Designing Augmented Reality Tangible Interfaces for Kindergarten Children

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Abstract. Using games based on novel interaction paradigms for teaching children is becoming increasingly popular because children are moving towards a new level of inter-action with technology and there is a need to children to educational contents through the use of novel, attractive technologies. Instead of developing a computer program using traditional input techniques (mouse and keyboard), this re-search presents a novel user interface for learning kindergarten subjects. The motivation is essentially to bring something from the real world and couple that with virtual reality elements, accomplishing the interaction using our own hands. It's a symbiosis of traditional cardboard games with digital technology. The rationale for our approach is simple. Papert (1996) refers that "learning is more effective when the apprentice voluntarily engages in the process". Motivating the learners is therefore a crucial factor to increase the possibility of action and discovery, which in turn increases the capacity of what some researchers call learning to learn. In this sense, the novel constructionist-learning paradigm aims to adapt and prepare tomorrow's schools to the constant challenges faced by a society, which is currently embracing and accelerating pace of profound changes. Augmented reality (Shelton and Hedley, 2002) and tangible user interfaces (Sharlin et al., 2004) fitted nicely as a support method for this kind of learning paradigm.

Keywords: Augmented reality, Interactive learning systems, Tangible Interfaces.

1 Introduction

Using games as a way for better educating children is becoming increasingly popular because children are moving towards a new level of interaction with technology and there is a need to approach them towards the educational contents. This can be done through the use of novel, more attractive technologies.

The power of digital games as educational tools is, however, well understood. Games can be successfully used for teaching science and engineering better than lectures [1], and e.g. Mayo and colleagues even argued they could be the "cure for a numbing 200-person class." [1]. Games can also be used to teach a number of very different subjects to children all ages. For instance Gibson describes a game aimed at

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teaching programming to pre-teens school children [2]. Belotti and colleagues [5] describe an educational game using a state-of-the-art commercial game development approach, and enriched the environment with instances of developed educational modules. The research goals for these approaches are essentially to exploit the potential of computers and reach a demographic that is traditionally averse to learning.

On a more specific line, there is also interesting research on using Augmented Reality (AR) games in the classroom. From high-school mathematics and geometry [3] to interactive solar systems targeted at middle school science students [4], the range of applications is relatively broad.

However, there is a clear lack of solutions and studies regarding the application of these technologies with kindergarten children, who are aged 3-5 years old and therefore have different learning objectives.

In this paper, we present a tangible user interface for an augmented reality game specifically targeted at promoting collaborative learning in kindergarten. The game's design involved HCI researchers (the authors), kindergarten teachers and 3D designers. We evaluated the system during several days in tow different local schools and we recorded the children's reactions, behaviors and answers to a survey we also conducted.

Instead of developing a computer program using traditional input techniques (mouse and keyboard), this research presents a novel user interface for learning kindergarten subjects. The motivation is essentially to bring something from the real world and couple that with virtual reality elements, accomplishing the interaction using our own hands, thus, children don't need to have previous experience using computers in order to use this system. The interface is, essentially, a symbiosis of traditional cardboard games with digital technology.

2 Related Work

Technology today provides exciting new possibilities to approach children to digital contents. There are numerous areas where Augmented Reality (AR) can be applied, ranging from more serious areas to entertainment and fun. Thus, the process of viewing and manipulating virtual objects in a real environment can be found in many applications, especially in the area of education and training which are very promising applicants, since it is often necessary to use resources enabling a better view of the object under study. Other applications include the creation of collaborative environments in AR, which consist of multi-user systems with simultaneous access where each user views and interacts with real and virtual elements, each of their point of view.

Given the scope of our work, we divide the review of the literature into two broad aspects: the use of augmented reality technology in the classroom, and approaches targeted at promoting collaboration in the classroom by means of novel technology – not necessarily based in augmented reality.

The use of augmented reality systems in educational settings, per se, is not novel. Shelton and Hedley [6] describe a research project in which they used augmented reality to help teach undergraduate geography students about earth-sun relationships.

They examined over thirty students who participated in an augmented reality exercise containing models designed to teach concepts of rotation/revolution, solstice/equinox, and seasonal variation of light and temperature, and found a significant overall improvement in student understanding after the augmented reality exercise, as well as a reduction in student misunderstandings.

Some other important conclusions about this system were that AR interfaces do not merely change the delivery mechanism of instructional content: They may fundamentally change the way that content is understood, through a unique combination of visual and sensory information that results in a powerful cognitive and learning experience [6].

Simulations in virtual environments are becoming an important research tool for educators [9]. Augmented reality, in particular, has been used to teach physical models in chemistry education [10]. Schrier evaluated the perceptions regarding these two representations in learning about amino acids. The results showed that some students enjoyed manipulating AR models by rotating the markers to observe different orientations of the virtual objects [10].

Construct3D [9] is a three-dimensional geometric construction tool specifically designed for mathematics and geometry education. In order to support various teacher-student interaction scenarios, flexible methods were implemented for context and user dependent rendering of parts of the construction. Together with hybrid hardware setups they allowed the use of Construct3D in classrooms and provided a test bed for future evaluations. Construct3D is easy to learn, encourages experimentation with geometric constructions, and improves spatial skills [9].

The wide range of AR educational applications also extend to physics. Duarte et al. [11] use AR to dynamically present information associated to the change of scenery being used in the real world. In this case, the authors perform an experiment in the field of physics to display information that varies in time, such as velocity and acceleration, which can be estimated and displayed in real time.

The visualization of real and estimated data during the experiment, along with the use of AR techniques, proved to be quite efficient, since the experiments could be more detailed and interesting, thus promoting the cognitive mechanisms of learning.

Promoting collaborating behaviors is crucial in the kindergarten educational context. Therefore, we briefly analyze approaches that use technology as a way to achieve higher levels of collaboration in the classroom.

Children communicate and learn through play and exploration [16]. Through social interaction and imitating one another, children acquire new skills and learn to collaborate with others. This is also true when children work with computers.

Using traditional mouse-based computers, and even taking into consideration that two or more children may collaborate verbally, only one child at a time has control of the computer. The recognition that group work around a single display is desirable has led to the development of software and hardware that is designed specifically to support this. The effect of giving each user an input device, even if only one could be active at a time was then examined and significant learning improvements were found [17].

Stewart et al. [18] observed that children with access to multiple input devices seemed to enjoy an enhanced experience, with the researchers observing increased incidences of student-student interaction and student-teacher interaction as well as changing the character of the collaborative interaction. The children also seemed to enjoy their experience more, compared with earlier observations of them using similar software on standard systems.

There are also studies about the design of user interfaces for collaboration between children [14]. Some results present systems which effectively supported collaboration and interactivity that children enjoyed, and were engaged in the play [14].

Kannetis and Potamianos [13] investigated the way fantasy, curiosity, and challenge contributes to the user experience in multimodal dialogue computer games for preschool children, which is particularly relevant for our research. They found out that fantasy and curiosity are correlated with children's entertainment, while the level of difficulty seems to depend on each child's individual preferences and capabilities [13]. One issue we took into account when designing our AR game for kindergarten was that preschoolers become more engaged when multimodal interfaces are speech enabled and contain curiosity elements. We specifically introduced this element in our design, and confirmed the results described in [13].

3 An Augmented Reality Tangible Interface for Kindergarten

As with any game, the solution space dimension was very high, so we collaboratively designed the game with kindergarten teachers, focusing on a biodiversity theme, using traditional book-based activities as a starting point.

The developed system was based on a wooden board containing nine divisions where children can freely place the game's pieces. The pieces are essentially based on augmented reality markers. Several (experienced) kindergarten teachers provided us with a learning objective and actively participated in the entire game's design. For instance, they listed a series of requirements that any game or educational tool should comply when dealing with kindergarten children. They can be aged from 3 to 5 years old, and therefore have different teaching and caring needs, when compared with older children or other types of users. Among the most important requirements were:

- Promote respectful collaborative behaviors like giving turns to friends, pointing out mistakes and offering corrections;
- Promote learning of the given subject.
- Promote a constructivist approach, where children learn by doing and by constructing solutions;
- The previous requirement also implied that the physical material of the tangible interface had to be resistant and adequate to manipulation by the group of children;

In our case, the learning objective was the study of animals and the environments (sea, rivers, land and air) they live in. Each division of the board's game contains a printed image of a given environment.

Given the manipulative nature of such game, the game's pieces had to be made from a special material, which is particularly suited for children, a flexible but robust material. Each of the game's pieces displays a 3D animal that can be manipulated, as in a regular augmented reality setting. The board also contains a fixed camera, which processes the real time video information. Figure 1 illustrates the overall setting of the system, which can be connected to any kind of computer and display. In the figure, we show the system connected to a laptop, but during classroom evaluation we used a projector, to facilitate collaborative learning.

The goal of the game is to place all the markers (game board pieces representing animals) in the correct slot of the board. We only give feedback about the correctness of the placement of pieces in the end, when the player places a special marker that is used for that purpose, i.e. a "show me the results" marker. Two different versions of the game were developed, to assess the impact of the feedback's immediacy on the children's levels of collaboration: a version where feedback can be freely given at any time (whenever children place the special marker to see the results, as shown in Figure 2); and a version where feedback is only given at the end of the game, i.e. when all the pieces have been placed in the board (again, by placing the special marker).

Fig. 1. The developed system, when used in a LCD display configuration

Figure 2 shows a screenshot of what children see displayed in the screen. The markers display 3D animals, which can be freely manipulated. The animals that are correctly placed have a green outline, incorrectly placed animals show a red outline. Following the teachers' suggestions, we also added audio feedback, with pre-recorded sentences like "That's not right, try it again!" This encouraged children, especially when positive reinforcement was given in the form of an applause sound.

The game also features a detailed logging mechanism with all actions recorded with timestamps. This was developed as an aid to evaluating the effects on collaboration levels. The system logs the completion times of each game, the number of incorrectly placed markers, the number of feedback requests (which can be considered the number of attempts to reach a solution), and other variables.

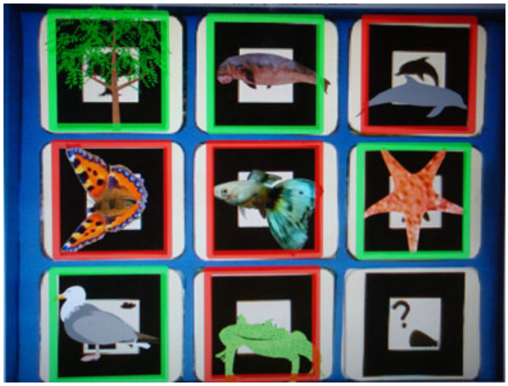

Fig. 2. The game's screen, showing feedback as a red or green border around the animals

4 Discussion

The results obtained so far indicate that using our augmented reality system is a positive step forward towards achieving the goal of reducing the distance between children and knowledge, by learning through play.

The system has a very positive impact on the whole class collaboration. This is much harder than it seems, since kindergarten children have very low attention cycles. They get distracted very often, and they have trouble collaborating in an orderly manner. An important contribution from this paper, in terms of design issues that promote collaboration, is the importance of providing immediate feedback in virtual reality games such as the one we have developed. It is crucial that designers targeting kindergarten children are capable of exploiting the innate curiosity in these tiny users in order to achieve good levels of collaborative interactions.

Motivation, enjoyment and curiosity are important ingredients for any kind of educational game, but they are even more important when it comes to kindergarten user interfaces. Interaction with tangible board pieces (the AR markers) may be well suited to very young children because of their physicality, but this is could not be sufficient to achieve good levels of motivation and collaboration.

5 Conclusions

Augmented reality technology and tangible interfaces are well accepted by today's kindergarten children and by their teachers as well. Large projection screens and a good blend of the physical game pieces with their virtual ones can prove effective for increasing motivation and collaboration levels among children. In the learning field, we also concluded that by playing the game the children's number of wrong answers decreased, which suggests the game could help kindergarten children to learn simple concepts.

Since kindergarten children loose the focus of their attention frequently, specially with a game, we feared that the game could harm the learning process. These results suggest that the game didn't make any harm to that process, since the next day's posttest results showed a positive improvement. According to teachers' feedback, the game looks like a promising way to complement the traditional teaching methods.

About motivation, we observed high levels of motivation while children played the game because most of them were clearly motivated, e.g. they never gave up the game until they found the solution. Curiosity was another driving factor towards motivation. Children wanted to see all the 3D animals but for that to happen, they had to wait until all markers were placed. In terms of maintaining motivation, this was a crucial design issue.

This research focus was around promoting collaboration. We analyzed several variables such as the number of collaborative comments made by children, number of constructive collaborative corrections made by children, including pointing gestures and the number of attempts made until reaching a solution. Results suggest that immediate feedback played an important role, increasing the number of collaborative behaviors and interactions among kindergarten children.

We also studied the impact of display size, but the results showed that differences were not significant, although by observation, and also according to teachers' feedback, the larger display seemed to better promote collaboration levels than the smaller display. Future work should consist of expanding the experiment in order to better assess the role played by the display size in collaboration levels. Future work will also include more tests with different schools, as well as investigating other features and design issues that could positively influence collaboration in kindergarten.

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