SmartBuilding: a People-to-People-to-Geographical-Places Mobile System based on Augmented Reality

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Abstract— **People-to-People-to-Geographical-Places systems connect places to communities. Generally, these systems require users to perform complex tasks using mobile phones. Thus, the creation of powerful interaction techniques and the design of effective and easy interfaces are key requirements. The system we propose in this paper, named SmartBuilding, is a mobile Augmented Reality system that supports the sharing of contextualized information in indoor environment, depending on the user location. This system shifts the interaction with the user from the classical desktop logical metaphors towards a more natural interaction style based on augmenting and annotating an indoor environment. It combines the world perceived by the phone camera with information concerning the user location and his/her community, enabling users to create several working areas and access to augmented content. SmartBuilding proposes an innovative interface that adopts the mobile device sensors to identify the content to be shown and to control the user interaction. Results on the usability of the proposed approach are positive.**

Augmented Reality; mobile user interfaces; context-awareness; People-to-People-to-Geographical-Places systems.

I. INTRODUCTION

Web 2.0 and social software are changing the way in which millions of users communicate. Users are not only receiver of content, but they contribute to the content creation in a bottom-up way, generating social networks and communities [3].

Changes in the people habits are also due to the great diffusion of mobile devices that enables users to be connected “anytime, anyway”. The adoption of these devices enables also the diffusion of localization technologies. The most adopted is the Global Positioning System (GPS), for outdoor environments, while, in indoors environments recent location sensing systems range from RFID, requiring explicit installation, to standard wireless networking hardware, see [1][9] for example, or Bluetooth tags, suffering of several problems, such as long time for device discovering and passing through walls. More recently, WiFi triangulation and video detection approaches have been proposed.

According to Gartner, one of the ICT enterprise world leader, Location-Based services are at the second place in the first ten more required mobile devices applications in 2012 [7]. Moreover, according to Gartner, the request of this service will strongly increase in the next years. Gartner predicts that Location Based users will increase from 96 millions in 2009 to 526 millions in 2012. This kind of services is second in the top ten list for the high value that they have for users. In fact, they answer to several user necessities, from productivity to social network and entertainment needs.

Several People-to-People-to Geographical-Places systems have been proposed in literature [10], aiming at connecting social networks and communities to physical places. Actually, new powerful devices enable systems to incorporate place and people in new and powerful ways.

Augmented Reality (AR) is a technology that allows computer generated virtual imagery to exactly overlay physical objects in real time [22]. The integration of user localization, AR and of the feature offered by the top-of-the-range devices (on-board camera, accelerometers, compass, GPS etc.) enables the device to combine the camera preview with AR information in real-time. Thus, a mobile device can be seen as a window onto a located 3D information space, enabling “to browse, interact, and manipulate electronic information within the context and situation in which the information originated and where it holds strong meaning” [5]. Following this approach, information can be provided and created considering the context and the user profile. Mobile devices are small, thus researchers have to face the challenge of designing usable interfaces for device screens with limited dimensions and invent new interaction modalities.

In this paper, we propose a system, named SmartBuilding, which follows the metaphor of the “Cooperative Building” proposed in [19], .i.e. room elements with integrated information technology to support formal and informal communication. The approach we propose does not require specific hardware, except the user mobile devices, whose usage is largely diffused, and adopts innovative interfaces, which control the user interaction using the mobile device sensors.

II. RELATED WORKS

Several research projects, such as [4][14][16][19], investigate People-to-People-to-Geographically-Places systems displaying notes and messages [10].

E-graffiti [4] is a context-aware application, which detects the user’s location and displays notes dependent on that location. The application is evaluated and results show that location-specific notes were appealing to users. GeoNotes [16] is a location-based messaging system, which allows users to provide their contents in order to create a social and dynamic information space. It does not allow remote access to notes. All these systems provide a traditional menu-based interface.

Augmented reality has been adopted by the Augmented Reality Post-It (AR Post-It) messaging system, which, similarly to our approach, uses the mobile phone as an augmented reality (AR) interface allowing users to view electronic messages in an AR context [19]. There is the need of a paper marker in each specific location where messages are available, i.e. on the fridge.

Microsoft Research proposed Notescape, a tool that creates a "mixed reality" where virtual sticky notes appear to float in the physical space around the user's body [14]. The notes, using a mobile camera, follow the users as they move from place to place.

An AR interface has been adopted by CAMAR (Context-aware Mobile Augmented Reality), a system enabling users to interact with smart objects through personalized control interfaces on their mobile AR devices [15]. Similarly to our approach, it supports context-based contents augmentation and the sharing of contents among user communities. The main difference with the system we propose is that SmartBuilding does not need additional hardware: we associate the contents to a specific point of the room, while in CAMAR the interaction is limited to particular objects or markers.

The adoption of onboard sensors, like orienteer and accelerometer, to intercept user interaction, enables to implement novel and natural user interfaces. Even if not strictly related to the mobile technology, it is important to underline how Nintendo adopts low cost accelerometers in Wii controllers to enrich user experience and augment game usability. Wii controllers are equipped with onboard sensors and speakers to keep the user gaming experience analogically real. User movements reproduce the real actions and are captured and replicated on the screen, keeping the user involved in the experience; the controller speaker gives the player a better sense of immersion. Recently, mobile phones are providing the same interesting features, sometimes offering a more powerful technological platform: they are capable of detecting orienteering and acceleration and have the computational power to augment the preview obtained by the onboard camera. These devices may shift the user interaction from the classical keypad or button input towards on the phone movement [8]. As an example, Labyrinth Light [12], an Android application, controls a ball on a plane by reading the on board devices sensor. In a more complex way, Google Sky Map projects the user in an AR sky space. The device sensors are used to understand where the user is pointing his/her cellular phone and augments the screen with information about stars and planets.

Adopting the same technology, Layar [13] makes sets of data viewable on top of the camera of the mobile phone as one pans around a city and point at buildings. Layers are equivalent to web-pages in normal browsers. Real estate, banking and restaurant companies have already created layers of information available on the platform. The recent version 3.0 enables also to augment reality with 3D objects.

ARToolKit uses computer vision techniques to calculate the real camera position and orientation relative to marked cards, allowing the programmer to overlay virtual objects onto these cards [1]. Differently, in our approach the marked cards are adopted only to initially localize the user.

III. THE PROPOSED SYSTEM

SmartBuilding aims at augmenting a physical building with spatially localized areas in which users can share formal and informal multimedia documents and messages. The mobile devices are capable of projecting the user in an augmented world of information, controlling the camera interaction with on-board sensors (i.e. accelerometer and orientation). By moving his/her device in the surrounding space the user abandons the 2D desktop metaphor (i.e. folders and icons) and adopts spatial movements for exploring a new information space. The device screen becomes the touchable interface of this world and the user position and his/her profile provide the context.

SmartBuilding offers support for formal and informal communications. Indeed, it is possible to create administration areas, where formal communication is provided, as an example, describing some office procedure. Others information areas can be available for team work, or informal communication can be exchanged among specific user groups. Thus, the system enables each user to distribute his/her augmented content to specific colleagues, supporting selective content sharing and collaboration among people belonging to the same community. Voting and commenting features are also available and support information filtering.

A. The informative space

The device is used as a hand held lens giving a moving view on the AR scene. It is important to point out that the user needs to hold the device and, therefore, his/her maneuverability is quite reduced.

Basing on these observations, we decided to adopt the Azimuth orientation sensor, creating, as a consequence, a 360° space. This space constitutes a cylinder surrounding the user and ideally lays near the walls of his/her room. In our approach, the Azimuth is the main dimension of the augmented reality. The Pitch orientation sensor is adopted combined with the accelerometer, to detect how the camera is orientated in the space vertical dimension. This information enables to provide feedback to user by prospectively deforming the projected objects according to the device spatial orientation and is at the core of the area pagination system later presented.

Each environment of the building is equipped with a "Quick Response" (QR) code [21], having a twofold use: (i) it univocally encodes the room and (ii) it enables to locate the user position in the environment. The environmental setup of the system requires the user to direct the camera towards the QR code by pointing a viewfinder visualized on this/her camera preview. The obtained resolution of the room

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marker enables us to deduct the shooting user-QR distance. In addition, the shooting angle, obtainable by comparing the shut QR side dimensions, allows us to determine more precisely the user position in the room. The devices also communicate the current state of the Wi-Fi signals from the various access points to the central server. Thus, it is possible to deduce each position variation by considering the azimuth variation, by integrating the detected acceleration variation and by interpolating the new Wi-Fi [18] signal, i.e. the strength of each access point carrier, of a user with his/her previous configurations and with those of the others.

B. *The augmented interfaces*

The environmental setup feature and the state variation of the device permit to reconstruct the user position. The augmented reality is corrected respect to the user orientation in the room obtaining the invariance to the user position for the projected objects in such a way that all users are able to find the information connected to the same physical place. This mechanism enables to associate each augmented information stream to a concrete area of the real environment.

As an example, Figure 1 shows a portion of the augmented space of the Software Engineering Lab. The information concerning the location is depicted in the lower left-hand part of Figure 1, while information on the Software School and on the events concerning the lab is depicted on the left and on the right of this figure, respectively. The user can access the information using the interaction styles proposed in the next sub-section. Let us note that in the right-hand lower corner of the screen depicts the position of the augmented areas inside the considered room [11]. This feature can be disabled.

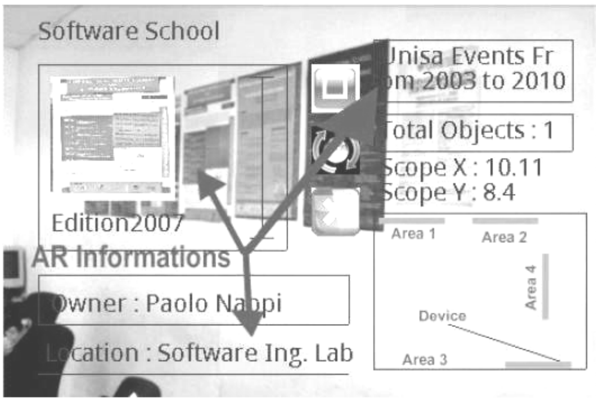

Figure 1. A screenshot of an augmented informative space

The interface in Figure 2 also displays the information concerning the owner of the area. A touch action on this area enacts the displaying of more details on the owner, if the user has the permissions, see Figure 2.

Selecting an icon in the lower part of Figure 2, the user communicates with the owner activating a telephone call or by email, he/she can see the owner web site or, using Google Maps find his/her position on the hearth. This interface allows the user a quick passage from the AR modality to other applications.

Another example of augmented area is shown in Figure 3, where the list of the users working in a given room is associated to their office door, on the external side. Thus, it is possible to verify the user state, if they are or not in the room and to leave them a message that they will receive when they enter their office.

Figure 2. Contact information of an AR area owner

A “Notes” area is available in each room registered with the system. This area represents a communication space related to the room and its occupants, displaying short messages painted directly on screen with fingers and stored as images, named Sticky Notes. Figure 4 depicts this augmented space populated by the users of a room concerning common interest facts. We noticed that the adoption of a paper background for messages provides a more realistic appearance.

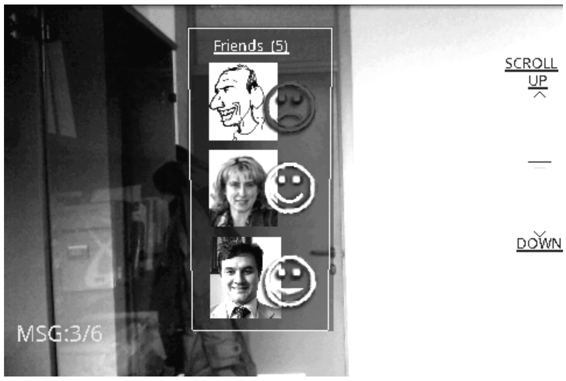

Figure 3. A Room Users’ area

In addition to the “Room Users” and “Notes” areas, the system supports content sharing as follows: users can create areas to share documents with their colleagues, as an example to support group work. Each area can contain several contents: Sticky Notes, Text Notes and any other kind of files (including multimedia content) supported by the devices.

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The creation of a new area is activated through a menu choice: the system exposes to user a viewfinder and a button, to localize the new area position. In addition, during the creation phase, the user is required to provide the area name. When an area is no longer used, its contents can be saved on the supporting web site for further consultation.

C. *The new interaction style*

SmartBuilding offers two different user interaction styles: it is possible to directly manipulate the AR contents or use an indirect interaction style, based on SDK list selection. In the former case, the augmented areas are visually paginated.

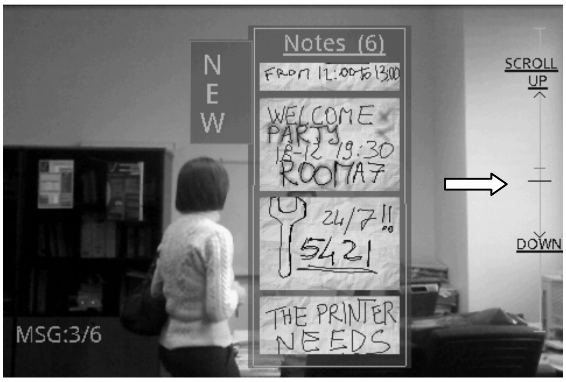

Figure 4. The Notes Area associated to the room white-board.

Because the users' movements are quite reduced when they hold the phone, there was the need of simplifying the user interaction. In particular, when the objects to show in the areas exceed the available size, a pagination mechanism is required. In the right-hand sides of Figures 3 and 4, the proposed pagination control is depicted. It is represented by a vertical segment and by a shorter horizontal segment, indicated by an arrow in Figure 4.

The main characteristic of this mechanism is that a simple gesture enables the user to change the visualized objects: the user can request the objects located in the next page of the selected area by tilting upward his/her device. The symmetrical gesture takes his/her navigation backwards. Exploiting the phone orientation sensor, it is possible to detect the Pitch movements of the device for controlling the pagination system. When the user changes the pitch direction, an analogous movement is induced on the paginated objects. In this way, the user perceives the objects to move according to the inclination given to the device. The area shape is also prospectively deformed according to the phone inclination.

Up and down movements cause the segment to accordingly move. The scrolling mechanism is activated only when the device inclination exceeds the thresholds represented by the "SCROLL UP" and "DOWN" markers.

When a user clicks on an icon, the contextualized action is fired. As an example, in the case of "Notes" and user defined "Document" areas, the click on an object causes the corresponding editing application to be launched. When the user needs to create a new note or document, he/she is required to select a distribution list choosing among the users of the system. The creation of these objects is directly supported at interface level by the button "NEW", as shown in Figure 4 in the case of "Notes".

If the indirect manipulation is preferred, the classical list mechanism, exposed by the Android SDK, is adopted to drive the user action in choosing the objects. When the user touches an area, a scrolling list is presented.

In addition to visual feedback, user involvement in the proposed experience may be enhanced by audio and haptic feedbacks. According to Henrysson et al. [8], we adopt the device speaker and its vibration to add multi sensorial feedbacks to user actions.

IV. EVALUATION

To assess the usability of the proposed system we carried out an evaluation study. In particular, following the traditional approach proposed in [11], we analyzed the user reactions to the functionalities provided by SmartBuilding.

To evaluate a context-aware AR system it is also important to consider that AR representations combine rendered graphics with the real world environment and require a specific type of interaction among virtual artifacts and the real world.

For example, user localization can be difficult if the user moves too fast, and, therefore, the system has problems in showing the appropriate contents in the appropriate location. Thus, we also evaluate the usability of the system following the directions proposed in [6], adapting it to the case of mobile phones.

In the following, we illustrate the techniques used in these evaluation studies and we present the obtained results.

A. *Preparation and User tasks*

After a short introductory session on using the device (mainly focused on menu, back button and SDK menus) and the proposed system, the subjects, provided with the appropriate paper documentation, were required to accomplish the following tasks:

- Task 1 – Users had to leave a text note on the Room Area on a door of the building.
- Task 2 – Users had to read and comment the event information in the Software Engineering lab.
- Task 3 – Collaboration. The subjects were structured in groups; each group owns a virtual area. Each group performs a simple collaborative session in which the group members upload on the Group Wall material concerning a lecture they have taken part (1.5 hour). Each group comments and votes the contribution of their peers of the other groups (1 hour).

At the end of each task, we collected feedback from users about their experience with SmartBuilding by submitting them a task evaluation questionnaire. We followed the template After Scenario Questionnaire (ASQ) proposed by IBM [11]. It consists of three questions aiming at determining user satisfaction concerning the task completion, evaluating their satisfaction regarding the ease of

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completing, the time taken and the support information available during the task. It is designed using a 7-point Likert scale anchored at *1* by Strongly Agree and at *7* by Strongly Disagree.

Once the tasks were accomplished, the participants filled the Computer System Usability Questionnaire (CSUQ) [11] consisting in *19* questions evaluating user overall system usability focused on *3* subscales: System Usefulness, Information Quality and Interface Quality. Also in this case a 7-point Likert scale anchored at *1* by Strongly Agree and at *7* by Strongly Disagree has been adopted, but each answer contains an open “Comment” space to collect deeper details about user impressions.

To integrate the evaluation of mobile augmented characteristics, we added to CSUQ questionnaire the additional questions proposed in [11], concerning the user perception of: System Lag, Image Disparity, Resolution, Rendering Quality, Maneuverability and Environmental Conditions. We also added some specific question tailored on the nature of our system. To evaluate in detail some aspects of the proposed interface, we formulated the following additional questions scored on a Likert scale anchored from *1*, Very good to *7*, Poor:

1. The horizontal movement of augmented objects is …
2. The vertical scrolling control is …
3. The vertical inclination feedback is …
4. The environment lighting affects my performance.

In particular, we added question 4 to investigate if in case of a system mixing on the same screen an environmental preview with synthetic objects, the room lighting may disturb the user sight.

B. Participants

Subjects of the evaluation were eighteen students attending to the fundamentals of Computer Science course of the Environment Evaluation and Control program (University of Salerno).

A user profile questionnaire has been proposed to the participants before the evaluation started. Ten participants have a good experience in the usage of mobile devices and no more than 30% of the sample had good computer skills.

The participants were located in a didactic laboratory.

The system was setup localizing the “Notes” area on the white-board of the laboratory, the “Room” area on the door of the course teacher and three separate group areas have been created in the lab for Task 3.

C. Results

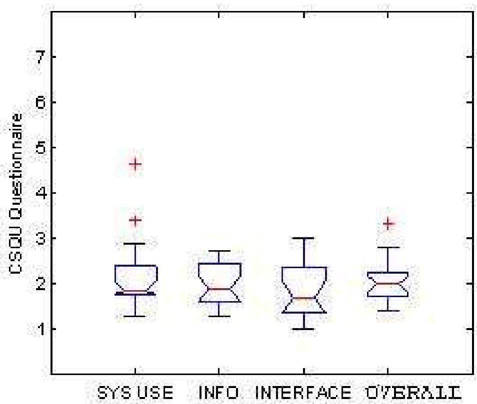
Analyzing the result provided by ASQ questionnaires concerning Task 1 (Avg. score 3.33), Task 2 (Avg. score 3.11) and Task 3 (Avg. 2.66) we noticed a diffused user satisfaction. In particular, subjects preferred Task 3, probably for its collaborative nature.

In general, we noticed that the worst perception about the easiness of completing the tasks has been signaled by less computer skilled users and by less mobile expert ones. We separated the CSUQ questionnaire results from the Augmented Mobile specific ones, since the former is suitable to determine the overall system usability, while the latter provides a specific evaluation of usability aspects concerning the proposed augmented reality interface. Figure 5 reports the CSUQ results aggregated in three categories.

The participants diffusely perceived the system as useful (average of SYS USE was 1.83). Analyzing the single question scores, it was evident that the great part of the subject sample felts confident to be able to accomplish the assigned tasks in an effective, quick and comfortable way. Just two subjects, not particularly technical skilled, expressed negative judgments.

The system is also evaluated in terms of the quality of the information provided and robustness (INFO factor in Figure 5). Also in this case the evaluation is positive. A specific question group of CSUQ questionnaire is devoted to evaluate the interface quality (INTERFACE). In particular, two specific questions required the users to score how the interface is pleasant and how much they liked it. Analyzing the individual answers, we noticed that, also the number of subjects not liking the interface was limited.

The OVERALL usability factor provides the overall system rating and is defined by the full set of items of the three sub-factors. As depicted in Figure 5, this factor reaches a satisfying score of 2.



Legenda:
SYS USE="system usefulness", INFO="information quality", INTERFACE="interface quality", OVERALL="overall usability score"

Figure 5. The CSUQ questionnaire results.

Concerning the Mobile Augmented Questionnaire, we aggregated the various questions proposed in [6] with the four additional ones proposed in Section 4.1, in the three categories described in the Legenda of Figure 6. Also in the case of Mobile Augmented evaluation, the user perception was positive. In particular, best results were obtained by the “GRAPH” category that evaluates the perceived graphical resolution and rendering qualities. Image disparity is a critical factor in augmented reality interfaces. Indeed, if the AR content reproduced on the camera is offset from the real world view, the user can be disoriented. User impressions on the proposed augmented reality interface were good for the most of subjects. The system lag (COMM/NET factor) did not affect the perceived system quality and did not impact on

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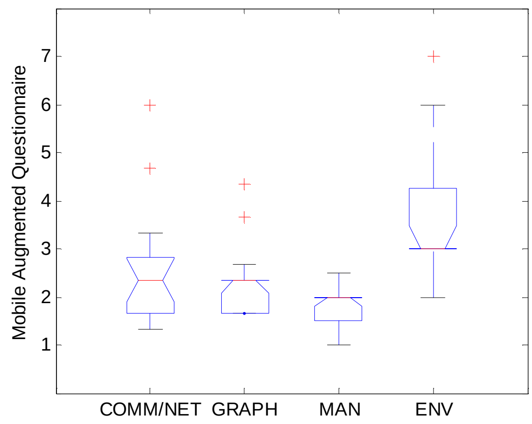
the maneuverability (MAN), which is the movement of the user is not limited to match the augmented information.



Legenda:
COMM/NET="system lag", GRAPH="image disparity, resolution and rendering quality", MAN="maneuverability", ENV="environmental conditions"

Figure 6. The Mobile Augmented questionnaire results

Analyzing the "environmental conditions" questionnaire result category, it was also evident that the system is affected by changes in the environmental lighting. Indeed, we observed that, the proposed interface is suitable for typical working room lighting.

V. CONCLUSION

In this paper, we have presented SmartBuilding, a People-to-People-to-Geographical-Places system aiming at creating an informative space surrounding the user where contents are created and displayed using Augmented Reality interfaces. The SmartBuilding Augmented Reality interface tries to improve the user interaction providing pagination mechanisms based on the device sensors.

The results of the usability evaluation of the proposed system have been positive. The evaluation revealed some problems with the environmental lighting, thus, we are going to develop new interfaces suitable for different lighting conditions (i.e. home working rooms or laboratories). At the present, we are investigating how to adopt the proposed technology to define collaborative methodologies to support work group and learning. Future work will also be devoted to make SmartBuilding, developed only for Android platform, portable on different mobile devices.

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