HotCity: Enhancing Ubiquitous Maps with Social Context Heatmaps

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ABSTRACT
In this paper we present HotCity, a service that demonstrates how collecting and mining the interactions that users make with the urban environment through social networks, can help tourists better plan activities, through sharing the collectively generated social context of a smart, connected city, as a background layer to mapped POI. The data for our service stems from the collection and analysis of 1-month worth of collected human-physical environment interactions (*i.e.,* Foursquare check-ins) data for Oulu, a medium-sized city in Finland, where our service is deployed in ubiquitous public displays. Our analysis demonstrates that a good model of the city's dynamics can be built despite the low popularity of Foursquare amongst locals. Our findings from the field-based trial of the HotCity service yield several useful insights and important contributions. We found that the method of using a heatmap as an intermediate layer of environmental context does not negatively affect the experience of users at the cognitive level, compared with a more traditional map and POI type of interface, where temporal aspects of context are not present. In the concluding sections, we discuss how this cloud-based service can also be used in a variety of ubiquitous computing platforms.

Categories and Subject Descriptors
H.5.1 [Information Interfaces and Presentation (e.g., HCI)]: Multimedia Information Systems- *Hypertext navigation and maps*

General Terms
Design, Experimentation, Human Factors

Keywords
Ubiquitous maps, heatmap visualization, social context

1. INTRODUCTION
The concept of *venues* in social networks has become popular with social networks based exclusively on them (*e.g.*, Foursquare), actively used by several million users. Other networks (*e.g.*, Facebook or Google+) integrate more formal venue representations with their existing structure. These representations allow users to explore venues, but do not allow content tagging (*e.g.*, checking into them). A large volume of human-physical interaction data is being generated daily from location-aware social networks. Research by Lindqvist *et al.*[18] demonstrates that this data is generated not randomly but under a very specific context, as users will only generate such data for venues they consider important, interesting or indicative of a social identity and lifestyle choice. Access to this data opens up significant new opportunities for the provision of informed services to a range of interested parties, particularly to tourism services.

When visiting a city, tourists traditionally seek information by looking at the city map, reading a guidebook, or visiting a tourism office. Although useful to display cartographical information effectively, such city maps lack *citizen-generated information*. By citizen-generated information, we mean, "Which are favorite restaurants?" "Where to find best prices?" To overcome such limitation, a new category of city guidebooks emerged in recent years, dubbed "personalized guides," which are often written by previous city visitors, locals, and can even be algorithmically manufactured by counting visits to tourist points of interest (POI's)[23].

Although useful, these providers aim at the general public and are not tailored to the individual visitors' needs, tastes or interests. Focusing on mobile phones, Chevrest et al.'s [5] GUIDE mobile applications offered a digital version of a city guide. Contrary to a tourism office, and more similar to the city maps and guides, a mobile device can be carried around while visiting a city. However, up to date information is only available at the expense of a working Internet connection on the device, which is often not the case while traveling.

In the real sense of an explorer, a visitor might not carry devices or guides ambulating across a city [13]. In this case, public information displays across a city can be used to provide information captured from several sources [10, 16]. Early research on public displays was mostly conducted on single-purpose bespoke public displays, for example Plasma Posters [6] or GroupCast [17]. Recent advances in public display technology have enabled increasing numbers of displays to be deployed and installed in public locations. These deployments are increasingly making a transition from static "broadcast" displays to interactive ones. This transition to interactive displays, where members of the public are empowered to control and use the display, has opened a range of new research challenges and at the same time has broadened the design space for public displays. Whereas on "broadcast" displays the primary challenge is designing for the effective sharing of information with the public, interactive displays' main design requirement is that of interaction: designing and implementing a mechanism for members of the public to browse, navigate and identify information that the display makes available.

Therefore, in this paper we created an exploratory infrastructure for sharing geo-fenced high-level and user subjective place information that is harvested from local's social networks (*e.g.*, Foursquare), by means of a map *mashup* that highlights mobility traces and "heatmaps," all accessible through a public display deployment. Our main hypothesis was thus that a "heatmap" visualization of social context, added as a middle layer between a spatial background (*i.e.*, street map) and point of interest overlays, would not negatively impact the cognitive load during information seeking tasks.

2. RELATED WORK

Context-aware mobile recommender systems, such as Magitti [2], infer the user activity and displays suggestions for related activities. Various sensing methods have been used to capture urban movement across a city, including geo-tagged photos, mobile phone logs, smart card records, taxi/bus GPS traces, and Bluetooth sensing [3, 9, 11, 15, 20]. These demonstrate that it is possible to develop a better understanding of city-dwellers' space use over time, and subsequently inform important decisions about development, growth, and investment across a city. In other words, understanding how various groups of people move in a particular area, and when, provides better context for understanding the types of potential audiences for services in those areas, but also in terms of long-term investment and development decisions [20].

However, to achieve higher granularity, researchers are increasingly turning to alternative datasets. Analysis of user-generated content is becoming increasingly popular, for example using geo-tagged photos to extract "place" and "event" information [21] from Flickr. This approach was adopted by one of the first attempts at identifying tourists and visitors in a city [9] by analyzing geo-tagged photographs from a 3-year period, focused on identifying locations visited by individuals exhibiting short and focused activity in terms of photographs taken.

Other related work [4, 12] has used granular Wi-Fi data, but so far limited to campus scale. Often, mobility analysis attempts to cluster locations based on similarity to each other in terms of volume of visitors. For instance, researchers have demonstrated a bottom-up approach to grouping locations into clusters that exhibit similar temporal mobility patterns in terms of volume of visits [12], and subsequently labels these clusters according to a tacit understanding of both the locations as well as the mobility patterns there [4].

We can find in literature several examples of overlapping dynamic content on a map: Alves et al.'s [1] KUSCO mined the web for creating ontologies based on semantic associations to POIs for enriching the description of a place; Crandall et al. [7] organized photos' location based on visual and temporal features to pinpoint from where did the picture got taken; Hotmap [8] focused on location highlighting techniques for the most frequently viewed locations; and Tammet *et al.*'s [21] crowdsourcing approach from geo-tagged databases to locate, describe and rate tourism targets in any area of the world.

In this work, our goal is to evaluate the user usability aspects of highlighting popular spaces, missing from [8]. Our hypothesis is that, providing a highlight as a background layer, instead of a foreground layer, informs the user of location importance without obfuscating their understanding of the maps' cartography. More importantly, we extend previous work with crowdsourcing approaches [20] by incorporating social network activity (*e.g.*, Foursquare) to dynamically update and harvest local citizens whereabouts and preferences. Lastly, our public display deployment approach raises a new set of challenges and requirements not found in literature, which we share here.

3. COLLECTING AND DISSEMINATING SOCIAL CONTEXT OVER THE CLOUD

The service we developed (HotCity) is inspired by cloud computing and Satyanaranyan's concept of cloudlets [22] in Ubicomp scenarios. The deployment and the evaluation of the proposed service, took place in the context of the 2nd International UBI challenge 2013.

Our cloud-based service. HotCity aggregates information from other cloud sources such as social media (*e.g.*, Foursquare) and citywide sensors (*e.g.*, Wi-Fi location positioning) provided by panOULU's infrastructure [19] and produces citizen-based spatial knowledge. Our goal is to explore user interaction with HotCity's generated information using a urban infrastructure. Users are able to access the information through the UBI hotspots that are located around Oulu. A UBI hotspot is an interactive, touch-enabled outdoors display that offers a multitude of services to the city locals. On these we present maps of downtown Oulu, upon which we superimpose our social data visualizations, thus aiding users to easily discover the vibrant and interesting areas of Oulu under user-specified context (*e.g.*, "Now" or "Friday evening").

We used Foursquare, Facebook and Google Places APIs as data sources (Fig. 1). In particular, Foursquare API helped us to retrieve current information such as real time check-ins but also historically derived information such as total check-ins in a location. Using Facebook API, we gathered information such as total "Likes" and "Tags" (people tagging posts or images with venues and locations). Finally, using Google Places API, we collect useful information about the ratings of a location. Our system also displays geo-tagged Wikipedia articles, in order to allow users to see important landmarks in Oulu. These are obtainable through the Wikilocation.org API.

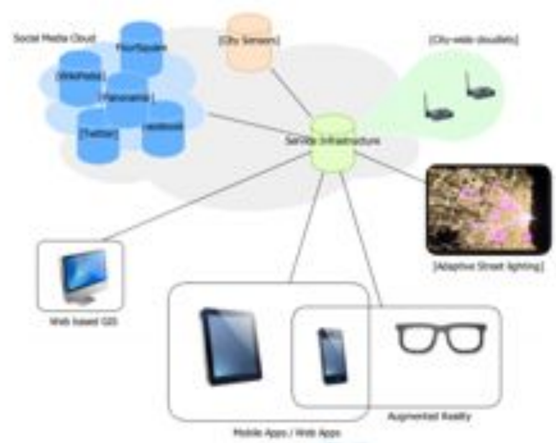

Figure 1. System Architecture

More importantly, we leveraged local knowledge and expertise to emphasize appropriately the dynamic social behavior of the city. We collected data directly from the APIs, by setting up "listening posts," *i.e.*, fixed locations within the city, which cover the commercial and social areas of interest, according to local expertise. At 30-minute intervals and per listening post, we retrieved the local businesses data at the vicinity of the listening post, by querying Foursquare, Facebook and Google Places APIs.

We chose 30-minute intervals to *reduce* our margin of error per check-in, as Foursquare APIs does not provide the check-in time. Foursquare's check-in timeout policy keeps a user checked into a place for a maximum of 3 hours or until he checks in to another venue. Lastly, we aggregated the data as: time of query, current number of check-ins, total amount of check-ins, tags, likes and ratings. As such, the data *does not capture distinct check-ins*, but rather how many people appear to be checked into a venue at any point in time. If social media users added a new place by "check-in," our dataset was dynamically extended to include it in our analysis. In previous work [14] we find that even if the frequency of social interactions (*i.e.*, check-ins) is low, collecting this data over a period of time gives accurate descriptions of urban dynamics surrounding an area of interest.

More crucially, our system is capable of disseminating the collected information to a range of ubiquitous devices and services, including desktop, mobile, wearable and city infrastructure devices. For this paper, however, we focus on the delivery to public ubiquitous interactive displays, which we describe further next.

4. SHARING SOCIAL CONTEXT DATA WITH UBIQUITOUS PUBLIC DISPLAYS

4.1 Open UBI-Oulu Infrastructure

The city of Oulu is equipped with a city-wide ubiquitous computing infrastructure, which includes a free public access Wi-Fi network and ubiquitous outdoor large interactive public displays called "UBI-Hotspots" [19]. These displays are double-sided with two LCD panels back-to-back. Each LCD panel is equipped with a touch screen foil, control computer, local hard drive, two cameras, an NCF/RFID reader and a loudspeaker. In addition, a display unit may also contain access points for panOULU WLAN, panOULU BT and panOULU WSN networks. The UBI-hotspots offer a pronounced channel for presenting visual information. Each hotspot is either in a passive or an interactive mode. In the passive mode the entire screen is reserved for a digital signage service dubbed UBI-channel.

The UBI-Hotspot interactive mode is triggered either via touching the touch screen display or face detection. In the interactive mode the screen is divided between the UBI-channel (Panel A, Fig. 2) which displays general content and further two touch screen panels called UBI-portal (Panels B and C, Fig. 2) which can be used by application developers to provide a service. A Ubi Application is launched by clicking its respective icon in the UBI-portal.

There are three layout options that are supported for the panels and HotCity uses the layout shown in Fig. 2 (bottom). We chose this layout in order to allow for maximum space for the map and to keep the application controls at the bottom of the screen, so they could be comfortably accessible for most users despite their physical height. Figure 3 shows the locations of the UBI-Hotspots in Oulu city center.

There exist six outdoor hotspots, however, for the purposes of our experiment, we deployed our system on just one, so that we could narrow down the collected interaction data to just the hotspot where experiments took place.

Figure 2. Ubi application layout options (top) – HotCity panel layout (bottom)

Figure 3. Location of outdoor UBI-Hotspots in Oulu (blue markers). Our experiment took place at the circled hotspot.

4.2 The HotCity Service

Though we collect data from various sources, for this service we use data exclusively from the Foursquare API, since we are still investigating how data from the various social networks correlates to each other. For our application, we chose to use Panel B as a control panel for the information to be presented on the map (Fig. 2), which was organized in four information "tabs": "Home" returns the application to the beginning; "Categories" shows a list of POI categories; "People" allows filtering by real-time current check-ins; and "Hot Areas" allows the user to control the temporal aspects of the heatmap. The larger Panel C held the map and also some basic controls over the map (zoom, heatmap visibility and wiki-point visibility). With this layout, we developed a service that conveys a range of contextual information to the user in a multi-layered view (Fig. 4):

- Layer 0 (background) is the city map, which affords users spatial understanding of their surroundings and the points of interest (POIs) in the city. This heatmap is calculated from check-in data throughout the hours of the day; hence it shows which areas of the city are bound to be "busy" or otherwise "active" at specific times.
- Layer 1 is a heatmap of check-ins in venues, which allows for spatial visualization of an area's social "buzz." The heatmap

also has a temporal dimension that can be controlled by the user, by selecting their desired day of the week and time of day.

- Layer 2 presents categorized points of interest (POIs) within the city, as provided by the Foursquare service and geo-tagged Wikipedia articles for Oulu. An interesting twist to the POI layer is that popular venues are presented with a "flame" icon and a number with the amount of people currently checked in. The POI layer can be filtered by selecting categories or by showing just the POIs that currently have more than a specified amount of people.

Figure 4. Detail of HotCity map (Panel C) showing the heatmap, POIs with their various icons and Wiki articles.

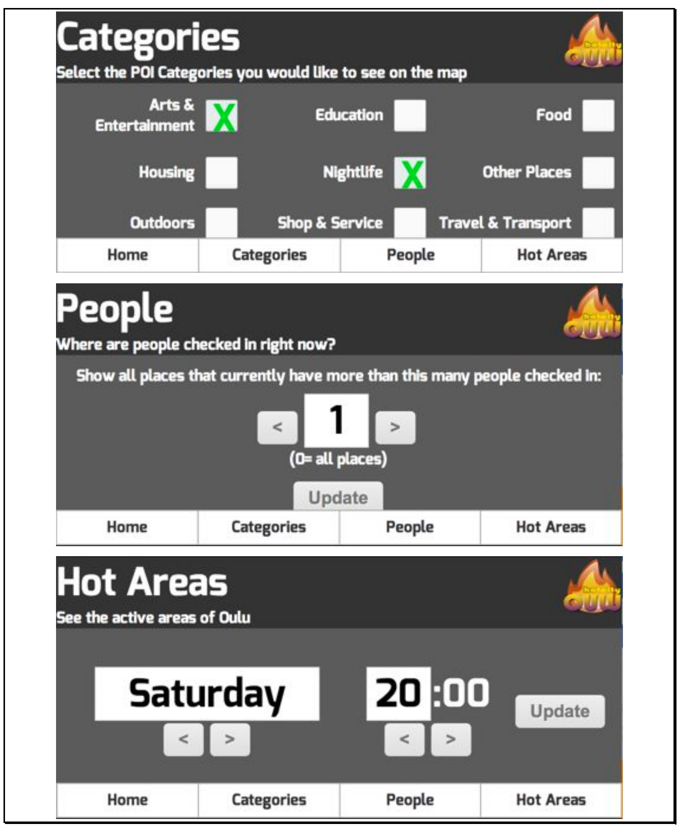

Figure 5. Panel B information tabs, i.e. the control options for users. POI category, people and date-time selection

Figure 6. Panel C user instructions

5. EXPERIMENTS WITH SOCIAL MAPS

5.1 Using Social Context in Maps

We used a scenario-based approach for assessing the heatmap's information affordances, where visiting a new place includes the use of ubiquitous maps and requires a plan. This scenario includes three unique and non-trivial planning tasks – firstly, the user is in a completely new location for which he is unprepared. The user has not made previous plans and has to rely on whatever information can be gathered by our service. The user not only has to think about the places which they will visit but also how far apart they might be, considering they do not know anything about this new place. The scenarios are as follows:

- Task 1: "It's your second day in Oulu and you are walking in the street. Having nothing specific to do, you have enough time to find and visit a landmark (outdoor place)."
- Task 2: "It's 2PM on Wednesday and you near Mannerheim Park, so you have to find a restaurant around this area to go."
- Task 3: "It's Friday evening (8PM) and you want to go out for a drink to see the nightlife of Oulu but first you want to find a restaurant to eat."

We selected between-subject experiment design with two distinct groups of users for evaluation – those with and without the heatmap on the map – in order to perform the three tasks. For each intervention, we recorded the elapsed time to complete the task, followed by a short user subjective questionnaire to determine complexity, ease of use, learnability, confidence and perceived utility.

We further investigated if users' perceptions were affected by their own use of social networks, with a separate questionnaire. All users were shown instructions before the experiment started (Fig. 6) and were told how the service works.

Figure 7. Participants interacting with the HotCity application on UBI-Hotspots during the experiment.

5.2 Participants

We recruited 30 participants (16 female and 14 male) from around the city, resulting 15 participants for each of our group. Only five were Oulu residents, the rest being visitors. The oldest ones were 58 and 56 years old, four between 41-48, nine between 30-38, six between 15-20 and lastly nine between 22-28 years old. We asked our participants about social media usage practices (*i.e.*, which network and frequency of use) and also the type of actions taken through these networks that relate to spatial context (*i.e.,* tagging friends, defining locations or checking-in). We found that most of the users were familiar with social networks like Facebook (6 participants said that they never use Facebook and majority didn't use Foursquare) and with the concept of tagging locations or friends in photos or post and checking into a location using social media, though this action is the least popular (twelve participants stated they do it but the frequency is very low)(Fig. 8). This is important, as we needed to be sure that participants understood how the map visualizations were created.

We also asked our participants about the source of information they use when planning a visit to an unfamiliar city. Figure 9 shows that most of the participants seems to prefer and trust information from friends and relatives (1st) and tourism websites (2nd) most. Fewer participants use information from community websites, which rank closely to guide books. Finally, traditional information sources such as local information offices and brochures are used rarely. This suggests that participants trust information from people they are familiar with. Moreover, these findings also confirm that users tend to trust information that is available on the Internet, *i.e.*, information that is compiled by independent individual Internet users. Finally, traditional information sources rank in last place, in their planning activities to a new location.

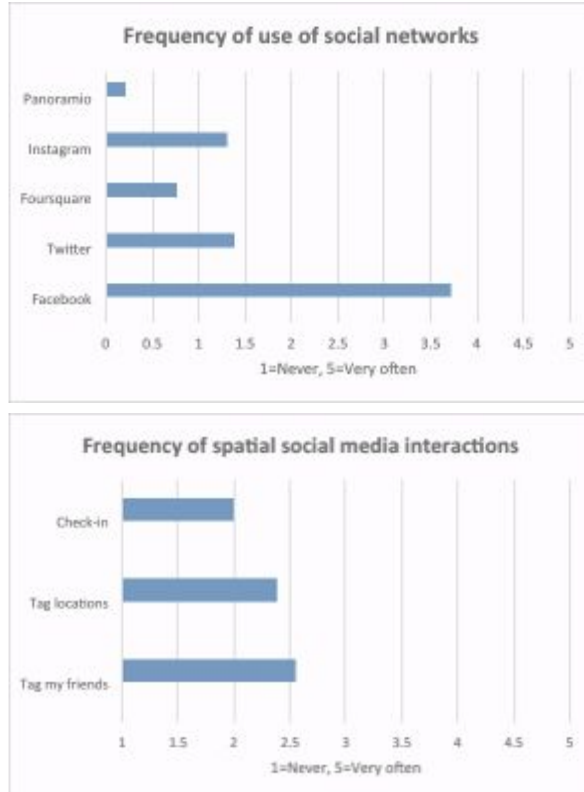

Figure 8. Participant Familiarity measures with online social networks

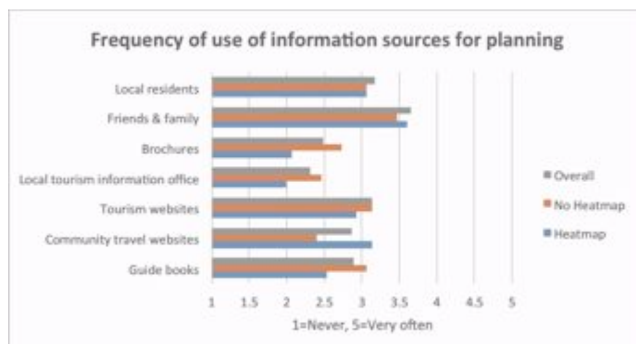

Figure 9. Participants preferred sources of tourism information

6. EXPERIMENTAL RESULTS

6.1 Usage statistics

Our system logged all user interactions while performing the tasks under the given scenario. Hence we were able to objectively quantify their performance according to time, number and type of interactions and finally the venue selected (Table 1).

In terms of time, we observe that having the heatmap seems to reduce the overall time taken in all tasks; however, the difference is not statistically significant (Fig. 10).

Table 1. Time taken to complete tasks

	Heatmap	Mean	Std. Dev.	p-value
Task 1	0	296.2	74.442	0.55
	1	322	139.987	
Task 2	0	167.27	48.457	0.57
	1	177.64	49.683	
Task 3	0	178.6	95.727	0.19
	1	217.79	58.749	

Figure 10. Average time to complete tasks

When examining the type of and the frequency of interactions with the system (Table 2 and Fig. 11) we observe that statistically significant differences occur in toggling the Wiki POI button (those with the heatmap felt it was not necessary and switched these off), navigating to the "Home" tab (those without the heatmap went back to the start more often) and the POI Categories selection checkboxes, which is probably a result of confusion occurring in those participants without the heatmap, who had to start from scratch more often and hence redefine the desired categories. For the rest of the interaction options, though we notice differences, these are not statistically significant. Nevertheless, it is interesting to see the high number of examined Foursquare POIs for each participant in contrast with the Wiki POIs, which were seldom used. The "People" tab was not often visited and even less were the times when participants actually chose to filter POIs by the number of current check-ins. This result indicates that current activity is not seen as a significant factor in deciding which POIs to consider.

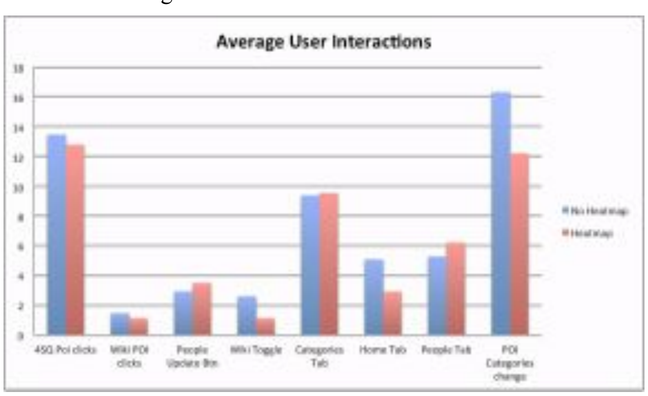

Figure 11. Average user interactions with the system by interaction category

Table 2. Average interactions per participant group

	Heatmap	Mean	Std. Dev.	p-value
Foursquare clicks	0	13.47	9.109	0.81
	1	12.79	6.053	
Wiki clicks	0	1.47	1.125	0.51
	1	1.14	1.46	
People Update Button	0	2.93	1.981	0.67
	1	3.5	4.485	
Wiki Toggle	0	2.6	1.502	**0.00**
	1	1.14	0.864	
Categories Tab	0	9.4	3.418	0.90
	1	9.57	3.502	
Home Tab	0	5.07	2.492	**0.01**
	1	2.93	0.997	
People Tab	0	5.27	2.282	0.50
	1	6.21	4.66	
Categories change	0	16.33	5.341	**0.01**
	1	12.21	2.547	

Finally, we examined the chosen venues for all three tasks. Table 3 shows the number of distinct chosen venues for each task for the two participant groups. We cannot find significant differences here apart from Task 1. However, we performed a spatial analysis by calculating the convex hulls (bounding polygon) that included the coordinates of all choices for each task. In this analysis we found that those users that had the heatmap available displayed a more exploratory behaviour and were keen to examine options further away, lured by the indications shown by the heatmap.

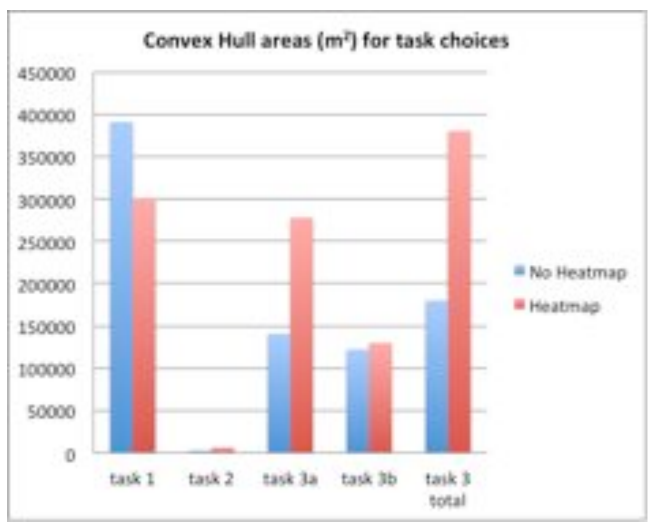

Figure 12. Convex hull area coverage per task per participant group.

Table 3. Distinct venues chosen by participant groups

	No Heatmap	Heatmap
Task 1	10	6
Task 2	3	3
Task 3	18	18

Figure 13. Convex hull area coverage per task per participant group (Left: without heatmap, Right: with heatmap).

6.2 Subjective Ratings

At the end of each experiment, we asked our participants four basic questions, oriented towards uncovering their personal opinion on the confidence with which they made their choices, their anticipated future use of such a service, the ease to learn the system and finally the perceived complexity of the system (Fig. 13). We found that the ratings are not that much different and in fact, we could not establish statistical significance for the difference of means.

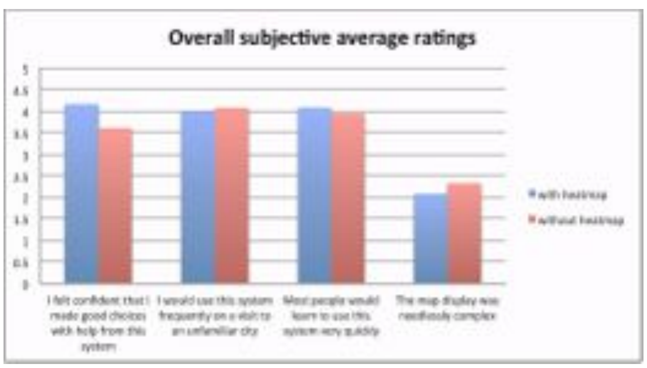

Figure 13. Overall subjective ratings (1=strongly disagree, 5=strongly agree).

Figure 14. Percentage breakdown of users in each response category for choice confidence.

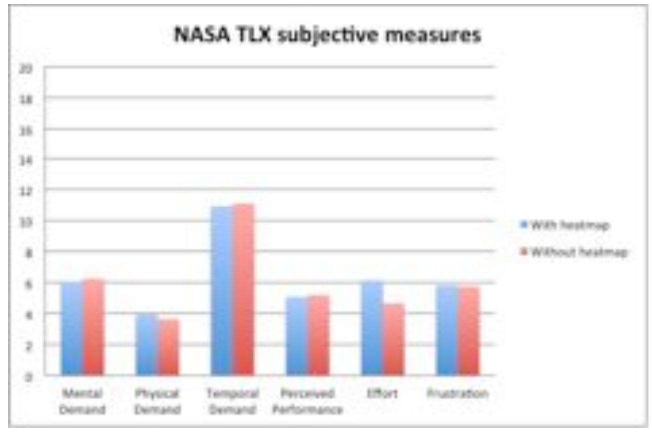

Figure 15. NASA TLX questionnaire results

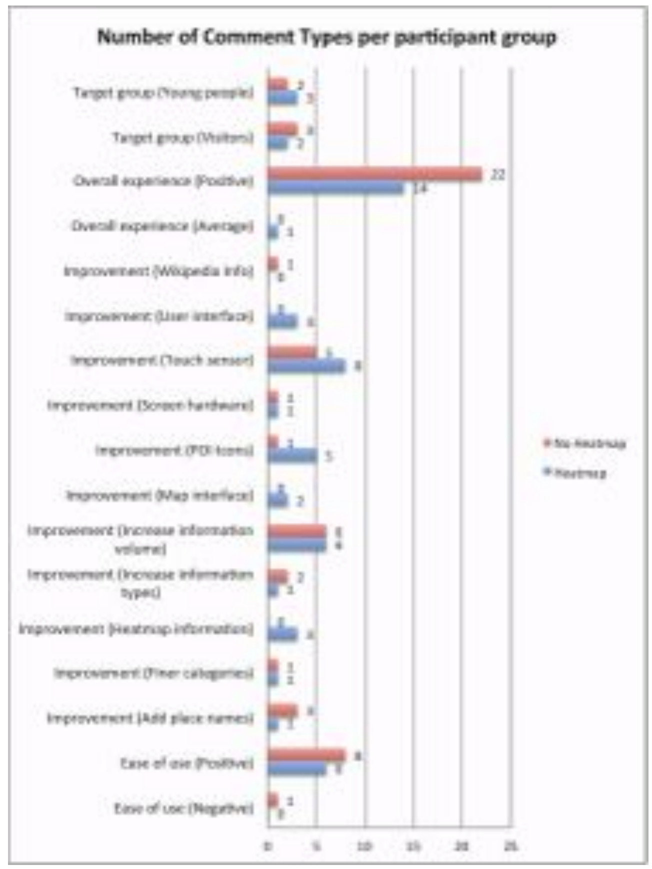

Figure 16. Breakdown of category-content groups for user comments and feedback.

However, particularly for the user confidence in making their choice, there is distinct qualitative difference in the answers given by participants as highlighted in Figure 14. Approximately 1 in 3 heatmap users felt strongly confident in their choices while no-one from the no-heatmap category fell in the "strongly agree" category.

Further to the simple subjective ratings questions, we issued a NASA TLX questionnaire to our participants, in order to delve deeper into subjective opinion (Fig. 15). An analysis for statistical significance in the means of these results again revealed no difference. From these results however, it is interesting to note that mental demand, effort and frustration is rank quite low on the scale. Disappointingly, a low score is also observed in perceived performance, which does not tie in to the confidence levels reported in the simpler subjective rating questions.

6.3 User Comments & Feedback

Users were encouraged to give free-form comments and feedback at the end of the experiment. We collected 113 comments in total (57 from the heatmap group) and categorized these comments in four broad categories, "Overall Experience," "Ease of Use," "Improvements" and "Target Group." These categories emerged naturally from the content of the comments. Each category was then broken down further, according to the actual content of the comment. In total we classified the comments into 17 category-content groups, as shown in Figure 16.

We observed a large number of positive comments for the overall experience and ease of use of the system from our participants, both in the heatmap and non-heatmap groups (Table 4). Many participants, despite being pleased with the system overall, had issues using the UBI-hotspot hardware, particularly because the touch sensor did not always accurately translate touches and resulted in unexpected behavior in the system. Additionally, some users commented that the glass screen on the hotspot was overly reflective and that the lighting conditions made the application difficult to view in the open-air setting (Table 5).

Table 4. Sample Overall experience comments

P_ID	*Overall Experience Comments*
O1	It was easy and logical to find the asked information.
O2	The system was clear to use
O3	I am not sure that I did good choices with the help of this system because when using I am following somebody else's opinions. They may have been some beanie-headed teenagers
O15	it was a good application, after I learned how to use it
O15	It's a useful application for knowing where and what kind of services exist, then you can go to their webpages to see more and get more information
O17	It was nice to know where people are spending time
O18	Heatmap was good, for some reason you ended up choosing a place from the area that is hot
O19	Good idea behind the app, to combine many information soucres. Trip Advisor is not that good.
M8	Good thing with the popular areas, one can find the way to the right places
M11	It is interesting, where people really are/go
O12	I made my decisions based on where the flame icons are
E1	It was quite easy to find the information
E2	Handy and clear.
E2	It is nice you can see popular places because it is difficult to know where people usually go

Table 5. Sample hardware improvement comments

P_ID	*Hardware Improvement Comments*
O2	The screen did not take the touch, which made it harder
O4	The system works but the screen doesn't
M3	The touch sensor is bad, one gets confused if I did something wrong
M11	Easy to use if the touch sensor works, otherwise it gets annoying to poke the glass many times
M13	The glass on the display is the wrong kind of one, reflects own image, application looks dark, there should be some kind of visor above the display
O5	The display was difficult to use
O12	There should be a cover above the screen or one should be able to rotate the screen as per how the sun shines

Several other participants commented on the information present in our service. They thought that having more information about venues would help them make better choices. This obviously stems from the fact that the information we present comes directly from Foursquare and that many venues have very little information about them, usually just a venue name, category and number of check-ins. Other venues have much more complete information, such as opening hours, menus, descriptions, user tips etc (Table 6).

Table 6. Sample POI and Venue Information comments

P_ID	*POI and Venue Information Comments*
O16	It was bad that there wasn't more information about the places
O18	When there was more information about the places, it was easier to make good decisions
O18	There was surprisingly little amount of information about the places
O19	There should be an explanation why some POIs are flames and some are not. Are the flames also places?
M3	Points are a little bit too small, could be bigger but the zoom helps
M3	Icons could be clearer, why the shape of a balloon?
M12	If the icon would tell what is the name of place or kind of place they are, one would not have to open all the icons
M12	Would be good to have different coloured icons, different categories and the icons shown on next to category in the tab
O5	On the map, there should be the name of the place, at least I make decisions based on the name of the place
O6	Choosing a place to visit was quite random, because there are no place names, the ground for decisions is mainly the location. If you wanted more information you should click many icons, I doubt I would have patience for that.
O12	Maybe one can begin with this system and find places to visit and the use google to find more information
M4	Numbers instead of icons and a list on left to say the name of numbered point
M4	It should be seen clearer what kind of poi these are (I don't want to eat in a pizzeria but I still might accidentally open a pizzeria icon)

Table 7: Sample Target Group comments

P_ID	*Target Group Comments*
O3	The application would help non-locals
O15	Quite nice app when visiting a new city, you get a picture of what's going on
O16	Young people use social media and tag places and sign in. Old people would go to the wrong places when using this application
O18	For the old people it would be difficult to use this app, they would not learn
M3	Requires familiarizing, especially old people
O6	I'm sure young people would learn to use this application
O7	Older people can find the map problematic and complex
E4	If you are non-local, it's very good service to use
M5	If one arrives to an unfamiliar place, it is good
M6	Good for someone that hasn't been here before

With regard to POI representation, an interesting observation was made by several users who requested that the map interface is improved by adding the name of POIs as a snippet of information either on the POI icon itself or on a list at the side of the map. It appears that venue names are a major influencing factor for some of our participants, with location not really playing as great a role. This is an interesting point worth deeper investigation. Other users made a few comments about the nature of the icons, requesting different icons for each category or complaining that the semantics of the icons were not immediately obvious to them (although all users had to read an introductory note explaining the icons at the start of the experiment). Finally, a number of participants commented on the type of users they thought this system would be appropriate for. It appears that their opinion converges towards unsuitability for older adults and particularly good for visitors of a city who are unfamiliar with it (Table 7).

7. DISCUSSION & CONCLUSIONS

To examine our hypothesis, we used quantitative and qualitative data from our participants. Our findings from the field-based trial of the HotCity service yield several useful insights and important contributions. We found that the method of using a heatmap as an intermediate spatiotemporal layer of environmental context did not appear to have any negative or positive effect on the experience of users at the cognitive level, compared with a more traditional map and POI type of interface, where temporal aspects of context are not present. While a clear advantage of one over the other method is not apparent, there is some evidence that the heatmap system may overall offer a better quality user experience.

Our findings from the convex hull spatial analysis suggest that this method of presenting information can yield advantages to users, encouraging them to explore areas that might have otherwise not considered. Overall, users felt more confident in their choices when the heatmap layer was present and this shows that with some improvements as suggested by our participants (*e.g.*, making a legend and explanation of the heatmap information coding semantics), there is significant potential in using such a visualization option to enhance ubiquitous maps. A potential pitfall in this case is the fact that environmental social context is considered by participants to be particularly relevant for the younger generation. However, we believe that a clearer explanation of how the heatmap data is generated might encourage elderly users to take advantage of the information as well. To investigate potential quality of experience advantages further, we would like to conduct a further field trial where the users are not guided by our scenarios.

An unexpected finding from our study was the extent to which venue names play a role in the choices that users make. Several users suggested that they would have benefited from venue names to eliminate unnecessary browsing of venues. So far we are not aware of literature that has examined the role of venue naming in selection tasks, hence worthy of further exploration. POI icons are also an area worth further exploration. We attempted to convey temporally relevant semantics through our icons by displaying the number of people currently checked in on the icons themselves. However this was not immediately obvious to our participants and the same applied for the "flame" icon metaphor that conveyed historically popular places. More work in this area is necessary as we believe that past user experience with map-POI systems might be influencing perception on the nature of data such a system can convey, limiting users' perception to just spatial relationships.

A final point to note from our work is the importance of complete profile information for venue owners/managers. We noticed in user comments quite strongly how an incomplete profile of a venue in a digital service leads to low likelihood of choice. With the use of Foursquare, Facebook, Google places and other social networks that facilitate venue representation, it is important for local business owners to seriously consider adopting a formal presence strategy in these social networks. As their use for venue selection will only grow in the coming years, with more services and *mashups* being developed by third-party developers, the importance of an accurate and complete profile in social networks is paramount.

8. FUTURE WORK

In this paper, we presented our findings with the dissemination of social context as spatiotemporal heatmap visualization in ubiquitous public displays. As described in our system architecture, our service can be flexibly deployed to a range of devices, including mobile, wearable and static infrastructure systems. We started a trial of a mobile version of our system, show in Figure 17. However the analysis of this is still ongoing and will be presented in a future article.

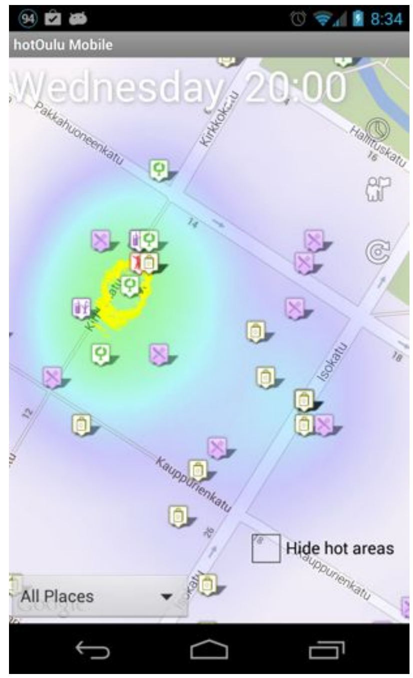

Figure 17. The mobile client of HotCity as a native Android Application. Temporal heatmap aspects are controlled by tapping the clock icon (top right), the flag-person icon toggles the POI layer visibility and the circular arrow refreshes data. POI categories can be filtered by the dropdown widget on the bottom left.

We have also developed an augmented reality client for our service, which works by augmenting simple static maps with the dynamic information present in our service (Fig. 18, Fig. 19). This is work-in-progress, to be evaluated in the coming months. Our focus with that system will be on collaborative aspects of information finding, through sharing information with a single or multiple devices in groups of visitors.

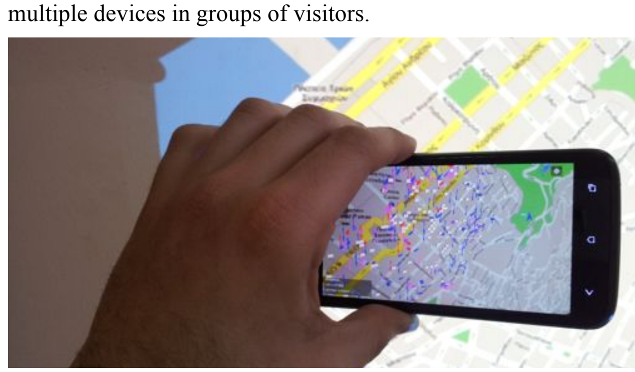

Figure 18. Augmented Reality application on a large public display static map (projection)

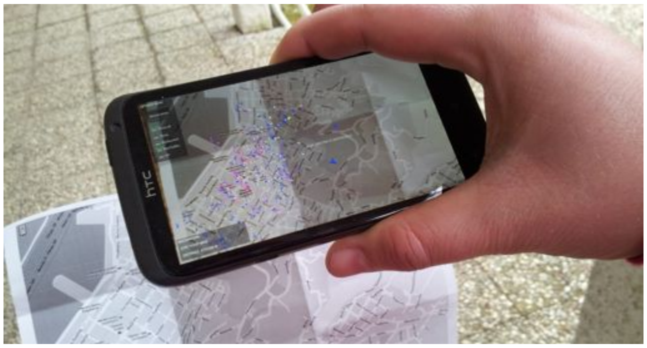

Figure 19. Augmented Reality application on a personal paper map

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