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Toward Guidelines for Designing Handheld Augmented Reality in Learning Support

Marc Ericson C. SANTOS[a*], Takafumi TAKETOMI[a], Goshiro YAMAMOTO[a], Ma. Mercedes T. RODRIGO[b], Christian SANDOR[a] & Hirokazu KATO[a]
[a]*Interactive Media Design Laboratory, Nara Institute of Science and Technology, Japan*
[b]*Ateneo Laboratory for the Learning Sciences, Ateneo de Manila University, Philippines*
*chavez-s@is.naist.jp

Abstract: Developing systems using emerging technology such as augmented reality is difficult because there are limited guidelines to inform developers during the design process. In particular, there are no established guidelines for learning support systems based on handheld augmented reality. To gather such design guidelines, we first summarize existing guidelines for handheld augmented reality in other fields of application. We then provide our synthesis of these guidelines into five design guidelines. We share our own experience of how we observed these guidelines in developing FlipPin – a handheld augmented reality system for learning new vocabulary. We then propose an additional guideline based on our experience.

Keywords: design guidelines, handheld augmented reality, learning support, mobile devices

1. Introduction

Designing effective user interfaces using emerging technologies is challenging because there are no existing design guidelines or interaction metaphors (Gabbard & Swan, 2008). Experienced developers rely on best guesses and intuition which novice developers have yet to develop. In some cases, developers propose completely new ways for users to perceive and interact with information. Thus, there is limited prior experience to inform the developer during the development process. To address this challenge, it is important to gather and synthesize prior experiences into design guidelines.

Augmented reality (AR) is an emerging technology that may be useful for education (Santos, Chen et al., 2014; Bacca et al., 2014). In AR, virtual information is presented on the real environment as if it coexists with real objects (Santos, Luebke, et al., 2014). It enables many compelling experiences in science education (Kaufmann & Schmalstieg, 2003; Ibáñez et al., 2014), language learning (Santos, Luebke, et al., 2014; Liu & Chu, 2010; Hsieh & Lin, 2006), history and culture (Rodrigo, et al., in press; Di Serio et al., 2013), etc. Among the many forms of AR, handheld AR (HAR) – AR running on handheld devices like smartphones and tablet – may be the easiest to deploy because of the increasing availability of handheld devices in schools. Although some design guidelines for HAR application exists, these guidelines were formed around more mature application areas of AR. There are limited design guidelines for developing HAR for learning support.

To gather design guidelines that may be applicable to learning support, we summarize existing guidelines for HAR applications. We then provide our synthesis of these guidelines and explain how we applied these to the design of FlipPin – a HAR system for learning new vocabulary. Based on our observations, we suggest that these guidelines are also applicable for learning support. Moreover, we recommend one more guideline for further investigation.

2. Related Work

Gabbard and Swan (2008) explain that design guidelines are important to inform the development process. When design guidelines are not available, developers need to conduct user studies to help guide their design. These user studies must be made as general as possible so that the findings could also be applied in other scenarios. Eventually, these individual findings are accumulated into design

guidelines and standards. Figure 1 shows how user studies help both the formation of design guidelines and development of a particular interface. Similar to Gabbard and Swan, we try to design our user studies with FlipPin (Santos, Luebke, et al., 2014) to have wider generalization.

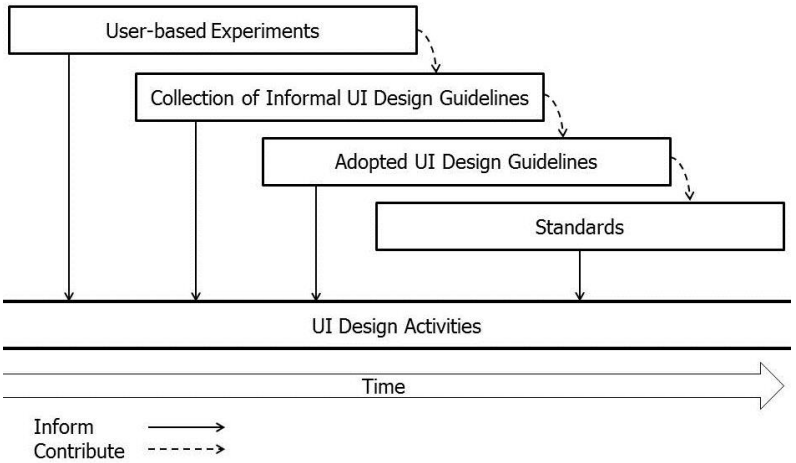

Figure 1. Gabbard and Swan's diagram for the development of design guidelines and standards for user interfaces (UI). The diagram emphasizes on the dual-purpose of user studies (user-based experiments). Experiments can both inform the design of a particular interface and accumulate into design guidelines. These guidelines, in turn, contribute to both UI design and establishment of standards.

Gabbard (2001) lists a comprehensive collection of design guidelines found in the virtual reality and AR literature from 1987 to 1999. Most of the guidelines focus on AR using head-mounted displays as the presentation device. The guidelines include insights on many aspects of AR systems such as visual feedbacks, tracking user location and orientation, data gloves and gesture recognition, users and user tasks, object selection and manipulation, etc.

Improvements in handheld devices (camera, processing power, large screen, etc.) and tracking and rendering algorithms have enabled developers to create AR applications running on smartphones and tablet computers. Some of the design guidelines from HMD-based AR may apply to HAR. However, HAR also has different usability issues that arise from the use of handheld devices (Santos, Polvi et al., 2014). Some design guidelines for HAR application exist. However, these guidelines were formed around more mature application areas of AR such as tourism (Kourouthanassis et al., 2013), navigation (Ko et al., 2013) and games (Wetzel et al., 2008).

3. Summary of Design Guidelines

Table 1 lists the design guidelines proposed by Kourouthanassis et al. (2013), Ko et al. (2013) and Wetzel et al. (2008) based on their experiences in making HAR applications for tourism, navigation and gaming, respectively. We found a total of 23 guidelines including 5 for tourism, 6 for navigation, and 12 for games. Although these guidelines are developed around specific types of commercial application, there are several overlaps that may be true for many HAR applications. For example, finding a specific place with the help of HAR is common for all these application areas. Another example would be the use of intuitive icons and menu navigation, which is also applicable to non-AR handheld applications. We summarize the 23 design guidelines into five design guidelines that we think may be applicable to HAR in learning support.

3.1 Design Guideline 1: Present Context-aware Content

AR is essentially a context-aware technology by its definition of presenting virtual objects or digital information on to a real environment (the context). As such, guidelines G3 and G4 in Table 1 emphasize on the purposeful use of the real environment. Moreover, developers should manage the presentation of virtual elements so that they do not obstruct the view of the real environment, as suggested in G8. Aside

from the location as the context, developers can also detect and use other contexts, such as time and user intentions. Based on this context, content can be filtered, as suggested in guidelines T1 and N2.

Table 1: Design Guidelines for HAR in Tourism, Navigation and Games

Application Area	Design Guidelines
Tourism	T1. Provide context-aware content by understanding the users' context using sensing and marker technologies. T2. Provide relevant content by allowing the user to personalize, expand, or limit the presented information. T3. Protect the users' privacy. T4. Provide user feedback on the status of the application. T5. Use familiar icons and interaction metaphors.
Navigation	N1. Allow users to navigate hidden virtual information by operating the camera. N2. Limit the amount of information using the user's context, search result ranking, and/or user input. N3. Use familiar icons consistently and provide quick support to clarify icon meanings. N4. Allow users to modify the breadth of their search. N5. Provide a help menu for HAR features. N6. Support operations using only one hand.
Games	G1. Focus on game design by designing the game experience first before deciding the technologies required for implementation. G2. Stick to the theme of the game by selecting technologies that are relevant to the time period and ambience. G3. Make the user interact with a combination of real and virtual objects. G4. Situate the game in meaningful environments, rather than simply placing virtual objects in arbitrary space. G5. Keep the interaction simple. G6. Allow users to easily share their experience. G7. Encourage interaction with other players, non-players and virtual characters. G8. Show the real environment by managing the virtual objects to not block the entire view of the real environment. G9. Use potential technical problems as game elements, thus part of the gaming experience. G10. Adapt, not directly convert, games from other formats to HAR. G11. Add meaningful virtual content that contributes to the overall game experience. G12. Select the most appropriate tracking method for your target game.

3.2 Design Guideline 2: Provide Content Controls

Aside from automatically managing content based on the users' context, HAR applications should provide ways for the user to adjust the amount and quality of the content. HAR applications are susceptible to presenting too much information, leading to cluttered screens. To address this, T2, N4 and G8 in Table 1 suggest that applications should allow users to hide, expand or personalize the presented content. For content hidden from the current view, N1 recommends to have hidden content be accessible via camera movement, such as appearing/disappearing depending on where the camera is pointing.

3.3 Design Guideline 3: Preempt Technical Difficulties

As an emerging technology, HAR is susceptible to many perceptual and ergonomic errors. Although AR technology is mature for several applications, AR researchers are still improving its related

technologies like tracking, sensor fusion and graphics rendering. Developers should compensate for this error by providing feedback to users on the current status of the application. For example, T4 recommends informing the user about the loading time of virtual data and if there is tracking instability. In some areas, it's possible to mask technical difficulties such as including it in the game experience, as recommended in G9. G12 recommends choosing the tracking method that would work best for the application. Lastly, N5 suggests having a help menu to assist users with common errors.

3.4 Design Guideline 4: Preserve Intuitive Icons and Menus

Icons and menus still apply for HAR applications. T5 and N3 suggest the use of familiar icons and menu structure, such as those from WIMP interfaces. In general, G5 suggests keeping the operations simple especially because we are dealing with a smaller screen compared to desktop computers. For novel icons and menus, T4 and N5 recommend features to assist users with operating the system.

3.5 Design Guideline 5: Promote Social Interactions

Aside from using HAR to support intuitive interaction between the users and the real environment, AR should support interactions among users, and between users and other people, as recommended by G7 in Table 1. Moreover, G6 suggests that HAR applications should provide ways for users to easily share their experiences whether face-to-face or through digital means of communication.

4. The FlipPin Application

We developed a HAR application called FlipPin which aims to teach new vocabularies on a real environment. To use FlipPin, users point the handheld device to objects marked by fiducial markers. Then, three-dimensionally registered sprite sheet animations illustrate the action of a verb. Users can hear proper pronunciations by pressing the "listen" button and read the translation of the target word by pressing the "translate" button. The application runs on iPad2 tablet computers and uses the ARToolKit for tracking. For more details, we discussed our design, implementation and user studies further in a previous paper (Santos, Luebke, et al., 2014).

Figure 2. The FlipPin interface (left) and the sample real environment (right)

4.1 Designing FlipPin

We tried to observe the five design principles discussed in Section 3 in developing FlipPin. First, we *present context-aware content* by applying three-dimensionally registered content. For example, in Figure 2, we illustrate the music playing ("spielen" is German for "to play") as virtual musical notes emerging from a real CD player. We *provide content controls* by rendering the content for the closest fiducial marker only. The content then switches to the next content when the user points the handheld device to a different marker. Moreover, we provide controls for toggling the text panels on and off. We made the text panels transparent to minimize obstruction of the view of the real world, while keeping the texts legible. We *preempt technical difficulties* by using fiducial marker-based tracking instead of point cloud based tracking. Point cloud-based tracking may be unstable to use for this type of scene with many movable individual objects as show in Figure 2, right. Moreover, in this scenario, the fiducial markers point the user to the real objects that are linked with virtual content. We *preserve intuitive icons and menus* by using the interface elements of the iPad, such as buttons and labels. Keeping the iPad interface elements allows users to apply their prior knowledge of using the iPad. However, instead of buttons with text labels, graphical icons may be more familiar for the users. Finally, we *promote social interactions* by locating the content in a place where people could study and chat with each other. In our user studies with FlipPin, the real environments that we used were an office (Figure 2, right) and a refreshment area where people eat snacks. We observed that even after using the HAR system, users would tend to discuss the content related to the objects marked by fiducial markers.

4.2 Lessons Learned

Based on our experience of developing FlipPin, we think that the five design guidelines that we derived from guidelines inspired by other fields of application are also useful for making applications for learning support. Such guidelines are important to inform developers of HAR applications given the developing nature of AR technology.

Aside from these five design guidelines, we propose the following guideline for further investigation:

4.2.1 Design Guideline 6: Pay Attention to Manipulability

Manipulability refers to the ease of handling the device when operating a HAR application (Santos, Polvi et al., 2014). One of the unique features of HAR is that it expects the user to handle and pose the handheld device in unconventional ways. We recommend limiting the amount of virtual information presented through AR to prevent fatigue. The rest of the information can be presented using more conventional display methods for handheld devices. We also recommend having interactions that allow users to rest before proceeding to the next subtask. For FlipPin, the users pointed the device to real objects in less than 20 seconds. Then, they put the device down and repeat the word to themselves. In addition, N6 in Table 1 recommends supporting one-handed operations.

5. Conclusions and Future Work

Guidelines are important to design effective HAR applications. However, in learning support, there are limited design guidelines to inform developers. In response, we synthesized five design guidelines based on other researchers' experiences of designing HAR applications for tourism, navigation and gaming. We then explained how we applied the five guidelines to our own application for learning support. Furthermore, we recommended an additional design guideline based on our experience. We think these guidelines are helpful in designing HAR applications for learning support.

In this paper, we offer the six design guidelines for further investigation. For easier memorization, the six design guidelines could be referred to as the Six Ps. The Six Ps are: **P**resent context-aware content, **P**rovide content controls, **P**reempt technical difficulties, **P**reserve intuitive icons and menus, **P**romote social interactions, and **P**ay attention to manipulability. We hope that these design

guidelines would be also helpful to other developers, especially for those who are beginners in HAR development.

Currently, our guidelines focus on usability and easing cognitive load which is important in learning support. To improve on these guidelines, we plan to compare it with existing guidelines for non-AR handheld applications for learning support. We expect these guidelines to grow our understanding of the best practices in the field. We can then modify the Six Ps or add some new guidelines. We also plan to continue developing FlipPin and other learning support systems that use AR. Through user studies, we can find possible improvements on the interface, as well as contribute to the growing knowledge on HAR design, especially in the field of learning support.

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