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Design of Augmented Tactile Books for Blind Children

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Abstract

We present the design of the first prototypes of augmented tactile books. These books not only play sounds but also engage the children by proposing original digital models of interaction based on recent research in the domain of sensorimotor psychology. The prototype books were designed using rich tactile material to be touched on the pages as well as miniaturized electronic components – embedded in the pages themselves – to detect several different gestures on the page such as the action of simulating walking with two fingers. Here we describe and then informally test three prototypes. After receiving encouraging feedback, we continued this project by designing a small series of 12 prototypes to perform a formal evaluation with two types of users: professionals and blind children.

Keywords

Tactile books, blind, children, interactive books, literacy.

Introduction

Tactile books are especially important for the development of blind children as well as children with partial sight or various other disabilities, although they can also be interesting for any child. These books not only help them develop tactile skills but also provide them with fun and pleasure, as books do for any child. Tactile illustrations are images that can be perceived in the same way as graphical illustrations in normal books. Nevertheless, blind children have major difficulties in recognizing what is actually depicted by tactile illustrations produced using standard techniques (e.g., relief drawing with swelling paper or wax strings, thermoformed illustrations). Several reasons may explain this difficulty, the main one being that this kind of drawing does not correspond to their primary perception, as images correspond to a projection of sight, even when they are schematized in the case of a simple drawing. Therefore, a tactile image must be read analytically and reconstructed mentally. Indeed, this process is incomparable to the immediate pleasure of a sighted child upon discovering a graphical illustration (Valente 2).

To make the tactile reading of images easier, more intuitive, and fun, the tactile illustrations need to be linked to interactive elements and sounds, which are not only enjoyable but also guide the reader. These elements make the tactile discovery more intuitive and enjoyable for children and require less mediation from the adult; they also entail less cognitive overload. Authors have been working together for over 20 years on projects combining these interactive elements with tactile illustrations (Casson et al., Archambault et al.). LDQR (literally "Daydreaming Fingers") is an associative editor of tactile books for blind children.

Valente proposed simulating actions through a set of gestures performed by two fingers (5-7) such as using them as legs to walk on a page or to caress, scratch, rub, or tap. Previous

studies (Valente et al.) have shown that these inclusive gestures help blind and sighted children to identify the represented objects, and that they are highly inclusive.

Recent progress in the miniaturization of electronic components – especially sensors – and processors means that we can embed them inside the books instead of simply overlaying them over the tactile zones like buttons. The idea is to provide children with a more immersive reading experience using scenarios in which they can trigger the verbal components (recorded voices read by actors) and non-verbal elements (music, sound effects) with their hand gestures. Various kinds of sensors are inserted into the page and connected to a processor that is located in the cover and communicates with an external component to implement the scenario and play the audio components. In this respect, this process involves adapting a visual illustration in relief with added sounds and then augmenting it with original digital models of interaction, thus moving from somesthetic to gestural touch.

The project "*Livres Tactiles Augmentés*" (Augmented Tactile Books) began after we realized that we could use this technology to integrate some of the gestures proposed by Valente into books in order to encourage younger readers to manipulate and experience the body using two fingers.

Page Prototype Design

Two students enrolled in the Master of Electronics at University of Burgundy, Farooq and Amene, worked on page prototypes using various kinds of cheap and modular sensors to detect the gestures. These prototypes were based on the Arduino ecosystem, including hall-effect sensors, touch capacitive sensors, conductive fabrics, and so on. The system can detect the following gestures on a page:

- tapping on different kind of fabrics;

- simulating walking on a page with two fingers;
- climbing up several steps;
- opening a door or window;
- touching a textile flower;
- moving a “boat” on a page;
- rotating a “planet” on a page.

The pages were made of cardboard, with the cables stuck down using adhesive tape; active components like hall-effect sensors, and in some cases, conductive material like copper tape were also fixed onto the page. All sensors were wired to an Arduino Nano controller located in the back cover of the book. Cables went through the binding as shown in Fig. 1 and were soldered onto a printed circuit board (PCB) on which the controller and a few necessary electronic components were also soldered. The power came from the USB cable plugged into the controller and connected to a computer. Indeed, in these early prototypes, the software was located on a computer, which ran the scenario and played the sounds according to the touch events sent by the book via the controller. In future prototypes, we will discard the need for a computer, as will be discussed below.

Prototype 1 – "Petite main se promène"

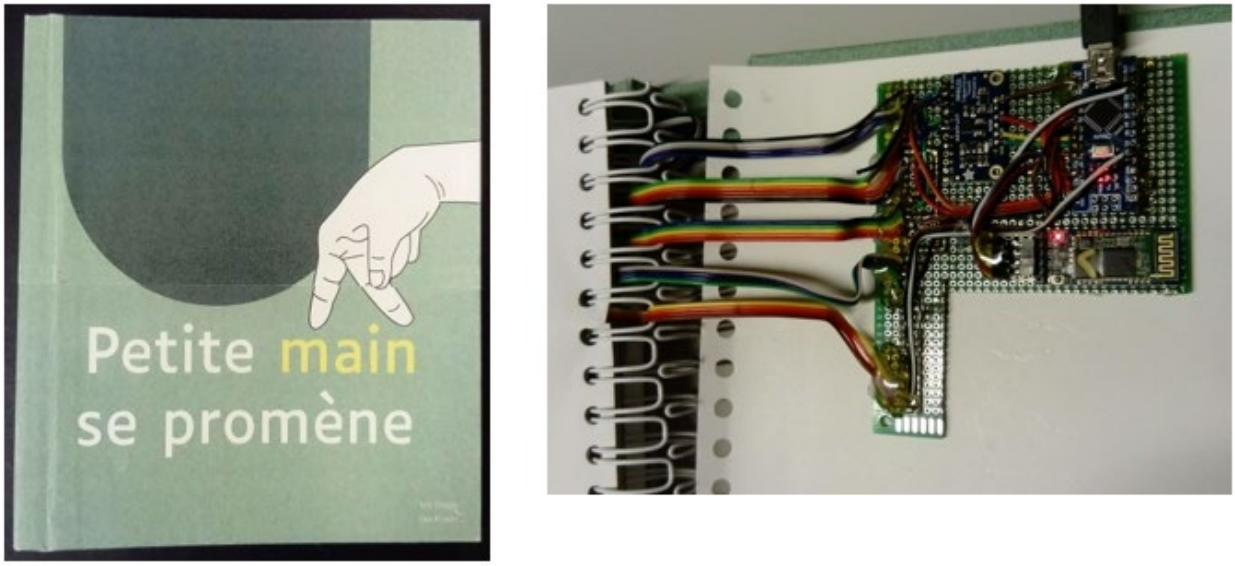

Fig. 1. Prototype 1 "Petite main se promène": Cover and Electronic Board.

The prototype book designed by Farooq was based on a short story called "*Petite main se promène*" ("Little hand goes for a walk") in which the child simulates walking with two fingers on the four pages of the book. Fig. 1 illustrates the prototype cover on the left, showing the gesture of simulated walk with two fingers, and on the right, the electronic board located on the cover of the book.

Fig. 2. Prototype 1 "Petite main se promène": Page 1 (three steps), Page 2 (three flowers) and Page 4 (mouse needs to hide).

On the first page, three steps can be climbed by our character represented by two fingers to simulate walking. The steps are covered with copper, and they are about 1 mm high, as we are limited in terms of the height of the illustrations given the necessity to be able to turn the pages. The capacitive effect is used and implemented on the Arduino board, which detects the touch of the child's finger on one of the steps. A "footstep" sound is then played.

On page 2, the child is invited to touch some flowers made from conductive fabrics. Different sounds are played when the contact of a finger is detected. Page 3 presents a door that can be opened. The hinge is made from fabric with electrical resistance that changes proportionally when folded. Finally, page 4 shows a small mouse hooked onto the page with Velcro. The child is asked to hide it from the cat. On the page, there is a small curtain covering another Velcro piece where the child can attach the mouse. The system recognizes if the mouse is under the curtain using a Hall effect sensor and a small magnet placed inside. Pages 1, 2, and 4 are presented in Fig. 2.

Hall effect sensors are also used to detect which page is open. There are four magnets embedded in the four pages at different levels along the book hinge with four corresponding sensors in the back cover at the same levels. When a page is closed, its magnet is situated near the corresponding sensor, while it is far away when the page is open. These sensor values thus indicate which page is open.

Fig. 3. Prototype 2 “Mes Chemins”: Page 1 (simple path), Page 2 (path with coating) and Page 4 (path with a river to cross).

Another prototype book was designed by Farooq during his Master to explore the technical possibilities of simulated walking with fingers as shown on the cover presented in Fig. 1. The four-page book is entitled “*Mes chemins*” (“My paths”) and the characters of the story walk along a path. On each page, the path is presented vertically, and the reader has to walk along it with the fingers. On the first page, only the path is shown; the reader subsequently encounters different coatings and additional items (e.g., a river to cross). Pages 1, 2, and 4 are shown in Fig 3. The system used for the pages was identical to the precedent prototype, and the book was also connected to the computer for reading the story and playing the sounds. The main technical problem was the limited number of usable pins on the microcontroller.

If two fingers simultaneously touch a conductive material, the controller will only detect one zone. So, when the child walks with the fingers, one finger should be lifted before the second finger touches the book. However, this is not easy to do, or otherwise, it gives the impression of jumping or running instead of walking. It was therefore necessary to make small conductive zones around 24 mm wide by 20 mm long (spaced 1-2 mm apart). Each zone had to be

connected to a pin of the controller, and in this case, the path was 4 cells wide by 10 cells long, with a total of 40 cells. An Arduino Nano as 13 digital pins. A multiplexer or an Arduino Mega could be used, but this would result in a larger electronic board and more expensive hardware, which would still be insufficient if we wanted to cover the whole page (about 20 cm x 20 cm).

The chosen solution was to connect together a few conductive zones and ensure that the contiguous zones were not linked. We set up an arrangement so that the distance between two different zones was at least 20mm (see Fig. 3). We used conductive ink for this test: the zones were painted with conductive ink, and copper tape connected them to the wires in the cardboard page.

Prototype 3 – Entitled

Fig. 4. Entitled: Page 1 (planet orbiting), Page 2 (window) and Page 5 (island).

These prototypes were shown to a children's book author Lucie Felix for her to test the types of gestures that we were able to detect. The author also worked on a scenario for a new prototype with a real story. The third prototype book was designed by Amene during his Master research. On page 1, a planet orbits around the sun, and on page 2, the reader can open the window and hear the sound of the surroundings. One-page features three puddles, and another

has an island surrounded by a beach. This prototype book was created using the same techniques as the precedent prototypes (capacitive touch, hall effect, etc.).

Prototype Tests

Before carrying out a proper evaluation, these books were tested informally with specialists working with blind children as well as several blind children. The preliminary conclusions were that the children liked the book and that the technology worked correctly to simulate the desired effect. Unfortunately, the device was too fragile for the children.

Despite these encouraging results, we could not carry out proper tests with the children using these prototypes, because they did not function for the duration of the evaluation. In particular, the conductive ink was far too fragile, although, admittedly, we did not test different conductive inks, so more tests could be done.

Discussion

The development of these three prototypes allowed us to create several techniques to implement a set of hand gestures to be used with an interactive book. We can simulate several actions such as walking with two fingers, jumping, or running, opening a door or windows, and moving objects by detecting their positions with magnets. We can also replicate different environments such as footsteps walking on a hard path, through dead leaves in a forest, or in shallow water.

The initial feedback from children and professionals was enthusiastic, but the tactile books need to be studied more formally, which is the next step in our research. As the first prototypes were not solid enough, they could not be used for a proper evaluation. Indeed, the planned evaluation will include around 12 copies of a prototype book, which will be sent to professionals throughout France who work in different kinds of establishments (e.g., special

schools for the blind, support centers). These professionals will conduct experiments with blind children and then complete questionnaires. As the developers will not be available to repair the books, the second step of this project will be to develop more solid prototypes using the same electronic effects. The scenario of the third prototype was slightly revised by the author, and a second version entitled *"Kapi Capitaine"* (Captain Kapi) was prepared with a small electronic company to create a more solid version. Further, the workshop of LDQR, which has over 20 years of experience in making tactile books, built the tactile parts.

An issue was raised at the start of the project about whether or not to use a computer. The three first prototypes as well as the Kapi prototypes all use a computer, because in addition to the implementation of the story, we wanted to record data about the use of the book. Log information is stored and later analyzed with the questionnaires. For the future books to be distributed schools or children's families, it will be better not to use a computer, as it would prevent the children from independently using the books and require the use of a computer nearby. Another idea would be to use a smartphone. The book could communicate via Bluetooth or WIFI with a smartphone, which is capable of implementing the scenario. Speakers can be connected (wired or via Bluetooth) to the smartphone. This solution is convenient, because it does not require a specific device, as smartphones are widely used nowadays. However, this system still has a drawback: even though smartphones are less cumbersome and easier to connect without a cable than a computer, the children would need their parents or professionals to set up the phone, thus making it unavailable for other uses. Another solution would be to create a specific device like an accompanying box, which would contain a cheap computer (e.g., Raspberry Pi), a speaker, and a battery. This box would implement the story and play the sounds with minimal commands (on/off, volume) and be inexpensive to produce. We also considered putting the computer and

battery in the cover and hinge of the book, but this would need to be integrated into every book. By contrast, the external box could be used for several books.

Conclusions

We presented the first part of an ongoing research project to design several prototypes of augmented tactile books in which child readers become engaged in the story using hand gestures. The first prototypes were successful as a proof of concept, although their solidity was insufficient to perform a formal evaluation. The children's reactions were encouraging and motivated us to initiate the second phase of the study, which was briefly summarized in the discussion above: the development of a series of more solid prototype books and a formal evaluation. This second phase was in progress at the time of writing this article.

On the technical side, further studies are needed to be able to develop a series of books without implementing all the software from scratch each time (including the microcontroller software). We expect to propose a model with several pages, including the normalization of the wiring, protocols for the communication between the pages and the controller, and between the controller and the device implementing the story (i.e., computer, smartphone, or external box), and a method for the identification of the pages.

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