Integrating Interactive Learning Experiences into Augmented Toy Environments

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Abstract. The Augmented Knight's Castle is a pervasive computing playset which enriches the children's pretend play by using background music, sound effects and verbal commentary of toys that react to the childrens's play. We argue that such an augmented playset offers ideal possibilities of seamlessly integrating interactive learning experiences: toy figures such as the king, a knight or a farmer teach children about the life in the Middle Ages from their perspective and depending on the context of play. In addition to these interactive stories, a variety of other learning scenarios can be integrated (e.g., children learn songs or poems from the troubadour by simply pointing at the figure with a magic wand). Radio Frequency Identification (RFID) technology is used to automatically and unobtrusively identify the toys in the playset. Mobile devices equipped with RFID readers are introduced into the playset to provoke further interaction and to enhance the play.

1 Introduction

Playing with toys is an essential part of the childhood. Besides being a recreational amusement and pure fun, playing also serves as an important function for the psychological, physiological and social development of a child [1, 2]. To further support creativity and inspire the fantasy of children, traditional toys can be enriched by adding multimedia content to them. The ideal entertainment and learning experience then comes from the combination of physical experience, virtual content, storytelling and the imagination of the user [3].

By adding audio components to the Playmobil Knights Empire Castle, we present an entertaining and exciting multimedia playground [4] that fosters the children's pretend play and offers ideal possibilities of integrating interactive learning experiences into the children's play (see Fig. 1). Based on the current game situations or learning scenario, sound effects, background music, verbal commentaries or verbal stories are played.

The idea of equipping toys with electronic or virtual components is not new and there have been several approaches and ideas in this field with related aspects. A good overview and classification of pervasive games can be found in [5]. Only few approaches are designed for children, such as the Zowie playsets [2], which act as tangible user interfaces to a virtual play world on a computer. Several projects focus on story telling of children: StoryMat [6] is a play space where children can

collaboratively record and listen to their own stories. The storytelling environment StoryToy [7] has the objective to tell stories or play sounds based on children's interaction with toy animals of a farm. The KidStory project [8] takes the approach to incorporate children in the design and development of augmented storytelling spaces or rooms. A stronger focus towards learning is taken by the research of the Special Interest Group 'Narrative and Learning Environments' [9], which examines the advantages of embedding narrative in technology-based learning environments.

Educational games and toys often have a limited degree of freedom of play such as learning with characters where a toy character takes on the role of a buddy or teacher. This role is impersonated either as a virtual interface agent or an augmented puppet that is often connected to a multimedia learning game on a computer. Pervasive computing games and toys that seamlessly connect the virtual learning content with the physical toys offer many interesting possibilities for educational toys. In addition to that, they can help to facilitate the social skills development of children with social disorders or mental diseases such as autism and even help to detect them [10].

Fig. 1. The rich play and learning environment of the Augmented Knight's Castle playset

The remainder of the paper is organized as follows: In section 2, we discuss the possibilities of integrating interactive learning experiences into the children's play and present different learning scenarios that have been integrated in the augmented playset. Section 3 gives an overview of the technical realization and section 4 concludes with a brief discussion and outlook.

2 Interactive Learning Experiences

An important part of the children's pretend play is their own fantasy or imagination which supports the immersion into the play. Stapleton's mixed-fantasy framework

[3], which is based on the physical, virtual and imaginary reality, helps to better understand and structure our approach of integrating learning experiences into pervasive computing playsets (see Fig. 2). The physical reality is the playset including the toy figures and objects with which the children interact while playing. The imaginary reality is the children's imagination and the story that unfolds in their mind. Traditional toys would only consist of these two realities. Adding the virtual reality (i.e., the virtual counterparts of figures, objects and buildings of the playset, including the multimedia and learning content), results in a mixed reality that accounts for the entertaining playing and learning experience.

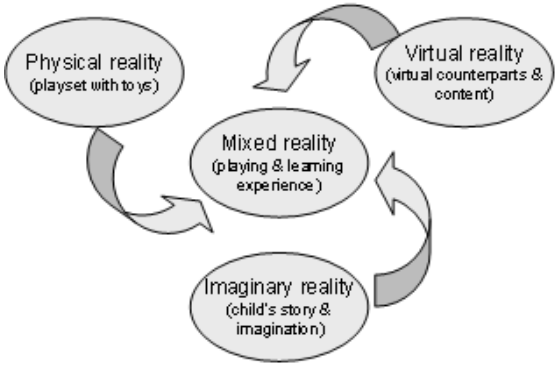

Fig. 2. Mixed-fantasy framework [3] applied to augmented toy learning experience

We chose the Playmobil Knight's Empire Castle as a playset since it is a realistic image of the real world of the Middle Ages and it provides many different buildings, objects and figures that allow building an interesting and exciting environment for the children. Additionally, the topic "Middle Ages" offers many anchor points for learning scenarios (e.g., music, clothing, festivals, troubadour literature, chivalry, heraldry, or knights tournaments). Another suitable topic would have been modern city life or the Roman Empire.

Fig. 3. Three different forms of interaction that trigger learning experiences

Besides sound effects, we also play background music and verbal commentaries that adapt to the current play situation. This atmospheric but often overlooked [11] music and the realistic illustrations of the figures, buildings and objects of the playset intensify the immersion into the game: the virtual reality and the physical reality support the imaginary reality. We are planning to further enhance the playing

experience by adding light, scent, vibration, or other actuators through which the virtual can reach out to the physical reality.

Another important point for the learning scenarios is the semantic mapping between the physical and virtual realities, i.e. the appearance of the physical toy figure is semantically connected to the role or function such a figure played in real life in the Middle Ages. In other words, a particular toy figure is connected to specific parts of knowledge about the Middle Ages that semantically fit its role or function [12]. This semantic mapping empowers children to easily understand the role or function of a play object, and therefore allows fast and intuitive understanding.

While designing the augmented playset, we pursued different forms of interaction between the child and the playset that trigger or are part of learning scenarios (see Fig. 3 for examples):

1. The toy figure is placed by a child at specific locations in the playset. For example, the child places the troubadour close to the knight's tournament, where the troubadour starts reciting poems or telling stories about tournaments.
2. A child uses a smart toy such as a magic wand, sword or magic bottle that acts as a point-and-touch device to select a toy figure, building or object. For example, the child points with the smart toy sword at the red dragon who tells the child about legends involving dragons.
3. A mobile phone enabled as point-and-touch device is used by the child to select objects in the playset. For example, the child points at the alchemist that challenges the child's knowledge with a short quiz.
4. The playset gives tactile, visual and audible feedback to the children. For example, the magic tree starts moving when a certain figure is placed close to it or the magic bottle is glowing after the child shakes it. Moreover, feedback is given by playing sounds, music or verbal commentaries.

From the variety of imaginable learning scenarios we currently implemented the following scenarios to be able to further investigate the children's acceptance of our concepts. The examples are given using the first form of interaction. During the course of play the other two forms of interaction can also be used. To maximize the integration of the learning experiences in the children's play, the figures tell their stories from their individual perspective of their role/function. They also address the children directly simulating a dialogue between them and the children. The complexity of the content and the form of presentation can be adapted to the age of the children:

- The king explains what it is like to live with his family and court in a castle in the Middle Ages, including different topics, e.g., life in a castle, royal family, craftsmen and guilds, weaponry or heraldry. As shown in Fig. 4, the king invites the child to follow him through different areas and settings of the castle. The king explains for each setting (e.g., defense weaponry, craftsmen and drawbridge) different facts and asks the child to place him to a different location or to leave him at the current location in order to explain more details.
- The troubadour teaches songs and poems and sings together with the children. The children are encouraged to create their own poems or songs which they can record and play back. Furthermore, the troubadour talks about his life in the Middle Ages, poetry and Courtly Love.

- A knight explains the children how to become a knight and talks about his quests, tournaments and chivalry and explains different forms of weaponry.
- The alchemist gives insight into the science of the Middle Ages and general topics of interest such as mathematics, chemistry, herbs, magic or astronomy. Moreover, he encourages the child to place him anywhere in the playset to learn more about specific buildings, objects or people.
- To become acquainted with and stimulate learning of a foreign language, simple foreign language modules are integrated. For example, a magic spell lets one group of the knights only speak in a foreign language. Another figure helps the children find out what is going on and helps them translating what the knights have said. In a different setting, children can simply point with their mobile phone or smart toy at an object and get the name for it in a foreign language.

Fig. 4. The king explains details about the life in a castle to the child

3 Technical Realization

Designing a truly pervasive computing game and learning experience, we required that the augmentation does not interfere with, block or compromise the traditional play in any way (i.e., toys are handled in the way children are used to). Furthermore, we did not want the children to wear any special equipment such as head-mounted displays since this would also interfere with their free play. RFID technology represents a suitable means to bridge the physical and virtual world in an invisible or at least unobtrusive manner [13] and is our choice to detect the position of objects in the playset (in our case 13.56 MHz RFID technology). The stationary and mobile readers with antennas cover several important areas of the playset. The RFID tags of different sizes are attached to or incorporated into the pieces of the playset to uniquely identify them (see Fig. 5). Since a reliable detection of tags is dependent on the orientation of the tags to the antenna field, we incorporated up to three tags in different orientations to play figures (e.g. tags in the head, at the back and at the foot of a figure). This approach also allows us to detect if a figure is standing or lying on the ground.

The two approaches of integrating mobile devices to the playset and enable them as point-and-touch devices both rely on the custom-build mobile RFID reader module (Skyetek M1-mini RFID reader controlled by a BTnode that is used as a Bluetooth

device server). In the case of the mobile phone, the mobile RFID reader module is attached to and powered by a Nokia 6830 that connects to the module via Bluetooth. The same module is incorporated into toys such as a magic wand, sword or magic bottle (see Fig. 6).

Fig. 5. Antennas embedded in the playset (left) and RFID transponders to tag toy pieces (right)

In addition, the module of such smart toys is extended by a sensor board that includes, among others, light and 3d-acceleration sensors and a microphone. These sensors bring context into the play which can be added to the point-and-touch interaction to make the play more engaging. The microphones allow detecting if the children are playing silently or if they are talking or making noise. In addition, the acceleration sensors can be used to perform gesture recognition such as the shaking of the magic bottle or the circular movement with the magic wand. Actuators on the other hand reach out into the physical reality and provide feedback to the children. We incorporated vibration modules into the magic wand and several game objects to give tactile feedback; or LEDs into the magic bottle for visual feedback.

Fig. 6. Two smart toys: the magic bottle (left) and the magic wand (right)

RFID data of all the readers are filtered, aggregated and then enriched with object information (e.g., the name or type of the tagged object) by our RFID middleware [14] and stored as object data in a symbolic location model of the playset (e.g. figure king located at court of castle). That means, the location model represents the actual play situation as sensed by the RFID hardware and provides an abstraction of the RFID-specific details.

Based on the current playing or learning situations and settings, sound effects, background music and verbal commentaries are played either as a response to an

action (e.g., the fanfare is played when the king comes out of his quarters) or randomly (e.g., a dog barks or birds chirp). In the current implementation, the kind of reaction is preconfigured using state machine-based software architecture in the playset logic that allows reacting to more complex situations over a certain length of time. State transitions are triggered by conditions that can be formulated using logical operators and a simple query language for the location model. States themselves can perform actions such as sound or music playback. The whole set of preconfigured state machines creates the audio playback of the sounds, music and verbal commentaries. In a similar way the learning scenarios are modeled using state machines that react to a certain configuration of toy figures. For example, the king that explains the life in a castle is modeled using different states depending on the location of the king. For each state different verbal commentaries and stories can be played.

4 Conclusion

We presented the Augmented Knight's Castle, which offers ideal possibilities to integrate interactive learning experiences for children besides enriching the children's pretend play by using background music, sound effects and verbal commentary and stories in reaction to the children's play.

The RFID technology proved to be an appropriate means to automatically and unobtrusively detect the state of play. While implementing the learning scenarios, the state machine-based software architecture showed some drawbacks. The approach is sufficient for many play and learning situations that can be easily modeled using state machines and the provided query language. However, for more complex play situations the state machines become very complex and the model turns out to be not flexible enough. For this reason, we are considering different models to detect play situations and react to them and to be able to manage different interconnected story lines such as ontology-based approaches or self-learning systems.

Critically analyzing the two approaches to integrate mobile devices into the playset (extended mobile phones and mobile sensor and actuator devices embedded into toys), we can say that both approaches have their advantages and disadvantages: a mobile phone has strong functional capabilities and can be applied very generally, but lacks the usability as a toy. The strength of an embedded mobile device in a toy is its seamless integration and intuitive usage, but all functions have to be custom built and implemented.

To determine the acceptance of the learning experience and to evaluate different aspects of interaction and learning scenario design, we are currently planning a user study. Among others, we are interested in the differences regarding age and gender towards the acceptance of the learning scenarios and the usage of smart toys and mobile phones. In the planned study, children will play with the Augmented Knight's Castle in different set-ups that are video taped to be able to qualitatively and quantitatively evaluate our approach. Before the evaluation, the educational content such as the stories and facts about the Middle Ages will have to be designed more professionally with the help of pedagogically and didactically trained staff.

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