Reuniting group in densely crowded environments using situated dynamic signage

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ABSTRACT

Large crowds can occur at events such as political gatherings, sport matches or pilgrimages. Frequently, participants attend in groups (family, friends, and like-minded people) to support each other and/or to share the experience. If groups are separated during the event, this can lead to stress and discomfort, and can thus negatively affect their experience. In this paper, we propose an approach reunite groups that use situated dynamic signage and the structure of the environment. Additionally it can be used without being able to read and does not require people to carry a mobile device. We evaluated two examples applications of our approach using the pilgrimage to mecca as example scenario. The results indicate that group member can use the approach to navigate to a group-specific meeting point and that participants find its use in such a highly spiritual setting acceptable.

Keywords: Dynamic signage, crowds interfaces, cross-cultural interface, public displays, user studies.

1. Introduction

Political gatherings such as demonstrations, sports events such as the world championship or concert such as big open air events can attract very large crowds. These crowds have a common purpose but also have to deal with the challenges of being part of such crowds, e.g. navigating in an unfamiliar area that densely crowded, attending to their own needs, or ensuring their own comfort and security. One of the most challenging events of this type is the hajj the pilgrimage to mecca, one of the five pillars of Islam

In 2018, 1.75 million Muslims from all over the world converged on mecca to perform hajj. They were joined by 1.4 million Saudi Arabians in performing a set of rituals during the five-day pilgrimage, while moving between different locations in and around Mecca. In doing so, people frequently travel in groups of family, friends or compatriots. Due to the scale of the event, finding ones group after having being separated is a big problem. In this paper we thus investigate whether situated dynamic signage can help people to reunite with their group in case they were separated in a densely crowded area. We propose an approach that uses spatial partitioning, static and dynamic signage, and the structure of the environment to direct group members to a group-specific meeting point.

The remainder of the paper in structured as follows. We first present an analysis of the example scenario as well as key issues and constrain resulting from it. We then discuss related work and briefly evaluate it in the context of our methodology we used in carrying out this research, and then introduce our approach to support the reunification of groups in densely crowded areas. In the next section, we report on a user study we conducted to evaluate the approach before discussing the main results we obtained. A brief summary concludes the paper by night lighting its main contributions and future work.

2. Scenario

In order to design, test and evaluate an approach to enable groups to reunite during large events, a number of scenarios are conceivable. We chose to use the Muslim pilgrimage for a number of reasons as outlined below. Within the Muslim faith, the pilgrimage to mecca (the hajj) is one of fife so called pillars that define what constitutes correct behavior. During the pilgrimage, millions of people perform a series of rites in different sites and around mecca.

The great mosque in mecca is an important location during the hajj and visited repeatedly. Several rituals are performed at this site, and it houses the ka'bah (a small black building of great religious importance). The large roofless plaza at the center of the building is highly symmetrical, with the ka'bah at its center. The surrounding multi-story structure contains a large space supported by pillars. A number of corridors lead from the outside of the building through the pillared hall to the central plaza.

This scenario exhibits a number of interesting properties and challenges. Due to the densely crowded environment, it is easy to become separated from one's group. In addition, a very diverse set of people with different abilities and backgrounds participate in the event. Pilgrims come from many walks of life, speak different languages and not everyone can read written text (e.g. in Arabic). People wear special clothing that makes it difficult to carry many things such as mobile phones. The pilgrimage is also a highly spiritual event, which means that any approach to help people reunite with their group should not dramatically change the appearance of the environment and should not interfere with people's experience. Consequently, a solution that succeeds to reunite groups in this setting is likely to work well in less challenging scenarios.

Use different modalities to support navigation. Frequently, social networking applications such as foursquare or face book also provide means to localize friends. However, it is difficult to carry mobile devices during the Hajj and not everyone has access to them or is capable of using them. Generally, the use of a mobile device in a dense, moving crowd can be dangerous as it might disrupt the flow and/or lead to people tripping or falling. Consequently, none of the discussed approaches seems to provide a solution that would work well in a very densely crowded environment. In the context of the Hajj, a further drawback relates to the nature of the event: any system that would interfere with the experience (e.g. taking out a mobile phone during prayer) would arguably miss the mark. In the following, we thus first describe our approach to the problem before detailing our proposed solution.

3. Related work

There are a number of areas, which are relevant to the problem of reuniting groups in crowded areas. In addition to traditional means such as static signage and agreed meeting points, mobile systems as well as dynamic signage can support people in this task. Static signage [1] is a very common tool that people use to navigate unfamiliar area. When it is designed well and placed at the right locations [13], it enables large numbers of people to reach their destination. If groups agree on a meeting point before their visit, static signage can help them to meet up after being separated. Key disadvantages of this approach are lack of universal readability, lack of personalization and lack of scalability: if all groups who were separated meet up at the same location, that location may become very crowded. Hamhoum et al. [4] proposed an approach to overcome this issue by augmenting regular signage with codes and symbols, which corresponds to a set of locations. Using a spatial partitioning in combination with the signs allows for fine-grained crowd control if groups are assigned a symbol prior to their visit. The approach presented here extends [4] by dynamically assigning codes to groups based on their trajectory, and by combining dynamic and static signage. Dynamic signage provides more flexibility than static signage without necessarily requiring people to carry a mobile device. Ahmed Sheikh A and Abdul [14] developed a novel system implemented as a mobile application to inform pilgrims about the importance things around the Holy Ka'bah . Gaudi [6] is an example system that provides individual directions via a network of public displays. In its initial version, it lacks scalability due to being a single-user system and its use of annotated arrows. K. Moumane, A. Idri, A. Abran [16] evaluated the usability of mobile applications running on different mobile operating systems, including Android, iOS and Symbian. The results obtained a set of mobile usability problems that are related to the mobile design. Cross-modal displays [9,12] use moving imagery and cross-modal cueing on a personal device to facilitate imagery. Due to the difficulty of carrying and using mobile devices, sensing tactile cues in a crowd and the frequent use of floor-projection, this approach is not well suited for densely crowded areas in general and the Hajj in particular. Mobile systems can help people to find their group after being separated. Abdel Mouty and Christian Kray [15] Evaluated mobile applications in virtual environments. Many mobile guide systems have been developed in research [3, 10] and commercially [1], which use different modalities to support navigation. Frequently, social networking applications such as foursquare or Facebook also provide means to localize friends. However, it is difficult to carry mobile devices during the Hajj and not everyone has access to them or is capable of using them. Generally, the use of a mobile device in a dense, moving crowd can be dangerous as it might disrupt the flow and/or lead to people tripping or falling. Consequently, none of the discussed approaches seems to provide a solution that would work well in a very densely crowded environment. In the context of the Hajj, a further drawback relates to the nature of the event: any system that would interfere with the experience (e.g. taking out a mobile phone during prayer) would arguably miss the mark. In the following, we thus first describe our approach to the problem before detailing our proposed solution.

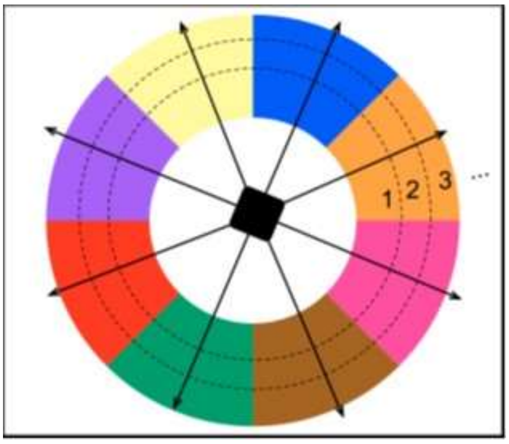

Figure 1. Spatial partitioning of Great Mosque into coloured wedges defined by corridors; wedges are further subdivided into concentric sections (labeled 1, 2, 3 …)

4. Approach

We first designed an approach and then discussed two possible instantiations in a focus group with people who had previously participated in the Hajj. Based on their feedback, we refined the designs. Our approach combines two basic idea: (1) dynamic assignment of visual codes to groups, and (2) mapping these visual codes to specific sections of the environment. Fig. 1 shows a schematization of the Great Mosque, and a spatial partitioning (colored wedges) – different subdivisions for other spaces would be possible as well (cf. e.g. [4]). Each colored wedge is situated defined by a corridor, and is further divided into a number of subsections (labelled 1, 2, 3 in the figure) via concentric circles that define the borders between subsections. If we can assign specific subsections to a particular group, then we greatly reduce chances of large numbers of people trying to meet at the same location and we reduced the size of the area where groups should meet. By assigning each subsection a visual code, they can be communicated to groups. The visual code consists of a color (indicating the wedge) plus a marker (indicating the subsection within the wedge). We created two different designs for the markers: one similar to the sides of a dice (one to six circular dots) and one showing different symbols related to the Muslim faith (e.g. the Ka'bah, the Quran). Figure 2 (a) depicts the visual codes in the dots and in the symbol condition. Feedback from the focus group led us to limit the number of subsections per wedge to six. Static signs alongside the corridors indicate to pilgrims, which subsections are adjacent to them, and which way they need to move to reach other wedges. Figure 2 (b) depicts such an example. The top part indicates the current wedge via the background color shown, and the symbol (or dot) specifies the adjacent subsection. The bottom part indicates in which direction people have to move in order to reach wedges of different colors. Arrows signal whether to turn left or right; if no arrow is shown, people have to keep walking along the corridor. In the sign shown in the Figure 2(b), people are adjacent to the third subsection of the orange wedge for example (labeled '3' in Figure 1).

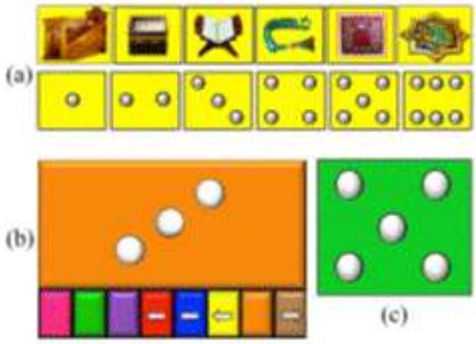

Figure 2. (a) Visual codes assigned to sections: symbols (top) and dots (bottom); (b) static signage along corridors; (c) example content of dynamic displays

The final component is a public display that dynamically assigns specific subsections to particular groups. These displays are mounted at entrances to crowded areas, e.g. at the gates of the Great Mosque. They cycle through all combinations of colors and symbols/dots, showing only one at any time (see Figure 2(c)). For example, the display may first show the Quran on yellow, then the Ka'bah on yellow, and so on until all symbols have appeared once on yellow background. It then repeats all symbols in the same order on blue background and then on all other colors. The assignment of codes to groups occurs as groups pass by a public display. The jointly look at the dynamic display and memorize the visual code shown at that time (e.g. "red 3" or "blue Quran"). If later on the group is separated, they use this visual code and the static signage to navigate to the same subsection of a specific wedge. Since the dynamic display cycles through all combinations, groups are equally distributed over all subsections. Feedback from the focus group on an earlier design was very positive: the majority thought it would be useful for pilgrims and that it would be acceptable to install in this place of or ship. Further comments regarding size and placement of signs were incorporated into the design presented in this section.

5. User study

In order to evaluate our approach, we carried out a user study. The main aims of the study were to assess whether the approach enables group members to find each other, and to characterize its properties, strengths and drawbacks.

5.1. Participants

We recruited 20 participants (aged from 20 to 56 years) from various societies affiliated with the Muslim faith in City. Ten of them were male, ten female. Half of the participants had been on a pilgrimage102 to Mecca. The other had not been but claimed familiarity with the Hajj.

5.2. Stimuli

As it was unfeasible to run the study at Mecca (e.g. due to logistics, scale, bureaucratic hurdles), we designed a lab-based study that simulated key aspects of the proposed approach. The stimuli were shown on a 50” screen and consisted of the signage shown in Figure 2(b) and (c). In order to simulate movement – i.e. pilgrims approaching a sign on foot – we created animations that scale up each sign from filling 15% of the screen to filling the entire screen. Pre-tests suggested duration of 15s for these animations. In order to test the memorability of the color-symbol/color-dots combinations, we also introduced a distraction task. Here we used the same screen to show slides consisting of a photograph depicting activities, events and objects relating to the Hajj, and a short sentence describing the content of the photograph. On some slides, the photograph and the sentence were consistent, whereas on others they were not.

5.3 Procedure

Participants had to fill out questionnaires at the beginning and end of the study. The initial one asked about their background and demographic details, and the final one asked them compare the two conditions (dots, symbols) tested in the main part of the experiment. Each of the two conditions consisted of six trials. Before the trials, participants were briefed about what they had to do. Each trial was structured as follows: first participants had to walk in place in front of the screen (to simulate movement towards the sign) and memorize the visual code (e.g. as shown in Fig. 2(c)) that it showed when it filled the entire screen. During the second phase, participants had to perform a distraction task: they were shown images relating to the Hajj with sentences that either matched the image or not. After 15s, the image and the sentence disappeared and people had to indicate whether the matched or not. This was repeated eight times per trial. In the third phase, participants had to stand on a paper circle in front of the display, which had three directional arrows printed on it (left, right, forward). They were then shown examples of static signage (similar to Fig. 2(b)) for 15s as they would experience them following a corridor. Participants had to indicate the direction they need to take to reach the location assigned to the visual code. They could do so by putting one foot on the corresponding arrow on the paper circle. This was repeated six times per trial. At the end of a trial, we asked people to tell us the visual code they had to remember. At the end of each condition, participants filled out a questionnaire rating the condition. We recorded the entire experiment on video, and used the footage to extract direction choices and the visual codes that participants recalled after a trial.

5.4 Results

Due to space limitations, we cannot present all results we obtained but the following paragraphs summarize the most relevant findings. Overall, we recorded no recall errors and no incorrect direction choices. There were also no cases, where participants were unable to pick a direction within the 15s while a static sign was shown. On average, people responded in a little less than 12s, and we found no notable differences between conditions or between pilgrims and non-pilgrims. The questionnaire at the end of each condition included an assessment of the workload (based on the NASA TLX [5]), which was rated on a Likert scale ranging from one (very low) to five (very high). Both conditions received a low average workload rating: 1.64 for the dots condition and 1.55 for the symbol condition. In addition to workload assessment, a section with questions from the IBM Computer Usability Satisfaction Questionnaire [7] was included in the questionnaire. These were also rated on a five-point Likert scale (one corresponding to the lowest rating, five to the highest). The average rating for the dot condition was 4.5, and 4.45 for the symbol condition. A further question queried participants whether the installation of such as system at the Great Mosque in Mecca would be acceptable. In the dots condition 80% (16/20) of the participants found this acceptable, whereas 20% (4/20) were unsure. Nobody rejected the idea. In the symbol condition, 100% (20/20) of the participants found the installation acceptable. We also asked whether participants thought that the system would be helpful for pilgrims visiting Mecca. Answers were given on a five-point Likert scale, where one corresponded to strong disagreement and five to strong agreement. The average rating for the dot condition was 4.5 and for the symbol condition 4.55.

6. Concluding Remarks

The study and thus the results we obtained were subject to a number of limitations. We tried to simulate movement but results might have been different if participants had truly had to walk longer distances in a realistic environment. Since we observed no errors, it is also possible that the distraction task was too easy and/or too short, which could have affected the outcome. Nevertheless, the results provide initial evidence that people can use the system to obtain a visual code and then use it to find the corresponding meeting area. The approach incurred a low workload, and was rated highly in terms of usability. Formal and informal feedback indicated that installing such a system at Mecca would be acceptable, and participants considered it to be useful for pilgrims visiting the city. Overall, qualitative feedback from the focus group and free text response from the questionnaire seemed to slightly favor the symbol condition – possibly due its tighter link to the spiritual nature of the pilgrimage. Promising directions for future research include evaluating the approach in different scenarios, deploying it in a real world environment, and assessing its scalability in detail.

7. References

[1] Arikawa, M., Konomi, S., and Ohnishi, K. Navitime:Supporting Pedestrian Navigation in the Real World. IEEE Pervasive Computing, vol. 6, no. 3, 21-29, 2007.

[2] Arthur, P. and Passini, R. Wayfinding - People, Signs, and Architecture, McGraw-Hill, 1992.

[3] Cheverst, K., and Davies, N., and Mitchell, K., and Efstratiou, C. Developing a Context-aware Electronic Tourist Guide: Some Issues and Experiences. In Proc. Of CHI 2000, ACM Press, New York, 17-24, 2000.

[4] Hamhoum, F. and Kray, C. Scalable Navigation Support for Crowds: Personalized Guidance via Augmented Signage. In Proc. of COSIT 2011, Springer, Berlin Heidelberg, New York, 40-56, 2011.

[5] Hart, S. G., and Staveland, L. E. Development of NASA-TLX (task load index): Results of empirical and theoretical research. Human mental workload 1, 3 (1988), 139-183.

[6] Kray, C., Kortuem, G. and Krueger, A. Adaptive navigation support with public displays. In Proc. of IUI 2005. ACM Press, New York, 326-328, 2005.

[7] Lewis, J. R. IBM computer usability satisfaction questionnaires: psychometric evaluation and instructions for use. International Journal of Human- Computer Interaction 7, 1, 57-78, 1995.

[8] The Ministry of Hajj, Kingdom of Saudi Arabia. Hajj. http://www.hajinformation.com/main/f.htm, 17/09/2013.

[9] Olivier, P., Cao, H., Gilroy, S. W. and Jackson, D. G. Cross-modal Ambient Displays. In Proc. of HCI 2006, Springer, Berlin, Heidelberg, New York, 3-16, 2006.
[10] Pielot, M., Poppinga, B., Heuten, W., and Boll, S. PocketNavigator: studying tactile navigation systems insitu. In Proc. of CHI 2012. ACM, New York, NY, USA, 3131-3140, 2012.
[11] Royal Embassy of Saudi Arabia, Washington DC, USA. http://www.saudiembassy.net/latest_news/news1027120 1.aspx, accessed on 17/09/2013.
[12] Rukzio, E., Muller, M, and Hardy, R. Design, Implementation and Evaluation of a Novel Public Display for Pedestrian Navigation: The Rotating Compass, Proc. of CHI 2009, ACM Press, New York, 113-122, 2009.
[13] Xie, H., Filippidis, L., Gwynne, S., Galea, E. R., Blackshields, D., and Lawrence, P. J. Signage Legibility Distances as a Function of Observation Angle. Journal of Fire Protection Engineering, 17, 1, 41-64, 2007.
[14] Ahmed Sheikh A. Al-Aidaroos, Ariffin Abdul Mutalib, Multiple input modality mobile application for pilgrims, in: Knowledge Management International Conference (KMICe), 12–15 August 2014, Langkawi, Malaysia, pp. 512–517.
[15] Delikostidis, Ioannis, Thore Fechner, Holger Fritze, Ahmed Mahmoud AbdelMouty and Christian Kray, Evaluating mobile applications in virtual environments: a survey, IJMHCI 5.4 (2013): 1–19. Web. 28 Mar. 2017. doi: http://dx.doi.org/10.4018/ijmhci.2013100101.
[16] K. Moumane, A. Idri, A. Abran, Usability evaluation of mobile applications using ISO 9241 and ISO 25062 standards, SpringerPlus 5 (1) (2016) 1–15, http://dx.doi.org/10.1186/s40064-016-2171-z.