An augmented interactive table supporting preschool children development through playing

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ABSTRACT

This paper discusses the opportunities and challenges of Ambient Intelligence (AmI) technologies in the context of child development, and presents the methodology and preliminary results of the development of an augmented interactive table which offers to preschool children various AmI educative and entertaining applications. The overall objective of this work is to assess how AmI technologies can contribute to the enhancement of children's skills and abilities through common play activities during the various stages of their growth and development.

Keywords: Ambient Intelligence, human computer interaction for children, smart games, learning, skills monitoring, tangible interaction

1 INTRODUCTION

Ambient Intelligence (AmI) is an emerging field of research that is gaining the attention all over the world and especially in Europe (IST Advisory Group, 2003). Smart environments that combine a number of interoperating computing-embedded devices to facilitate everyday life in an unobtrusive and natural manner are no longer a futuristic concept. As a matter of fact, AmI is becoming a key dimension of the emerging Information Society, since many of the new generation industrial digital products and services are clearly already shifting towards an overall intelligent computing environment.

As a result, AmI is bringing major changes in the way people interact with interactive products and services, their content and functionality. People and their social situation, ranging from individuals to groups, and their corresponding environments (office buildings, homes, public spaces, etc.), are at the centre of the design considerations.

The work reported in this paper, which is conducted in the context of the Ambient Intelligence Programme of ICS-FORTH (Grammenos, Zabulis, et al, 2009), constitutes an initial step towards investigating the role of Ambient Intelligence technologies in the child's developmental stages.

According to Barnett (1990), play contributes to overall child's development. First, playing enhances the child's physical and motor development which involves height, weight, general appearance/tone of the body and coordination of large and finer muscles. Second, it contributes to the child's cognitive development which includes forming self-concept and forming concepts of size, shape and colors. Finally, playing contributes to the child's social and emotional development which includes establishing relationships, developing behavioral controls and social skills that make them acceptable in their family, school and community. It is common knowledge that child's play is very revealing. How children play, learn, speak, and act offers important clues about their development.

Children's physical and cognitive abilities increase over time as they go through the developmental milestones. The Swiss psychologist Jean Piaget (1970) showed that children not only lack knowledge and experience, but also perceive and understand the world differently than adults. Therefore, it is very challenging to design and develop Ambient Intelligence applications for young children that will cater for their interaction skills and capabilities.

This paper presents a preliminary attempt to develop an augmented interactive table called Beantable, for children in the age-range of 2 to 7, and the related AmI applications which aim at integrating AmI technologies during play time. The purpose of Beantable is to support children's development through the monitored use of appropriate smart games in an unobtrusive manner. Beantable aims to provide intuitive and seamless tools to monitor and enhance the child's playing experience, through appropriate smart games. Additionally, adaptation and personalization techniques in the domain of educational games (Vasilyeva, 2007) are revisited here in an AmI perspective, aiming at exploiting the interaction possibilities offered by AmI.

Section 2 of this paper discusses the background and the related work, followed by a detailed description of the Beantable design and characteristics, as well as the hardware and software set-up of the prototype in Section 3. Section 4 presents the usage scenario of Beantable and the developed games. Finally, Section 5 reports the results of an expert walkthrough and the preliminary outcomes of an informal testing with children. The paper ends with overall conclusions and future work.

2 BACKGROUND AND RELATED WORK

In the literature there are a few examples of work that focus on augmented interfaces geared towards young children. NIKVision (Marco, et al, 2010) is a tabletop prototype designed to be mainly used by kindergarten children. Interaction is carried out through the physical manipulation of conventional toys on the table surface suitable to be installed in nurseries, schools and public spaces such as museums. Mansor, et al. (2008) designed the DiamondTouch™ Tabletop game based on a traditional dolls house with a virtual reconstruction on the tabletop. Smart table, an interactive learning center, is a commercial interactive table designed for preschool and elementary age children (4 to 11 years old). Other applications which exploit some features of tangible interaction and augmented reality towards supporting children interaction, playing and learning, are based on tabletop interfaces. Examples include the Smart Jigsaw Puzzle Assistant (Bohn, 2004), which is a fully operational augmented jigsaw puzzle game using miniature RFID tags, as well as SIDES (Piper, et al, 2006), a cooperative tabletop computer game for social skills development.

However, none of the above applications have the capacity to be personalized to individual children's needs, skills, and abilities, and more importantly, none of them is capable of evolving in order to address different developmental stages of children as they grow up. The main difference of Beantable with respect to the mentioned applications is that it monitors the interaction level of the child with any given game application and adapts its functionality accordingly to different forms of play. For example, in the case of a game that does not capture the attention of the child, the system is able to efficiently change the mode of interaction or offer an alternative game that is more engaging to the child while it satisfies the same developmental goals. The main characteristics of Beantable can be summarized as follows:

- **Interaction monitoring**: Taking into account the way a child plays, the selection of materials and game themes, and the way the child takes part into an activity, the system can extract indications of the achieved maturity and skills.
- **Game adaptation**: Through the use of smart games and appropriate guidance based on scaffolding (Berk and Winsler, 1995), Beantable provides the child with many opportunities for games, in order to support overall development, empowerment of imagination and creativity, as well as strengthening of initiative (and not just knowledge).

Beantable aims at meeting not only the needs of the children, but also the needs of their parents and educators. For children, Beantable acts as an object that carries various toys. For parents, the Beantable system acts as a tool that provides them with general information on their child's physical and mental development progress. At the same time, for educators and development experts the system can actually act as a diagnostic agent, as it provides them with analytical data that can be extracted from the interaction history and can be used to examine whether the child is meeting all the necessary developmental milestones.

The actual interaction of the child with Beantable covers part of the child's needs for activity, exercise and pleasure, and enhances social interaction and communication skills. At the same time, this interaction supports the overall development and enhancement of the child’s sensory, motor, cognitive, and social abilities based on the child’s individual biological and cognitive maturation pace (rather than based on social and cultural trends).

3 DESIGNING AN AUGMENTED INTERACTIVE TABLE

3.1 Physical artifact design

In the context of AmI, interactive devices must be unobtrusive, hidden or embedded in traditional everyday objects and furniture augmented with ICT technology without compromising general health and safety requirements. It is also very important for the equipment to be easy to install, easy to move around in the room and it shouldn’t take too much space. To this end, artifact-oriented approach has been adopted in the context of this work which introduces independent AmI augmented artifacts in the environment.

The first developed artifact is an augmented interactive table, Beantable, appropriate for use by children in age-range of 2 to 7 (Figure 1). The table, which has been custom built, is a wooden prototype with dimensions of 116cm (L) X 105cm (W) X 46cm (H), and has been designed to be robust yet transferrable. The height of the table can be adjusted to fit children’s needs as they grow. The hardware infrastructure (i.e., desktop computer, projectors, cameras, infrared beacons, etc.), that is required for the operation of the AmI applications is embedded in a way that is invisible to the eye. A main display device with a standard resolution of 1024 X 786 pixels is located on the top side of the table surface and has dimensions of 56cm (L) X 40cm (W).

The main display device is enabled with multi-touch and force-pressure sensitive capabilities, and is able to recognize the location and the rotation of physical objects that are placed on it provided that each physical object carries at least one fiducial marker (visual pattern printed on paper which has topological characteristics that make the fiducial easy to detect and track by visual recognition algorithms) at its bottom. The minimum size of each fiducial marker is 3X3 cm. Beantable comes with a custom made chair, with dimensions of 68cm (L) X 51cm (W) X 78cm (H), which is able to detect when the child is sitting on it and captures body posture data. Both the table and the chair have a soft yellow color which according to pedagogical experts is neutral and easily recognizable to children.

In addition to the above, the Beantable setup will also include the following components:

- A wall-mounted sensor module that captures data used for:
  - body posture recognition
  - head position estimation

- speech recognition
- gaze tracking
- gesture recognition

- A secondary device displaying a 3D animated model acting as a virtual child's partner during playing. The virtual character implements body animation, lip-synching, and shows emotions through facial expressions and voice.
- A smart pen that uses various sensors measuring the applied pressure weight, the position and orientation on the screen, and movement acceleration.

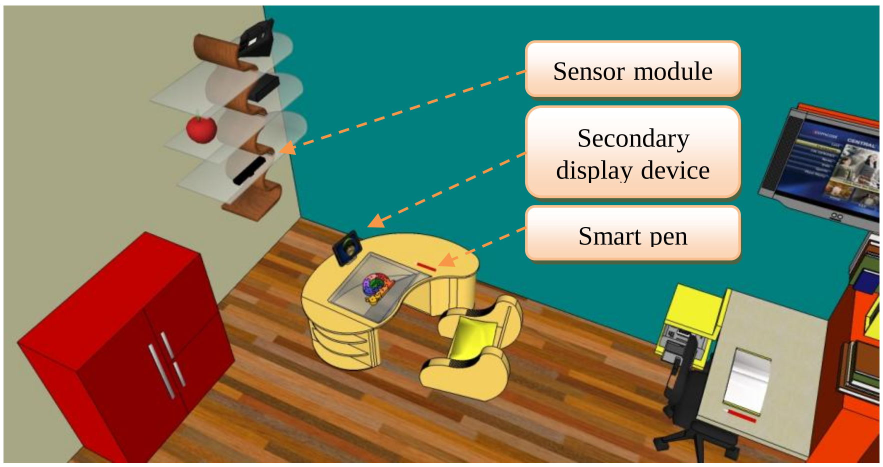


Figure 1 A room equipped with Beantable

3.2 Hardware and Software set up

An important feature of the interactive table is the use of vision-based back projection which facilitates the support of multi-touch interaction and object recognition, while ensuring gesture interaction quality under variable lighting conditions. Even though back project introduces space-related requirements, it eliminates the need for the installation of ceiling mounted cameras or hanging projectors, which would require for the fiducial markers to be placed on the top surface of each physical object and wouldn't allow a natural multi-touch interaction experience. The software used for the multi-touch and physical object recognition is an open-source software called reacTIVision (Kaltenbrunner and Bencina, 2007). The hardware set up includes (see Figure 2):

- Intel Core i7 PC
- A mini portable led projector located inside the artifact
- A mirror for reducing the projection distance
- 2 cameras located behind the screen with wide lens to maximize quality of the captured image
- 4 infrared beacons located behind the screen covered with thin fabric to diffuse the light smoothly

- 1 custom-designed high robust triplex glass covered by a window frosted glass film
- 2 cooling fans located at specific points that facilitate natural air flow and which are controlled by software running on a microcontroller
- 2 temperature sensors
- 1 stereo speaker set
- 4 pressure sensors located just behind the screen
- 4 pressure sensors located under the chair

Figure 2 Beantable hardware set up

4 USAGE SCENARIO AND GAMES

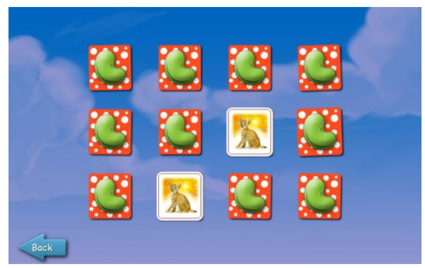
An important objective of Beantable is to ensure that the various technological artifacts that are developed have the playing process as their focal point. To this purpose, games involving physical objects, such as puzzles, were selected as a testing domain and common game practices were considered while building the actual usage test scenarios. In these scenarios, Beantable is the child's playmate during her / his growth. The interaction of the child with the Beantable begins the moment the child sits on the custom made chair. The sitting action initializes the starting screen that shows a menu (see Figure 3) of smart games that are appropriate for the child's age and skills based on previous interaction history.

Each smart game is composed of various micro games and it is built progressively by the child. As the child completes various levels in a micro game, more parts and features are added to the smart game. Consider, as an example, a variation of the classic game "Snake and Ladders" in which each building block (ladder, snake, etc.) is dynamically added as a reward from the successful completion of various levels in one of the relevant micro games.

Each micro game targets specific child skills and abilities according to the ICF classification (CAD, 2001), and supports their enhancement and development. It also acts as a monitoring and evaluation tool based on information given from pedagogical and child development experts and data captured during interaction. Eventually, combining appropriately designed micro games will result into the creation of motivating smart games that will attract the attention of the child throughout the age range targeted by the system.

Figure 3: Beantable menu

Figure 4: Winnie the Pooh



As examples of the aforementioned micro games, two jigsaw puzzles ("Winnie the Pooh" and "The Three Little Pigs"), as well as a classic memory game (Pick & Match), were developed and tested with young children (see Figure 4, Figure 5, Figure 6). Jigsaw puzzles composed of physical parts were selected as a testing game because most children are tactile learners, i.e., they learn best by touching and manipulating physical objects with their hands (see Figure 8). Puzzle games are not only entertaining, but can also provide a variety of learning opportunities. Michalewicz and Michalewicz (2007) categorize this type of learning as the "Eureka factor".

During playing, Beantable is able to identify the location and rotation of any piece of the puzzle on the surface and provide scalable and personalized guidance. For the moment, auditory feedback is provided on each successful match between two pieces and the game ends with applauses when the child fully completes the puzzle. Furthermore, there is visual information about the completion progress of the puzzle game.

Figure 7 Interaction with custom made stamp

Figure 8 Playing with jigsaw puzzle

Memory games are an optimal way to stimulate a child's brain and help enhance mental power and strength. Pick & Match allows the child to interact either by using fingers in the context of natural user experience or by using a custom made stamp (see Figure 7), which is appropriate for very young children with difficulties using multi-touch devices. Auditory feedback is used in this game as well.

5 EVALUATION

Two levels of evaluation have been conducted so far on the preliminary Beantable prototype. The first evaluation level involved expert walkthroughs which were conducted by three accessibility and usability experts from the FORTH Human-Computer Interaction Lab. The second evaluation level involved prototype testing with three children of ages 3, 3.5, and 6. The main objective was to assess the overall system usability and provide recommendations on how to improve design. The findings of both evaluations are reported below.

5.1 Expert walkthroughs evaluation

The experts were asked to play the preliminary developed micro games in order to uncover any potential violations of usability standards in the design, as well as identify any areas of the design that could potentially cause problems specifically to children.

Overall, the experts found the design of the game applications intuitive and engaging and pointed out only minor problems with the presentation of the menu and the game information. Regarding the physical design of the table, the experts found it ergonomic and commented on how its circular design would facilitate cooperative gaming. Their only concern was that the chair was too heavy for a younger child to drag or lift to get closer to the table. The main suggestions that the experts made on the design and logic of the games were:

- Increasing the difficulty level of the memory card game by adding more cards every time the child solved the puzzle.
- Projecting a border on the screen the size of the actual puzzle. The border image will help the child understand the physical dimensions of the puzzle and where to place the actual puzzle pieces.
- Projecting the image of the solved puzzle upon which the child could build the actual puzzle. This feature could be used for younger children that need help with solving the puzzle.

Changes based on the above observations and suggestions were implemented before moving to the second level of evaluation, the informal user-based evaluation.

5.2 Informal user-based evaluation

Three children were invited to participate in the preliminary user-based evaluation of the Beantable prototype with the consent of their parents, who were present but did not play any specific role in the experiment. Two of the children were boys with ages 3.5 and 6, and one was a girl 3.5 year old. They were each asked by the evaluator to sit on the table and select a game from the menu to play. All three of them were able to open, close and play the games with very little given instructions by the evaluator. They all reached the highest level of difficulty of the memory card game (24 cards) and completed the two puzzles with ease. What was really impressive was the fact that even though the button labels that appeared in the dialog boxes were written in English, they knew which button to select based on its color, green for yes, red for no. They all expressed that they liked the games and that was also evident by the fact that they remained engaged throughout the evaluation and selected to play all three games.

Figure 9 From left to right: a girl 3.5 old and two boys 3.5 and 6 years old respectively

6 CONCLUSIONS

AmI technologies have the potential to enhance the child's playing experience and to be accepted by young children, provided that they are carefully designed and tested. The main characteristic of the proposed system is the capability to monitor the child's interaction during playtime and to adapt the game according to the child's performance in an unobtrusive and personalized way. This adaption and experience enhancement is based on the recorded interaction history data regarding the child's skills and abilities.

Currently, the prototype table has been assembled and all the necessary software building blocks have been installed. In cooperation with child development experts, fully functional smart games are being developed, along with the software required for supporting the monitoring functionalities using the wall mounted sensor. Upon full completion of the system, a large-scale evaluation experiment is being planned, involving children, pedagogical experts and parents.

Based on bibliography, a knowledge base (ontology) of children's skills, abilities and developmental milestones in the targeted age range is currently under development in order to support the whole system's functionality and share with other AmI applications in the context of AmI home environment, nursery or kindergarten. Moreover, further types of smart games are being designed in order to fully exploit the potential for cooperative interaction offered by Beantable.

Beantable will be installed and tested under almost real-life conditions in a complete AmI home environment located in the AmI Research Facility of ICS-FORTH.

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