

The Augmented Knight's Castle – Integrating Mobile and Pervasive Computing Technologies into Traditional Toy Environments

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Abstract. The Augmented Knight's Castle is an augmented toy environment that enriches the children's pretend play by using background music, sound effects, verbal commentary of toys, and different forms of tactile and visual feedback in reaction to the children's play. Moreover, interactive learning experiences can be integrated into the play (e.g. to teach songs and poems or to provide the child with facts about the Middle Ages). We describe the different possibilities that are realized in our augmented playset, based on various mobile and pervasive computing technologies. Radio frequency identification (RFID) technology is used to automatically and unobtrusively identify toys in the playset. Mobile phones and "smart toys" equipped with sensors and RFID readers are introduced into the playset to enhance the play and to provoke further interaction.

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 and visual and tactile feedback to a traditional toy playset, we created an entertaining and exciting multimedia playground that fosters the children's pretend play and offers ideal possibilities of integrating interactive learning experiences (see Fig. 1). Based on the current play situations and settings, sound effects, background music and verbal commentaries are played, buildings, trees or other objects of the playset start shaking or moving, or light effects such as the glowing of a magic bottle are displayed.

To provoke further interaction, mobile devices that implement the touch-me paradigm [4] to identify toy objects are integrated into the playset. That means, children can use the mobile devices to touch pieces of the playset either as part of a

learning scenario, a story that unfolds, or simply as part of free play. We pursue two approaches to add mobile devices to the playset: First, mobile phones that are enabled as touch-me devices, and second, mobile touch-me devices with integrated sensors and actuators that are embedded into toys enabling them as “smart toys”.

In addition to the enriched play and learning experience, such augmented toy environments can help to facilitate the development of social skills of children with social disorders or mental diseases such as autism and even help to detect them [5].



Fig. 1. The Augmented Knight's Castle Playset

The remainder of the article is organized as follows: In section 2, we describe the possibilities of the Augmented Knight's Castle playset as an augmented toy including typical play and learning scenarios. Section 3 gives an insight into the technical realization using pervasive and mobile computing technologies. The lessons learned are critically discussed in section 4. In section 5, we point out the differences of our approach to related work. The article concludes with a summary of our contribution in section 6.

2 The Augmented Knight's Castle Playset

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 augmenting a traditional toy environment. 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 consist only 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 [6].

The mixed reality of the Augmented Knight's Castle playset combines the advantages of both the physical and virtual reality (see also [7]): It is physical in the sense that the pieces of the playset can be touched, moved, manipulated and rearranged in a variety of ways. It includes the social aspect of traditional toys since children play together by sharing the same playset and their stories. The virtual aspect of the toy (e.g., the learning scenarios), which reaches out into the physical by music, as well as sound effects, verbal commentary, and tactile and visual feedback, allows stimulating the mental and intellectual capabilities in a way traditional toys are not capable of. Finally, the children's immersion into the play can be even further deepened by a rich toy environment that comes alive through the augmentation.

We chose the Playmobil Knight's Empire Castle as a playset since it is a realistic representation of the Middle Ages which provides many different buildings, objects and figures that allow creating an interesting and exciting environment for the children. An important factor for the children to easily understand the role or function of a play object and its virtual content (i.e., to allow fast and intuitive understanding), is the semantic relation between the physical and virtual realities [8]: In our playset, the appearance of the physical toy figures is semantically connected to the function such a figure had in real life in the Middle Ages. Furthermore, the topic "Middle Ages" offers many anchor points for play and learning scenarios (e.g., music, clothing, festivals, troubadour literature, chivalry, heraldry, or knights tournaments). Another suitable topic among others would have been "Modern City Life" or the "Roman Empire".

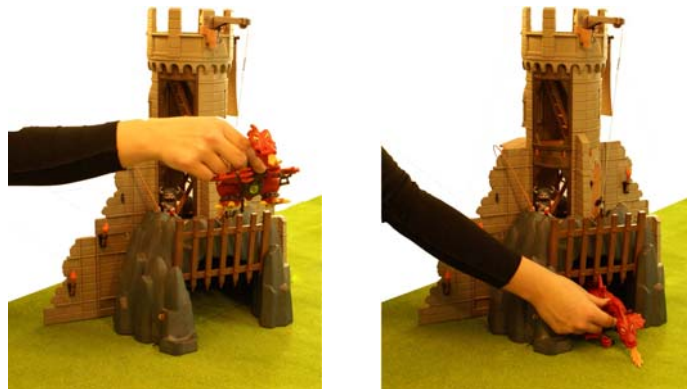


Fig. 2. The red dragon is set free from the dungeon

While designing the augmented playset, we pursued different forms of interaction between the child and the playset that trigger, or are part of, playing and learning scenarios [6]. :

1. A toy figure or group of figures is removed from or placed at a specific location 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. In another example, the red dragon is removed from the dragon tower making a roaring sound (see Fig. 2).

2. A child uses a smart toy (i.e., a toy piece that is augmented to detect other figures and perceive the play context) 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 dragon legends (see Fig. 3 a).
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 puzzle, question or riddle (see Fig. 3 b).
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.



Fig. 3. Point-me-touch-me paradigm using (a) a smart toy sword, and (b) a mobile phone

Based on the current play situations and settings, which are combinations of the four interaction forms, audible, tactile or visual feedback is given as a response to an action (e.g., the fanfare is played when the king comes out of his quarters). In addition, such effects or feedback can happen randomly (e.g., a dog barks or birds chirp). So far, the feedback of the playset is mainly on an acoustical level with a number of additional tactile features such as vibration of smart toys and building. But it is possible to even further enhance the playing experience by adding light effects, scent, smoke, or other actuators.

The following play and learning scenario illustrates the play experience from the “user’s” point of view, in our case the two children Tom and Jenny:

The scenery consists of several separated areas of the playset (see Fig. 1): The formidable castle belonging to the king and his knights, the plain in front of the castle where the inn is situated; the legendary dark forest with the hidden fairy spring and the enchanted tree; and the mighty dragon tower owned by the dragon knights located behind the dark forest. Tom chooses to play the dragon knights while Jenny represents the king’s knights.

A great feast is taking place in the throne room. When Jenny takes the king and the queen to the room, a fanfare and exultation can be heard. Then, as long as king and queen remain in the room, the participants will celebrate and eat frolicsomenly. In the

meanwhile, the king's knights are preparing the treasure carriage in the inner ward; horses are whinnying, a dog is barking. Idyllic background music is playing.

Jenny takes the king from the room puts him into the inner ward: The celebration stops, and an impressive blare of trumpets accompanies the king's appearance. The draw bridge is lowered and the carriage and its escort are leaving the castle. As they pass the plain, the sounds of the carriage and the gallop of the horses are perceived.



Fig. 4. Confrontation between dragon knights and king's knights

In the meanwhile, Tom prepares the dragon knights for an assault on the carriage to take control of the treasure. He places several dragon knights in front of the dragon tower, where horses' neigh and the sounds of knights preparing for battle are heard. When he sets the dragon free from its dungeon, a mighty and ground-shaking roar is perceivable on the whole playset (see Fig. 2). The dragon knights move out to the nearby dark forest, where an owl is howling. Then they encounter the king's knights. Since the dragon knights are superior in numbers, the king's knights flee back to the castle after a short fight, leaving the carriage and the treasure behind (see Fig. 4). During the confrontation the background music becomes more dramatic and the clangor of swords and the yells of the fighting knights can be heard. The dragon knights bring the treasure back to their dragon tower and start celebrating.



Fig. 5. (a) Receiving the healing potion from the fairy, (b) and administering it to the injured king's knight

Since one of the king's knights has been injured very badly, the golden knight sets out into the dark forest to ask the fairy at the spring for help. When he enters the forest, mysterious sounds and music is perceived. The fairy and the animal at the spring greet the golden knight. Since he brings a gift, the fairy presents the knight a

magic healing potion (see Fig. 5 a). The magic bottle starts vibrating, and lights around the bottle start dancing. Jenny shakes the bottle to mix the magic potion and the light on top of the bottle starts glowing. She offers the healing potion to the injured knight who thanks her with some refreshing sounds and comments (see Fig. 5 b).

After a certain while of inactivity, the king verbally offers Jenny and Tom to show them around in the castle and reveal them some secrets about it. Jenny places the king at the draw bridge to start the “castle tour” and the king tells the story of the construction of the castle’s walls and explains the importance of the moat and the draw bridge in keeping intruders away (see Fig. 6 a). Tom, however, is more interested in the smith who is forging a sword so he places the king in the courtyard where the smith and carpenter are working. The king explains Tom the different weapons of the Middle Ages and the smith is providing details about the fabulous sword that he is manufacturing (see Fig. 6 b).



Fig. 6. (a) “Castle tour” starting at the draw bridge, (b) and continuing at the courtyard

Jenny gets more interested in playing with the troubadour who starts reciting a poem and encourages her to recite a poem she knows or to come up with a poem of her own. After that, the troubadour tells the story about the last poetry contest that had taken place at the castle and his courtly love towards one of the princesses. He closes with a little song which the children know and they both join in the singing.

3 Using Mobile and Pervasive Computing Technologies

Designing a truly pervasive computing playset, we required that the augmentation does not interfere, block or compromise the traditional play in any way, but 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 [9], our playset can therefore be categorized as an augmented toy environment. The following sections describe the basic playset using radio frequency identification (RFID) as an automatic identification technology, the integration of mobile phones and smart toys, and the software system that enables the enriched play and learning experience.

3.1 The Basic Augmented Playset

RFID technology represents a suitable means to bridge the physical and virtual world in an invisible or at least unobtrusive manner [10] and is our choice to detect the position of objects in the playset. We use RFID technology that operates at 13.56 MHz and complies with the ISO 15693 standard. The RFID hardware from Feig¹ consists of one ID ISC.ANT.MUX multiplexer, which performs time multiplexing to query tags in four different antenna fields, and several ID ISC.MR100 readers and antennas of different sizes. Fig. 7 shows the playset and gives an idea on how the RFID technology is unobtrusively integrated into the playset.



Fig. 7. Invisible integration of RFID antennas into the playset

The advantage of RFID technology that operates at 13.56 MHz (which is using inductive coupling) is the well defined read range that can be adjusted in size by using different antenna sizes (i.e. the small area of the gate is observed using a 10 cm x 10 cm antenna, whereas the courtyard of the castle is observed using a 20 cm x 30 cm antenna).



Fig. 8. (a) Figure of king with RFID tags, (b) Flag of castle with RFID tag

The RFID tags of different sizes are attached to or incorporated into the pieces of the playset to uniquely identify them (see Fig. 8). To tackle the problem with tag

¹ www.feig.de

orientation in antenna fields [11], we tagged most 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 play objects to their virtual information such as name, images, stories or sounds. The RFID antennas are either attached to toy buildings or to different types of floor elements such as the fairy spring, to detect the presence of toy pieces in their proximity.



Fig. 9. (a) Enchanted tree, (b) with mobile RFID reader and (c) with custom-built antenna

In order to be able to observe the close proximity of larger toy objects that are moved over the playset in the course of play (e.g., the carriage), we incorporated mobile RFID readers into these Knight's Castle application via Bluetooth. The BTnode operates a Skyetek M1-mini² RFID reader with an external antenna integrated into the surface of an object. As an example, Fig. 9 shows the enchanted tree with the mobile reader module at the back and the custom built external antenna. During the play, the reader is covered with brown plastic tape to hide it.

We defined the following read areas in our playset: The courtyard, the drawbridge, the prison, the living quarters, the tower of the king's castle, the plain in front of the castle, the inn, the ruin of the magician, the forest with the fairy spring, and the dragon tower. In addition, there are two mobile read areas 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 and landscape elements) but especially the mobile RFID readers, implicate that the setup of the playset is not predefined but allows modifications according to the current play context and the preferences of the children.

The RFID readers, the multiplexer, and the RFID reader modules, which are based on the BTnode, are connected to a computer (hence called "base station"), where the tag observations are filtered (i.e., to remove false-negative reads) and aggregated by our RFID middleware Accada [12]. The middleware also provides an abstract interface to the RFID hardware to easily exchange the hardware from different vendors without changing the software (see Fig. 14).

² www.skyetek.com

3.2 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 RFID reader module based on the BTnode platform (see previous section) similar to the approach of [4]. As shown in Fig. 10 a and b, 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 Bluetooth connections (see Fig. 14).



Fig. 10. Mobile phone with RFID-reader and external antenna (a) front and (b) back view; and (c) mobile phone that embodies the role of a magic potion

To enrich the play, the mobile phone has the capabilities of playing audio and video files, as well as displaying images and text. Enabled as a touch-me device, pieces of the playset touched by the children can thus be identified (see Fig. 3 b). This allows a mobile phone to represent many roles during a course of play:

- It can act as an information device displaying multimedia content related to the piece of the playset that is touched. This role can also be the interface to integrate learning experiences into the play.
- 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 represent a virtual bottle containing a magic potion, which might have been found at the enchanted tree (see Fig. 10 c). The potion can then be administered to a wounded knight to heal him by touching the figure.

Many other different roles (e.g. flowers, food, or gifts) are conceivable whose representations 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 children's pretend play. A typical reaction is an affirmative verbal commentary of a figure or a sound effect. 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 administered a magic potion before).

3.3 Mobile Devices Embedded into Toys

Despite all the multimedia and haptic functionalities that support the role(s) a mobile phone can represent, as a technical device, it cannot change its look-and-feel, 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 when more people are used to Near Field Communication (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. This kind of toy is also called “smart toy”.

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. 3 a and Fig. 11). The external antenna of the RFID reader is adjusted to the form factor of the toy to specify the sensible area to touch other objects with (e.g., the opening of the bottle or the top part of the magic wand). The BTnode controls the RFID reader and sends the IDs of the RFID tags to the base station via a Bluetooth L2CAP connection.



Fig. 11. BTnode with RFID reader and sensor board embedded into a toy wand and bottle

The smart toy itself embodies one or more roles in the playset [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 children’s play. At least one toy should be included into the play that allows selecting a figure and display information about it (or play corresponding audio or video). In our case, we chose the magic wand for this.

To take advantage of the embedded BTnode platform and to allow other forms 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 microphones allow detecting the current noise level caused by the children and react accordingly. In addition, the acceleration sensors can be used to

perform gesture recognition such as shaking the magic bottle or a circular movement with the magic wand. Simple gestures such as shaking can be analyzed on the BTnode. For more complex gestures, the data of the acceleration sensors is streamed to a component on the base station that determines the gestures performed by the children. The component relies on the Georgia Tech Gesture Toolkit (GT2k) [13], an open-source toolkit with the objective to support the research and development on gesture recognition.

Actuators reach out into the physical reality and provide feedback to the children. We incorporated vibration modules into the magic wand and several play objects to give tactile feedback. LEDs in the magic bottle give visual feedback to the children to signal that the magic potion in the bottle is active.

3.4 Augmented Knight’s Castle Software System

The filtered and aggregated RFID data of all the readers are stored as object information in a symbolic location model of the playset that is enriched with additional object information (e.g. figure king located at courtyard of castle). The object model is managed in the Object Monitoring System (OMS) and provides an abstraction of the RFID-specific details. It furthermore offers a programming model to define generation of events and actions based on the information in the object model. The static part of the object model that represents the locations of interest, which are monitored by RFID readers, is predefined (see Fig. 12). For example, if the toy figure of the golden knight is placed closed enough to the enchanted tree (i.e., the RFID reader detects the tag in the toy figure), the OMS retrieves related information such as name and descriptions, and creates an object node for the golden knight which is placed in the object model as a child node of the enchanted tree. Once the figure is removed from its physical location at the enchanted tree, the node of the golden knight is removed. The object model therefore changes continuously while the children are playing and represents the current play situation as sensed by the RFID hardware in almost real-time.

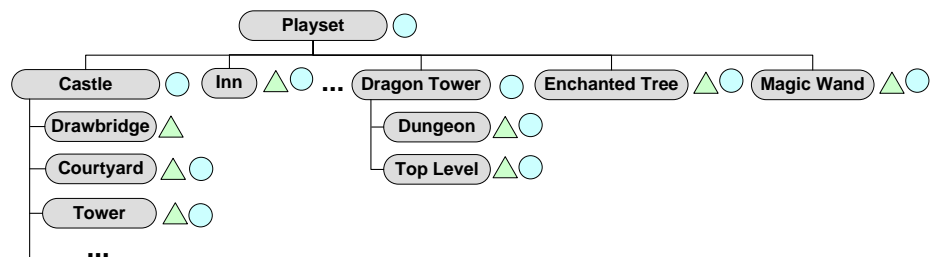


Fig. 12. The predefined instance of the object model for the Augmented Knight’s Castle (triangles denote connected RFID readers or sensors, circles denote related state machines)

The play logic determines, based on the current playing or learning situations and settings, which sound effects, background music and verbal commentaries are played or which actuators are activated either as a response to an action or simply randomly. In the current implementation, the play logic is realized using the state machine-based

software architecture of the OMS that allows reacting to more complex situations over a certain length of time. A state machine is used to model play processes over time where a state represents a certain play situation (e.g. the red dragon is in the dragon tower). State transitions are triggered by conditions that can be formulated using logical operators and a simple query language to access the information of the object model. States themselves can perform actions such as playing sounds or activate actuators. The set of all state machine definitions creates the audio playback of the sounds, music and verbal commentaries and the tactile and visual feedback. 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.

In a similar way the learning scenarios are modeled using state machines that react to a certain configuration of toy figures. Fig. 13 displays an example of a state machine definition in which the king gives the children a tour through the castle. The example only contains two locations: The draw bridge and the court yard. The whole definition includes several other locations of the castle. At the draw bridge, the king explains the function of the walls, the draw bridge and the moat. In the court yard, he talks about the different craftsmen guilds and, if a craftsman is present, he will add special information and stories about his work and life. The state machine is modeled in a way that one location is visited only once. If the figure of the king is not moved for a certain amount of time, the tour is halted and can be resumed later on..

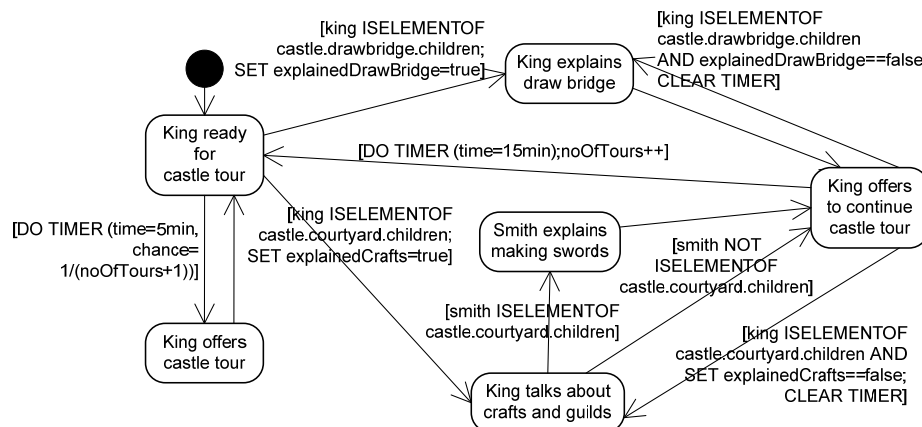


Fig. 13. Part of state machine definition for the learning scenario “King explains castle life”

The complete hardware and software setup can be summarized as follows (see Fig. 14): The *Base Station* hosts the *Accada Reader* components that manage the RFID readers at static locations. The data of these components is transferred to the *OMS* that contains the object model and the state machine definitions. The RFID readers of mobile locations and smart toys, which are based on the *BTnode* platform, feed their data directly into the *OMS*. The *Augmented Knights Castle Application* handles the more complex play logic (based on the notification events of the state machines), manages the gestures recognition with the *Gesture Toolkit*, and controls the sound system using the *Sound Library*. The *Augmented Knights Castle Mobile Application*

deployed on the *Mobile Phones* manages the events of the connected RFID reader and communicates play logic events with the *Augmented Knights Castle Application*.

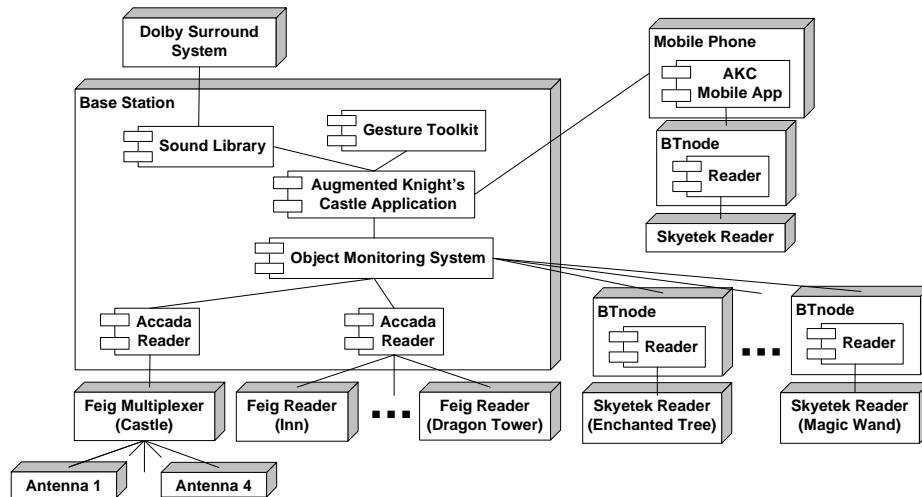


Fig. 14. Deployment of the hardware and software components of the playset

4 Discussion

Designing and implementing the Augmented Knight's Castle over the course of one year led to many improvements and lessons learned. The following sections discuss the most important points concerning the RFID technology, the integration of mobile devices into the design of the play as well as the learning scenarios.

4.1 RFID Technology

RFID technology proves to be an appropriate means to automatically and unobtrusively detect the state of play. The advantage of RFID technology that operates at 13.56 MHz (high frequency, HF) for our application is the limited read range that allows clearly specifying the zone to be observed by an RFID antenna. Since a read zone is directly related to the size of the antenna coil, read areas of different sizes can be built easily. Moreover, for HF systems it is possible to design and build custom-made antennas using copper wire or foil.

In our first implementation, we operated all antennas with one multiplexer. However, the time to multiplex all antennas was up to 3 seconds, which could result in a delay of 3 seconds between the play action of a child and the sound or music played based on that action. To optimize the reaction time, we now only operate four antennas using the multiplexer. The other antennas have dedicated readers or are operated using the mobile RFID reader module. The advantage of replacing static

readers with mobile ones is the increased modularity of the playset. The children can rearrange the playset in the course of play (e.g. putting the inn to a different place on the floor). The only limit of the mobile readers is set by the number of Bluetooth connections the base station can handle. Each Bluetooth module at the base station can only communicate with 7 mobile readers.

The small RFID tags we use are perfect in form factor and size to be attached to and integrated into the toy pieces. Using more than one tag per object proves to be an adequate way to increase the chance of detecting objects. Read errors or missed reads are compensated by the other tags. Moreover, due to the limited read range of the small tags, the system can infer whether an object is standing or lying on the ground according to the RFID tag that is read (e.g., if the tag in the head of a figure is read, the figure must be lying since it is never read while standing).

The RFID middleware we utilize (Accada Reader) can be easily setup and configure, and furthermore allows the straightforward exchange of reader hardware or the usage of the visual reader simulator of the Accada Reader component for testing purposes. Using the OMS makes the development of the Augmented Knight's Castle software component straightforward. No additional code has to be implemented to deal with RFID specific data. The play and learning logic is implemented using the provided declarative programming model (see section 4.3 for drawbacks).

4.2 Mobile Device Integration

Critically analyzing the two approaches of integrating mobile devices into the playset (extended mobile phones and mobile sensor and actuator devices embedded into toys, i.e. smart toys), we can say that both approaches have their advantages and disadvantages (see Table 1). Overall, it can be observed that a mobile phone has strong functional capabilities and can be very generally applied, 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.

In a particular play setting, the designer has to decide if either of the two approaches or a combination of both fulfills all the desired functionalities. If displaying videos or images is required, or if there are several roles a mobile device should represent, mobile phones are the devices of choice. If the emphasis is put on the seamless integration of mobile devices into the play, smart toys should be used.

Another important factor is the age of the children: Young children have difficulties operating a mobile phone and should therefore use smart toys. Older children are more used to mobile phones, either from personal experience or from the usage of other mobile devices such as video game consoles. To them the usage of mobile phones and other technical devices might encourage their engagement in the play since it resembles the user interface of computer or video games.

4.3 Play and Learning Scenario Design

While implementing the play and learning scenarios, the state machine-based software architecture showed some drawbacks. The approach is sufficient for many simple play and learning situations that can be easily modeled using state machines and the provided query language. However, for more complex and intricate play situations, the state machines become very complex and difficult to understand and maintain. For these reasons, we are considering different models to analyze play situations, to react accordingly, and to be able to manage different interconnected story lines such as ontology-based approaches or self-learning systems.

Designing good play and learning scenarios and stories is a challenging task that requires didactical and pedagogical knowledge. Therefore, we intend to improve the educational content such as the stories and facts about the Middle Ages with the help of pedagogically and didactically trained staff before conducting a user study.

Table 1. Analysis of the two approaches of mobile device integration

	Approach 1: Mobile phones	Approach 2: Mobile devices embedded into toys (smart toys)
Pros	<ul style="list-style-type: none"> • High deployment of mobile phones in the population, even among children. • No extra device needed. • Multimedia capabilities (audio and visual) • Representation of many roles in the playset (e.g. magic potion, sword, magic wand). • Basic haptic capability (using the vibration alarm). • Can easily be replaced by another phone if broken. 	<ul style="list-style-type: none"> • More seamless integration into the playset. • Look-and-feel of toy itself represents the role(s) in the playset (e.g. sword for fighting). • Choice of toy supports intuitive usage of touch-me paradigm. • No installation procedure prior to playing. Can be used instantly. • Sensors bring context into the play (e.g. shake magic potion before usage).
Cons	<ul style="list-style-type: none"> • No seamless integration into playset (it's a technical device). • Touch-me paradigm not as intuitive. • Representation of roles only through multimedia and haptics. Mobile phone cannot change its look-and-feel. • Installation procedure of playset software prior to play. • Additional RFID reader needed (NFC-enabled phones in the future). 	<ul style="list-style-type: none"> • Only limited roles represented by a single toy (e.g., sword to fight and select). • Several toys have to be embedded with mobile devices. • Has to be custom-built. • Haptics and output have to be embedded additionally. • Limited display and audio feedback possible. • If broken, new replacement has to be built.

5 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 [9] and [7]. 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 screen as output device differs from our approach of integrating mobile phones into the playset: A lot of the attention of the children's play is focused on the computer. This would happen only for very short times when using mobile phones. Using smart 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 [14]. 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 [15] music triggers real immersion into the game.

A slightly different approach was taken with StoryMat [16], a play space where children are able to collaboratively record and listen to their own stories. One child plays with the toys on a soft interactive play mat and the story that the child tells is recorded. Another child playing on the mat can record his or her own stories. In addition, if play actions match the ones of prerecorded stories, the recording is played and the play action is projected on the mat. In this way, stories of one child can trigger another related story of another child. In our approach we also give the children the possibility to record their own voices and sounds to extend the multimedia of the playset.

A stronger focus towards learning is taken by the research of the Special Interest Group 'Narrative and Learning Environments' [17], which examines the advantages of embedding narrative in technology-based learning environments.

Another category of pervasive games that are related to augmented playsets and share many similarities are augmented tabletop games (e.g., KnightMage [18], or False Prophets [19]). 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 personal digital assistant (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. In the smart jigsaw puzzle assistant, a hybrid tabletop game that augments the physical pieces of a jigsaw puzzle with RFID tags [20], the application on the computer updates its internal state of the puzzle with each new piece that is added to the physical version of the puzzle. However, the player has to intentionally place a puzzle piece at a RFID reader. A more seamless integration of RFID is applied in a smart card game by [21]. Cards with RFID tags are detected by an antenna in the table to display the state of the game, count points and identify cheating players. The STARS platform [22] to develop augmented tabletop games consists of a table with an integrated RFID antenna to detect physical game tokens that are placed on the table.

6 Conclusion

We presented the Augmented Knight's Castle, which enriches the children's pretend play by using background music, sound effects, verbal commentary and tactile and visual feedback in reaction to the children's play actions. 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 phones and smart toys were added to the playset to further enrich the children's play and make it more engaging.

To determine the acceptance of the Augmented Knight's Castle, especially of the learning experiences and the integration of mobile devices into the playset, we plan to conduct a user study with children of different age groups. The objective of the user study is to improve the play and learning experience, to evaluate different aspects of interaction and the design of learning scenarios and to come up with general recommendations on the integration of mobile devices into playsets.

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