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INTERACTION EXPERIENCES IN MOBILE AUGMENTED REALITY

Nur Intan Adhani M. Nazri[a*], Dayang Rohaya Awang Rambli[a], Daniel C. Doolan[b]

[a]Computer Information Sciences, Universiti Teknologi PETRONAS, Perak, Malaysia
[b]School of Computing Sc. & Digital Media, Robert Gordon University Aberdeen

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*Corresponding author
nur.adhani_g01752@utp.edu.my

Graphical abstract

Abstract

The world of mobile computing has been advancing at a tremendous rate over the past numbers of years and is set to continue well in the future. The vast majority of interaction between the user and mobile of today makes use of touch screen displays that have now become the de-facto standard in all smart phones. This paper presents a mobile Augmented Reality (AR) application making use of different kinds of interaction techniques to investigate user experience and the usefulness of the AR technology. Comparisons are drawn with a ported version of the application that makes use of the more traditional touch screen interaction paradigm (2D), thus allowing users to accurately gauge their interaction style preference. The application also makes use of finger-based gesture, auditory (3D sound) and haptic based feedback to ground the user and create a richer experience. Our results shows that though the user feels that 2D interaction is easy to use, they find that using gesture based AR interaction is more fun and enjoyable in this mobile AR application.

Keywords: Augmented reality, mobile device, interaction, user experience

1.0 INTRODUCTION

Nowadays, the exponential advances of digital technology have brought a world of discovery with the potential of providing tools to support every conceivable aspect of human life. It has changed the way people think and learn, thus offering innovative and creative ways of interacting and presenting content to the user. Such innovation includes the rise in mobility and portability of mobile devices. Users are now utilizing their mobiles not only to connect through calls, messages, social networks (e.g. Facebook and twitter) and email, but also as an all-in-one multi-tasking tool. For example, as personal assistants, media center, office desk, navigator, game console and tour guide amongst others.

However, despite this widespread commercialization, most of the interaction between humans and mobiles are based on 2D touchscreen displays [1]. Thus, by introducing AR, it can even provide a new direction for the real world that we are living in, that is by placing virtual objects into the scene. In AR systems users are conscious of their surroundings while interacting with AR applications and the virtual content added to it [2].

Our proposed solution is to introduce a multimodal interaction technique together with the integration of multimodal feedback. Our unique solution allows direct interaction with the virtual objects, through the use of gesturing, device metaphor and additional user stimulus is provided by the use of auditory and haptic feedback.

Our experiments reveal that interaction in mobile AR is difficult due to several issues such as the acquisition of user inputs due to the small display size. Current techniques are often limited to pure 2D pointing, dragging and clicking through a devices touchscreen [4]. We were able to find from user feedback that 2D manipulations are easily controlled, though interaction in 3D space is more practical and engaging. In the context of the user experience, the gesture of flicking requires certain qualities from the user of both a temporal and spatial nature. While, flicking using touchscreen is practically instantaneous and requires less focus from the user, our experiment also shows that gesture interaction establishes a cognitive link that makes users feel as though they are able to move an object as they would in the physical world. We also find that although AR technology is well established, the uptake of people readily using it is quite low.

This paper is organized into several sections. Section 2 provides an underlying background and review of the current state of the art that is AR. This is followed with an outline of the prototype that was developed as part of the study. Details on the methodology used are also highlighted and finally, the results of the experiment are presented and discussed.

2.0 RELATED WORK

2.1 Concept of Mobile Augmented Reality

Mobile devices are becoming an essential tool to everyone with well over 96% (6.8 billion people) of the world's population actively embracing this new platform of pocket based computing [5]. Gartner state that, as smartphones are becoming more affordable, it helps to drive the adoption in current and emerging markets. Of the 1.875 billion mobile phones to be sold in 2013, 1 billion units will be smartphones, compared with 675 million units in 2012. Gartner also predicts that 1 billion smartphones will be sold in 2014[6].

A mobile AR application's efficiency is affected from the performance of the 3D libraries and complexity of the rendered objects. It consumes more processing power making it a challenge when instigating high level mechanisms [7]. However, mobile AR systems also affect the mobile user experience. The mobile user experience comprises the user's perceptions and feelings before, during and after their interaction with mobile presence either through an application or browser [8]. The process of designing and creating a mobile user experience that will readily engage the participants has led to the development of strategies, ideas and frameworks on how to create a richer experience[9].

2.2 Interaction Experience in Mobile AR

The interactive experience provided by mobile AR has led many designers to take a keen interest in this area due to the ubiquitous availability of high-end smartphones with in-build camera and touchscreen technology. Such methods of interaction allow for control with greater precise than ever before [10]. However, touchscreens provide opportunities to interact within a two dimensional space only, thereby making it difficult to control objects in the 3D world [11], in other words the manipulation of the 6DOF poses of an object. Interaction is a (physical or logical) communication means between the user and the application. It is where users are able to seamlessly access information and services regardless of the device they are using, even when the system or the environment changes dynamically [11].

A study has been done by Lee *et al*. where they proposed a new interaction method called "Freeze-Set-Go" (FSG) [12], [13]. It enables the user to 'freeze' the real view and continue to easily manipulate the virtual object within the AR scene. The proposed method succeeded in helping users to interact with the mobile AR environment in a more accurate and comfortable way. Although the FSG technique has proven its functionality, it is still lacking in providing an updated 'real' view as the physical objects remain as a still picture. In short, despite its strength in the shaky environment, it is still lacking in the level of immersion and realism envisaged by the user.

Hurst and Wezel [14] have done a study of interaction where they explored different approaches that rely on multimodal sensor input and focus on providing a more engaging experience. The work revolves around finding alternatives to touchscreen based interaction in mobile AR and manipulate the information delivered by the sensors integrated in modern mobile devices (camera, compass and accelerometer). A comparison is drawn with three different interaction modes, that of touchscreen, position and orientation of the device. Similarly, the main concern is the small screen size, some of the virtual objects cannot be moved using finger based interaction. It seems too big to fit in the camera and requires the user to hold the device in uncomfortable positions.

The preceding paragraph reveals that interaction in mobile AR is difficult due to several issues such as the acquisition of a precise interaction due to the small display size, shaky viewpoints as one hand is needed to hold the device and the other hand to interact with the object, with typical interactions often limited to pure 2D pointing and clicking the device's screen. This is because mobile AR requires the user to manipulate objects in 3D space to make it more interactive and not solely through pure 2D picking techniques [4], [14].

Based on the above mentioned views, it's evident that there is a need to focus on this area because interaction is a crucial medium of engagement between the user and the mobile device having a direct bearing on the user experience and level of satisfaction.

3.0 MOBILE AR PROTOTYPE

The most important issue in designing any real-time AR system is HCI that mixes the virtual object and environmental information in a user friendly way to interact naturally and can give a better user experience [15]. We constructed our mobile AR game prototype with the vision to examine user experience through a series of interaction trials. The application was firstly developed to allow touchscreen interaction, it was then enhanced to allow gesture based in-camera control of the 3D AR elements, the latter thereby providing a benchmark for comparison. The game itself is based upon the user navigating around a maze.

3.1 AR Marker

In past years AR markers made use of distinctive black and white patterns, advances in this area now provides the facility to use arbitrary imagery as markers. One can therefore readily use the printed matter visible on a physical product as the basis of a marker. In the case of the chocolate bar the front of the wrapper (Figure 1) when viewed through the application provides general information about the company and product along with an animation. The reverse of the wrapper allows the user to play the game.

Figure 1 Start the application to go to the main menu

3.2 AR Game

We design our prototype on the Android platform due to its domination of the market by using Vuforia SDK. The prototype is compatible with Android 2.3 and above.

The game is basically played by moving an avatar through a maze whilst collecting bubbles. Some instructions are also provided at the start screen (Figure 2). In this game, players will be given a time limit to finish the game and users will score a point for each air bubble they collect. When the marker is viewed from a distance the current score and navigation buttons will be visible as they are located on the periphery of the maze. To gain fine control of the avatar users typically find it easier to move the camera closer to the marker, thereby restricting their view to a small segment of the maze. The game also features a number of highlighted bonus areas with varying awards granted depending on the type of area.

Figure 2 (a) At the back of chocolate wrapper, there is a game plane where user can play game. (b)The user can read the instruction and click 'start' to play game

3.3 System Overview

Figure 3 depicts the system overview for the proposed approach. First, the camera will detect the marker and will retrieve the information (or 3D object) from the database. When the user makes a gesture like move with their finger within camera's field of view, the resulting movement will be detected. As a result if should the avatar collide with the users gesture an according force will be applied, thereby moving it about the maze. At the same time audio and haptic output will be delivered as an incidental effect of the gesture.

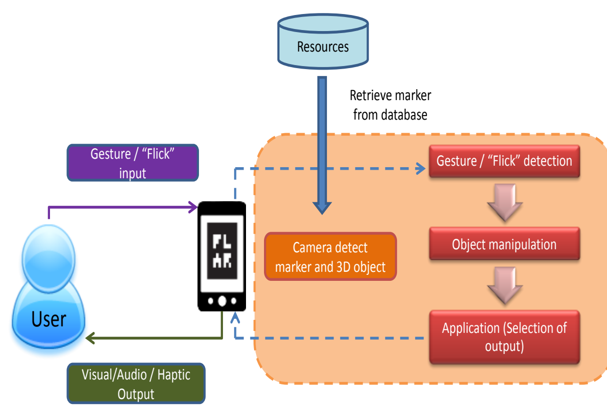

Figure 3 System overview

Table 1 shows the key prototype functions of the system. The AR system should be able to facilitate augmentation on the physical object in response to the capture of unique markers. Moreover, it will automatically adjust the camera view based on the position of the camera phone. Furthermore, the prototype should allow network connectivity where the user would be able to glean further information about the company and product. In addition it should also allow multimodal feedback to enrich the user experience.

Table 1 Key prototype functions

Task	Action
T1: Allow augmentation on the unique textured marker in the real world (Real world context)	The system should be able to make the 3D object appear on the screen when pointing Android phone camera to the marker provided.
T2: Network connectivity	To allow user to pull up further information about the company and product.
N1: Adjust view based on the camera phone position and orientation	Once the marker is detected and the AR scene is superimposed alterations of the cameras position and orientation should be reflected in the rendered onscreen view.
T3: Facilitate gesture based interaction	Gestures carried out by the user within the view frustum of the camera should be reflected in the avatars in game reaction to same, through the direction and force applied.
T4: Allow multimodal output feedback	The application should be able to provide auditory and haptic based feedback in response to interactions and collisions.

**N = Navigation, T = Task*

The prototype interface is designed with a combination of 2D and 3D components. For example, the brick wall, the bubbles, and avatar are all 3D objects, whilst the instructions, countdown timer, score panel and application control buttons are 2D object situated on planes floating above the 3D scene. Figure 4 below gives a sense of how differences in interaction style between the 3D gestured based modality on the left in comparison to the 2D touchscreen interaction.

Figure 4 User gesturing to move the avatar-*3D interaction*

When a flicking gesture intersects with the avatar a corresponding force is applied in relation to the speed of the flick thereby it is a combination of spatial and temporal attributes. When forces are given to the avatar, it will cause it to rotate on the same axis (in the same direction when user flicks it) – torque. As expected the velocity of the avatar will drop to zero over time (as illustrated with the change from P1 to P2 in Figure 5).

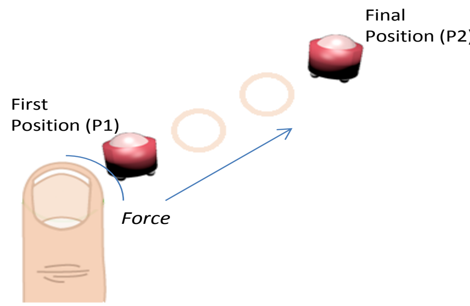

Figure 5 Flicking the avatar

4.0 RESEARCH METHOD

The process of capturing data on feedback and interaction styles was based on the use of questionnaires and observation. A total of 119 participants (56 male, 63 female) were randomly selected in this study. The age of participants ranged from 10 to 60, with the majority participants are between 15 to 40 years old (60%). They were asked to complete a survey after using the AR application.

The questionnaire was designed with the aim to understand the interaction style preference of the participants. Moreover, we would like to know whether multimodal output feedback able to support the process of interaction.

The questionnaire consisted of three sections used to determine the respondent's profile, familiarity with the mobile device and AR technology and the general interaction experience based on the test application. The design of the survey was based on the Questionnaire for User Interaction/ Interface Satisfaction (QUIS).

5.0 RESULT AND DISCUSSION

5.1 General Information on the Familiarity with Mobile Device and AR Technology

Figure 6 shows the types of mobile device owned by the participants. Not surprisingly, 89% of the participants own a smartphone. The percentage is significantly greater than those who own a tablet. Just 11% of those surveyed do not have smartphone and 79% do not have tablet.

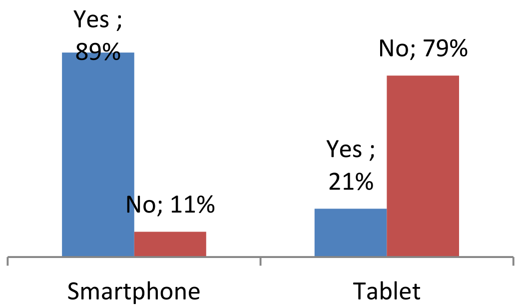

Figure 6 Mobile device that participants have been using

Results also indicate that Android is the most popular operating system with percentage of 85% followed by iOS at 5% and the remaining 10% made up from other operating systems. Just under half of the participants at 47% had heard of Augmented Reality in the past. Clearly AR is still a new and developing technology when considering general mobile users.

5.2 Interaction Experience using Mobile AR

Figure 7 details the user interaction experience when playing the AR game. We compare in-camera captured gesturing with standard touchscreen interaction to gain some sense of how the system compares to what users are more familiar with.

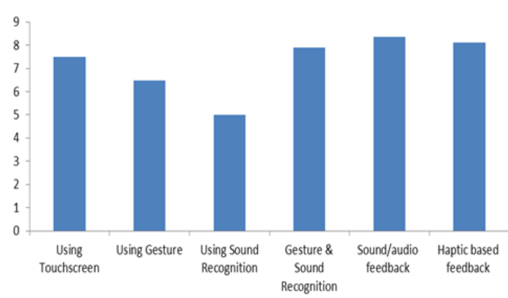

Figure 7 User interaction experience

With an average of 7.9, users generally found that it is quite easy to interact with the game using the standard touchscreen interaction style they were all familiar with. The in-camera gesture based interaction on the other hand achieved a slightly lower rating of 6.5 (Figure 7).

One should of course take into account that for many this was the first time ever attempting this form of interaction. Furthermore, participants had taken a liking the overall experience with the inclusion of audio feedback in the application with the average response of 8.4. This shows that sound really affects the experience of interaction in mobile AR. The participants also like the haptic based feedback (vibration) included in the game.

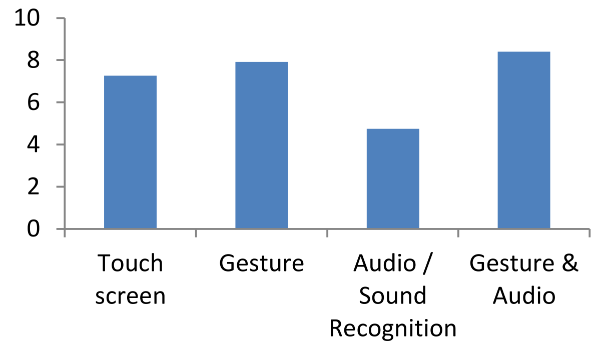

Figure 8 Method of interaction preferred in general

Figure 8 gives an overview of people's perceptions to selection of different interaction styles. Not surprisingly, participants would prefer touchscreen by quite a significant degree (rating of 7.3). However, in this study, gesture interaction is preferred by user by quite a significant degree with an average of 7.9. Interaction via audio (i.e. the likes of Siri) was quite close at 4.8 whilst combination of gesture and sound was the most preferred option with an average rating of 8.4. This shows that user definitely looked forward to interact more with this application.

6.0 CONCLUSION

In this paper we introduce a new way of interaction within the mobile AR environment that can enhance the user experience creating a visually more tactile experience. A review of recent literature revealed that current interactions are often limited to pure 2D pointing and clicking of a devices touchscreen even with respect to AR applications. Some AR application allow for interaction by modifying the relationship between the device and marker.

The findings showed that though the user feels that 2D interaction is easy to use, they find that using gesture based 3D AR interaction is more fun and enjoyable, where they can perceptibly interact with the on screen AR objects in a more physical and meaningful sense.

Even though gyroscope and accelerometer is integrated in smartphone, precise interactions in the mobile AR environment are again the common interaction problem in mobile AR. Our future work aims to build upon in-camera gesture based AR interaction by means of developing collaborative games where people can partake in the experience in a more social environment.

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