Tactile and Tangible Interfaces in Handheld AR for Children

Santiago González-Gancedo[1], M.-Carmen Juan[1], Ignacio Seguí[2] and Francisco Abad[1]
[1]*Instituto Universitario de Automática e Informática Industrial (ai2), Universidad Politécnica de Valencia, Camino de Vera s/n, 46022 Valencia, Spain*
[2]*AIJU, Ibi, Alicante, Spain*

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Abstract: This paper presents a comparative study between tangible user interfaces (TUIs) and tactile user interfaces (TacUIs) in handheld AR, with a contribution to the state of the art in HCI oriented to children. While TUIs work with the manipulation of physical objects, TacUIs work with virtual representations of them. In our evaluations to compare these two interactions with primary school children, we found that the TacUI was the fastest for completing the task, what makes it better suited for educational purposes. The TacUI was found easier to use by the children, although the TUI was found more solid and less slippery. Our conclusions should be of interest not only to educational researchers, but also to the general HCI community working on tangible and tactile interfaces.

1 INTRODUCTION

Augmented Reality (AR) is a field with a great potential of use with children, providing a very stimulating environment that not only helps visualising 3D objects, but also enhances motivation and enjoyability highly. AR has evolved fast in the recent years, specially concerning to the area of Human-Computer Interaction (HCI), and designing user interfaces that help the students visualise and explore AR environments.

Tangible User Interfaces (TUIs) deal with the manipulation physical objects. The hardware used to work with TUIs and AR in education is very frequently based on markers printed on books, such as the well-known MagicBook (Billinghurst et al., 2001), or on other objects, such as cards (Juan et al., 2011). These systems have the great advantage of working with a video see-through metaphor that provides a high sense of presence and immersion with a direct view from the user perspective.

Tactile User Interfaces (TacUIs[1]), in opposition to TUIs, do not deal with physical objects, but with metaphors or pictures of them displayed on a sensible surface, and therefore the differences in the user interaction and perception may be different. TacUIs can be divided in touch screens (capacitive or resistive) and projection based (Jones et al., 2010). Since we use handheld devices in the research, we contextualise this paper under touch screens. TacUIs play an important role in handheld interaction contributing to AR providing a new interaction channel.

Figure 1: Set used for the evaluation with the children consisting on a TUI and a TacUI in the handheld device.

The relation between TUIs and TacUIs in handheld AR has not been examined previously to our knowledge. In this paper we present a novel study that compares these two different forms of user interaction. Based on related work studied, we developed an experiment based on one of the most common uses of AR in education and entertainment, which consists of visualising 3D objects from different points of view. We measured and analysed the differences from an objective perspective (time spent by the user to interact with the system) and from the user's subjective perspective (satisfaction with the system and the in-

[1]To our knowledge, there is not any standard term for Tactile User Interfaces, so we introduce TacUIs.

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teraction).

This paper is structured as follows. Section 2 reviews work related with our study. Section 3 explains the proposed experiment and its apparatus. Section 4 describes the design of the study. Section 5 shows the statistical analysis and the results of the study. Finally, section 6 discusses the conclusions of our research and the future work.

2 RELATED WORK

There exists a large body of research in AR aimed to children. For instance, Sayed, Zayed, and Sharawy (2011) presented ARSC, a low cost visualisation tool of 3D objects that reduced the learning time. The authors used desktop computers with web cameras to visualise objects on markers. They tested the system with students between 10 and 17 years old, and 89% of them were satisfied with it. The ARSC set decreased the expenses and increased the visualisation ability (Sayed et al., 2011).

TUIs have also been studied with children. Juan et al. (2010) combined AR with tangible cubes, in which each side there was a marker. The users wore a Head-Mounted Display (HMD) to visualise the AR scenes, freely manipulating the cubes with both hands. The authors compared the AR system that displayed videos to traditional cubes with images on the sides. They tested the system with children from 7 to 12 years old, and concluded that despite the HMD was uncomfortable, children enjoyed more the AR system (Juan et al., 2010).

In our research, we have paid special attention to previous work in TacUIs and handheld devices. Wagner, Schmalstieg, and Billinghurst (2006) presented a collaborative handheld AR game aimed to sort a collection of artworks by date of creation using either a paper, a PC, or a PDA. Users preferred paper and PDA over the PC, and they also preferred the AR PDA game over the paper game (Wagner et al., 2006). Very recently, González-Gancedo et al. (2012) studied handheld devices with virtual reality (VR) and AR to be used in the classroom. They compared VR and AR for their use with handheld devices in a game about the water cycle. Children from 8 to 10 years evaluated the system, and the authors concluded that the combination of VR and AR improved motivation end enhancement, although it did not improve the learning outcomes in comparison to a simple VR game (González-Gancedo et al., 2012).

This related work motivated our research, and we attempt to study the relations between TUIs and TacUIs in handheld devices in order to create reference for future developments. In this paper we try to state the advantages and inconveniences of both interactions given our experience.

3 EXPERIMENT

3.1 Description of the Experiment

In our game (Fig. 1) the handheld device was a tablet PC with a 3MP camera and a capacitive screen. In order to perform a fair comparative we decided to modify the traditional AR system. In terms of geometric operations, the translation of the object is determined by the AR system in the traditional way, but the rotation around the upward axis relative to the marker is determined dynamically.

The game can be played in two modes. In the tangible mode the child only uses the handheld device merely as a visualisation system, and she can control a TUI device to rotate the marker. We built this interface that allowed easily the rotation of the marker but not the translation. In the tactile mode, the marker is static, and the interaction is only through the tactile screen. The user can touch and move the finger horizontally in the screen, but vertical displacements do not have any effect. The handheld device was in a fixed position using a stand to compare better the TUI and the TacUI.

The AR system placed a model of the Taj Mahal with several objects in different parts of the virtual scene located in such a way that it was necessary to rotate the model to see the objects hidden in the back. The objective of the game was to count the number of objects in the scene. Since children were studying nature and water in other activities, the objects were drops of water represented as characters.

4 EVALUATIONS DESIGN

4.1 Participants

A total number of 51 children from 8 to 10 years old – with a mean age of 8.65±0.74– took part in the study. The gender distribution was: 29 boys (57%), and 22 girls (43%). They were attending the Escola d'Estiu at the Polytechnic University of Valencia.

4.2 Procedure

The children were divided in two groups depending on the order in which they would play with both interfaces: *Group A* (26 children) children who used the TacUI first and then the TUI, and *Group B* (25 children) children who used the TUI first and then the TacUI.

Each child tested the two types of interaction individually. In each game the time to achieve the task was measured, and the child had to fill in a questionnaire afterwards. Consequently, we used four different questionnaires (QTc1, QTc2, QTn1, and QTn2; *Tc* stands for tactile and *Tn* for tangible), which contained the proper questions to be asked after using each type of interaction in first or second place. However, each child had to fill in only two questionnaires, one for each interaction.

5 RESULTS

5.1 Time Analysis

The time to complete the task of counting the objects in the scene was measured and studied as an independent variable. We performed a mixed-design ANOVA analysis to take into account the two interactions the same child used, and to consider several factors simultaneously.

The mixed-design ANOVA reveals that there were significant differences in the interaction factor ($F[1,36] = 4.94$, $p = 0.03$), and in the order factor ($F[1,36] = 33.13$, $p < 0.01$). Since both factors have two levels only, a simple post-hoc analysis comparing the mean of each level revealed that the users took less time to complete the task using the TacUI than using the TUI with a significant difference. Similarly, we concluded that the users took more time to complete the task the first time they played than the second time. No significant differences were found for the age, gender and group factors.

5.2 Satisfaction

We analysed the results of questions 1) degree of enjoyability, 4) degree of ease of play and 6) global game rate. All of these questions have very high scores: #1 4.60±0.64, #4 4.58±0.66 and #6 4.64±0.49. Moreover, there are no significant differences in questions 4 and 6 for the studied factors. The only arguable point is in question 1, where the ANOVA test shows a relatively high p-value and a small effect size in the order factor ($F[1,36] = 2.96$, $p = 0.09$). A post-hoc analysis reveals that the possible difference would mean that the second game was more enjoyed than the first game. We believe that the difference is meaningful and not only caused partially by chance, but also by the order factor, as we can see from the answers to the question 3. In this question, 93% of the children said they would like to play again after the first game, and we could see during the evaluations that they were very excited to play the second game, what in our opinion has affected the results in question 1.

The children appreciated the AR very much, as the high scores to a question about its appreciation reveal for the tactile game (mean 4.80±0.40) and for the tangible game (mean 4.91±0.28). It is very interesting to note that no significant differences were found between both games ($t[46] = 1.10$, $p = 0.28$, Cohen's $d = 0.32$), which is an excellent result because it means that the use of AR was very similarly enjoyed with both interactions.

5.3 Interaction

The children were asked to choose the type of interaction they thought it was easier to use. When the TacUI was the last one to be used there was a 70% of children who preferred it to the TUI, but when the TacUI was the last one to be played, the TUI preferences dropped to 48%. As we can see, there is the effect that children chose more the last game they used, which is a common tendency that we have experienced in previous studies with children (González-Gancedo et al., 2012). When the children used the TacUI in second place, there were significant differences in the proportions of TacUI and TUI ($\chi^2 = 5.57$, $p = 0.02$, $h = 0.80$) with a large effect size. This result evinces the preference of the TacUI. The difference is, however, no longer significant when the TUI was used last ($\chi^2 < 0.01$, $p = 1.00$, $h = 0.08$). From the difference in the significances we can conclude that the tactile screen caused a more powerful impact on the children.

The preference for the two types of interaction was measured in another question, where the bias towards the last game is also present. The most extreme proportions are found in the tactile game played the second time, where the tactile game was chosen by the 78% of the children, and the tangible game by the 22%. In such case there are significant differences and a very large effect size ($\chi^2 = 12.52$, $p < 0.01$, $h = 1.20$).

6 CONCLUSIONS

We designed an system to compare TacUIs and TUIs under very similar circumstances. The handheld device was used as video see-through, taking some of the advantages of HMDs, but resulting in a more comfortable way to the children. Our proposal is very well suited for schools, since handheld devices are affordable and multipurpose, what can contribute to create richer multimedia experiences for the students.

In the experiment we evaluated, the TUI consisted on a rotatory base on top of which the AR marker was placed. The children could rotate the marker to see the 3D objects from different perspectives. This interaction was compared to the TacUI, where the rotation was calculated from the horizontal movements of the finger on screen. The results indicate that it took significantly less time to the children to use the TacUI than the TUI. Since both interactions were used with the same game in very similar circumstances, we can strongly affirm that overall, children spent significantly less time dealing with the interface in the case of the TacUI, allowing them to focus more on the task to do rather than manipulating the device. From this perspective, TacUIs are better suited for applications where the main goal is to understand and solve a problem, like in the educational field.

As for the children's perspective, we could see a very high level of satisfaction with the game using the two interfaces, and no significative differences were found. The children were very engaged with the game. All of them wanted to play again after using the TacUI, and most of them after using the TUI. However, there was no evidence that the interface used influenced this engagement. The AR system appealed the children very much without being affected by the interaction method. Thus, our visualization metaphor is similarly engaging for children using any of the interfaces.

The children seemed to prefer the TacUI mainly for being easier and faster to use, and some of them also thought it was more comfortable. On the contrary, the TUI was preferred in some cases, surprisingly for very similar reasons. These children found the screen too fast to use and too slippery (some children tended to touch with their fingernails, which does not work), and they preferred the more stable interface that the TUI was. In general, more children preferred the TacUI, although this difference was not always statistically sustainable. Despite preferring the TacUI, the appreciation of the TUI was very high, so we can discard that the preference of TacUI is due only to disliking the alternative. Finally, it is very possible that in older ages we would find a high increase on preference of the TacUI, as the children's physical skills improve and do not have troubles with the screen.

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