction provides a chain of cognitive actions and new discoveries.

B. Basic Policy of Method

We propose a sightseeing spot communication system, which utilizes sharing of four-frame stories. A tourist takes photos during their trip, and creates short stories of four frames which introduce the trip. The created stories are shared using our system, and other users read the shared stories to learn about the introduced spots. In order to consider four-part narrative structure, which is traditional in Japan, we limit the length of the stories to four frames. This structure is used internationally, one of the famous

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examples is SNOOPY's story [8]. Limiting the length of story simplifies the process of story creation.

The scenarios for both modes of use, creating a story and sharing a story, are as follows:

1) Scenario for the story-creating process

1. A tourist considers a four-frame story using photos taken at sightseeing spots when he encounters interesting objects such as scenery, buildings, shops, food, etc. During this time of consideration, it is important to conduct sightseeing with an awareness of whether there is anything suitable for a story around oneself, thereby developing sensitivity for sightseeing.
2. If the tourist can construct a story, they create a four-frame story by taking some photos and editing them. Editing methods include attaching text comments, appropriate characters and graffiti. More than one spot may be included in a story.
3. The created story is sent to the system's server in order to share the story. Location information for each photo in the story, obtained via GPS(Global Positioning System), is also stored on the server.

2) Scenario for the story-sharing process

1. A user browses the shared four-frame stories from a location outside of the spots introduced in the story. However, the user cannot read the last frame of the story outside of the spots introduced in the story. This mechanism stimulates the user to wish to know the ending of the story, and to visit the introduced sightseeing spots.
2. The user conducts sightseeing based on the shared story that they are interested in. A photo of each frame in the shared story is shown at a corresponding position on an electronic map. Thus, the user can visit the spots that were introduced in the stories that interest them. At the sightseeing spots, the user can see all frames of the story, including the last frame.

IV. SYSTEM DETAILS

In this section, we describe our prototype system.

A. Development Environment

Our system is assumed to be used during sightseeing. Thus, the system needs to be developed for mobile computers. In our prototype system, we use the iPhone as a mobile computer. The system was developed as an iPhone application in Objective-C. The server requires a database function, for which we use XML and PHP.

B. System Architecture

Fig. 2 shows the architecture of our prototype system, which consists of an iPhone and a server. The server stores the four-frame stories uploaded by the user in a database. A unique ID is attached to each uploaded story. Photo data for each frame in the story are assigned a name with the ID of the story and its order in the story, and stored in an image folder. For each frame, the database stores its ID and location information obtained via GPS(Global Positioning System). The program to upload to and download from the server uses PHP(Hypertext Preprocessor). The iPhone device reads this PHP program in order to access the database.

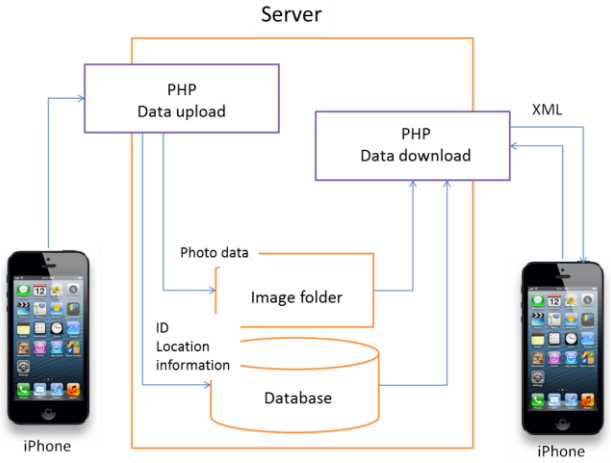

Figure 2. System architecture.

C. System Functions

Our system consists of the following three functions:

1) Store the photos taken at sightseeing spots, 2) create a four-frame story, and 3) browse the shared four-frame stories. In this section, the details of these functions are described.

1) Photo Store Function

With this function, the user can take and store a photo. There is a camera button on the lower left of the main screen. When the user pushes this button, the equipped camera is activated. The user takes photos and stores them in the local memory of the iPhone. The stored photos are shown on the electronic map. Therefore, the user can see the photo image and the location where the photo was taken, and select some of the photos to use in making a story.

2) Story Creation Function

With this function, the user selects a photo from the stored ones in the iPhone, and edits the photo by adding texts, characters, and graffiti to the photo. Fig. 3 shows an example of screens during the creation process. Our system provides six functions to edit photos, each of which corresponds to a button at the bottom of the screen.

1. Pen button: When the user writes some graffiti on the photo, they tap this button. The pen color can be selected from three colors: red, blue, and green. The pen also has five width settings.
2. Callout button: When the user adds some text in a speech bubble, they tap the callout button. A speech bubble of default size appears on the photo. The user writes some text in the speech bubble, and then

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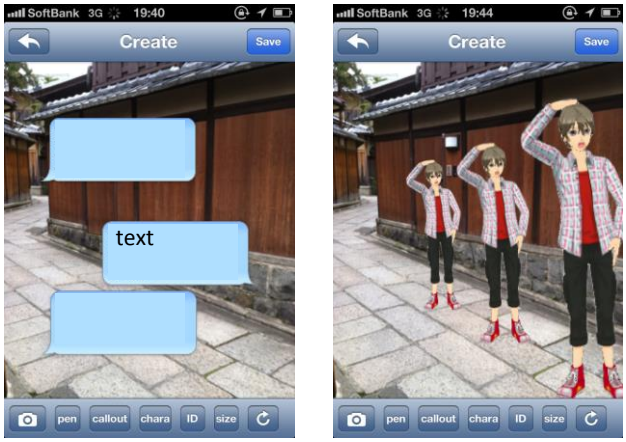
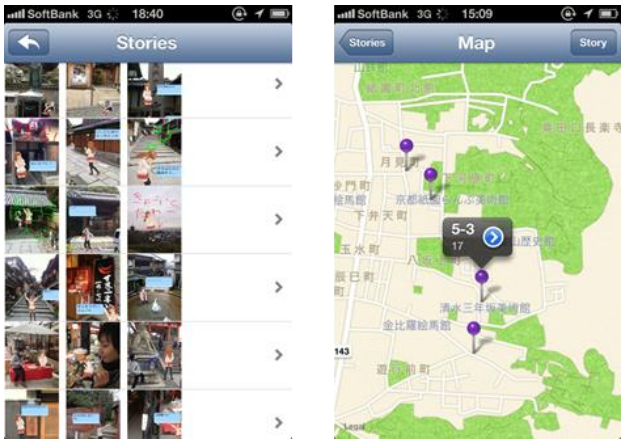


(a) Use of speech bubbles (b) Use of characters

Figure 3. Examples of story creation function

moves it to an appropriate position in the photo (Fig. 3(a)).

3. Chara button: When the user taps this button, a list of the characters in this system is displayed. The user selects one of the characters, and double taps the position where they want to place the character. The character appears in a default size at the tapped position (Fig. 3(b)).
4. Size button: The size of text in a speech bubble, the speech bubble itself, and characters is changed by tapping the size button.
5. ID button: The order of the edited photo in a story is assigned by tapping the ID button. After tapping this button, the user inputs the order.
6. Save button: After editing a photo, the user taps the save button. When all frames in a story are created, they are uploaded to the server.



(a) List of shared stories (b) Locations of photos in a story

Figure 4. List screen of four-frame stories

3) Story Browse Function

Using the browse function, a user can see the shared four-frame stories and learn the locations where the photos in the story were taken. Fig. 4(a) shows an example of a screen of the list of shared stories. The user selects one of the stories that they want to read. Then, the user can read each frame of the selected story, and learn the locations where the photos in the story were taken. Fig. 4(b) shows an example of a screen indicating the locations of a story. Thus, when the user sees an interesting photo or story, they can go to the place introduced in the photo or story by using this map function.

When a user sees this list of shared stories from a place, other than where the photos in the story were taken, the last frames of these stories are not available for the user (Fig. 4(a)). This trick gives the user motivation to go to the sightseeing spots introduced in the stories that they found interesting.

V. EVALUATION EXPERIMENT

A. Experiment Method

We conducted an evaluation experiment with 12 human evaluators, who are students in Ritsumeikan University in Japan and are selected randomly from among applicants, in order to verify the effectiveness of this sightseeing spot communication system. The experiment was conducted with Kyoto as the experiment area, and subjects strolled in the eastern area of the city centered around the Kiyomizu-dera temple. The reasons why this area was chosen for the evaluation experiment are:

(1) The area is suitable for casual sightseeing by foot, because there are various famous spots including historical places, cultural places, etc.
(2) Tourists are able to enjoy the streetscape of Kyoto, which has many narrow alleyways.
(3) Many of the evaluators in this experiment had not visited this area before.

The evaluators in the experiment were 11 men and 1 woman in their twenties who live in the Kansai area, which includes Kyoto. The first experiment was carried out in December 2012 with half of the evaluators, and the second one in January 2013 with the remaining evaluators. They were assigned randomly to three groups regardless of their gender, age, previous experience of sightseeing in Kyoto, etc. Each group consisted of two persons.

Each group enjoyed the streetscape freely in the target area with at least one iPhone device installed with our prototype system. First, at a start point in the area, we explained the target area and how to use our system easily to the evaluators, and instructed them to return to the start point in 90 minutes. One observer accompanied each group to observe the behavior of the evaluators.

We asked the evaluators to answer a questionnaire in order to gather evaluation data on the usefulness of the system. In this questionnaire, questions about the following three facts were asked:

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(1) For each story the evaluators created: "why did you want to create this story?"
(2) For each visit to a spot which was introduced in a shared story: "why did you want to go there?"
(3) For the whole process of sightseeing using this system: "how would this system affect your sightseeing?"

B. Evaluation Results

1) New discoveries about the appeal of sightseeing spots

First, we will examine the effect of creating stories during sightseeing. We expected that the act of looking for topics for stories would provide tourists with new discoveries about the appeal of sightseeing spots.

In answer to the question "How would this system affect your sightseeing?" evaluators gave replies such as, "I focused on various objects in the sightseeing spots to look for a topic for a story," "I walked with greater care than usual because I wanted to find some interesting objects to create a story," etc. Most of the evaluators conducted their sightseeing actively and creatively by searching for interesting episodes and objects during their sightseeing, and by thinking about using these for story creation. For example, one of the groups created a story about interesting signs. They could also find some interesting objects in addition to funny signs because they looked around with curiosity.

A further interesting finding is that this system fosters a competitive spirit in the tourists. Some of the evaluators reported this fact in the questionnaire. Because the created stories are shared with other users, the evaluators made an effort to create a good story to get others' attention. Therefore, they looked around themselves carefully to find something funny or interesting. That is, it can be said that the communication of sightseeing spots based on four-frame stories is effective for the realization of creative sightseeing.

At the end of this evaluation, the evaluators talked about the stories that they had created. Such feedback from other users is good motivation for creating good stories. One of our future tasks is implementing a function for receiving feedback from other users in order to sustain motivation.

2) Navigation function by sharing stories

One of our aims in this study is to invite tourists to visit various new sightseeing spots by sharing their experiences as a story. In our system, the locations where the photos in a story were taken are shown on an electronic map. As a result, the behavior of visiting spots introduced in the shared stories occurred three times in the first evaluation, and seven times in the second evaluation. The reason that the number of such visits by the second group was larger was that the first group conducted experimental sightseeing under conditions where there were no shared stories in the system. That is, the evaluators in the first group could not see the shared stories at first, so they focused on the creation of stories.

The visits to the introduced spots can be classified into three categories based on motivation:

(1) Eight visits were motivated by interesting photos in the shared story.

(2) Three visits were motivated by the distance to the introduced spot.

(3) One visit was motivated by the desire to complete an incomplete task.

Examples of the first motivation are photos of scenic views, a shop displaying favorite characters, and something unique. In answer to the question "Why did you want to go there?" some evaluators replied that they read an interesting story, and the story unfolded there. That is, they became interested in the photos by reading the shared stories. The second motivation is caused by the map function. In this system, a user can learn the locations of photos in shared stories. The evaluators found interesting spots close to their current position, and were able to go there easily.

Moreover, it was demonstrated that the users shared information about less famous spots by sharing four-frame stories, and that this communication yielded new discoveries about the appeal of these spots. An evaluator stated that he wanted to go to ordinary places using our system, whereas he had tended to go only to major spots introduced in guidebooks. Another evaluator also reported that he obtained interesting information about unique sightseeing spots that could not be focused on by simply following a tour guide.

By using this system, users encounter various perceptions of sightseeing spots. For example, one frames of two different shared stories are based on photos taken at the same shop. In one frame, the character good in the shop is perceived to be cute, but in the other, it is expressed as humorous. This was reflected by one of the evaluators, who reported that he realized that there are various ways of thinking about sightseeing.

3) Effect of adding narrative to sightseeing information.

In this section, we describe the effect of sharing stories based on photos, rather than sharing only edited photos. From the evaluators' answers to the question "Why did you want to create the story?" we found that there are three methods of creating stories:

(1) The theme of story is decided previously.

(2) The story is created in chronological order of sightseeing.

(3) The ending of the story is decided first, and the other frames of the story are created subsequently.

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Figure 5. An example of shared stories in this experiment(Since the story is written in Japanese, the text in the figure are translated into English.).

In the first method, the evaluators set a theme for their story such as interesting spots or funny signs, and created all four frames based on the theme. In the stories created by this method, the evaluators used characters which matched their feelings at the sightseeing spots. They also expressed their feelings for the spots by adding some text in speech bubbles, which could not be expressed only by using characters.

In the second method, the evaluators created four frames, which expressed only their experience of sightseeing. The evaluators who created their stories in this way added some information to the photos using characters, speech bubbles and graffiti to introduce interesting sightseeing spots. Fig. 5 shows an example of a story created this way.

In the last method, the evaluators got an idea for the ending of the story first, and then looked for the other three spots to create the remaining three frames. In this case, they conducted their sightseeing wanting to take specific photos which could lead to the ending. Thus, the observers saw that the evaluators looked at various objects at the spots in order to discover something interesting.

From the experiment results, we can identify the following effects of adding narrative to sightseeing information:

(1) Motivation to visit spots: All of the evaluators in the second half of the experiment said that "we wanted to go there because we wanted to know the ending of the stories." This motivation is derived from adding narrative to sightseeing information and the trick of making the final frames unavailable.

(2) Self-expression: The evaluators tried to create good stories that would attract attention from other users. This behavior makes their sightseeing creative (see Section V-B-1).

(3) Discovering less famous sightseeing spots: The shared stories are triggers to go to the spots introduced in the stories. In the questionnaire, there were some answers, such as "we had not been interested in that spot, but the stories and its edited photos were very fun, so we went there."

VI. Conclusion And Future Work

This paper proposed a sightseeing spot communication system based on making and sharing a sightseeing story. Users of this system make a story of four frames about their sightseeing by editing pictures taken at sightseeing spots, and share it among other users. An evaluation experiment demonstrated that our proposed system is effective in terms of making the sightseeing individual and creative. In addition, by reading the shared stories, people are interested in new spots introduced in the stories.

Our future works aim to evaluate this system with more evaluators quantitatively, because this paper showed the results from 12 evaluators, and compare with other application. In addition, we limit the length of story to four frames, but there are may choices of story length, such as two, six or eight frames. The effect of story length and giving the choices to users should be revealed.

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An Opportunistic Tourism Navigation System using Photography Location Recommendation

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***Abstract*— In recent years, a style of sightseeing, which is planned by individuals and focuses on strolling has become widespread, while sightseeing navigation systems have attracted attention. However, most existing navigation systems support efficient sightseeing by giving users information such as the shortest route to their destination. Accordingly in this research, we propose an opportunistic sightseeing navigation system, which navigates users to a destination while recommending some photography locations that exist on the way to the destination, and adapts to the users' moods. An evaluation experiment conducted in Kyoto, Japan, demonstrated that conducting casual sightseeing on foot using this system enabled opportunistic sightseeing suited to the users' moods, which led to user enjoyment.**

Keywords-Tourism Navigation System; Opportunistic Planning; Benefit of Inconvenient; Photography Location

I. INTRODUCTION

A. Background

In previous tourism trends, many tourists participated in tourism where the destination, route, and time were all pre-determined by a travel agency. However, in recent years, many tourists decide on their destination and route by themselves and enjoy their trip freely. Tourism conducted in this way is called "autonomous tourism", whereby tourists design their own itineraries to their preference [1].

In other words, the present trend is for tourists to visit their preferred places at their preferred times. However, many navigation systems for sightseeing that have been developed in recent years place a high value on efficiency, thus are not suitable for tourists who prefer to stroll casually.

In this study, we focus on "Opportunistic Planning" [2], which is a plan based on the principle of flexibly adapting to opportunities at the place, situation, and time. We consider that these principles will be effective in supporting casual sightseeing on foot. We propose an opportunistic sightseeing navigation system for casual sightseeing on foot. The system recommends sightseeing spots according to the tourist's situation (i.e., their available time for sightseeing or the distance to a destination) and interests. This system changes the photography locations opportunistically when the user's interest changes or when the user happens to encounter another attractive photography location. Users can enjoy casual sightseeing on foot freely because sightseeing spots are recommended to them during sightseeing. We expect that adapting to the user's situation and changes in interest will lead to discoveries of new attractions in sightseeing areas.

B. Relationship between of Photography and Sightseeing

In recent years, people who take photos in sightseeing areas have increased dramatically in comparison to the age when only analogue cameras were available. This is because camera functions in current mobile devices have increased in resolution and multi-functionality. Moreover, due to widespread Internet use, photography is now not only enjoyed by the photographers themselves. Especially, use of social media such as Twitter and Facebook has spread rapidly in recent years. Such sites include functions to contribute photos, by which users can enjoy sharing the pictures they have taken. Taking photos at sightseeing areas can be considered an effective means to record one's memories of sightseeing. Moreover, by showing pictures taken at sightseeing areas to others, it is possible to recommend sightseeing areas to others.

Panoramio is a service, which connects photographs to maps. Panoramio is one of several photo-sharing services with location information, by which the user is able to view photos shown on a map. Users can share their photos with other users and can view photos contributed by other users on a map. In this way, using photos can stimulate the users' desire to go to the location. In this research, we focus on photography that is frequently carried out during sightseeing, and propose a system that navigates to sightseeing spots by recommending attractive photography locations.

A brief outline of this paper follows. In Section 2, we introduce studies related to this study. Section 3 and 4 describe system proposal and system function. Section 5 describes evaluation of the system and consideration. Finally, Section 6 describes conclusion of this paper.

II. RELATED WORKS

A. Trends in Sightseeing Navigation

With the advancement of mobile environments in recent years, many sightseeing navigation systems have been

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developed for mobile devices. For example, NAVITIME [3] has functions such as searching for the shortest route by mixing train, bus and walking, and transport transfer guide information. As such, it is very convenient for sightseeing that places a high value on efficiency, but is not suitable for casual sightseeing on foot.

In addition, a sightseeing navigation system for casual sightseeing on foot was proposed in a study by Takagi et al. [4]. The system recommends landmarks to the user based on individual preferences of food, history and landscape by presenting photos of landmarks.

The user then chooses a landmark and heads for their destination. However, as recommendation of landmarks is only based on the user's pre-input preferences, this system cannot adapt to changes in the user's interest or situation during sightseeing. On the other hand, Takagi et al.'s study indicates that photos of landmarks have an impact on the user's choices and interests. Figure 1 shows the main screen of this system and a photo of a landmark.

(a)Main Screen (b)Photo of a Landmark

Figure 1. Previous System, Screen

B. Benefit of Inconvenience

In sightseeing, a person can feel a sense of uneasiness due to not knowing detailed routes and buildings, etc. of the places they are visiting for the first time. However, this uneasiness can be transformed into excited anticipation of what lies ahead. This kind of navigation is based on the theory of the "Benefit of Inconvenience" [5], which suggests that inconvenient things bring benefits. A navigation system that uses the "Benefit of Inconvenience" has the effect of providing opportunities to look around and discover new aspects of the sightseeing area without keeping the user glued to the system screen by not providing detailed route indications. In the study by Takagi et al. [4], the effect of the "Benefit of Inconvenience" was actually demonstrated.

In the current study, we propose a system based on the theory of the "Benefit of Inconvenience" that shows map information via aerial photographs, whereby it is more difficult to understand route details than using a normal map. Moreover, the system can convey the ambience and scenery of the sightseeing area to the user using aerial photographs, and enables the user to discover photography locations and other spots suitable to their interests. Also, the navigation to these locations consists of showing the direction from the user's position to the destination, without showing a detailed route.

III. Outline of Proposal

A. Basic Policy of System

In this study, we propose a tourism navigation system that supports users searching for sightseeing spots using photography locations that are adapted to the users' interests. First, users input their destination and available time for sightseeing in the tourism area. The system recommends photography locations using photos from the information on the location, distance to destination and the user's available time for sightseeing. The photography locations recommended by this system include rare sights, food, landscapes and other things associated with the tourism area. Moreover, the system recommends not only famous sightseeing spots introduced in guidebooks, but lesser-known sightseeing spots. Therefore, the users are encouraged to go to the location by viewing attractive pictures. Users select a spot from a list of recommended spots, according to how they feel at that moment, and head for the spot based on the system's navigation.

As users of the system increase, we assume that in future, the data of photography locations can be collected from photos taken by general tourists. That is to say, users will upload picture data with location information as in Panoramio. However, in this system, data of photography location is registered in the system ahead of time. Based on the theory of "Benefit of Inconvenience", the system limits the amount of information that is displayed when navigating to the photography locations. Specifically, the system navigates with only a map screen using aerial photographs, whereby it is difficult to understand route information and the direction to the photography location. Users head for the photography location and use the ambience near the photography location that they can perceive from the aerial photographs, and direction, as hints. The system aims to attract the users' eyes to the surrounding landscapes, by comparing the aerial photographs and real landscapes and searching for the photography locations.

In this study, we propose a sightseeing navigation system that changes photography locations opportunistically in response to users' changeable feelings and supports more free casual sightseeing on foot. In sightseeing, there are many varieties of places that users want to visit and these depend on the user's feelings at that time. This system

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recommends destinations while repeating navigation in accordance with the user's moods, for example when their feelings change and the user wants to visit other places. Specific to the situation, users choose photography locations that are recommended by the system and repeat the action of heading for the location as a way to move to destination. However, if while casually walking, the user's interests change to other things - for example, they take a photo at another place and are satisfied - the system provides a new recommendation of other photography locations. Accordingly, users can change the next photography location, in consideration of their mood or the situation at any time.

B. *System Flow*

1) First, the user decides their destination and the target time for the destination. The system uses these to calculate which walking routes are possible, and recommends some photography locations.

2) From the list of recommendations, the user chooses a photography location in accordance with their feelings at that time.

3) The system shows a map screen with aerial photographs and directions to the destination calculated from the location information of the photography location and the user's current location.

4) The user strolls freely while searching for the photography location or other spots where they want to take photos.

5) The user requests the system to recommend the next photography location when the user reaches the photography location, finds a favorite place or has a change in interest.

6) The system calculates the remaining time and recommends new photography locations.

7) The user heads for their destination, repeating Steps 2~6.

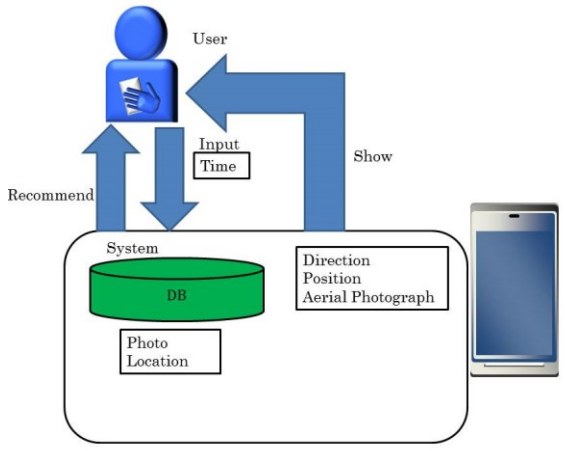

Figure 2. System Structure

Figure 2 shows this systems' structure.

IV. OUTLINE OF SYSTEM

A. *Development Environment)*

The proposed system was developed as an application for mobile devices using the Android OS, for the following reasons.

- Android mobile devices can be carried and used at sightseeing areas.
- Android mobile devices can use GPS function to obtain location information.
- Android mobile devices can use Google Maps to obtain map information.

The development environment was Eclipse, and the system was implemented in the Java programming language.

B. *System Functions*

In this system, we prepared photography locations between the vicinity of Yasaka Shrine and the vicinity of Kiyomizu Temple in Kyoto, Japan. The reasons for this choice are that there are many sightseeing spots such as historic buildings, appealing alleyways, souvenir shops and cafés, and Kyoto is suitable to casual sightseeing on foot.

1) Initial screen

First, the user inputs their destination and available time for sightseeing in minutes. The time is managed by the system and a navigation screen is shown with a countdown timer, which then starts. The system places a pin at the destination obtained from the previously inputted information. The user can confirm whether the location is correct or not by tapping the pin.

2) Photography location recommendation screen

The system shows photography location candidates by calculating possible routes from the inputted time and location information of the user's position and destination. Figure 3 shows the recommendation screen. Photography locations are retained in a database, which stores location information and a photograph as data for each photography location.

Next, the selection method of the photography locations will be explained. The system calculates the walking time from the user's position to the photography location, and from the photography location to the destination. When the total time is shorter than the remaining time for sightseeing, the photography location is recommended. In this system, all spots that meet this condition are recommended to the user. The system places a pin at the photography locations, and the user can view a photo of the location by tapping the pin. The user selects their preferred place and decides on visiting a photography location.

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Figure 3. Photography Location Recommendation Screen

3) Navigation screen

After the user decides on the photography location, the system changes to the navigation screen, obtains the user's location information, calculates the direction to the photography location and displays a compass. The system shows the map as an aerial photograph. The system starts measuring elapsed time as soon as the screen changes to the navigation screen.

The user searches for the photography location using the aerial photograph map and compass as clues. Figure 4 shows the system's navigation screen.

Figure 4. Navigation Screen

When the user touches the "Refresh" button, the map's central position is refreshed to the user's current location, and the new direction is calculated. There are two reasons for not renewing the user's location at all times: 1) In order to make it easy to comprehend the ambience of the environment from the aerial photograph showing a stationary landscape; 2) So that the user can search for things that interest them and stroll freely without clinging to the map information.

When the user touches the "Camera" button, the mobile device's camera initiates and the user can take a photo when they have found a favorite spot.

When the user touches the "Next" button, the system recommends new photography locations. This button is used when the user has found the recommended photography location or the user wants to go to another location. The system recommends locations that are further from the destination than the user's current location. Thus, the user can take a roundabout way and conduct casual sightseeing on foot freely. This enables opportunistic sightseeing in accordance with the user's mood without being bound to the user's location or the photography location. Furthermore, when there is little time remaining and no photography locations satisfy the conditions, the system starts to navigate to the destination. In this way, the user can go to their destination while changing the visited locations according to their feelings.

V. EVALUATION EXPERIMENT

A. Experiment Site

In our evaluation experiment, we set the start point as Yasaka Shrine and the destination as Kiyomizu Temple in Kyoto, Japan. There are four reasons for conducting the experiment in Kyoto.

- Most streets between the two locations have few cars and are easy to walk in.
- Many streets or buildings are historic and appealing.
- There are many souvenir shops and restaurants.
- There are many narrow streets suitable for casual sightseeing on foot.

B. Evaluators

We conducted this experiment with the cooperation of seven students who live in the Kansai area, which includes Kyoto. The evaluators were separated into three groups based on a preliminary survey that asked how many times they had visited Kiyomizu Temple or Yasaka Shrine and what they want to see during sightseeing. The purpose of this group division was to investigate how the results of limiting the route information is affected by the number of visits. Moreover, the aim of separating three groups by their tourism preferences was to investigate how this affects users' choices of photography locations or the type of photos they take. Table 1 shows the evaluator group composition.

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TABLE I. EVALUATOR GROUP COMPOSITION

	Group 1	Group 2	Group 3
Number of People(Male : Female)	2(1 : 1)	3(3 : 0)	2(0 : 2)
Number of Previous Visits	0	Over 3	1~2
Want to See	Streets	History	Food

C. Experimental Procedure

The experiment was conducted for each group with the start point of Yasaka Shrine and destination of Kiyomizu Temple. Each group set their available time for sightseeing freely and headed for Kiyomizu Temple using the system. The first author accompanied the evaluators and observed the circumstances of the experiment. After the experiment, the evaluators were asked to complete a questionnaire, via which we expected to examine the results and problems of this study.

D. Purpose of Experiment

In this experiment, we conducted evaluation by paying attention to the following points, in order to confirm this study's outcome.

1) Realization of opportunistic sightseeing, and its difference to regular sightseeing

In this system, the users do not decide on the details of the route. They can stroll freely according to their mood and can choose photography locations that they want to visit, in contrast to conventional navigation systems that show the shortest route. We aimed to investigate how free situations like this affect the users' actions and whether that effect gives users satisfaction in comparison to conventional navigation systems.

2) Influence on sightseeing of photography location recommendation, and of addition of camera function

We aimed to investigate whether the user's eyes are attracted to the surrounding environment, not to the system screen, by "searching" for recommended photography locations.

In addition to this, we aimed to evaluate whether the system prompts users to discover new attractions in the tourism area with the function of taking photos.

3) Balance of anticipation and uneasiness with navigation using only aerial photograph maps and direction information

In this system, users are navigated using only aerial photograph maps and direction information. This is more difficult and inconvenient than conventional navigation systems. The uneasiness that this navigation style, based on the "Benefit of Inconvenience", inflicts on users is moderate. We aim to inspect whether the system can change this uneasiness into anticipation during sightseeing.

E. Experiment Results

1) Group 1

For both of Group 1's members, this was their first visit to Kyoto. Accordingly, they conducted sightseeing carefully by refreshing their location information frequently, and often got lost. From these points, we can consider that navigation using only aerial photograph maps and direction information inflicts uneasiness on people for whom it is their first visit. However, on the other hand, the Group 1 members looked around well in order to search for the recommended photography location carefully. They initiated the camera function of the system and took photos five times.

2) Group 2

The photos chosen by Group 2's members were inconsistent, and were a mixture of rare sights and streets. Since all three members had visited Kyoto several times, they were familiar with the surroundings, rarely updated their location information, and did not lose their way.

Moreover, the photography locations chosen by Group 2 did not approach Kiyomizu Temple; instead, they went around and sometimes left the Kiyomizu Temple area. The members conducted sightseeing opportunistically and freely, interrupting or diverting their route to go to photography locations. However, because they diverted so much there was no time, so they stopped in order to walk to Kiyomizu Temple. For this reason, they regretted their preset time. From this result, we determined that the system can support users in conducting sightseeing that matches their moods at that time by recommending photography locations regardless of the user's position and the genre of sightseeing. On the other hand, we also discovered issues in the system, including that users could not change the destination or time.

3) Group 3

All of Group 3's members had previously visited Kyoto, but they cautiously confirmed their position at the start of the experiment.

However, they gradually decreased the frequency of refreshing their position while walking and searching for photography locations. In addition, although this group said that they wanted to visit locations focused on food, they did not choose a photography location related to food. They gave the reason that they wanted to visit photography locations recommended for other genres. However, as they stopped by a sweetshop and a café, they took actions that matched their feelings. This group used the camera function positively, taking over ten pictures.

VI. CONSIDERATION

1) Realization of opportunistic sightseeing, and its difference to regular sightseeing

In this system, users do not only choose a photography location according to personal preference, and follow a route while looking for the place; they can also freely change the photography location according to their moods while they head for the photography location. In the evaluation experiment, users freely changed the photography location according to their feelings at that time,

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decided on a course spontaneously, took very roundabout routes, and sometimes stopped or went away from the destination. Thus, they were able to conduct sightseeing freely. Moreover, they answered that they were able to enjoy sightseeing using this system more than sightseeing using a normal sightseeing navigation system, by always acting in accordance with their feelings.

2) Influence on sightseeing of photography location recommendation, and of addition of camera function

This system was able to prompt users to turn their attention to their surroundings by letting users look for the scenery in the photograph by recommending the photograph. From the fact that all groups used the camera function of the system and took pictures over five times, we can consider that the system allowed users to consciously discover new appeal of the sightseeing area.

3) Balance of anticipation and uneasiness with navigation using only aerial photograph maps and direction information

This system allows flexibility in the user's route, by not assigning the route during navigation. Instead, the navigation uses only aerial photograph maps and direction information, which inflicts uneasiness to many users but also provides a further sense of anticipation. In addition to this, users were able to enjoy sightseeing by taking their favorite routes more than in regular sightseeing. However, problems arose, including that this style of navigation can inflict such uneasiness that it was easy for users visiting Kyoto for the first time to lose their way.

VII. CONCLUSION

A. Problems

In this study, we proposed a sightseeing navigation method that adapts to users' feelings opportunistically, and its efficacy was demonstrated. However, the system requires a function to change or extend the sightseeing time, because in the evaluation experiment there was a group that did not have enough time. Moreover, the navigation system needs to be developed in order to add a function that supports when users want to change their destination depending on their moods. In future, we will examine an even more opportunistic sightseeing navigation system. In addition to this, we will develop a sightseeing navigation system that can recommend photography locations that to some extent consider the weather or the user's feelings, guessed according to the user's selection of photography locations, not only using the available time for sightseeing.

B. Conclusion

In this research, we focused on photography that is frequently conducted in sightseeing and proposed an opportunistic sightseeing navigation system that navigates to the destination by recommending photography locations one by one. The method of navigation uses aerial maps and direction to photography locations based on the "Benefit of Inconvenience", without showing or appointing a detailed route. It was demonstrated that the freeness of sightseeing using navigation that always follows the moods of the user, the recommendation method of photography locations and the display method of the navigation led to enjoyment of the sightseeing. Moreover, the system allows users to pay attention consciously to their surroundings by promoting searching for the photography locations and taking photos, and enables new discoveries in the sightseeing area.

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Disaster Information Sharing System Using Pictograms Only

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Abstract- In the case of disasters, people's comprehension of the situation of the surrounding area is an important factor in deciding corresponding actions. In an area overflowing with people and rubble, it is dangerous to act recklessly. In this paper, we propose an information sharing method to ascertain present status and support decision of corresponding actions when a disaster occurs. Users of the system can decide a course of conduct and avoid risks such as injuries by ascertaining the situation of the surrounding area ahead of time. The disaster information collection system currently in operation in Japan is difficult to use for users unfamiliar with machine operation and is not intended for use by non-Japanese. This work aims to support such people during a disaster. This system uses pictograms that express meaning using shape and color instead of language. It expresses information visually and aims to provide easy operation by using mainly maps and pictograms. Moreover, this system adopts a social media model, which was recognized to be effective in the 2011 Tohoku Earthquake. We promote use of the system when a disaster occurs via a means for using the system in non-disaster situations. In this paper, we describe the system's effectiveness and prospects for the future with an evaluation experiment targeting experts on disaster prevention, non-Japanese and general users.

Keywords-Pictogram; Disaster Mitigation; Social Media; Information Sharing;

I. INTRODUCTION

Japan is affected by many disasters; in fact, the country is an area that suffers a concentration of disasters. Although this area is only 0.25% of global landmass, it is the site of 20.5% of all earthquakes of magnitude over 6.0, 7.1% of all active volcanoes, and 16.0% of disaster-related damage costs worldwide [1]. Furthermore, Japan is expected to be affected by a large earthquake such as the Nankai Trough Quake and an earthquake in the Tokyo Metropolitan area within 30 years. For these reasons, interest in seismic countermeasures has increased and the government is beginning to take various measures. However, current disaster risk management is undertaken with local inhabitants, so measures for people unfamiliar with the area, such as tourists, are barely considered.

Meanwhile, Japan is aiming to make the country a global travel destination, which is being treated as important policy in the 21st century [2]. As an example, Kyoto city is visited by one million foreign tourists every year, and foreign visitors across Japan are expected to increase in the future. Paris is a famous model of an internationally competitive sightseeing city, visited by 45 million tourists every year, 60% of whom are from overseas [3]. When a disaster strikes such sightseeing cities, many tourists will suffer from heavy damage. They are unfamiliar with the area, local language, culture and disasters. The safety of foreign tourists is critically important, and actions to protect them are the responsibility of the region and the nation. We focus on the problem of language in this research. Most disaster information systems and services use letters to provide necessary information. When a disaster occurs, foreign tourists will be in a precarious situation because they are not likely to have sufficient ability in the local language, which limits their methods to collect information.

On the other hand, there are many people who are not used to advanced information systems and services. As an ongoing problem, proportion of elderly population is rapidly increasing in Japan. Information collection in a disaster is difficult for the elderly, because many aged people are not proficient at using advanced information technology and services. A new approach is needed to support them collect disaster information by easy-to-use human machine interface.

In this study, in response to these situations, we aim to propose a unified and integrated method to share information for disaster victims who have various different requirements.

In the next section, related work is described. We present outline of proposed system in Section 3, and system architecture in Section 4. Then evaluation experiment is presented in Section 5. Finally, a conclusion and future work are described.

II. RELATED WORK

A. Universal Design of Disaster Prevention Pictograms

Kunoki et al. of Ritsumeikan University considered the provision of unified design of disaster prevention pictograms at tourist sites. They conducted an investigation into signs and guide plates at Kiyomizu Temple, a famous tourist attraction, as a target and suggested a method for improvement [4]. The summary of their results is as follows.

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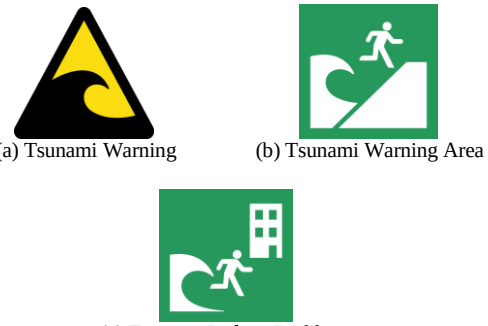
1) Guide plates that display foreign languages or use pictograms are only about one quarter of the total.

2) Methods to express color, shape and content are different depending on the place. There is no sense of unity and this hinders understanding.

From the summary of results, Kunoki et al. advocated the necessity of offering information utilizing universal design to provide efficient evacuation guidance. These problems have been noticed by the Fire and Disaster Management Agency (FDMA) in Japan too. They are considering concretely implementing universal design [5]. Figure 1 shows sample models under consideration by the FDMA.



(a) Tsunami Warning (b) Tsunami Warning Area

(c) Tsunami Refuge Building

Figure 1. Graphic Symbols for Tsunami Signs

B. *Analysis during the 2011 Tohoku Earthquake*

In the 2011 Tohoku Earthquake, the Tokyo metropolitan area suffered from disaster for the first time after being developed as a modern city, and there were many people who had difficulty returning home. This is relevant to this study, as it is useful to design our system through analysis related to information media.

1) Analysis of Victim Behavior

From the summary of a Cabinet Office survey conducted via the Internet, there were 5.15 million persons who had difficulty returning home in the metropolitan area, which includes Tokyo, Kanagawa, Chiba, Saitama and Ibaraki [6]. The results of the survey into how people returned home are shown in Figure 2.

In Figure 2, n = 5,372 persons who were affected by the disaster and responded to the survey. The most common method of returning home was on foot, accounting for 37.0% of the total victims, and the second most common method was by car. The percentages of walking and car are very similar. The reason for these being the most common is that trains ceased operation immediately after the earthquake.

2) Necessary Information for Returning Home

Disaster victims felt that certain information was necessary while returning home, as shown in Figure 3. In descending order, information on their families' safety, investigation of the damage, and time until the trains and subway would resume operation, were the most cited. If we exclude family safety information, we can see that victims need information about items required to return home.

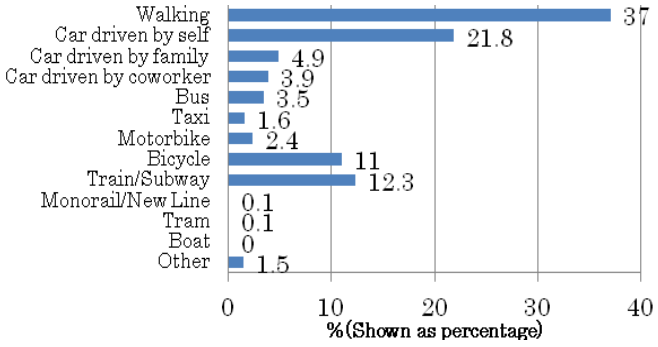


Figure 2. Methods of Returning Home

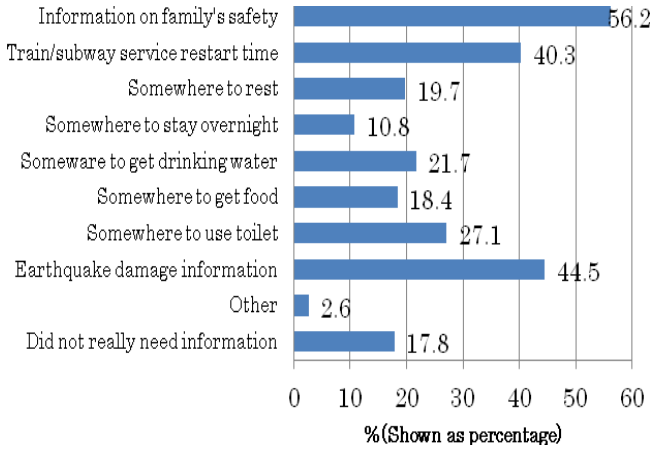


Figure 3. Necessary Information

3) Future Methods of Obtaining Information

Figure 4 shows the results of a survey conducted about future methods of obtaining information hoped for by disaster victims. This survey targeted people who tried retuning home in a disaster. Results are grouped for three conditions related to whether victims were capable of returning home. In particular, the provision of information by TV is strongly hoped for. This reason is considered to be that TV is capable of providing information visually, and that people watching TV can know an overview of the disaster in various places. The number of people who wish to be provided information by cell phone is high, because it is easy to use while on the move. In particular, there is a tendency for this to be desired by people who tried to return home but were prevented. This may be estimated as due to the necessity for information to decide a new course of action after being prevented from returning home.

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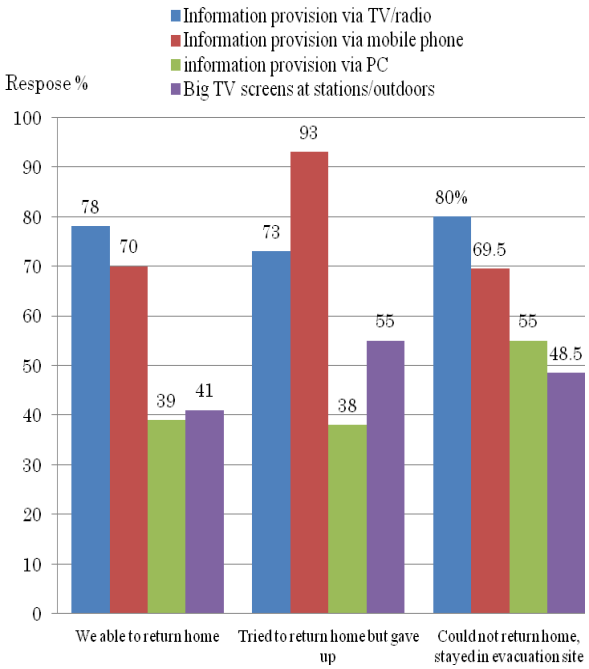

Figure 4. Desired Sources of Information in Future

C. Social Media

The effectiveness of social media was recognized during the 2011 Tohoku Earthquake, exemplified by Twitter. The "wisdom of crowds" was constructed from many users' posts (Tweets) [7]. This is revolutionary as being the first system in which victims themselves provided information, in contrast to previous systems in which the victim is only provided information by the system. Official hash tags were provided by Twitter from the day after the disaster occurred. Examples of hash tags include '#j_j_helpme request rescue', '#anpi safety', and more. Various kinds of information was posted on Twitter, such as the appearance of the disaster-hit area, means of transport, available toilets, evacuation sites, places for lodging, and more.

D. An Information Collection Support System for disaster-affected areas using Mini-blogs

Yokobe et.al., proposed an information collection system using social medias and mini-blog to collect information when disaster occurs [8]. In this paper, the evaluation results using Twitter are shown. This research assumes the following two conditions:

1) The useful information for victims is sent from disaster-affected areas.

2) The reliability of information is evaluated by people in the area where the information is sent.

Based on these assumptions, the system deletes information which is sent at an area away from the disaster-affected area because the information is decided as unnecessary and unreliable. Specifically, assuming that information with exact location data has high reliability, the reliability of each tweet and user of Twitter is evaluated based on the location data and the responses from people living around a location where the tweet is sent. From the results of the evaluation, it is shown that tweet including a name of the place has high relationship with the disaster-affected area. This fact implies that a name of place is important in deciding the reliability of tweet. However, it is known that most of tweets do not have information of its location data. Thus, the detection of reliability based on location data is not available in many cases.

III. OUTLINE OF PROPOSED SYSTEM

A. Pictogram

Pictograms are graphic symbols that express things or general ideas instead of using words. For example, signs such as 'emergency exit' and 'disabled access' are well known. In Japan, pictograms are adopted in places that are heavily used by the general public. Their biggest advantage is to enable communication of information without the restraints of language. In this paper, we devise a solution for problems contained in the present Japanese disaster information gathering and transmission system.

B. Visual Provision of Information

When victims need to evacuate or return home during a disaster, they are interested only in their present location and surrounding area. When a victim posts information, this can be expected to be a report of situation of their neighborhood. Recently it is easy to calculate present location by using GPS (Global Posting System) or networks. Also, the GIS (Geographic Information System) service is free of charge and easy to use too. We constructed a framework to show the information of present location and surrounding area using these two services. The system shows information automatically and visually, so it is easy to use. This is a highly important function in a disaster information system.

C. Overloaded Communication Lines

Cell phones and smartphones are one of the most frequently used methods to gather information when a disaster occurs. However, the calling function can barely be used, and mail and Internet is delayed significantly by limiting or congestion of communication lines. When we gather information using information infrastructure, the system needs to operate in this kind of situation. With this in mind, we propose a system built as a smartphone application.

D. Disaster Information to Provide

In this system, we deal with the kinds of information that were required during the 2011 Tohoku Earthquake. By determining information types beforehand, we can anticipate the degree of increase in comprehension and avoidance of misunderstanding. Furthermore, provision of information is separated into two types: information displayed by default and information displayed by user operation, as shown in Figure 5.

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TABLE I. PROVISION OF INFORMATION

Pictogram	Meaning of Pictogram
	Usable Means of Transport
	Evacuation Site
	Place for Medical Treatment
	Place for Rest

(a) Information Displayed by Default

	Food, Drink
	Available Toilet
	Place for Available Network
	Available Accommodation

(b) Information Displayed by User Operation

In the default settings, we limited the amount of pictograms to be displayed, so that it is easy to obtain information from the pictograms. The system can add pictograms to the display according to the user's needs. In addition, if the user taps a pictogram, the time of the posting and the contributor are displayed as annotations.

E. *Dissemination of System*

At the present time, various measures are in place against disasters. However, their rate of utilization is a low percentage in total telecommunication services. We can consider that this is due to the fact that the service is not known among disaster victims. Information sharing systems cannot demonstrate effectiveness if they are not widely known.

Accordingly, we propose a social media model as a method to raise the rate of utilization. This model is can also be used outside of disaster occurrence, and the users can freely change the genre of information. Disaster information is treated as one genre. During non-disaster times, users can view information pictograms about places (for example, tourist attractions and store information) and read comments posted by other users. In addition, users can post pictograms and comments themselves and add to other users' contributions. This system is different from current social media that mainly use text, because it mainly uses maps and icons made from pictograms. We expect that the amount of information will increase because disaster victims can post information themselves. We aim to design a system to be used by victims when a disaster occurs, by encouraging them to use and familiarize themselves with the system during non-disaster times. This study assumes such a form of utilization for the system.

IV. SYSTEM ARCHITECTURE

A. *System Description*

This system uses a client-sever model in which the client is a smartphone application and the server is a web application utilizing a database and PHP programs. The database stores the pictogram type, location (latitude and longitude), contributed time, contributor and pictogram ID inputted by the user. PHP programs respond to requests by the client, acquire information from the database, then send the client information registered in server about their current surroundings.

B. *Disaster Data Collection*

The system's initial screen is showed in Figure 5. The user can collect information on their current surroundings via map information and icons on this screen. The functions of each button are described.

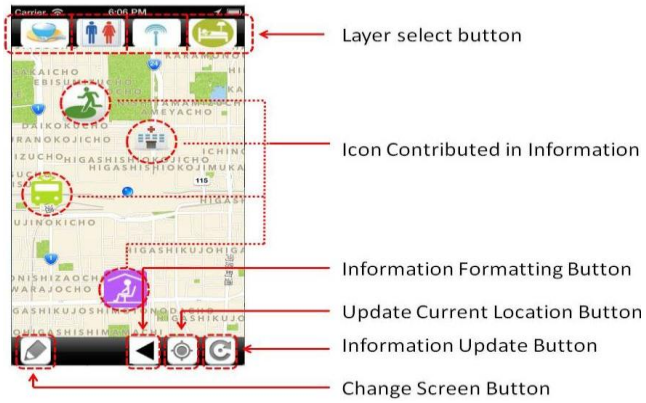

Figure 5. Information Collection Screen

The following is a description of the system flow during information collection.

1) *Acquire latitude and longitude of current position from GPS and network.*
2) *Using current position information, acquire information on the surrounding area up to a 3km radius from the database.*
3) *Display map information for the surrounding area up to a 3km radius and place the pictograms in designated positions on the screen.*

By tapping an icon, the users can find out the contributor and posted time, which can aid in judging the situation, as showed in Figure 6.

Figure 6. Annotation when Tapping an Icon

When the user changes the information genre to information about disasters, the system displays only

important information. Other information can be seen by tapping the Layer Select Button.

There are two methods to update information. The 'Information Update Button' updates information. The 'Information Formatting Button' updates information and also changes the information genre to default. Both actions update the user's current location and center the map on the user.

In this way, this system expresses information using shape and color without words, by which the user is able to collect information on their surrounding area.

C. Contributing Disaster Information

During disasters, the time and operations required to contribute information should be minimal. In this system, users can contribute with three steps, as shown in Figure 7.

1) *Change to "Contribute" screen*
2) *Select the pictograms corresponding to the information the user wants to contribute from the icons at the bottom of screen*
3) *Tap "Contribute" Button*

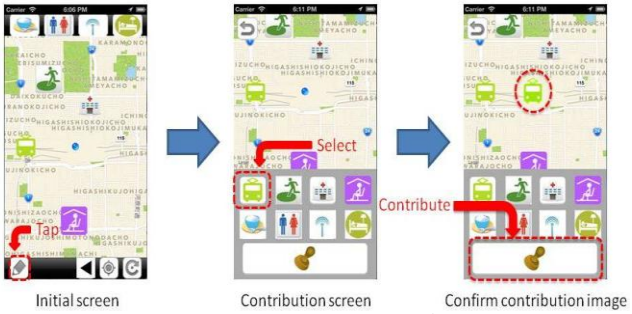

Figure 7. Contributing Information

Via this operation, the client-system sends the server information that includes the current position (latitude and longitude), pictogram name, time of contribution and pictogram ID determining whether to display the default display or layer selection. This information is obtained from the system automatically, with the exception of the pictogram name, so the system saves the user's time. In non-disaster situations, users can post comments and photos in the system, but if the information genre is changed to disaster, these functions are automatically suspended and text-based communication is prohibited. This reduces the amount of communication.

V. SYSTEM EVALUATION

A. Evaluation Method

To verify the effectiveness of the system, we conducted an evaluation experiment separated into two patterns: for experts and for normal users.

Three persons belong to Kyoto's Disaster and Crisis Management Section and twelve persons belong to Konan Fire Department participated in the experiment as experts, performed simulated operation of the system and answered a questionnaire survey after we explained about the system.

Two students from China and six students from Japan participated in the experiment as normal users, and answered the same survey without hearing an explanation of how to use this system. Three of the students had not used social media or smartphones before. The items of the survey are listed below.

1) *Do you think comprehension of the situation during a disaster would increase by using this system?*
2) *Were the sizes and designs of pictogram appropriate?*
3) *Was the system sufficiently easy to use?*
4) *Are the types of information provided sufficient?*
5) *Do you have other points of feedback or improvement?*

B. Expert Evaluation

The following is a summary of the evaluation by the experts.

1) *Response to Question 1*
   - a) *There are big advantages for evacuating to shelters and obtaining information for returning home*
   - b) *Information is available quickly, as it is expressed using easy-to-understand pictograms*
   - c) *Users can be psychologically reassured, as they can gather information on their surrounding area*
   - d) *Comprehension of the situation can be increased, as information about the destination is easy to understand*
2) *Response to Question 2*
   - a) *Pictograms were appropriate (13 out of 15 experts)*
   - b) *Users should be able to change the size of the pictograms (2 out of 15 experts)*
3) *Response to Question 3*
   - a) *If users already have smartphones, the system could be operated without problems*
   - b) *Limiting the amount of provided information leads to ease of use*
   - c) *Mental barriers to using this system are higher for elderly people*
4) *Response to Question 4*
   - a) *Information about unavailable facilities, not only available facilities, is necessary*
   - b) *Information about means of transport (operation status and area) is necessary*
5) *Response to Question 5*
   - a) *Need accurate and safe user-contributed information*
   - b) *Setting display periods for pictograms would improve management of information*
   - c) *Wish to utilize Wi-Fi spots during disaster situations, for example bus stops*

C. Non-Japanese User Evaluation

The following is a summary of the evaluation by non-Japanese users (Chinese).

1) *The provided types of information and size of pictogram are appropriate.*

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2) *It is easy to ascertain the situation in the surrounding area via the combination of GIS and pictograms.*
3) *If we have experience of this system as social media during non-disaster times, we can use it when a disaster occurs.*
4) *We could not understand the difference between 'Evacuation Site' and 'Place for Rest' only from the pictogram.*

D. General User Evaluation

The following is a summary of the evaluation by general users.

1) *The provided information types, size of pictograms and denotation are suitable on the whole.*
2) *It is easy to use this system because it only uses pictograms.*
3) *If we have operated this system once, we can use when a disaster occurs.*
4) *Because the display is based on maps, we could ascertain both the geography and situation of our surroundings simultaneously.*
5) *We could understand the meaning of the information quickly, as there was no need to read text.*
6) *The pictograms for 'Evacuation Site', 'Place for Rest' and 'Available Accommodation' are too similar to distinguish. They should be revised or guidelines should be made.*

E. Consideration

The results of our evaluation experiment are as follows. Although some deficiencies in the provided information and comprehension problems for some of the pictograms were pointed out, we were able to confirm that this system can be used as an easy-to-operate disaster information sharing system through evaluation from experts, non-Japanese and general Japanese users.

Advantages and disadvantages are shown below.

1) *Advantages*
   a) *Contributing and sharing the information is easy*
   b) *Various people can use the system*
   c) *The disaster situation can be grasped intuitively*
2) *Disadvantages*
   a) *The system cannot transmit details of the provided information*
   b) *There is no guarantee of accuracy of user-contributed information*

Perceptions of color and shape vary between countries and cultures, because differences in sensitivities derive from the environment in which a person is raised. In this evaluation experiment there were only two non-Japanese evaluators, so we were unable to verify such differences. In future, we will pursue additional evaluations targeting more non-Japanese of multiple nationalities.

VI. CONCLUSION

In this paper, we focused on the importance of supporting persons who are affected heavily during disasters, such as those who are unaccustomed to using information-processing equipment, those who cannot read or speak the local language, elderly people, and foreign tourists. We designed a system whereby disaster victims can share information using pictograms instead of language, and correlate their current position on a digital map. The numbers of foreign tourists in Japan will increase more and more. Moreover, the proportion of elderly persons will increase in Japan's aging society. Therefore, this system aims to support such people, and we are convinced that this support will be required in future.

In future work, we will conduct further evaluation experiments and conduct questionnaires with large numbers of non-Japanese and persons unaccustomed to using information devices as targets, and improve the system accordingly. Additionally on the server side, we will also implement system functions that reflect the results of the experts' assessment, and clarify their effectiveness via further experiments.

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Engaging Practitioners to Deliver Government Carbon and Energy Phased Reduction Targets: Toward a Web 3.0 Approach

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***Abstract*—The construction industry is under pressure to increase the sustainability of its practices to meet United Kingdom's commitments to alleviating climate change. This paper, through the use of a mixed method approach, explores the readiness and level of engagement of construction stakeholders in adopting government sustainability agendas. Limited sustainability best practice, regulation awareness, and information provision deficiencies emerged as key themes from the initial survey. Subsequent combined consultations explored stakeholders' knowledge, understanding, attitudes, values and behaviours, and helped identify key barriers to sustainability engagement. This has informed the participative development of a "one-stop-shop" web-based platform that provides integrated access to sustainability resources in the form of interactive, dynamic, and user-oriented services, delivered via discrete "widgets", that exploit web 2.0 concepts, including semantics, user profiling, and professional networking. The innovative dimension of the solution lies in its open, scalable and polymorphic context-based widgets approach that reconfigure and update themselves to respond to changing user context and (sustainability related) queries, while enabling serendipitous information and knowledge discovery. The authors believe that the proposed web portal (a) has the potential to engage further practitioners in delivering sustainable interventions, and (b) contributes to the ongoing debate and shaping of Web 3.0 and beyond.**

Keywords-User engagement; Web 3.0; Knowledge Management; Ontology; Sustainability.

I. INTRODUCTION

Studies indicate that creation and operation of our built environment is responsible for some of the most serious global and local environmental changes [1, 2, 3], accounting for at least 50% of all energy consumption in Europe (European Commission, 2005). In the United-Kingdom (UK), more than 50% of all carbon emissions can be attributed to energy use in buildings [4]. The UK Chancellor of the Exchequer announced in the 2008 budget that the UK government aspires to achieve construction of zero carbon homes from 2016, Public sector buildings from 2018, and all other non-domestic buildings from 2019 [5]. The Welsh government has set aspirations for zero carbon for new buildings earlier than proposed in the rest of the UK [6]. Consequently, the construction industry is under pressure to increase the sustainability of its practices, the implication of which is a requirement on the industry's behalf to understand the demands both from society and its clients, and its sense of corporate responsibility, which, in turn, implies major changes in its working practices [7, 8]. The large scale consultation reported in this paper indicates a clear need for a dedicated resource to enable shared and value-added relevant resources of knowledge and expertise to inform sustainable and energy regulatory compliant design and construction activities. This is the core mission of the Script project, which sets the objective to develop an advanced Web-based "one-stop-shop" platform providing value added sustainable construction experience shared amongst communities of practitioners. Through our initial consultation, it has become apparent that such a "one-stop-shop" platform should address a number of attributes that exceed Web 2.0 capabilities and prompted the authors to explore and contribute to the ongoing debate about the realm of Web 3.0 and beyond. The paper first introduces the methodology that underpins the research and initial consultation results. The authors then discuss perceived features of Web 3.0, interpreted in the context of the "Script" platform. The latter is then further supported by the description of the underpinning system architecture and resulting interface. The paper then illustrates the core aspect of the Script platform, i.e., the sustainable construction ontology and its method of development. The validation of the platform is then discussed, focusing on its fulfillment of an enhanced users' sustainable knowledge experience. The paper concludes with a critical discussion of our Web 3.0 definition and approach, its limitations, and directions for future research.

II. THE "SCRIPT" METHODOLOGY

Requirement capture and elicitation are some of the most critical tasks of any software development project. A socio-technical approach is employed underpinned by the following three research questions (RQ):

- RQ1: What are construction stakeholders' sustainability information needs and government provision deficiencies?
- RQ2: What are construction stakeholders' engagement barriers with governmental carbon and energy reduction targets?

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- RQ3: Can the (above) elicited information needs and engagement barriers inform the development of a reference "one-stop-shop" Web platform for sustainable construction?

These questions were explored via three mixed-method studies. The first study, which addressed RQ1, employed an online Europe-wide survey (February – April 2009) from which 252 responses were received with participants being demographically representative of the total population sampled. Quantitative data were analyzed in SPSS and qualitative data were coded thematically in NVivo. Limited sustainability best practice, regulation awareness and information provision deficiencies emerged as key themes from the consultation and provided the ground to address RQ2. To address this question, the methodology employed a further study focused on industry consultations in Wales. This involved three workshops (c.70 participants in total) and a series of 15 semi-structured interviews with key industry representatives (May – September 2009). The first two workshops explored stakeholders' knowledge, understanding, attitudes, values and behaviors, and helped identify key barriers to sustainability engagement in Wales, which were then debated and confirmed in a third workshop hosted by the Low/Zero Carbon Hub in Wales (Wales LZC Hub). The Wales LZC Hub is a coalition that is supported by the Welsh Government, the building industry, housing, and voluntary sectors, to help meet the policy targets. A number of issues have been captured through our intensive industry consultation and entails a need for construction stakeholders to understand the changing landscape of sustainability and associated legislation, which, in turn, demands easy and timely access to fragmented and multi-faceted information. Moreover, construction stakeholders involved in new or refurbishment projects are faced with: (a) complex legislation related to low carbon buildings, (b) a plethora of overlapping commercial tools supporting the process of delivering low carbon buildings, (c) numerous guidelines and documentation, (d) an increasingly rigorous energy certification process, and (e) lack of clarity on types of financial assistance and eligibility criteria. Also, while a great deal of expertise already exists in detailing and constructing low-energy buildings, much of this expertise is fragmented and exists in various forms, with no real systematic means or mechanisms to assist construction stakeholders in their low carbon decision-making [7]. In this context, it is imperative to make building energy expertise widely available. The findings from these workshops fed forward to a series of interviews where identified barriers were discussed from a variety of socio-technical perspectives. RQ3 formed the focus of our third study, which involved the script platform requirement elicitation from extensive consultations with industry stakeholders including online surveys, semi-structured interviews, collaborative workshops and focus meetings (a mix of one to one and small group consultations). Moreover, 2 workshops and 13 focus meetings (a mix of one-to-one and small group consultations) were organized (February – November 2010). A total of 27 stakeholder organizations took part in the consultations, including: construction companies and practitioners, advisory groups, umbrella professional organizations, consultants, policy makers and education and training bodies.

III. SCRIPT CONCEPT

The Semantic Web and Web Services are transforming the Internet from a network of information to a network of knowledge and services. Using the read-write nature of Web 2.0 applications, new knowledge is inferred based on mashups that occur at the data, rather than at the application level. Web 3.0 in its present manifestation exploits Semantic Web technologies integrated into large-scale Web applications [9]. In fact, the foundations of Web 3.0 services involve Resource Description Framework (RDF) for linking data from multiple distributed databases or Web sites. The SPARQL query language (a SQL-like standard for querying RDF data) enables Web services and applications to use native graph-based RDF stores and extract RDF data from traditional databases. Once the data is in RDF form, the use of Uniform Resource Identifiers (URIs) for merging and mapping data from different resources facilitates development of multiple distributed and fragmented site mashups [9]. RDF Schema (RDFS) and the Web Ontology Language (OWL) provide the ability to infer relationships between data in different applications or in different parts of the same application [10]. The term "linked data" is often used to describe the evolving RDF development space, and "Semantic Web" is increasingly being used to describe coupling linked data with RDFS and OWL. These capabilities are currently being exploited to enable enterprise data integration and related functions [9].

As noted earlier, the Script consultation indicates a need for far greater sophistication than is currently employed in the nearest comparable web resources for knowledge harvesting and sharing. The need to efficiently categorize information coupled with requirements for bi-directional channels for knowledge sharing and enrichment, including professional networking capabilities and access to dynamic information elements aimed at a large constituency, suggested a novel framework employing the concept of 'widgets' (discrete information or service containers). This allows scalability and logical categorization of information, knowledge, and services, augmented with the capability for different users to 'personalize' their Web experience according to their individual needs. As the user is in control of which widgets are visible at any given time, a key benefit of this system is that, rather than having to trawl through a long list of search results for different subject areas in relation to the topic being searched, the system automatically categorizes the results within those widgets of particular interest to that user. Figure 1 illustrates the mock interface used to capture and confirm users' expectations of the modus-operandi of the proposed Web solution. Using the example of a search over "Ground Source Heat Pumps (GSHP)", the system would display widgets that contain information about the search query, including (a) what are

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they, (b) Legislation and regulations, (c) Guidance documents, (d) Manufacturers, suppliers, and installers, (e) projects which have used GSHP, (f) training and skills.

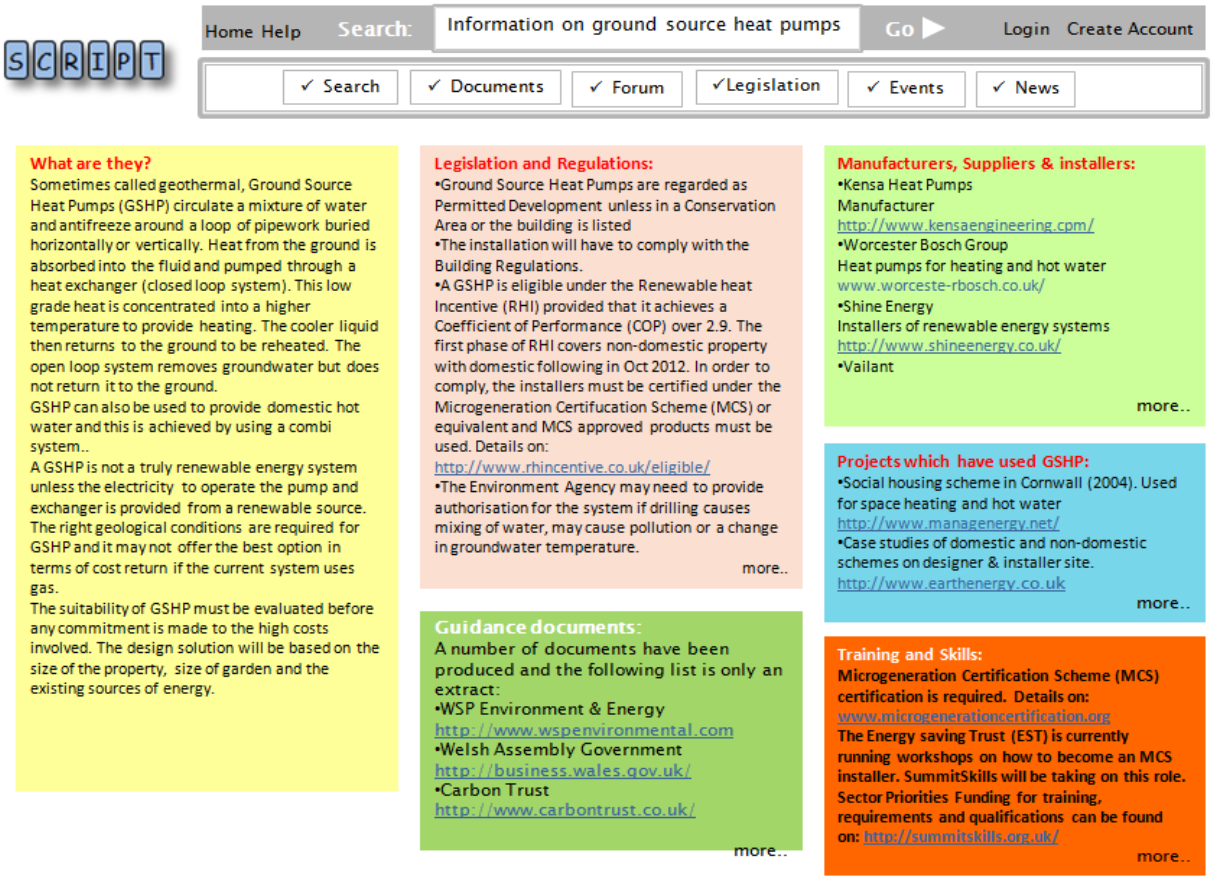

Figure 1. User-centric Concept Elicitation

The proposed Script concept involves features, such as semantics through ontology and user-profiling, widely accepted by the Web 2.0 community. In fact, Web 2.0 is a somewhat overloaded term that can refer either to user-generated and/or managed online content, or the provision of applications via the Web [11, 12]. In an effort to fully understand the changing construction landscape, different actors have built various repositories, organized events, etc., but with little or no coordination or awareness of what one another is doing, and lack of clear guidance and assistance on energy regulatory compliance. A plethora of portals, which operate on an ‘‘information push” basis have been developed [7]. There is little or no attempt to capture the user experience. Also, on viewing these various sites for the first time, in the process of searching for sustainable construction information, there is a feeling of confusion and uncertainty in what constitutes the best and, particularly, the most important information. A key barrier to engagement with sustainability is the fragmented nature of sustainable construction information and knowledge, which is exacerbated by the indiscriminate nature of currently available search engines on the web. Our consultations indicate that a sustainable construction dedicated search facility would greatly alleviate this problem. The way to achieve this is by creating and making available to the system a sustainable construction domain ontology that ‘understands’ a user’s search queries, thereby facilitating disambiguation, while ‘learning’ from a user’s queries. Figure 2 illustrates the current script user interface with its semantic widgets approach. The following section discusses the script underpinning system architecture and services.

The innovative dimension of the Script solution lies in its open, scalable and polymorphic context-based widgets that reconfigure and update themselves to respond to changing user context and (sustainability related) queries, while enabling serendipitous information and knowledge discovery.

IV. THE SCRIPT WEB 3.0 PLATFORM

The Script Platform has been developed using a Service-Oriented Architecture (SOA) and consists of a set of interoperable services, accessed: by a choice of web-based or mobile device-based clients. The architecture of the Script platform is shown in Figure 3. It should be noted that these services can be utilized independently of the platform

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or within the platform brokered by our kernel. In this context, we identify three types of provision that can be implied:

- Direct provision of services, with each service being delivered as a separate discrete service.
- Indirect provision of services occurs within the platform. With this provision mechanism, each service invocation is mediated by the kernel. In this method, the user (client) requests functionality from the kernel and the kernel delegates the execution of this functionality to the appropriate service.
- Inter-service provision. A service can request functionality directly from another service within the system. This occurs frequently for our ontology as other services utilize its functionality.

Figure 2. The Script Web3.0 Concept

Each service has an associated Application Programming Interface (API), which serves as a description for possible access requests. The API defines a set of methods that a service can offer and a set of associated parameters. In the design phase, care was taken to ensure that the API provides maximum flexibility.

Figure 3 also shows how the services within the Script platform interact. All communication within this system is done using Simple Object Access Protocol (SOAP) and, for communications purposes, the system can be divided into four levels:

- The client level contains the client software with which users interact with the system. Currently, Web-based and Android application clients have been implemented.
- The kernel level facilitates the communication between the clients and other levels of the platform. The kernel acts as a broker, delegating requests to other services within the system, and also as a service

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directory allowing services to be added/removed dynamically.

- The services level is the set of services that provides the key functionality of the platform. These services include:

➢ The Knowledge Base Service contains a corpus of related guides, regulations and various existing documentation related to sustainability in construction.

➢ The Search Service performs semantic searching on the platform knowledge base. The submitted query has a set of associated ontological concepts for improving the precision and the recall of the returned results.

➢ The Professional Networking Service enables users to collaborate using social networks, such and LinkedIn and Twitter, while the communication is facilitated with voice-over-IP instruments, such as Skype and Google-Talk.

➢ The Events Calendar Service is notification/reminder of the important events from the engineering community. Users can subscribe and synchronize these events with their personal calendar.

➢ The News Feeds Service provides aggregation of information and updated news relevant to the users' interests and discipline(s).

➢ The Forum Service allows users to interact by sharing data and information within the platform.

➢ The Sustainable Sourcing Service allows users to lookup products (based on their current location) from certified suppliers.

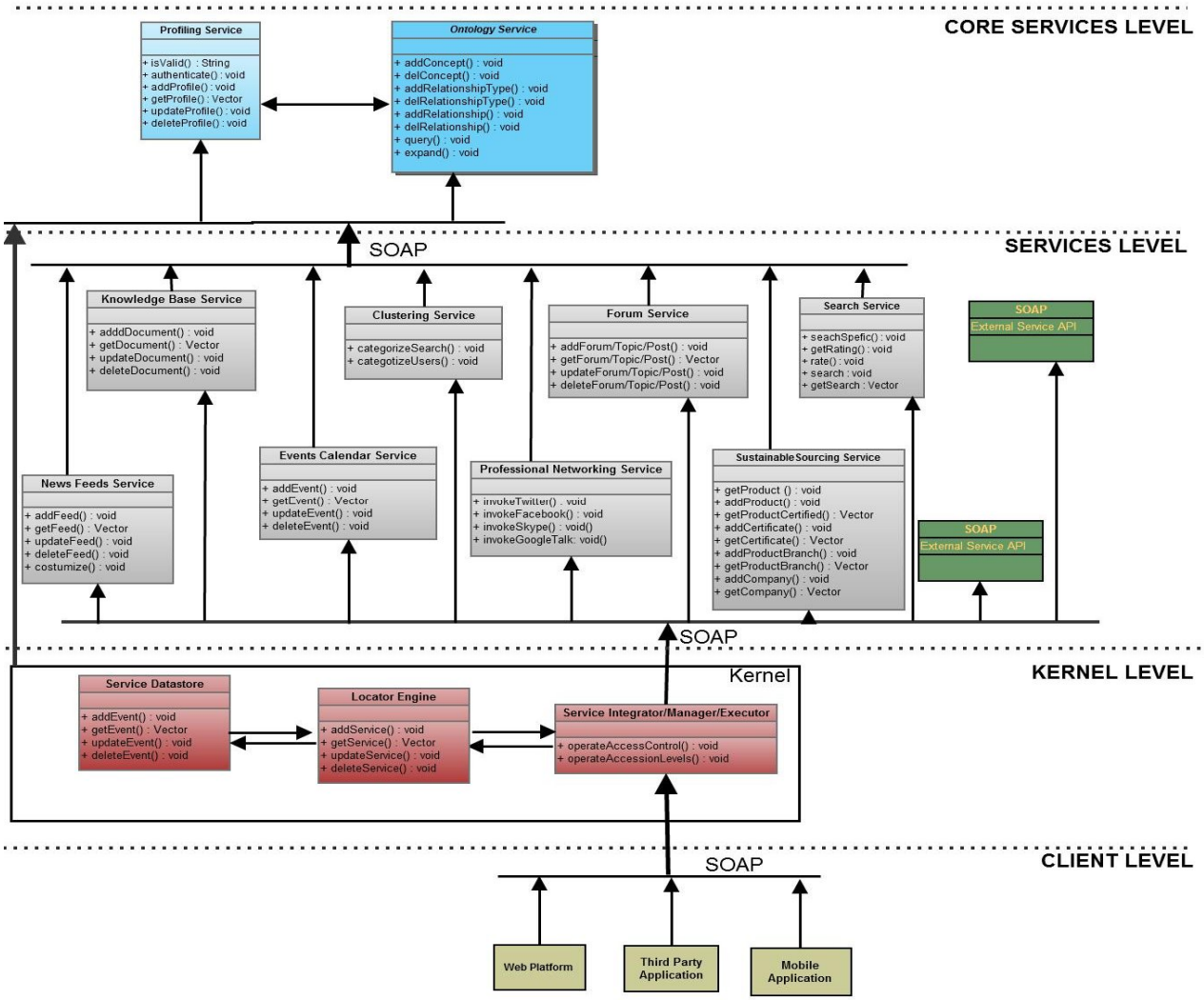

Figure 3. The Script Architecture

- The core services level describes the services that are not only used directly by users, but are also utilized by other services within the system. This is the level in which the ontology service is

integrated alongside the Profiling Service. The latter manages the identities of users and controls the access to the platform. Each user has a set of associated interests and disciplines, which are used as input data for other services, such as searching, professional networking or news feeds.

V. VALIDATION OF SCRIPT PLATFORM AND UNDERPINNING ONTOLOGY

Utilization of automatic or semi-automatic methods for the construction of ontology is not uncommon, and several different examples can be seen in the literature. Rezgui [7] outlines a system where a new ontology for the construction domain is automatically constructed based on a set of existing ontologies for specific related sub-domains and from other semantic resources. Wachter and Schroeder [13] describe a semi-automatic system that enables ontology construction within the Bioinformatics domain based on pdf document collections and the PubMed online database. Wu et al. (2009) describe a methodology utilizing Latent Semantic Analysis [14] to construct an ontology for the semantic web by harvesting concepts from Web Service Description Language (WSDL) files. The authors then apply the process to locate similar Web services based on the similarities between concepts, achieving an average precision of approximately 60%. The authors present promising results, but also state that an important conclusion is that ontology construction can never be fully automated, but well designed semi-automatic systems can provide significant value in assisting domain experts/ontology engineers in their work.

Testing and validation relied on the group of users involved in the initial requirement assessment phase and on an increasingly expanding constituency as the platform was extended to further users. We also monitored user activity by employing Google Analytics. The initial feedback has been positive and encouraging. The analysis of users' comments helped identify some key issues to be addressed in future releases of the platform, as summarized below:

- The ontology needs to be refined and the concepts should be expanded to increase the relevance in searching.
- A new widget is needed reflecting updates taking place within the platform, such as new documents being added, new versions of documents being uploaded, or new events being added.
- Explanation of the different types of documents needs to be available on the platform: due to the nature of the documents available, it is important to support end-users in understanding the exact terminology used to define regulatory (directives, decisions, etc.) and other documents (white papers, project results, etc.)
- A social networking widget is needed, where users can access various social profiles such as LinkedIn, Twitter, Facebook.
- The integration with mobile devices represents an important issue to address. It was identified that many of the visitors prefer mobile devices for retrieving their information.
- The legislation should be extended to UK legislation and possibly to Europe.
- Graphical Interface: The interface should be more intuitive to generally improve the usability of the platform.

To validate the ontology that has been developed, a series of tests have been performed utilizing keyword suggestion functionality. To carry out the validation, users of the sustainable construction platform have been asked to enter a predefined query which has been formulated by a domain expert and were then asked to comment on the relevant terms suggested thus indicating the percentage level of accuracy of the ontology.

To conduct this experiment, ten pre-defined queries were entered. Matching these queries to concepts in the ontology produced a result set of 131 terms with 72% of these terms being deemed accurate matches by the domain expert. Once this initial mapping was produced, the accuracy of the related terms was also examined. To conduct this experiment, each relationship relevant to the queries was analyzed by a domain expert. In total, there were 242 relationships, 73% of which were deemed to be correct.

VI. CONCLUSION AND FUTURE WORK

The Semantic Web, from a Web 3.0 perspective, relates to the development of an environment where data, information and knowledge are inferred, processed, and accessed: in a human friendly manner. The Semantic Web is the symbiosis of Web technologies, knowledge representation artificial intelligence concerned with constructing and maintaining (potentially complex) models of the world. Beyond the potential for maintaining new business models, such as online communities, online market places and advertising supported site, new semantic web paradigm promises to offer facilities for using user profiles (including personal data) with a view of achieving a higher order of knowledge integration and mining enabled by ontology engineering [13]. As noted earlier, the innovative dimension of the Script platform lies in its open, scalable and polymorphic context-based widgets that reconfigure and update themselves to respond to changing user context and (sustainability related) queries, while enabling serendipitous information and knowledge discovery. The authors believe that the proposed web portal (a) has the potential to engage further practitioners in delivering sustainable interventions as inferred through our portal validation work, and (b) contributes to the ongoing debate and shaping of Web 3.0 and beyond. In that respect, key features for a true Web 3.0 environment from our Script portal perspective include:

- Machine processable contents supporting (user) profile-based searching and serendipitous information discovery across the sustainability domain.

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- Sustainability knowledge appraisal, nurturing, validation and feedback through virtual professional communities. For instance, construction products with defects or lack of performance can be quickly made known, while best practice are shared.
- Machine generated ontology for domain conceptualization with potential for evolutionary refinement. The Script ontology has been generated from a large sustainability document corpus while requiring minimal expert input / validation.
- Plug and play capability of third party services that exploit the Script ontology and user profiling. This provides the advantage of widening the scope of users' accessible knowledge while exploiting their profile for filtering information and avoiding information overload.
- Regional and global awareness in terms of sustainability related events, trainings, and continuous professional development.
- Strong sense of professional community belonging with a shared sense of sustainability and social corporate responsibility.
- Management of virtual and physical objects through Radio Frequency Identification (RFID) and Internet of things. For instance, through our Product database, virtual products (such as a building product or equipment) can be purchased, allocated an RFID tag, and then on managed across its lifecycle from delivery, installation, operation, to decommissioning / recycling.

This prompts a discussion on what could form evolutions beyond Web 3.0. The Script platform is currently being enhanced and further developed to embed the capability of transforming buildings and their components / systems into virtual objects with semantics and behavior which can be queried, managed remotely, and operated at optimum performance levels. Moreover, given that Semantic Web technologies are maturing as a means of describing tangible artifacts, we could use their representational power to describe things in the real world. One view is that the physical objects will become Web-accessible in that they will be able to be represented via metadata. Just like applying semantic technologies to problems of interoperability in ubiquitous computing environments, describing physical things will expand our scope beyond the current Web. This forms the focus of the authors' ongoing work and planned enhancements to the Script platform.

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Modeling of the Organ of Corti Stimulated by Cochlear Implant Electrodes

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***Abstract* – Cochlear implants are used by deaf people to recover partial hearing. The electrode array inserted inside the cochlea is an extensive area of research. The aim of the electrodes array is to directly stimulate the nerve fibers inside the Organ of Corti. The electrical model of the physical system consisting of Organ of Corti and the electrodes is presented in this paper. This model allowed to run Spice simulations in order to theoretically detect the minimal voltage sufficient for nerve fiber stimulation as well as the impact of the electrode voltage on the duration of nerve fibers stimulation. Besides, the perturbations introduced by one electrode on the neighboring electrodes were theoretically studied. Finally, the study of power consumption was performed, which is of great importance in such embedded system.**

Keywords: cochlear implant, electrical analog, transient simulations

I. INTRODUCTION

Cochlear implants are an electrical device used by severely deaf people to gain or recover partial audition. They allow direct stimulation of the auditory fibers using an electrodes array designed to reproduce the stimulus that would be generated by a healthy cochlea.

To do so, an external part of the hearing devices is located outside the ear and contains a microphone that captures the acoustic waves and transforms them into an electrical signal used by the data processing unit. Then, this signal is transmitted to the receiver, located within the patient's head, close the skull. The receiver is composed of a demodulator and a set of electrodes driven by electrical signals that will contract the cochlea and stimulate the auditory nerve [1] [2].

Cochlear implants directly stimulate the nerve fibers inside the cochlea, and requires surgery to pull the electrodes array inside the scala tympani (Figure 1).

The connection between the electrodes in the scala tympani and the auditory nerve fibers is critical for efficient nerve fibers stimulation.

In an healthy ear, when a sound wave is produced, it strikes the eardrum and this vibration is reported in the oval window using ossicles. The oval window is the very first part of the cochlea. This oval window vibration creates a wave propagating inside the scala vestibuli, which is filled with perilymph.

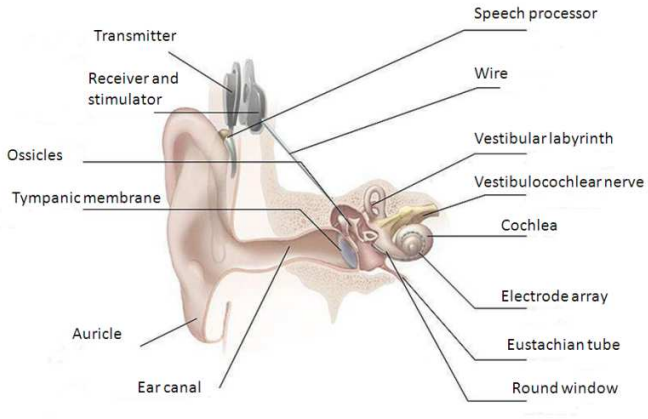

Figure 1. Cochlear implant device [2]

According to biophysical theories [3] [4] when a mechanical wave propagates inside the cochlea, the Basilar Membrane (BM) distorts to absorb the wave energy, resulting in a height variation of the BM which compresses the organ of Corti. As shown in Figure 2, the organ of Corti is composed of Hair Cells (HC) (Outer Hair Cells (OHC) and Inner Hair Cells (IHC)), which have stereocilia at their end. When BM vibrates, stereocilia position change allowing potassium channels to open [5] [6]. Opening of the potassium channels creates the depolarization of the HC allowing complex mechanisms to take place (reviewed in [7] [8] [9]), and finally, resulting in neurotransmitter released in the synapse. Once released, these neurotransmitters travel to the post synaptic cell (the nerve fiber) and creates the depolarization of the nerve fiber. This depolarization, if sufficiently important, generates an Action Potential (AP) running through the nerve cell membrane [10] [11].

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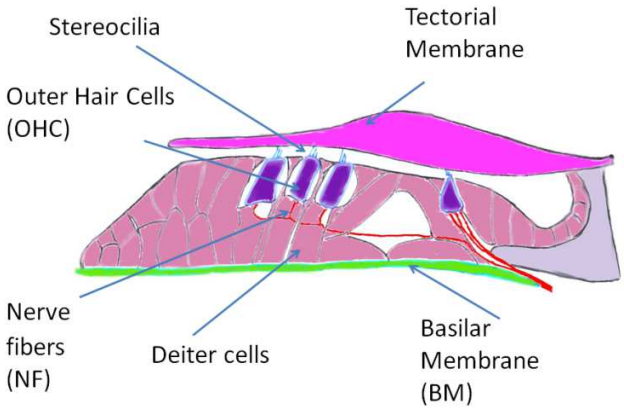


Figure 2. Organ of Corti

The aim of the electrodes array of the cochlear implant is to generate an AP once a sound is perceived.

Consequently to obtain the same Action Potential at the nerve fiber using only electrode stimulation, two possibilities exist. First the direct nerve fiber stimulation can be made by changing the nerve membrane potential in order to produce a membrane depolarization above the threshold of Voltage Sensitive Na+ Channels (Na_v) to create an AP [12]. The second solution consists in opening the potassium channels of the stereocilia to recreate the complete stimulation process. As HC or stereocilia are disfunctionning in the vast majority of implanted patients, only the first mechanism is considered in this paper.

Electrical model of electrodes inserted within the cochlea have been proposed by Hartmann et al. [13], where the spatial distribution of electrical potential was measured for intracochlear stimulation. In addition, electronic model of electrode/neuron coupling is available in [14] in order to reveal the most efficient coupling conditions. However, both models lack of physical connection with AP generation. In this paper, we present an electrical description of the electrode and organ of Corti in order to obtain theoretical minimal stimulation voltage sent to the electrodes for AP generation. Furthermore, this model allowed us to link the stimulation voltage with the duration of the nerve fibers stimulation. Finally the impact of surrounding electrodes were theoretically investigated.

The next section presents the theoretical model developed for the Organ of Corti associated with the electrodes. Then, simulation results from Spice software are presented. Finally, the conclusion and future work direction are presented.

II. MATERIALS AND METHODS

The electrical equivalent circuit of human tissue used in this paper is the one presented in figure 3 and extracted from Cole and Cole impedance model [15], which has been shown to fit experimental data. The human tissues considered were the one present in Figure 2. The value of Rs, Rp and Cp were obtained using a gain response extraction over frequencies analysis. As the maximum hearing frequency is 22khz, it was considered in this paper that Rp could be neglected as it models the energy loss in high frequencies.

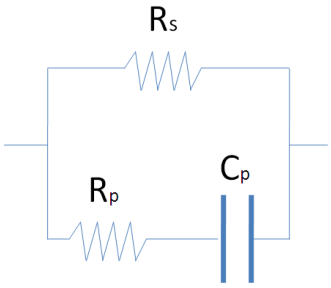


Figure 3. Human tissue electrical analog **[*15*]**

To obtain the numerical values for Rs and Cp for all the tissues or interfaces, we use the physical equations for the capacitance (parallel-plate capacitor) and for the resistance computation (cylindrical resistance model) [16] [17].

The values of the relative permeability and electrical conductivity for the nerves were extracted from [18] or from [19] for platinum as electrodes are mainly composed of it. However as far as the authors know, no relative permeability or electrical conductivity was available for Deiter cells or Basilar Membrane tissue. As Deiter cells are mainly composed of microtubules [20], which are involved in mechanical transport as actin proteins found in muscles cells and because the width of the BM is negligible compared to the Deiter cell height, we chose to take the relative permeability and electrical conductivity of muscle cells to characterize those two tissues.

On the other hand, the computation of the capacitance and the resistances (C_{patch}, Rp_{patch}, Rs_{patch}) between two electrodes is more complex, as highlighted Figure 4, those variables depend on the distance between the two electrodes. The Cable Model Theory was used to compute those variables as the space between two electrodes is composed of various tissues rendering the Cole and Cole model implementation difficult. We simplified the tissue between two electrodes as only made of Deiter cells, then we implemented the Cable Model Theory in order to obtain a general impedance depending on the electrodes distance.

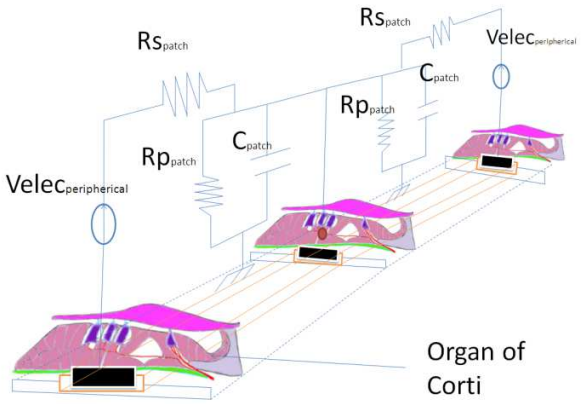


Figure 4. Two surrounding electrodes influences the nerve fibers targeted.

To compute Rs_{patch}, the cylindrical model of resistance was considered. The cylinder going from the first electrode to the second electrode, as defined in Figure 5.a, was used to compute Rs_{patch} (expressed in (1)):

$$R_{spatch} = \frac{1}{\sigma_M} * \frac{l_{spatch}}{S_{spatch}}$$

$$with \quad l_{spatch}(y) = \int_0^{Y_{tot}} y * dy$$

$$and \quad S_{spatch}(y) = \int_0^{2*\pi} \int_{-\frac{X1}{2}}^{\frac{X1}{2}} \rho * d\rho * d\theta \qquad (1)$$

where Y_{tot} is the distance between the two electrodes, X_1 is the distance between one electrode and the corresponding nerve fibers. Those values were respectively extracted from [22] and [23]. y is the variable shown in Figures 5.a, 5.b and 5.c. σ_M is the electrical conductivity of muscle cells.

Rp_{patch} models the resistance between the two longitudinal edges of the cylinder defined previously. Hence, this computation changes as expressed in (2), as it models all the losses through the ground from one electrode to another one.

$$R_{ppatch} = \frac{1}{\sigma_M} * \frac{l_{ppatch}}{S_{ppatch}}$$

$$with \quad l_{ppatch}(y) = \int_0^{Z1} dz$$

$$and \quad S_{spatch}(y) = \int_0^{2*\pi} \int_0^{y} \rho * d\rho * d\theta \qquad (2)$$

where we supposed Z_1 equal to X_1 for simplification purposes.

We defined Cp_{patch} as a squared parallel plate capacity (Figure 5.c) (developed in (3)):

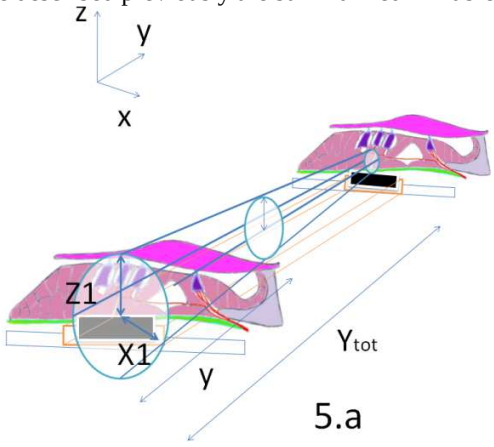
$$C_p = \varepsilon_0 \varepsilon_M \frac{A_{patch}}{d_{patch}}$$

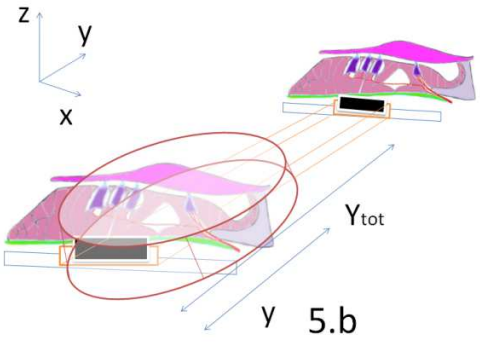
$$with \quad d_{patch}(y) = \int_0^{Z_1} dz$$

$$and \quad A_{patch}(y) = \int_0^{y} dy_1 \int_0^{X_1} dx \qquad (3)$$

where ε_M is the muscle relative permeability.

For reader's convenience, the value of the capacitance and resistance described previously are summarized in Table 1.





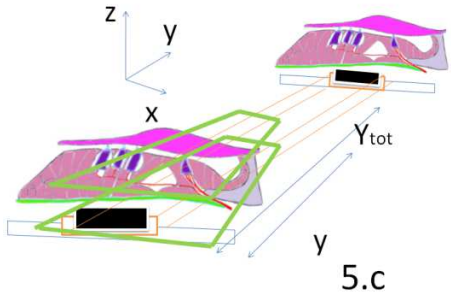


Figure 5. Physical model of Rs_{patch} (5.a), Rp_{patch} (5.b) and Cp_{patch} (5.c)

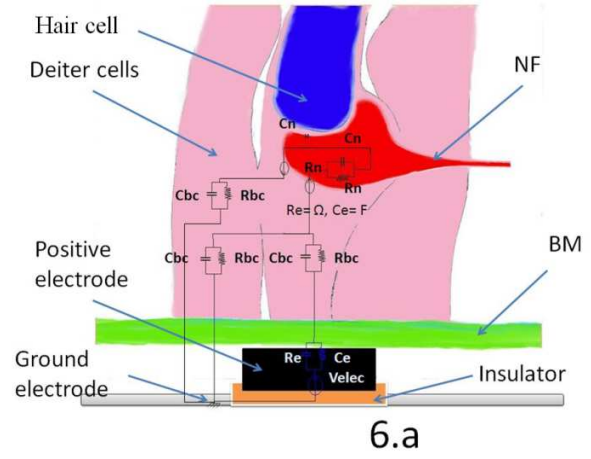
The electrical description containing only a single electrode is shown Figure 6.a. The input voltage generator is directly connected to the electrodes analog model (low frequencies model), which can be eventually considered as a perfect conductor compared to the other resistance values. Then the current can flow to the nerve cell or can go back to the ground. The current loss through the physical isolation between the electrode and the ground is neglected as the insulator has a low loss tangent (high resistivity). The membrane rest potential of a nerve cell is around -70mV, explaining the two -70mV voltage generators, in figure 6.a. We defined the analog equivalent circuit of a nerve cell using a resistance (R_n) in parallel with a capacitor (C_n) (this electrical description should not be confused with the Hodgkin-Huxley model [24], which is used to model ions flow through the nerve cell membrane and not the electron flow).

In addition, the electrical description of the system starting from the nerve and going through all the body to the earth was not considered because very little electrical current is going through this pathway.

TABLE 1. RESISTANCES AND CAPACITANCES USED IN THE ELECTRICAL MODEL

Electrodes	**Re= 1.5 Ω, Ce=11 fF**
Basilar Membrane and Deiter cells	R_{bc}= 933 Ω, C_{bc}= 300 nF
Nerve fibers	R_n= 1076Ω, C_n= 3µF
Cable Model Theory	Rs_{patch}= 8 MΩ, Rp_{patch}= 1265 Ω Cp_{patch}= 92.6 nF

Figure 6.b exhibits the electrical description of the overall system with two surrounding electrodes added. They are composed of a voltage generator, the platinum electrode equivalent circuit and the cable model (Rs_{patch}, Rp_{patch} and C_{patch}), to connect the peripheral electrodes with the nerve fiber that we want to activate.



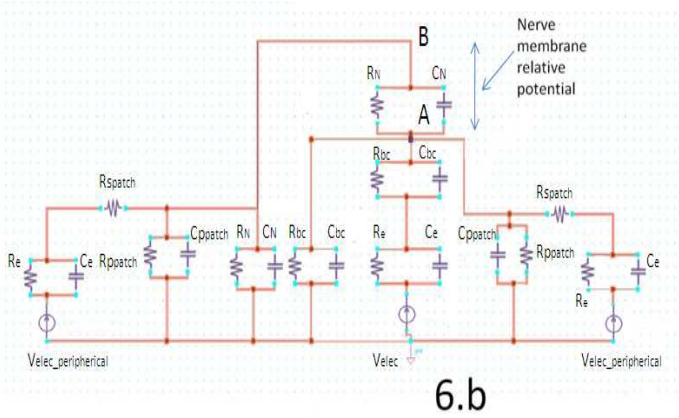


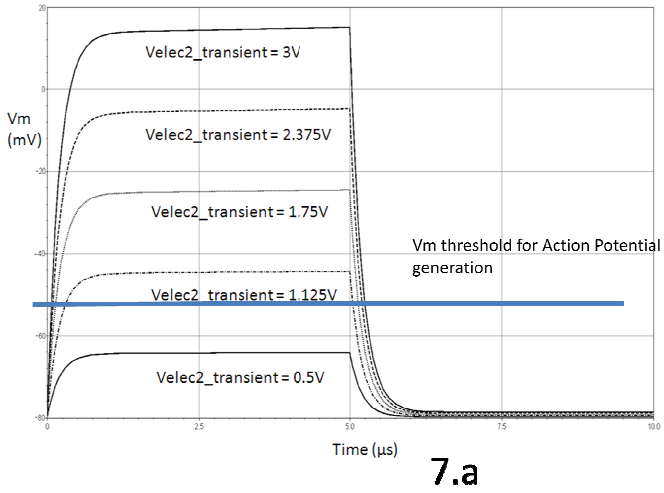
Figure 6.a. Electrical analog of the electrode and nerve.
Figure 6.b. Electrical analog with three electrodes

The main goal of the addition of the two surrounding electrodes was to study theoretically the influence of these on the stimulation of selected nerve fibers (or more precisely of the packet of nerve fibers that should only be stimulated by the central electrode). These perturbations, if significant, could make the sound reconstitution inaccurate.

III. RESULTS

The membrane potential (Vm) (which corresponds to the difference of potential between point A and point B in figure 6.b) had to vary of 30mV to generate an AP. The electrode stimulation (Velec) was made using a DC source. Neglecting the effect of the capacitors, Vm varied linearly with Velec and the variation of 30mV was reached for an electrode stimulus around 0.9V.

When a nerve fiber is stimulated constantly, it will not produce an AP indefinitely but rather produce a succession of randomly spaced AP called spike trains. The spike train length that could be produced by a sound of given intensity has to be reproduced with the electrodes of the cochlear implant. We performed transient simulation including the capacitors effects by injecting a square voltage with a period of 150ms. This experiment was repeated for input square voltages varying from 1V to 5V (Figure 7.a). The aim of this simulation was to study if the voltage amplitude sent to the electrode would affect the spike train duration and starting time. Figure 7.b reveals that the delays for Vm potential to reach its maximum value were around 0.1µs, which were small compared to the duration of a nerve AP (few ms). This result pointed out that theoretically the electrode voltage magnitude had a very insignificant effect on the spike train duration. In addition, the recreated spike train starting time has negligible delay with the electrode stimulation starting time.



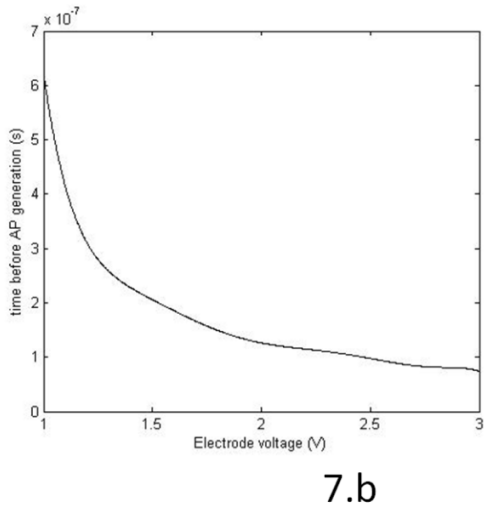


Figure 7.a. Transient simulation with different electrode voltage as input and Vm voltage as output.
Figure 7.b. Time before AP generation depending on the elctrode voltage

A general overview of the spike train related to the Vm amplitude is presented in Figure 8. The AP generated were obtained from basic mathematical functions in order to model the nerve fiber AP created after square voltage electrode stimulation. The interspike time was taken randomly and greatly depends on the amplitude of the stimulus [25]. However, the electrical analog presented in this paper does not account for this effect.

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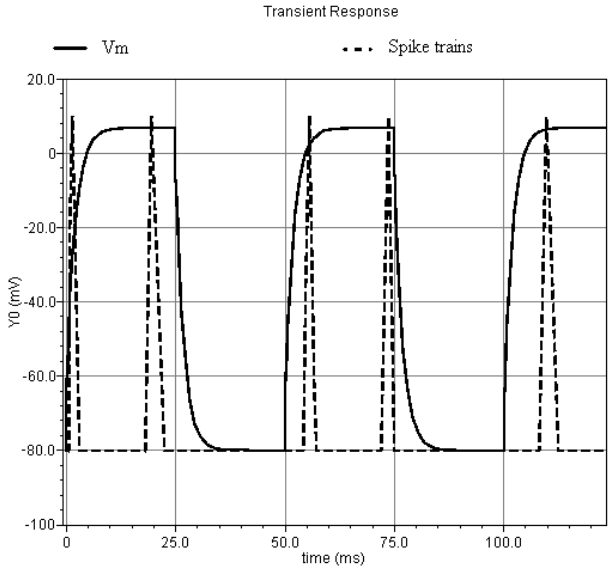

Figure 8. Spike train generated by the electrode input voltage

We performed also a parametric simulation using the electrical description of Figure 6.b, where the surrounding electrodes are added. The central electrode had a DC voltage of 1V and we varied the voltage of the surrounding electrodes between 0.9 and 5V. According to RC values used in figure 6.b, analytical computation showed that when the voltage of the surrounding electrodes was maximum (5V), the nerve fibers (above the central electrode) membrane potential Vm variation was 0.5mV, which was not high enough to stimulate these nerve fibers (the ones that should be stimulated only by the central electrode).

The overall system consumption is a great significance as cochlear implants are not convenient for the user to recharge. The study of the power consumption is presented Figure 9.

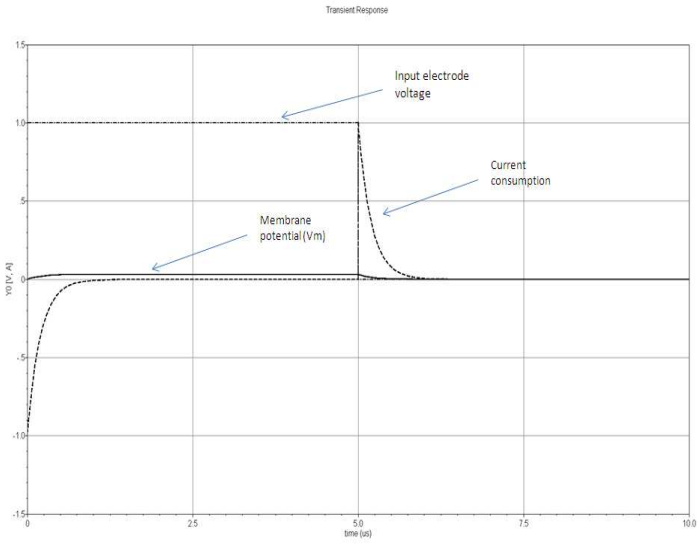

Figure 9. Current consumption during one stimulation period

The current peaks during each input signal transitions could reach 1A. Consequently, the maximum power consumed during a square input signal generation by the electrodes was around 1W (peak value), whereas the mean power consumed per period was around 50mW. These results may be used for the electrode array design to define battery size as well as electrode minimum width.

IV. CONCLUSION

The theoretical electrical description presented in this paper was used to carry out simulations allowing the detection of the minimum voltage needed to ensure nerve fibers stimulation. This voltage was found around 0.9 V. Furthermore, the current peaks during each input signal transitions could reach 1A (peak value), and the mean power consumed per period was around 50mW. These results may be used as requirements for the electrode array design and corresponding control electronics.

It has also been suggested that two consecutive electrodes were not disturbing one another and that the duration of the stimulation did not depend on the input electrode voltage. A more complex model, including the spike trains frequency (which is the number of spikes generated per second) related to the electrode input voltage is being currently developed.

Besides physical tests are ongoing to ensure that the theoretical results obtained match the measurements. Deaf people using cochlear implants were asked to kindly submit themselves to cochlear implant reprogramming in order to test if the threshold of 0.9 V was sufficient; if not, it would greatly affect the perturbation between electrodes.

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Towards a Framework for Business Models in Event Management

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***Abstract*—The choice of the right business model has proven to be an important success factor, regardless of the industry. Although in literature and practice the concept of business models has been broadly discussed, a comprehensive definition of business models in the context of event management has not been provided so far. Due to the rising experience-orientation of society – both in private and in business context – event management has emerged to an industry sector of increasing importance. By now, event management represents an interdisciplinary field which requires efficient and effective interactions of all involved business partners. This article describes the derivation of the constituent elements of business models in event management and classifies them to a business model framework. The derived business model framework depicts the underlying relationships between business model elements to the concepts of strategy and business processes.**

Keywords-Business models; event management; business model components; business model framework

I. INTRODUCTION

The last two decades have been characterized by a strong development of society towards experience orientation [1]. In literature, this phenomenon is called "fun-society" [2]. Companies and event agencies satisfy this increasing demand of multi-sensual incentives through a diversified offer of events [3]. In doing so, companies and event agencies increasingly use new media and social networks to communicate their marketing activities to the specific target groups. Besides the use of new media and social networks, companies increasingly rely on live-events as communication tool, which supports the establishment of long-term customer relationships, as they enable a direct and personal contact to the recipients of marketing activities [4]. Besides the establishment of a sustainable customer loyalty, live-events allow to tailor information to the specific audience to overcome information overload, which represents nowadays a frequently occurring problem [5].

Recent studies about current trends in event management have shown an increase of expenditures in live-communication from 1.38 billion in 2005 to 2.55 billion in 2012 in Germany, which represents an increase of almost 85% within 7 years [6]. Within the same period the contribution of the total advertising budget that companies provide for events has increased from 14% to 19%. Additionally to this trend that companies initiated as advertising and image improvement, the last years have also been characterized by an increase of society events, motivated by the rising demand of "special experiences within leisure activities" [7].

In the light of these developments, a large service sector for managing and carrying out events has emerged [8]. This sector includes, e.g., event agencies, technical providers, caterer, carriers of event agencies, artists, etc.

Event agencies are driven by two central motives to organize an event: "Own initiative" and "foreign initiative". Event agencies that organize an event by their "own initiative" intend to achieve the maximum profit. Within "foreign initiative" events agencies are commissioned by external companies, public / state institutions or private persons, in whose name they act as service provider to plan and carry out the event.

Experts predict further growth in the event management sector which comes along with an increase of competitors in this industry sector [9]. Thus, agencies – whether service providing organizations or independent organizations – should be aware of their business models and the competitive advantages which come along with their business model to establish their organization in the market and prevail over competitors in the long run.

Generally speaking, a business model represents a conceptual tool containing a set of concepts, objects and their relationships amongst each other [10]. A business model supports companies to express their business logic [10], by offering an abstract view on a company's organizational structure and its value creating activities [11], [12], [13], [14].

Regarding event management, so far literature and practice has mainly concerned about event marketing, not taking into consideration the entirety of key aspects that make up business models in event management. Although in recent time business model research has increasingly focused in specific industries such as the software industry [15] or electromobility [16], aspects about event management to date have not been covered by a scientific approach. This paper describes the derivation of a framework of business models in event management containing the basic elements of business models in this industry as well as a description of these derived business model elements to the concepts of strategy and business processes. The goal of the proposed framework is to support companies in event management to compose their business models according to their key

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competencies. In doing so, start-up companies as well as companies that have been active in the market place for some time receive support for the definition of their business model.

The research work presented in this paper follows a design-oriented methodology. Subject matter of design science are artificially created artifacts [17]. These artifacts are classified amongst other things into constructs and models. Constructs represent a collection of terms with the goal to describe artifacts that are in the matter of interest whereas models describe specific artifacts under consideration of the derived constructs [17]. Constructs in the context of the research work in this paper represent business models, business model elements, business processes and event management. Models are described by the target groups (companies – particularly CEOs / COOs) in the event management industry) and an explanation of the relationship between the constituent elements of a business model to the concepts of strategy and business processes by the use of several examples.

The remainder of this paper is organized as follows. Section 2 introduces basic definitions of business models and event management and differentiates these concepts from each other. Section 3 presents the basic elements of business models in event management. These elements form the basis of the event management business model framework in Section 4. Section 5 summarizes the paper and provides an outlook on future research. As specified in the outlook the newly created artifacts will be evaluated in future research using rigorous IS research methods.

II. TERMINOLOGICAL AND CONCEPTUAL BACKGROUND

This section explains the basic definitions and concepts for the derivation of the business model framework in event management. The first sections provide a basic understanding about business models and business model elements in general, followed by an explanation of the underlying definitions and characteristics of event management.

A. Business Models – Basic Concepts and Definitions

The business model concept is used as a management tool to understand and analyze an enterprise's current business logic. Thereby business models support companies to plan, design and test new business concepts that represent future orientations and therewith enhance current concepts [15]. Timmers, e.g., defines a business as "an architecture for the product, service and information flows including a description of the various business actors; and their roles; and a description of the potential benefits for the various business actors; and a description of the sources of revenues" [18]. The academic analysis of business models represents an emergent research field. Already early works from 1957 [19] and 1960 [20] discuss business models in a broader sense. However, when the dotcom bubble burst in the late 1990s, extensive studies dealing with the business model concept have extremely emerged [21], [22]. Thereby, evolving business activities from traditional to web-based business have been the main driver for the rising importance of business model research [22].

Fig. 1 shows that business models are often seen as an intermediary between a company's strategy and its business processes [24] [23]. This aspect reflects in different levels of granularity [27]. Business models provide an architectural as well as a conceptual basis for implementing a company's strategy into executable business processes [24], whereas strategy represents the planning layer, as it encompasses all tasks required for executing strategic management activities [25]. Finally, the layer of business processes represents the level of implementation. It represents the concrete process implementation of a scenario in executable process steps [26], [27], [28]. Fig. 1 shows the business model in its role between a company's strategy and its business processes:

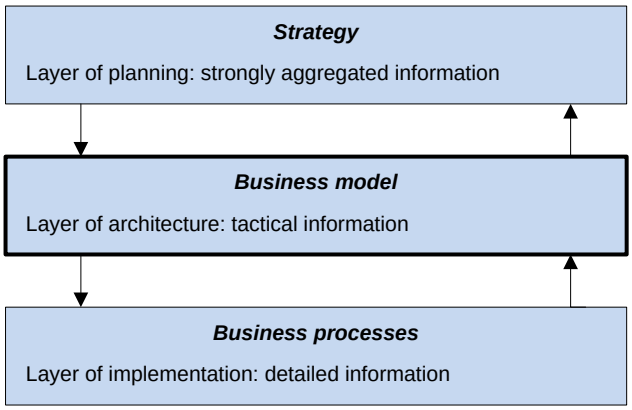

Figure 1. Delimitation of the business model to the concepts of strategy and business processes [29].

Business strategy focuses on competitive aspects whereas the business model describes collaboration of all participating business resources. Finally business processes describe how a business models is transferred in practice.

B. Business Model Elements

Business model elements do not represent an entire business model, but they describe the integral parts that make up a business model. One problem that often occurs in literature and practice is the interchangeably use of the terms "business models" and "business model elements" [30]. To derive a framework for business models within a specific industry (in this context event management), a business model first has to be broken down into its constituent components. Hence, underlying dependencies within the business model itself and to related concepts such as strategy and business processes can be depicted [12]. In literature, several studies and analysis about the constituent elements of business model elements in general have been carried out [23], [31], [32], [33], [34], [35], [36]. The business model elements derived by Di Valentin et al. form

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the basis for the business model framework presented in this paper [31]. Thereby, 12 articles about the constituent elements of business models have been analyzed and conveyed to a conceptual framework. According to the literature studies, the main pillars of business models consist of the following four elements [31]:

- *Value Proposition*: Perceived value that a company promises to its customers [37].
- *Resources*: The products and services that a company requires to create a unique service offering [38].
- *Architecture of Value Creation*: Design of the corporate information, product and service flows, required to implement a business model. Hence, this element forms the structural basis of a company, including its technological and organizational infrastructure [11].
- *Revenue Model*: The different ways in which a company generates its revenues [39].

C. Events and Event Management

A "special event" represents an orderly scheduled occasion [40] with cultural, personal, leisure or organizational objectives [41]. It can be classified into the following categories: Leisure events (recreation, sports, etc.), personal events (anniversaries, weddings, etc.), cultural events (folklore, heritage, etc.) and organizational events (sales, commercial, etc.) [41], whereas the latter is in the focus of the framework provided in this paper. In organizational context, companies mainly use events as communication tool [42]. Thereby, the following characteristics are relevant: Activation of the participants, uniqueness, positive experience, selected target groups with contact intensity, authenticity and exclusiveness of the in situ experience [42].

Event management encompasses measures about aspects like organization, execution and controlling required for an event [43]. Furthermore, managing an event overlaps with many aspects about project management, which is considered as the entirety of executive functions like organization, technics and measures for initializing, definition and planning projects [8]. As many project related aspects can be also applied to events – both are temporally limited and carried out once – event management is characterized by many project-related characteristics. In terms of business models, influencing factors on event management have to be taken into consideration. These influencing factors are split into three categories:

- Surrounding conditions,
- shifts in the market place and within competitors and
- customer interface.

Surrounding conditions encompass social and legal frameworks, as tragic incidents like mass panics have a strong influence on the safety stipulation of public events. Furthermore, increased charges in event management come along with an impact on existing pricing policies [44]. Particularly in terms of public events, the customer interface is of great importance as directed advertisement represents an important success factor within the preparatory stage of an event.

III. Business Model Elements in Event Management

This section presents the business model elements for event management which have been derived and enhanced on the basis of the business model elements by Di Valentin et al. Thereby, each sub-section presents one business model element.

A. Target Groups: Clients and Visitors

Event agencies focus their offerings to two main target groups: "Potential clients" and "visitors". Potential buyers make use of the agency as service provider. Thereby, a large group of people may be addressed such as companies that intend to present a new product at an event or celebrating an anniversary, cities and municipalities, sports associations and / or private persons. It is essential for these target groups to already provide in the initial phase the right frame conditions and concrete characteristics for the planned event.

One further target group present "potential visitors" of the event, whether the event is public or private. To meet the visitors' expectations agencies must already prognosticate in an early stadium, which requirements are expected by the visitors from the event. Based on these estimations, the event offering has to be arranged [8].

B. Product Portfolio

An event managers' product represents the event itself, which is consumed by the visitors. The agencies conceive, plan and realize all possible kinds of events. The event manager's task is to carve out a coherent concept and to ensure a smooth execution of the event. A successful implementation of the event represents the tip of the event management iceberg. Fig. 2 shows the efforts in event management:

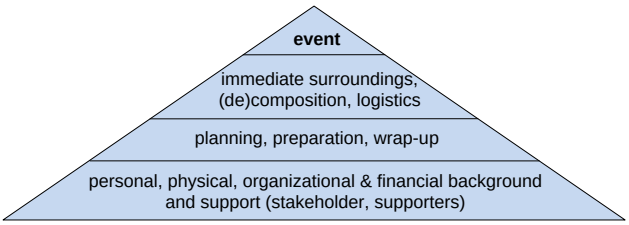

Figure 2. Expenditures in event management [43].

Fig. 2 demonstrates that expenditures for the preparation and post-processing of an event as well as the preparation of an appropriate infrastructure is not visible, however they come along with the largest amount of efforts. It also shows that activities of planning must be finished before the event starts [43]. The main goal of event management is to offer visitors a unique experience. A special challenge for event agencies is to give periodical recurring events an individual flair [43].

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C. Resources and Competencies

The main competencies for event management agencies represent employees including their knowledge, core competencies and experiences. Effective organizational structures as well as rapid responses on external influences are inevitable aspects to prevail over competitors in the market place. Additionally, an event management agency's core competencies should be continuously enhanced and adjusted to the service offering.

D. Network of Business Partners

Events are highly complex services that are generated by more than one partner [45]. The event manager acts as orchestrator as s/he coordinates the services of the business partners and controls the coherence of the final product (see Fig. 3).

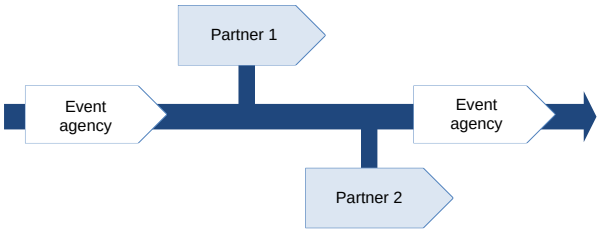

Figure 3. Coordinator – orchestrator model.

A network of authentic and competent business partners is of great importance for the event manager. The network includes, e.g., advertising agencies, caterer, technicians, logistic support suppliers, artists, decorators, security companies and service employees. Based on a large number of service providers that are involved in the process of organizing an event, unfulfilled obligations of partners have a great impact on further areas of the planned event. Hence, mistakes made by business partners can decide whether an event will be successful or not.

E. Revenue Model

Planning and managing events comes along with a high financial risk for event agencies. Hence, event agencies have to determine the break-even point and prognosticate occasional costs [46]. Comparing estimated costs with those of former carried out event represents an advantage. Moreover, running costs of the event managing agency have to be taken into consideration in the calculations. The costs are compensated by incomes, e.g., through entrance fees, consuming of drinks and foods, stall rent, share of the turnover, sponsor incomes as well as incomes from exclusive rights and state subsidies.

In case the event is a remittance work, there exist two different earnings models. Either the service is refunded by a previously agreed form allowance or the expenditures are paid after hours. In the first case, the event manager is generally provided a fix budget.

IV. Framework for Business Models in Event Management

Fig. 4 shows the framework for business models in event management. It has been derived based on the previously carved out business model elements for event management. The framework shows the business model in its intermediary role between business processes and strategy. Thereby, underlying interdependencies between the business model elements to the concepts of strategy and business processes are explained. The blue boxes represent the main pillars of the framework consisting of "strategy", "business models" and "business processes". The blue arrows between the different layers show that the business model is related to both concepts: strategy as well as business processes. The derived business model elements are classified to the business model layer. A description of the interdependencies between the business model elements is described in [31]. However, the dashed arrows show that the business model elements are in a mutual influence. The main characteristics of the business model element target groups are clients and visitors. The product portfolio is described by the provided services as well as the coherent concept for the execution of an event. An event agencies resources and competencies are described by the existing know-how whereas the business partner network is responsible for the coordination of services and business partners. The revenue model summarizes the financial flows of the underlying business model.

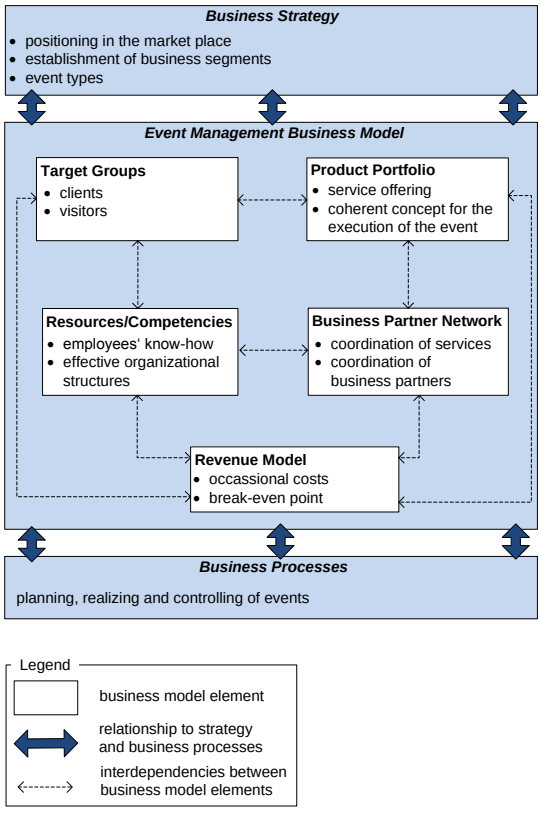

Figure 4. Framework for business models in event management.

In the following, the relationships between the business model elements to the concept of strategy are going to be explained: On strategic level, information gained within the *Network of Business Partners* can be used for optimizing decision support and control of strategic consistency with the rest of the organizational structure of the event management agency. The business model element *Resources and Competencies* requires to be strongly focused on an event agencies strategic positioning [13]. Therefore, an event agencies resources and competencies have to be generated for each *Target Group* to keep an event agency's customer loyalty on a high level [47]. The way, in which *Resources and Competencies* (of an event agency's employees) are combined create new possibilities for carrying out events [12]. Hence, an ideal and efficient allocation of resources consequently depends on an event agency's strategy. In order to carry on boosting an event agency's business model, the *Product Portfolio* must be designed to continuously offering customers – whether visitors of an event or clients – an added value. Revenues within the *Revenue Model* can be determined by calculating financial key measures such sales per event within a certain market or customer segment [48].

The relationship between business models and business processes can be described as follows: Changing demands within the *Network of Business Partners* cause service level agreements to change. In order to bring about the changes which are necessary to provide the services or goods conforming to the service level agreements, the business processes that are carried out within the organization of an event may have to be changed. Within the business model element *Target Groups* processes offer the possibility to align all business activities to the customer's preferences. This comes along with a higher degree of customer satisfaction after a successfully carried out event. The *Revenue Model* focuses on actions being carried out on operative level that have an influence on the financial structure. An efficient allocation of *Resources and Competencies* form the basis for the accomplishment of a successful event. On strategic level a decomposition of business processes offers clarity about the required resources and competencies for the execution of an event which run into the *Product Portfolio* to be offered [49].

V. CONCLUSIONS AND OUTLOOK

This paper presented a framework for business models in event management. To be able to obtain a basic understanding of business models in a specific industry sector, first the underlying components of business models have to be derived. So far, in literature and practice there is no consensus about the constituent elements of business models in event management. Hence, in a first step, the basic definitions of "business model", "business model elements" and "event" have been derived. In a next step, the key components of business models in event management have been defined, which form the basis for the presented framework for business models in event management. This framework consists of the derived business model elements and describes the underlying interdependencies between the derived business model elements to strategy and business processes.

The elaboration of this research work has shown that in recent years, many scientists addressed the concept of business models. So far, however, these concepts have not been sufficiently applied in the field of event management, although this industry is characterized by a growing number of companies. In the light of these developments, theoretical foundations should be further considered in future research work about business models and event management.

In future research, the derived artefacts will be implemented and evaluated according to rigorous design-science methods. Furthermore, the underlying interdependencies between the derived business model elements will be analyzed to enhance the current version of the framework. A transformation mechanism will be developed to transform changes on the business model in executable business processes, as changes within a company's strategy and business model have an influence on the underlying business processes. Therefore, a value chain for the industry sector of event management will be derived, which consists of the main value creating activities in event management.

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Privacy-Centric Modeling and Management of Context Information

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***Abstract*—Context-aware computing has been an intensively researched topic for years already. Consequently, there exists a plethora of usage scenarios for context-aware applications as well as several approaches for the modeling and management of a user's context information, many of which focus on the efficient and scalable distribution of the latter. With the ongoing rise of smartphones as everyday mobile devices and their steadily increasing amount of sensing and communication capabilities, we finally find ourselves at the edge towards a widespread usage of these techniques. However, apart from technical issues such as how to reliably determine a user's current context, privacy still remains a crucial factor for these systems' acceptance rate. Therefore, inspired by earlier works on privacy in context-aware computing and the authors' beliefs in the necessity to put users in control, this paper presents a novel approach for modeling and managing a mobile user's context information in a user-centric and privacy-preserving way. To this end, this work's contribution is twofold: First, based on widely recognized requirements for privacy in context-aware applications, we propose a privacy-centric context model which allows for an intuitive and context-dependent definition of a user's privacy preferences, directly integrating privacy aspects into the context model itself. Second, we present a generic and flexible architecture for the management and distribution of context information in a privacy-preserving way fit for a multitude of different usage scenarios.**

***Keywords*—context-awareness; context modeling; privacy-by-design; context-dependent privacy policies; context obfuscation.**

I. INTRODUCTION

Both privacy-preserving computing of personal data as well as the automatic extraction of context information – possibly from a smartphone's sensor readings – are very active areas of research. One can think of many use cases for context-aware applications, such as proactive route planning services taking into consideration the current traffic volume and a user's appointment schedule, smart mechanisms automatically adjusting a phone's audio profile based on the user's current activity and occupation, or buddy finder apps alerting the user when sharing the current location with close friends of her. In addition, there are applications such as the SmartBEEs context aware business platform [1], which do not act based on a single user or a peer-to-peer basis, but leverage the combined knowledge of multiple users' current contexts and their surroundings' state, e.g., for business process optimization.

Quite a number of slightly varying interpretations of what context actually is can be found in literature. We base our understanding of context on the famous definition given by Abowd et al. [2], declaring context to be any information that can be used to describe the situation an entity resides in. Strictly following a user-centric approach, for this paper we assume a user's smartphone to be the primary source of information about her current context. How different kinds of context information can be acquired from sensor data is not within the scope of this work though. In order to offer high levels of service quality, algorithms for context recognition typically aim at maximizing the resolution, freshness and accuracy of their classification results. However, when talking about preserving a user's privacy, different – and sometimes even contradicting – objectives are to be pursued. For example, in many situations it might be perfectly sound to deliberately reduce the resolution of a piece of context information before sharing it with others in order not to reveal too much. The privacy issue gets additionally tightened given the fact that due to the popularity of smartphones, we are heading towards a full supply of small electronic devices with broadband internet access and extensive sensing capabilities. Enabling the acquisition of a user's context information with the help of her smartphone's sensors and eligible reasoning mechanisms in return also enables spying on this person. Thereby "one person's sensor is another person's spy", as [3] puts it.

Many approaches for modeling and managing context focus on the generation, processing and efficient distribution of context information as well as the realization of context-aware applications built thereon. Some works, however, argue that not only the usability and utility of context-aware applications are paramount for a wide acceptance, but also the establishment of appropriate privacy mechanisms which make the users feel comfortable within such ubiquitous computing environments. Concordantly, in this paper we propose a new method for giving the full control over the release and resolution of personal, private or characterizing context information to the data's owner. Our work's contribution is twofold: First, we define our *Context Representations* (CoRe) model, which presents a novel approach for modeling a user's context information in a privacy-centric manner. Second, we introduce the design of our *Layered Architecture for Privacy Assertions in Context-Aware Applications* (ALPACA) together with its privacy levels and describe the flexible interplay of the different components.

The remainder of this paper is structured as follows: In Section II, we will make our problem statement and present a comprehensive list of privacy requirements. We will then have a look at related work on privacy in context-aware applications in Section III. Section IV presents our privacy-centric CoRe model, which marks the base component for our logical and physical system architecture described in Section V. After discussing our results in Section VI, we conclude.

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II. Problem Statement and Requirements

Given these preliminaries, with this work we aim at designing a generic solution for the modeling and management of a user's static and dynamic context information. Consequently, we consider it essential to primarily focus on putting the user in full control over the capturing, release and resolution of her personal data. As already stated before, we assume a user-centric, smartphone-based approach here. Hence, from a privacy-oriented point of view the less data is going to leave the user's mobile device, the better. Yet in order to enable a multitude of context-aware applications and services, there is usually a need for communicating one's current context information to other parties. For privacy reasons, however, we argue that there must not be any party but the user herself able to access or control her complete context information at any point in time, thereby ruling out any solutions based on a trusted third party approach. On the other hand, proactively providing a central component with some kind of "handpicked" context information seems nonetheless desirable in some situations, e.g., in order to allow for the efficient realization of multi-subject context-aware applications. A truly generic solution should hence be able to serve all kinds of context requesters while never sacrificing too much of a user's privacy.

Based on existing works on privacy in context-aware applications [4]–[7], we have identified and complemented a set of different techniques and requirements for realizing different aspects of privacy. Naturally, a comprehensive approach for context modeling and management should incorporate all of these mechanisms. In the following, we will name and briefly explain the most important of these requirements:

- A minimum set of **access control** operators such as $grant$ and $deny$ has to be available in order to be able to define different requesters' access rights. Additionally, users should be allowed to define their privacy preferences in a **context-dependent** way.
- **Variable granularity** can be used to reduce a piece of context information's resolution or accuracy. As an example, consider a user reading her e-mails. Different granularities of her currently modeled activity context might contain `read-e-mail`, `computer-work`, `office-work` and `working`.
- **Intentional ambiguity** and **plausible deniability** can be used in order to lower the confidence and validity of a piece of context information, respectively. Notice that these kinds of "white lies" present everyday actions in the offline world such as, e.g., not answering telephone calls in order to pretend not to be present.
- **Adjustable freshness** and **temporal resolution** are other means for intentionally reducing a piece of information's quality, e.g., regarding its age or capturing time. It can hence be used in a similar way as intentional ambiguity to obfuscate a user's context.
- We define **consistency** of a user's privacy preferences as another important requirement, stating that a context requester must not be able to retrieve ambiguous or contradicting pieces of context information.
- **Notifications** can optionally be sent to a user upon each request of her context information. This can hence be used as a social means able to prevent the intentional abuse of contextual information.
- **Symmetry** is especially important in peer-to-peer scenarios, stating that a certain party has to reveal just as much of its own information as it requests.
- Considering that completely denying a request for a piece of a user's context information might itself reveal much, we define **completeness** to be the principle of answering any request with a plausible response.
- Other useful concepts in context-aware applications are **anonymity**, **pseudonymity** and **k-anonymity**.

Additional requirements are security, scalability, extensibility and usability. In order to seamlessly protect a user's privacy, it also seems beneficial to closely band together the modeling and management of a user's context information. With this work's problem statement and privacy requirements being established, we will review related work in the next section.

III. Related Work

This section presents related work on privacy mechanisms for context-aware applications. Several different categories of approaches can be found in literature. Some of them rely on trusted third party (TTP) solutions for efficient context dissemination, whereas other systems adopt a peer-to-peer (P2P) based approach in order to avoid such central points of attack. On the other hand, there are rule languages for defining access control based on contextual information as well as different obfuscation techniques for adequately reducing the richness of a user's context information before their release.

A common architectural model for the realization of context-aware applications is the use of a TTP acting as some kind of middleware for the aggregation of its users' context information. It is necessary for all of the system's participants to fully trust this component. The CoPS architecture introduced in [7] implements such a central privacy service. While allowing for different granularities of context items, it does not permit the definition of context-dependent access rules. Another TTP-based approach called CPE [5] enables the definition of context-dependent privacy preferences, but lacks mechanisms for releasing information in different granularities. With a focus on context-dependent security policies, the CoBrA platform [8] deploys the Rei policy language [9] in order to enable the definition of access control rules depending on a user's current context. Beyond that there is much literature on different techniques for the obfuscation of contextual information. As an example, [6] presents another centralized approach focussing on context ownership and offering obfuscation mechanisms for several kinds of context information based on SensorML process chains, obfuscation ontologies and detailed taxonomies describing dynamic granularity levels. In contrast to these systems, purely P2P-based approaches such as [10] get along without any central component. As a major drawback, such architectures can hardly be efficiently deployed in applications depending on up-to-date context information of a whole group of users at the same time.

Hence, to the best of our knowledge we are not aware of any approach able to fully satisfy the requirements given in Section II and tackling the issue of preserving a user's privacy

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in context-aware applications comparable to our framework's user-centric design. Therefore and based on these requirements, we will now introduce our privacy-centric CoRe model and the ALPACA system architecture for context modeling and management in Sections IV and V, respectively.

IV. Privacy-centric context modeling

Based on the given requirements, we will now present a novel approach for modeling a user's context information in a privacy-preserving way. As the name implies, our *Context Representions* model is designed to store several heterogeneous representations of one and the same kind of context information, each of them being intended for variably trustworthy groups of requesters. Subsequently, we introduce a user-friendly and flexible trigger mechanism that allows for context-dependent definitions of privacy preferences on behalf of the user. To this end, the trigger functionality has been devised to (optionally) depend on both the subject's, the requester's as well as the environments' current context. In Section IV-C we will join the latter with our model in order to describe how our approach is able to dynamically cope with inconsistent policy definitions at runtime.

A. Modeling context information using representations

In accordance with many existing approaches for context modeling (cf. [11] for a comprehensive survey), we adopt a tree-based view on a user's overall context information as depicted in Figure 1. In this hierarchic scheme, the root node aggregates all different categories of a user's context information. At the second level distinctions between the basic context categories are made, such as a user's current location or activity. However, this catalog is not fixed and can readily be extended to hold any additional kind of context information in case new types of sensors or inference mechanisms become available. Each of the tree's second-level nodes may be a parent to an arbitrary number of corresponding *Representations*, each reflecting the given category in a different way, e.g., concerning the respective item's resolution or – in case of a white lie – maybe even its validity. One should thus notice that in contrast to existing context models such as MUSIC [12], which use the term "representation" in order to label the data formats used for communication (such as XML, JSON, etc.), we define distinct *Representations* of a context information to differ from each other on a semantic level, independent from any encoding. As an example, consider the three different *Representations* of the user's current location in Figure 1: The representation on the left holds the exact GPS position fix of the user. In contrast, the one in the middle only states the user's location on a city level, while the third uses a non-geographic, symbolic location identifier that cannot be mapped to a geographic one – at least not without any further knowledge about the user. The idea behind providing multiple representations of the same category is that from a privacy-centric point of view, a user should be able to communicate different versions of her current context information to different parties. Which representation is to be released to whom might, e.g., be based on the trust level assigned to a requester and the current context itself.

Following an ontology-based modeling approach, our context model consists of the three base classes shown in Figure 2, namely $Context$, $Representation$ and $Audience$. The

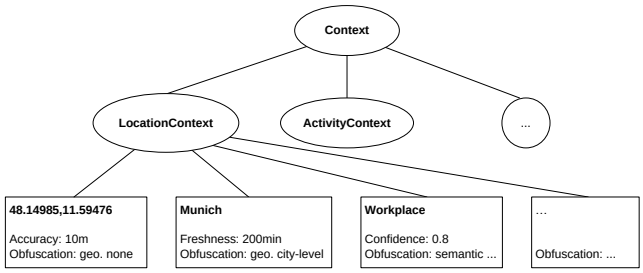

Fig. 1. An example context tree with its second-level *Context* nodes linking to an arbitrary number of *Representations*, each indicating its level of obfuscation based on the semantics of the underlying information.

first two of them can have subclasses such as *ActivityContext* and *ActivityRepresentation*, respectively. As already explained, a certain subclass of context may be described by multiple instances of *Representation* at the same time. Our model's basic structure was inspired by the ASC model by Strang et al. for enabling service interoperability based on a shared understanding of and transformation rules for different, yet logically equivalent scales [13]. Quite the contrary, however, our CoRe approach can be used to model different representations of the same kind of context information, which – according to the requirements stated in Section II – do not necessarily have to share the same (or at least similar) meanings at all. Especially, in our case there must of course not exist any transformation rules which allow for a simple conversion from a low-resolution representation to a high-resolution one.

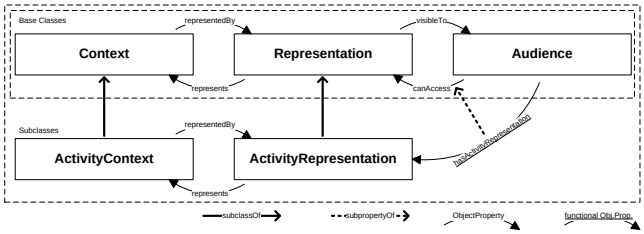

Fig. 2. The classes, subclasses and properties of the CoRe model. Each subclass of *Context* might have an arbitrary number of *Representations*.

As an enabler for the definition of privacy preferences based on our model, a representation instance can be assigned to a certain *Audience* using subproperties of the *canAccess* property. An audience can be any entity requesting the user's context information and might be defined both statically (e.g., based on group membership) and context-dependent, such as "entities near me". As we will see in Section IV-C, however, an entity must not be assigned to more than one representation of the same class of context information at the same time. We accomplish this by marking every subproperty of *canAccess* as being *functional*. In order to be able to automatically assess the resolution of a representation of a given class, each *Representation* stores additional information about its *obfuscation level*. A generic labeling approach for these levels seems unfeasible, considering the great differences in semantics that different classes of context information might possess. Hence, each subclass of *Representation* is expected to define its own obfuscation scales. Returning to the abstracted tree-based view of our model, the base class *Context* can be interpreted as the root node in the hierarchy. Subclasses thereof, such as

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ActivityContext and *LocationContext* form the second-level nodes, which might link to an arbitrary number of appropriate subclass instances of *Representation*.

B. Defining context-dependent privacy preferences

In addition to the model's base concepts just described, we have designed a trigger mechanism which allows for a simple, yet flexible and effective definition of context-dependent privacy preferences on behalf of the user. With our system following a conservative, whitelist-based approach (cf. Section V-A) in order to protect a user's context information from accidental leakage, explicitly defining a release trigger is the only possibility for a user to share any piece of information with others. The corresponding classes and properties can be seen in Figure 3. Broadly speaking, a *Trigger* can be used for setting up preferences defining how the system should respond to any requests for context information. A trigger fires each time the set of *Conditions* associated with that instance matches the currently known overall situation, possibly taking into account the current states of both the user's, the requester's and the surroundings' contexts. As an *Effect*, one or more *Representation* instances of the requested user become accessible for the given *Audience*. From [7] we have adapted the idea that accessing a piece of context information by a certain requester might have side effects such as notifying the user, as we agree on that being a proper means suitable for possibly containing data abuse. If desired, a user can hence also specify which *SideEffect* should be activated when a certain kind of *Representation* is requested by a certain audience. Additionally, a user is able to define the obfuscation level, accuracy, confidence and freshness properties the now-accessible representation has to fulfill for this audience under the circumstances described in the corresponding conditions.

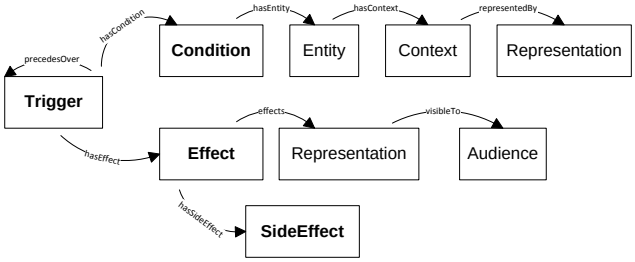

Fig. 3. The structure of the *Trigger* mechanism enabling users to define context-dependent privacy preferences. Each *Effect* might also have *SideEffects* describing reactions to requests for context information.

C. Dealing with inconsistent privacy preferences

We will now describe how our context modeling approach can be used in conjunction with the trigger mechanism in order to detect any inconsistencies arising from ambiguous or conflicting privacy preferences. For this work, we define a set of privacy preferences to be inconsistent if it enables any requesting entity to access more than one representation of the same class of context information at the same time, as this situation is clearly prone to harm a user's integrity. The issue becomes evident when considering two contradicting representations, e.g., a user's true and fake location information. If one requester is granted access to both representations, the result is not only ambiguous, but also likely to negatively influence the user's respectability due to being caught lying. Logically, such situations might occur when a requester is belonging to more than one (possibly dynamically defined) *Audience*. Hence, there has to be a way for detecting and solving such preference conflicts. In order to prohibit such situations from occuring, we use the underlying ontology's built-in reasoning capabilites to dynamically check the model's state for consistency. By defining all subproperties of *canAccess* to be *functional*, we assure that each entity is allowed to see at most one representation of the same class. This check is performed each time a trigger fires. In order to solve conflicting situations, the *precedesOver* property can be set. In a practical implementation, the first time an inconsistent state is detected, a user might be notified about the conflict and be able to choose which of the triggers involved should precede over the other.

This section presented a novel approach for privacy-centric context modeling as well as a trigger mechanism for a context-dependent definition of a user's privacy preferences. In the next section we will describe the privacy layers and components of the ALPACA architecture built upon our model.

V. Privacy Layers and System Architecture

We will now introduce our *Layered Architecture for Privacy Assertions in Context-Aware Applications* and its four different privacy layers. These layers resemble what we believe to be a good compromise about a privacy-aware user's sensation of different levels of information accessibility and reduction of complexity. Afterwards, we will introduce our architecture's central component, the *Privacy Manager* and describe an example setup and communication flow.

A. Different layers for different audiences

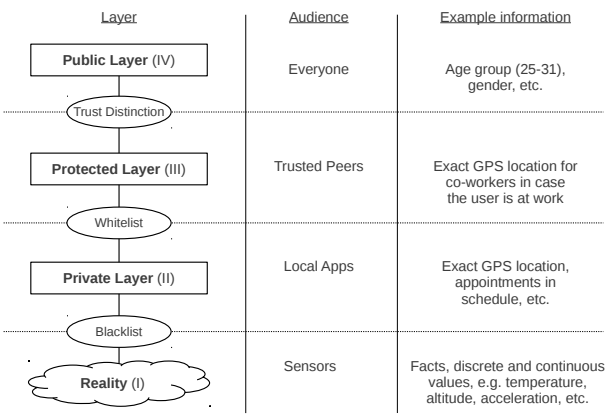

Fig. 4. The four different privacy layers defined in ALPACA and their most likely audiences, as well as some example context items for each layer.

As shown in Figure 4, ALPACA defines four logically different layers which can be mapped to a user's privacy levels, as well as some kind of privacy gateways between these layers. At the bottom layer we put *reality*, possibly containing more information than any kinds of sensors and reasoning mechanisms will ever be able to capture. Although one does not have to implement anything on this layer, we still have to define it as this layer is what is aimed to be reflected in any context model. However, even today a user might

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feel uncomfortable knowing that each of her smartphone's sensors is recording data all the time. Hence, a user can set up a context-dependent blacklist for defining which sources of context information should be turned off under certain conditions.

The next layer is the *private layer*, holding all the information a user wants to have available for herself, i.e., context-aware services and applications running exclusively on her mobile device. Consider for example locally run apps which adapt their appearance and behaviour according to the user's current context. In order for such services to be responsive and proactive, this layer enables access to the most fresh and sophisticated context representations. Naturally, these high-resolution representations are probably not intended for everyone else as well. Thus, the trigger mechanism described in Section IV-B is used as a context-dependent whitelist for the release of certain representations to the upper layers.

Context information which pass this whitelist enter the *protected layer* and might hence be available for some other entities, too, such as trusted services and peers. For example, a user might be reluctant to share her current whereabouts with everyone, but maybe with some of her friends in her spare time or with her employee during working hours. Naturally, the number and composition of context representations available on this layer will hence change dynamically based on the user's privacy preferences and current context.

Additionally, a user might be willing to share some kind of information about herself with anyone, meaning that these information are available on the *public layer*. This might, e.g., be true for information that are somehow obvious anyway, such as personal profile data containing the user's gender or age group. However, a user might still define notifications to be displayed when these kinds of information are being requested. That said, notice that our system's user is of course not forced to abide by these layers in the way we just described, but rather can individually choose which level of visibility fits her own situation by the use of appropriate release triggers.

B. Components of our hybrid system architecture

We will now briefly describe the flexible architecture of the ALPACA system, as well as the *Privacy Manager* as its core component responsible for managing access to all of the user's context information. Figure 5 gives a component-oriented view of our system. It is up to the privacy manager instance running on the user's mobile device to enforce compliance with the privacy preferences set up by the user at any time. Therefore, it is the only component which has full access to all representations available in the context model in order to be able to fulfill the user's blacklist and whitelist preferences. The privacy manager decides on the release of context information on a per-request basis, thereby realizing some kind of lazy rule evaluation. This is necessary given the context-dependent nature of the user's preferences: As explained in Section IV-B, the release of a certain context representation might well depend on the requester's current context. Hence, in such cases, the requester has to communicate his own context to the requested user's privacy manager, which will then decide on whether or not to release the requested information.

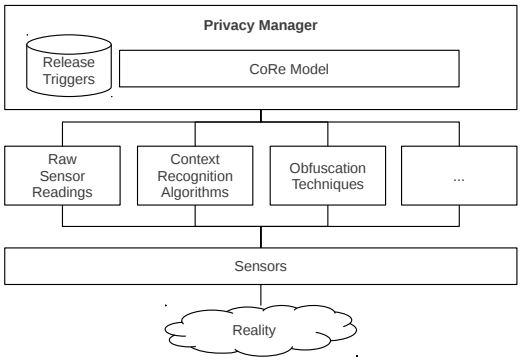

Fig. 5. The client-side components of the ALPACA framework: The *Privacy Manager* acts as an exclusive interface to access a user's context information for both local, peer-to-peer and third-party applications.

In accordance to the definitions of the different privacy layers, those representations belonging to the private layer must inalienably be managed on the mobile device itself. However, in order to enable the efficient and scalable implementation of applications based on, e.g., the current contexts of several users, there might also exist less trustworthy, yet possibly distributed instances of the privacy manager and the user's context model on the protected layer. If so, the privacy manager residing on the user's device will commit any updates in the set of currently released context representations to the external instances of the model. Naturally, not all representations currently released by the user's whitelist will be sent to the latters, but only those assigned to the respective application identified by the corresponding release triggers' *Audience* definitions. The ALPACA architecture can hence be considered flexible in the sense that it can be used both in a purely P2P-based fashion as well as in classic client/server-based applications without the need for a true TTP.

C. Communication flow in ALPACA

Having introduced the privacy layers and software components of ALPACA in the previous sections, we will now describe the basic communication flow in an example setup of our system. For the sake of clarity, however, we will only refer to the P2P-based case with one internal instance of the privacy manager here.

As illustrated in Figure 5, we assume a number of different sensors, algorithms for context recognition as well as obfuscation techniques to be available on the user's smartphone. These are responsible for capturing a user's real context and transforming it into instances of the *Representation* class for our context model, also providing the necessary meta information such as, e.g., *freshness* and *obfuscation level*. Every time one of the available sources of context information produces fresh data, the model will be updated. Additionally, the context-dependent blacklist defining which sensors and inference mechanisms to turn off under certain conditions will be re-checked. Now different audiences might request some of the user's context information from the privacy manager. Hence, it will first check which audiences the requester belongs to. In case the requesting entity is a local service that the user wants to have full access to her high-resolution context information, the privacy manager will return all matching

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representations from the private layer. Otherwise, the privacy manager will take the requester's context information contained in the request in order to re-interpret the user's whitelist based on these information, thereby possibly firing some of the release triggers. Eventually, given that no inconsisteny is detected, the privacy manager will return the appropriate representation to the requester. In order for our system to be able to answer every incoming request even in case there is no such representation, some kind of highly obfuscated standard representation will be returned (cf. Section II).

VI. Discussion

We will now dicuss the pros and cons of our privacy-centric approach for modeling and managing a user's context. Strictly following a user-centric point of view, all decisions in the design process have been taken in order to offer a maximum level of control and privacy concerning the release of a user's context information. As a result, our approach is able to fulfill the different privacy requirements presented in Section II, which were collected from existing works on privacy in context-aware applications: In order to be as generic as possible, we decoupled our model from the generation of context information, thereby making it independent from existing sensors, as well as reasoning mechanisms and obfuscation techniques. The latters are able to realize the concepts of variable granularity, plausible deniability and the like. In practical implementations, new sensors and inference algorithms can simply register themselves at the privacy manager, which will inform the user about the additional context sources and obfuscation levels being available for the definition of her privacy preferences. Also, our framework will always give an unambiguous answer – according to the user's context-dependent preferences – to any incoming request, thanks to the automatic detection and remedy of inconsistent privacy preferences based on the underlying ontology's internal reasoning capabilities and modeled precedence rules, respectively. However, for a secure implementation our system must be run on some kind of trusted computing platform able to prevent the privacy manager from being circumvented by malware.

The ALPACA architecture exhibits considerable flexibility with regard to the fact that it can be used both exclusively on a user's mobile device as well as in P2P and client/server applications. Making usage of distributed instances of the context model and the privacy manager running on a server in the Internet can also help against network layer attacks trying to locate or identify a user by her current network location. However, there is a natural trade-off between a user's privacy and the amount of context information stored on distributed servers likely to be under someone else's administration. Finally, although having designed our trigger mechanism to be intuitive and user-friendly, it is not clear whether a majority of users will be likely to adopt such a restrictive whitelist-based system, facing peer pressure and their own reluctance towards manually configuring release triggers.

VII. Conclusion

This paper presented a novel approach for modeling a user's context-information in a privacy-centric way. We introduced our ontology-based CoRe model, which can be used for managing multiple, semantically different representations of the same class of context information fit for differently trustworthy groups of context requesters. In order to enable context-dependent definitions of a user's privacy preferences, a flexible whitelist-based trigger mechanism has been created. Eventually, we presented the design of our ALPACA system architecture and discussed our approach.

At the time of writing, we are currently working on a prototype implementation of our system allowing us to conduct a user study for evaluating the feasibility of our trigger mechanism. As for our future work, we aim at finding additional mechanisms capable of ensuring context consistency over several consecutive requests by a single entity. Furthermore, we want to analyze how to also protect the requesting entities' contexts, as well as how to handle possible deadlock situations resulting from mutually exclusive privacy preferences. Finally, we will try to find new obfuscation techniques for different types of context information and integrate them into ALPACA.

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Towards Context-Driven User Interfaces in Smart Homes

The Cloud4all Project's Smart House Demo

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***Abstract*—One of the challenges in AAL and smart homes is the delivery of user interfaces that accommodate the needs and preferences of a diverse group of users for providing a "personal" user interface. Various technical solutions and frameworks for adaptive user interfaces have been proposed in the past. In this paper, we describe a smart house demo application within the Cloud4all research project. This demo combines the Universal Remote Console (URC) approach for pluggable user interfaces with an adapt-at-runtime approach of the Global Public Inclusive Infrastructure (GPII), thus enabling the provision of personal user interfaces that can be fine-tuned to fit a specific runtime context. Some preliminary example user interfaces for smart house appliances are provided.**

Keywords-Cloud4all; URC; AAL; smart house; adaptive user interfaces; GPII; user preferences; user preference set

I. INTRODUCTION

User interfaces for smart house and Ambient Assisted Living (AAL) environments should adapt to the preferences and needs of their users. We then call them "personal user interfaces". In addition to being personal, they should also take into account the user's device and its characteristics (e.g., screen size), and situational parameters of use (e.g., brightness or noise level in the environment). These parameters that drive adaptation are often summarized as "context" or "context of use".

Context-driven user interfaces are important for applications that are used by diverse types of users. Various technical approaches for the delivery of context-driven user interfaces have been proposed, including employment of abstract user interface models at design-time, and dynamic approaches at runtime (see Section II).

Context-driven user interfaces have not been widely adopted by the industry yet. Among the various reasons, the following are of particular interest for us:

1. Designers tend to imagine visual user interfaces that are designed with "pixel fidelity" rather than thinking in abstract structures. For example, a designer would develop a drop-down menu rather than an abstract "pick one from many" interaction element, and a red "Click me" button with rounded corners rather than an abstract "function trigger". Therefore, if we want to get designers to develop flexible user interfaces, we need to let them design a visual user interface as a basis for a context-driven one.
2. Similarly, developers and designers are familiar with tools that let them design the user interface in the traditional (i.e., visual) way. They will not switch to new tools that require them to learn new design paradigms. Therefore, if we want them to design for flexibility and adaptivity, we will have to allow them to use the development tools that they are familiar with, albeit with some possible extensions.
3. Most companies regard the user interfaces of their products as vehicles for conveying their corporate identity to the user. They want the users to identify themselves with the brand by looking at the product's frontend. Naturally, designers don't want "their" user interface to be changed in a way that could jeopardize the user's identification with the brand. At a minimum, they want to be in control of possible adaptations that could occur at runtime. Therefore, if we want industry to adopt possible adaptation approaches, we need to support them in designing "their" user interface, while allowing for tweaking the user interface at runtime along predictable lines for the purpose of personalization. Also, they should be able to design or let third parties (e.g., user interface experts) design alternative user interfaces that would make their products accessible to users of particular user groups and/or particular circumstances. This could help companies to overcome legislative requirements on accessibility without losing control over which user interface variation would be used under which conditions.

The European Cloud4all project [1] addresses the need for adaptive user interfaces in mainstream products despite these challenges. Cloud4all is part of the international Global Public Inclusive Infrastructure (GPII) effort, whose purpose "is to ensure that everyone who faces accessibility barriers due to disability, literacy, digital literacy, or aging, regardless of economic resources, can access and use the Internet and all its information, communities, and services for education, employment, daily living, civic participation, health, and safety" [2].

As part of its development and dissemination work, Cloud4all is providing a simulation of its adaptive user interface technology on the example of a smart house and its

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appliances. This simulation has been recently set up and will soon become available for the interested public [3].

The remainder of this paper is organized as follows: Section II provides an overview of related work on user interface adaptation at design time and/or runtime. Section III introduces the technical framework that underlies Cloud4all's smart house demonstration. Section IV gives a glimpse into the early development stage of the smart house demonstration, describing a few appliances and their adaptive user interfaces. Finally, in Section V we draw some conclusions and provide an outlook on further research and development within the Cloud4all smart house demo project.

II. RELATED WORK

User Interface Management Systems (UIMS) (e.g., COUSIN [4], HOMER [5]) are early predecessors of today's adaptive user interface systems. They featured a separate user interface management layer so that the user interface could be adapted to the runtime platform (desktop) and other parameters of use. UIMS and similar approaches have not been widely adopted for various reasons. According to [6], one of them is that designers want to control the look and feel of the interactions at a lower level than the UIMS abstraction allowed.

The User Interface Markup Language (UIML) standard by OASIS [7] has been designed to allow for the generation of platform-specific user interfaces, driven by rules for presentation and behavior that are unique for each runtime platform. However, UIML does not provide a vocabulary for user interface components and the development of such a vocabulary, together with an appropriate set of rules, is cumbersome. Also, UIML does not facilitate fully context-driven user interfaces since adaptation happens at design-time rather than runtime.

Of particular interest to us are approaches that focus on the automatic generation of user interfaces with dynamic runtime adaptation mechanisms. Pebbles [8] allows an author to provide an abstract user interface description at design-time which is used to render a control interface on a mobile device at runtime. Similarly, SUPPLE [9] uses a constraint-based algorithm to solve an optimization problem for a concrete layout at runtime. More recently, MyUI [10] has suggested defining abstract user interface models (based on state transitions) and interaction design patterns at design-time, and combining them at runtime based on a specific use context. Although these approaches can facilitate useful adaptations at runtime that may increase the level of accessibility for users with disabilities, they lack the ability for a designer to control the end result of the rendition process, and are therefore deemed unsuitable for mainstream use.

In the area of Web-based user interfaces, the Composite Capabilities / Preference Profile (CC/PP) standard [11] was specified to allow for fine-grained server-based adaptations to a client's runtime platform characteristics and user preferences. However, it has not been widely adopted by industry since it puts the onus on the Web browser manufacturers to create and maintain CC/PP files for each individual Web browser version and runtime platform. The Fluid project [12] with its "user interface options" component offers a way for authors to make their Web pages adaptable to their users along a small set of presentational aspects such as font size, line spacing and button size. This approach works well for users and devices that need some fine-tuning ("tweaking") of the Web page, but does not cater for radical changes in device characteristics (e.g., screen size) or user needs (e.g., simplified user interface).

Finally, the Universal Remote Console (URC) framework [13] facilitates pluggable user interfaces based on an abstract user interface model (called "user interface socket"). Authors have full control over each pluggable user interface, since they can be specified as fine-grained as needed by the author. A distributed URC ecosystem (including a resource server) facilitates contributions of pluggable user interfaces by third parties (e.g., HCI experts and user groups), thus creating a market for user interfaces that is separate from the market of applications. However, there is still a risk for some users (in particular users with severe or multiple disabilities) to be left out due to the high effort of creating specialized pluggable user interfaces for each user group. This has motivated us to work towards a more flexible approach by combining URC's pluggable user interfaces with the runtime "tweaking" capabilities of Fluid, as employed by the smart house demo of the Cloud4all project described in this paper.

III. TECHNICAL FRAMEWORK

Cloud4all's smart house demo application is based upon the URC framework [13] which is standardized as ISO/IEC 24752 [14]. Based upon the URC framework, the Universal Control Hub (UCH) architecture [15] facilitates a middleware-centered approach that can accommodate any networked target devices and applications (such as smart house appliances). Also, through the URC-HTTP protocol [16], it allows for any Web-based controller (such as smartphones, tablets, TVs and any other device featuring a Web browser) to be used.

On the client side, we employ up-to-date mainstream Web technologies, such as HTML5, CSS and JavaScript for HTML DOM manipulation. This allows us to provide a basically cross-platform user interface code (HTML5 & CSS) that can be tweaked in its structure, presentation and user interaction at runtime (JavaScript code) to respond to a concrete context of use. In principle, we can thus react to the following parts of a use context:

1. *User needs and preferences*, in particular those pertaining to the user interface. ISO/IEC 24751 (*AccessForAll*) defines a framework and vocabulary for expressing such personal user interface preferences but has not been widely adopted due to complexity and flexibility issues. Cloud4all is contributing to a revised framework and registry-based vocabulary for user preference sets, which is intended to be a basis for the revision of AccessForAll. Thus, personal preferences will impact the automatic activation of a suitable pluggable user interface (which can be provided at design time by any party and which is available from the

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resource server), and will also drive the "tweaking" of this user interface at runtime in the browser.

2. *Device capabilities*, in particular user interaction aspects such as screen size, and mouse vs. touch based interaction. We are working on including device aspects in a user's preference set to describe specific conditions under which a preference value should become active. In the smart house demo, controller device capabilities will impact the selection of the pluggable user interface and the "tweaking" of this user interface in the browser at runtime. Controller devices to be demonstrated will include modern smartphones, tablets and desktop browsers.
3. *Situational parameters*, such as the situation in which the user interacts with an application (e.g., driving, sitting, walking), and impediments such as ambient noise and high brightness. Conceptual development within Cloud4all is underway to allow for user interface adaptations based on ambient noise and brightness levels. The integration of these concepts into the smart house demo will facilitate the "tweaking" of a personal user interface at and during runtime in the browser. (By listening to changing conditions in the browser, we will even be able to fine-tune the user interface in the course of a running session.)

Currently, the Cloud4all smart house implementation is still in an early stage (see Section 4 for a sneak peek). It allows for manual selection of a persona (as "user simulation") and of a controller device (as "controller simulation" in a desktop browser). Once a stable version of the AccessForAll framework exists and a decent set of preference terms are available in the registry, we will implement this in our smart house demo to facilitate an automatic selection of suitable pluggable user interfaces and their "tweaking" at runtime.

As the Cloud4all approach is designed to perform automatic user interface adaptations based on different users and their controller devices, the user will not need to manually trigger such adaptations. However, the user will be able to control such adaptations in an appropriate way. Ultimately, this will need a "matchmaker" in the cloud (i.e., the matchmaker will be available as a service on the Internet), a key component of the Cloud4all architecture [17]. The matchmaker is responsible for identifying suitable runtime adaptation parameters for specific user preference sets and a specific context of use.

IV. THE CLOUD4ALL SMART HOUSE DEMO: A SNEAK PEEK

The Cloud4all smart house demo employs the latest Web technologies, i.e., HTML5, CSS and JavaScript. Accessibility is an essential requirement for this demo, so, for example, all content — including content manipulated by JavaScript — is keyboard accessible and provides sufficient contrast between text and background. An early prototype using the Adobe Edge Preview tool was abandoned because it did not allow the required accessibility features.

The current demo allows the user to select one of seven personas to whose preferences the simulation should be adapted, and to select a specific controller to be simulated (see Fig. 1). The personas were selected from those created by the European projects AEGIS [18] and ACCESSIBLE [19]. For each of these personas, we created a *preference set* that describes the accessibility features and assistive technologies that they need. These personas are merely a convenient way of grouping and demonstrating various accessibility settings, not a way of classifying users. Tools that allow users to define their preferences are being developed in Cloud4all and other projects that contribute to GPII.

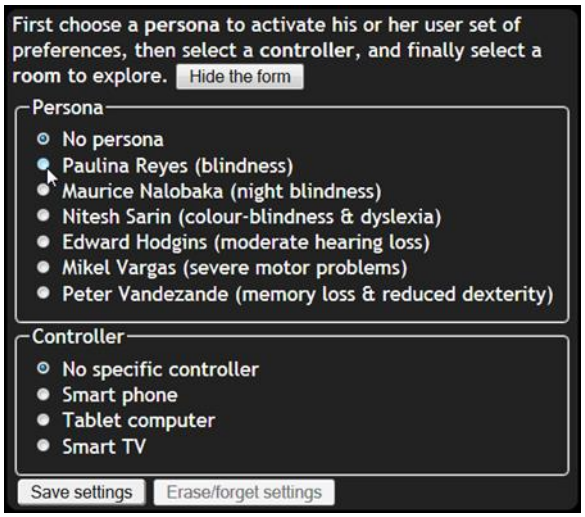

Figure 1. The persona and controller selection panel.

After having chosen a persona and a controller, the user can select from a set of appliances to be controlled ("target devices"). For the sake of simplicity and demonstrability, the smart house demo includes a simulation of smart house appliances in the Web browser rather than having real appliances connected as a back-end. The target devices are displayed in a virtual smart house depicted as a floor plan (see Fig. 2).

Figure 2. The overview screen for selection of a target device. The mouse cursor is positioned to select the living room. Selection can also be done via the keyboard alone.

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After selecting the target device, the system provides a user interface for the target device in the browser; this user interface is adapted to the persona's preference set and the selected controller (see Fig. 3 and 4). In a later version of the simulation, the user will be able to explore the differences between the adaptations by switching to a different persona and/or controller after selecting a device.

As examples of currently implemented pluggable user interfaces, we present the control clients for a stove (Fig. 3) and a coffee machine (Fig. 4). Both user interfaces are implemented as Web clients and are available in two versions each: a "standard" and a self-voicing version for visually impaired users (without needing a native or third-party screen reader). The self-voicing versions announce necessary information and events upon user interaction. This is achieved by including pre-recorded audio files in the web client (via HTML5 <audio> tags). All Web client versions are keyboard accessible.

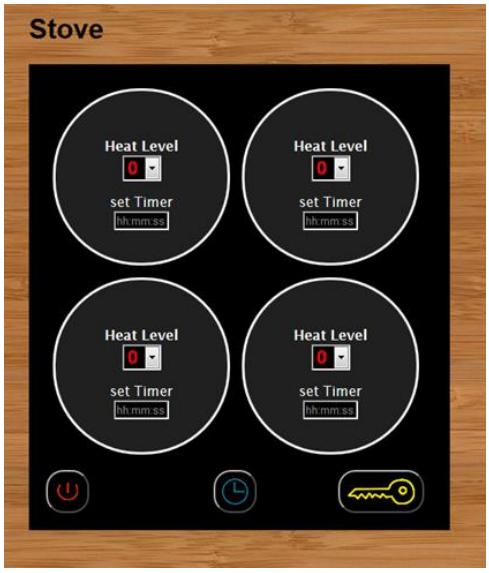

Figure 3. A Web client for a stove. It allows for individual control of four cooking plates (heat level 0-9 for each plate). In addition, it provides extra features, such as a child-lock to prevent a child from turning on the stove, and a timer for automatic switch-off for each plate.

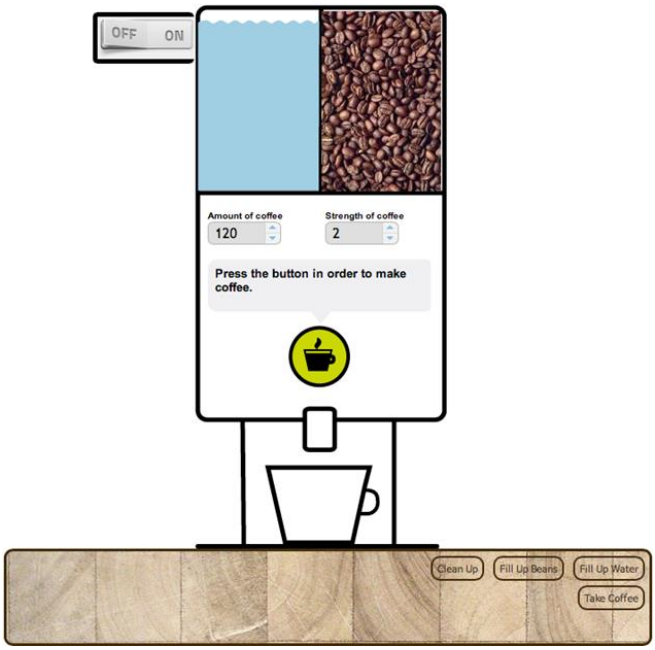

Figure 4. A Web client for a coffee machine. The upper-left button indicates that the coffee machine is switched on. The user can select the strength (1-3, i.e., weak to strong) and the size of the coffee cup (50ml to 150ml). The user receives notifications if either the water or the coffee reservoir is empty or the machine needs cleaning.

V. CONCLUSION & OUTLOOK

In this paper, we have introduced the smart house demo application of the European project Cloud4all. Its technical foundations are the URC framework, the UCH architecture, and the GPII preference set for user preferences and contextual conditions.

The smart house demo and its architecture address the previously mentioned industry concerns on adopting context-driven user interfaces (see Section I) in the following ways:

1. Based on the URC technology, designers can create a visual user interface as a "pluggable user interface" in a first step (see examples in Section IV). The pertinent abstract user interface can then be derived in a second step, resulting in the "user interface socket". The socket is required for enabling alternative (pluggable) user interfaces, possibly using other modalities.
2. For designing a visual user interface, Web designers can use the tools and technologies they are familiar with (in particular HTML5 editors and Web programming environments). However, they will have to add some JavaScript "glue" code manually for retrieving and displaying the values of the pertinent socket elements, and updating them upon user input. (This manual step could be eliminated by special extensions to the HTML editing tools.) Also, they will need to include some framework code (provided to them via a link) that will allow for tweaking the user interface at runtime based on a user preference set and contextual information. (This will also enable user-initiated adaptations at

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runtime via a personal control panel, as currently developed by GPII.)

3. Regarding the control over the context-driven user interface at runtime, device manufacturers will have to live with the fact that their user interfaces are tweaked at runtime along previously known dimensions, such as font size, button size, and line height. However, they might construe completely third-party made user interfaces as damaging their corporate identity. Therefore, we need to make sure that the device manufacturer's user interfaces are used as default, and third-party user interfaces for special user groups (with disabilities) and special contexts are first approved by the device manufacturer before they are released to be used at runtime. This can be achieved via a certification process on the resource server which acts as an "app store" for user interfaces in our architecture. At the end, we hope, the resulting context-driven user interfaces will highly increase usability and accessibility of their devices, which will more than outweigh the device manufacturers' discomfort on giving away some control over the user interface at runtime.

The smart house demo application will soon be made available publicly as a showcase of pluggable user interfaces that adapt to a user's needs and preferences, to the controller's capabilities, and to situational constraints. It presents a showcase of emerging user interface adaptation technologies developed within GPII, which will allow for real context-driven user interfaces. The combination of the URC framework and context-driven runtime adaptations is deemed to be a major advancement in adaptive user interfaces for smart houses, Ambient Assisted Living environments, and beyond. URC allows the provision of a variety of pluggable user interfaces at design time, in order to accommodate for a heterogeneous user population with widely differing needs in terms of modalities and user interaction mechanisms. The client-side context-driven adaptation approach, based on user preferences, device capabilities and situational parameters, allows for low-level modifications ("tweaking") of user interface features at runtime, starting from one of the pluggable user interfaces provided at design time. We believe that such a hybrid approach is well suited to accommodate the needs of a broad range of users with disabilities, as well as providing enough incentives for mainstream industry to be adopted in the long run.

Currently, the Cloud4all smart house demo is still at an early stage, populated with a few exemplary appliances and user interfaces only. Further development work is planned to address:

- Full support for the AccessForAll (ISO/IEC 24751) framework, and its registry of preference terms. Based on a user's preference set, the matchmaker will be able to automatically provide a first approximation of runtime user interface, and to adapt it at runtime to better suit the user's preferences and needs.
- In addition to the automatic selection of an appropriate user interface, the user should be able to fine-tune its settings via a personal control panel. For example, a blind user would automatically be provided with a self-voicing user interface, for which they could fine-tune the speech rate and volume at runtime.
- Integration of more appliances and controller devices, together with pertinent user interfaces for all personas.
- Integration of a real identification feature for the user, employing a USB stick or NFC token rather than having to select a persona. (However, we will keep the persona selection panel for demonstration purposes.)
- Automatic detection of browser and runtime platform (including mobile devices) rather than having to select a controller device manually. Based on this information, the matchmaker will be able to automatically select an appropriate pluggable user interface and adapt it at runtime. (However, we will keep the controller selection panel for manual adaptions, for demonstration purposes.)
- Automatic adaptation of user interface features based on situational parameters of use, such as ambient noise and brightness levels. Again, the matchmaker can use this information to adapt a user interface at runtime.
- Usability studies on identifying appropriate ways of letting the user trigger and control automatic user interface adaptations. This is a core issue for overall user acceptance of the GPII framework since users want to be in full control of the user interface, but at the same time do not want to be distracted by frequent prompts on user interface issues.
- Usability evaluations and comparison of alternative user interfaces with regard to their usability and acceptance level for a specific user group (optional).

These activities are planned to be conducted in the course of the Cloud4all project. In addition, other parties are encouraged to contribute to this open-source effort within the GPII realm. Interested parties are welcome to contact the authors in this matter.

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User-Centric Adaptive Automation through Formal Reconfiguration of User Interface Models

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***Abstract*—This paper presents work in progress on a novel approach for modeling and implementing user-centric adaptive automation based on formal modeling and reconfiguration of user interface models. The approach addresses automation as relevant parameter in human-machine interaction; it is responsible for increasing workload during monitoring and control of complex technical systems and thereby for human errors in interaction. By actively involving the user into the adaptation process through user-side applied reconfiguration and system-side, workload depended adaptation, the user gets a deeper insight to the automation of the system and automation gets adapted to his or her needs. Thus, the main contribution of the work presented in this paper is the close integration of the user into the adaptation process of automation, resulting in a user-centric adaptive automation approach.**

Keywords-formal modeling; human-computer interaction; adaptive automation

I. INTRODUCTION AND MOTIVATION

In the course of the last decade, the increasing automation of complex controlling tasks has significantly changed how control of complex technical systems is done. Examples from the chemical and energy industry show that the main task of operators is to monitor the (automated) technical process rather than to control it [1]. Research in cognitive psychology has revealed important consequences of automation with respect to the human operator's workload in monitoring and control of technical processes, especially in critical, non-standard situations [2]. High workload is closely related to error rate, as well as to factors that influence the error rate in human-machine interaction, such as motivation, well-being, or situation awareness [3, 4].

Adaptive user interfaces are developed primarily in order to reduce workload and to increase human performance by adapting interaction to a specific user [5]. Thus, it seems obvious to adapt user interfaces in order to suit particular users' needs and to introduce into the adaption process the degree of automation as an important parameter influencing human factors in human-machine interaction [6]. Here, the degree of automation defines whether the user has more or less control over the process, which system information in a critical situation is provided, or how the granularity of input operations is defined. Still, adaptive user interfaces require information and data about the situation of user-system interaction to trigger and initialize certain adaptations. Here, mental workload has been identified as one primary reason for errors in user-system interaction. Especially in context of automated systems, the degree of automation is associated with potential increase of mental workload and thereby is an indicator whether the degree of automation is too high or too low and whether it should be adapted or not. Weert [7] describes how mental workload can be measured based on different physiological factors, such as heartbeat rate, facial expression, perspiration, or eye blink rate. Out of these factors, pupillometry has been identified as promising measurement for workload, especially in context of adaptive automation to increase human performance [8].

Motivated by these findings in cognitive psychology and work on adaptive automation, this paper presents an approach to combine system- and user-side triggered adaptation of the degree of automation as being integrated in a model-based and executable approach for describing user interfaces based on a formal and graph-based modeling approach for the creation of user interface models. This close integration of model-based creation and system-/user-side adaptation tries to make a first step into the direction of a "human-machine symbiosis", without losing the focus of creating computer-based systems [9]. This gap between modeling and implementation highlights the problem of transforming models into executable code, as has been described in context of software development [10].

Therefore, the model-based approach described in Section 2 is executable and offers mechanisms for model-intrinsic adaptation through graph transformation systems. Therefore, the presented approach is graph-based and is transformed into reference nets, a special type of Petri net. Still, computer-based adaptation of automation assumes the accessibility of automation in a system's architecture as a formal model or description. Based on this observation, Section 3 presents a modeling approach for integrating automation with the user's current workload into an adaption concept, targeting formal user interface reconfiguration using predefined adaption rules. These adaption rules getting instantiated based on the measured data and being applied in a next step to the formal user interface model. Finally, Section 4 will conclude the paper and will discuss future work aspects, such as a planned evaluation study

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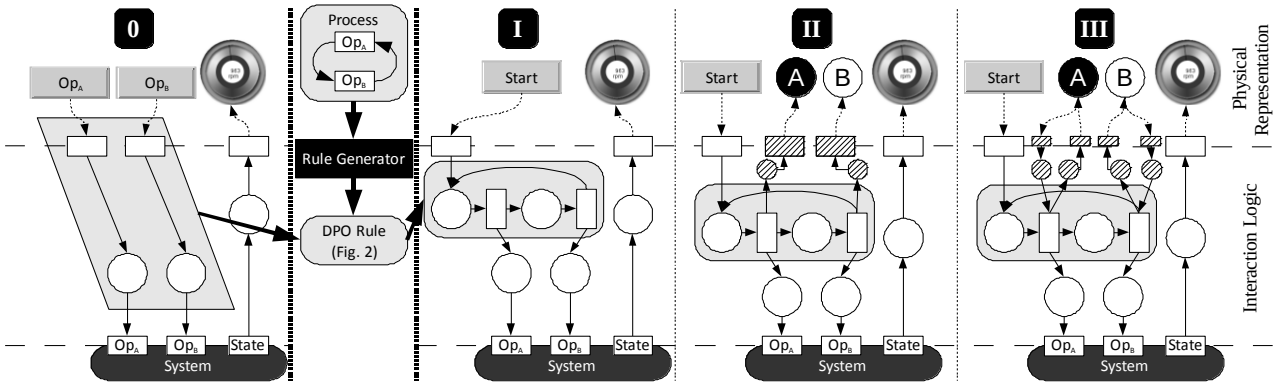

Figure 1. Example of a simple user interface reconfiguration to adapt automation.

investigating the influence of system-/user-side adaptation of automation to user's performance.

II. FORMAL RECONFIGURATION OF USER INTERFACES

The adaptation of a user interface responding to the degree of automation, individualization for a certain user (or user group), as well as the necessity of the modeling approach to be executable, are the main arguments for the use of formal methods. This is because only fully formal models can be processed algorithmically in a computer-based system. For this reason, we developed a preliminary formal approach for modeling user interfaces in a two-layered architecture (see Figure 1, Section 0). The first layer represents the physical appearance of the user interface, which is directly accessible through the human user. Thus, it offers a set of input and output elements (button, slider, text fields, etc.) allowing the user to interact with the system and presents information (graphs, displays, instruments, etc.) to notify the user of the state of the system and any changes in it. The underlying second layer models the behavior of the user interface as a set of data processing routines that process events caused by the user and create certain data for controlling the system and, vice versa, process data sent by the system to be presented to the user. This two-layered architecture was used in various evaluation studies to reconfigure user interfaces (UIs) and to investigate the influence of reconfiguration to the human-computer interaction [11, 12].

For modeling the second layer, which is also called interaction logic, we developed a formal and visual modeling language called Formal Interaction Logic Language (FILL), accompanied by a visual modeling tool called UIEditor [13]. The UIEditor is able to model physical representation (such as a visual user interface), run a created user interface, and, finally, reconfigure the user interface based on a formal graph-transformation system. To execute a given user interface, interaction logic provided as a FILL graph is first transformed to a reference net, a special type of Petri net [14]. Reference nets provide formal semantics for FILL and makes interaction logic executable using Renew, a Java-based modeling and simulation tool for reference nets [15]. The simulation of a modeled user interface can be exemplary shown along the initial interaction logic (see Figure 1, Section 0). Here, the physical representation contains of two buttons labeled "Op_A" and "Op_B", as well as an interaction element showing a single value on a certain scale, for instance, the current rounds per minute (rpm) of a pump. Thus, "Op_A" and "Op_B" could be operations to increase and decrease the rpm of the pump in the controlled system, which is represented as third layer (see Figure 1). The initial reference net-based interaction logic does nothing else than sending press events resulting from the user to the system and sending the current rpm value from the system back to the user interface's physical representation. Therefore, press events of a button trigger transitions to fire in the interaction logic, as far as they are associated to that button (as it is indicated as dashed arrow in Figure 1). The same is true for the connection to the system and the callback mechanism for the rpm value.

To apply reconfiguration to a reference net-based interaction logic, transformation rules, which first have to be generated algorithmically, can be applied to the reference net and thus change the behavior of the user interface. The rules used in UIEditor's reconfiguration component are based on the DPO (Double PushOut) graph rewriting approach [16]. An exemplary rule is shown in Figure 2. A DPO rule is divided into three different graphs, or Petri nets: The left side (L), the interface graph (I), and the right side (R) of the rule. The parts of the original graph G to be rewritten are defined by defining a matching function m. By applying the rule to

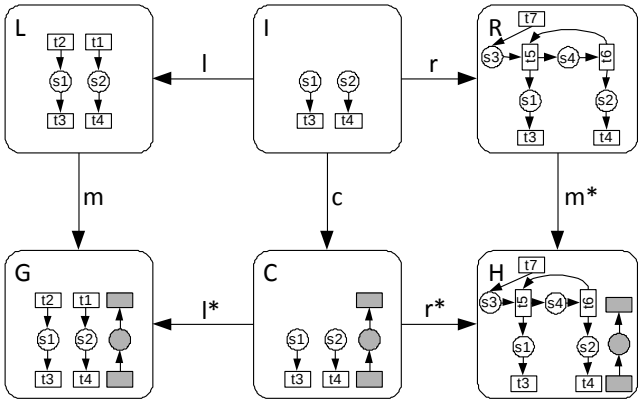

Figure 2. Double pushout (DPO) graph rewriting approach.

G, the difference between L and I is deleted from G (resulting in C), and the difference between I and R is added to C, yielding the final result, H. Figure 2 shows the rule that is applied to the initial interaction logic (see Figure 1**,** Section 0), where the result is shown in Figure 1, Section I, accompanied by a change of the physical representation. Here, a specific part of a control process (e.g., alternating increasing and decreasing of the pump's rpm) has been integrated into the interaction logic to automate the indicated process. Thus, automation becomes part of interaction logic as will be described in greater detail below. In many cases, this kind of reconfiguration of the user interface requires modifying the physical representation in respect to newly added interaction elements for input data or changes in how information is represented, as shown in Figure 1.

Thus, adaptation of user interfaces is implemented based on formal reconfiguration techniques that are used and integrated in a transformation-rule generator using context information, such as an automation model and user's current mental workload. The main contribution of using formal methods is that the model is still executable after creating and reconfiguring the user interface, where the whole adaptation process is implemented in the same formalism. This prevents solutions to be loose combination of different modeling approaches, which run the risk to be incompatible or losing information by changing between different modeling concepts [10]. The section below presents a coherent solution of adaptation of automation based on the former described self-contained modeling approach.

III. ADAPTATION OF AUTOMATION

For adaptive automation based on formal user interface modeling, it is assumed that the automation concept is fully accessible through an external formal model that matches the underlying concept of formal user interface modeling; therefore, the automation model should employ a Petri net–based representation. Based on this assumption, automation can be further understood as formal abstraction of interaction processes between the human user and any given system that has been technically implemented. Thus, in our sense, automation is part of the above-introduced interaction logic.

Assume a discrete and recurrent process of two operations "Op_A" and "Op_B", which have to be executed in iterative fashion, such as the process shown in Figure 1 and described before. According to the first assumption, this process can be introduced into reference net–based interaction logic as indicated by the bold arrow in Figure 1,

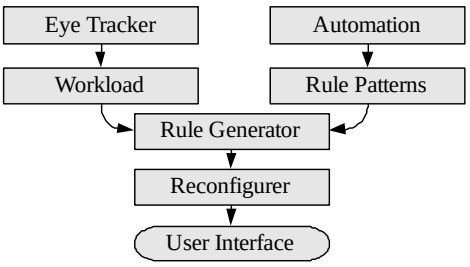

Figure 3. Conceptual architecture of the automation adaption module for the UIEditor.

which represents the application of the DPO rule shown in Figure 2. The automation of this process can then be started by the user pressing the newly added "Start" button. From this point on, the user is only able to monitor the system's state by observing the tachometer-like output widget, showing the current pump's rpm being controlled. Thus, using the initial interface, s/he is not able to follow the operations that are automatically executed by the interaction logic.

As Parasuraman [1, 2] described, workload increases during critical situations because the user has to understand the system's current situation, as well as how the automated control processes are reacting to the situation. The user has to gain insight into the automated process, resulting in increasing mental workload, sometimes dramatically. To adapt automation to this situation, the initial user interface can be reconfigured (see Figure 1**,** Section II), by adding more interaction elements providing deeper insight into the automated process. Two lamps are added to the physical representation accompanied by an extension of the interaction logic, now showing which operation is executed at any given moment. This makes interaction more finely grained and viewable to the user. A further reconfiguration extends the first by changing the simple lamps into buttons (see Figure 1, Section III), where the user is now able to control the automated process. Another possibility would be to remove the automation from the interaction logic and give all control back to the user without restriction or even, contrarily, to reduce the interaction and fully automate the process. The first would result in the initial user interface (see Figure 1, Section 0).

The second aspect for introducing adaptive automation into formal user interface models is that a system exists that is able to measure user's workload (beside other possible measurements) as s/he interacts with the technical system. Therefore, adaptive automation will be implemented as a component of the UIEditor framework, which combines the perceived mental workload of the user and his/er individual requirements. Here, three components have to be realized: the workload identification component, which observes the user through such means as an eye-tracker and calculates the workload from the captured data. The second component is the rule generator, which generates formal reconfiguration rules to be applied by the existing reconfiguration component in the UIEditor. The third component will be based on UIEditor's reconfiguration editor, which is able to apply individual reconfiguration operations to the interaction logic and thereby to the automation model by the user himself; called user-side adaptation above. Here, the user triggers the reconfiguration, selects the specific part of interaction logic to be reconfigured, and chooses the rule to be applied.

Various works have identified pupillometry as a possible indicator of user's workload [7, 8, 17]. Thus, the rule generator is triggered by the workload identification component to generate and apply reconfiguration to the user interface, what is called system-side adaptation (see Figure 3). Rules are then generated from rule patterns that have already been derived and described in automation research, resulting in a reconfiguration as shown in the above-

described example, depending on the amount of detected workload (see Figure 1). Rule patterns consist primarily of specific structures to be added or deleted from reference net-based interaction logic and algorithmic implementation necessary to detect relevant parts of the reference net to be transformed. In conclusion, the combination of system- and user-side adaptation results in an integrative user-centric approach for adapting automation based on formal user interface models.

IV. Conclusion and Future Work

In this paper, we presented a new approach to implement adaptive automation as part of a user interface modeling approach using formal methods to describe interaction logic. This integrative approach is a first step towards closing the gap between modeling, execution, and reconfiguration of user interfaces and integrating adaptive concepts to adapt user interface to user's needs, as well as making the degree of automation accessible for system- and user-side adaptation. Based on visual modeling and graph-based languages accompanied with algorithmic transformation of reference nets, user interface models get executable and can be reconfigured by graph rewriting systems. Considering automation as part of interaction logic, reconfiguration can also change automation beside further individualizations of the user interface concerning user's needs.

Finally, the described work in progress will be evaluated and further elaborated in context of former applied studies [12, 13]. Here, we investigated the influence of individualization of user interfaces using reconfiguration on monitoring and control of technical systems. The reduction of errors was in focus of these studies showing that it is possible to reduce errors through reconfiguration of user interfaces for interaction with technical system. Therefore, we will investigate the former introduced approach of adaptive automation concerning usability and applicability in a real monitoring and control scenario of a technical system (e.g., a simple simulation of a nuclear power plant), as well as analyze its influence on errors in interaction as measurable variable. We will run the test with two groups; one group will do predefined control tasks supported by system-side adaptation of automation, as well as user-side individual reconfiguration, whereas the control group will undertake the same tasks without support by the reconfiguration system.

The above introduced example (cf., Figure 1) is only one aspect of how automation fosters increasing workload and how it is possible to work against this effect through formal user interface reconfiguration. Therefore, future work will seek to identify further features of automation and to generate rule patterns in order to offer a comprehensive library that can deal with various situations and types of automation. Furthermore, an extension of the UIEditor tool for modeling, running, and reconfiguration via modularization and a more finely grained leveled architecture will be developed and implemented due to necessary refinement in the interaction logic model. Finally, the integration and reconfiguration of automation without necessarily including the user but other models and requirements will be part of future work.

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A Multi-Method Approach to Assessing the Usability of Mobile Job Advertisements

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***Abstract*—Accessing the Web from mobile devices has become increasingly common even when searching for job information. Nowadays, most job board offerings are mobile-optimized. However, the search results often refer to job advertisements (ads) and external career pages that are not completely optimized for mobile access. As a result, mobile users may be confronted with inadequate usability or a dissatisfactory user experience. In this context, the purpose of this study is to assess the usability of job ads posted on job portals to identify deficits and best practices. This paper is a work in progress and presents the intended multi-method approach as well as some preliminary findings for an exemplary sample of job ads posted on a German job board.**

Keywords-Usability, User Experience, User Interfaces, Heuristic Evaluation, Mobile Recruiting

I. INTRODUCTION

Recent studies point out that about 69 percent of all Internet users access the web using mobile devices [1]. In this context, it is becoming more and more common to use these devices in order to retrieve job information as well. In Germany, 58 percent of all online job seekers are already accessing job information via mobile devices; in high-tech industries or the media sector as many as 63 percent browse the mobile Internet for a new professional challenge [3]. Thus, mobile optimization is becoming essential in order to maintain reach among target groups and to keep up with the changing usage of media channels.

According to a multi-year study on mobile recruiting in Germany [5], HR managers attribute a growing relevance to mobile devices in personnel recruiting. In 2011, 95 percent of the participating HR managers stated that addressing potential candidates via mobile devices is becoming increasingly important. The proportion of companies and organizations using mobile recruiting technologies and applications rose from 8 percent in 2009 to 25 percent in 2011. A mobile optimized career website is offered by 17 percent of the companies according to the afore-mentioned study [5]. More recent analyses suggest that 24 percent of all German companies already offer a mobile optimized career website, followed by 17 percent with company-owned iPhone applications by the end of 2012 [3]. A study focusing on large enterprises in Germany revealed that as many as 80 percent of the companies provide a mobile career website and about 30 percent have a mobile career app [14].

Mobile recruiting activities of individual companies are complemented by job boards. Their providers aggregate job ads and career information across companies and sectors. In 2011, an analysis of the Apple App Store already identified ten mobile job board applications for the German market [4]. Employers who place job ads on job boards usually get a package for the online channels supported by the portal. When doing this, job board providers mobile-optimize access to their own portal functions, but may not alter the design of the job ads provided by a company. In that case, the search results of the job board can refer to a career website or a job ad that is not mobile-optimized. Thus, the mobile users may be confronted with inadequate usability or a dissatisfactory user experience.

As a result, all three interest groups are confronted with setbacks concerning their individual goals: The job seeker does not get the information he/she was looking for or has a poor user experience. Consequently, he or she probably decides to discontinue the app usage. The employer placing the job ad may experience a negative impact on the recruiting process, its employer branding, or may even lose a potential applicant. The job board provider, in turn, loses an app user, i.e., reach, which constitutes the basis of the job board business model. But even if a user does not directly discontinue the app usage, the design of the mobile ad and its content does play a major role concerning job ads' efficacy in terms of recall and retention [19]. However, regular usability guidelines for mobile websites cannot be applied directly to mobile job ads. Job ads provide very specific information within a focused area of application and thus require adapted criteria for usability analysis. But, despite the importance of these aspects and their high practical relevance, neither specially focused developer guidelines nor scientific research studies on mobile job advertising exist.

To fill this research gap, the study at hand aims to identify deficits and best practices on a mobile-optimized job ad design, proposing a multi-method approach. The research framework will be described in Section II, followed by the intended research methodology in Section III. Some preliminary findings and an outlook on further research are discussed in the last part of the paper.

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II. RESEARCH FRAMEWORK

Requirements for the design of mobile-optimized job ads can be found in guidelines for the user-interface design of mobile applications or mobile websites, e.g., the well-known *Best Practice Guidelines* of the World Wide Web Consortium (W3C) [24]). Here, recommendations are given regarding image format support, style sheet support, page weight, or color usage. However, two problems exist concerning the usage of such guidelines: firstly, the development as well as improvements of modern smartphones are occurring at a furious rate. As a result, guidelines on principles for mobile development rapidly become outdated [9]. Secondly, those guidelines merely refer to technical capabilities and do not address the importance of different design aspects from the user perspective or usage context [15]. Some existing approaches, such as Nielsen's usability heuristic [18] or the adapted metric of the Microsoft Usability Guidelines (MUG, [22]), present a more holistic view on aspects influencing system usability. The MUG guidelines are based on the ISO 9241 usability definition, defining usability as the "Extent to which a product can be used by specific users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use" [13]. Besides structural evaluation in the form of heuristic analysis, user-oriented usability tests constitute an important evaluation method in order to measure efficiency, effectiveness as well as user satisfaction [12, 13]. User satisfaction can be measured by experience-based rating scales, product liking, or level of acceptance of the task solving effort [13].

As this study aims at giving practical recommendations for the design and development of mobile job ads, a multi-method approach with regard to both −structural evaluation as well as user based testing of usability aspects− will be adopted. In order to not just ensure success in terms of usability, but also in terms of a company's communication success, research on design aspects influencing the reception of job ads' content will be conducted additionally. The intended research approach will be described in the next section.

III. METHODOLOGY

Usability analysis can be classified in empirical and analytical methods. Empirical testing can comprise user and task observations of prototypes and final products by field or laboratory studies, including walk through and thinking-aloud analysis [2, 7, 18]. Heuristic evaluations, in turn, refer to assessment by a small group of evaluators according to a predefined set of usability guidelines or criteria [18]. As described above, mobile development often draws on technical guidelines and best practice standards, leading to the problems of being quickly outdated as well as not seeing the goal of overall usability concerning user satisfaction and usage acceptance [9, 15]. Heuristic usability evaluations however, by implementing a systematic inspection of user interface design aspects, enable the identification of usability problems to which special attention should be paid [18]. Here, two main methodologies are available for evaluation. Firstly, validator tools offer a standardized evaluation and in-depth analysis of websites determining how well the site performs on mobile devices. Secondly, a heuristic evaluation can be carried out by looking at interface design in accordance with certain rules as listed in the guidelines. Here, a small number of evaluators (at least three) assess the compliance of a user-interface with usability principles, the so-called heuristics [18]. As presented in Figure 1, phase 1 of the study at hand implements two methods of usability evaluation for an exemplary set of mobile job ads: (1) A tool based usability evaluation by the *W3C mobileOK Checker* [25] and the *mobiReady testing tool* [17] validator. Both tools provide an overall value of "mobile fitness" as well as a detailed report on specific technical checks. (2) A heuristic analysis by evaluators, i.e., usability experts. The evaluation heuristic was defined by considering usability criteria of common standards, e.g., the W3C guidelines [24], the BBC Mobile Style Guide [10], the mobile applications of the MUG [22] or the Microsoft Mobile Design Guidelines [16].

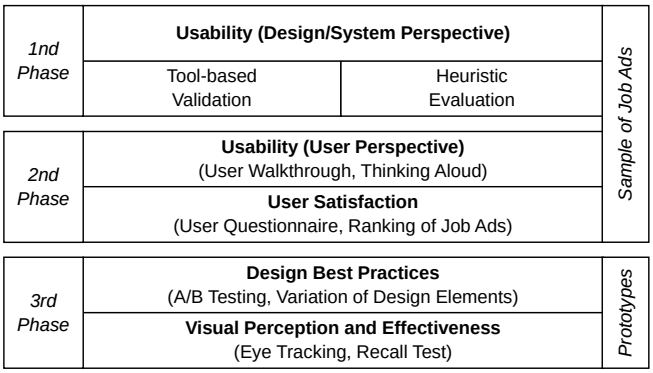

Figure 1. Study's Multi-method Approach

In phase 2, empirical user testing is carried out to consider how users perceive mobile job ads and to identify usability issues and misconceptions from the user perspective [18]. Here, test subjects are asked to search for a job on the job board and to utilize presented job ads for this purpose (user walkthrough) by applying a thinking aloud approach for the analysis. This enables us to identify the job ads' major aberrations and drawbacks with which the user is confronted when attempting to achieve his or her goal and to evaluate design aspects within an actual usage context. Following this procedure, the test users will be asked to rate the likability of the observed job ads as well as to rank them in order of their preference to get a measure of the users' final satisfaction with the ads [13].

As mentioned above, the aim of the study is not only to evaluate pure usability aspects but also to assess the communication efficiency of the job ads. For this purpose, A/B testing will be combined with an eyetracking and a recall analysis in phase 3. Within the so-called A/B testing, various user interface design alternatives are analyzed to obtain design recommendations, i.e., design best practices. Here, only one single design attribute is varied and evaluated, like typeface or button design. Analysis of the different versions can either be done in a live setting by, e.g., tracking conversion rates of design alternatives or within an experimental laboratory environment [11]. An experimental setup enables a

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combination of A/B testing with other types of analysis, e.g., to better understand user interaction and visual perception of the presented job ad [6]. For this purpose, one of the most advanced usability testing methods is the eyetracking technique, which can be conducted directly on a mobile device (using head-mounted systems) or based on a simulation/representation of the design artefact on a desktop-based configuration. Thus, researchers are able to gain information on unconscious perception and information processing, which can be used to optimize user interfaces [6, 20]. As it has been shown that content related design aspects like structure or visual design have a major influence on user perception and comprehension [8], these aspects were included in the study. To allow for aggregated group analysis and because the focus of this part of the study was on visual perception and not on user interaction, the study incorporates a desktop-based test configuration. Factors for design variation to be considered are, i.e., length and complexity of job description, single column vs. two column layout, or media richness. Aspects for such a variation can be identified within the preceding heuristic analysis and usability testing as well. The eyetracking analysis will be followed by recall tests on the user perception of the job ads' content. Here, users will be asked to name companies, job titles or to recall employer brands in order to measure ad efficacy [19]. The combination of the results from the eyetracking and recall testing is intended to gain recommendations for improving both, usability as well as communication effectiveness of the job ads. Aspects of the information quality [21] provided in the mobile-optimized job ad and its implications on the ease of finding appropriate job information in job portals is not analyzed but might be subject to future research.

IV. Status Quo and Preliminary findings

The implementation of the multi-stage research approach to assess the usability of job ads within the research project is a work in progress and not completed yet. As a first step, the heuristic evaluation was applied to a sample of 13 exemplary job ads from a German job board. As mentioned above, available mobile design guidelines were analyzed and consolidated to define an appropriate heuristic. By doing this, e.g., the formerly advised maximum page size of maximum 20 KB [24] was identified as no longer being up to date, since processing power and data transmission have improved tremendously [9]. Therefore, some more recent studies suggest that mobile pages should ideally not exceed 50 or maximum 100 kilobyte [23]. Other criteria refer to more detailed aspects like touch screen optimization, automatic redirects to mobile sites when accessed by mobile, the integration of inbuilt mobile functions like click-to-mail/-call, design aspects like font, contrast and images, as well as content related aspects concerning the appropriateness and relevance of information, e.g., job description, company, qualification or application. As shown in Table I, a catalog with criteria subdivided into the categories access/navigation (ACN), design (DES), content (CON), and interactivity (INT) was derived. The catalog contained more than 30 criteria for the evaluation of the job ads and was intended to complement the tool-based assessment of "mobile fitness" mentioned in the preceding section. The tools calculate the mobile fitness as a percentage of mobile optimization. Likewise each category of the heuristic evaluation was measured by a percentage representing the extent to which the job ads comply with the criteria in the category as well as from an overall perspective.

TABLE I. Areas of Heuristic Evaluation

Category		No. of. Criteria	Areas of Analysis (No. of Criteria)
ACN.	Access/ Navigation	9	Mobile accessibility (3), use of mobile technologies (2), mobile optimized navigation (2), ease of access to additional sources (2)
DES	Design	12	Layout and structure (3), text and readability (3), mobile optimized embedding of media (6)
CON	Content	10	Corporate identity, appropriateness and relevance of employer and job information (8), contact channels
INT	Interactivity	5	Click-to-mail/-call, social media integration, locate job on map, option to apply mobile

The sample of job ads was assessed by eight evaluators using these heuristic criteria. An overall result was calculated based on the ratings of the two validation tools (VAL) and the consolidated heuristic evaluation (HEU). At this stage of the study, no weighting of the criteria, categories or types of tests was applied. This means the overall result was calculated as the arithmetic average of the partial results. Table II shows the preliminary results for this analysis in phase 1 of our study. The table also shows the lowest (Min.) and highest (Max.) rating as well as the difference (Diff.) between the highest and lowest ranking job ad within each category and for the overall result.

TABLE II. Preliminary Results of Usability Analysis

	VAL	HEU	Heuristic (HEU) by Category				Overall
			ACN	DES	CON	INT	
Avg.	27%	50%	43%	56%	77%	24%	38%
Min.	12%	38%	22%	37%	45%	3%	26%
Max.	54%	69%	74%	83%	98%	48%	48%
Diff.	42%	32%	51%	46%	53%	45%	22%

The key finding is that each of the examined job ads needs to be improved in order to provide an acceptable mobile user experience. None of the thirteen tested job ads achieves an overall rating of 50 percent. This is mainly caused by the dissatisfactory results for most of the job ads in terms of technical validation. However, the results provided by the validators and the heuristic rating differ greatly in the majority of the cases as presented in Figure 2. Many of

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the job ads achieve results between 10 and 20 percent in validation; only two of the job ads rated 50 percent or more. For the heuristic evaluation, all job ads reached 38 percent or more; five of them even achieved 50 percent or more. This is due to the fact that the validators are somewhat outdated (feature phone focus) and do not consider the context of use as does the heuristic evaluation. Over all, the weakest category of the heuristic criteria is “interactivity”: not one of the examined job ads fulfilled half of the criteria. In contrast, the majority of the job ads achieve quite good results in the area of “content”, but this was also the category with the biggest difference between the lowest and highest ranking job ad. The job ads with above-average heuristic results lose their top positions in the overall rating because of their low score in validation. The top positions in the overall rating have only average scoring in heuristics which is bolstered by a good validator score, possibly indicating a kind of trade-off between technical optimization and adoption of the technical capabilities of up-to-date smartphones.

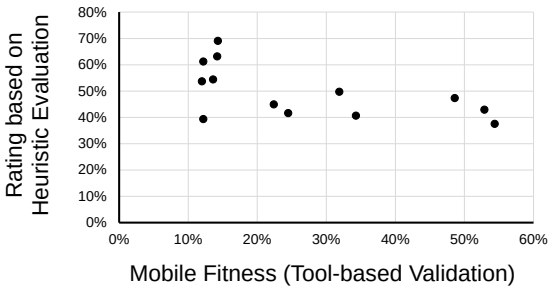

Figure 2. Usability Validation vs. Heuristic Evaluation

Overall, each of the analyzed job ads has plenty of room for improvement. In most cases, the technical “mobile fit” in terms of validation turns out to be poor. The performance of the mobile job ads in the areas of “content”, “design” and “navigation” is better, but far from good. Most notably, all of the tested job ads fail in the area of “interactivity”, where a good concept could really set a mobile job ad apart from the competitors. Next phases of the research project will contrast these results with the findings of assessing usability and effectiveness of the job ad design including the user perspective. Considering the deviations between tool-based validation and heuristic validation, it will be interesting to see whether the results from the heuristic perspective can be supported by the findings of the empirical testing. The relevant research progress will be presented at the conference.

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An Exploration of Relationships between Culture Images and User Experience of Gesture Interaction

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***Abstract*—The application of gesture changed the mobile interactive process greatly, as well as User Experience (UE). For better UE, it requires information feedback triggered by gesture to accord with users' cognition, which is closely related to their culture and values. Many previous studies have described the differences of interaction under diverse cultural atmospheres, which confirms that cultural factors do affect the interaction process, but does this also hold for mobiles? Whether the UE is good? This study carries out a series of empirical research towards this end. The task flow of 20 apps based on Android was analyzed for extraction of gestures used with higher frequency. The ink-rhyme effect of Chinese calligraphy culture was integrated into interactive feedback to form gradient mode, which is applied to the three most familiar gestures to users— tap, press, slide. The participants judged the mode based on Hassenzahl's surface usability questionnaire to assess UE. The results showed that cultural factors improve the user's emotional experience, but have little impact on the operating experience. It is demonstrated that the integration of cultural factors enhances UE, especially emotional experience, and shows no negative impact on usability.**

Keywords—Culture Images; User Experience; Gesture Interaction; Emotion.

I. INTRODUCTION

Gestures based on touch screen help people get rid of the dependence on traditional input device. They shorten distance between people and equipment, enrich the pleasure of interactions and enhance users' satisfaction. All of these provide infinite advantage for gesture interaction [1][2]. However, damage caused by improper cognition and recognition of gesture in practice will upset users.

The feedback activated by gestures needs users' rational cognition. In order to understand feedback mode better, cultural and value recognition from users are of great importance [1]. In a way, culture can be understood as the medium and tool used to think, work, and study [3]. Many studies have shown that selection, receiving and cognition of information will be affected due to different cultural backgrounds. Thus, the integration of culture and interactive system is very necessary [4]. However, what forms the culture will be absorbed, and whether it has positive influence on UE, are still problems that worth exploring.

In order to further develop our investigation, the following research questions should be taken into account: i) How to choose the object of study in a wide variety of gestures? To answer this first question, the research of 20 apps based on Android helped extract the typical gestures. ii) Which kind of form will cultural factors be blended into interaction? In this part of study, one of the representative of traditional Chinese culture — calligraphy was used as research object. The reason why we did not chose other cultural category is that we know it better than other items among countless cultural items. iii) How to evaluate the UE of interactive system integrated with cultural factors? In older to answer the third question, Hassenzahl's surface usability questionnaire based on semantic scale was used to identify the UE [5].

The study reveals the relationship between feedback merged with culture elements and UE. It showed that better emotional experience was produced by cultural feedback, such as excitement, fun and deep impression. On the other hand, there was no much impact on operational experience, but a bit of cognitive burden for users.

Section 2 of this present study carried out detailed induction and analysis of previous related research, which provided instructional method for the subsequent experiments. In Section 3, 20 apps were used to extract typical gestures used in higher frequency. The ink-rhyme effect of Chinese calligraphy culture developed into two different modes in Section 4. Through the experiment of the fourth section, we understand the relationships between cultural factors and UE of interactive system. Combined with the discussion about the UE in Section 5, the conclusion showed that culture factors had a positive impact on emotional experience, but added a certain cognitive burden to users.

II. RELATED WORK

A. Gesture Interaction

Touch gestures are considered to be the most direct way of human-computer interaction [6]; they have convenient way to input, and reflect abundant semantics [7]. Currently, gestures based on the mobile platform can be subdivided into multi-touch gestures, stroke gestures, and combinational gestures. Even if multi-touch gestures produce an advantage as being more mature, they have not fully realized in

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mainstream platforms, except operations related to rotation and scaling [1][8]. Multi-touch gestures, as they were, are mostly applied to a mobile platform, but have no unified standard. Previous Studies have pointed out that, integrating concepts of time and displacement, gesture can be reduced to action unit, which will converse into a basic set of gestures specific to whole system [9]. This research provides basis and reference for extraction of typical gesture based on mobile platforms.

B. Cultural Factors in Interaction

The effect of culture on interaction has been confirmed by many research institutes [10][34][35], e.g., in image search task, Chinese are more likely to generate search keywords describing the overall properties of the target images than European and Americans (EA); EA assigns more space to the main objects than Chinese [10]. However, how to blend culture factors with interactive system still needs further discussion. Chi-Hsiung Chen and his colleagues, scholars from Taiwan, suggested that culture reflected on three levels: surface layer (visual and material), middle layer (behavior and habits) and inner layer (thoughts and spirit) [11]. In 1993, Ockman proposed the fusion point of culture and design relied on users' tastes, habits and lifestyles [12]. Tien-Li Chen and Pei-Fen Hong also pointed out those cultural images can be divided into two directions, namely, implicit and explicit [13]. Thus the integration of culture and design is from the inside to the outside. It is user-oriented and should consider users' behavior and habits in some kind of conditions, through direct or indirect sensory effects. Then it is showed through the sensory effects directly or indirectly.

Chinese aesthetic culture represented by the calligraphy is becoming a new source of design inspiration [14], the simulation technology of calligraphy effect has been the subject of many studies [15][16][17]. Imitations of calligraphy brush strokes; however, it is a kind of retrieving of outer appearance shape, which is in lack of behavioral interpretation for calligraphy culture. Calligraphists will strengthen the tendency of their creatures by controlling the ink-rhyme [18]. Ink-rhyme is an extremely subtle factor in calligraphy art, but also is directly controlled by the behavior. Taking ink-rhyme effect as a breakthrough point of culture and interactive systems, in conjunction with other conditions, is likely to promote re-creation of artistic context and UE.

C. User Experience

UE is related with the process of interaction, it is a combination of user's behavior, results and emotion [19]. UE take emotion experience as more advanced level, including hedonics, aesthetic and pleasure [5][20]. Sascha Mahlke from Industrial University of Berlin thought UE could be defined from four dimensions: perceived usefulness, ease of use, perceived hedonic quality, perceived visual attractiveness [21]. UE, therefore, is a process of focus on cognition and feelings, based on usability and affection. However, there still exists a question whether cultural factors have a positive effect on UE.

III. STUDY 1: TYPICAL GESTURE EXTRACTION

The purpose of this study was to extract typical one in a wide variety of gestures used in mobile terminal. The intention is to take gestures that users are most familiar with as variables for further research.

A. Material

We used 20 apps based on Android. According to the report that Linda Sui published in Strategy Analytics, which can be found at [28], there were 530000 smartphones supplied in the fourth quarter of 2012, 86% of which were based on Android. The selection of study platform was strongly supported, because the vast majority of the Chinese smartphone users were more familiar with Android. The apps were the top 20 selected from list at the end of May of Peasecod [29], which was reported to occupy more than 50% of mobile apps management market [30]. Table 1 contains the selected apps and games, together with their study IDs and times of installation.

TABLE I APPS WITH THEIR STUDY IDS AND INSTALL TIMES

Apps			Games		
ID	***Name***	***Install Times***	***ID***	***Name***	***Install Times***
1	QQ	110	11	Temple Run	19.61
2	WeChat	98.64	12	Tank ON	0.36
3	Qvod Player	29.09	13	Find Something	12.96
4	QQ Zone	52.15	14	Daddy Was A Thief	0.71
5	UC Browser	70.61	15	Carrot Fantasy	8.95
6	Sogou Input	79.26	16	Shine Runner	0.51
7	TTPOD	38.29	17	Subway Surfers	6.27
8	360 Guard	61.87	18	Angry Birds	21.2
9	Ink Weather	32.02	19	Fruit Ninja	19.03
10	Taobao	40.03	20	Pop Star	8.41

unit: million

B. Variable identification

In order to understand how gestures operate on an interactive system of smartphones, each of the stimuli used for the evaluation was identified. Table 2 contains definition and legend of the gestures, which could be consulted in the touch gesture reference guide provided by Luke Wroblewski [31].

TABLE II GESTURES WITH THEIR STUDY IDS, LEGEND AND DEFINITION

ID	Legend	Gesture	Description of Action
1		Tap	Gently touch the screen and left
2		Double Tap	Touch the screen twice quickly
3		Press	Touch the screen for a period of time
4		Slide	Move fingertip over surface without losing contact
5		Drag	Hold the object on the screen then slide

6		Zoom	Touch surface with two fingers and bring them closer or apart
7		Rotate	Touch surface with two fingers and move them in a clockwise or counterclockwise direction
8		Press and Slide	Hold the screen with one finger, slide with another one
9		Press and Tap	Press surface with one finger and briefly touch surface with second finger
10		Other Gestures	e.g. shake

C. Task and Paocedure

Firstly, these 20 apps and games were underway of the task flow analysis. After separating the function module of each app, every step of the task was refined to single gesture's application, and marked with circle standing for the gesture ID. Take Tecent QQ [32] as the example: to enter the application, users first need to tap the icon to login, then tap their account and password to input box. After tapping "OK", user will come to QQ's message function module to continue their operation. From such a short task flow, it can be seen that the completion of this task requires at least four taps. Figure 1 shows task flow analysis of QQ on a wider scale. Corresponding to the analysis, type and frequency of gestures used in QQ are counted in Table 3. For the sake of an overall understanding of the whole situation, gesture analysis can be applied to the rest of apps in the same way.

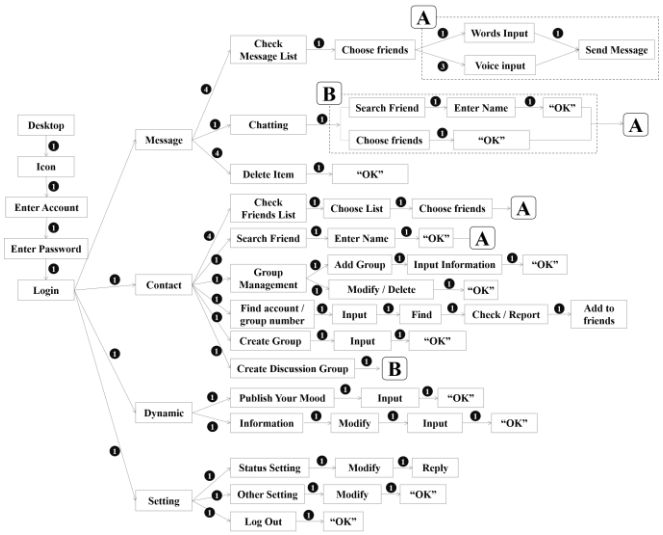

Figure 1 Task flow analysis of QQ

TABLE III GESTURES USED IN QQ WITH THEIR STUDY IDS AND FREQUENCY

ID	Gestures	Frequency	ID	Gestures	Frequency
1	Tap	64	6	Zoom	0
2	Double Tap	0	7	Rotate	0
3	Press	4	8	Press and Slide	0
4	Slide	3	9	Press and Tap	0
5	Drag	0	10	Other Gestures	0

D. Result

All of the 20 apps were analyzed in the method shown in last part, the results were shown in Table 4.

According to the frequency statistics, "tap" was at the highest frequency. The rest of the top four gestures were "slide" (M = 7.2, SD = 2.936), "press" (M = 2.3, SD = 1.567), "drag" (M = 0.2, SD = 0.632). Among them, "tap" was the most favorite gesture with users, as the use of which was far more than other gestures. "Drag" was unusual gesture with the same level of "zoom" and "double tap". "Rotate", "press and slide", while "press and tap" were barely used in smartphone based on Android.

TABLE IV GESTURES WITH THEIR APPLICATION MEAN AND SD

Gesture	Tap	Double Tap	Press	Slide	Drag	Zoom	Others
Mean	65.100	0.200	2.300	7.200	0.300	0.200	0.200
SD	15.300	0.421	1.567	2.936	0.675	0.632	0.422

The results may be due to the following points: i) The hardware limitations, e.g., the size of the screen limits the operations by two or more fingers, because of bad usability. It is proven in this view that some apps, like Meitu [33] use combination of tap and slide instead of rotation or zooming. ii) The standard of gesture design is faultiness. It will be easy to be accepted if the design meets users' mental model and daily habits [1]. Intensive mapping is generated between gestures and computer mouse: the function of tap is similar with the left mouse button and press likes the right button.

In summary, we took "tap", "press", and "slide" as stimuli in Study 2 to explore cultural factors effects on interactive UE.

IV. STUDY 2: CULTURE FACTORS AND USER EXPERIENCE

The purpose of Study 2 is to investigate the impacts of two different feedback models on UE.

A. Participants

40 participants, 20 males and 20 females were involved in this study. Two persons (males) gave invalid responses. Therefore, there were 38 valid responses from participants aged ranging from 20 to 34 years old. Thirty one (31) were undergraduate and postgraduate students from department of industrial design, while four were professionals with education, logistics and engineering. All of them were skilled users of Android and influenced by Chinese culture since childhood.

B. Stimuli

There were three experiments based on tap, press and slide, while included two contrast feedbacks in each group

experiment. The independent variables were different feedback modes: gradient mode and flat mode. Gradient mode was dynamical feedback for integrating with ink–rhyme effect. Flat mode was a kind of feedback that responded directly after users' action.

The dependent variable was UE, which was measured by surface usability questionnaire. In previous studies, surface usability was gained through semantic scale. This method was developed by Hassenzahl in 7 aspects: intelligibility, predictability, clarity, dependability, controllability, familiarity [22]. In fact, emotion was also an important factor that affected UE, such as pleasure, innovation, impression and fun. Taking all of these into account, 11 items would be used to measure.

The dependent variable would be influenced by plenty of other aspects. In this experiment, interfacial elements, interactive action, results of feedback were all the same, to shield the UE differences caused by them. Thus, feedback mode could be regarded as the main reason for perceptive diversity.

C. Material

Materials were three groups including six interfaces designed on independent variables and controlled variables. Each interface corresponded to one feedback mode. Experiments were performed on the same mobile phone, with 4.3 inch IPS screen, which had a resolution of 1280 * 720 pixels, 342 ppi per inch.

D. Task and Procedure

Participants were first made to read an information sheet outlining the aim of the study. By agreeing to participate, a demographic form was filled. The main study was conducted in the second part. In this part, participants needed to enter the Task 1 according to the cue on the interface, tap the number "1" that appeared randomly on the screen. By this time, the background of the number changed from 10% black to 60% black directly. This task was repeated 10 times, in order to deepen the experience of feedback. When Task 1 was finished, participants had to give a ranking score on printed questionnaire for the stimulus they had just felt to its feedback effect. Task 2 was a contrast experiment with Task 1. The only difference between them was the gradient feedback mode with ink-rhyme effect. Task 3 and Task 4 were for "press". The interface background of the former one deepened directly with the confirm button's appear, tapped "OK" to go on the experiment. The latter one inherited from the gradient mode. In sliding experiments, the sequence of "1-2-3-4-5" appeared randomly, which required participants to connect numbers in sequence. Feedback modes of Task 5 and Task 6 were flat and gradient feedback.

In order to exclude the influence caused by position and order, controls and tasks appeared randomly in the experiment.

E. Results

Measure of concentricity and difference tendency were used here to analyze the general level and discrete case dependent variable. Table 5 was the results of the dependent variable descriptive statistics from UE experiment. It revealed that the experience of gradient was significantly higher than flat's for the average level of innovation, excitement, impression, fun had clear differences between different feedback models. In addition, "press" task was showed stronger sense of operation from gradient feedback, which was not familiar with the users yet. Flat feedback of "slide" task seemed not easy to understand. As a whole, the variance of flat feedback being higher than gradient's, indicated that users' understanding of experience of gradient mode tended to be consistent.

TABLE V RESULTS OF DEPENDENT VARIABLE DESCRIPTIVE STATISTICS

Feedback		Easy-understanding	Clean	Clear	Trust	Control	Familiarity	Easy- operating	Innovation	Excitement	Impression	Fun
Tap Flat	M	4.03	4.34	4.13	3.55	3.97	3.63	4.05	2.52	2.26	2.60	2.44
	D	.891	.393	.604	.578	.513	.942	.484	.472	.415	.408	.578
Tap Gradient	M	4.11	4.24	4.00	3.68	3.97	3.53	4.03	3.21	3.05	3.37	3.21
	D	.475	.348	.378	.438	.621	.472	.459	.387	.430	.563	.333
Press Flat	M	3.66	3.37	3.50	3.71	3.16	3.39	2.87	2.87	2.32	3.08	2.50
	D	.909	1.13	.893	.956	.973	.887	.906	.777	.739	.784	.604
Press Gradient	M	3.79	3.61	3.89	3.76	3.68	2.84	3.50	4.13	3.95	4.08	3.87
	D	.843	.887	.863	.751	.775	.823	.797	.529	.567	.587	.529
Slide Flat	M	3.71	3.52	3.53	3.61	3.13	3.59	3.08	2.95	2.84	2.97	2.79
	D	1.08	.905	.797	.840	.874	.791	.831	.700	.515	.459	.711
Slide Gradient	M	4.03	3.74	3.89	3.76	3.50	3.63	3.61	3.76	3.71	3.87	3.74
	D	.459	.632	.475	.402	.635	.347	.786	.294	.427	.388	.415

M stands for Mean; D stands for Variance

Although the 11 items covered nearly all aspects of the UE, they were likely to have ranging overlap. Consequently, principal component analysis was applied to extract factors from three sets of data. Expression of principal component was obtained after rotation of Varimax with Kaiser Normalization, which is a kind of data rotation method. The results were as follows in Table 6. From the table, we can

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know that at the tapping comparative experiments, four pairs of factors (innovation, excitement, impression, fun) had a high degree of positive correlation with Factor_1, which was named emotional factor as it reflected the emotional experience of users. Three pairs of factors (control, easy-operating, clean) were found to have positive impact on Factor 2, which mainly showed the operational experience. Rest of items had significantly higher load on Factor 3, which stood for the subjects' cognitive level. Thus Factor 2 and Factor 3 were named operational factor and cognitive factor. In comparative experiments of press and slide, emotional factor had similar state to experiments of tap, but operational and cognitive factors were not apart, indicating that emotional experience of subject was more obvious than the other two.

TABLE VI EXPRESSION OF PRINCIPAL COMPONENT

Gesture	Component Score Coefficient Expression
Tap	FAC_1=-0.098*tap_1-0.046*tap_2-0.045*tap_3+0.057*tap_4+0.052*tap_5-0.119*tap_6+0.040*tap_7+0.281*tap_8+0.276*tap_9+0.279*tap_10+0.295*tap_11;
	FAC_2=-0.184*tap_1+0.326*tap_2-0.037*tap_3+0.096*tap_4+0.382*tap_5-0.006*tap_6+0.375*tap_7-0.032*tap_8+0.000*tap_9+0.058*tap_10-0.030*tap_11;
	FAC_3=0.652*tap_1-0.001*tap_2+0.487*tap_3+0.230*tap_4-0.142*tap_5+0.©214*tap_6-0.118*tap_7-0.006*tap_8+0.017*tap_9-0.086*tap_10-0.068*tap_11;
Press	FAC_1=0.258*press_1+0.222*press_2+0.216*press_3+0.201*press_4+0.17*press_5+0.21*press_6+0.132*press_7-0.054*press_8-0.054*press_9-0.025*press_10-0.025*press_11
	FAC_2=-0.083*press_1-0.044*press_2-0.002*press_3-0.022*press_4+0.045*press_5-0.18*press_6+0.081*press_7+0.259*press_8+0.268*press_9+0.222*press_10+0.258*press_11
Slide	FAC_1=0.243*slide_1+0.261*slide_2+0.180*slide_3+0.146*slide_4+0.210*slide_5+0.236*slide_6+0.176*slide_7-0.076*slide_8-0.072*slide_9-0.078*slide_10-0.059*slide_11;
	FAC_2=-0.075*slide_1-0.092*slide_2+0.017*slide_3+0.042*slide_4-0.045*slide_5-0.111*slide_6+0.041*slide_7+0.269*slide_8+0.294*slide_9+0.289*slide_10+0.274*slide_11;

Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

Combined with the results of descriptive statistics, emotional experience of gradient mode was clearly stronger than the flat one, namely, users considered gradient feedback more innovative and interesting, to create more passion and leave deeper impression. In contrast with experiment of tap, users thought there was no difference of operational and cognitive experience according to two feedback modes. Compared to experiment of press and slide, users got better cognition, but poorer operational experience of flat feedback than the gradient one. It is believed that the impact on UE of two different feedback modes was mainly focused on emotional experience. The gradient feedback improved UE to some extent, meantime, it increased users' cognitive load, which was primarily caused by unfamiliarity.

V. DISCUSSION

The overall objective of this paper was to investigate the relationships between cultural factors in interactive systems and UE. In review of related work (Section 2), the application of cultural factors in design was considered as deep sense of users' behavior or habits expressed by sensory effect directly or indirectly. In study 2 (Section 4), ink-rhyme effect was applied to mobile interactive feedback model, the results proved that interaction with cultural meaning feedback had an impact on the UE. On the emotional experience, the cultural element had a positive influence, but no significant improvement of operational experience. The application of cultural factors was so creative that it was unfamiliar to users, as a result, it caused some cognitive burden.

UE is a complex sensory, consists of a comprehensive experience, which is highly susceptible to environment, users' emotions and external factors. Emotional experience serves as one of the most important parts of UE; however, traditional human-computer interaction research is still concentrated upon functional usability [23]. With increasing concerns about emotional experience [24][25][26], feedback integrated with cultural elements has been proved to have better emotional experience. All of these offer much food for thought and different choices to designers. Combining cultural factors to interaction will help users to understand their cultural images, significance, stories and emotion [27], as well as usability.

VI. CONCLUSION

In this paper, two studies were used to evaluate the relationships between feedback of cultural meaning and UE. Study 1 helped to extract typical gestures those were familiar to users. Study 2 was the experiment of UE measurement, which made us understand the complex relationships between feedback of cultural meaning and UE.

The results showed that gradient mode had a positive correlation with emotional experience, users thought it more innovative and interesting in creating more passion and leaving deeper impression. Data also suggested that the integration of cultural factors did not affect the operational experience of interaction, but added a certain amount of cognitive load, which primarily caused by unfamiliarity.

The direction of further research will focus on the application of ink-rhyme to practical interactive systems, which will be investigated in more complex interaction processes. We also hope to expand cultural factors to have a method or model to extract the elements from culture.

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The Case for Integrating Needs and Preferences in the Internet of Things

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***Abstract*— This paper was written because the authors believe the Internet of Things has enormous potential to enrich the lives of all people, but particularly those people sometimes referred to as "disabled", who are excluded from participating in normal life processes that present fewer barriers to others and by that exclusion experientially impoverished. Further, we believe that there are grounds for personalization or individualization to be the accessibility delivery mechanism of choice to meet the diverse needs of this non-homogenous group of people in diverse contexts and in fact, of all people. From demographics it is clear that if the accessibility of the Internet of Things is not approached effectively, then a problem will be created for people with disabilities and older people. The paper gives a direction forward driven both by results from practical research with real users and theoretical considerations of what approaches are available to apply to this problem. We believe that Ambient Assisted Living (AAL) is a significant aspect of the Internet of Things.**

Keywords- Internet of Things, Accessibility, Standards

I. INTRODUCTION

A. The Problem to be Addressed

This paper presents an argument for integrating accessibility in the Internet of Things (IoT) in a particular way. It describes and makes the case for an approach to integration and presents some of the requirements that need to be considered.

Accessibility is a huge and very complex domain and it is essential to address it if the Internet of Things is not to impoverish our humanity by excluding many people from its numerous benefits. There is a need to incorporate accessibility in a way that supports its use by everyone and in all environments. We approach the argument first from demographics, and then consider common difficulties in using Information and Communication Technology (ICT) devices in several use cases that demonstrate the complexity of the field. Our central argument is that accessibility is so complex, from computational and human understanding perspectives, that an approach that makes it simpler for everyone is required. We go on to suggest what we believe should be the approach of choice in dealing with the complexity of modern technology in a way that works for all users. We present all of this in a context of evolving models of accessibility and social context.

The Internet of Things is not yet well defined but is a developing field. In one view of and application of IoT, items and computers are labeled with an electronic identifier consisting of a unique number called an IP address. The attachment of the labels supports the development of networking infrastructures where devices can autonomously communicate with one another and share control and communication. The successful implementation of IoT will require:

- An IP address which can be associated with every possible source object that needs one (usually).
- Software applications that can communicate with and manage the data from an ever-growing number of the enabled devices.
- Consideration of requirements for ensuring IoT devices are accessible to all persons needing to directly access them or who are impacted by systems they connect to. We develop this in detail later in the paper.

The networking of devices has the potential to benefit people currently with requirements not well served by the design of mainstream systems and devices to date, especially if the network infrastructures or devices support the use of assistive or alternate technology. Examples might include a medicine cabinet that is continuously aware of the status of each medicine bottle stored inside the cabinet such as its name, contraindications and expiry date. It could communicate the need for replacements to the medical professional as well as to the drinks cabinet to warn of the need to avoid alcohol (if required). Another example is a fall detector linked to both the telephone system to call help, the cooker to switch off any item which the user can no longer control, and the central heating system to ensure the person is kept in a comfortable situation until they are rescued.

Practical research carried out at Middlesex University as part of a European Project has indicated a number of potential problems that occur when users require special features. The accessibility features within current ICT systems are often well hidden, meaning that users requiring those features need greater technical skills than others to reach them. This is impractical and unacceptable and could result in the IoT devices becoming a greater problem.

Many users have particular access requirements that are critical in that they are often unable to access some particular systems at all unless those systems are designed with

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mechanisms to meet those access requirements. Such users are often described as "disabled", which effectively places the cause of the access challenge at their door – it makes it "their fault". This is not the only way to attribute causal factors and the authors particularly reject it in favour of a more balanced view where accessibility is thought of as a relationship between user and product and accessibility challenges represent a mismatch of product characteristics to required features.

For other users the lack of particular access mechanism means that their use of the system is possible but less than optimal. We believe the needs of every user can be best met by the adoption of an equitable system that does not apportion blame but considers accessibility as a relationship and develops systems and products that can be adapted to meet individual preferences. However, the term "disabled" is embedded in our cultures and is difficult to avoid. In this paper, where we present examples and results using the term, we are referring to those users for whom particular accessibility requirements are critical. That does not detract from the thesis that adaptation to individual preferences should be the approach to meet the needs of every user.

B. What is the Internet of Things?

There is no single agreed definition of the Internet of Things; different groups working in the area have different ideas of what it is. A fundamental distinction in the positions organizations take relates to whether the "people" dimension is considered part of the system. For example, The European Telecommunications Standards Institute (ETSI) [1] describe IoT in a "machine to machine" fashion as,

"Communication between two or more entities that do not necessarily need any direct human intervention. M2M services intend to automate decision and communication processes [2].

Whereas the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) [3] gives this description

"A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies [ITU-T Y.2060]" [4], which implies that people need to be considered.

In this paper, we take as a tenet that the IoT involves people at some points. There are several different ways that people might be involved.

- Some systems have direct human interfaces. In any such system, it is necessary to consider the requirements of all potential users in using those interfaces. Methods for consideration of the accessibility of interface technologies have been given much attention, for example in the Web Content Accessibility Guidelines (WCAG) 2.0 [5] and many other sets of guidelines. Technical and other guidelines, such as these, are essential but they are not always used and are not sufficient nor do they provide optimal accessibility [6] for every user.
- Some systems may have no direct human interface but cascading effects on human interfaces in interconnected systems may need to be considered. A burglar alarm monitoring a factory might raise an alert on a system that it is connected to. As well as the need to address the accessibility of any such connected human interfaces there may be implications for the humans using that system of the information content transmitted by the alarm. The High Definition Multimedia Interface (HDMI), which is a standard concerned with the transmission of video data between computer monitors, digital televisions, video projectors and related devices and might be thought of as a machine-to-machine transmission standard not involving humans, was designed without the capability to carry closed captions as required for example by The Federal Communications Commission [7], which alone had a significant impact on a large number of humans and created further difficulties in lack of interoperability between systems adopting mechanisms to get around its limitations.

To meet both these requirements (systems with human interfaces and systems without but which might interconnect with those that do) we will argue that it is needed to look at both the accessibility of the device or system under consideration and the accessibility of possibly interconnected systems with a systemic (holistic) view in a common framework and that taking the tenet that we need to build systems that can respond to and adapt to individual preferences is an approach that can do that. It can provide an approach that can be used in different parts of heterogeneous systems with consistency.

C. Structure of this Paper.

This paper describes how the Internet of Things and personalization can have a greater positive effect for people with disabilities by describing firstly what is the `Internet of Things' and the numbers of older and disabled people who could benefit. In Section II the argument from demographics using a traditional medical model is presented. In Section III the paper focus on real world accessibility issues that people with disabilities can experience with current technology. Section IV then describes the solutions that exist for users with respect to Ambient Assisted Living, in which fine-tuning the match between system design and user needs and preferences can have overwhelming positive effects for the end user. The paper continues in Section V to describe a number of models of accessibility including the medical model of disability, the one or many sizes fit all approach, the approach offered by testing a product with groups of users, usually with disabilities. This section concludes by addressing the issue that the way to optimally meet the needs of every individual consumer is to establish communication between each consumer and producer. The paper concludes in Section VI by stating that in the context of changing demographics across the world there is a need to address accessibility effectively in The Internet of Things if we are not to exclude and impoverish many people.

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II. DEMOGRAPHICS

In this section, we present the argument from demographics using a traditional medical model. This is necessary because it isn't possible to discuss demographics using "the individual" as the basis of approach and because there is so much existing culture and research that addresses it this way. In later sections, we show how the model is flawed as a way to deal with accessibility in the IoT.

The IoT has the potential to benefit many people currently not well-catered for by supporting control of information and communication systems using a personally accessible mechanism. More than one billion people in the world live with some form of disability, of whom nearly 200 million experience considerable difficulties in functioning and carrying out daily living tasks [8]. The increased ageing of the population will lead to an increase in this number and an increase in the number of people with disabilities requiring accessible interfaces. In 2000, there were 606 million persons aged 60 or over throughout the world. Fifty years later, the number of persons aged 60 or over is projected to expand by more than three times to reach nearly 2 billion in 2050 [8]. The International Classification of Functioning, Disability and Health defines disability as, "the ... result of complex relationships between an individual's health condition and personal factors, and of the external factors that represent the circumstances in which the individual lives". [9]. Technology such as Radio-Frequency Identifiers has the power to make people more or less disabled by altering the external factors and enabling people with disabilities to interact with items of technology which have been adapted to interact via a radio frequency interface.

To ensure that older citizens and those with disabilities can benefit from the Internet of Things it is necessary for services to be designed in a way so that they can be used by people with a sensory, cognitive, physical or multiple disabilities. It is also necessary to ensure that the functionality of the objects being controlled meets the needs of the end user. This will require designers to understand the full range of needs both in terms of utility and operational control. Addressing these needs properly would require a drastic change in the mindset of designers so that they consider all people as `normal' customers or as customers of `normal' products.

Establishing an appropriately user-sensitive design culture may be difficult. Recent research with the committee members of the British Standards Institute identified that 33.3% of those questioned said yes to the question "Do any of your standardization activities involve the standardization of products or services where the accessibility for older and disabled people needs to be considered?" Whilst 76.7% had said yes to "Do any of your standardization activities involve the standardization of products or services which are designed to be used by people? This suggests that older citizens and those with disabilities are not a typically recognized subset of the group 'people'. Also, as we explain later, the complexity of people's needs in different contexts is huge. Even without the need for a mindset change it is not realistic to expect designers to absorb and operate with that complexity. Something new is needed.

III. CURRENT REAL WORLD ACCESSIBILITY ISSUES

The integration of digital technology into everyday life has the potential to be of great benefit to older and mobility-limited people and people constrained by cognitive, emotional, social or other constraints by enabling them to carry out a wide range of tasks, including accessing many public services, using entertainment systems and communicating both remotely and locally.

The range of people who can access ICT systems and the contexts in which they can be accessed can both be extended by following accessibility guidelines such as Web Content Accessibility Guidelines (WCAG) 2.0 [5] and other hardware and software standards/guidelines. Such standards will have increased benefit in the design and practical application of the combination of technologies which is the IoT. As we argue elsewhere, however, they have many limitations and challenges.

Accessibility support and information provision on commercial media company websites is often hard to find and highlights an apparent lack of sensitivity to the importance and needs of customers with disabilities [10]. An inspection of three leading providers' sites on the World Wide Web illustrated this well. This inspection focused on the task of finding accessibility information pertaining to the companies' mobile products. It was found in one case that the information was not provided. In the other two sites inspected, the information was deeply buried and difficult to find. On one site a link was provided in a small font that, for example, those with vision problems are likely to miss. On another it was found that no explicit link existed, causing an extensive search, including use of keyword search and a lengthily browse through numerous options. The sub-tasks of scanning for obscure links, scanning large numbers of search results and, in general, protracted search seem to imply the assumption that all users are comfortably capable of these actions. There was no evidence of designers taking into account the difficulties that the typical users of accessibility features are likely to have.

IV. AMBIENT ASSISTED LIVING

The Internet of Things provides unprecedented opportunity to explore the space of possible life-enhancing solutions for specific individuals. However, the complex and varied nature of peoples' cognitive, perceptual and physical condition, and their life circumstances mean that bespoke solutions are needed. The case of Ambient Assisted Living is one where fine-tuning the match between system design and user needs and preferences is particularly critical. This is true both of the service design and of the interaction design. The nature of this type of system is that it is designed to support day-to-day living for a complex variety of user needs and contexts, and needs that are prone to significant changes over time. We identify two key distinct

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levels at which design for individual needs is critical. These are firstly the service level and then the interaction level.

Complexity, asynchronous processes, time dependent behavior, and safety concerns are typical of the design problem for home environments. The definition of AAL we use here assumes different possible distributions of control between the technology, user control and third party control. One of the key elements of design is how control is distributed between these actors. One is the degree of control that a user requires over the technology. Will a person, or a technology controlled by a person procedurally, or controlled by a person declaratively, or by a secondary person, or automatically by technology, or combinations of these fulfill a task? The assessment of an individual's service requirements is partly a question of designing an optimal distribution of tasks. There is a danger that AAL technology may wrest too much control from the individual.

There are also hedonic considerations in design that should be weighted appropriately alongside considerations of functional requirements. Finding the 'optimal' solution for task performance is not simply a matter of considering the efficiency of candidate design solutions, particularly with reference to the distribution of control. For example, it may be quicker to prepare meals if the beneficiary has minimal involvement. However, even a severely restricted individual may prefer to have control over the process. Tasks such as cooking are ones that have an important personal cache, and to simply surrender control to a device would not be acceptable. A further consideration is privacy. Removing control from individuals implies a greater level of ambient monitoring where data is collected from sensors embedded in the domestic environment, and possibly sharing of data with third parties. This may even include video footage.

The 'calm computing' notion originally championed by Weiser (1990) [11] envisions that the environment anticipates and responds to perceived user needs. In this vision, the user is not actively manipulating devices and at times may not even be aware of the complex combination of sensors, processors and actuators around them. This is the philosophy used in 'smart home' prototypes that were designed by Microsoft and others, in which domestic technologies were activated by human movement, environmental change and timing, but not by direct intentional human input. The concern is that such a model for AAL ignores both pragmatic and hedonic requirements of users. As discussed, users desire to have tasks done a certain way or just simply to have control, means that AAL design must be conceived on an individual service level, rather than simply automating processes that the beneficiary may find difficult. It is better to see AAL as a collection of individual services for which the degree of automation relative to direct user control is determined on a case-by-case basis.

At the interaction level, the design of control devices for ambient technologies is critical both to its accessibility and its range of utility. The perceptual and motor skills of potential AAL users vary considerably. This issue is compounded by the fact that older users in particular will be prone to diminishing capacities. Such devices may be embedded in wheelchairs, domestic fittings or individual utilities, presenting a raft of potential design issues for interaction design. Therefore, design needs to allow for customization/personalization both initially and throughout the service lifecycle. Optimization of user controls such as joysticks involves the comfortable efficient and maximally effective control of the device. This may take a radically different solution dependent of the nature of the user's abilities. For example, a user may be best able to manipulate a joystick using their wrist rather than the front of the hand. Another may find that gripping a golf ball attached to the joystick allows greater control. It is important to allow for customizable input in design. The subtleties of input requirements should be researched early in projects, but the user should also be given the chance to 'finish the design'.

A further reason for supporting personalization is that user capacities are likely diminish progressively with age. Usability requirements are therefore subject to change over time. It may be that the requirements for text displays on device controls change several times during the lifetime of a product. Recent work, (e.g., Biswas et al 2011 [12]) has shown that some quite fine differences in perceptual and motor abilities can lead to significantly different requirements for interactive device design. This is particularly critical for AAL, where multiple use devices tend to be embedded in the physical environment.

Some progress has been made on providing for customization in AAL. One example is Casensa [13], a context-aware system that can be installed in houses of elderly to support them in everyday life activities. Users are given the power to create the supportive smart behavior of the house and have control over the activation and deactivation of the smart home facilities. It also allows for critical communication between ambient living devices and caregivers, which is particularly useful in cases where the elderly beneficiary may have diminished abilities, (e.g., dementia sufferers).

V. MODELS OF ACCESSIBILITY FOR THE INTERNET OF THINGS

In this section, we look very briefly at the IoT accessibility requirement from the perspective of some models of accessibility provision. We explain why it is so important to incorporate needs and preferences in IoT network and device architectures and point at some ongoing work in Needs and Preferences and supporting delivery architectures. In fact there are many accessibility models, we describe here only a few and make no attempt to be exhaustive.

A. Accessibility as a Relationship and Changing Models of Disability

Traditionally and historically persons even imagined as having characteristics not conformant with the norm have been separated from society and "blamed" for what has been often seen as "their problem". A full treatment of this and ongoing societal changes would look at perception and complexity, psychological, sociological, philosophical models, organizational theories, history, religion and indeed

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the nature of the universe and all that [14]. Such a treatment is beyond the scope of this paper and we rely here on anecdotal evidence and received historical wisdom of which examples are legion, ranging from the treatment of witches in Middle Age Europe to Eugenics and the treatment of disabled persons by the Third Reich [15]. Here, we merely observe and describe the changes underway.

Over a long period the view of "disability" has shifted and continues to shift, towards a view of accessibility as a relationship between system provider or producer and consumer or user. Approaches to accessibility can be seen as ways to manage that relationship.

1) The Medical Model

The medical model of disability takes the view that a "disabled person" has some characteristic(s) that lead to that person being unable to use some system or product in the fashion that some others can. Hidden behind the "in the fashion that some others can" phrase is often the view "in the way that we designed it and expect it to be used". It is a view of the situation that posits people and behaviors as completely understandable and classifiable. Unfortunately, it fails to capture the richness of human behavior and functioning.

The International Classification of Functioning, Disability and Health [9] is a widely-accepted medical-model approach. This is an extensive complex classification of human functioning that some find difficult to understand and use. The medical model is only a model rather than a true representation of real people. As medical science advances so our understandings of conditions, behaviors and needs are refined and improved. This implies that in practice there is a gap between real needs and the model (otherwise the model would not need to develop and advance). The model isn't the person in the context, it merely predicts something about the functioning or behavior of the person and every model does this imperfectly. This gap between predicted need and actual or experienced need is often crucial in that it prevents delivery of a system from being optimal for every user. In addition, the nature of the model contributes one component of a computational complexity issue described below

2) One or many Sizes Fit All

The Medical Model has some aspects with the flavor of "One Size Fits All" ("this is what you are getting so it works for you") or "Many Sizes Fit All" ("here are a few possibilities, one of them must work for you"). Imagine selecting a suit from a rack of suits for sale and no single suit has a perfect fit and contrast this with a tailor-made suit. The suit from a rack may not fit any person perfectly and for some particular person there may be no size that fits at all. Approaches to accessibility in the "Many Sizes Fit All" camp would include bundling together media modalities in a delivery package, such as captions and Audio Description along with a video or providing multiple ways into a building, some having wheelchair ramps and some having steps only. Clearly "Many Sizes Fit All" is an improvement on "One Size Fits All" and it has been widely used as a model to deliver accessible systems and products. It suffers from a number of limitations:

- It has the same gap between system and user as the medical model because it "guesses" what the user needs.
- On the one side of the relationship we have extremely varied users and contexts. On the other side, we have solutions, which are also extremely varied and also evolve over time, particularly in ICT where we have rapidly changing technology. Bridging between these two has a computational complexity close to exponential. Without some other mechanism we can only solve a limited number of cases with exact solutions. Given the diverse nature of individual needs it may be that not all cases can be solved optimally. That is, its likely that not all users will have a solution that is ideal for them in the context they are in and possible that no user at all will have a solution with a high usability.
- Delivering all potential sizes in one package is unacceptably demanding on delivery systems and packages. In the ICT domain, trying to do so bloats data and uses unnecessary network bandwidth. In the world of supermarket car parks it means making every parking space large enough for families (which might be possible but wastes significant resources) and making each one close enough to the store that nobody has to walk far (which is not possible at all).

3) User Testing and Other Approaches

Space precludes description of all of the models which are employed to manage the accessibility relationship but all of them exist because of the complexity of the problem space and all of them attempt in some way to limit this complexity so as to make the problem solvable. The unfortunate characteristic is that in some way they all also compromise and limit the solutions, e.g., a commonly-used mechanism is that of testing a product with groups of users, usually with disabilities. This is a similar exercise to methods such as think-aloud protocols [16] which are commonly used in mainstream usability testing. The aim of such techniques is to establish generalizable results from a small sample of population. For example, if a mobile device's menu structure is found to be navigable by a sample of 15-20 non-impaired users it is broadly assumed to navigable by a whole population. However, this approach cannot be applied in the same way to a population of users with disabilities. It cannot be "exhaustive" with persons and contexts. Such exercises expose the product to only certain persons and it may not meet any individual's needs optimally. In fact, in many cases making a product meet the needs of one individual in the group may make it fail to meet the needs of another. For example, the needs of some persons for simplified information can conflict with needs associated with some cognitive "disabilities" for information to be presented in multiple forms. Individualization is the only mechanism that can get around this to deliver optimally to every user in every context.

4) Matching to Individual needs and Preferences

An implication of our discussion of models is that the only way to meet the needs of every individual consumer

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optimally is to establish communication between each consumer and producer – anything else will have some element of guesswork about the needs of the particular consumer or some element of putting users in groups in which they may or may not (often not) fit. However, the idea, even with modern social network systems, of having a conversation between producer and every consumer around the use of every product in every context is computationally infeasible. What is needed is some way to manage the relationship that reduces the complexity whilst optimizing the needs of both parties in the communication – consumer and producer. As we mentioned above, in the case of media, it isn't reasonable or economically possible or sensible to deliver every possible alternative media format permutation to every user in every context. But in ICT it is feasible to deliver exactly what that user needs if we can find ways to build automated delivery systems that can do that.

A common way to reduce the complexity of problems involving relationship between two parts is to introduce an intermediate representation. Examples include the PBMPlus Image formats conversion kit [17]. PBMPlus set out to solve the problem of converting any of M image formats to any other of those M formats. At first sight it would appear to require M x (M – 1) convertors (every format to every other format) but by introducing a small number G of general formats and converting via the appropriate intermediate general format the number of required converters is reduced to 2 x M x G. Where M is large and G is small this is a much smaller number of convertors. A similar approach was taken in [18]. The approach would appear to apply to all problems where it is necessary to map one large domain to another, as it is here (an intermediate representation reduces the combinations and "manages" the relationship). It is particularly useful where the operation is expensive (so we keep G small to minimize costs) and whilst ICT solutions that meet the requirements of an individual are often cheap (because ICT is cheap and flexible), identifying those solutions is often expensive, on the scale of the Internet of Things ridiculously so – the world cannot afford to deal with the accessibility requirements of each device, person and context separately. It should be noted also that great care needs to be taken to design the intermediate representation, itself a model, so as not to exclude particular mappings. An intermediate representation between producer and consumer then would reduce the computational complexity of managing the relationship and improve the results quality.

A great deal of work is underway in ICT Accessibility to develop individualization approaches and a common way to do this is based around sets of individual preferences associated with a user and applying in specific contexts. A small sample of that work might include:

- ISO/IEC 24751 Individualized Adaptability and Accessibility in Learning, Education and Training, currently under revision and to be re-titled as Access for All [19, 20, 21].
- IMS Access for All – a family of specifications of personal needs and preferences and matching metadata, latest version is 3.0[22].
- W3C IndieUI (Independent User Interfaces) Indie UI: User Context 1.0 [23].
- Global Public Inclusive Infrastructure (GPII)[24].
- A11yMetadata Project and Schema.org[25].
- Preferences for Global Access [26].
- Document Accessibility Profile [27].

This list is far from exhaustive and there are many technical standards we have not been able to include.

Other groups such as the ISO/IEC Joint Task Advisory group working on Guidelines for incorporating accessibility in standards and ISO/IEC Special Working group on accessibility [28] also consider individualization important enough to incorporate in their roadmaps.

Individualization based around sets of individual preferences provides an intermediate representation between producer and consumer, that being the individual preferences that a user has for that context. There are not yet completely accepted definitions of the words "preference" and "need" and different groups working in the area use them differently, but the general principle is that systems including content and human interface can adapt to a set of individual preferences at or close to delivery time and thus come closer to meeting a individual's needs optimally. There are many ways individual preferences can be used, from static adaptation of interface to fetching matching content or requesting the production of content that matches. Examples and Use Cases for Individualization Using Preferences:

- A video is being delivered with captions. That may be because the user has an expressed preference that auditory content be replaced with or augmented by textual content (for example the user may be deaf or it may be that the environment is noisy).
- A user may have some vision impairment and require that text rendered on a screen is in a large font or alternatively the contrast is enhanced (each achieves a similar result)
- A user may have difficulty using complex instructions and need that instructions are presented in simplified language. Another user might find a simplified interface frustrating and slow to use.
- A user with limited dexterity at some times of day might have a preference to operate a device by voice input at those times and by physical means at other times.
- A security video camera watching a house for movement might be set up so as to send text alerts, or video pictures to a remote location. A homeowner using such a camera might be driving and wish to be alerted to something the camera has detected by an auditory means. Preferences for that context and user (while driving) of auditory-for-visual or auditory-for-textual could trigger the delivery an auditory alert. The preference "textual for visual" might for a different context, say at the theatre, trigger the delivery of a textual (quiet) alert for the same event.

In each of these cases, given appropriate network infrastructure, a system might respond to specific user

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preferences expressed in ways that are machine-readable and system-interpretable. Those preferences might be expressed in terms of required media modality adaptations or substitutions or interface customizations.

Making human interfaces to IoT systems and the messaging and media in those and in connected networks individualizable is likely to improve their accessibility significantly. However, on its own that won't solve the complexity problem. To solve that standardization is needed so that when an interface uses preferences for a particular user and context the same set of preferences is used across devices and contexts. Specific preferences relevant to a device and to a context may be different but some needs remain the same or closely-related. What is to be avoided is "unnecessary difference" in technological detail. We need to find the commonality (of technical and human needs) and build approaches around that.

For example, the need for enhanced visual display we mentioned above might be satisfied on one display by increasing a font size and on another by increasing the contrast and the solution adopted might be determined by the functionalities available on the device itself (consider for example the limited display functionalities of very cheap L.E.D. displays - a ubiquitous-device use case might require these) or by a combination of the display functionalities available and the environmental conditions at the time (say sunlight or shade). The "common preference" in this case would be for enhanced display and adaptation of fonts or contrast would be the solution. There are other solutions to this interaction need, such as delivering a different modality. We might in this case be able to deliver the information in auditory form – if we knew it was consumable – a factor of other user needs (being able perceive auditory content) and the environment (not too noisy to hear for that user and an environment in which sound is acceptable). However, in another case entirely it may be that increased contrast is both the preference and the solution.

There are common interoperability issues here that are often addressed by the development of appropriate standards and indeed many standards are in development to meet that need (some of which are mentioned above) and others are planned. Some specific requirements for IoT systems are developed later in this paper.

B. The Internet of Things

1) Relevance of Individualization

If we accept that the Internet of Things has many places where its necessary to have human interfaces or where there are implications for closely-connected systems and if we accept that people and contexts are so varied that there is a serious complexity issue in making those human interfaces and the information carried accessible then we must accept that building our management of the accessibility relationships in IoT is best done with personalization approaches. Any other way is too computationally expensive. It is far from feasible to expect every device designer to know about and use accessibility guidelines that characterize every "disability" and every human functionality.

An exciting use case and requirement is that of doing individualization not just "in" the heterogeneous networks that will be the backbone of the IoT but across those networks.

- Consider a user requiring screen enhancement on a television screen. It's a strong possibility that the user might require similar enhancement on any display they are using. With individualization integrated in IoT we might for example be able to know on what that user required in similar contexts and to be able to provide it without asking. This is extremely useful in situations where a user is not able to ask for what they require.
- Consider a device that transmits auditory information so a user can listen (perhaps a baby alarm) and a user who requires text-for-auditory in some contexts. It might be that the user has that requirement because the environment is noisy (preventing hearing), or it might be because the user is in a theatre listening to a performance (though not a baby alarm!) and so is unable to wear a listening device or disturb others, or it might be because the user has temporary or permanent hearing impairment. By knowing the context we might be able to infer what the user would require in a different context entirely without user input. Doing this requires architectures in which individualization is integrated with IoT.
- Consider the benefits to a person unable to cope with complexity of being able to approach a cash machine or ATM and be provided with a simplified interface without asking for it.
- Consider the benefits to a blind user travelling on a bus of information concerning the whereabouts of the bus and the next stop being delivered in auditory form directly to a personal device but consumed by sighted people as text.

2) Requirements and Issues for Integrating Preferences in IOT

In order to deliver adaptation to individual needs and preferences across heterogeneous networks to meet the kinds of use case we have described a number of interdependent technical issues need to be approached – some are open questions not yet solved. We list some here along with tentative and even speculatory suggestions for mechanisms, considerations or areas to explore towards solutions:

- Where are individual preferences stored?
    - In the cloud? How can that interoperate across different vendor clouds?
- How can we handle privacy given that in some cases we can deduce information about an individual from their preferences, particularly from multiple contexts? For example, if a user required enhanced visual access across multiple contexts it might suggest they have a visual impairment.

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- Where and how are "solutions" ("this works well in that context") stored and where in IoT architectures can the engines that match solutions to devices live?
- How can we determine whether the design of a device, system, or protocol will have impact for accessibility of systems connected indirectly to it?

Finally, whilst not completely accessibility-related, how can we ensure, particularly in loosely-coupled IoT systems such as those built around RFID [29] that ethical considerations are applied to those systems in which they are embedded.

VI. CONCLUSIONS

This paper has shown that in the context of changing demographics across the world towards more elderly populations there is a need to address accessibility effectively in The Internet of Things if we are not to exclude and impoverish many people. We have argued from practical and from computational complexity and purely theoretical considerations that current widely-used models of accessibility, including "medical models" and "one size fits all" are inadequate to meet the task and even "many sizes fit all" is inadequate alone and that we will need to use a combination of "many sizes fit all" and individualization or personalization to address the problem.

Our conjecture is that combining AAL and personalization in the IoT can in the future enrich the lives of many and that we need to start building infrastructure support for that approach in the heterogeneous networks and devices that will form the IoT.

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Process of Gamification

From The Consideration of Gamification To Its Practical Implementation

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***Abstract*— The trend toward software gamification is increasingly important. But, it often implies the modification of a few simplistic surface elements (colorful aesthetic, personalization, points, badges and leaderboards, etc.) without actually integrating gamification into the overall design. Gamification is often downgraded to interface look and feel and point systems without questioning design practices. This article proposes a design approach focused on gamification. This user-centered approach aims to identify the factors to be taken into account in gamification design (intention, situation, task, users). The authors introduce a design guide consisting of a design process and a toolbox. It aims at facilitating effective gamification design by providing the means to overcome the difficulties encountered with interaction design process.**

Keywords*— *Gamification; design process; user-centred design

I. INTRODUCTION

The human-technology relationship has evolved dramatically in the last 50 years, as the designers develop systems that are not only usable, but also persuasive and funny. Recently, the term gamification appeared, defined by Deterding et al. [1] as "*An informal umbrella term for the use of video game elements in nongaming systems to improve User Experience (UX) and user engagement*" (p.2).

Gamification aims at improving the technology use by applying in non-gaming or professional contexts video game techniques. Very often, these techniques are based on the concepts of motivation, enjoyment, engagement, commitment, attractiveness, emotion, etc., which, once implemented, are expected to improve user and business performance (e.g., Zichermann and Cunningham [2]; Kim [3]). According to Nicholson [4], meaningful gamification "*is the integration of user-centered game design elements into non-game contexts"*.

However, the concepts used are rather vague and unorganized. Indeed, at the beginning, gamification was mostly communicated through what Robert called slideshareatture (live presentation or downloadable slides [5]). Those practices are evolving (e.g., Werback and Hunter [6]; Kumar and Herger [7]) and, following that trend, the objective of this paper is to brainstorm, rationalize and define a general process for gamification design.

After defining gamification in section 2, the authors will present the gamification process in section 3 followed by a toolbox consisting of four elements in section 4. They will introduce gamification core-principles, a context analysis guide and user-centered principles (task support, motivation, attractiveness). These principles are illustrated with definitions, charts and examples. Finally, the authors will offer a decision tree to help determine if gamification can improve a project. They will discuss the quality of this approach by analyzing interface examples that implement gamification elements in section 5. In Section 6, the paper is concluded and future work is described.

II. KEYS CONCEPTS RELATED TO GAMIFICATION

The notion of the gamification loop developed by Liu et al. [8] introduces a design process that consists of a challenge with winning conditions, a point system, a leader board and rewards linked to sub-goal achievements (badges). The authors also mention the modification of the user's social and network status as well as the need for a "game-like" interface.

Several authors have emphasized the importance of going further than this kind of gamification design. For example, Kim [3] explains gamification from a social game designer point of view. She states that adding points, badges and leader boards is not enough to create a game-like experience because they are only feedback elements. Game design is about relying on intrinsic motivation through autonomy, mastery and purpose. She insists that we need to understand the social style of the users and their level of expertise, as well design an engagement loop. She concludes that game elements are to be used according to specific user profiles.

Three more articles can be mentioned for their interesting contribution to the gamification design definition. Werback and Hunter [6] introduce gamification concepts and provide a list of gamification elements (dynamics, mechanics and components). Gamification design is separated into six steps: "Define business objectives; Delineate target behaviors; Describe your players; Devise activity cycles; Don't forget the fun!; Deploy the appropriate tools".

Kumar and Herger [7] call gamification design a "Player Centered Design" that involves five steps: "Know your player; Identify the mission; Understand human motivation; Apply mechanics; Manage, monitor and measure". They define a template Persona, and game mechanics to be used.

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They also insist on the need for ethical and legal considerations.

Finally, Robinson and Bellotti [9] offer a taxonomy defining the gamification elements to be used depending on the level of anticipated user commitment.

As mentioned before, gamification being a quite recent trend, we have tried to analyze it and contribute to the gamification field by developing a design process which can be easily applied by designers, and guide the selection of elements based on the context of use of their system.

III. DESIGN PROCESS FOR GAMIFICATION

A. Method

This process has been designed based on two studies led by in Marache-Francisco and Brangier [10, 11]. It comprises an extensive literature review, which aimed at describing gamification [10], as well as an experiment led on 10 designers [11]; the goal was to identify the dimensions through which gamification design was perceived.

Based on this previous work, we have defined the gamification design process as consisting of two major steps (Figure 1): context analysis and iterative conception. We have also built several tools to guide the designers through gamification processes. We will describe our process and relate it to the literature which has led us to that design.

B. First step : Context Analysis

One concern is that gamification cannot be efficient if it is not designed based on a good understanding of the users and the context of use, as Nicholson [4] pointed out. A context analysis is thus a prerequisite; intentions must be analyzed and considered in the context of the situation, the task, as well as the user(s) profile(s). The toolbox provides a context analysis guide to help the designer during that phase (IV – B). It also provides gamification core principles (IV – A), which are to be considered during all the design phases.

The User Centered Design Field comprises several methods, as described in the ISO/TR 16982 [12], which can be interesting to apply during that first phase of gamification design. For example, observations, interviews, questionnaires, diaries, focus groups or personas. The creation of gamified interfaces should be based on solidly established, real data, which can be collected directly from users, or through indirect sources.

C. Second step : Iterative Conception

The second phase is about the choice of the gamification experience to design for. We select first the elements using the conception grid (IV – C) and the decision tree (IV – D) and then plan the evolution of the interaction. Again, the gamification core principles (IV – A) provide additional elements to consider.

Once this is defined, an iterative conception phase takes place. The concepts are materialized through mockups or prototypes, and tested on representative users until the system proves to be efficient.

IV. TOOLS BOXES FOR GAMIFICATION: INFORMATION TO BE INTEGRATED INTO THE GAMIFICATION DESIGN PROCESS

A. Gamification core principles

The first design tool – the gamification core principles – regulates the conception process. It comprises six principles:

- **Freedom of choice** (Marache-Francisco and Brangier [11])**:** giving the user the freedom to exercise the user's own will, for example being allowed to disable functionalities, or to opt out of the gamified system;
- **Benefits and meaningfulness** (Deterding [13]): The gamification influences must be relevant both to the owners of the system, who expect positive consequences, and to the end users themselves. Otherwise, non-meaningful elements will either have a bad influence on the perception of the system by the end users or be ignored by them;
- **Personalized experience** (Nicholson [4]): Different user profiles can lead to several different designs. This is where the added value of gamification comes from, through tailored triggers;

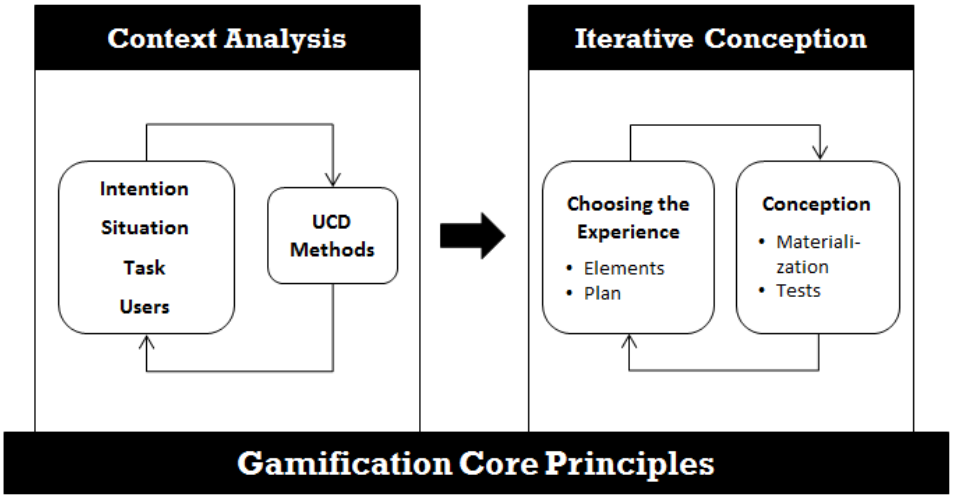

Figure 1: Gamification process principles.

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- **Long-term interaction** (Kim [3]): Designing with the evolution of the interaction in mind, especially concerning the motivational elements;
- **Unwanted secondary effects anticipation**: Unwanted effects can include stress induced by pressures from efficiency requirements (Apter [14]), loss of the feeling of privacy and credibility, gaming the rules of the system, or focus on quantity over quality to obtain some reward (Montola et al. [15]);
- **Legal and ethical matters** (Werbach and Hunter [6]; Kumar and Herger [7]): They take into account the existing legal context, for example, data and privacy, and the interest of the end users.

B. Context Analysis Guide

The second tool indicates factors, which have an impact on the perception and the efficacy of the gamification elements. The guide advises on data collection and analysis.

- **Intent:** (1) Goal (task or motivation-centered); (2) concrete actions targeted. Note: The initial intent evolves based on new parameters arising from the analysis;
- **Situation:** (1) Context (for example, work or leisure); (2) Social Environment; (3) Motivators and Pain points;
- **Task:** (1) Goal; (2) Structure; (3) Other actors involved;
- **User(s):** (1) Characteristics (for example: gender, age); (2) Personality; (3) Culture (e.g., Khaled [16] investigated the differences between individualism vs collectivism); (4) Experience / Competency / Knowledge; (5) Motivators or Pain points.

C. Conception Grid

The conception grid consists of three categories of gamification design elements: task support, motivation and attractiveness.

This has been defined based on a comprehensive literature review [10] combined with an experiment we have led on gamification perception by designers [11]. Indeed, the first classification has been refined based on a better understanding on how to teach gamification to fit at best designers' perception of it.

It is, thus, defined as follow:

- **Task support:** adapting the interaction to a given user with game-like targeted communication (Järvinen [17])] in order to increase his knowledge and abilities;
- **Motivation**: motivating the user through emotional and persuasive elements (accomplishment with self and social challenges and relevant feedbacks; self-expression and relationships mechanisms);
- **Attractiveness**: elements designed to generate positive emotions with an immersive universe, appealing interactions and the use of surprise (e.g., Hohl et al. [18]).

Below is an inventory of the main elements which can be integrated into the gamification proposal. Two display modes are created for this tool: cards summarizing the elements by category (Figure 2) and tables which describe each element and its use (Table 1). We have tried to be as comprehensive as possible when identifying the gamification elements, using the literature mentioned before as well as Antin and Churchill [19], the game mechanics playdeck by Schonfeld [20] and Graf et al. [21].

TABLE 1. CONCEPTION GRID: EXAMPLES OF DESCRIPTIONS

Element	Description
Means Rhetoric	**Definition**: Providing information about how to reach a goal. **Example**: Tips provided during splash screen
Creating / Personalizing	**Definition**: Allowing the user to express his individuality. **Example**: giving to option to personalize one's avatar
Sensory-Motor (Marache-Francisco and Brangier [10])	**Definition**: Elements to communicate and interact with the user. Units (Fox [22]): sound effects, music, verbalization, vibration, shaking, animating the body, colors, images, metaphors, 2D/3D, effects (e.g.,comics, round shapes), minimalistic interface, typography, animation through coding or movement. Composites (Dyck et al. [23]): Heads-Up display (data displayed on the screen to avoid having the user to look away from his focus of attention), Attention aware interface (elements changing their appearance depending on their relevancy for the user at a given moment), Context aware view behavior (dynamic adaptation of the screen with pan and zoom to display a relevant interface), Calm messaging (delivering information on a non-intrusive way without needing an explicit user action), Atmosphere / theme. **Example**: communicating an alert on a battlefield with sound and visual effects to attract the user attention

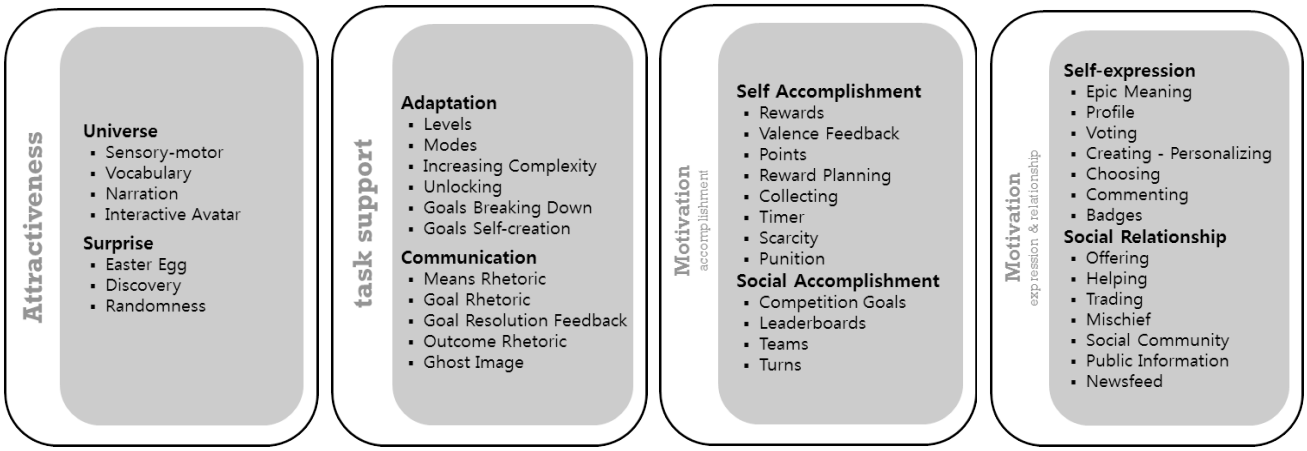

Figure 2: Gamification elements cards

D. Decision tree : When and how is gamification an asset ?

The last tool, i.e., the decision tree, consists of questions which guide the selection of the gamification elements. It offers recommendations of conception choices.

First, the decision tree covers the choice of gamification elements categories to consider based on the design intent. The context analysis will influence this phase (Figure 3). The social engagement loop described by Kim [3] is a good example of a personalized experience definition (a gamification core principle), i.e., that the intent depends on the user profile. The novice users have to learn about the system (knowledge, competency), the regular users need new things to do to keep using the system (engagement), while the enthusiasts need recognition elements, such as exclusive features, to keep being interested (engagement).

Second, the decision tree helps to analyze the task and suggests gamification elements based on its structure, the use and the importance of efficiency within the task's context (Figure 4). The elements will be communicated with the Communication and Universe (sensory-motor) categories.

Third, the tree analyzes the motivation category of gamification elements. It first questions the motivators which will be meaningful for the end users and induce certain elements over others (Figure 5). Those categories can be combined if relevant.

Figures 6 and 7 offer other parameters which help deciding whether to use social elements or not, and which accomplishment elements are relevant.

According to Denny [24], the badges effect might only be observed if the behavior suggested is valuable for the end user. Regarding Accomplishment elements, leaderboards are to be designed with care to avoid demotivating. The end users should be compared with meaningful people and they should not be placed at the bottom of a ranking, but instead between other users (Zichermann and Cunningham [2]).

The motivation elements should be displayed and supported with task support elements and a relevant communication with the Communication and Universe (sensory-motor) categories of gamification element.

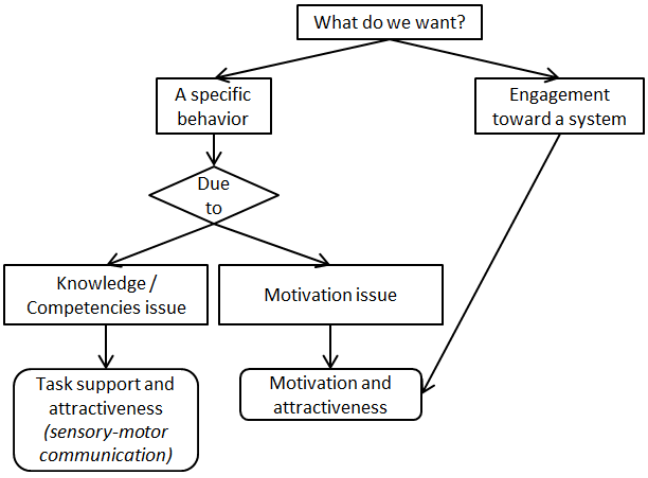

Figure 3: Decision tree: the intent

Concerning Attractiveness, efficiency should be considered. Depending on the context or user profile, we should avoid – or give the possibility to turn off – elements which are not relevant to the task or are out of phase with the system (e.g., narration interfering with the evolution as mentioned by Langer et al. [25], Easter egg). According to Bowser et al. [26], experts prefer a direct interface, while casual users appreciate badges and achievements.

Concerning the Universe sub-dimension of Attractiveness, the metaphor and its scope (punctual or wide-spread) should be chosen depending on the population and the context (e.g., avoiding a childish look and feel for adults systems). Finally, randomness should be used with caution as it can demotivate the end users.

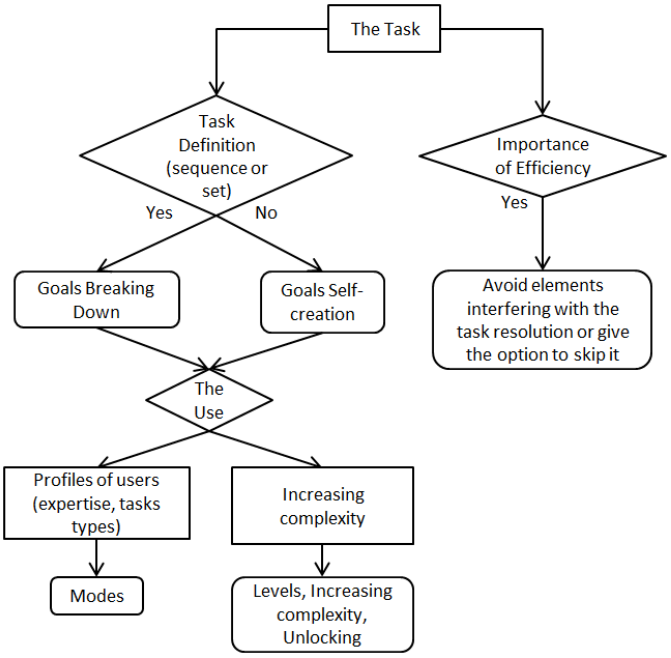

Figure 4: Decision Tree: the task

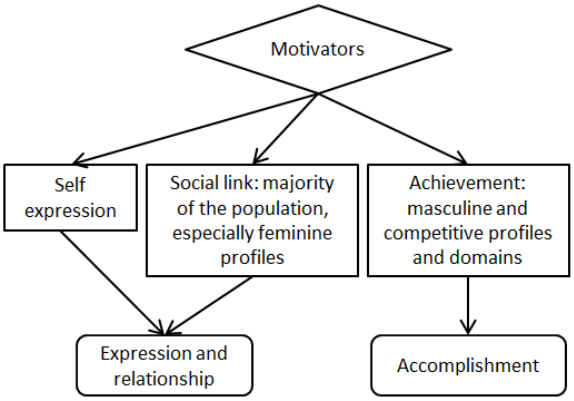

Figure 5: Decision tree: motivators

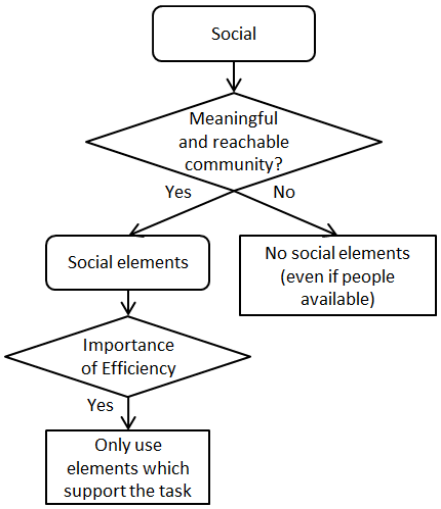

Figure 6: Decision tree: social elements

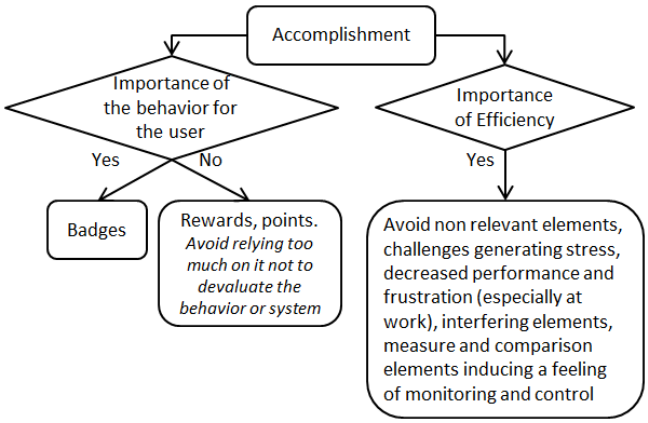

Figure 7: Decision tree: accomplishment elements

Finally, it is important that the core principles of gamification are paralleled with the use of the decision tree, for example:

- Is it meaningful for the end-user?
- Which secondary-effects can be triggered?
- How to prevent it?
- Could it lead to ethical or legal issues?

V. EXAMPLES OF GAMIFIED SYSTEMS

The following use cases illustrate the impact of context on the selection of gamification design elements. It highlights the need and relevancy of a guiding process.

Healthy behaviors are promoted differently in Fitocracy [27] and Blues Buddies (Rao [28]) because of their context of use. Fitoracy aims at motivating people to exercise. They can monitor their progress, be rewarded, share information and tips, be part of relevant groups, and challenge each other. Blues Buddies game uses very different game elements as the end-users are depressed people who cannot be motivated through competition and comparison for obvious psychological reasons. Social relationships and attractiveness are thus used differently.

A community system has been designed by Cheng and Vassileva [29], which aims at connecting students online so that they can share documents and insight about their classes. The reward system is interesting, as it is dynamically designed to shape the users' behaviors. Their goal was, firstly, to motivate them to share information, and, secondly, to motivate them to rate those first elements to limit information overload. Thus, more points are rewarded for sharing at the beginning of the session, while the comments lead to more points after a while.

The WantEat mobile phone application developed by Rapp et al. [30] aimed at motivating people to make the most of a Cheese trade fair. It consisted of missions such as tasting and commenting on cheeses, points, leaderboards and a gift (t-shirt). It is interesting to note that people liked the personal expression part (comments), but were not interested in the other users' comments. We can infer that the social community aspect of that system was not meaningful to them, as it consisted of strangers not related to them.

Finally, LinkedIn [31] as another example is described through the gamification elements categories defined in this document:

- **Task support**: goal information, call-to-action, global task divided into sub-tasks displayed in an attractive list whose evolution is visually displayed;
- **Motivation**: expression and relevance through a public profile, the use of a meaningful social community, a document sharing system, the possibility to join groups, comments and voting;
- **Attractiveness**: the sensory-motor elements are used as the indicators, dialogues are visuals, and there are attractive metaphors, vocabulary, and colors.

Besides, the users are free to dismiss suggested tasks and the elements are relevant depending on the goals of the users.

VI. CONCLUSION AND FUTURE WORK

As seen previously, creating gamified interactions is a particular design work that requires considering recommendations to produce relevant categorizations which offer effective interaction design. An effective gamification process can:

- Guide design and decisions;
- Provide a common representation within a collaborative project;
- Keep designers focused on key-elements;
- Establish functions, needs, desires and goals priorities;
- Focus designers in a single direction and on the aims that are to be achieved;
- Provide simplified, effective and useful descriptions to help understand complex gaming situations;
- Indicate through guide cards the problems related to unclear a gamification proposal;
- Highlight specific characteristics of interactions.

Our gamification process promotes user-centered design, providing the means to overcome the difficulties encountered with interaction design process.

The controversial aspect of the gamification method and tools comes from the fact that scientific studies are rare and experimentation is often impossible. We need more studies

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to understand better how gamification can be successfully applied and to refine our process (e.g., adding factors on the decision tree). We also plan to test this process on a case study in order to demonstrate its usefulness.

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Citizen-centric eGovernment Services

Use of indicators to measure degree of user involvement in eGovernment service development

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***Abstract*—Citizen-centric eGovernment is about user involvement in all stages of the lifecycle of an eGovernment service. The wishes and requirements of the citizens and the administration are not always aligned. User involvement is an important measure to make sure that services become citizen-centric. NET-EUCEN, a EU-supported thematic network on citizen-centric eGovernment, has proposed a framework with a set of indicators to measure user involvement in eGovernment service development and provision. The indicator set is presented and some limitations are discussed.**

Keywords – citizen-centric; user involvment, user participation; eGovernment; NET-EUCEN.

I. INTRODUCTION

Citizen-centric eGovernment is about delivering electronic services focusing on the wishes and requirements of the end-users. In order to capture these requirements, it is important to involve users throughout the whole life cycle of the service. This paper discusses such user involvement and how to measure it using a set of indicators.

User involvement in systems development has been discussed and practiced in the Scandinavian countries since 1975 [1]. Bjørn-Andersen and Hedberg [2] gave the following reasons for involving users in the development of software systems:

- improving the knowledge upon which systems are built,
- enabling people to develop realistic expectations, and reducing resistance to change, and
- increasing workplace democracy by giving the members of an organization the right to participate in decisions that are likely to affect their work.

In a meta-analysis of 25 studies on user engagement, Hwang and Thorn [3] found user involvement beneficial, but the magnitude of the benefits depends on how involvement and its effect are defined.

User involvement is not only important for system development projects. In his book "The Lean Startup", Eric Ries [4] emphasizes the need to learn from customers in order to build products and services that will succeed in the market. He advocates the use of a build-measure-learn feedback loop, where products and services are continuously validated by real customers to find out if they are fulfilling the expectations of the customers or not.

Also, eGovernment researchers have advocated user involvement in development of eGovernment researchers. Richard Heeks [5] remarks: "Of all the stakeholders, the users are those who tend to be most rooted in current system realities, and who best understand when technology-/rationality-driven models will be inappropriate. Giving users a bigger say in systems development can therefore help guard against e-government failure."

In November 2005, the United Kingdom Presidency of the Council of the European Union held a Ministerial eGovernment Conference in Manchester. The ministers approved unanimously a declaration [6], which, among other items said: "During 2006 and 2007, Member States will, through the European Public Administration Network, exchange experiences in developing policies which are inclusive by design, for example, in citizen-centric service delivery or the use of multi-channel architectures".

Blakemore et al. [7] were asked by the European Commission eGovernment Unit to do a 24 months study on citizen-centric eGovernment. The project, called cc:eGov, held a number of workshops and produced a set of "Think papers" to discuss different aspects of citizen-centric eGovernment. The final outcome of the project was a handbook [8]. The study did not emphasize user involvement in the development of services, but were more concerned with transformation of government to be more attentive to the needs and wishes of the citizens.

The European Commission also initiated other projects to explore citizen-centric eGovernment, e.g., "OneStopGov". The project was started in January 2006, and was a thirty six month EU-funded research and development project that aimed at specifying, developing and evaluating a life-event oriented, all-inclusive, integrated, interoperable platform for online one-stop government [9].

User involvement in the whole lifecycle of eGovernment services received focus in 2010, with the establishment of the NET-EUCEN thematic network [13]. One of the activities of this network was to develop a framework for measuring user-centricity at all stages of the service lifecycle. This framework and its indicators will be discussed later.

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II. PERSPECTIVES ON ELECTRONIC GOVERNMENT

Electronic services are, under most circumstances, beneficial for the users. eGovernment services typically includes at least three categories of services:

- Electronic access to government information, where citizens can service themselves (self-service).
- Online transactions with the government through use of electronic forms.
- Access to, and the ability to interact electronically with governmental officials, often through multiple channels (e-mail, chat, SMS).

The two first categories are normally available at all times and from all geographic locations. The last category is limited by the availability of government staff.

eGovernment services can be seen from two different perspectives: the administrative perspective and the citizen perspective. These two perspectives may be in conflict. Verdegem and Hauttekeete [10] argue that eGovernment development suffers from deterministic conceptions, and that, consequently the user seems to be neglected; only minor attention is given to the impact of the electronic service on the customer.

A. Administrative perspective

From the administrative perspective, electronic services can save both time and work for government staff. The City of Copenhagen [11] has calculated the average cost to the municipality for different types of contact with the general public. The cost of a visit by a person is estimated to be close to 10 Euro, while a telephone conversation costs close to 5 Euro. Self-service through Internet costs only 0.40 Euro. These calculations indicate a potential for considerable savings by shifting the contact with the general public to the digital channel, whenever appropriate.

The success of an electronic service can be measured as the ratio between users of the service and the users making personal appearance or telephone calls.

B. Citizen perspective

Citizens want services that are efficient and easy to use. Bertot and Jaeger [12, p. 164] made the following observation: "While users may appreciate the cost savings to agencies for any number of reasons, their primary interest is in their ability to interact with eGovernment services with ease."

For citizens the main objective is to get information, submit forms, or interact with the administration with a minimum of trouble. Neither physical visits to government or municipal offices nor sending ordinary letters are considered efficient.

C. Possible conflicts between the perspectives

In practice, the two perspectives are not necessarily aligned. The following subsections will show some examples for each of the three categories of services mentioned above.

1) Information retrieval

For information retrieval, it is important that citizens can find the information they need. The web site structure must fit the perception of the users, and not the organizational structure of the administration. But, too often, government organization is used as a model for the hierarchical structure of the web site. A citizen may not know what department is handling his or her problem. An alternative solution is to fit the content to current life situation or the intentions of the citizens [9]. If you are a student, you look for certain services related to student loans, housing. etc. If you are a parent, you are more interested in kindergartens and schools, and if you are old, you may want information about care services. Government websites often use words and expressions that are not commonly used by the citizens. A good search mechanism with use of synonyms may help citizens to find what they are looking for.

2) Submission of electronic forms

For the administration, the use of electronic forms may be efficient, especially when the content of the form can be pipelined into back-office systems. But for the user, an electronic form may not be very efficient if the user has to type in information found in paper documents that could otherwise be copied and sent by mail. A user-centric solution would not ask for information the government already possesses. It would also allow the user to save the current work and get back later. If the form has multiple pages, it would allow the user to move back and forth. It would also provide help on how to fill in correct information, and validate this information to make sure that the user does not have to resubmit at later time.

3) Interaction with the government

For the administration, it could be efficient to limit the number of channels for communication. By providing more channels, it is possible to give the citizen options. The possibility to use chat when being in a public place is often preferable to the use of a phone, since chat provides more privacy.

The above cases have shown some examples of misalignment between the administration perspective and the citizen perspective. In order to fit the eGovernment service to the needs of the users, user involvement should be present in the design phase, the development phase, and the assessment phase.

III. NET-EUCEN

NET-EUCEN [13] was a thematic network supported by the European Commission. The network started its activities in April 2010, and the final review meeting was held in May 2013. The network had 23 initial partners, but the network grew to 231 members during the work period.

NET-EUCEN focused on "user-driven services". The involvement of users goes beyond consultations with users or user representation. Users and government staff work together to determine what services to provide and how to provide them. The perspectives, views and skills of the users are complementing the skills of the public service officials.

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As part of the network activities, the network developed a framework to define and measure user-centric services. This framework builds on user involvement in all stages of the service lifecycle.

- User involvement in the design stage. The users are involved in development of ideas and concepts. Focus is on needs and requirements of the users, not technological constraints.
- User involvement in the development and implementation stages. Users are engaged in the initial implementation of the service in order to evaluate its features. Mock-ups and prototypes are used to continuously check that the service is aligned with user wishes and requirements. The aim of the user involvement is to improve the service and to optimize the outcome of the development and implementation.
- User involvement in the deployment and running stages. Users validate the service through testing of flexibility and interoperability. Test results are used to improve and customize service according to changes in political, economic or social environment.

Based on this definition, the network examined case descriptions submitted to the ePractice portal together with cases submitted by network partners. Most of the descriptions on the ePractice portal did not discuss user involvement at all, but case owners were requested to submit additional information. The findings of this study revealed that very few cases were fully aligned with the above definition.

The next step was to construct an indicator set for measuring user-centricity.

IV. INDICATORS FOR CITIZEN-CENTRICITY

One of the aims of the NET-EUCEN network was to construct an indicator set to measure the user involvement in eGovernment projects. The indicator set was developed in workshops with NET-EUCEN partners and invited experts. The resulting indicator set [14] consists of three indicators for user involvement addressing different stages of the lifecycle of the service, and a fourth aggregate indicator to show total user involvement. In most cases, a service is improved during its lifetime through iterations. Figure 1 shows the lifecycle model.

The indicators measure user involvement in the development of a single service only. But, it would be easy to aggregate scores from several services to show how an organizational unit responsible for the services involves users in their portfolio of service development projects

To decide on a set of indicators is not easy, since too many and too complex indicators will make it hard to use, while few and simple indicators may not produce correct measurements. The three first indicators are calculated from a set of binary variables (yes/no answers). The proposed indicator set focuses on user involvement only. The limitations of this rather narrow focus will be discussed later.

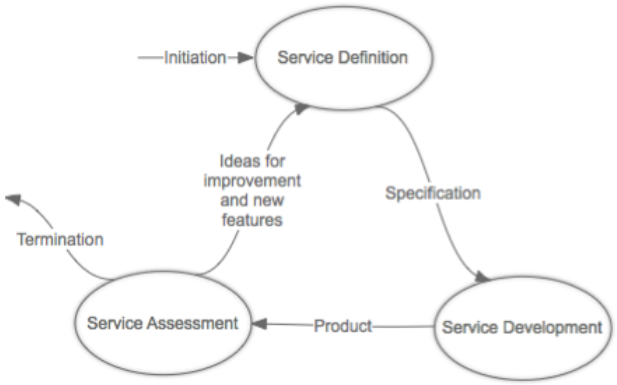

Fig. 1. eGovernment service lifecycle model

A. Indicator 1 - Definition (of the service)

This indicator measures the actual user involvement in the definition of the service.

TABLE 1. VARIABLES FOR INDICATOR 1

Engagement of citizens/users in elicitation of needs	Yes = 0.25 No = 0.00
Involvement of users in the service definition	Yes = 0.25 No = 0.00
Involvement of users in functionalities definition	Yes = 0.25 No = 0.00
Involvement of users in the complete interaction definition	Yes = 0.25 No = 0.00
I1	Max score is 1.0

The first variable is addressing the involvement of users in processes being precursory to creation of lists of actual user needs. Such processes may address how to facilitate user involvement, and what additional user groups include. The second variable is about user involvement in the definition of the service. This is where the list of user needs is developed. The last two variables measure involvement of users in defining the functionality of the service, and the interaction between users and the service.

B. Indicator 2 – Development (of the service)

This indicator measures the involvement of users in the development process.

TABLE 2. VARIABLES FOR INDICATOR 2

Involvement of users/testers in common shared environment	Yes: 0.20 No: 0.00
Involvement of user in interface test and refining	Yes: 0.20 No: 0.00
Involvement of user in functionalities test and refining	Yes: 0.20 No: 0.00
Involvement of user in check of documentation / guidelines	Yes: 0.20 No: 0.00
Involvement of ALL user categories in the tests	Yes: 0.20 No: 0.00
I2	Max score is 1.0

The first variable measures the availability of a common shared environment, where users can share and discuss their opinions related to design issues. The next three variables address user involvement related to different aspects of the

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service itself: user interface, functionality, and documentation. The last variable emphasizes the importance to involve all user groups in the design process, since different user groups may have different perceptions on user interface, functionality and documentation. In such cases, user involvement may be an important driver for individual customization of the final service, e.g., the possibility to turn on additional functionality on demand.

C. Indicator 3 – Assessment (of the service)

This indicator measures the involvement of users in the (continuous) assessment of the service.

TABLE 3. VARIABLES FOR INDICATOR 3

Involvement of ALL user categories in the assessment	Yes: 0.33 No: 0.00
Instrument used gather the users' feedback: phone calls	Yes: 0.0825 No: 0.00
Instrument used gather the users' feedback: web modules	Yes: 0.0825 No: 0.00
Instrument used gather the users' feedback: consultations	Yes: 0.0825 No: 0.00
Instrument used gather the users' feedback: workshops	Yes: 0.0825 No: 0.00
Scope: improvement of the service usability	Yes: 0.165 No: 0.00
Scope: definition of new features	Yes: 0.165 No: 0.00
I3	Max score is 1.0

At this stage, the service is up and running, and used by active users. The involvement of all categories of users counts for one third of the score. It is important to include all categories of users, since they may have different assessments and ideas for improvements. Another one third of the score is allocated to the use of four different instruments for data collection. In order to reach all user categories, it may be necessary to engage users by different means. The last one third of the score focuses on the use of the collected data, if data is used for improvement of the usability and if data is used for defining new features.

D. Indicator 4 – Aggregation of previous indicators

The last indicator is an aggregate of the scores from the three previous indicators. These three indicators are weighted as equal, since user involvement at all stages is considered equally important. This aggregate score is computed as:

$$I4 = I1/3 + I2/3 + I3/3$$

E. User involvement in practice

The indicators do not prescribe specific methods of user involvement. The actual involvement can be done in different ways. Bertot and Jaeger [15] suggest the following range of tools and techniques:

- Focus groups and interviews (with experts and users);
- Usability, functionality, and accessibility testing throughout the design and development process;
- Encouraging real-time comments and suggestions about the services being used;
- Log file and transaction log analysis;
- Providing interactive help screens or telephone assistance; and
- Developing and adhering to measures and standards of service quality.

User involvement may be done on different levels. On the political level user organizations may be involved as representatives for all users, on the system level, some users may speak for the rest, and on the individual level, the user him/herself may be involved in customization of the service.

What methods to use, and which users to involve, will need to be decided for each development project based on the reach (number of users), size and other characteristics.

V. WHAT THE INDICATORS DO NOT MEASURE

The indicators shown in the last section were developed in workshops with network partners and invited experts. The indicators focus on user involvement, and the scores are calculated from a set of binary values (yes/no).

The problem with this "checklist" approach is that it neither quantifies the amount of user involvement, nor the quality of the involvement. The indicators may therefore not reflect the actual benefits received from the user involvement.

User involvement could be quantified by number of users participating and the time spent by the users. However, such quantifications may have limited value, since the optimal involvement will vary from project to project.

Qualitative measures could be efficiency gains as experienced by the users, the usability of the service, the usefulness of the service and such things as availability and accessibility. The users involved would be expected to address such issues, but these aspects themselves are not assessed.

The indicators do not measure the actual depth of user involvement. The involvement can of course be minimal, and the score can still get high.

The initial NET-EUCEN indicator set had some non-binary variables, e.g., percentage of activities that included user involvement, and percentage of user categories involved. During the validation process, these were substituted with binary values, since it was difficult to establish correct values for these variables.

VI. CONCLUSION AND DISCUSSION

The work of the NET-EUCEN network was normative. The network was committed to promote the idea of citizen-centricity through user involvement. The indicator set was one of several measures to draw attention to how users can be involved in lifecycle of eGovernment services. The indicators were chosen to give a high score to those organizations involving users in all stages of the service development.

Citizen-centricity is a mindset. It requires respect for the users as being experts on use. The whole idea of user

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involvement is to listen to, understand and respect the opinions of the users. Collaboration and dialogue, even co-production needs an environment of mutual respect and willingness to see the different perspectives.

User involvement can lead to better services, and even more important, provide an insurance against failures.

A new trend within eGovernment is the movement towards open data. Open data is about giving citizens access to government data through standardized formats and interfaces. Open data brings new opportunities for citizen-centricity. In the future, citizens may develop or orchestrate their own services by interconnecting building blocks with open data sources. The next step for citizen-centric government will then be to provide both data and relevant building blocks. Citizens may then be able to build services themselves.

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