Spookies: Combining Smart materials and Information technology in an interactive toy

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ABSTRACT
This paper describes the use of textile material as a user interface to an interactive toy called Spookies. Both traditional textile and smart textiles have been used in order to communicate the function and the interaction. The project has generated ideas that can be used in the Spookies concept as well as toys in general.

Keywords
Smart textiles, smart materials, interactive toy

INTRODUCTION
Smart textile is a generic term for a group of materials often described as materials that can think for themselves. These materials represent the next generation of materials and they can react to stimulus from their environment and thereafter, in different levels, adapt their behaviour to the circumstances [3] [14]. Combining electronic devices and new textile materials gives an opportunity to develop new interactive products in textile with a new type of behaviour and use, and a new type of user interface. The traditional computer user interface, input by a keyboard and output by a display, will then change to something else. Several projects show the potential of combining smart textiles with data processing units. The application areas differ between play, games, music, medicine or sports. Smart textiles can be used for data transmission using optical fibres as in the Smart shirt project [4]. In the Smart shirt project signals from electrodes is transmitted through optical fibres to a data processing unit. Another example of signal transmission is to weave conductive fibres into the textile architecture [2]. There are also examples where smart textiles are used when constructing textile keyboards [5] [12]. Textile antennas and electrodes are other examples when smart materials and textile constructions creates traditional technology in textile. The embroidered music balls [11] describe textile as a user interface to music performance. The balls are made of textile and integrated with sensors that allow children to perform and manipulate music with physical hand gestures such as squeezing and stretching. The idea is an example of physical use of an abstract material. In proceeding of IDC 2003 Eisenberg [1] discusses the potential of using Smart materials in future educational technology from different aspects. A potential benefit of smart materials can for example be to fill the gap between complex computational technology and understanding.

This paper describes textile as a user interface for an interactive toy by relating it to the state of art in smart textiles. Textile as a user interface is also described through two design examples, using traditional textiles and smart textiles. The research method is research through design. This method could be described as a method where a design concept, idea or product is used as a tool in the research. The tool is used in order to find the question in a certain research problem. In this case the tool for the research is an existing toy concept called Spookies. Questions addressed in this project have been. How can textile be used as a user interface to Spookies? What are the possible smart materials to use in order to communicate the

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interaction? How can smart material be applied in the toy? How will the use of smart material affect the product?
The paper begins with a description of the Spookies concept, functionality and interaction design. The design of and use of traditional textiles, are thereafter described. Thereafter follows a description of experiments where thermochromic colours are used in order to create alternative feedback in Spookies.

Spookies concept

"Spookies" is a toy that encourages a free play. A free and active play can be defined as a play including the following parameters [6] [7]:

Pretending: lets children use their imagination, act and be creative.
Spontaneity and Improvisation: distinguish the play from games and sports letting the children change the play spontaneously.
Physical activity: provides a richer more interactive and engaging experience.
Social Interaction: a central aspect, the joy of being together with friends.

The concept of "Spookies", figure 1, contains 14 different units organised in seven pairs. Each unit has one function and units in a pair are wirelessly connected. The play can be based on the communication between the units but it is also
possible to combine the units in order to build more complex units.

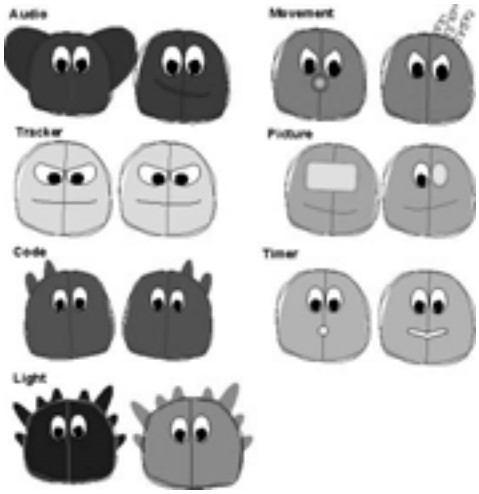


Figure 1. The Spookies concept.

The Audio pair represents a central part in the concept enabling direct communication between the children, the couple is specialised in transferring sound. The Listener is equipped with a microphone to pick sound and the Speaker returns all sounds received from the Listener. This pair gives an example of a pair that contains an input- and an output unit. Tracker is a pair that does not consist of an output and input unit. Instead both units can receive and display information, always reflecting the state of the other unit. The Tracker pair measures the range to one another and the output consists of eight diodes. The distance is related to the number of diodes that lightens up. Code is a pair without input and output units that support interests in sending secret signs, codes and languages. A message is sent by pressing a horn. The other unit vibrates to inform that a message has been sent. To receive the message the user has to find the very same angel as the sending unit, up, down, left, right, forward or backward. Light Spookies consists of an input and output units that support play with light and darkness. The Dark input unit, recognises two states, light or darkness, and sends a signal to Light, which is the output unit. A light signal lights up Light with the aid of diodes. Movement is a pair detecting and announcing movement. The Sniffer detects movements and sends a signal to the Vibrator (output unit) who vibrates in order to announce the movement. Picture Spookies is another input- and output pair providing the play with the fun of visual imagery. The Photo unit is equipped with a camera to take pictures and send them to the Image spook. Time Spookies is an output and input pair. Timer, the input unit measures and handles time. Whistler, the output units, plays melodies when activated.
Besides the opportunity of playing with each pair using the communication between the units it is also possible to combine them. The combination of different "Spookies" opens up for a more complex function and for a logic play with information technology. The rule of combining is that an upper "Spookie" masters the one below. An example of that is a kind of Spy game; the Sniffer is put above a Listener. The output units, Vibrator and Speaker may then be placed in another room waiting for a signal that someone has arrived in the other room. On activation, when someone arrives, Sniffer sends a signal to Vibrator who announces that someone has arrived into the other room. It is then possible to use Listener to secretly listen to conversations in the other room, see figure 2. The are a lot of combinations, some of them are not fun at all but it is up to the children to find out that by themselves It is the children who should find their own way of using "Spookies" as a tool in their play, with or without combinations.

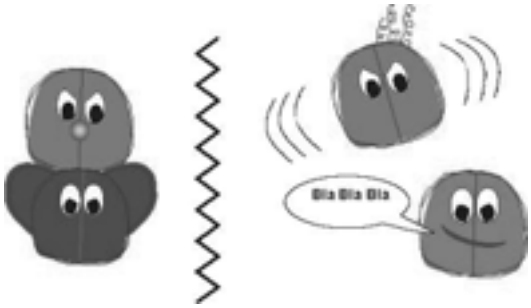
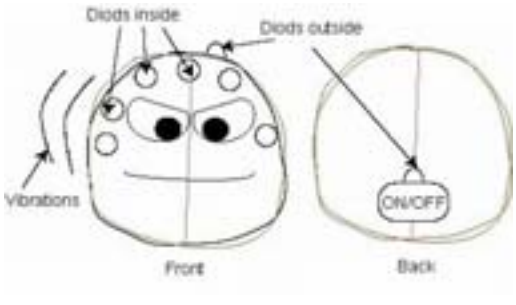


Figure 2 Example of Scenario

The user interface

The first generation of Spookies is an example of embedded technology where the technology is hidden behind a textile shell. The textile together with hidden mechanical buttons, diodes and vibrations act as the user interface between the technology and the user. All units have a primer form with different details that describes the function of each unit. The listener has for example big ears. Each unit has an on/off status that is activated by a pressure on the back. In both on/off and activation integrated mechanical buttons and stretch sensors are used. As feedback vibrating motors and diodes are used. In code a diode lights up when there is a communication between the two units. The Tracker pair uses diodes in another way. The diodes are placed behind the textile and the numbers of lighted diodes are related to the distance between the units. The closer they are the more diodes are lighted. As described, diodes and vibrations are used in several ways to deliver feedback to the user. Figure 3 shows an overview of dynamic feedback delivered from the different units.



The concept and the design of the units have been tested and analysed using different levels of prototypes, from early paper prototypes to prototypes with proper function. By observing children while they played, the concept as well as the design of units has been adjusted. For example, letting the units look more like pets, made some children to start taking care of the unit instead of participating in the game. Form and weight was also important. Designing them like balls or making them to light made children to throw them. In the concepts units have been added and excluded until an active play has been achieved.

In order to communicate the difference between the pairs and units even more, "Spookies" were made in a unique knitted fabric [7] with a relief shown in figure 4. With colour, pattern and relief there is both a visual and a tactile feedback that shows the difference between different units and pairs.

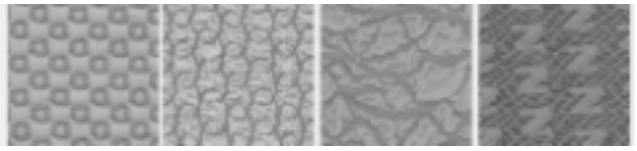


Figure 4. Samples of knitted fabric

The textile design of the unit was important in order to communicate the different functions as well as keeping the play active. When designing the knitted pattern it was more important to create big variations than trying to visualise the function in a symbolic pattern. The final interface of Spookies is shown in figure 5.

Figure 5 Prototyping, testing and result process

SPOOKIES INTERFACE USING SMART MATERIALS

The first generation of Spookies is an example of embedded technology where the technology is hidden behind a textile shell. The textile together with hidden mechanical buttons, diodes and vibrators act as the user interface between the technology and the user. The interaction in Spookies is characterised by simple and physically input and symbolic output. Further research has focused on how smart materials can enhance and express the interaction?

Smart materials can be divided into three groups:

1. Passive smart material, can only sense the environment, they are sensors.
2. Active smart material, can sense stimuli and also react to them besides the sensors function, they are sensors and actuators
3. Very smart materials, they can take one step further having the gift to adapt their behaviour to the circumstances. These materials are not common and more on research level.

The basis of a sensor is that it transforms one type of signal into another type of signal. There are different materials and textiles constructions that have the capacity of transforming signals. Examples of sensors are:
1. Thermocouple materials, transform thermal signals to electrical.
2. The softswitch technology [12]. The softswitch technology is a composite material that transforms a mechanical pressure to an electrical signal.
3. Fibre Bragg sensors, from mechanical through optical to electrical signal.
4. A three layer construction where the outer layers are conductive and separated by a non conductive layer. When pressing the material, the two outer layers will conduct and an electrical signal will be generated.

Actuators respond to a signal and make things move like colour change, release substances, change shape and others. Examples of actuators are:
1. Shape memory materials transform thermal energy into motion. They are materials that can revert from a shape to a previously held shape due to the action of heat. Shape memory can for example exists in the form of threads. The company Corpo Nove [13] has created a smart shirt were

the trained memory shape is a straight thread. When heating the shirt after washes, the creases in the shirt disappear.
2. Chromic materials [14] change colour due to different stimuli. The most common ones and the only actually available on the market are those who change colour due to temperature or light. Other stimulus could be pressure, electricity, liquid or electron beam.
3. Electroluminescent materials are wires or coatings that create shining textiles [2]. Unfortunately they are example of actuators that requires a high voltage supply to be activated.

Besides sensors and actuators there is a group of materials that are conductive. Conductive materials are fibres or coatings that transmit signals [2] [14]. They are usually not categorised as sensors or actuators but are usable in several cases. The fibres and coatings with conductive properties are constructed in different ways:
1. Metals like stainless steel, copper or silver. (Low resistance)
2. Polymers blended or coated with metals. (Relative low resistance)
3. Doped polymers (Low-High resistance)
4. Carbon fibres (High resistance)
Materials with low resistance have high conductivity while high resistance materials generate a heat when conducted to current. Initially conductive fibres were used instead of traditional wires in smart textile applications. There are also applications where carbon fibres are used for heating, in car seats for examples. Future potential of these materials is to substitute traditional electronics to electronics made of textile. Examples of that are textile electrodes, textile antennas [2], keyboards and capacitors. Printing circuits on textiles is also a future area for conductive coatings.

EXPERIMENT: COLOUR CHANGE MATERIAL

The smart textile overview shows the potential and generates ideas of how these materials can be used in Spookies. Questions that still remain are: How can smart materials be integrated in the product? In what way will the use of smart materials affects the product? In order to explore that it was decided to apply an active smart materials on the knitted fabric. The chosen material was a thermochromic print that could be applied in different ways, over the whole fabric or on certain parts of the pattern. Chromic materials, as they are called, change colour due to different stimuli. Thermochromic material reacts to temperature change, when temperature raise the colour disappears. Blending thermochromic with traditional colour or printing thermochromic colour on a coloured surface gives the illusion that the actual colour change from one to another. In the experiments thermochromic material was applied on the knitted structures as well on certain details like the eyes and the on/off button. The principal of activating the material was to apply a conductive high resistance material on the back of the colour change layer in order to heat the area, see figure 6. The material could then be combined with the data processing unit in the toy.

Figure 6. Principle of construction

The knitted pattern was applied with colour on whole surfaces or on part of the surfaces like the relief. By conducting heat to the surface in different ways, different changes in the pattern were obtained.

Example 1

In the first example the print was applied on the whole or parts of the surface and the whole surface was conducted with heat. Colour change on whole surface was applied on the Listener who could change colour on the ears when activated, see figure 7

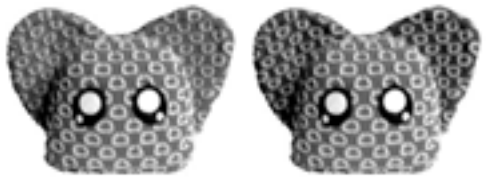


Figure 7. The Listener changes the colour of the ears.

Applying colour in the structure gives feedback in the structure of the fabric could be used as a feedback when different units are activated in a built combination, see figure 8.

Figure 8. Colour change in structure

Example 2

In the second example the print was applied on the whole surface and different parts of the surface conducted with heat, figure 9

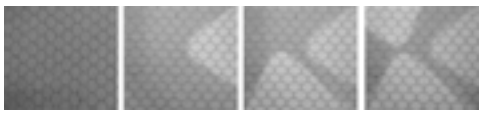


Figure 9. Different parts heated

The idea was implemented in the Tracker pair in order to visualize the distance between the units, see fig 10

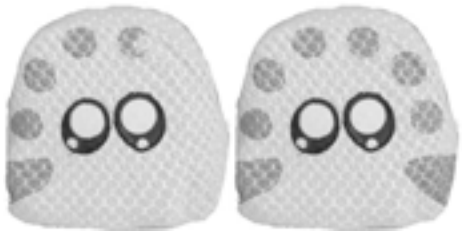


Figure 10. Colour change in Tracker

Example 3

Attributes like the eyes and on/off parts where also printed with colour change materials. Changing colours could be used on On/Off parts, see figure 11.

Figure 11. On and Off feedback.

But it is also possible to change eye colour on units where the visual sensing is an input, in Light or Dark, see figure 12.

Figure 12. Eye feedback on Dark unit

The result from the experiments shows the many variations offered by just using thermochromic materials and high resistance materials. The feedback is a bit slow, especially compared to diodes that have a more direct on and off feedback. Putting the feedback directly in the material gives a feedback that is more integrated in the unit itself compared to a diode integrated somewhere in the construction. Children's feedback on the prototypes was a mix of surprise, excitement and curiosity. For example when the Listener announced activity by changing colour, was a type of feedback that related more to the actual function than just a lighted diode. Another example of feedback that seemed very clear to the children was the change of eye colour on the two visual sensing Light and Dark Spookies. An example when there is a strong analogy between output and actuator material.

DISCUSSIONS AND FUTURE WORK

This project has explored the textile material as a user interface to an interactive toy. The project shows the potential in using both traditional and smart textiles as a user interface. Using Spookies as a tool for the research has been a useful frame when exploring a new and extensive area of possibilities. Using the concept as a frame for the research has not just generated design proposal for the specific toy. The ideas are also examples of how smart textiles can be used for interactive products in general. A passive but both expressive and structured textile material communicates the actual function of each unit in Spookies. The use of smart and dynamic materials, on the other hand, communicates the interaction. It is also important to note that the knitted fabric in traditional textiles has served as material that has opened up for a variation in use of the colour change print. It shows that textile interfaces also includes a consciously creation of traditional materials and techniques. The feedback in the experiment was dynamic and enhances each unit uniqueness and own personality, which is a vital part of the interaction in the concept. Applying colour change material into the fabric makes the overall all impression that the textile user interface relates to the technology in another way. The feedback fills the gap between the textile and technology which opens up for a curious exploration of the toy and the technology behind it.

The Smart material overview shows a variety of materials that could be used in Spookies and other toys. Any sensing technology that goes from pressure to electrical signal is of interest to use in the different acts that activate the units. The structured knitted technique also opens up for a three layer solution. Other interesting sensors are the thermocouple sensors. When holding a unit there will be a thermal raise from the body temperature which could be used to activate a unit in a physical way, just by holding it.

Shape change material could be used in order to achieve another type of feedback than colour change. For example apply it in the structure so that the structure could change from creases to a smooth surface. When shape memory materials become stronger like a real muscle it could be used to change the whole form of the unit.

An alternative to colour change feedback is the lightning effect of electroluminescent materials. These materials have the advantage of being visible in both light and dark environments.

There are several ways to use conductive materials in Spookies. High resistant materials can be used in order to generate a heat feedback or to activate thermal actuators like thermochromic colours. Making components in textile will open up for possibilities to implement electronics in the filling or in the textile shell in another way. When the research on printing circuits has progressed that is certainly of interest for this application.

Another aspect of using smart materials is the improvement of the sustainability of the product which is important due to the kind of use. Today electronic components are embedded in foam in order to protect the technology but also to hide it as much as possible to keep the feeling of a soft figure. The applied textile feedback is more sustainable than integrated diodes and that is only a start. Electronics in a toy that encourage an active play are exposed and for sustainability over prolonged use it is necessary to examine how that can be solved. Research shows that further electronics are possible to substitute.

Thermochromic colour is one example of a smart material. Further experiments must continue to explore the possibilities to use others. Besides experiments on feedback activation is another area for investigations. Sensing materials and constructions integrated in different parts or surfaces can substitute mechanical button and sensors. Parallel with the research on material it is important to do appropriate user tests and evaluate how the materials could be used in different situations. Can smart materials bridge the gap between the child and technology? Can these materials be used in order to explain and communicate information technology to children? If so, how is that achieved?

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