HaptiGames - Personally Fabricated for the Visual Impaired

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CHI PLAY '18 Extended Abstracts, October 28–31, 2018, Melbourne, VIC, Australia
ACM ISBN 978-1-4503-5968-9/18/10
https://doi.org/10.1145/3270316.3270592

Abstract
With 3D-printers becoming more available, affordable, and easy to use, they can be used as a tool to produce more flexible textures and even more complex tangible objects for visually impaired people. Similarly, the Arduino system allows end-users to easily create electronic devices, both for learning as well as hobby approaches. With these Personal Fabrication Processes, people can easily produce haptic sense-able and electronic advanced games, focusing on the design of games for impaired people. We present three basic games enhanced for visual impaired people designed with these rapid prototyping technologies: BrailleMemory, a Braille learning game with RFID enhancement, a haptic Yahtzee scorecard and 3D game cards for a building block game.

Author Keywords
visual impaired; maker; game; 3D printer; Personal Fabrication.

For learning Braille within a game we developed Braille-Memory, a 3D-printed game with electronic success control to improve the learning experience. Both Braille letters as well as normal letters are 3D printed on game cards. An integrated RFID-tag allows their identification and check of a pairwise match. Furthermore, haptics and optics make it also interesting for normal sighted persons to try this game either with sight (just for learning braille) or blindfolded for training the tactile sense and feeling the challenges of correctly identifying Braille letters. As an open source system based on tools with a low entry barrier like 3D-printer and Arduino, the system can easily be extended to other game variants (e.g., Braille-Scrabble) or to identify reliefs or full 3D-objects translated into Braille words.

While reviewing the system with a small group of visually impaired people two other games turns out to be interesting for the group for adaption: Making an haptic Yahtzee scorecard and replacing printed game cards for a building game, which where used to describe the figure one should build. Making modular 3D-designs in OpenSCAD and reusing it allowed a fast and iterative design and production with 3D-printing of both games in several stages.

Related Work

To design and produce games for visual impaired, we want to build on simple and widely available production tools. 3D-Printers are such a technology, that are either available in a FabLab or Makerspace, or that the technology enthusiast already has at home. It can be used to print Braille letters as well as to produce small object representations, which can be used to support Braille learning of whole words. VizTouch by Brown et al. [1], for example, presents a graph representation as 3D-model which can be printed, while Stangl et al. proposed entire 3D printed, tactile books for children [6]. Using these technologies and an open-source approach for a learning system has another advantage: Apart from using a 3D printer at school or home, one can also rely on the maker community as multiplier and to make improvements and extensions. Makerspaces are already used not only as community hub, but also as an additional education hub. Within small labs, this kind of technologies can be integrated into school education as pursued

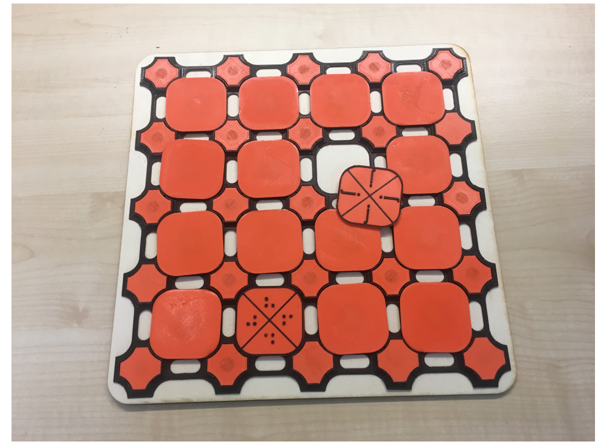

Figure 1: 3D printed memory game with both braille and black letters. A grid structure prevents moving of the pieces while sensing.

by politics (STEM for children [2]) and Universities (FabLab@School at Standford University), Furthermore, the community itself becomes more and more interested in making things that matter, trying to become more inclusive as well as helping community members or others, prominent examples are ATMakers, BurnersWithoutBorders, Makers4Good, e-Nable and HumanitarianMakers. One recent example is the BecDot [3], a Braille learning tool developed by a father for his youngest daughter, using NFC-Tags in combination with a smartphone and a Braille display for word learning.

With modern tools at hand, we are now able to develop new learning toolkits based on these ideas. Furthermore, we are also able to just give impaired people desired tools and games custom-made to their needs and desires, as shown by the other two games.

Game design

Modern personal fabrication production methods like 3D printing allow fast and iterative development. Especially for games, user feedback while playing can be used to improve the games and find new ideas. In our case, we started with the memory game as own idea, with user feedback further improvements could be found. Furthermore and more important, the testing and discussion leads to the development of the next two game modifications for Yahtzee and a building game. This process can be of course continued while displaying the games.

BrailleMemory

The basic idea of the BrailleMemory (Fig. 1) is simple: Finding the correct pairs of normal and Braille writing, or two braille letters depending on sighting abilities. For easiest production, these cards are made with a 3D-printer, for easy access either with one at home or in a local makerspace. The design is made in OpenSCAD[1] with parametric layout for an easy adaption and modification of the cards. This includes resizing: Newman et al. [4] found out that beginners preferred to start with bigger symbols, and later move to the smaller ones when tactile sensing abilities improve. Furthermore, while trying to make both normal and braille letters haptically senseable, we also tried to make the system visually appealing: Learning braille works best visually, followed by a combination of visual and haptic elements. Therefore, learning Braille should start as early as possible to prevent the worst learning way if only haptics is possible [5].

The game play can be divided into several steps: First of all, while we have a set of cards for the entire Braille alphabet and its translation, learning should start with a smaller subset. For Beginners, we assume that finding correct pairs is the best way at the beginning, since no additional workload for localization is necessary. With more players and experienced ones one could finally start a Memory game, which trains both orientation and correct translations. After selecting and turning a pair by one player, each player has to have a chance to sense the letters haptically for memorizing its location. To simplify the control of matching pairs, i.e., the correct translation we included a control system based on RFID tags. Placing these game cards on a controller box with an RFID reader and speech module, the controller box will tell the correct letter.

[1] http://www.openscad.org

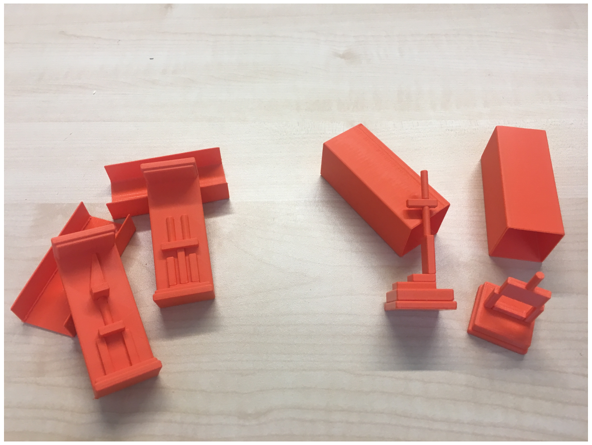

Figure 2: 3D game cards describing a build as relief (left) and complete figurine (right).

Building Blocks

The original game used a set of game cards to describe different types of towers by one person for recreating them with wooden blocks. While these buildings can be easily

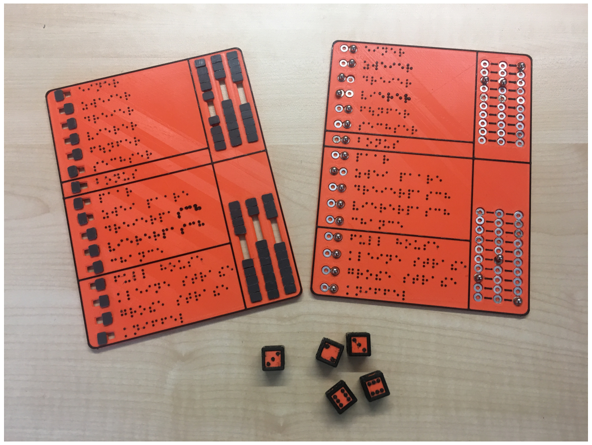

Figure 3: 3D printed score card. Complete 3D printed version (left) and improved version with magnets and washers (right).

done blind, reading the card is of course not possible for blind people. In a first approach we replaced the card with a miniature figurine of the shown building, done parametric with OpenSCAD again. Since this figure is very fragile, and scaling it up will take a lot of space for all 33 cards, we modified the design to a relief version (Fig. 2): A mirror wall cut through the middle of the building and works as stabilizing back plate, reducing also the depth to almost half the size. Only one object was not symmetric in a way that it was not possible to be able to show it correct this way.

Yahtzee score card

For the Yahtzee score card (Fig. 3) we decided to use a combination of check boxes for each kind of score and two independent abacus for upper and lower part. In a first attempt we tried to use a full 3D-printed version, and then iteratively came to a magnet version, with a nice haptic sensation and safe storage of values even while moving: Metallic, magnetic washers are glued onto the scoreboard, with a round magnet on top of it as a switch. The hole in the middle of the washer then secures the magnet at its position, until it is moved with a fingertip to the next washer and falls and locks into the next ring.

Technical Background

We used some standard 3D-Printers (Ultimaker 2, Prusa i3), with the Ultimaker 3 for two-color prints. This causes longer printing times as well as slightly more complex design and preprocessing, and it is just for optical expression and not necessary for replicating the system.

2.5mm Washers are used for the Yahtzee score card with 5mm round magnets.

For Braille memory we used NTAG216 RFID stickers as tags inside the game cards. These stickers are programmed with an ID corresponding to their corresponding normal letter if possible or a certain ID otherwise to simplify reading and programming. RC522 readers and an Emic 2 text to speech converter connected with the controlling Arduino Nano is used for speech feedback over an integrated 8 Ohm speaker. For improved audio feedback this can be replaced with a MP3 player module. All design files, done in OpenSCAD as well as programs and necessary tools are kept as simple as possible to allow an easy replication, modifications, and extension for own game ideas and will be available as open source.

Limitations and Challenges

The main challenge while developing the system was to make it ready for eyes-free interaction as much as possible. This includes that we got a tactile coordinate system as well as speech feedback for the memory game, while the other two games just rely on the haptic sense. While 3D-printer becomes better from printing quality, normal FDM printers surface quality is still not good enough for a nice haptic sensations - both the flat back surface on the Ultimaker glass build plate didn't feel good. Similar the sharp surfaces from the levels and end drops are not pleasant. Further surface finishing is therefore required or using more advanced printer, luckily we have still a rapid technological in 3D-printing technologies.

Conclusions and Future Work

We showed that with modern personal fabrication tools we could developed custom-made game systems for a group of people with special needs. Basic structures are reusable and can be iterative improved. Each game is both designed to have both a nice look and feel, and can be played blindfolded to get a feeling for the challenges of designing games for visual impaired people. The games are developed according to ideas of visual impaired people, which are in the process of testing them, their feedback is used for iterative improvements.

Acknowledgements

This project was funded by the German Federal Ministry of Education and Research under the project Personal Photonics (Grant 13N14065).

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