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A Cymatics Based Testbed for Flexible Braille Language Display

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Abstract
Tactile technology is not mainstream but it is indeed widely needed. Using the systematic patterns that different sound waves produce on material with small particles, can help in the development of tactile tablets. There are currently no effective, commercially available standalone devices that the visually impaired people can easily carry and interact with them via touching and hearing. Therefore, this project aims to fill this gap by designing a testbed for studying the principles of a sound driven flexible braille language display. Input from both processor and camera can be presented on a Cymatics plate. Input from camera requires image processing to extract elements from images. Results have showed great results for text extraction, however further work needs to be done on images that contain letters alone. First eight capital English alphabets are associated with specific patterns. With industrial fabrication of tiny vibrators and further work on the system, the first tactile tablet will be ready in market.

Keywords: *Cymatics; braille; tactile; display*

1. Introduction

Cymatics is the study of visualizing the effects of waves and sounds on particles [1].A basic Cymatics experiment can be done using a plate with small particles (like sand) on topof it while scraping a violin on the side of the plate. The sand particles will start creating geometric patterns on the plate, and as the sound differs, different patterns will start to appear [2].

When changing the side of the plate that the violin bow scratches, different patterns appear. Sophie German tried to explain the theory behind the appearance of Chladni patterns and wrote mathematical equations. She stated that sound waves create vibrations through the plate. There are some areas where the plate vibrates and areas where the plate is still. The sand moves away from the vibrated areas and gathers in the still areas [3].

Sound and vibration can have systematic effects on materials [4]. If a plate with small particles is vibrated at a specific frequency and amplitude the effect of that vibration will appear on the particles. If the frequency or amplitude is changed, the patterns will change as well. It was also found that if the frequency is increased, the complexity of the patterns along with the number of nodes and anti-nodes will increase [5]. If on the other hand the amplitude is increased, the motion will become rapid and unstable; which could create small eruptions, where the particles are thrown up in the air [6]. Experimental results have also proven that Patterns produced on different types of materials are different, for example patterns on paper board and patterns on polystyrene board are different, and the reason for this is that every substance has a different resonance frequency, which results in every plate creating different patterns [7].

Resonance frequency is the frequency at which the material vibrates the most [8]. All harmonics of the resonance frequency are also to be considered resonance frequencies of the object. In Cymatics, it is important to operate around the resonance frequency of the material to produce the best results.

Cymatics science emerges from the standing wave phenomena that are based on the wave theory of sound. A wave is a disturbance travelling through a medium or through space. If the medium is limited at one end so that it has some sort of barrier it will cause the wave to reflect. The result is two waves; the original wave and the reflected wave travelling at the same time but in opposite directions. These waves combine, they either add when they are on top of each other and this is known as constructive interference, or they subtract when they are opposite to each other and this is known as destructive interference. This combination of the waves is what is known as the standing wave. The areas where the wave appears to not be moving are called nodes, and the areas where the wave appears to be in motion are called antinodes [9].

In the contemporary world of technology, the use of wearable technology is proliferating in every field from medical science to arm forces. Coupling such technology with powerful algorithms and Internet connectivity opens unlimited potentials to develop technologies that overwhelm human capabilities.

Cymatics field is lacking in terms of definitions and theories. A straightforward relationship between the generated patterns and the input sound was not found. By studying the relationship between signals and resulted patterns, Cymatics will be finally ready to be implemented on all of its intended applications like medicine, communication and art.

When Braille was invented, it was an advanced and original method to involve visually impaired people into the world of letters and literatures [10]. By transforming visual language into tactile language, visually disabled people could expand their domain of communication [1,11]. Technology has been a wide source for knowledge and information and has contributed to the development of human race. However, as the world advances through tangible and visual technology, the visually impaired people are being left behind. The only way that the visually impaired people can access tangible technology is through bulky accessories that are hard to be carried everywhere. Furthermore, these accessories sometimes require the usage of sound for the user to interact and receive information. Hence, to address the needs of the visually impaired, this project delivers a testbed for a standalone device that is more flexible and efficient in terms of user friendliness and tangible interaction.

There are currently no effective, commercially available standalone devices that the visually impaired people can easily carry and interact with them via touching and hearing. Therefore, this project aims to fill this gap by designing a testbed for studying the principles of a sound driven flexible braille language display. The system is based on principles of text extraction and a Cymatics based systematic sound display. The system application could be extended for a systematic tactile display of music and sounds which will allow the people with impaired hearing to appreciate the auditory art.

2. Prototype Description

This project deals with the design and development of a testbed for the study of Cymatics based flexible Brail language display. The system consists of two main modules. The first module extracts text from images taken through the camera and the second module produces an appropriate pattern on the Cymatics plate. This testbed is limited to presenting capital letters on Cymatics each letter at a time.

2.1 System Architecture

Initially the experiment was performed using a function generator and an oscilloscope. This setup was done to test the plates and materials and to record initial results. In this setup, the oscilloscope was used to set the amplitude of the function generator before each trial. The function generator was then connected to the vibrator which had the plate on top of it and the frequency was varied while the produced patterns were observed and recorded. In the final setup, the function generator and oscilloscope were replaced with Matlab. A signal with certain frequency and amplitude was generated using Matlab. The signal was passed to the amplifier using an AUX cable. The amplifier was needed because the amplitude that the laptop gave was too low to produce any output on the plate. The amplifier was connected to the vibrator that had the plate on top of it. The final system setup is presented in Figure 1.

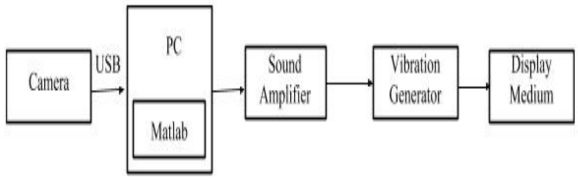

Figure 1: Final System Block Diagram

2.2 Functionality

The system will take an image through the camera. Then the image will transfer through USB cable to Matlab software, which will process it and send an appropriate signal to the vibration generator. The vibration generator is connected to Matlab through an AUX cable. On top of the vibration generator exists the Cymatics plate where the patterns will appear. The wave that goes out of the vibration generator will generate different patterns depending on the image acquired from the camera Different frequencies produce different patterns. Each pattern is associated with a capital letter; hence each letter has its frequency. When a letter is detected, a sin wave with the letter frequency is sent to the vibration generator. The flow of the system is shown in Figure 2.

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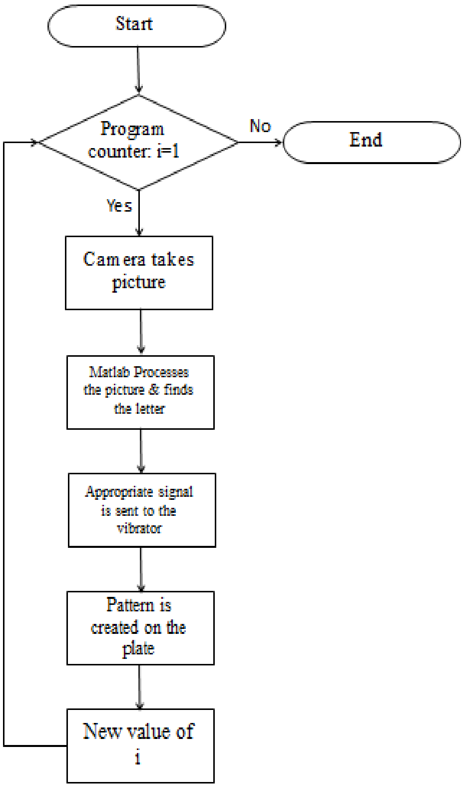

Figure 2: System Flow

3. Design and Analysis

3.1 Text Extraction

Images are represented in MATLAB as two-dimensional array. Each element of the array is a pixel that contains the color data of the image. Matlab contains an image processing toolbox. The camera is synchronized with Matlab by creating a webcam object. The snapshot function will capture pictures and save them in Matlab directory. The image is converted to JPG form to be processed. MSER which stands for Maximally Stable External Region. MSER regions are sectors of an image that have homogenous color intensity and are surrounded by a contrasting background. MSER is used in this scope because the camera is taking pictures of a letter in a natural setting. MSER picks out all uniform regions that can also include non-text areas. There should be a second tool that picks only the text areas. One approach could be by checking the stroke width variation. Stroke width is a quantity that represents the width of curves of characters. Since text is usually written in one font; the stroke width of the characters has minor changes unlike natural scenes. After finding the region that has a small stroke-width variation which contains the letter, it is important to retrieve the letter from the region. MATLAB has a function called "Optical Character Recognition" that receives an image and gives back the text along with its location. The flow for text extraction is shown in Figure 3.

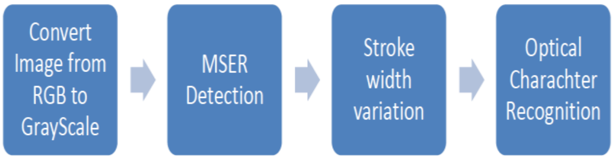

Figure 3: Text extraction process

3.2 Tools

Matlab was used in this context as it has an image processing toolbox that is more user-friendly than other complicated programming languages. Also, Matlab makes it easy to communicate with a webcam and acquire photos and videos. A vibration speaker or a vibration generator was used. A normal speaker operates by moving the diaphragm up and down with the voice coil which makes air particles move to produce the sound. There is a permanent magnet that is placed at the base of the speaker. This permanent magnet is the reason the voice coil moves. When current passes through the voice coil, a magnetic field will be produced which will either repel or attract to the magnetic field of the permanent magnet. A webcam with USB cable was essential for the communication with Matlab. There were no much requirements on the chosen camera except of clarity and adaptability with Matlab. Thus for this work, Microsoft LifeCam-3000 was used. The main requirements that are needed in the amplifier are the frequency response and the output power. The frequency response should match the frequency range of the vibration generator. The output power needs to be high enough to vibrate the material on the Cymatics plate. Thus a 100 W amplifier was used in this work. Material, shape, and size of the plate are parameters that affect the output patterns. Different plates were tested and the plate that produced more patterns was chosen. The chosen plate was a square metal plate with a perimeter of 96 cm. The type of particles chosen to vibrate on the plate doesn't affect the resulted patterns. However bigger particles like rice will result in more accuracy of reading for visually-impaired people. The north, south, west and east of the plate need to be identified to distinguish patterns that have similar shapes but different directions.

4. Result and Discussion

The system was tested in different ways which resulted in different outputs, some of which were successful and others were not. Firstly, the tests were carried out using a function generator which produced patterns at specific frequencies and amplitudes, some of the results of these tests are shown below. The two similar shapes displayed were obtained at the same frequency and amplitude, but the only difference is the vibrating particles on the plate. Figure 4 (a) shows the pattern obtained with sand, and Figure 4 (b) shows the pattern obtained with rice.

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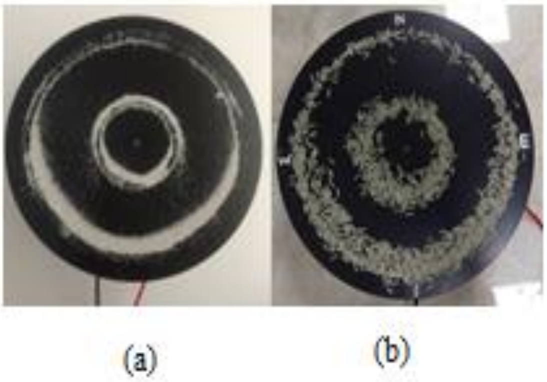
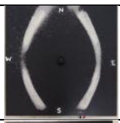
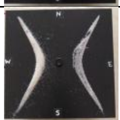
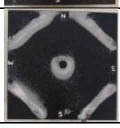
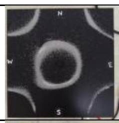
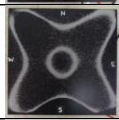
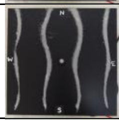
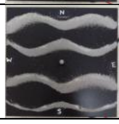


Figure 4: Pattern (a) sand (b) rice.

It was decided to do the tests with rice because rice is more tangible; which means it would be easier to touch and trace by the visually-impaired people.

While using the function generator, no amplifier was required since the output of the function generator was sufficient to create the output needed on the plates. The experiments were next carried out using Matlab, the output of the laptop alone was too small to vibrate the vibrator enough to create any patterns on the plates, so without using an amplifier while using matlab no results were obtained. Several amplifiers were used before the right one was found, the tested amplifiers mostly did not amplify the signal enough to make the vibrator work and give results that could be recorded. When the right amplifier was found, the experiments were carried out and eight different patterns were obtained and captured along with the details about the frequency and amplitude they were formed at. Each of the eight patterns was assigned to a letter from the first eight English alphabet as shown in Table 1.

Table 1: Output results for letter A to I

Letter	Pattern	Frequency (Hz)	Amplitude (V)
A		78	10
B		90	7.5
C		90	10
D		175	20
E		225	12.5
F		380	6.25
G		440	6.25
H		455	6.25

When operating at high frequencies, the frequency range between patterns became bigger. For example between 3039 Hertz and 4273 Hertz, there were no generated patterns at all. Also, results have showed that amplitude has an effect on generated patterns with low frequencies only. For example at frequency 90 Hertz, two different patterns were generated at different amplitudes. Varying amplitude with high frequencies will only affect the formation speed of the pattern. The results of the second phase of the project were obtained using Matlab for image processing testing. As is shown below the text was detected from the images and the words in the picture were given as the output in Matlab.

The results of text extraction showed (Figure 5, Figure 6 and Figure 7) that the OCR function can never work with an image that has only one letter. The image needs to have at least one word for the OCR function to extract text from it. In this system only capital alphabets need to be extracted; therefore, for each letter a word that starts with it is used. For example, the word Apple is used to detect A and discard the rest of the letters. The final system architecture which is connecting both Cymatics and image processing together was tested and successfully worked; the required output was obtained out of the final system.

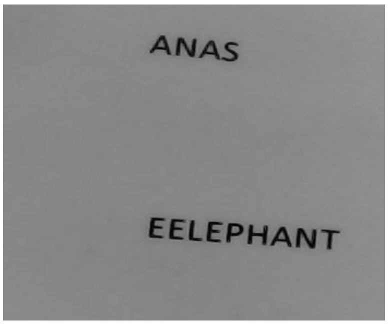


Figure 5: Input Image from Camera

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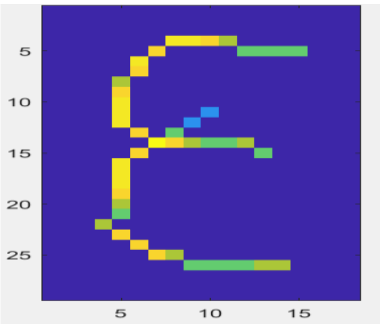

Figure 6: Letter E after Thinning

```
ans =

    'ANAS

     EELEPHANT

     '
```

Figure 7: Results of Text Extraction on Matlab Command Line

5. Conclusion

The project was successfully implemented. The aim of this project was to design and develop a testbed for the study of Cymatics based flexible Brail language display Braille language tablet to help visually impaired people communicate and use technology easily. This project deals with the design and development of two modules. The first module extracts text from natural images via image processing tools and sends appropriate signals to the speaker. The second module provides a systematic representation of sound through Cymatics.

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