Printing Tactile Picture Books for Blind Children

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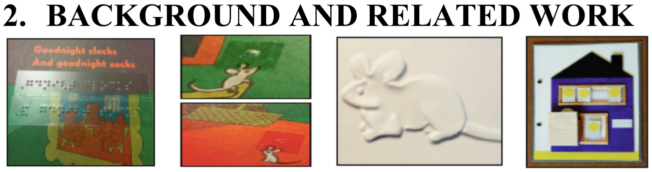
1. INTRODUCTION

Parents of blind children have very rare children's books they can fully enjoy reading together with their children. An ideal book for blind children should contain tactile patterns. While parents are reading the story through this book, children can also "read" the pictures by touching and feeling tactile patterns. Blind children are able to satisfy their own intellectual curiosities about the pictures. Early reading experiences through tactile pictures are beneficial for blind children's cognitive and emotional development. Even though children's books with tactile pictures are good, they are rare. Out of the thousands of children's picture books available for sighted children, few have been translated into tactile picture books currently. Translating pictures in children's books into tactile model is still a time consuming and difficult process. Most parents of do not have the luxury of time nor do they possess the right skill to make tactile picture books for their children.

Our research aims to develop technology that will allow parents to scan 2D pictures in children's books and print them as 3D tactile models that can be touched and felt by blind children. This technology offers attractive alternatives to existing methods for making tactile pictures (Sec. 2). Our approach divides the process of converting 2D pictures into 3D tactile models into five steps (Sec. 3). We conducted a pilot study on combination of four printing methods and four materials in order to understand their pros and cons (Sec. 4). We are currently investigating more printing methods and materials as well as answering other research questions related to tactile picture books (Sec. 5).

2. BACKGROUND AND RELATED WORK



Braille text Symbol Relief Craft

Figure 1: Four common types of tactile pictures for blind children

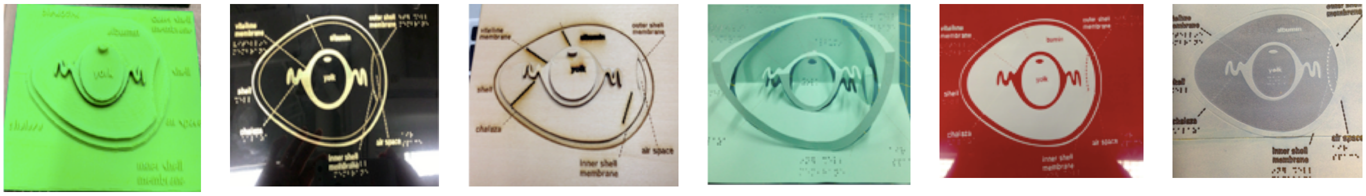
Today's tactile pictures for blind children typically takes one of the following forms. (1) Braille, the most common, explains pictures with translated written texts of captions. However, it has a big barrier for preschoolers because they have to learn braille first. (2) To present a simple feature of pictures, tactile symbols are also commonly used. In a tactile version of *Goodnight Moon*, the existence of a mouse was presented by a single dot to show its movements that allow children to follow its spatial exploration in the context of the story. (3) Tactile reliefs are one possible option, made by embossing paper. Children can explore scenes actively by touching realistic features so that they learn by themselves how real objects look. (4) Tactile crafts are also used, using a variety of materials to indicate different properties. In an example of the house, parents use fabric, cardboard, even basswood, to characterize the window, the roof, and the curtain. It allows parents to combine miscellaneous materials according to their children's recognition levels, interests, and needs.

Researchers have studied computational approach to creating tactile pictures. Jayant et al. [1] found that tactual perception is the most effective modality for blind people to read graphical images. Lander et al. [2] studied automatic algorithms for making figures in STEM textbooks tactually accessible. His team developed the Tactile Graphics Assistant (TGA) tool. This tool uses optical character recognition (OCR) to detect annotation text in a figure and translate the text into Braille. But the solution does not handle the figure's visual features such as lines, curves, and textures. In this research, we study how visual features can be converted into tactile patterns and printed by a 3D printer or by a laser cutter.

3. APPROACH AND UNIQUENESS

Our objective is to develop an interactive system a parent can use to design and print tactile pictures. In order to read a page in a children's book such as *Goodnight Moon*, the parents can simply scan the page into a computer and use our system to convert the page into a 3D model and print it out as a tactile picture. In our design, the process of designing and printing tactile pictures consists of five steps:

1. **Import pictures:** Parents can use a scanner to scan pictures, use smart phones to take pictures, or select pictures in already digitalized books.
2. **Format Optimization:** Parents can use a program to automatically convert a selected 2D picture into a 3D tactile model. The model will be in a format readable by a 3D printer or laser cutter (e.g., `.stl`, `.ai`).
3. **Printing:** Parents can choose one of the several methods to print the parts of the 3D model. The methods available 3D printing, silhouette cutting for overlaying, origami cutouts, and etching.
4. **Assembly:** Parents can assemble various parts into a single model, such as gluing objects onto a platform.
5. **Post Processing:** In some cases, parents need to remove supporting materials or sand rough surfaces to finish.



3D Printing Plastic | Etching Painted brass | Engraving & Overlay Wood | Popup Origami Paper | Etching Aluminum | Engraving Foam

Figure 2: Examples of tactile pictures we made by different combinations of printing methods and materials.

3D Printing	Etching	Engraving & Overlaying	Pop-up Origami
+ Mostly tangible + No limits on thickness of base - Longer processing time - Hazardous removing scaffolding	+ Thin and portable + Mostly able to make regular book-like pictures - Hard to get material - Risk a sharp edge	+ Effective representation for different depths of each region + Easily modified after completion by adding layer - Iteration might be needed	+ Relatively simple + Familiar paper folding - Should be manually folded - Hard to express small details and curves

Wood	Painted Brass	Aluminum	Foam
+ Intensely engraved + Various adaption of power, speed, and frequency - Danger of combustibility - Bad smells of burning	+ Smooth engraving on surface - Subtle differences between normal area and etched area - Risky settings needed; high power, speed, and frequency	+ Etched more deeply than other metallic materials + Textures can re presented - Leaves hazardous dust - Should be carefully cleaned after etching	+ Obvious results according to the settings + Easy to get material - Easy to shrink by laser (heat) - Limitation on low max power, speed, and frequency

Table 1: Pros and cons of the four printing methods (top) and materials (bottom) identified in our pilot study.

4. RESULTS AND CONTRIBUTIONS

4.1 Results

As proof of concept, we ran a pilot study based on a diagram of an egg from a children's book on science. We tested four printing methods in combination with four materials to turn this picture into various 3D tactile models. Examples of the models we made are shown in Figure 2. The printing methods we tested include 3D printing, etching, engraving & overlaying, and pop-up origami. The materials we tested include wood, painted brass, aluminum, and foam. Table 1 summarizes our preliminary findings on the pros and cons of these printing methods and materials.

4.2 Contributions

The technical contribution of our pilot study is a preliminary understanding of the pros and cons of different printing methods and materials for making tactile pictures, and finding adaptabilities of diverse materials. We will continue to study more options. We will consider acrylic, leather, glass, rubber, cork, plaster, copper, melamine, and marble, which are materials that might be cut by a laser cutter. We will consider plaster, crayon, wax, and sugar, which are materials that can be used by 3D printers. We will evaluate these materials based on how well the tactile details of a picture can be perceived and distinguished by blind children. We will systemically test different hardware settings, such as speeds, power levels, and frequencies. The cost, safety, and usability of the interface will also be considered since these are factors the parents of blind children will care about if they want to adopt our technology to print tactile children's books at home.

In addition to printing methods and materials, we will consider other research questions related to tactile picture books. We plan to study which books or stories are suitable for creation of tactile pictures. We will classify books into several categories such as fairy tales, science, and geography. We will select several example pictures from each category and test various printing methods and materials on these pictures. Depending on the category, the specific details of the pictures such as objects and their movements may be distinctive. We will study which printing method and material are mostly suitable for each case, as well as how a picture should be simplified. Not every detail is critical for blind children to understand the main concept of a picture. We will study which factors should be gauged to determine the level of tactility. Also we will test whether interactive elements such as levers and speakers should be added to enable manipulations and provide feedbacks. If user studies suggest that interactivity is important, we will study how and where interactive elements can be integrated with a printed tactile model. Lastly, based on the these user tests, we will define requirements for functions and attributes that the tactile storybook design software for parents should perform.

5. REFERENCES

[1] Jayant, C., Renzelmann, M., Wen, D., Krisnandi, S., Ladner, R., Comden, D. (2007). Automated Tactile Graphics Translation: In the Field. *ASSETS '07*.

[2] Ladner, R., Ivory, M., Rao, R., Burgstahler, S., Comden, D., Hahn, S., Renzelmann, M., Krisnandi, S., Ramasamy, M., Slabosky, B., Martin, A., Lacenski, A., Olsen, S., Croce, D. (2005). Automating Tactile Graphics Translation. *ASSETS*