StoryToy the Interactive Storytelling Toy

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ABSTRACT
Children are drawn away from traditional toys and towards computer games at an ever younger age. Pervasive Computing may reverse that trend as it can bring similar levels of interactivity as available in computer games to traditional toys. In this a paper a storytelling environment is presented consisting of an audio replay engine and a tactile user interface based on a sensor network. The implemented user interface has the form of a farm made out of cloth with stuffed animals as actors. Around the farm and inside the animals are wireless sensor pods that transmit the manipulations of the characters to the replay engine. Several stories and games with differing levels of complexity were created and tested on children of ages between two and six. This demonstrated that with audio feedback alone one can already offer an equally enjoyable level of interactivity as provided by computer and console games. It also showed that with a 'roadmap' of complexity, the same platform can grow with the child.

Keywords
Toy, storytelling, sensor network, tactile interface.

1. INTRODUCTION
With Pervasive Computing there are many new ways and opportunities for humans to interact with their environment. This poses a dilemma, because as the environment and the devices in it get more complex, the requirements of ease of use get more stringent. At least that is the basic premise of Ambient Intelligence [1], which can been seen as an application centric view on Pervasive Computing. What is needed is a way to ensure that applications that populate our future surroundings are easier to use (and to learn to use) than their current counterparts. There is one area where this, in general, appears to be less of an issue: toys and games. These have a special quality that compels users to interact with them before they fully know how to use them. How to play a game is often learned by playing it, with little knowledge upfront. One reason is that toys are often not task driven but some are and are still easy to grasp. If we apply Pervasive Computing to toys while preserving their usual ease of use we may be able to extract principles of user interaction that can be applied to more serious applications. Making the latter more instinctive and enjoyable to learn to use [2]. In a way, Pervasive Computing applied to toys can be a kindergarten of technologies where we learn how to use them best.

Applying technology to toys does not automatically go with the preservation of ease of use. At the moment there is an noticeable gap between traditional toys and high tech toys. Some toys have a low threshold because they are cuddly and fluffy and some are technologically advanced but few are both at the same time. Also, for most electronic toys it is not obvious how to use them, while typically for using traditional toys one needs little or no instruction. We wanted to create a toy that bridges the gap, that is both low threshold and high tech. The technology used should be advanced but not obvious, and the children should be able and willing to use it without instruction. Also, we want the technology to be, at least in potential, low cost, because in that case it can be pervasive without the costs of the whole system being prohibitive. Wireless sensors fit these technological requirements. They can facilitate advanced interactivity without being visible [3]. We have chosen storytelling because it is fun, has rich opportunities for interaction and because it has a special role in the cognitive development of children [4].

In the following chapter we first discuss other efforts in the field of storytelling, then present our own environment and proceed to compare the two. In chapter three we discuss the different types of stories our platform supports, in order of increasing complexity. The experimental work we did is presented in chapter four, followed by future work and our conclusions.

Figure 1: User Interface of the storytelling farm StoryToy.

2. RELATED WORK
Interactive storytelling has been a subject of research for some time already, see [4] and reference therein. However, the focus of this research has been to a large extent on the technique of storytelling from an educational point of view or on the creation

of supporting technology. We want our storytelling environment to look like a traditional toy and be as easy to use but, at the same time, offer a rich interactive experience.

We now discuss two research areas in which interactive storytelling environments are the main subject. The fist area comprises story capturing systems, i.e. systems that listen to stories created by children. The second area comprises tangible user interfaces for controlling stories.

2.1 Story Capturing

In 'Making Space For Voice' [5], Cassel and Ryokai point out that more technology should be aimed at supporting children's own stories. Products should 'listen' more instead of imposing content created by adults. In this context they present 'StoryMat', a mat on which children can bring their 'make believe play' to a higher (storytelling) level by listening to and looking at stories made by peers. While the child is playing, its voice and the position of the toy-animal are recorded. By means of a beamer a graphical representation of the animal can be projected on the mat. This combined with playing back the recorded audio, makes it possible to show the story to other children. Cassel and Ryokai state that the children will tell more complex stories themselves by looking at and listening to the stories of their peers. They will also use more advanced language and more often play the role of narrator. According to the paper, StoryMat was deemed successful because the children got inspiration from the stories of their peers, which were presented while they were playing and where they were playing.

In Rosebud [4] the child tells a story about one of its stuffed animals. A computer interface recognizes the animal and asks the child to type a story about that animal. The interface works as an audience/teacher because it asks the child to elaborate, edit and expand. The voice that asks these questions does this from the perspective of a peer. Subsequently, the child has to record (audio) the story, which is then stored in the animal. Because it is stored in the animal stories can be easily exchanged with other children by exchanging animals. In SAGE [4] there is more emphasis on the audience aspect. Using a simplified programming language the child has to design its own audience. They can design the persona they will tell a story to, as well as, what questions that persona will ask, and what kind of simple movements (representing emotions) a stuffed animal will carry out while interacting with that persona. In interaction mode they or other children can tell their stories to these listeners. In PETS [6] the emphasis is on making a story about a toy and designing it's movements in correspondence to that story. The toy will act out these movements while it tells the story. Thinking about the toy's emotions is the starting-point for designing the movements of the toy. Druin et al. point out that emotions are the key words in young children's stories. Although the toy is robotic, it is coated with all kinds of soft materials to give it a stuffed animal look.

2.2 Tactile Interfaces

There have been some earlier activities within Philips that explored storytelling and toys. The TOONS toys, for example, were developed in the NexTV project as interactive devices in an interactive TV environment. They were designed to be used in a game setting as well, meaning in a setting that was not tied to a broadcast. The aim was to engage children aged 8-12 in the process of telling a story on a TV screen [7,8]. POGO is an interactive system that provides children with a set of tools to use in the creation of stories. The POGO project created a prototype environment incorporating new interaction models for children [9]. Both projects focused on improving the environment the children learn and play in and explored new ways to interact with the environment. Both projects developed physical objects or toys to be used in that environment.

Others were also active in this area. Tangible Viewpoints [10] enables the user to place three pawns representing the (viewpoints of the) characters in a story on an interaction-surface. Around these pawns an aura is projected indicating the importance of the viewpoint in the current telling of the story, and story segments that relate to that viewpoint. A lens-shaped object is used for selecting a story segment. The pawns can be taken off the surface, but moreover, they can be put together which makes only the story segments visible that are related to both (or all three) viewpoints.

In genieBottles [11] three bottles represent three genies, and their state of being open or closed indicates whether a genie is able to cooperate in the story. One open bottle will result in a story told by one genie, and three open bottles will result in a story told like a conversation.

2.3 StoryToy

Our StoryToy is an environment with multiple characters that can tell a story. The user interface is presented in Figure 1. All that is visible is a farmhouse, several stuffed farm animals and some marked locations around the farm, like the road, a pond and a stable box. In the current set-up we have implemented three modes of operation: *free play*, *reactive play* and *story play*. The latter two modes are detailed in chapter 3. The active mode of operation is determined by the location of the duck. When the duck is placed in the pond the system enters the *reactive play* mode. If the duck is placed on the road (the story patch), the system switches to *story play* mode and the first line of the story is told by the narrator or one of the animals. If the duck is in the stable box, the system is in *free play* mode, which basically means that the system is turned off and the child can play without the technology taking part.

Figure 2: Child interacting with the Farm.

The story mode in particular offers something that other storytelling toys do not offer: multiple characters that can work together. The farm animals can have conversations and are able to react to each other's actions. They can experience an adventure together and the child can play a role in that adventure. The fact

that the animals work together without any visible technology makes the farm appear magical (see Figure 2.).

Each character of current StoryToy has an embedded motion sensor connected to a wireless transmitter. The location of the duck is sensed using magnetic switches and a magnet in the duck. All sensor events are communicated to a receiver connected to a PC via the serial port. A Java program translates the sensor events into audio responses that are send to a wireless speaker inside the farm. For telling the stories a simple state transition model is used in which sensor events represent state transitions. With each state transition an audio clip is played.

2.4 Comparison

In the general area of interactive storytelling one can observe a move towards making technology less visible. However, technology is still prominent in the other projects referred to with regards to visibility and costs.

Important about StoryMat is that it does not use a desktop as part of its user interface, like PETS, Rosebud and SAGE do. The child's voice and the position of the animals are recorded by the computer in an unobtrusive way while the child is playing. The beamer used in StoryMat is still costly, however, and the possibility of occlusion limits the freedom of movement of the child or interferes with the experience. Positive about Rosebud and StoryMat in comparison to PETS is that the toys themselves are low-tech. They are simply stuffed animals. Because of that the children's own toys (with an added sensor) can be used for telling the stories. A soft and natural feel is ensured because the toys are basically just stuffed animals. The same applies to the characters in StoryToy.

Technologically advanced toys that are on the market, such as Furby or Yano The Interactive Storyteller have a soft and furry coating, but still they feel rather mechanical. The advantage of adding mechatronics to toys is that it enables them to move or show their emotions autonomously and to react on the child's input in more ways. Furby and Yano can tell a story on their own but you can not play a story with them. We explore the cooperation of multiple characters that tell a story together with a child.

This cooperation of different elements that tell a story together is something that we do see in projects in the tangible interfaces area. However, in the projects referred to, these elements are not toys. In Tangible Viewpoints the interaction is not like real playing because the pawns themselves are not the main controls for navigating the narrative. In the genieBottles project the interaction is very natural and self-explanatory, however very limited. The interaction model used (a genie is either released or not which means that it is cooperating in the story or not) is original, but probably less suitable for young children. An interaction model where picking up a toy means that it instantly reacts might be more suitable because young children like the immediate feedback they get.

In the projects we have discussed there are basically two types of content: content made by the children themselves and authored content made by adults. The projects in the area of story capturing focus on the first category and do not feature cooperating toys nor non-linear stories (stories with multiple outcomes). A straightforward explanation for this may be that it is difficult for children to create non-linear content. Projects in the area of tangible narratives focus on the second category. Because we aim for young children (age between 2-5), we do the same. Our main focus is on pre-defined story content and not on supporting the child to create its own stories. However, we did use a traditional playing environment, so the children always have the possibility to act out their own stories, perhaps inspired by the pre-defined interactive stories or by simple but expressive audio clips in the *reactive play* mode. We regard the capturing of stories created by children with StoryToy to be an interesting area of for future exploration.

3. LEVELS OF INTERACTIVITY

In this chapter we will describe the different types of interaction that StoryToy supports. In *free play* mode StoryToy is like any other traditional toy, all activity needs to come from the child. In r*eactive play* mode audio is used to support the child in its play but the system does not offer a story. In *story play* mode we support linear stories and branched stories. With linear stories the child only controls the progression of the story, e.g. when to go to the next line. With branched stories the child also controls the direction a story takes, e.g. whether to follow the advice of Cow or Pig. Within the two general interactive operation modes, the reactive play mode and the story mode, different kinds of interactive content can be used. Regarding the interactivity of this content, we envision multiple levels of complexity, which we explain in the following paragraphs.

3.1 Reactive Play

This level is suitable for very young children, from age two, and has direct feedback as its most important aspect. The child can trigger any of the animals at any time. In its most basic form, when an animal is picked up the sound appropriate for that animal is reproduced. For instance, picking up the cow results in a mooing sound. In addition to just playing back the animals' sounds, other and more expressive audio can be presented. The animals can for example talk about their emotions or desires. In this case not as part of a story but just as stand alone remarks. The animals can also react to their immediate environment including other animals near them. The pseudo random remarks can be used to make the interaction a little more engaging. For instance, an animal can express a desire when picked up, or automatically when the child is passive for a while. When the child fulfills the animal's desire, a compliment or notion of gratitude can be given by the animal as reward. E.g. Cow says: "Moo. It's so hot, please bring me to the pond so I can go for a swim." When the child has fulfilled the request, cow says: "Moo. (splashing sound) Ooh thank you very much, this water is nice and fresh."

3.2 Linear Stories

The second level of complexity is formed by the linear story. In one of the current implementations of this level each storyline ends with explicitly mentioning one of the animals. The child then has to pick up that animal. If the correct animal is picked up the sound associated with that animal is played and the story progresses to the next line. If the wrong animal is picked up this will be pointed out by phrases like 'that is not the sheep' or 'that is the calf'. If the child waits too long a reminder like 'I am waiting' or 'please pick up the pig' is played. A narrator is not required, the

animals can also tell the story themselves. During the story segments picking up the animals will either not result in a reaction or result in a simple reaction like playing back the animal's sound.

3.3 Branching Stories and Games

In this mode the child can make choices. Picking up animals or placing animals at certain locations can be a means for making a choice. An advantage of this mode compared to the linear story mode is that the interaction gets more diverse. In addition, the choices can be used to steer the story in a certain direction. The children can select from different plots or choose a certain animal's viewpoint. In multiple protagonist stories (for example four animals that experience an adventure together), these two can easily merge together: The animals can not only have different feelings about what is happening in the story, they can also have different opinions about what should happen. Of course also more traditional multiple viewpoint models can be used, like those in which different characters see or have seen different parts of the same event. Such structures are too difficult for the youngest children, especially when a synchronized model is chosen in which the story has to be played over again to hear a different view about a specific moment in story time. The classic example of witnesses that have seen a murder each from their own perspective is regarding its content not suitable for young children. Other subjects can be thought of however. Examples of little stories we created include one in which an apple is stolen from one of the animals, one about animals who can't find each other during a hide-and-seek game, and one in which the animals talk about an adventure, each boasting about their own role and blaming the others.

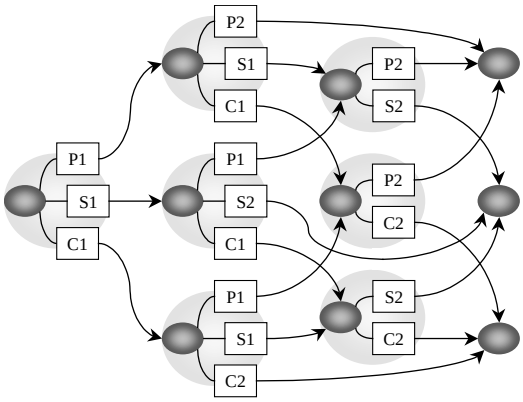

Figure 3: State transition diagram of a decision making process.

The multiple protagonist story model turned out to be valuable, because the choices can then be based on the propositions of the different animals. This ensures an unlimited amount of options from which to choose. With one central character the options are limited by the sensors in the physical environment and to questions that have the other animals as subject, direct object or indirect object. (Where shall I go? Who should I talk to? Who has stolen my apple? etc.) In some of the stories that we have created, we used the following decision-making process: When an animal is picked up for the first time in a scene or during a dialogue it makes a proposition, when it's picked up for the second time that proposition is chosen. The animals do not present their propositions all at once because we do not want the story segments to become too long and it would be too hard for the child to remember which proposition was associated with which animal. In any case, it is important to make the link between an animal and its propositions as clear as possible. This can be done by making sure that a proposition always follows the picking up of the animal that is proposing it.

An example of the model mentioned is presented in Figure 3. The initial sentence, associated to the state on the far left, may be: "We're bored, what shall we do?". P1 is the proposition of the pig, S1 of the Sheep and C1 of the cow. If the cow is picked up C1 is played. For example "Let's play hide-and-seek!". They system moves to bottom state in he second column. If the cow is picked up again C2 is played, the audio segment that shows that cow's proposition is chosen. For example: "Ok, if you all agree, we'll play hide and seek. Go hide yourselves, I'm counting." The system moves to the final state, on the bottom of the column on the far right.

Using open-ended or collapsing story branches (different storylines that come together again) makes it interesting to play a story again and adds real meaning to the choices. Making such stories can be a lot of work because the different branches all have to lead to interesting storylines. You can however also provide choices without using open-ended or collapsing story branches. We developed stories in which all the options at a decision point have to be tried out in no particular order. E.g. Cow says: "I'm bored, what shall we do?" Now all the other animals can make a proposition when picked up, but that doesn't mean that each of those propositions has to be worked out to a storyline. It doesn't matter in what order the animals are picked up. Once they are all picked up and all the propositions are heard, the story can continue to a next scene or dialogue. This next scene might be an event that follows from one of the propositions, or maybe the animals conclude that all the propositions were boring and that there's nothing fun to do in the farm, and decide to escape from the farm.

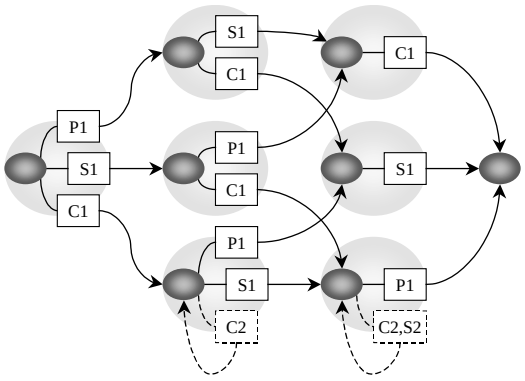

Figure 4: State transition diagram of a scene in which each animal needs to picked up at least once. The dashed lines indicate responses that do not result in a state change.

An example of a state transition diagram of a such a scene is presented in Figure 4. The story continues to a next scene/dialogue when the storylines of all the animals are heard in no particular order. When an animal is picked up for the second

time it can say for example “I have no ideas anymore, maybe you should ask the others”. The story will then remain in the same state, as shown in the dotted examples, which are left out from the rest of the scheme for reasons of clarity.

This same model can also be used for events rather then only for dialogue. E.g. Cow asks: “How do we escape from the farm?” Now all the other animals make a proposition when picked up, for example: “Let’s all jump over the ditch”. When picked up again, the proposition of the animal is acted out, and the attempt to escape fails. When all the attempts to escape the farm have failed, the story continues.

Little games can be elements of branching stories, but can also be standalone. Multiple-choice puzzles can easily be applied to the system, and they can also be woven into the stories. Memory games like Simon-says are equally easy to apply. Finding correct sequences is another interesting game-element. For instance, we created a story in which the animals have to stand on top of each other to enable chicken to climb on top of them and retrieve its stolen egg from a bird’s nest high in a tree. In this story the child has to find the correct order to place the animals on top of each other. The stack of animals collapses when the child places a heavier animal on a lighter animal.

A story or a game can also be presented in the form of a song. One can think of Old MacDonald and his farm. During the replay of the song the child chooses in which order the animals feature in the song.

3.4 Children’s Stories

The most complex level we envision is that children create their own stories. For the younger children, this could be a combination of the reactive play level and the branching story level. Idea is that the children can create their own story, using their own fantasy but by using story content that is provided by the system. This may seem to be a contradiction, because you can not predict the children’s intentions and you can not deliver all the story content that their fantasy would use. However, by making concessions on both sides, that is making the story content less specific (to avoid conflicts with the child’s intentions) and acknowledging that the child has not as much freedom as in free play, a model can be developed. This model could have different states that are based on the positions of the different characters. The goals of the characters might be based on these states. For example in a castle environment, a knight’s goal might be to escape from the prison or to rescue the princess or to obtain the treasure, depending on the positions of the knight itself and the other objects/characters. Note that we have not implemented any of this yet.

There is also an option for older children to enjoy StoryToy that goes outside the environment itself. We can create a graphical design interface for these children so they can create intricate stories for StoryToy on a PC. It would be interesting to explore how to facilitate the creation of such stories by children given the peculiarities of the replay environment.

4. EXPERIMENTS

We are currently conducting preliminary experiments to explore how children aged between 2 and 6 respond to the different interactive stories that StoryToy offers. These tests take place in the children’s room in Philips HomeLab. Philips HomeLab is a research facility that offers researchers the possibility to study how people interact with Ambient Intelligence [12] in a home environment. Based on these experiments we roughly predicted the different kinds of stories which would be suitable for children of different ages as shown in Figure 5.

It is too early to draw solid conclusions from the experiments, but we can share some first impressions. For one the environment appears indeed mostly self-explanatory. The first natural reaction of a child when confronted with StoryToy is to pick up the animals, and that already starts the interaction. Out of curiosity or by listening to the directions given by the animals the children try out the various combinations of animals and locations in the farm and are thus drawn into the stories.

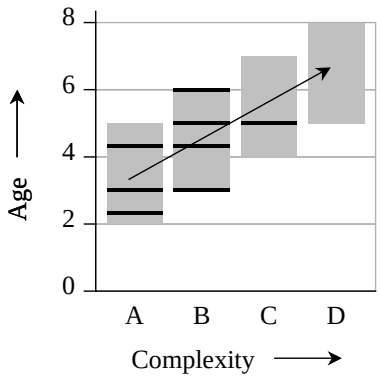

Figure 5: Suitability of StoryToy stories of different complexity for children of different ages. A=reactive play, B=linear stories, C=branched stories, D=Children's stories. The gray rectangles represent the estimated combinations of suitability. The solid lines in them represent actual tests with children of a certain age.

Reactive play (A) is most popular with the youngest children. For a 5 year old it quickly looses its appeal.

The linear story mode (B) seems enjoyable and good to understand for the younger children from about age 3. It contributes to the clarity of the story told if picking up an animal leads to the storylines of that animal. It is easy for the children to understand which animal is saying which part. Also giving a different voice to each animal and make their storylines start with a specific sound characteristic for that animal promoted clarity. The oldest children liked the stories in most cases, but for them the interaction in the linear story mode seems too limited. Just picking up an animal to let the story proceed is not enough interaction to really draw them into the story. Some children (ages 3 and 4) acted out the storylines. For instance, if a storyline would express that one animal went to another animal they would physically move the first animal to the second animal. This was not as indented and sometimes meant the wrong animal was picked up. We can make use of this behavior to increase immersion into stories in the future.

The branching story mode (C) offers more enjoyment for older children (age 4-6 years). The more complex dialogues that are formed in this mode give even more life to the toys. The decision moments give the children an opportunity to think and reflect, and to focus their attention on a specific animal. Because every animal

always reacts at every decision-making moment, the children feel like they really influence the story, even in the cases that they only influence the order of events. For the younger children (age 2-3 years) these longer stories are hard to follow. In most stories the animals do not react when picked up during the story segments. Even though we kept the segments short, this still appears to be a barrier for some of the younger children. They really need direct and immediate feedback to stay interested.

5. FUTURE WORK

The future work we envision comes in several categories: technology, application and testing. Regarding the input technology, we currently use motion sensors and magnetic switches only. Our platform can easily accommodate other sensing technologies. For instance, we intent to implement RFID detection and more generic location detection. We are also investigating other types of sensors. Output is currently limited to audio responses. Next to that we envisage controlling LEDs embedded in the animals and/or the environment including ambient lighting. Other options are mechatronics and the use of rudimentary displays. All these extensions are just to expand the experience, i.e. to enrich the interactivity, and should not go at the expense of our basic premise of the unobtrusiveness of the technology.

Next to the technology we want to expand the application itself. We intent to explore even more complex storylines, which may turn into real audio adventures. We also think it is interesting to explore in what ways the environment could support the children in telling their own stories. Finally, we intent to do more comprehensive and systematic testing of StoryToy on children.

6. CONCLUSIONS

The most important conclusion is that you can have interactive stories and games that are quite complex just with audio feedback and traditional toys as input device. Furthermore, these stories and games prove to be very enjoyable to young children and adults in the right mindset. We also showed that by having a 'roadmap' of complexity we can make the same environment work for children of different ages. Not many toys suitable for a two year old are still fun to play with for an eight year old.

7. REFERENCES

[1] www.philips.com/research/ami/

[2] Hoonhout, H.C.M., Stienstra, M.A. Exploring enjoyability: which factors in a consumer device make the user smile? In: D. de Waard, K.A. Brookhuis, S.M. Sommer, and W.B. Verwey (eds.) *Human Factors in the Age of Virtual Reality* Shaker Publishing, Maastricht, The Netherlands, 2003, 341-355.

[3] Fontijn, W.F.J. Sensor Based Interactive Story Telling Environment. *Workshop Playing with Sensors, Int. Conference on Ubiquitous Computing* (Nottingham, UK, Sept. 7-10, 2004).

[4] Cassell, J. Towards a Model of Technology and Literacy Development: Story Listening Systems. *Journal of Applied Developmental Psychology, 25, 1* (2004), 75-105.

[5] Cassell, J., & Ryokai, K. Making space for voice: Technologies to support children's fantasy and storytelling. *Personal Technologies, 5, 3* (2001), 203–224.

[6] Druin, A. et al. Designing PETS: A Personal Electronic Teller of Stories. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems* (Pittsburg, USA, May 15-20, 1999). ACM Press, New York, NY, 1999.

[7] www.extra.research.philips.com/euprojects/nextv/

[8] Stienstra, M.A., Hoonhout, H.C.M. TOONS Toys: interaction as means to create a fun experience. *Int. Workshop 'Interaction Design and Children' 2002* (Eindhoven, The Netherlands, August 28-29, 2002).

[9] http://www.design.philips.com/about/design/section-13518/

[10] Mazalek, A., Davenport, G., Ishii, H. Tangible Viewpoints: A Physical Approach to Multimedia Stories. In *Proceedings of ACM Multimedia '02* (Juan-les-Pins, France, Dec. 1-6, 2002). ACM Press, New York, NY, 2002.

[11] Mazalek, A., Wood, A., Ishii, H., genieBottles: An Interactive Narrative in Bottles. In *Proceedings of SIGGRAPH conference* (Los Angeles, USA, August 12-17, 2001). ACM Press, New York, NY, 2001.

[12] www.research.philips.com/technologies/misc/homelab/