

# A Mobile Phone Guide: Spatial, Personal, and Social Experience for Cultural Heritage

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**Abstract** — *We have built a mobile phone-based guide system to strengthen the user experience in a cultural heritage site by supporting spatial awareness, personalization, and social connectedness. Our mobile phone guide implemented on a Java-enabled mobile phone provides both audio and visual content that is tailored by tracking user movement with GPS, collecting various user inputs and demographics, and allowing for socially acceptable eavesdropping via wireless networking. We applied our system to a cemetery site and present the results of a user study. We also conducted a performance evaluation to verify the effectiveness of both content filtering in personalization and content synchronization in social connectedness. Spatially, our results validated that our system provided a satisfying physical exploration of historic space. With respect to personalization, the content presented to visitors was well tailored to their real-time feedback over the course of their visit. Socially, the effectiveness of our sharing interface motivated visitors to frequently synchronize content among themselves. Our system will hopefully broaden the appeal of mobile phones as electronic tour guides providing adequate support for spatial awareness, personalization, and shared group experiences.*<sup>1</sup>

**Index Terms** — **Mobile entertainment, heritage sites, user experience, historical media content.**

## I. INTRODUCTION

Mobile technologies are emerging into days of our everyday lives [1]. Among variety of mobile technologies, a mobile phone is the most popular and essential technology people carry with themselves everywhere. A wide variety of technologies exists in both research and consumer products of held-held electronic guidebooks for the betterment of the cultural heritage experience [2], [4], [5], [6]. While most previous systems, such as the Antenna products or Sotto Voce, have used custom hardware or PDAs to enhance users' experience, we use mobile phones that support both location-awareness and a rich, user-friendly interface. As phones get more powerful, they are very likely to become the platform of choice for museum tours. Antenna, for example, already includes a service for their customers to download audio tours to their phones. As more people use their own devices, the historic sites will need to invest less in hardware support costs.

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Aoki et al. suggest that tour guide systems should balance the interaction demands of three primary entities: the information sources, the visitor's companions, and the physical environment [5]. In our design of a mobile phone guide for cultural heritage, we embody these principles, focusing on the spatial, personal, and social aspects of a visit, and bringing together the location information of the visitor, his/her user profile and interaction history, and the interests and activities of the visitor's friends. Each of these can have an influence on visitors' interaction with the media content during their tour. By designing for spatial, personal, and social considerations of the environment, we aim to help users navigate the historic information space and consume potentially vast quantities of historical media.

The contribution of this work is as follows. First, design of the spatial-awareness in a phone-based tour guide avoids the explicit use of location to trigger content, and instead structures the experience based on an authored linear narrative. Second, for personalization, we enable visitors to interact with graves suggested to them in a customized manner based on their user feedback. Our most important contribution is our effort to encourage social interaction by specifically designing a sharing interface which is novel and attempts to address the most common complaint about computerized tours.

This paper is organized as follows. In section 2, related works are given. We deal with implementations in section 3. Section 4 describes evaluation and results. Finally, section 5 concludes our work and offers a brief outline of future work.

## II. RELATED WORK

A wide variety of research prototypes and commercial products attempt to create hand-held electronic guidebooks aimed at improving cultural heritage experiences. First, we summarize a few key related projects that particularly focus on spatial, personalized or social dimensions. Then, we point out other work in the commercial arena.

### A. Spatial

There have been numerous efforts to support mobile tour systems using location-awareness [6], [7], [9]. Cyberguide [2] was an early mobile tourist guide for the Georgia Tech campus and adjacent neighborhoods. Location-based services [11] are proliferating, thanks to modern cell phones. Such services allow users to search for local restaurants, movies, stores and so on by entering a queries based at least in part on their location. Some researchers believe that in the near

future, augmented reality and Geo-Tagging services will be combined to provide users with location-based information based on location or on sensed physical objects [6], [13]. In a broad sense, these systems are similar to ours in that they recommend content based on locations. However, we only use location to offer visitors a sense of where they currently are as well as where they might want to go in the information space, and explicitly avoid doing content retrieval by means of a tightly coupled mapping between the content and the user's fine-grained location. Instead our system structures the experience based on an "authored linear narrative" that helps a visitor understand what he or she might want to explore in this historic space. At a basic level, such linear narratives serve a function similar to authored signage in curated museum exhibits; they tie a disjoint set of objects or places into a coherent whole. We utilize GPS to present the user with an egocentric map display that shows them where they are, what interesting graves (either on or off the tour) are nearby, and where their friends and family are located.

### B. Personalized

The ARCHEOGUIDE project [8], like many other tour guides [2], [3], [7], [9], [10], [16], [18], attempts to enhance the experience of historic locations using user context. Context-aware guide systems, such as the Electronic Tourist Guide [10] and others [15], [17] are similar to ours in that they recommend venues based on the user's stated or inferred preferences. Those systems are targeted at helping users tour unfamiliar areas by providing a wealth of relevant information based on location, whereas our project attempts to use customization to tailor potentially vast quantities of historical media to their tastes. For better personalization, we allow visitors to interact with the guide book in a customized manner suggested by their user profile including their demographics and the themes in which they have expressed an interest. Additionally, over the course of their visit, we offer visitors specific content elements tailored to their feedback. PEACH [22] is PDA version of a museum tour with location detection, user modeling, and adaptation. The PEACH system constructs a user model through a widget, which enables the visitor to express whether she likes or dislikes a given museum artifact. A more directly adaptive approach is attempted in the *Magitti* project [21], which is not designed for tourists, but for young urbanites interested in all kinds of leisure activities. *Magitti* provides recommendations based on predictions of the user's activities, using context-aware sensing and machine learning techniques.

### C. Social

Most visitors come to the cemetery (or any historic site) in groups—from small groups of friends or relatives, to entire school buses of children on class trips. A major failing of most electronic tours is that they do not provide adequate support for shared group experiences. Our work attempts to overcome the inherent limitations of many

electronic guidebooks that focus on individual experiences rather than supporting a group tours. Sotto Voce [5] is a guidebook designed to support social interaction between visitors and their companions by suggesting the use of an eavesdropping metaphor that would allow visitors to split up and then naturally come back in sync, but does not support long-term shared experiences. The Lighthouse project uses voice communication to facilitate collaboration between physical and virtual visitors to a museum [20]. To encourage social interaction, we have designed the tour to support shared group experiences. We have designed the system to support group coordination by allowing members to see each other on a map and, inspired by Sotto Voce, eavesdrop on each other's audio stream. However, going beyond the capabilities of Sotto Voce, we enable group members to create a shared experience by synchronizing the audio controls of all people who are eavesdropping on each other. Our initial inclination was to follow the Sotto Voce project in building the simplest interface possible, rejecting complex controls such as sending/receiving or connecting/accepting/rejecting to specific visitors, like friends or family. Our design is different from Sotto Voce in that we allow visitors to control each other's audio experience when eavesdropping. We believe that the potential disagreements that result from a lack of security are likely to be resolved socially.

### D. Commercial

Antenna Audio [4] supplies museums, historic sites, and cultural attractions worldwide with audio-visual interpretive tour solutions using a hand-held wireless device. It incorporates various technologies such as audio, radio, multimedia, and web services. For example, the High Museum of Atlanta has adopted Antenna Audio solution to develop tour guide systems for visitors to the museum. They have systems that support group mode, but it is designed for large tour groups and does not have the flexibility of our approach. Their solutions manage to enlighten visitors' experience through intuitive controls and high-quality audio and through non-linear, self-paced exhibition viewing. Eyeled project supports localized mobile systems in which the position of the mobile device is determined by the use of infrared beacons able to transmit a unique identifier that are installed throughout the museum [23]. Another example is the Mauerguide project [4] in Berlin where visitors can trace the history of the Berlin Wall by means of multi-media, GPS enabled PDA. Similarly, our cemetery experience follows a linear story and attempts to engage visitors by creating tension along a dramatic arc.

## III. MOBILE PHONE PROTOTYPE

In this section we describe the design goals, approaches, and implementation of an educational and entertainment-based mobile experience for a cultural and historical site.

### A. High-Level Design Goals

- Education and Entertainment:** learning about the site and experiencing the exhibit is the one of the many reasons people visit cultural heritage sites. However, sharing the experience with friends and family, and having a memorable experience in which the visitor "gets the sense of the place" are often prioritized more highly than education [5]. Conventional electronic guidebooks easily satisfy visitors' educational desires with in-depth digital media, both auditory and visual, that are otherwise hard to integrate into the physical space. Even though most electronic guidebooks provide rich content, they do not help visitors have satisfying group experiences, nor do they offer the kind of dramatic or narrative content that can lead to an emotionally memorable experience.

- Social Interaction:** using an electronic guidebook hinders visitors from interacting with their companions because the systems are typically designed for individual users. To fulfill the diverse demands based on user preference, our system aims not only at providing visual and auditory information about historical events, but also serving as a communication channel between visitors and their companions.

- No Extra Infrastructure:** Woodruff et al. point out that system designs that are applicable in a museum are not plausible in a historic site [5]. In particular, location-aware systems that need to install supplementary sensors to have the visitor's position detected are not feasible (e.g., because of policies to keep artifacts in the site intact). Thus, location-awareness systems that require supplementary sensors to be installed on site are usually not an option; in our experience at the cemetery, this was the case.

- Low Barrier to Entry:** lastly, a concrete motivation for installation on one's own mobile phone and the compatibility of software with various mobile phones are two essential factors to be considered, as this system runs on one's own device. As visiting cultural heritage is voluntary activity, the visitors will be willing to use their own phone if our system enriches their experience without adversely affecting the device. We believe that leveraging mobile phone support for Java MIDP and CLDC, safe and widely available mobile standards, will enable this in near future.

### B. Proposed Approaches

Our mobile entertainment application seeks to strengthen the user experience in a cultural heritage site by supporting spatial awareness, personalization, and social connectedness. Fig. 1 shows the overall architecture of our application. In this section, we discuss how our application addresses the three goals.

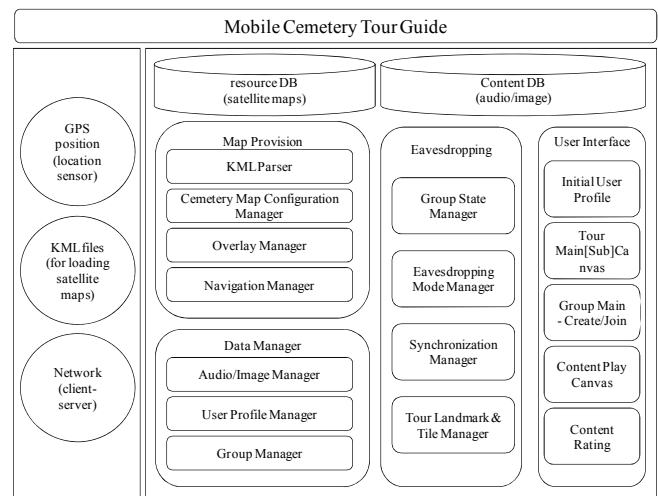


Fig. 1. A system overview of a mobile cemetery tour guide.

#### 1) Spatial Awareness: GPS mapping

We adopt location-awareness to offer visitors a sense of where they currently are as well as where they might want to go in the information space, rather than just using location for content retrieval. On one hand, GPS alone is not reliable enough to use for fine-grained sensing. On the other hand, we do not intend to implement complex system logic to overcome the relative inaccuracy of GPS to provide location-based content retrieval during navigation. Instead, our system relies on a linear tour to give the visitor a framework for the experience. GPS is only used to support a visitor's navigation by allowing them to sense where they are by seeing their location in the map, and to explore the map to seek interesting content at each grave along the linear tour.

When users get physically close to a grave, the grave icon will start blinking. Users may browse the map with a navigational cursor, using the up/down/left/right direction keypad on the phone. If users move their browsing cursor too far away from their current position, directional arrows pop up, showing them which direction to go to get back to their position on the map. All of these details are shown in Fig. 2.

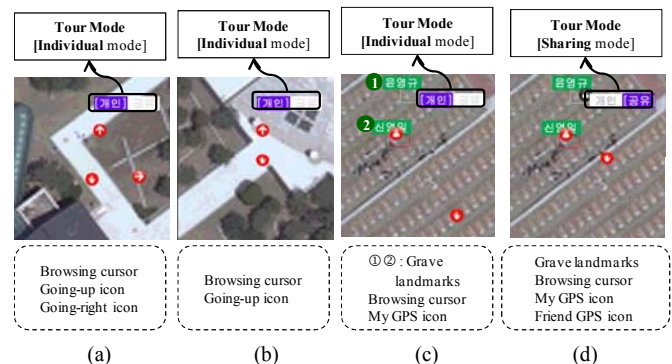


Fig. 2. Zoomed-in map showing content hotspots and other visitors: the "little person" icon indicates the user's current GPS location, the "little hand icon" is for letting the user browse the map, and the two small arrows are for informing the user of the fact that she is browsing the map away from the current GPS location.

The above implementation is realized through Fig. 3 which describes GPS-based map browsing algorithm in the prototype.

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**Algorithm for GPS-based Map Browsing**

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// Draw navigation cursor for letting the user browse the map
1: DrawImage(NaviPalmImage, getWidth()/2, getHeight()/2);
// Draw small arrows for informing the user of the fact that she is
browsing the map away from the current GPS location
2: if (Gps.X > Visible_Tile_X) then
3:   DrawImage(arrowRightImage, getWidth()/4*3, getHeight()/2);
4: else if (Gps.X < Visible_Tile_X) then
5:   DrawImage(arrowLeftImage, getWidth()/4, getHeight()/2);
6: end if
7: if (Gps.Y > Visible_Tile_Y) then
8:   DrawImage(arrowDownImage, getWidth()/2, getHeight()/4*3);
9: else if (Gps.Y < Visible_Tile_Y) then
10:  DrawImage(arrowUpImage, getWidth()/2, getHeight()/4);
11: end if
// Current GPS positions are displayed
12: if (NetworkHasGroupInfo() == FALSE) then
13:   if (IsTileVisible(Visible_Tile_X, Visible_Tile_Y)) then
14:     DrawImage(Me_Icon, Gps.PixelX, Gps.PixelY); // My GPS
15:   end if
16: else
17:   if (IsTileVisible(Visible_Tile_X, Visible_Tile_Y)) then
18:     DrawImage(Friend_Icon, GPSNetworkInfo.PixelX,
19:     GPSNetworkInfo.PixelY); // Friend's GPS
20:   end if
end if

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Fig. 3. GPS-based Map Browsing Algorithm

## 2) Personalization

A further requirement of our design was that the content presented to visitors should be tailored to their context. There are two classes of context used: demographics and various user selections made throughout the tour. Examples of useful context include the visitor's expressed interests, current location and any content preferences he/she might have. When launching a tour, the system collects the visitors' demographics, the themes they have expressed interest in, and their initial content preferences (e.g., content categories) to create a suitably tailored tour. The tours are highlighted based on the user's demographics and expressed thematic interests. User context is also used when presenting content to the visitor. For example, if users get close to graves that they might be interested in, these graves will be highlighted for them on the map screen.

Additionally, over the course of a visit, the system monitors the content visitors listen to at each grave, infers their interests from the common characteristics of each audio clip, and chooses individual audio clips from sets of clips at content point based on these inferred preferences. To determine which media content is provided to the users, we developed a content recommendation module based on both the characteristics of each audio clip and user feedback on the clips. As a method for recommending content clips based on user preferences, a similarity measuring equation was used [26]. Here, user preference  $P$  is described in terms of the vectors,  $P = (w_1, \dots, w_n)$  of the  $n$  distinct terms

$T = (t_1, \dots, t_n)$ . Similarly, the metadata of content  $C$  is described in terms of vectors,  $C = (u_1, \dots, u_n)$  with  $n$  items which are the same as those in the preference vector, that is  $n$  terms. In this representation,  $w_i$  is the weight value of the user preferences on a certain property of the content, and  $u_i$  is the weight value of the content on the property corresponding to  $w_i$  ( $w_{category} > w_{keyword}$ ).

The recommendation module calculates the similarity between user preference and potential content at the current grave, and finds a content piece with maximum similarity to the content list of the current grave. When the calculated similarity of a piece of content is above the preset threshold, it indicates that the user is likely interested in the content.

$$c_j(g_k) = \arg \max_{c_j(g_k) \in c(g_k)} \text{Similarity}(c_j(g_k), p(g_k)). \quad (1)$$

Here,  $c_j(g_k)$  indicates one element of  $j$ th content in a set of a list of content pieces at the  $k$ th grave and  $p(g_k)$  does a set of user preferences at the  $k$ th grave. As in (1), the system recommends the five highest similarity contents to the user. When a clip is recommended to the user according to his/her preference, a key button for rating is also provided, with a user feedback scale of -2(I hate it), -1(I don't like it), 1(I like it), and 2 (I love it). The system then retrieves user feedback on the recommended content pieces at the current grave. If no user feedback is given (as we expect will happen often), the system uses the initial content preferences. As in (2), it updates current user preference based on user feedback, so the updated user preference can be used in similarity calculation at the next grave.

$$w_i' = (1 - \alpha) \cdot w_i + \alpha \cdot \Delta w_i \quad 0 \leq \alpha \leq 1 \quad (2)$$

where  $w_i'$  is the weight of term  $t_i$  after update, and  $w_i$  is the weight of term  $t_i$  before update. The  $\Delta w_i$  is rating integer value from the user,  $-2 \leq \Delta w_i \leq 2$ .  $\alpha$  represents the learning rate that determines how quickly the user preference weakens old preferences and adopts new ones. Thus, user preference is updated as in (3). Then, similarity calculation at the next grave is done using (4).

$$P' = (w_1', \dots, w_n'). \quad (3)$$

$$\text{Similarity}(C, P') = \frac{C \cdot P'}{\|C\| \times \|P'\|} = \frac{\sum_{i=1}^n u_i w_i'}{\sqrt{\sum_{i=1}^n u_i^2 \sum_{i=1}^n w_i'^2}}. \quad (4)$$

In the same way, the recommendation module can evaluate the available contents at each grave using (4), and then suggest the five pieces of content with the highest similarity. Fig. 4 shows this procedure as a flow chart.

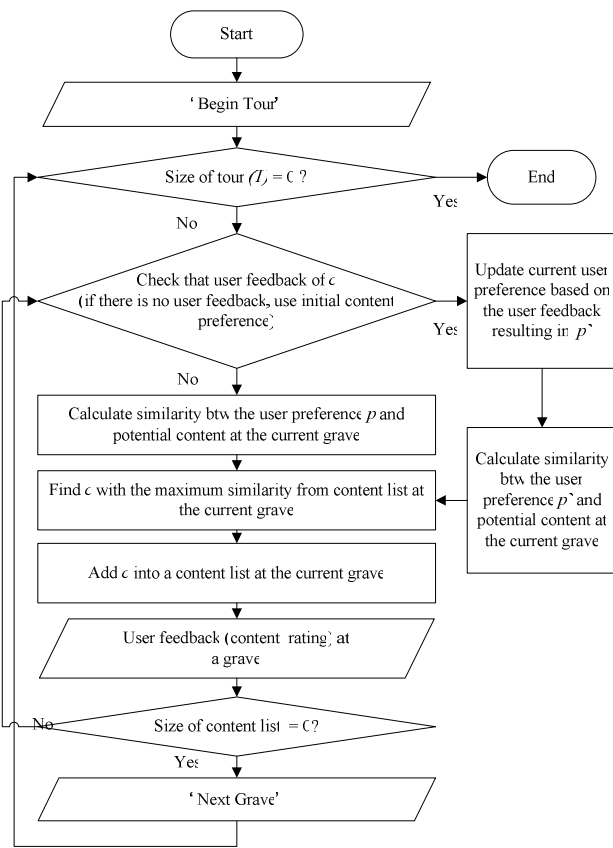


Fig. 4. The flow charts for content recommendation in personalization.

3) Social Connectedness: Eavesdropping

The last but most important aspect of our work is our effort to support social interaction, enabling visitors to share their experience by implementing an “eavesdropping” function. Visitors could eavesdrop on other group members when they are far away to see if they’re listening to anything interesting, and perhaps go find them if they would like to join them at their point in the tour. Our audio sharing metaphor is similar in spirit to the functionality of Sotto Voce, but has some subtle yet significant differences. In Sotto Voce, paired visitors share audio content as follows. When visitor A selects a specific object on his device, he always hears his own audio clip about the object. If A is not currently playing an audio clip, but his companion B is, then B’s audio clip can be heard on A’s device. In other words, personal clips are always played in preference to eavesdropped clips about a specific object. On the other hand, visitors in our cemetery experience can freely pause personal clips to eavesdrop on the others’ clips and then resume the personal clip where it is stopped before eavesdropping.

Moreover, there is an important difference in how we designed audio synchronization for sharing. In Sotto Voce, the way that audio playback on the paired devices is synchronized is as follows; if A and B are both listening to their own clips and A’s clip ends first, A will then hear the remainder of B’s clip as if it had “started in the middle.” In our cemetery experience, we allow the visitors to control the

others’ audio experience. For example, if user A (the eavesdropper) wants to share a particular audio clip with user B, user A simply selects that clip, since all “synchronized” listeners implicitly have control over what each other is listening to. We believe that difficulties or disagreements that result from this level of interaction are likely to be resolved socially. Fig. 5 shows the overall process of the phase in which one user eavesdrops on and controls the other in our audio sharing function.

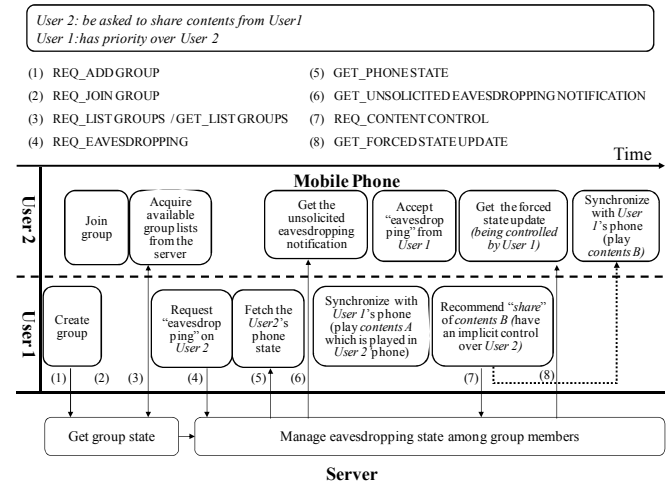


Fig. 5. A process flows for contents sharing among group members.

By relying on social negotiation, rather than an elaborate security and permission scheme, the interface for the group tour is simple and almost completely transparent, while at the same time providing maximal flexibility. For example, it may be possible that user A wants user B to listen to a particular clip, but it would be rather disruptive having audio starting suddenly on user B's side while he is either listening to something already, or browsing the map to find another grave that he can visit. We wanted to reach a satisfactory compromise between the simplest interface and undistruptive user interaction. When user A eavesdrops, user B is automatically synchronized (content-wise). If user A switches graves in grave mode while in sync, user B will switch graves in that mode too. Here, synchronized content contains both audio and visual about a specific grave. For the simplest yet most flexible interface, we leverage the fact that group members are supposed to be friends, and let social protocols be the "security," rather than a collection of annoying button clicks, etc. We decided not to synchronize the displays in map mode, because doing so prevents a group of people from trying to do other things while synchronized, such as browsing nearby graves.

In the end, our design has two benefits in addition to facilitating group interaction. First, the audio sharing interface is relatively simple at enabling listeners to implicitly have control over what the others are listening to. Second, there is no synchronization of the phone displays outside of grave mode, only audio mode (in grave mode, all users see the same

visuals, corresponding to the current audio clip). Users are thus able to browse the map while the audio is still playing, reducing the disruption to interaction.

C. Platform and Interface Controls

Our implementation of the cemetery media experience was programmed for a mobile phone and runs on Java 2 Micro Edition (J2ME). Fig. 6 shows the overall system configuration. To support mutual real-time eavesdropping among a group of people, paired mobile phones communicate with a server over the WLAN. To obtain location information in our system without any extra installation of sensing equipment on site, we adopted GPS technology with both the built-in GPS of the mobile phone, as well as an optional bluetooth-enabled GPS device for users to carry with their mobile phones. The system transfers the GPS locations to the server via WLAN.



Fig. 6. System configuration: platform and hardware setup.

The mobile phone has 240mm x 320mm display resolution, similar with most PDAs' resolution. For input, some current phones and PDAs use touch-screens for direct manipulation and rich interaction. Many mobile phones, however, only support traditional keypads. Chong et al. investigated user interface design requirements for mobile devices [12]. In an effort to support the widest range of devices, our design minimizes redundant or insignificant features, allowing us to control the interface with a typical phone keypad. We have avoided using menus where possible by having the keypad mapped to different functions in each of the two modes of the tour as shown in Fig. 7.



Fig. 7. User interface for user input control during tour.

IV. EVALUATION AND OBSERVATION

Our mobile tour guide seeks to strengthen the user experience in a cultural heritage site by supporting spatial awareness, personalization, and social connectedness. For this purpose, we applied our system to such a site. In this section, we present our methods for conducting a user study of our system and the results from that study. We also conducted a performance evaluation to investigate the effectiveness of both content filtering and content.

A. Experimental settings and procedure

For our study, we recruited 12 participants in groups of 2, with a study of up to 6 groups (3 friend groups and 3 family groups). We asked each group to experience our mobile phone-based tour guide system, letting the system log data in the background. Prior to their experience, the participants were given an introduction to the system they would be using. After the tour, participants were asked to fill out a questionnaire and participate in interviews. With respect to spatial awareness, we logged and gathered data such as users' position information during their tour (GPS data) and users' various commands from the user study.

To verify the effectiveness of personalization, we conducted a performance evaluation. To test with a huge amount of potential content, we expanded the number of story nodes implemented in the first prototype from three gravesites to seven. The entire experiment involved a total of 147 audio segments (covering seven gravesites) lasting from 20 seconds to 2 minutes. All participants were asked to listen to content of their choice with the system. We adopted two criteria for evaluating filtering effectiveness: precision and recall [24]. In our evaluation of social connectedness, we asked the participants to complete tasks in order to investigate the effectiveness of audio synchronization with our sharing interface. Participants took part individually in a single 15-minutes session during which they completed two trials. Each trial was done in two ways: (1) automatically, using our sharing interface, and (2) manually, not using our sharing interface. The first trial consisted of the task in which content of my partner should be synchronized on my mobile phone. The second task required my content to be synchronized with my partner's mobile phone.

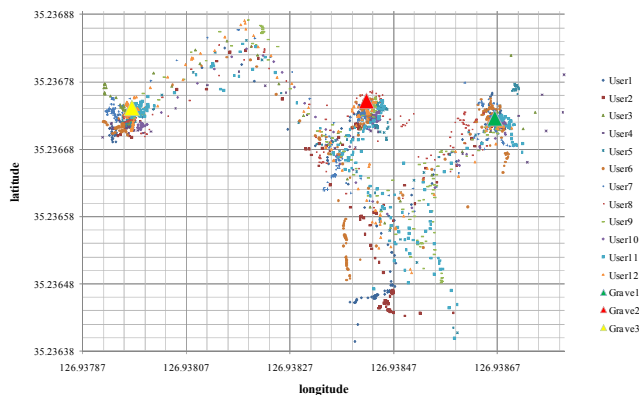
B. Results and Analysis

The evaluation brought to light specifics of the new experience our system provides as well as corresponding challenges.

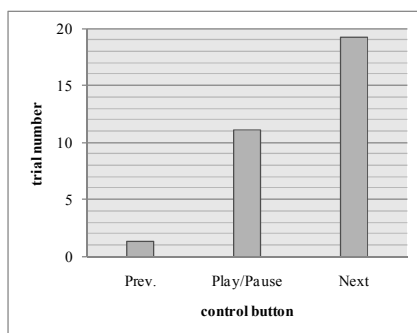
1) Spatial Awareness: GPS Mapping

It was revealed that the participants were satisfied with their overall tour experience without location-awareness through fine-grained sensing of GPS since they relied on a linear tour to get a framework for the experience. Fig. 8- (a) shows the GPS data from the twelve participants during our user study. On one hand, the latitude and longitude position data reveal inconsistencies and occasional errors with a fluctuation of about

5-10 meters difference between users. This implies that GPS alone is not reliable for fine-grained sensing such as knowing when a user is near a specific grave. Despite the inaccuracy of GPS data, the position of the users can provide a rough mapping for the spatial narrative. It was revealed that our linear tour assisted in prompting participants not to walk away from a main tour route. On the other hand, many users continued to interact with the system by pressing narrative audio control buttons to navigate the cemetery as shown in Fig. 8 - (b). Judging from the interviews, some participants enjoyed navigating with the help of both audio narrative and GPS-based map in the cemetery, while others commented that “It seems to be useful to have a visual map, but not so essential since audio narrative content is pretty clear for easy finding.” It is evident that they were going for navigation mainly by pressing the “Next” button while occasionally using the “Play/Pause” button and rarely “Prev.”. Thus, the data indicate that knowledge of a user’s position should not be the only factor determining which audio segment to play; however, as other attempts to use GPS for location-based systems have shown, GPS technology has limited absolute accuracy, but can still enable the system to make certain decisions at runtime. For example, decisions on a large range, such as knowing when a user is near a group of graves, will still be possible using GPS and we plan to design for location-awareness under this constraint in the future.



(a) GPS data for all participants

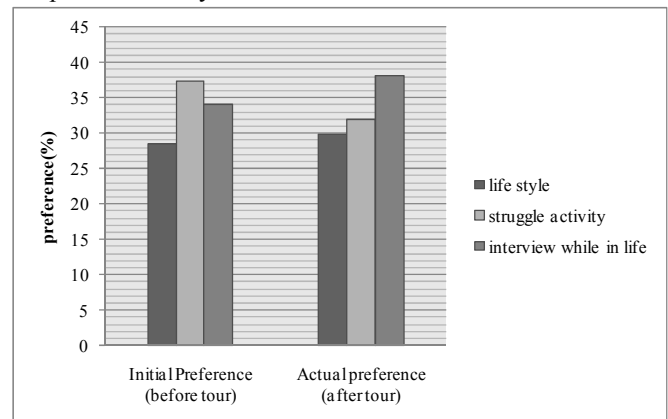


(b) Audio Control Buttons in Navigation Mode

**Fig. 8. Observation data: (a) GPS data for all participants, (b) audio control buttons in navigation mode.**

## 2) Personalization: content filtering

We validated that the content presented to visitors was better tailored to their real-time feedback over the course of their visit than to their initial user preferences. As shown in Fig. 9, the initial content preference of users was not consistent with actual buttons pushed over time for content choices during the tour. Overall, users explored “the interview while in life” content the most among three categories after tour. From the interview, we found that most of users liked “the interview while in life” content the most but prefer a variety of content.



**Fig. 9. Preferences in three content categories (a) before tour, (b) after tour.**

For the quantitative data analysis, we used the weighted harmonic mean of precision and recall, the traditional F-measure or balanced F-score [25] to verify the effectiveness of content filtering in our personalization module referring to (5), (6), and (7). In general, precision can be used as a measure of the ability of our system to present only relevant audio clips. Recall can be used as a measure of the ability of our system to present all relevant audio clips.

$$F - score = \frac{2 \cdot precision \cdot recall}{(precision + recall)}, \text{ where} \quad (5)$$

$$Precision = \frac{recommended \cap interested}{recommended} \quad (6)$$

$$Recall = \frac{recommended \cap interested}{interested}. \quad (7)$$

As shown in Fig. 10, we realized that F-score values of most graves using user feedback were higher than using only initial preference. As other attempts [26] to experimentally validate that people’s opinion about items can change as a result of their topical relatedness to a shown item have shown, our content filtering mechanism basically guaranteed that the ratings of topically related content were more likely to increase. At the same time, specific content with negative user feedback can be given low priority, even if that content is topically related.

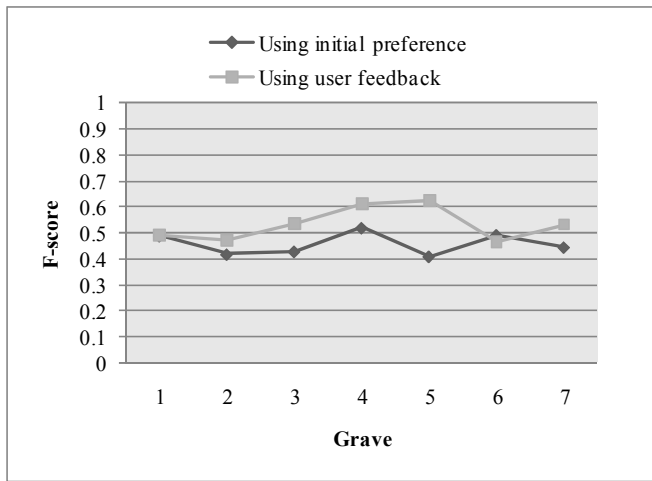


Fig. 10. F-scores in cases of using initial preference and using user feedback.

From the experimental results, we concluded that our system, especially content recommendations made using user feedback with rating interface, can reflect user preference constantly changing from grave to grave, with good filtering effectiveness.

### 3) Social Connectedness: audio synchronization

As a matter of prime importance, we found that our design of a sharing scheme with mutual eavesdropping and content control contributed to facilitating group interaction, that is conversation, by information sharing and content synchronization, both because of the existence of the sharing function itself and because of the ease of interface manipulation. In the interviews, most users commented that they had more chances for conversation by using the sharing function in our system guide than they had in any other electronic tour guide. They commented that they were able to exchange opinions regarding specific content they were currently sharing. They also said they could talk together without using the sharing function; however, they thought it was very troublesome to share content with manual synchronization.

For quantitative data analysis, we measured completion time according to the manner of each trial. Using these data, we calculated the average time of each of the 12 participants in each trial. Here, we present the average values of the two specified manners for doing the trials. Fig. 11 shows the time it took users to do content synchronization with and without sharing interface on two tasks. Average manual synchronization in the first task was 10.4 sec. and average automatic one was 3.9 sec. The average manual synchronization in the second task was 10.89 sec. and average automatic one was at 7.78 sec. We found it was inconvenient to synchronize a specific content clip without a sharing interface, since participants needed to adjust which category the clip belonged to and where the clip stood in the list of the category, one by one. In particular, it was revealed that our

sharing interface is very useful at the moment participants find a certain clip undeniably impressive and want to share it with their members immediately. Thus, our sharing module motivated participants to share content with the help of our simple interface.

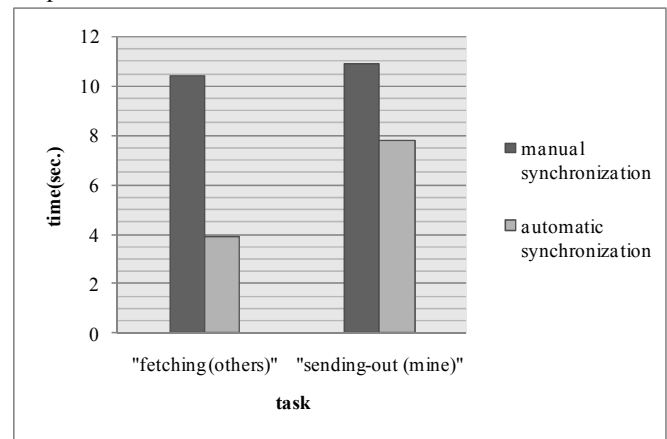


Fig. 11. Time it took users to do content synchronization with and without sharing interface on two tasks.

## V. CONCLUSION AND FUTURE WORK

We have built a mobile phone-based system to support users' spatial, personal, and social desires when visiting an historic cemetery. Our work on mobile entertainment systems has revealed several future research and design questions.

Spatially, while the overhead map view can be easily generated, it may not provide the best interaction for helping users understand their location. At this point the system does not provide orientation data, so users may make it to the right vicinity but face the wrong direction. Also, cultural heritage sites face the challenge of producing maps or aerial photographs without natural obstructions, like trees. Literature on cartographic interaction can shed light on how to deal with this issue.

For better personalization, mobile phones with small displays and slow input methods present a challenge for collecting the personal data required to customize the user experience. Users may be unwilling to fill in forms about preferences, especially if they do not plan to return to that place in the future. Our goal is to collect a minimal amount of personal information upfront and then non-intrusively infer visitors' preferences based on content selection and his/navigation of the same. We plan to implement and evaluate user modeling techniques to present more adaptive content recommendations.

Socially, in historical sites such as graveyards with densely packed points of interest, two people can be standing close together and looking at entirely different aspects of the site. We have implemented eavesdropping as one method to easily "skim" or "browse" interesting things another user might have discovered. Another technique would be to allow visitors to selectively share what they've been experiencing. System cues may help facilitate social interaction. We can look at how long the user has been listening and the user's recent

play items to help a social group find points of interest and avoid uninteresting items.

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