Evaluating Controls for a Point and Shoot Mobile Game: Augmented Reality, Tilt and Touch

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Abstract

Controls based on Augmented Reality (AR), Tilt and Touch have been evaluated in a point and shoot game for mobile devices. A user study (n=12) was conducted to compare the three controls in terms of player experience and accuracy. Tilt and AR controls provided more enjoyment, immersion and accuracy to the players than Touch. Nonetheless, Touch caused fewer nuisances and was playable under more varied situations. Despite the current technical limitations, we suggest to incorporate AR controls into the mobile games that supported them. Nowadays, AR controls can be implemented on handheld devices as easily as the more established Tilt and Touch controls. However, this study is the first comparison of them and thus its findings could be of interest for game developers.

Keywords: Mobile, player experience, videogames, controller, augmented reality, tilt, touch.

Index Terms: H.5.1 [Information Interfaces and Representation]: Artificial, augmented, and virtual realities

1 Introduction

Nowadays, mobile devices are the most widespread hardware platform. Furthermore, the owners of these devices install millions of applications per day, being videogames the predominant type. As a result, an immense number of people is interacting with mobile videogames at every second. Videogames currently produce more revenue than the film and music industries together. Additionally, they are not only used for mere entertainment but also for education, training or marketing. Consequently, both researchers and practitioners are making an important effort to recognize what makes videogames engaging.

It has been proven that the controller used to play a game has a significant effect in performance, but more important, in player experience. Although mobile devices usually lack external controllers, they come equipped with different sensors. Combining these sensors with their increasing processing power, other interaction techniques are available. For example, mixing the camera with computer vision algorithms it is possible to determine the position and orientation of the device in the real world. Thereby, virtual objects can be blended with the real world enabling Mobile Augmented Reality (MAR).

Comparisons of interaction techniques for mobile games have been limited to Touch and Tilt controls, even when MAR is supported in most of the current devices. Furthermore, MAR seems to reinforce the feeling of presence and immersion. This fact is important since naturalness, presence and immersion lead to an improvement in player experience.

Therefore, we have developed a point and shoot game for handheld devices which can be controlled using three interaction techniques. Firstly, a directional pad emulated with multi-touch controls. Secondly, a tilt control which fuses gyroscopes and accelerometers input to rotate the point of view. Lastly, a MAR control using a paper marker as a reference point between virtual objects and reality. A user evaluation was conducted to compare the effects of the three techniques in player experience and accuracy. We hope that our results will be useful for the overwhelming number of released mobile games and to motivate more research in this direction.

2 Related Work

In a desktop environment, the controller used for a driving game affected the steering performance, enjoyment and cognitive load of the player [1]. In pointing tasks, the performance is also affected by the controller [12]. Qualities of controllers such as naturalness [16], presence [15] and immersion [13] have been suggested to improve player experience. Players can show different preferences for controllers depending on their personality [10] and controllers can affect in-game personality [2].

In a mobile environment, a Tetris game controlled by moving the device was more entertaining than using the keypad [18], yet less accurate. A study involving the maze game [4] revealed similar results. That is, Tilt controls were more engaging for the player; however, keypad buttons provided the fastest and most accurate response. These studies used the camera to calculate the tilt in the absence of accelerometers or gyroscopes. Later user evaluations using accelerometers to play the maze game, suggested that the Tilt control was both faster and more fun [6]. Nonetheless, the superiority of Tilt controls could depend on the game since Space Invaders [3] and Pong [11] were controlled more accurately with Touch controls than with Tilt ones.

Several mobile games use AR controls. For instance, in Laser Cannon [5] the objective is to shoot coloured papers in the real world. Players suggested that AR was not only a novel interaction technique for mobile games but also led to new gameplay interactions.

To summarize: studies in desktop or consoles have proven that pointing and steering performance is affected by the controller. More important, the controller influenced the player experience. Comparisons on mobile games have been restrained to keypad, Touch and Tilt controls. Although Tilt controls are not always the most accurate ones, they are always the most engaging. Currently, MAR games are popular but studies lack formal evaluations and comparisons with the other controls.

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3 GAME DESIGN

We have implemented a mobile videogame based on the well-known Duck Hunt by Nintendo. The game objective is to shoot ducks that fly one at a time. To pass to the next duck you have to hit the current one. Nonetheless, after a certain amount of time the duck will fly away if the player has not hit it or has shot the three available shells.

The behaviour of the ducks is determined by a simple algorithm. When they are released, their speed and two timers are set based on the current game level. The first timer is the fly away timer and the second one represents the remaining time before changing direction. If the duck hits a boundary, it will change its direction, speed and direction-change timeout. For choosing the fly direction, the duck will choose a random direction opposite to the closest boundary. As the level goes up the ducks fly faster and change their direction in less time.

There are ten ducks per level and the user has five lives for the whole game. One life is lost when the user misses a duck and one life could be recovered after completing a level. The ducks fly inside a plane perpendicular to the original view ray. The player has to rotate the point of view and press the trigger exactly when the duck is in the shotgun crosshair. In the original game, an optical gun was used to aim and shoot, whereas in our implementation three different techniques are used to point with the shotgun. Each technique is explained in the following subsections.

The game interface shows the current level, the number of remaining shots and the ducks left for completing the level. Additionally, the number of misses and the score are shown. The implementation was made on the iOS platform using C++, OpenGL and Vuforia SDK for the augmented reality tracking.

3.1 Touch DPad Interaction

A virtual gamepad is used for this technique. The button for shooting is placed on the right side of the screen, and the rest of the screen is used for rotating the point of view. The first contact point of the user's finger is stored. The vector formed from the first contact point to the current finger position is used to modify the camera rotation (Figure 1). The x component of the vector modifies the rotation across the y axis whereas the y component modifies rotation across x axis.

Other options were tested, for instance, returning to neutral position when the finger was released, transferring only the vector difference from the previous position or using non-linear gain. Nonetheless, they were discarded during the pilot study.

3.2 Tilt Interaction

Another approach to control the game is to map the orientation of the device to the rotation of the camera (Figure 2). The shoot action is performed by pressing the button, similarly to the previous interaction.

Various sensors have to be used to calculate the orientation of the device, namely accelerometers, gyroscopes or magnetometers. It is possible to determine the orientation of the device in the absence of gyroscopes. Nonetheless, the refresh rate of the magnetometers is not high enough to play games. Equally, the lack of magnetometers leads to drift accumulation error on the axis parallel to the gravity. We have used accelerometers and gyroscopes as it is more appropriate for games due to their low latency. Therefore, between ducks appearances the camera orientation is reset to avoid drift error accumulation. This is also useful to allow players to change their posture while playing.

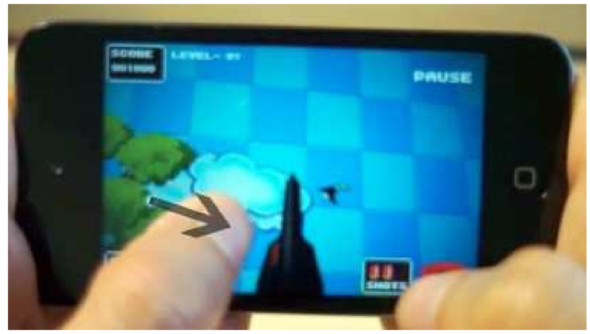

Figure 1: A player using the touch control to target a duck.

Figure 2: Tilt control: device orientation is applied to the camera.

Figure 3: Typical point of view from the player in AR mode.

3.3 Augmented Reality Interaction

The third technique is based on mobile augmented reality. In it, the camera detects the position and orientation of the device relative to a paper marker, and the video feedback is augmented with virtual content. Thereby, the device is the window from which the augmented world can be seen and the scenery is placed over the marker. To aim at a target, the player has to move the device as if it was the gun. Actually, during the evaluation the scenery was slightly forward and tilted to offer a more fair comparison (Figure 3). Quick movements or losing the marker from the camera will lead to marker losses. Whenever this happens the game is paused and a red crosshair indicates that the user should point to the marker.

4 User Evaluation

A user evaluation was conducted with 12 participants (1 female and 11 male). Their age ranged from 21 to 48 years (M=29.33 SD=8.9), two of the participants were left-handed. The main objective of the evaluation was to determine how the three controls affect player experience.

A Latin square was used to counterbalance the order effects. The same random seed was used for every participant, although it was different across techniques. Consequently, the game behaved in the exact same way for all the players. We checked that the difficulty was similar for the three random seeds used.

Users played the game seated using the three techniques. Before playing with each technique, the users had a training period. After playing the game with the three techniques, the users filled in a questionnaire. In addition, participants had to sort the interaction techniques according to their preferences and give qualitative feedback if desired.

In the evaluation, we gathered quantitative data of two types. Namely, subjective self-reported data from a questionnaire and objective measures obtained from logs of the game. In the results sections, we use correlations to combine objective with subjective ratings. Additionally, qualitative data was obtained through direct observations of the players and from their feedback. Qualitative and quantitative data are combined in the discussion section when qualitative comments were either coherent with or contradictory to qualitative data.

The questionnaire used to evaluate player experience consisted of four questions to assess enjoyment, immersion, nuisances and perceived accuracy. Enjoyment is generally described as the feeling of pleasure caused by doing something that you like; it is a central factor for players in computer games [17]. Immersion is related to enjoyment but it is a different construct deeply affected by the game controller [8]; it implies complete involvement in an activity, for instance due to intuitive controls. Nuisances are annoying or unpleasant issues that occur to players; nuisances have a significant negative effect as interrupting players would break the player experience [7]. Perceived accuracy is how competent players felt while performing a task without making mistakes.

There are questionnaires composed of several questions designed for measuring constructs like enjoyment or immersion [7][8][17]. However, these questionnaires are usually aimed at evaluating more complex games with plot and characters. In this evaluation, the game is based on pointing, which is a basic interaction task. Therefore, we used a Likert-scaled question per construct. Users had to score the four questions for each technique using a scale ranging from 0 to 10. For all the variables, higher values were positive except for nuisances. It is possible to successfully measure enjoyment with one Liker question [1]. Nonetheless, we added the previous definitions to each question. Thereby, the users had a clearer and more uniform idea of the concept that they were scoring. We also addressed the lack of reference points using a within-subjects design.

Objective measures were calculated and stored by the game in a log file. For all conditions and players, the reached level was recorded. The number of ducks left for completing the level was used to add a decimal component to the level integer value. In the AR mode it was also possible to record marker losses and the time that the player spent without seeing the marker. For every duck, the game stored the time spanned from release to hit. Accuracy was calculated as the proportion of successful shots to total shots. All the per-duck variables were averaged using only ducks from level 1 and 2; otherwise players who reached higher levels would have been at a disadvantage.

5 Results

The overall time of the evaluation was half an hour per participant. Participants reported no serious nuisances and generally enjoyed playing the game. Furthermore, several of them asked if the application was available for later use. All participants reached at least level 3 with all the techniques.

Data were analyzed using RM-ANOVA to detect significant effects of controller; Greenhouse-Geisser correction was applied when sphericity was violated. T-pair tests with Bonferroni adjustment were used as post-hoc tests.

5.1 Self-reported player experience

Enjoyment was 7.42 (SD=2.02) for Touch, 8.17 (SD=1.19) for Tilt and 7.92 (SD=1.67) for AR.

Immersion was 7.82 (SD=2.12) for Touch, 8.42 (SD=1.44) for Tilt and 7.50 (SD=1.62) for AR.

Nuisances was 2.67 (SD=2.27) for Touch, 3.00 (SD=1.95) for Tilt and 4.08 (SD=2.46) for AR; there was a significant effect ($F_{2,22}$=3.730, p=.040) in difference Touch<AR (p=.041). Enjoyment, immersion and nuisances are shown on Figure 4, left.

Perceived accuracy was 5.83 (SD=1.74) for Touch, 7.75 (SD=1.28) for Tilt and 7.42 (SD=1.44) for AR; there was a significant effect ($F_{2,22}$=9.384, p=.001) in differences Touch<Tilt (p=.025) and Touch<AR (p=.005).

Ranking positions were 1.58 (SD=0.79) for Tilt, 1.83 (SD=0.71) for AR and 2.58 (SD=0.66) for Touch.

5.2 Performance measures

Accuracy was 60.90% (SD=18.43) for Touch, 64.61% (SD=14.89) for Tilt and 67.48% (SD=20.60) for AR. Real accuracy and perceived accuracy are displayed on Figure 4, right.

Time to duck hit was 2.82 seconds (SD=0.63) for Touch, 2.43 (SD=0.51) for Tilt and 2.43 (SD=0.84) for AR.

Level reached was 5.31 (SD=1.86) for Touch, 6.24 (SD=1.98) for Tilt and 6.64 (SD=2.27) for AR; a significant effect was found ($F_{2,22}$=4.480, p=.023) in difference Touch<AR (p=.037). Level reached per technique is shown on Figure 5.

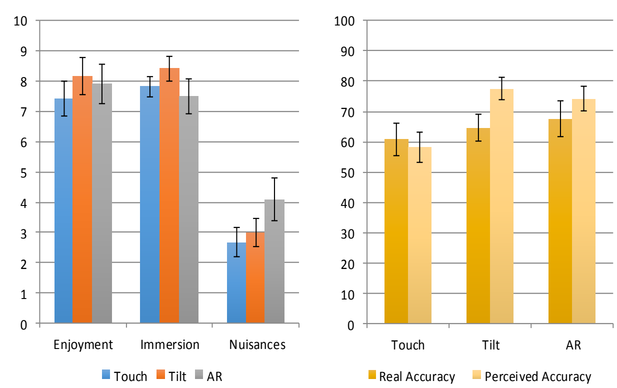

Figure 4: Left) subjective self-reported ratings. Right) real and perceived accuracy. Error bars represent SE.

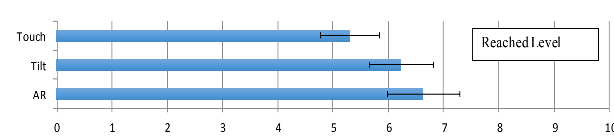

Figure 5: Reached level with each technique.

5.3 Correlations

Perceived accuracy and real accuracy correlated significantly (r=.646, p=.023) for Tilt and (r=.628, p=.029) for AR.

Enjoyment correlated with immersion (r=.780, p=.003) for Touch, (r=.748, p=.005) for Tilt and (r=.618, p=.032) for AR.

Enjoyment correlated with nuisances (r=-.720, p=.008) for Touch, (r=-.585, p=.046) for Tilt and (r=-.680, p=.015) for AR.

Nuisances correlated with immersion (r=-.767, p=.004) for Touch and (r=-.870, p=.000) for Tilt.

6 DISCUSSION

The three techniques were functional and basically obtained similar results for enjoyment and immersion. Across all techniques, enjoyment and immersion did not depend on pure performance.

Similarly to previous studies, Tilt was the most engaging and immersive control. Nonetheless, reached level and accuracy were the highest with the AR control. As AR had the highest nuisances, the player experience was diminished due to interruptions [7].

Although the Touch control was scored the worst control, qualitative feedback supported it in some points. It was usable in all positions and permitted to change posture during game play. Nevertheless, screen occlusions with the finger were more noticeable. Perceived accuracy correlated with the actual accuracy for the Tilt and AR controls. People did not perceive the Touch control as accurate, even when they were using it correctly. Furthermore, perceived accuracy with Touch was the lowest, possibly because it was the less natural technique.

A limitation of the study was that the AR technique could move the camera, although all the users tended to keep the same distance to the marker. A zoom control was tested for adding this feature to Touch and Tilt controls; however, it was removed since in the pilot study some users found it too complex. The questionnaire used for measuring player experience may appear simplistic. Nonetheless, the correlations between enjoyment, immersion and nuisances suggested that the players sensed the game as a global experience and that the variables were not perceived separately. Therefore, more complex questionnaires could not to be the solution to obtain richer self-reported subjective measures.

Fitt's Law exists for Touch, Tilt [8] and AR [13]; but it was not used in our study because it was more focused on game experience and the target ducks followed non-simple behaviours. Nonetheless, it may be valuable to determine if players' performance in games can be inferred from their performance in the basic constituent tasks of the game. It also appears interesting to measure the player perception of value for games endowed with the three techniques to check if it compensates the developing cost. However, value is hard to measure as nowadays most of the mobile games are free to play. Finally, mobile games based on the steering task could also be tested using the three controls.

7 CONCLUSION

Three different interaction techniques have been evaluated for controlling a point and shoot game. Augmented Reality (AR) control was objectively the best technique; however, according to users' perception, Tilt was better. Both Tilt and AR provided better accuracy and were perceived as more precise than Touch. Nonetheless, Tilt and AR are not playable in as many conditions as the Touch control. All the controls were scored equally entertaining and most of the existing mobile point and shoot games could implement them to provide more varied player experiences.

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