Tactile Graphics: Three Uses of 3D Printing for Visually Challenged Individuals

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Introduction:

Visualization and visual cues are a major asset of information-gathering in the world today. They are used to routinely convey information in a manner that is normally taken for granted by individuals who have the sense of sight. Without a doubt, tasks like learning math, reading, and viewing pictures and graphs are all easily accomplished when one has the invaluable ability to see. These tasks, in addition to numerous others, are vital for the acquisition of a well-rounded education, which is important to have in order to achieve success in life. Unfortunately for visually challenged individuals, those who are blind or have lowvision, they are constantly confronted with a degree of difficulty when it comes to obtaining and processing information that is presented completely in a visual format. This circumstance affects about 1.3 million people in the United States who are legally blind. As of March 2009, over 70 percent of blind adults in the United States were unemployed, and the high school dropout rate was about 50 percent for blind high school students. In addition, only a very small percentage of visually challenged people (about 10%) are actually literate in Braille, the leading means of reading and writing for visually challenged individuals, and only about 10 percent of blind children are learning Braille in America today. Thus, it is vital to find a way for the visually challenged community to be able to effectively learn to read and write without actually being able to see what they are reading [3].

Historical Perspective on Assistive Technology for the Visually Challenged:

Many years ago, as a solution to this problem, the Braille system of reading and writing was designed in 1932 to aid people who were visually challenged [3]. By design, Braille is a writing system that uses raised dots in order to convey a similar functionality to letters and numbers via tactile rather than visual feedback. This system of writing was designed to empower visually challenged individuals with the ability to read independently, therefore exposing them to the world. In actuality, however, as previously stated, only a very small percentage of those with visual impairments (about 10%) are actually literate in Braille, and only about 10 percent of blind children are learning Braille in America today. This can be attributed to a variety of factors, including a shortage of teachers qualified to teach Braille, the notion that Braille is slow to read and hard to learn, and the notion that technology replaces learning Braille [3].

Fortunately, there is much research being spurred on by some of the antiquated approaches to teaching the visually challenged. Assistive technology has been developed to allow accessibility for these individuals to obtain and process visual information that hitherto had been inaccessible to them. Some examples of this assistive technology include text magnifiers, readers. Braille note-takers. screen and document scanners with optical character recognition [4]. These devices, ranging from the most basic (such as text magnifiers) to the most high-tech (such as the document scanners) have opened up a whole new world of "sight" to the visually challenged. Consequently, they can approach and process information that, in years past, could only be conveyed via audio delivery or not at all.

UMBC Research:

In the spirit of this assistive technology, researchers at institutions like the University of Maryland, Baltimore County (UMBC) have found and are continuously devising ways to help the visually challenged to live more "normal" lives with regards to the above issues. In addition to the assistive technology that was mentioned above, there is a presence of 3D printers and 3D printing technology in this research field. The printer that was used at UMBC was the MakerBot 3D printer. The MakerBot is ideal for use at home or in research because it is user-friendly, versatile, and considerably less expensive than other 3D printers [5]. The MakerBot is able to create durable objects made from different kinds of plastic such as Acrylonitrile Butadiene Styrene (ABS), Polylactic Acid (PLA), and Polyvinyl Alcohol (PVA) [5]. Since its inception, there have been two models of MakerBot using these kinds of plastic, the Thing-O-Matic the older model, and the Replicator, the newest model introduced in January 2012 [5]. Following the advent of 3D printing technology, researchers have applied this new advancement to make assistive technology for individuals with a myriad of disabilities. The three projects the author of this report was tasked with for the summer of 2012 on using this 3D printing technology are AlphaBraille, a program to integrate alphanumeric text and Braille characters, VizTouch, a program to turn graphs and functions into 3D models, and Pictures, a program to turn photographs into printable 3D models. A discussion of all of these projects will follow.

AlphaBraille:

In order for one to get a well-rounded education, it is invaluable that one be literate. Obviously, one must be able to read, write, or point-and-click in order to access information - hence facilitating the acquisition of knowledge. As already established, visually challenged individuals are unable to read in the same manner that individuals who can see are. As previously mentioned, many years ago, as a solution to this problem, the Braille system of reading and writing was designed. However, the problem remains that Braille literacy is low among visually challenged individuals

Development:

From both this need for and lack of, Braille literacy in America, became the inspiration for the AlphaBraille software, a computer program that is written in Python and utilizes the opensource program OpenSCAD [7]. This program is a computer design program that uses its own programming language to interact with 2D images to build 3D models. AlphaBraille generates code in the OpenSCAD programming language to create a 3D model that utilizes both alphanumeric and Braille versions of a letter or number to form the same bit of text. Using this bit of text, the software generates two 3D models that can be combined and printed via the MakerBot 3D printer. The models are combined and each assigned a different color to be printed with the Replicator model of the MakerBot. The final print is a plate in which the embedded alphanumeric text is visible to low-vision and fully sighted individuals while the braille is printed on top of the plate for tactile feedback. This allows for wider accessibility.

Furthermore, a scalable Braille library was created in OpenSCAD [7]. Currently, this Braille library contains the code to create Braille representations of any letter (A through Z) and any numerical digit (0 through 9). The dimensions of these characters (the radius and height of the component dots and the distance that each dot is from one another) can be changed within the code of the AlphaBraille program where the OpenSCAD code is generated. Using the scalable Braille library, the program made the Braille extrusions in the prints as consistent with the standards for Braille size as possible (given the capabilities of the MakerBot printer) [8].



Figure 1: "UMBC" generated by AlphaBraille

Findings:

As prints were made with different words it was found that as the radius of the Braille dots increased and their height decreased, they became more durable in the print, thus becoming harder to break when one tries to read it with one's fingers. When printed from the MakerBot, the Braille dots become more brittle and easily breakable as they get smaller in radius. This presented an interesting situation because of the standards for the size of Braille print. The standards of the Braille size list minimum sizes, but not maximum sizes [8]. However, when AlphaBraille prints were given out for a demonstration at an ADA celebration event, the visually challenged individuals who participated in an informal presentation of it mentioned that the Braille dots were too big. It is believed that as 3D printing technology improves, it will be able to produce prints with Braille dots that are smaller yet sturdier, becoming consistent with the standards for Braille sizes [8].

Future Work:

In the future, researchers at the Prototyping and Design Lab at UMBC plan to run formal tests of prints yielded by the AlphaBraille software. The plan is to test how low-vision individuals can read the embedded alphanumeric characters and to test how low-vision individuals can read the Braille characters. Researchers also plan to devise methods to make the Braille characters sturdier and more compliant with the standards for the size of Braille characters. As far as development is concerned, text input is still crude, reading text from a prompt in the command line rather than any kind of windowbased input. Therefore, the plan is to put a window-based input into the program to make the interface more user-friendly.

VizTouch:

Mathematics and science are two subjects whose concepts require visual processing of graphs, charts, tables, etc. Thus, it goes without saying that those who are blind or are otherwise visually challenged have often found it difficult to learn concepts of mathematics - in particular, those employing these parameters. Thus. VizTouch was developed to facilitate the acquisition of such mathematical concepts. VizTouch was inspired by the low percentages of visually challenged individuals who are literate in the Braille writing system. It was intended to be an alternative method of teaching mathematics to visually challenged individuals rather than using Braille [1]. VizTouch enables end-users to input functions and datasets into the interface in order to generate 3D models to be printed out via the Replicator model of the MakerBot 3D printer.

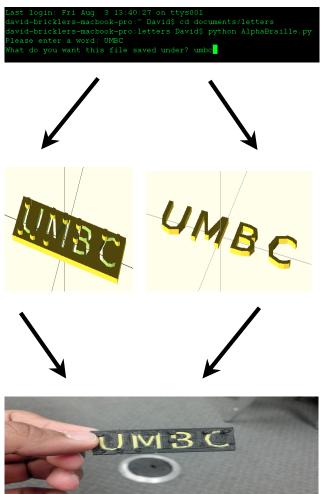


Figure 2: Text to model to Print

Two-Color VizTouch:

There were two improvements that were made on the design of VizTouch in the summer of 2012. The first was altering the code of the program to split up the printable model for the graphs into two different files in OpenSCAD. By making this change, the program was able to use the newer features of the MakerBot Replicator 3D printer to merge the two models into one printable model file. This merging enabled the printer to print the graph in two colors. This merging is significant because the presence of two colors enables those with low vision (or even fully sighted people) to be better able to see the contrasting colors. Additionally, it enables tactile feedback for those who may need it. The two-color prints will make the graphs generated

by this current version of VizTouch accessible to a wider audience than the graphs printed in the previous version. We found that due to technical issues with the Replicator, the two-color prints were difficult to produce with good quality. Some of the plastic that exited out of one nozzle would temporarily clog up the other nozzle. This blockage would stop the secondary color from coming out as it starts to make the lowest layers of the grid, thus making the grid more brittle and breaking more easily. It is hypothesized that the problem will be rectified as 3D printing technology improves.

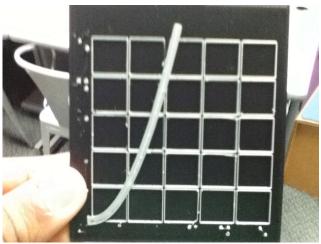


Figure 3: Two-Color VizTouch Print

Two-Function VizTouch:

The other improvement that was made to the VizTouch design was the alteration of the program's code so that the user could input two functions into the model of the graph. Each function line was extruded to a different height, so that the user could distinguish between the two functions. The two-function extension expanded the functionality of the software design and allowed more tasks to be done with the software. For instance, the two-function VizTouch could allow for easier comparisons between the graphs of two different functions since both functions are on the same graph. Also, since VizTouch has been extended to put two functions in the graph, it could be extended to put three or more functions on it as well, thus further enabling comparison between different function graphs in the same vein as the addition of two functions.



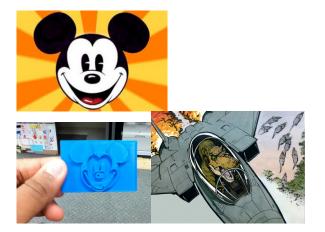
Figure 4: Two-Function VizTouch Print

Future Work:

Future plans include extending VizTouch to make bar and pie charts; to incorporate different textures to each of the functions to the twofunction VizTouch to make them more distinguishable without sight. Also, for the twofunction VizTouch, the plan will be to put different textures for both functions, and to find out whether that would be a more effective means of helping visually challenged people distinguish between the functions. There will also be a merging of the two extensions so that the two-function graphs can be printed in two colors. Finally, there will be a plan to run formal tests with the two-color and two-function VizTouch prints to evaluate their effectiveness among the visually challenged.

Pictures:

Visually challenged people have as much incentive as people who have sight to take, to view visualize and photographs. to Unfortunately though, since they are unable to see, it is hard for them to enjoy these abilities taken for granted by people who can see. Technology has begun to address this concern. Now, through automatic or human-powered interpretation, it is possible for legally blind people to gain information from photographs. In as much. several visually challenged photographers are now posting their work on Facebook, Flickr, and on other websites and blogs [2]. To aid efforts to improve the photography experience for visually challenged people this software was developed using OpenCV, an automatically generated computervision programming library [6]. As a joint effort between University of Maryland, Baltimore County and University of Maryland, College Park this software is a way to convert photographs into 3D models in OpenSCAD that can be printed via the MakerBot to bring tactile feedback to those who are visually challenged.



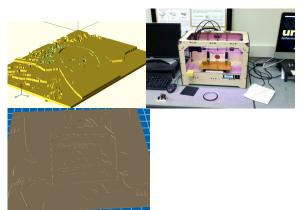
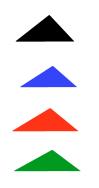


Figure 5: Photographs and Images as Models



Testing:

To test this photography software, several photographs and images were run through the program and converted into 3D models. The program as it is now only recognizes colors as either light or dark. According to several images being run through the picture there were only two height levels in the models or the plates that represent different pixels of an image. They were pixels that were raised and those that were on the level of the background plate. Dark colors, such as black, brown, red, or blue, were raised; while lighter colors, such as yellow, pink, lime-green, and grey remained on the level of the background. Also, different shades of grey were found to have different registry in the program. Up to a 40% shade of grey was registered to be raised in the program. This led to the 3D model of the pictures resembling something akin to a photograph that used only two colors, full black and full white and to be just as hard to discern what the picture is about.

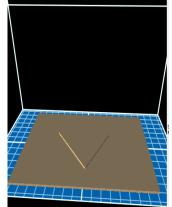


Figure 6: Black, Blue, Red, and Green Triangles as Distinct Entities in the Model

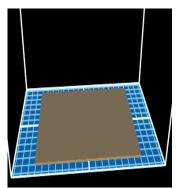


Figure 7: Lime-green, Yellow, and Light-blue Triangles Not Registering in the Program

In addition to distinctions that the program made between light and dark colors in hand- or computer-drawn pictures, the program was also able to effectively make such distinctions in photographs taken via cameras. However, it was noted that images that were blurrier were harder to export from OpenSCAD to a file that could be printed on the MakerBot. In addition, the more complex the image was, the smaller the areas of the photograph that were distinctly contrasted. This could lead to the problem of the end user of the print not being able to discern what the photograph is about due to insufficient tactile feedback.

Future Work:

Future plans of this research include running further photographs and images through the program to truly find the limitations of this program and how it can be improved. The exact development process was done from an outside source, so it is beyond the scope of this paper and the research that was done. However, current findings will be reported back to the orchestrators of this program.

Conclusion:

It is the hope of researchers at the Prototyping and Design Lab at UMBC that these three projects will help visually challenged people to live more "normal" lives. AlphaBraille, VizTouch, and Pictures, all make it easy for users to make 3D models for text, graphs, and photographs, and with te proven.



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