User-Oriented Design and Tangible Interaction for Kindergarten Children

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ABSTRACT
This paper describes a tabletop prototype that allows kindergarten children to take the benefits of the new pedagogical possibilities that tangible interaction and tabletop technologies offer to manipulative learning. After analyzing children's cognitive and psychomotorial skills, we have designed and tuned a prototype game suitable for children aged 3 to 4 years old. Our prototype uniquely combines low cost tangible interaction and tabletop technology with tutored learning. The design has been based on observations of the children using the technology, letting them freely play with the application during three play sessions. These observational sessions informed the design decisions for the game whilst also confirming the children's enjoyment with the prototype.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: Interaction Styles, Input Devices and Strategies.
H.1.2 [**User/Machine systems**]: Human Factors

General Terms
Design, Experimentation, Human Factors.

Keywords
Tangible Interaction, Children, Tabletop, User Center Design, Input Devices, Interaction Design, Game, Learning, Augmented reality.

1. INTRODUCTION
The educational and ludic possibilities offered by Tangible User Interfaces (TUI) are nowadays clear. These physical technologies are suitable for children providing they are designed to include aspects that are relevant to the child's development and incorporate social experiences, expressive tools and easy control. The combination of tangible technologies for input and a tabletop setting for interaction is not unusual but in many cases the resulting application is either not suited for kindergarten children or is so complex to install that it cannot be played anywhere except in the laboratory where it was conceived.

1.1 Physical and Tangible Toys for Children
Several research groups have been working on the development of TUI applications for children. Using physical toys as tangible bits, electronics are added to the toys, turning them into digitally interactive devices. In consequence, the toy retains its physical properties and so it is not bound by any restrictive rules or limitations on its use, thus improving the child's creativity and imagination. An example is the I/O Brush [10].

Equipped with sensors, physical toys are showing their potential in physical storytelling applications [6] [5]. Cassell and Ryokai [4], with their StoryMat interactive storytelling space, succeeded in involving pre-school children in physical manipulative and collaborative storytelling fantasy adventures.

1.2 Tabletop Interfaces for Children
Other applications for children are based on tabletop interfaces with multitouch interaction [3], [7], [9]. Mansor et al. [8] designed a DiamondTouch™ Tabletop game based on a traditional dolls house with a virtual reconstruction on the tabletop. Evaluations with children between 3 and 4 years old showed several difficulties with the interaction: children were seen to be frustrated whilst playing with the tabletop game as the system didn't respond to their little fingers' interaction. In fact, to achieve proper tabletop interaction for young children, there is a need to carefully observe children interactions when playing with toys. This is why along this paper, we will describe our observations of children playing with our tabletop, and how we have used this information to progressively design our console prototype and demo game.

1.3 Our Proposal
The design prototype described in this paper goes beyond common tabletop constraints and proposes a manipulative game application for children aged 3–4 years old. The points by which our research is different from previous works are:

- The emphasis on toy manipulation. The prototype is implemented as a tabletop, but interaction with the game is based on toy manipulation.
- The design focuses on robustness and simplicity in a hardware configuration that does not require high cost technology.
- The involvement of children (user contribution) during all the design process.

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- The possibility of combining tangible interaction and Embodied Conversational Agents (ECAs). This enhances the pedagogical possibilities of our tabletop.

2. NIKVISION DESCRIPTION

The first stage in this research was to build a platform on which games could be layered.

2.1 Hardware Configuration

On designing the prototype, the most important factors were: low-cost, technologically simple, easily installable, portable, and versatile in lighting conditions. As the prototype would be mainly used by small children, it also needed to be robust, safe, and suitable in size.

The computational process resides on a PC computer with Windows XP with the following input-output connections:

- Inputs: USB video camera and microphone.
- Outputs: television screen (video) and speakers (audio).

The tabletop (or playing surface) consists of a table sized 60 cm x 60 cm, and 45 cm in height (see fig.1). A USB video camera located under the table "reads" the toys the child is placing and manipulating on the table. In contrast with other tabletop configurations, this design does not show a computed image on the tabletop surface, but on a monitor displayed in front of the child. The kinds of games we are focusing in make use of an audiovisual language similar to cartoons, but with interactive actions performed on the tabletop with toys. Therefore, the monitor position is advantageous for us, as it is equivalent to the TV the child is used to watch, whereas image projection on the tabletop is less suitable to the cartoon audiovisual language. Moreover, as we are not projecting images on the table, we can work with visible light rather than infrared. This reduces the cost and allows us to use a wide variety of high quality cameras and diffuse lighting devices. The tabletop is made of diffuse translucent material, so that, the camera only sees what is directly on the table reducing the influence of external lighting conditions.

The resulting tabletop configuration is simple enough to be easily replicable and reconfigurable in different sizes and shapes and can be easily installed in kindergartens, schools, museums, and any place it is intended to be evaluated or used.

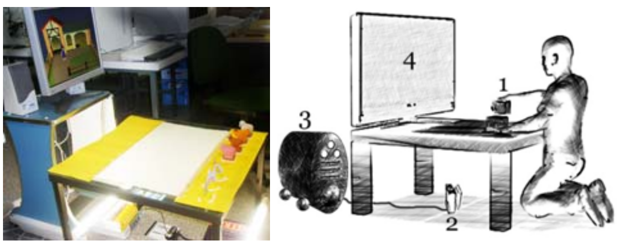

Figure 1. Tangible Tabletop prototype. 1. Tangible objects manipulated by user. 2. USB video camera. 3. PC computer. 4. TV set with speakers

2.2 Tangible Toys with Fiducials

Children play with wooden, plastic, or rubber toys that don't need any piece of electronics or active device as all the information is visual and captured by the camera. A black&white printed fiducial[1] is attached to the base of the toy so that the recognition software is able to identify each toy as it is placed on the table (see Fig. 2). Reactivision [2] software has been used for fiducial tracking because of its robustness and performance.

The objects that are tracked on the tabletop are represented in a 3D virtual environment that is shown on the monitor. This environment is implemented with Maxine software [1] which is a 3D engine for the management of virtual environments in real time. In Maxine it is possible to load geometrical models, animations, textures, videos or sounds as they are required in the virtual representation and it is especially oriented to the management of 3D interactive characters.

Figure 2. Wooden toys with fiducial attached to their base.

2.3 The 3D Game Virtual Scenery

2.3.1 Tangible Interaction

The tangible interaction is achieved by manipulating the tangible toys. During play, the children move the toys on the translucent surface of the table, putting the base of the toy in contact with the table to enable the camera to see the markers located under its base. The user can interact with the toys in the following ways (see fig. 3):

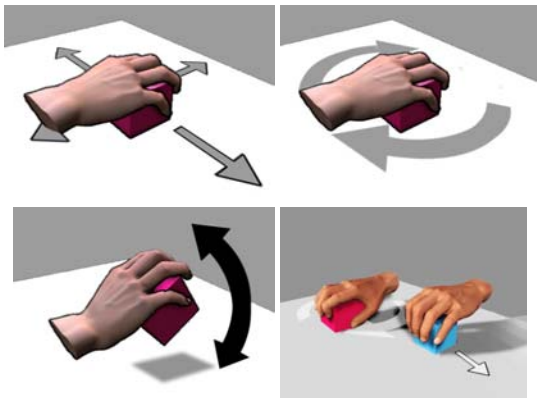

Figure 3. Up-left: drag toy on the desktop. Up-right: rotate toy. Down-left: "toy click". Down-right: Multiple interactions at the same time.

Move toy on the surface: The software tracks the position and velocity of the toys on the table and these are reflected in the game.

[1] Fiducial: visual pattern printed on paper which has topological characteristics that make the fiducial easy to detect and track by visual recognition algorithms.

Rotate toy: As long as the base with the marker remains on the table the software can track this orientation.

Hit toy: Children can grab the toy and "lift and hit" it on the surface (take a little jump with the toy). The visual software can detect that the toy has been removed from the table during a short time and it interprets this as a "toy click" (in analogy with "mouse click").

There is no limit on the number of toys that can be placed and moved on the desktop (providing there is free space on the table). This enables more than one child to play at the same time, and opens the application space to social activities.

The design of these key toy interactions were based on observations of children playing with their usual toys (cars, rubber animals, wooden cubes…) on surfaces. The objective was to implement tabletop interactive games where children give inputs to a digital virtual world that has been specially designed for them.

2.3.2 Designing a Demo: The Farm Game

This manipulative game consists of a virtual farm with a farmer as a virtual agent shown only on the screen. The farm animals are plastic animal toys with fiducials attached on their bases (see fig. 4). When children place animals on the table, they are represented on the screen as fully animated characters. They walk and make sounds when children drag them around the tabletop.

Figure 4. Left: Virtual Farm. Right: Animals manipulation on the table.

As a result of the testing sessions described in next section, interactive activities guided by the farmer were added as mini-games that children could trigger in specific zones of the farm:

Feeding the animals: Each animal has a place to eat. The farmer explains the necessity of feeding the animals and asks the child to place the animal where the specific food (fodder, barn, grass, etc) is.

Specific animal interactive activities: The hen has a nest where she can lay eggs. If the child does the "toy click" movement there (as described in the previous section) the 3D hen lays one egg.

3. INCLUDING CHILDREN IN THE DESIGN PROCESS

We had always wanted to have a user-centered approach to the work and so it was considered essential to have children contributing from the very beginning. Given their young age, in this study children acted mainly as users, but they were observed playing in a very early developmental stage of the prototype and thus informed the future designs. In this way the short trials that have been run have had the main aim of triggering the content development of the game and, at the same time, of uncovering any major usability faults.

In line with this approach, and having only a general idea of the game, we arranged three free individual play sessions in a time span of three weeks with three children aged 3 to 4. We let each child play freely in the setting to understand the real potential and limitations of the game. Between one session and the next, small improvements were added to the game according to the interaction the previous children had had. The play was observed by the designer involved in the development and by another researcher who was in charge of taking notes of the children's behaviors and reactions while playing. The sessions were video-recorded so that they could also be shared with researchers that did not attend the tests (see fig. 5).

Figure 5. Split-screen video with child playing and monitor output.

The sessions were intentionally unstructured and planned in a short time interval as their aim was to give to the developers a specific idea about the way children would behave in such a setting and what type of interactions would be most suitable for them.

3.1 Findings from the Play Sessions

The first session uncovered issues that had mainly to do with the physical arrangement of the technology like the lighting and the safety of the position of the hardware below the table. One problem detected was that if the child hit the lights or the camera with his/her feet then he/she had to stop playing in order to readjust the components.

When children handle the interactive objects, their psychomotor skills limit the precision of the movement. This was subsequently taken into account when designing the dimensions of the sensitive areas in the space, thus allowing more flexibility. Some actions need the toy animal to be oriented to the object it has to interact with. This action needs to be quite relaxed, as it was observed that children of this age take some time to manage the concept of orientation; it was also noted that having practiced this a little bit, the children succeeded in correctly orientating the toy. The setting of the game forces children to continuously look at the screen to find the response to their actions. At the same time they also have to look at the table and the objects they want to play with. As some of the objects has specific sounds associated to their proper actions in particular places, it was noted that this helped the child in understanding positive feedback to their action even when not looking at the monitor. This observation indicated that it would be good to implement a wider variety of interactions amongst the elements and to differentiate them with specific sounds so they do not require a change in focal attention. Based on the same principle, it was also decided to facilitate the correspondence between the actions on the tabletop and the events in the virtual space by clearly marking, in a visual way, key elements on the hotspots of the surface of the table where the actions were programmed to take place.

With these implementations in place, the second child had the chance to play with a more interactive game and the evaluation was able to focus more on the playful aspect of the game rather than on the technical aspects. For this second evaluation new animals and interactive activities were added.

The introduction of new elements highlighted some problems with the interpretation of some of the movements the children made with the elements; for instance, the child sometimes lifted the object to simulate the animal jumping. To ensure that this was not interpreted by the machine as a temporary disappearance of the object, we attached digital meaning to this gesture with an additional interaction, called the “toy click” (see hardware description section). This “toy click” was successfully tested in the third session.

The three sessions resulted in the previously described design of the game according to the technology potential and the user ability.

4. CONCLUSIONS AND FUTURE WORK

A tangible tabletop tutored prototype suitable for children has been designed and tuned. Our tabletop hardware design is, at the same time, simple and robust and has been shown to be a versatile tool for fast prototyping of tabletop games and new hardware tangible innovations.

A Farm Game oriented to kindergarten children, has been implemented and evaluated during three free play sessions. The tests performed have shown children acceptance and fun, but also have highlighted problems that have been or will be solved in short time.

The tabletop configuration is being improved: the table will be partly closed with the lights and camera attached inside, so that children can hit and move the table with no consequence.

The farm game is now ready for implementation as a complete storytelling game. The scripting work has started and this is being carried out with additional input from pedagogical experts and professional storytellers.

These two last achievements will be crucial for a formal evaluation session with a relevant number of children which will be performed in the next future.

Additionally, the farmer role is very simple for the moment, just guiding and greeting the child. More complex behavior with emotional content could be added thanks to the general agent’s platform we are using.

5. ACKNOWLEDGMENTS

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