Design Guidelines for Hybrid 2D/3D User Interfaces on Tablet Devices

A User Experience Evaluation

Katri Salo
Intel and Nokia Joint Innovation Center
Department of Information Processing Science
University of Oulu, Finland
katri.p.salo@gmail.com

Leena Arhippainen, Seamus Hickey
Intel and Nokia Joint Innovation Center
Center for Internet Excellence
University of Oulu, Finland
leena.arhippainen@cie.fi, seamus.hickey@cie.fi

Abstract— **There is a growing proliferation of 3D based applications in tablet devices, but there is a lack of studies evaluating user experiences of these user interfaces. In particular, most of these applications use a mix of overlaid 2D controls and embedded 3D controls for user interactions and there is little current understanding on how users perceive and experience these controls. This paper presents the results of a user experience evaluation made for the user interface of four 3D applications running on two different tablet devices. A number of results are obtained. First, the results show that users wish that applications had less 2D overlaid icons and more space for touch gesture interactions. Second, the number of on screen control elements complicates the activity and provides a more disappointing experience. Third, avatar control was difficult as there were no tips or clear cues on how to use them. Fourth, users expected to control and interact with the applications by using direct touch gestures in the 3D space. As a result, design guidelines for hybrid 2D/3D user interfaces were created.**

Keywords-3D; hybrid; tablet; user experience; user interface

I. INTRODUCTION

There is an increasing number of products and services which are available for mobile tablet devices. In particular, there has been an increasing proliferation of three-dimensional (3D) graphical-based applications, which have been developed for tablet devices. Dillon and Morris [1] state that users are often unwilling to use technology which would result in an unimpressive performance and this is particularly relevant to 3D applications which add complexity to the User Interface (UI). From the user's perspective, there needs to be more research in the touch screen field [2] and in the 3D implementation area [3][4].

This paper presents the results of a User eXperience (UX) study of existing 3D applications that are commercially available on tablet devices such as the Apple iPad and Samsung Galaxy Tab. We studied the user experience of four 3D applications, three games and one map application. The focus was on the UI controls and not on the games' playability. Of these, the games make heavy use of an overlaid UI with 2D icons, as well as touch gestures and embedded objects in the 3D space. Each application takes a different approach to solve similar problems and this study evaluates these choices from the user experience point of view and identifies the principal design challenges.

This paper is organized as follows. Section II presents research that is relevant to this research topic. Section III presents the research methods used. Section IV presents the results. Section V presents a discussion of the results. Section VI concludes the research paper.

II. RELATED WORK

In 1974, Elographics developed and patented the five-wire resistive technology, the most popular touch screen technology, which is still in use today [5]. In 1982, the first multi-touch system was developed at the University of Toronto; this system allowed users more than one contact point at a time. Gestural interfaces have become popular for the mass market during the past decade. In 2007, Apple introduced the iPhone and iPod Touch demonstrating their touch screen capabilities. [5]

Yee [6] summarizes five major criteria which are thought to contribute to the effectiveness of gestural interactions. First, the application or system interface should make it clear to the user that gestures can be used. Second, the gestures should be obvious and intuitive for the relevant tasks. Third, the users need to be allowed to gesture with minimal effort, e.g., interaction is simple to perform and without a need for unusual motor skills. Fourth, gestures should have a logical relationship with the application functionality that they represent, i.e., in the type of movement and type of interaction with objects that they are acting on. Fifth, gestures should be designed for repetitive use and minimal muscle stress. [6]

With touch screen gestures it is easier for users to carry out certain actions, depending on the task they want to accomplish [7]. It has been recognized that the aesthetical appeal of the interface is important for users [8] and it can also improve the user performance.

There is little to be found in literature on hybrid UIs; the available literature is more focused on virtual environments. Haan et al. [9] describe hybrid UIs as an incorporation of 2D UI elements in a 3D environment. This type of solution is often used in games. In a hybrid UI, the elements in use should not be unreasonably large, because they are intended as supplements rather than the main focus. The interface should be intuitive to use. Icons should provide tool tips so that it is also easy for inexperienced users to interact with. The icons should be provided with a symbol instead of text to save space for the embedded UI. [9]

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Yoon et al. [4] compared a conventional 2D image–based system and a web 3D system by using an online survey of furniture style preferences. The findings showed 3D to be superior to 2D for product examination and decision making.

3D is expected to emerge from films to personal consumer electronics. 3D can provide a greater immersion experience for users, but only if this added value is not restrained by poor image quality. According to Jumisko-Pyykkö et al. [10], an overall excellence of 3D is also influenced by the quality of the display. The final quality is determined by the users' perception, which is influenced by their characteristics and the context of use. [10][3]

III. RESEARCH METHOD

The use of hybrid 2D/3D UIs were studied by conducting user experience evaluations for four different 3D applications. Three were three games and one was a 3D map application. The selected games were Order and Chaos (O&C), Pocket Legend (PL) and Dungeon Defenders (DD), which are all mobile multiplayer online (MMO) games. These were selected because they have the same game objectives but different approaches to the user interface. The map application was the YesCitiz Barcelona (YB) demo version. The applications have an overlay UI, which is the layer where control widgets and other functions with 2D icons are found. The 3D space has an embedded UI with 3D objects and models. O&C and YB run on an Apple iPad, and PL and DD run on a Samsung Galaxy Tab. We selected two different tablets in order to observe how people hold the device and how they interact with the touch screen. For instance, we are particularly interested in which hand or fingers they use for holding and controlling the device. This paper discusses these issues when they are related to the viewpoint controls and both 2D and 3D embedded object interaction.

A. Test Setting and Methods

For studying how users experience the interaction with hybrid UIs, we used various methods; observation, interviews, user tests, a customized version of the product reaction cards [12] method and a discussion forum. After using each test application, the user was interviewed by using the product reaction card method. They selected five suitable adverbs from a list of 39, and gave a short argument for their selection. This provided information that either supported the observation or brought new findings.

In the evaluation, participants used each application for around 10 minutes. During the use, no detailed tasks to accomplish were given to participants. However, users were asked to move the avatar, familiarize themselves with the game environment and interact with objects (other players, enemies, etc.) when they appear. Users were asked to think aloud and reply to questions concerning the use of applications and the tablet device. If there were problems in proceeding or performing a certain function, they were given tips. The observation focused on the touch gestures, the use of the overlay and embedded UI objects and also the hand and finger positions while holding the tablet and controlling the application.

Before the actual tests, a pilot test was performed to identify potential problems, identify gaps and ensure timely evaluation completion. A pilot test was carried out and changes were made to the product reaction card method and the order in which the applications were shown to the users. It was decided to alternate the order of the applications in the future. O&C was the first game presented to eight users. This is because of different UI solution: the use of a hidden control widget. User evaluations were conducted in laboratory settings. The duration of the evaluations varied between 1-1,5 hours. All sessions were video recorded.

B. Participants

We had 12 participants, whose age varied from 23 to 34 years, while the median age was 28 years. The ratio between males and females was 1:1. The age group for the evaluation was selected based on the target user group, according to tablet and mobile gaming demographics [13][14]. One participant was left handed, and the rest were right handed. Seven users had prior experience with touch screen mobile devices while five had none. Only one participant actively used a tablet device. Eleven participants had prior experience with 3D technology, for example from films or games, but one had not. When participants described their gaming experience, eight turned out to be active gamers on several different platforms. The remaining four had no experience or they had used rather dated games a long time ago.

IV. RESULTS

This chapter presents the results on each test application and tablet. Sections A and B discuss the map and avatar control. Section C describes the user interaction with embedded UI objects, and section D discusses switching between the overlay UI and the embedded UI.

A. Map Controlling

YB differs from the game applications by only having a single UI overlaid component which just changes the camera orientation to 'north'. The interaction is based on direct gestures to the embedded UI. The application opens with a bird's eye view over the area, and the user must then zoom closer to street view, where the environment is modeled in 3D (Fig. 1). A pan gesture is needed to adjust the horizontal view and it was the most problematic for users due to its unfamiliarity. Six different touch gestures were tried. In addition, one user tilted the device in the air to pan the view, but this kind of feature was not possible. A few participants commented on the similarity of the rotate and pan gestures. The 3D modeling received positive comments and it was considered helpful. There were participants, who first tried to find the 2D control widget for controlling the UI, but eventually they understood that the application does not have any widget for zooming, rotating or panning. These participants had tested one or more of the games before the map application, so we suspect that they probably learned that 2D elements are used for interaction. One participant with no game experience said: *"… the map looks so neat- maybe that's why I was more eager to experiment with gestures compared to the games."*

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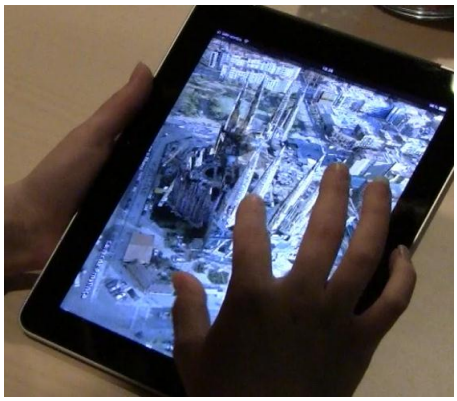

Figure 1. YB: Pan gesture used (right hand) to tilt in street view.

B. Avatar Control

Avatar control was necessary in three of the applications, O&C, PL and DD. Table I shows the order (*O*) in which the applications were used by each user, the amount of time (*S*) they spent trying to locate the avatar control widget and whether they had game experience (GE) or not (NE). The order of the tested applications is important, because previous usage has influences on the expectations and assumptions for the next one. O&C was the first game in 8 tests; PL was the second game in the 8 tests and DD as the third game in 6 tests. (Table I)

1) Hidden Avatar Control in O&C

The avatar control widget in O&C is located in the bottom left corner and is initially invisible until the user touches that area, at which point it becomes visible and controllable (Fig. 2). This was the most difficult gesture for the participants to figure out. In the beginning, most participants assumed that the avatar would be controlled by either tapping or sweeping the game space, or tapping an icon with a 'boot' symbol. Many said that a touch screen device mislead them into believing that the avatar is controlled in a similar manner as with a mouse and a keyboard-like point and click, or by a gesture in the game space. When participants opted to use their right hand for controlling the avatar, this blocked a lot of the view on screen (Fig. 2). They wondered why the widget could not be activated from the right side of the UI. A participant tried to solve the problem by flipping the tablet upside down, thinking that the UI would adapt differently. There were mainly negative comments on the use of an invisible widget as the participants did not feel it was necessary to hide it. In total, there were 11 different gestures that the participants tried to control the avatar, but in average they needed to try five gestures before finding the correct one. It took in average 67 seconds to find the correct gestures (Table I).

After getting used to the hidden control widget in O&C, some users eventually gave positive comments on the unrestricted control area, which is demonstrated in Fig. 2. In O&C it is also possible to have the avatar move automatically to a new position by clicking on an object with a special marker. This marker comes in the form of a 2D yellow arrow icon, which momentarily appears on the

TABLE I. SECONDS (S) FOR FINDING AVATAR CONTROL WIDGET AND THE ORDER (O) OF THE APPLICATION USE IN THE TEST. 8 USERS HAD PRIOR GAME EXPERIENCE (GE) AND 4 HAD NOT (NE)

GE/NE	Order & Chaos (O&C)		Pocket Legends (PL)		Dungeon Defenders (DD)	
	S	***O***	***S***	***O***	***S***	***O***
1GE	48	1	41	2	6	3
2GE	28	1	3	2	9	3
3GE	5	3	7	1	9	2
4NE	23	3	175	2	51	1
5NE	56	1	2	2	7	3
6GE	31	3	58	2	57	1
7NE	100	1	378	2	10	3
8GE	152	2	8	3	70	1
9GE	136	1	36	3	31	2
10NE	116	1	64	2	14	3
11GE	70	1	31	2	6	3
12GE	35	1	28	3	35	2
Average *S*	67		69		25	

Figure 2. O&C: Avatar control widget dragged through the game space.

Figure 3. PL: Control widget (left) is used with press and drag gesture.

embedded UI. None used this. One reason could be that it went unnoticed, since it typically appears on the bottom of the UI, where the other hand was using the camera control the overlay UI icons. It is possible that this arrow can be understood as a guide to a location as well.

2) Overlaid and Embedded Avatar Control in PL

To control the avatar in PL, the control widget has a symbol of a yellow, eight–pointed star. When pressed, the widget activates a yellow circle around it (Fig. 3). During the test, participants commented that this does not remind them of a control widget, but rather that it looks like a compass. Five different gestures were used. In average, it took three

gestures and 69 seconds (Table I) to find it, one reason being the unclear symbol. The other reason is that it is possible to control the avatar navigation by tapping the game space which causes a 'cross' indicator to appear and the avatar walks towards it. Three participants found this in-space tapping mechanism first, before noticing the control widget. Four participants never found this control option for tapping the space. For the eight users who did eventually find this in-space tapping option, it took an average of 144 seconds to notice it. These eight persons considered the in-space tapping action as a preferred choice to using the control widget. They stated that it was easy to use their thumb for this in-space navigation and this choice was affected by the smaller screen size of the Samsung Galaxy Tab.

3) Overlaid Avatar Control in DD

The DD avatar is controlled by a grey widget on the bottom left corner (Fig. 4), which was found rather quickly by all participants. The average time to find this widget was the shortest of all the games, 25 seconds (Table I). Participants experimented with different gestures to control the avatar. In total, five different types of gestures were tried, of which one is the correct gesture. In average, each user tried two incorrect gestures before finding the correct gesture to control the avatar. Tapping the game space was tried by eight, sweeping the game space by seven. A direct tap on the avatar was used three times and a tap for the overlay UI icons five times. Users felt that the symbol for the control widget was quite understandable (Fig. 5). Still many of them expected to have a possibility to control the avatar by touching the game space directly.

C. User Interaction with Embedded UI objects

In O&C, there are 2D icons such as talk bubbles or message scrolls appearing above the embedded UI objects to indicate interaction. If there was this kind of a cue, participants mainly tapped them, instead of tapping on the object (e.g., avatar) directly. A direct tap on an object is possible in this game, and three participants also tapped on objects (e.g., doors) which did not have any function. Another cue used in O&C for indicating interactable objects are colored circles below the avatar or enemy, which was easy to notice, and participants were then able to interact directly with them. It was observed that using two hands simultaneously was not comfortable for everyone.

In PL, a bow icon in the overlay UI is quite large and noticeable compared to the size of other icons on the overlay UI. It was tested by three participants in an attempt to interact with an embedded UI object. However, the two correct gestures were quickly discovered. Six participants were running through portals with a text "magic portal" above them; eight participants used the tap on the embedded object.

For the participants, the interaction mechanism with embedded UI objects in DD was confusing. There are three possible ways to interact, depending on the object. Also there are inactive objects with no functionality, such as doors or tables, yet two participants tapped these types of objects. Some objects such as caskets can be bumped into to open

Figure 4. DD: A tap used to interact with an embedded 3D object (under right thumb).

Figure 5. DD: A 2D icon (under right thumb) used to interact with a 3D object on game space.

them, and this was used by three users. The most used gesture was to tap an object directly, which was eventually done by ten users. There is an option to interact with a tap on a corresponding 2D icon, which appears momentarily on the overlay UI. This was used by six participants. Some of them had already tried to tap the embedded object, but nothing happened due to the distance from the object, or the touch pressure was too light. From then on, they continued to interact through the corresponding 2D icon. When participants were given a tip to find a certain object and then to try interacting with it, four expected it to happen by using a sword icon and five tapped a menu icon. One participant tapped a blue arrow icon.

D. Switching Between Overlay and Embedded Objects

According to participants, the icons were mainly "misleading symbols". A boot symbol in O&C was the most problematic; it was interpreted as a kick, walk and weapon to name a few. Also, the amount of icons was important; too many icons caused user confusion. The result was that the users focused more on the overlay UI icons than using what is available in the embedded UI. In an interview, it was remarked that: "… *if this is a touch screen device, why do you need icons to do stuff you could use gestures for?*"

In the embedded UIs, there are different cues (color, text) to inform the gamer that one can interact with an object. Eleven participants playing O&C did not need a suggestion to try interacting with the game space. The O&C UI was also

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easy to learn and more intuitive. The objects are often animated or color cued (enemies, avatars), or cued with a 2D symbol above the embedded object. This raises a question on whether the choice of having 2D icons in the embedded 3D UI is consistent with the idea of a 3D space. It seemed that participants were more prone to interact through these 2D icons whenever they were available. It could be possible that since O&C was the game which has the least number of overlay UI icons, more interaction happened on the embedded UI.

Even though PL has the most overlay UI icons, seventeen of them, the use of the embedded UI was active and quickly picked up. Since PL has the chance to control the avatar by tapping on the game space, it may have encouraged eight users to interact with objects. Of the overlay 2D icons, the icon with a large bow symbol was tried by three users. Also, the cues were simple, mainly text and animation.

DD has 14 overlay UI icons, and when there is a possibility to interact with an object, a 2D icon appears on the overlay UI (Fig. 5). So the gamer can choose between the icon and the object directly. Six users were interacting with the embedded UI objects (Fig. 4) directly without help, the remaining six were either encouraged to find a way to do that or they never noticed the possibility. The different overlay icons tapped for interaction had symbols of a blue arrow, two swords and a blue menu. It was a common error that a participant did not react in any way to an animated, glowing large white stone with text on it (Fig. 4). It is a portal to the next level, yet they passed it multiple times until they were advised to tap it.

V. DISCUSSION

Participants expected to use the touch gestures instead of interacting with multiple 2D icons. Even though Chehimi and Coulton [11] mention that mobile games should be playable with a single button, it is not always possible, especially in the MMO genre. Still the UI should be simplistic to give more room and chances for the touch gesture controls. It was apparent that the test applications did not meet Yee's [6] recommendation to design interaction for repetitive use and minimal muscle stress. Many participants felt that the control widget use was tiring and had problems to operate with it. A similar symptom was however not apparent with YB use, where the user has greater freedom to perform gestures.

In all the game applications, participants expected that the controls would happen with a direct touch on the game space, usually by tapping or swiping it. A few of the comments concerned the limited area for the touch, that when using a fixed control widget, one has to monitor where their fingers are. No one considered this input method particularly advanced. In PL, there is the possibility to use the tap gesture on the game space, which was preferred over the fixed control widget due to the unrestricted touch area and also because both hands could be in use.

Another issue was the typical location of the control widget, which was on the left in each application. The majority of the participants were right handed, and often held the tablet with their left hand, controlling with the right hand. This blocked the view on the game space, and caused another complaint. When it was suggested that they try controlling with their left hand, some felt that they did not trust the strength of their thumb to press and drag. The users then tried to control with their left thumb, but they soon reverted back to their left or right index finger. Most of the participants expected that it would be possible to change the control widget to the right side of the UI.

The biggest problem in games according to participants was the avatar control; there were no quick cues on how – to control the avatar movement. A brief animation of the gestures during the first steps of the application use could solve this. One commented that: *"… if a game is supposed to be played with two thumbs, then there shouldn't be important objects in the middle of the screen, you can't reach them.*" Similar observations were made during the tests when some female participants had problems with the Apple iPad and the simultaneous use of two hands.

A. Proposed Design Guidelines

Based on the findings from the user evaluations, we propose the following set of design guidelines to improve the user experience of the hybrid 2D/3D user interfaces in tablet devices:

1) Controls

- Place an easily identifiable control widget in a logical location on the overlay UI
- Promote the use of direct on-screen touch gestures
- Provide quick and interesting guidance for the principal gesture use.
- Reduce the need for an overlay UI control use
- Avoid implementing gestures which are too similar

2) 3D space

- Design clear and consistent cues for interactive embedded 3D objects
- Avoid use of 2D icons in 3D space
- Design location of interactive elements by taking into account user's hands and fingers positions

3) Icons

- Give the user a possibility to customize the icons' location
- Use simple and consistent icons in the overlay UI
- Minimize the amount of icons in the overlay UI
- Ensure that the size of the icons in the overlay UI is consistent
- Avoid placing icons too close to each other.

These guidelines are derived from the results of the study of the use of hybrid 2D/3D UIs. These can be applied when there is a need to use both 2D icons in the overlay UI and 3D objects embedded into space.

VI. CONCLUSION AND FUTURE WORK

A user experience study on 3D applications in tablet devices was conducted. Twelve participants used four applications in two tablet devices. The study found issues in a combined use of an overlay UI and an embedded UI,

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focusing in the control methods and interaction with embedded objects in a 3D space.

2D icons on the overlay UI negatively affect the use of direct gestures in 3D space. These overlay UI elements often result in an unsatisfying interaction, and reduce the user's interest on embedded objects in 3D space. Availability of 2D icons also distracts the user from interacting with embedded 3D objects. An application without a forced use of overlay UI controls gets users more interested in experimenting with the touch gestures and the 3D space.

Based on the study results, design guidelines for a hybrid UI was created with an emphasis on encouraging direct on-screen gestures and reducing the dominance of an overlay UI. In the future with 3D UI design, there might be a need to design only embedded UIs with 3D objects and totally avoid 2D overlay icons. Future studies will be conducted to validate these guidelines.

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