Bridging Location-based Data with Mobile Practices

Introducing a Framework for Mobile User-Studies

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***Abstract*—Increasingly, mobile services are using location-based information provided by GPS sensors. Especially HCI research deals with a growing interest in how people make sense of location-based information while on the move. Mobile user-studies can help to address this black box and provide the opportunity to combine location-based data with context related content of the mobile practices being performed. In this study, we address this relationship and ask how spatial information should be visualized in order to explore mobile contexts. We conducted a qualitative study to learn about the usage and interpretation forms of spatial information and further translated these findings into a basic framework for mobile user-studies, concluding with an evaluation.**

Keywords-mobile user-studies; location-based services; mobility; user studies; framework.

I. INTRODUCTION

Nowadays, mobile phones accompany most of us every day and everywhere we go. They have opened up new possibilities for the investigation of human behavior [31]. In particular, mobile, intelligent, and GPS-enabled smartphones allow for and demand an integrated view of location-based information and the mobile contexts in which the particular mobile practices are performed [14] [21]. HCI research has is greatly interested in how people make sense of location-based information while on the move. Currently, more and more mobile user-studies are being conducted to answer this question e.g., [11][26]. However, the relationship between spatial information and mobile practices is still underexplored.

In order to shed light on this question, we ask in this paper how spatial information and mobile practices (and their relationship) should be addressed in order to support mobile user-studies in an appropriate manner. The challenge herein is to map the geo-location data (referring to time, longitude and latitude) with the cultural and meaningful dimension of space to inform a framework for mobile user-studies. To do so, we conducted a context study with 19 users who allowed us to track their movements over three weeks. At a later date, we provided them with GPS-based paths of their own movements, which enable them to follow their movements on a map over the time. This alienated mobility data triggered narrations about mobility, i.e. the users were encouraged to report freely about the mobile contexts they identified. These mobility narrations allowed insights into how spatial information was used, referenced and interpreted when reporting on mobile practices. In particular, we discovered three main requirements from the interviews to inform mobile user-studies: (1) the visualization of movements, (2) the visualization of paths and places and (3) the integration of interpretation spaces. We continued by building a framework for mobile user-studies around these identified findings. We then evaluated the framework and concluded with a discussion regarding future enhancements.

II. STATE OF THE ART

In the following, we introduce current tools for mobile user-studies that can be clustered into three groups: (1) *experience-based studies*, (2) *location-based studies*, and (3) *integrated studies*. We will discuss the current approaches with regard to their ability to explore how people use location-based information, and state the necessity for a framework that allows this question to be addressed.

A. User-Studies in the mobile contexts

Fostered by the rapid dissemination of mobile devices and their ever-increasing role in our everyday lives, the field of HCI has yielded new approaches to capture peoples' behavior and actions with regard to location-based data by observing the use of mobile devices.

1) Experience-based studies

Early on (mobile) diary studies [1], as well as the experience sampling method [8] were viewed as appropriate methods for capturing users' behavior directly in a specific situation [17]. Both facilitate user-driven reporting of one's own behavior in mobile contexts. In diary studies, users– based on previous instructions by the researchers – decide when and which information is worth reporting. Forms of voice-based diaries or photo-based diaries [4] as well as combined methods have been designed for specific mobile contexts [9]. In all these studies, the diary entries have to be reported manually [6]. Brandt et al. [2] present variations called snippets, which are short diary notes recorded in specific situations and which allow the users to complete the entry later. These traditional paper-based diary studies include fields for writing down the location of an activity and are comparable to the experience sampling method, the main difference being that in experience sampling, participants are given a signal at a specific time to report details about his/her current situation. One Shortcoming of both diary studies and experience sampling is the effort needed to document the relevant data. Further location-data is not systematically addressed as a basis for interpretation, and as a result users lack proper support to reflect on locations [21][23].

2) Location-based studies

Beside these more qualitative approaches, quantitative logging approaches are being used increasingly to gather detailed information on mobile behavior. Life-logging is one such approach which aims to record user behavior automatically via "the continuous capturing of personal data, such as photos from one's field-of-view, location, audio, biometric signals and others, with the aim of supporting the later recall and reflection on one's life events and experiences" [12]. Data logging in general means that usage data, which would otherwise be very hard and time-consuming to capture, is automatically collected by a device with no user interaction whatsoever [11]. Due to the fact that mobile devices have become highly personalized tools for virtually everyone, they are more or less present and on hand at any time and place [10]. Mobile-data logging therefore represents a significant part of life-logging, allowing users' spatial footprints to be traced. Hence these services do not offer the integration of the user's-perspective.

3) Integrated studies

Further, approaches that combine experience-based studies with automatic data logging are coming increasingly into existence. The current stance of literature is dominated by a space-related understanding of mobility [15]. One characteristic of this research stream is strong sensor orientation which allows mobility patterns, like routines and mobility modes [19] to be discovered, thus enabling mobility systems to be improved [28], or sustainable mobility behavior to be fostered [3][22]. One example is given by driver logbooks that allow drivers to report information about certain journeys [21][24], or Froehlich et al's [11] system that combines the logging of phone data with mobile experience sampling by triggering surveys at specific moments of interest. They show that the acceptance of such a mobile system in everyday life requires both robust performance and non-intrusive data collection. Liu et al. [23] argue that such mixed methods are required to gather appropriate information about users' behavior. A major challenge of this research line is identifying encounters for temporal and spatial mobility patterns [20], and interpreting this data as forms of mobility activities. This can be addressed by using location-based data collected from social media applications (e.g. Foursquare or Twitter) [14], or mixed-method research using questionnaires, surveys or interviews that aim to describe the purpose of the activities, the means of transportation and personal details [5][16]. However, these complex frameworks do not look in detail at how location-based data is actually interpreted by users in particular mobility contexts.

B. *Motivating a framework for mobile user-studies*

We showed that researchers can benefit from the new options to capture, track, simulate, mimic and shadow the many interdependent forms of people's intermittent movement [30]. Hence, we do not move in an empty space but through streets and places. We go home, to work, to a restaurant, visit a friend or the sports club. Often we have a special preference within the selected transport mode, the company we choose for our journeys, types of coordination, or the selected route. In order to focus on such issues, we cannot refer to locations as being stated only objectively. Moreover, we have to ask how users can be supported in interpreting spatial data to re-construct the specific meanings of places that influence our movements and daily mobility [26]. Hence, mobile user-studies should not only take the objective spatial dimension into account but should also support the user in an appropriate manner to reflect on the actual mobility [7][13]. Yet there is very little going on in terms of trying to understand the role of real world context in relation to understanding, building or evaluating interactive mobile user-systems [18][26]. This leads us to the challenge of finding new ways to support people with their mobile phones to not only track spaces, but to allow the users to remember and interpret concrete mobility situations.

III. CONTEXT STUDY

In the following, we introduce the study conducted in order to discover how users make use of and interpret spatial data.

A. *Method*

We conducted an empirical study with 19 users. The user group was selected from a wider project, aimed at assisting elderly people with modern mobility support systems. The initial contact with participants was made through various local organizations for senior citizens. We selected a heterogeneous group of socially active seniors (N=19, 14 female and 5 male), in relation to age (between 57 and 80 years old, and an average of 69 years), local infrastructure (10 in high density areas and 9 in more low density areas), and also in relation to the transport systems typically used. The idea behind this selection was to obtain a wide spectrum of mobility experiences. We worked with the seniors in a participatory design-orientated Living Lab setting [25]. We provided all users with a modern smartphone and guided them in its usage. In regular schooling sessions that took place weekly over a period of about two years, the users improved their technological skills and increased their knowledge of mobile mobility services. Hence, although we were dealing with older adults, at the time of investigation all interviewees were skilled in handling mobility-related application services.

Mobility narrations were conducted in an interview-like manner with each of the 19 users. We asked them to interpret the prepared maps with the outlined GPS tracking data of their movements over the last two weeks. We provided all users with a Google account, which allows us to obtain GPS data produced by the participant's mobile phones in order to track their movements. Mobile behavior was recorded automatically by the Google service *Location History* [32]. During the trial, the participants led their daily lives routinely while the GPS mobile sensor was constantly tracking their outdoor movements. After two weeks of tracking we re-visited each participant and prepared the collected data for presentation. We used both paper-based as well as computer-based representations of the tracked mobility behavior as shown in figure 1. The picture shows the data of one day, as provided by the Google service. The digital version enables users to check the detailed travel times on demand and to zoom the map in and out. These forms of presentation provided information about the spatial movements in units of space and time gained from the mobile GPS sensors. With these representations, we triggered mobility narrations that led us back to elementary travel stories. These stories provided insights into how people read and make sense of their personal location-based data.

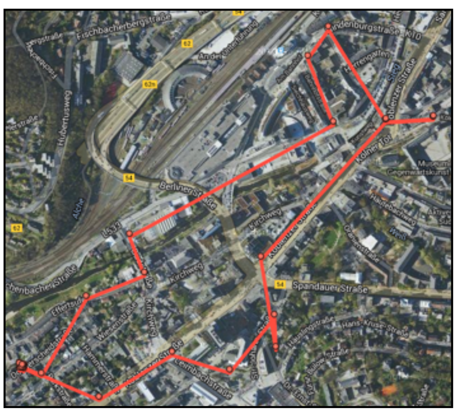

Figure 1. Shows the material provided to the users

Our study was conducted in a region in western Germany which has about 100,000 inhabitants and includes both urban and rural areas. All the workshops took place in participants' homes and lasted between 56 and 153 minutes. Pseudonyms have been used to ensure participants' anonymity and confidentiality.

B. *Identified Elements of locating practices*

In the following we outline the empirical findings from our study. The mobility narrations provide insights into how users align their mobile practices along the presented spatial information of past journeys. Three key elements which especially supported the users were (1) visualization of movements, (2) visualization of paths, and (3) interpretation spaces.

1) *Visualization of movements*

We started by asking users what they could see on the personalized maps lying in front of them. We made sure to ask open questions that leave participants space to explain using their own reference system. We obtained answers like the following example sequence #1:

Sequence #1: [locating mobile contexts]

> *I: So let's take a look at the details on the map.*
>
> *A: Yes, okay. It (the internet page) is just setting up. Goodness, that's amazing! What's this? Whereabouts was I then? Right here! I was in the internet café yesterday. As clear as day! Wow! […]And here. er. here I can see my way to my brother over there.*

In this sequence the maps are addressed as an important tool to help participants remember and identify their own past mobility practices as it is emphasized with expressions of joy: #1: *It (the internet page) is just setting up. Goodness, that's amazing! […] As clear as day! Wow!* Further, the geographic visualizations of their own GPS data was often used for orientation, to identify where the participants had actually been. However, although the users only see spatial references as red-lined GPS marks of their movements, they do not state purely geospatial descriptions. Instead, people refer to their mobile practices as if one could actually *see* them on the map ("*I can see what I have been doing*", or in "*I can see my way to my brother over there*" (#1)). Hence, people literally bridge the geographic data lying before them with their mobile practices. Coincidentally, both dimensions are connected through the narrative elements of "here" or "there" as their locutionary seat. The map with the referenced GPS coordinates was disengaged by the users in an interpretative process that turns geographic space into a meaningful area. Although the spatial character still exists within the indexical reference of the particles "here" and "there", the emphasis lies not on the geography but rather on the mobile practices performed. In other words, mobile contexts are easily identified by the users with the help of the maps and the referenced GPS locations, as the two examples (along with many others) show.

2) *Visualization of paths*

Additionally, it turned out that the visualization especially of paths supports the identification and interpretation of mobile contexts, as illustrated by the following sequences #2- 3:

Sequence #2: [categorizing located contexts]

> *I: Perhaps you could describe what you can see on the map?*
>
> *D: Well, for example, that's where I took the bill to Alfons. In the garden centre. It is only a short walk, I went on foot, because it is right here in the neighborhood.*

Sequence #3: [categorizing located contexts]

E: when I'm mobile I go to the gym, I go shopping, or go swimming with my neighbor, as you can see here below."

In these sequences not only the indexical character of the elements like "here" and "there" are addressed, but rather its deontic character that refers to a particular mobile practice. In sequence #2 it is paying a bill in a shop in the neighborhood, or in sequence #3 it is going home. Ascribing content to locations in this way is different from simply naming streets or areas of the city as it connects familiar meanings to the paths shown. In the excerpts, users refer explicit to these paths as "making sense". Within these ensembles, users are able to inscribe particular knowledge to the "geometrical" or the "geographical" space which makes it meaningful and socially readable. Thus, the paths drawn on the map work as preconditions to transform users' mobility practices into a legible form along the path that can be identified and described easily.

3) *Integration of interpretation spaces*

Further, in the course of the interviews it transpired that users locate their mobile practices within particular paths and places, as illustrated in the following sequence #6:

Sequence #4: [reading located contexts]

C: So I'm only here. From my place, I drove into Ludwig Street first.. This is Ludwig Street here. Then I went back and forth a bit, picked a friend up then went up [name of a village] to Berleburger Street and picked up another friend. And then we went to Giersberg (= area) to play cards here.

The user point out a "tour" of paths as a series of units (*Ludwig Street first, to. […]to Berleburger Street and […]to Giersberg (= area)".* Although the drawings on the map outline not the "route" (there isn't one) but the "log" of peoples' journeys – users interpret the outlined marks as footprints of the successive events that took place in the course of the journey. In sequence #4 the speaker refers to an event which happened at a particular place. Within the stated mobility context of *playing cards* the related mobility practices are expressed within certain preferences. Hence, although we are dealing with an objective tool – the map - the reference to this tool is quite selective and subjectively motivated according to the stated mobility practice of playing cards. Therefore, the conducted mobility is stated in a particular manner, namely as a regular activity that is shared with friends. If the user had talked about the workplace or the home, these descriptions would probably have been different. We can imagine for example that the way-finding would be much more straightforward without picking up friends, or would rely on using public transport. Hence, the map is not used in order to reconstruct the prior paths and visited places but to reconstruct particular activities and events from mobile practices that can be located or related to paths and places. We could further observe that users start to annotate the maps, what identifies paths and places as useful units providing users with spaces in which to describe and exaggerate their journeys.

IV. CONCEPTIONAL FRAMING

The three identified elements of (1) visualization of movements, (2) visualization of paths and places, and (3) integration of interpretation spaces turned out to be basic needs, necessary to make use of and interpret spatial information. The study especially reveals that designers should provide users' starting points to empower them to make sense of geo-location data. We found out that designers need to understand how users refer to their performed mobility and provide an appropriate basis for the interpretation of mobile contexts.

This motivates the creation of a framework for mobile user-studies that empowers users to actively make sense of the mobile practices they performed. Hence, we identified the following issues that go along with the three findings:

(1) "Visualization of movements" refers to the need to collect spatial movements in situ.

(2) "Visualization of paths and places" can be translated as the users' need to be supported in identifying journeys places within performed trips.

(3) "Integration of interpretation spaces" refers to the need to allow users' annotations on the performed trips.

TABLE I. IDENTIFIED ISSUES, DESIGN CHALLENGE AND TECHNICAL IMPLICATIONS

No.	Identified Issue	Design Challenge	Technical Implications
1	Visualizing GPS/ time data on a map	Collecting spatial movements in situ	Users' mobile phones need to continuously log position and time
2	Visualizing the GPS/ time data as paths	Identifying trips and destinations as the points of beginning and ending a performed activity	Based on available sensorial data the system needs to be able to determine the start and end of trips
3	Integration of interpretation spaces	Collecting information within the performed journeys and places	Based on the recorded trips the system needs to provide features to annotate trips and to select context information

V. A FRAMEWORK FOR MOBILE USER-STUDIES

In the following, we introduce in more detail how the identified requirements are translated into a framework for mobile user-studies. This framework allows studying in rich detail how users make use of and identify mobile contexts while on the move.

A. Addressing the challenge to locate mobile contexts

Collecting spatial movements in situ requires location data from the phones' sensors to be acquired. GPS immediately comes to mind as the most important sensor, but other sensors like wifi or Bluetooth signals can also be used to determine a users' location. In order to identify trips and destinations, it is necessary to analyze this data. In long-term studies, large amounts of location data are gathered which leads to high demands of computational power to process this data. E.g. we tested processing 1000 locations on a modern smartphone with clustering algorithms like DBSCAN. The computation of clusters took about 10 seconds. Yet for in-situ recognition of places and routes, such approaches are not suitable for processing a complete data set.

Thus these calculations need to be repeated at very short intervals to ensure in-situ recognition of trips. Further, the intensive workload on the devices would make them unusable due to battery drainage. Moreover, combining the GPS data with other sensor inputs like wifi or Bluetooth signals is problematic when using this approach. Thus we decided to gather location data and process the incoming stream according to predefined rules. This approach allows the researcher to define under which circumstances data should be stored and/or can be shown to users to ask for qualitative input like collecting information about a trip or destination.

We used a complex event processing approach (CEP) to implement a rule system on the client side. This has several advantages compared to performing statistical analysis of the collected location data. Firstly, using a CEP Engine (CEPE) allows the data to be processed stream-based. Thus only relevant, incoming location data is processed. The CEPE automatically filters relevant data (e.g. locations that were received within a given timeframe) based on the rules that were defined previously using a special event pattern language (EPL). Secondly, these rules can be (de-) activated or swapped easily without modifying the code of the application itself. Using CEPE on the mobile client allows on-the-fly modifications of data collection (e.g. triggering a questionnaire when a user leaves a spot that has been identified as relevant during the running study).

In our case, we used the Esper complex event-processing engine. Esper is an open source CEPE that has been ported to Android and is only about 6MB in size. Further we used the Funf framework to capture sensor data from more than 15 sources including location, wifi and running apps. This data is then sent to Esper. The patterns, which have been defined on the server, are downloaded via a REST API as soon as they are available. This API provides a JSON file, containing the EPL and the id numbers of the actions it should trigger, which in our case are surveys initially linked to particular places. To create such EPL patterns, knowledge of EPL syntax is required. To eliminate this necessity and to enable researchers without technical training to define EPL rules that allow for categorization locations, we created a graphical editor that is described in the following section.

B. Graphic rule definition to support categorization

As pointed out earlier, one of the main challenges is the collection of spatial information, and to react to this data e.g. by running questionnaires based on the user's mobility. Thus we developed a web-based editor that is based on the EPL and allows researchers to define events using a graphical user interface (GUI). The editor (Fig. 2) ensures that researchers formally define the situations which are relevant for the study in order to make them unambiguously recognizable by mobile devices equipped with the appropriate sensors.

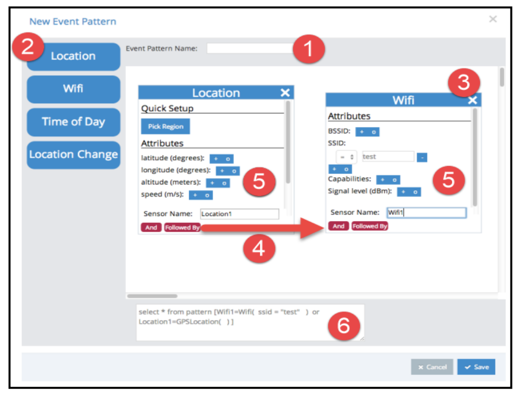

Figure 2. Web Based Editor for Event-Definition

This example shows how researchers can create event patterns that support the categorization of the participants' devices. Firstly (1) researchers name the patterns they are going to create. From the list of sensors (2) they can drag and drop different location-related sensor events to the canvas (3). The available sensor events are:

Location: Probably the most basic sensor event for location detection. This event will be triggered every time the device receives a location. This can also be specified in more detail by providing bounding areas of relevant locations (e.g. specifying that a questionnaire should be triggered when users are at a specific location, e.g. at university).

Time of Day: Basic sensor event to define a time. This event can be used to define rules that should only be matched at a given time of day (e.g. specifying that a questionnaire should be triggered at 3 PM on a Wednesday).

Location Change: This event detects a change of the geographic location without the need to specify a concrete GPS position. The researcher needs only to provide a time span and a distance. If there are location measurements in this time span that are further apart than the provided distance, the event is triggered.

Wifi: This can be used to determine if a user is connected to specified (or indeed any) wifi. This sensor can be helpful to detect if users are in a specific building (e.g.

triggering a questionnaire when users connect to their home wifi).

Further, the framework allows these sensor events to be connected through “AND”, “OR” or “Followed-by” connections. Per default, events are connected by “OR”; “Followed-by” and “`AND” connections are established by dragging lines between the events.

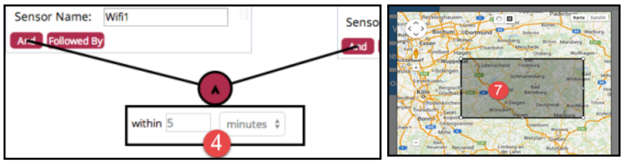

Figure 3. Left: Connecting two events - Right: Setting location attributes using “quick setup”

“AND”-connections imply that the criteria for the event is fulfilled simultaneously, e.g. the participant is at the specified location and connected to the specified wifi. “OR”-connections imply that one of the specified events has happened, e.g. the participant is connected to the specified wifi but is not at the specified location (or vice versa). “Followed-By”-connections refer to a sequential order, e.g. the participant happened to be at the specified location but left and connected to the specified wifi afterwards. For “AND” and “Followed-By” connections researchers can specify a timeframe for the occurrence of the involved sensor events (see (4) in fig. 3). For each of the sensor events, attributes can be determined (5) to further specify events. E.g., using the attribute SSID for wifi-events implies that events will only be triggered when the participants connect to a specific wifi network. It also demonstrates the “quick setup” of the location sensor to define attributes based on a selected geo region (7). The output of the event orchestration is shown below the canvas in fig. 3 (6). Here the generated EPL-snippet is shown. The snippet and the canvas are synchronized, thus any changes in one will be reflected in the other representation. These event pattern can be connected to actions (in our case triggering questionaires) that are executed when the event occurs. These EPL-snippets are pushed to the mobile devices along with their corresponding action. Principally this enables the researcher to specifiy or adapt his definition easily and to push it to the participants' devices immediately without changing any source code or adjusting settings.

C. Interface design to support the analysis of location data

After a survey has been started and data has been received from the users, researchers have to be able to view and analyze the collected qualitative and quantitative data. To enable this, we built a web-based route viewer (see Fig. 4), which allows researchers to inspect the routes, the participants’ names for those routes, and the respective surveys. This enables researchers to comprehend the participant’s thoughts on those routes, as participants name locations according to what they mean to them personally. The locations are managed in the route viewer. The route viewer provides a list of participants as shown on the lower left. If a participant is selected, all routes for this participant are listed to the right with the name designated by the participant. If a participant gives the same name to several routes, these routes are grouped together, thus facilitating the categorization of locations.

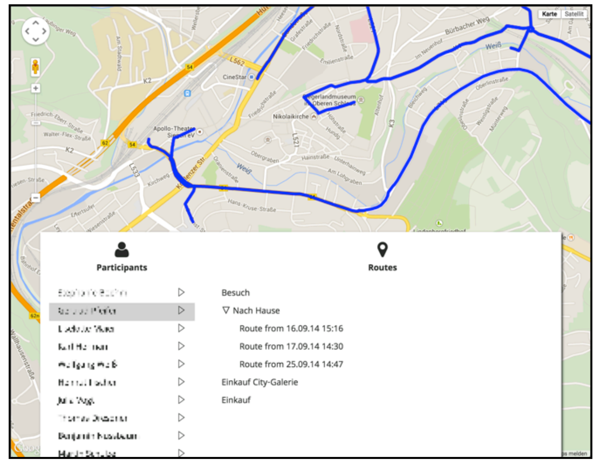

Figure 4. Web based route viewer

VI. EVALUATION

In order to evaluate the framework, we first conducted a test to check the its functionality by defining different events and testing whether the respective action is triggered. Secondly, we tested the web frontend with researchers to find out whether the identified issues were included properly.

A. Technical evaluation

Within the technical evaluation we equipped four students with mobile devices and pre-installed our framework. After this we defined several event patterns in the backend system. The first pattern was expected to trigger when the students were on campus. At first, we did not take into consideration that this event would be triggered each time a new location measurement is added to the CEPE. This resulted in two cases of students being prompted to fill out the same survey several times while they were present at the university. This was fixed by changing the event pattern definition slightly, so that it only triggers once a day. Next we defined a more complex event, intended to trigger when the student's phone detects a certain wi-fi network and switches on the screen of his phone. This was used as a way to detect precise in-door locations. This enabled us to define a survey which was triggered when the student was in the proximity of our offices and using the mobile phone. The problem with this approach was that the survey notification was triggered directly after the screen was turned on - a time when users usually want to accomplish a certain task. It would be possible to add a pause time after the event triggers in the CEPE, but our visual editor has not supported this feature yet.

B. Content evaluation

We further conducted a first content-orientated evaluation with five researchers from the field of information science and mobile media studies. Having introduced them to the framework, we let them use the described functions and conducted an interview afterwards that lasted about 30 minutes on average.

The participants confirmed that: (1) the implemented framework collects spatial movements in situ and visualizes them on a map; (2) Visualization of paths and places helps to identify journeys and important places; Further, (3) the participants used the annotation feature within the journeys performed in order to provide more detailed information about the trips conducted.

The five participants did however also name some critical issues: (1) Three of the users stated they would appreciate the option to annotate routes later, without the need to do it while being on the move. Participants pointed out that situations could potentially arise when one is pressed for time and therefore it would be more convenient to categorize trips later; (2) Further, we gathered initial insights into preferences concerning how to visualize trips on the map in order to support users in remembering and interpreting their mobile practices. Most of the participants strongly recommended visualizing single trips instead of cumulated routes. The clustering of trips where are annotated with the same categories was recommended; (3) Finally, participants stated that a time line is important for them, to help remember particular trips better. Two of the researchers stated their wish to view trips in a chronological order and to view trips of selective categories on the same timeline.

VII. Discussion and Concluding Remarks

In this paper, we argued in favor of mobile user-studies as a great approach to foster our understanding of mobile behavior. However, current services mostly address spatial information as fixed and restricted to longitude and latitude. We showed that location-based information is highly interwoven into sense-making processes and mobile routines. Therefore, mobile user-studies are needed to provide answers to how people actually use and interpret their performed mobility while actually being on the move.
In order to inform the design for a framework of mobile user-studies, we started with a context study to discover ways in which users make sense of spatial information in daily mobility. We especially gained insight about three requirements that were translated for building the framework: (1) visualization of movements, (2) visualization of paths and places, and (3) integration of interpretation spaces.

The evaluation showed major research issues for the future. The organization of trips was particularly stated to be a major issue. A future version should therefore be designed so as to assign collected content information within performed trips on maps that can be seen by both researchers and users. Moreover, the route viewer and the questionnaire editor are implemented as two separate applications. Currently, questionnaire data cannot be shown in the route viewer although it has the same access to the API. Hence in future we plan to integrate those two applications seamlessly.

The framework is openly and flexibly designed to allow researchers manifold options of collecting data on the move. Our challenge in the future is to find appropriate ways of integrating and making use of empirical data like questionnaires, open questions, photos etc. that can be selected in connection with a particular trip. Hence we have laid the basic groundwork that allows how people actually interpret their performed mobility to be studied, as well as making use of location-based information while on the move. But to answer this question in more detail, our second step has to be to build a graphic editor that visualizes what the framework can already achieve (by using the event pattern language): the integration of routes with user-interaction mechanisms.

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