Mobile Device-based Interaction Patterns in Augmented Toy Environments

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Abstract. We present the Augmented Knight's Castle, a pervasive playset, which enriches the child's pretend play by using background music, sound effects and verbal commentary of toys that react to the child's play. Radio frequency identification (RFID) technology is used to automatically and unobtrusively identify toys in the playset. Mobile devices equipped with RFID readers are introduced into the playset to provoke further interaction and to enhance the play (e.g., through the integration of interactive learning experiences). We describe two approaches of mobile device integration (mobile phones and mobile devices embedded into toys) with a preliminary analysis of their advantages and disadvantages. One objective of our presented augmented playset is to conduct a user study whose results will help us and others to improve the integration of mobile devices into augmented toys and playsets.

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 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 award winning Playmobil Knights Empire Castle[1], we present an entertaining and exciting multimedia playground that fosters the children's pretend play (see Fig. 1). Based on the actual game situations and settings, sound effects, background music and verbal commentaries are played. Radio frequency identification (RFID) technology is used to automatically and unobtrusively identify toys in the playset.

To provoke further interaction, mobile devices that implement the touch-me paradigm [4] through RFID are added to the play. That means, a child can use the mobile device to touch pieces of the playset, and images or videos can be displayed. We pursue two approaches to add mobile devices to the playset: first, mobile phones that are enabled as touch-me devices, and second, mobile devices which are

[1] www.playmobil.com

embedded into toys to enable them as touch-me devices. To better evaluate the two different approaches, we are planning to conduct a user study with children of different age groups. The results of the user study will help us and others to improve the integration of mobile devices into augmented toys and playsets and therefore enhancing the children's fun and play.

Fig. 1. The Augmented Knight's Castle Playset

The remainder paper is organized as follows: In section 2, we describe the basic setting of the Augmented Knight's Castle playset. Section 3 introduces the mobile device-based interactions in our augmented playset including a preliminary analysis of the two presented approaches. In section 4, we point out the differences of our approach to related work. The paper concludes with a summary of our contribution and a brief description of the planned user study in section 5.

2 The Basic Setting of the Augmented Knight's Castle

Designing a truly pervasive game, we required that the augmentation does not interfere, block or compromise the traditional play in any ways but that it seamlessly integrates with the toy playset (i.e. toys are handled in the way children are used to). Furthermore, we did not want the children to wear any special equipment (e.g., head-mounted displays). According to [5], our playset can therefore be categorized as an augmented toy.

RFID technology represents a suitable means to bridge the physical and virtual world in an invisible or at least unobtrusive manner [6] and is our choice to detect the position of objects in the playset. We use high frequency (HF) RFID technology that operates at 13.56 MHz and complies with the ISO 15693 standard. The RFID hardware from Feig[2] consists of one ID ISC.MR100 reader, one ID ISC.ANT.MUX multiplexer, which performs time multiplexing to query the tags in each antenna field, and 8 antennas in different sizes. Fig. 2 shows the playset and gives an idea on how the RFID technology is integrated into the playset.

Fig. 2. Playset with technology hidden (l.) and RFID antennas to observe the active zones (r.)

The RFID tags in the form of flexible RFID labels of different sizes are attached to or incorporated into the pieces of the playset to uniquely identify them. To tackle the problem with orientation of tags in antenna fields [7] we tagged objects with several tags of different orientation (e.g., back and bottom side of figures) to have at least one of the tags read in an antenna field. The 64-bit ID that is stored on the RFID tag is used as the key to map the pieces to their virtual information such as name, images, stories, or sounds. The RFID antennas are either attached to buildings or to different types of floor elements to detect the presence of game pieces in their proximity. The RFID readers are connected to the base station, on which the tag observations are filtered (i.e., to remove false-negative reads) and aggregated by our RFID middleware [8]. The middleware also provides an abstract interface to the RFID hardware to easily exchange the hardware from different vendors without changing the software.

Fig. 3. Enchanted tree with mobile RFID reader

In order to be able to observe the close proximity of larger objects that move in the course of play, we incorporated mobile RFID readers into these objects. The reader

[2] www.feig.de

module consists of a BTnode[3] that communicates with the base station via Bluetooth and that operates a Skyetek M1-mini[4] RFID reader with an external antenna integrated into the surface of an object. Fig. 3 shows, for example, the enchanted tree with the mobile reader module at the back. The reader is covered with brown plastic tape to hide it during the play.

The advantage of HF RFID technology for our application is the limited read range that allows clearly specifying a zone which will be observed by an RFID antenna. Our playset defines the following static active zones: the courtyard, drawbridge, prison and living quarters of the king's castle, the plain in front of the castle, the dark forest and the dragon tower. In addition, there are two mobile active zones that can move around and still observe their close environment: the carriage and the enchanted tree. The seamless integration of the RFID antennas in different modules of the playset (i.e. buildings, floor elements, and landscape parts) and the mobile RFID readers implicate that the setup of the playset is not predefined but allows changing it to a certain degree according to the desires of the children.

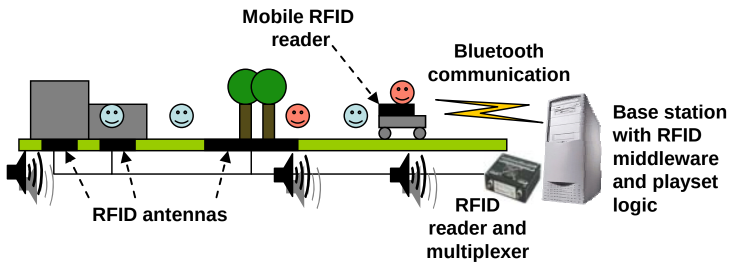

Fig. 4. Technical architecture of the playset

Based on the actual game 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). The kind of reaction is preconfigured using a state machine-based software architecture in the playset logic that runs on the base station. Event-action-rules can be defined to generate events from the raw RFID tag observations using comparison and aggregation operations. For example, an event could be triggered when the red dragon is leaving the dragon tower or the background music changes from idyllic to battle sound when at least three dragon knight figures are placed on the plain in front of the king's castle. These events then trigger the transitions of the state machines with which more complex reactions can be modeled than solely events would allow. A state can perform certain audio play actions (e.g., playing a roaring in reaction to moving the red dragon). Fig. 4 summarizes the technical architecture of the playset.

So far, the augmentation of the toys is on an acoustical level only. But it is possible to even further enhance the playing experience by adding light, scent, vibration, or other actuators.

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[3] www.btnode.ethz.ch
[4] www.skyetek.com

3 Adding Mobile Devices to the Playset

The benefits of adding mobile devices such as mobile phones to the Augmented Knight's Castle playset are a more interesting and interactive play. Mobile phones can be used for displaying images and videos, for playing sounds and music, and they can become pointing and touching devices bringing new forms of interactions and possibilities into the play. We pursue two approaches of integrating mobile devices to the playset: first, mobile phones that are enabled as touch-me devices, and second, mobile devices which are embedded into toys to enable them as touch-me devices.

3.1 Integrating Mobile Phones into the Playset

To enable the mobile phone as a touch-me device, we equipped a Nokia 6830 with our custom built BTnode RFID reader module (see previous section) similar to the approach of [4]. As shown in Fig. 5, the external antenna is attached to the top part of the mobile phone to allow the point-and-touch interaction with pieces of the playset. The application on the mobile phone is implemented in C++ for Symbian OS and communicates with the BTnode and the base station via two Bluetooth connections.

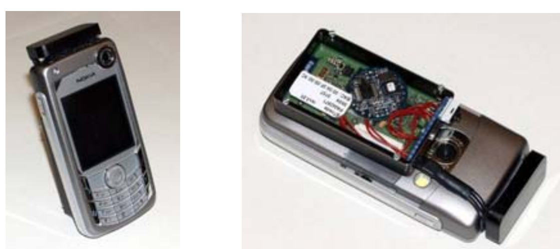

Fig. 5. Nokia 6830 with BTnode-RFID-reader and external antenna (front and back view)

The mobile phone has several advantages that support its integration into the playset: no extra device has to be provided since there is already a high deployment of mobile phones in the population of western countries even among children, who can just use their phones with the playset. Moreover, mobile phones can easily be exchanged if they break or malfunction. In the future, mobile phones with near field communication[5] (NFC) will become more widespread, which have already an integrated RFID reader and can act as touch-me device. For now, we have to first equip the mobile phone with an RFID reader. On top, the playset software has to be installed prior to play.

To enrich the play, the mobile phone has the capabilities to play audio and videos and display images and text. Enabled as a touch-me device, pieces of the playset that the child touches can be identified (see Fig. 6). This allows a mobile phone to embody many roles during a course of play: For example, it can act as an information device displaying multimedia content related to the piece of the playset that is touched. This

[5] www.nfc-forum.org

role can also be the interface to integrate learning into the play (see section 3.3). Another role is that of a weapon: The children can touch each other's mobile phones and figures on the playset to initiate a fight between the figures. It can also embody a virtual bottle containing a magic potion, which might have been found at the enchanted tree. The potion can then be administered to a wounded knight to heal him by touching the figure (see Fig. 6). Many other different roles (e.g. flowers, food, or gifts) are conceivable whose embodiment can even be further enhanced by one haptic capability of a mobile phone: the vibration alarm. In our playset implementation, the consequences of the application of such virtual objects are mere enhancement of the child's pretend play. A typical reaction is an affirmative verbal commentary of a figure or a sound effect played. In a playset that is oriented more towards role playing or tabletop games, a virtual game state could keep track of application of virtual objects (e.g., a knight can fight stronger if he has been drinking a magic potion before).

Fig. 6. Point-me, touch-me interaction between mobile phone and figure (left) and a mobile phone that takes on the role of a magic potion (right)

3.2 Mobile Devices Embedded into Toys

Despite all its multimedia and haptic functionality to embody a role, the mobile phone cannot change its look-and-feel of a technical device, which hinders a seamless integration into the playset. In addition, the touch-me paradigm of using a mobile phone is not very intuitive which might change if more people are used to NFC-enabled phones. These drawbacks led us to the approach of embedding mobile devices into toys for a more seamless and intuitive integration of the previously described interactions into the play.

Once more, we apply the BTnode platform with a connected Skyetek M1-mini RFID reader and embed it into different toys to enable them as touch-me devices (see Fig. 7 and Fig. 8). The external antenna is adjusted to the form factor of the toy to specify the sensible area to touch objects with (e.g., the opening of the bottle or the blade of the sword). The BTnode controls the RFID reader and sends the IDs of the RFID tags to the base station via a Bluetooth L2CAP connection. After activation, the toy with the embedded device is ready to use and no additional setup or installation is needed.

Fig. 7. BTnode with mobile RFID reader embedded into a toy sword

In the embedded solution the toy itself is the embodiment of one or several roles in the playset (see Fig. 8) depending on its role in real life: for example, a sword is used for fighting but can also be used to poke around examining objects. Therefore, the toys have to be carefully chosen since the role can only be communicated by the look-and-feel of the toy which also supports the intuitive usage of the touch-me paradigm. This has, of course, the downside that only few roles can be embodied by one toy and that several toys have to be equipped with a mobile device in order to enrich the child's play. At least one toy that can get information or selecting a figure should be included in the playset. In our case we chose the sword to also act as selection device but other toys (e.g. magic wand) are also possible.

Fig. 8. Touch-me paradigm of different toys with embedded BTnode and RFID reader

To take advantage of the embedded BTnode platform and to allow another form of interaction, we attached a sensor board to the BTnode 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 3d-acceleration sensors measure if a child shakes the magic potion well before it administers it to a figure and the sword fight is enriched by requiring movement of the swords. The data of the sensors are transferred to the base station, analyzed according to certain parameters and influences the results of the interaction. In the future, we plan to also embed haptics and other unobtrusive output into the toys (e.g. vibration or LEDs to let the bottle glow when it is active).

3.3 Interactive Learning Experiences

Integrating interactive learning experiences is one of the new possibilities offered by the integration of mobile devices into the playset: children can learn songs or poems from the troubadour of the king's castle by simply pointing at the figure of the troubadour with their mobile phone. Another possibility is a mobile phone mode where playset pieces that are touched tell their names in a foreign language promoting the learning of foreign language vocabulary. In addition, the children can access facts about certain themes of the Middle Ages by touching pieces of the playset using the toy sword with the embedded mobile device (e.g., accessing historical facts about chivalry by touching a knight), or they could play simple learning games using the mobile devices (e.g., pointing to figures on the playset in the correct hierarchical order of the feudal system in the Middle Ages). Different learning modules can be added or downloaded dynamically according to the age and knowledge level of the children. Third parties could easily develop their own themes and learning modules or games and incorporate them into the augmented playset.

4 Related Work

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 similar aspects. A good overview and classification of pervasive games can be found in [5]. These games or toys that combine the real and the virtual world are usually called pervasive games, hybrid games, smart toys, or augmented toys, depending on their exact purpose and design.

Zowie playsets (i.e., Redbeard's Pirate Quest and Ellie's Enchanted Garden) are tangible toys with integrated sensors for transmitting the state of movable playing pieces to a computer application [2]. Based on this setting, several computer-like games are implemented that integrate the real-world playset into their virtual world. The playing pieces function as a facilitator: the output comes from a computer screen, and the pieces are used as a kind of tangible user interface to perform the actions demanded from the storyline or play mode. The focus on the computer as output device differs from our approach of integrating mobile phones into the playset: A lot of the attention of the child's play is focused on the computer. This would happen only for very short times on when using mobile phones. Using mobile devices embedded into toys keeps the attention always on the playset.

StoryToy is a toy animal farm with an integrated storytelling environment consisting of an audio replay engine and a tactile user interface based on a sensor network [9]. It does not require a computer and has the objective to tell stories or play sounds based on the child's interaction with the animals of the farm. The story toy has several similarities to our basic playset (detection of game figures that trigger audio output), but does not integrate mobile phones into the toy probably due to the younger age of the target group. Besides sound effects, we also play background music that adapts to the actual play situation. This atmospheric but often overlooked [10] music triggers real immersion into the game.

Another category of pervasive games that are related to augmented playsets are augmented tabletop games (e.g., KnightMage [11], or False Prophets [12]). These games also have physical playsets that are enhanced with different pervasive computing technologies to keep track of the player's action, sense the location of game pieces, support the game with effects, or bring virtual parts of the game into the physical realm. However, the games are often not playable without technology any more. Moreover, they enforce rules and a flow of events due to their game nature in contrast to our enhanced free child's pretend play. The idea of adding a mobile device is applied in KnightMage, where a PDA equipped with an RFID reader supports the touch-me paradigm to get virtual information about game pieces.

RFID technology has been used also by other researchers for identifying game pieces such as cards or figures. Examples are the smart jigsaw puzzle assistant [13], the smart playing cards [14], and the STARS platform to develop augmented tabletop games [15].

5 Conclusion & Future work

We presented the Augmented Knight's Castle, which enriches the child's pretend play by using background music, sound effects and verbal commentary in reaction to the child's play. Tests and previous experiences using RFID in smart objects allowed us to successfully and reliably adopt RFID as an automatic and unobtrusive identification technology in the playset. Mobile devices were added to the playset to provoke further interaction applying the touch-me paradigm and enrich the child's play.

Critically analyzing the two approaches to integrate mobile devices into the playset (mobile phones and mobile 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 better weigh the advantages and disadvantages and make recommendations on the integration of mobile devices into the playset, we plan to conduct a user study with the presented playset. We intend to compare the acceptance of the mobile device integration into the playset and are planning to perform the user study with three groups of children: (a) children playing the basic playset without mobile devices at all, (b) children playing with the playset where mobile phones are added, and (c) children playing with the playset and toys with embedded mobile devices. This research setting will allow us to evaluate the acceptance of the two approaches compared with each other and mobile device usage in general compared to the basic augmented play without mobile devices. Ideally, the user study will also be performed with children of different age groups for the three different playset groups to examine the effect of age towards the acceptance of mobile devices in the playset. The results will help us and others to improve the integration of mobile devices into augmented toys and playsets and therefore enhancing the children's fun, play and learning.

Bibliography

[1] G. Butterworth and M. Harris, *Principles of Developmental Psychology*. Hillsdale, NJ: Lawrence Erlbaum, 1994.

[2] H. Shwe, "Smarter Play for Smart Toys: The Benefits of Technology-Enhanced Play," *Zowie Intertainment White Paper 3208*, 1999.

[3] C. B. Stapleton, C. E. Hughes, and J. M. Moshell, "Mixed reality and the interactive imagination," presented at First Swedish-American Workshop on modelling and simulation (SAWMAS 02), 2002.

[4] L. Pohjanheimo, H. Keränen, and H. Ailisto, "Implementing TouchMe Paradigm with a Mobile Phone," presented at Joint sOc-EUSAI conference, Grenoble, 2005.

[5] C. Magerkurth, A. D. Cheok, R. L. Mandryk, and T. Nilsen, "Pervasive Games: Bringing Computer Entertainment Back to the Real World," *ACM Computers in Entertainment*, vol. 3, 2005.

[6] R. Want, K. P. Fishkin, A. Gujar, and B. L. Harrison, "Bridging Physical and Virtual Worlds with Electronic Tags," 1999.

[7] C. Floerkemeier and M. Lampe, "Issues with RFID usage in ubiquitous computing applications.," presented at Pervasive Computing: Second International Conference, PERVASIVE 2004, Vienna, 2004.

[8] C. Floerkemeier and M. Lampe, "RFID middleware design - addressing application requirements and RFID constraints," presented at Joint sOc-EUSAI conference, Grenoble, 2005.

[9] W. Fontijn and P. Mendels, "StoryToy the Interactive Storytelling Toy," presented at The Second International Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2005, Munich, 2005.

[10] C. Magerkurth, M. Memisoglu, and T. Engelke, "Towards the next generation of tabletop gaming experiences," presented at Conference on Graphics Interface 2004, 2004.

[11] C. Magerkurth, R. Stenzel, N. Streitz, and E. Neuhold., "A multimodal interaction framework for pervasive game applications," presented at Workshop at Artificial Intelligence in Mobile System (AIMS), Fraunhofer IPSI, 2003

[12] R. L. Mandryk and D. S. Maranan., "False prophets: exploring hybrid board/video games," *CHI '02 extended abstracts on Human factors in computing systems*, pp. 640–641, 2002.

[13] J. Bohn, "The Smart Jigsaw Puzzle Assistant: Using RFID Technology for Building Augmented Real-World Games," presented at International Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2004, 2004.

[14] K. Römer and S. Domnitcheva, "Smart Playing Cards: A Ubiquitous Computing Game," *Personal and Ubiquitous Computing*, vol. 6, pp. 371–377, 2002.

[15] C. Magerkurth, R. Stenzel, and T. Prante, "STARS - A Ubiquitous Computing Platform for Computer Augmented Tabletop Games," presented at Video Track and Adjunct Proceedings of the Fifth International Conference on Ubiquitous Computing (UBICOMP'03), Seattle, WA, USA, 2003.