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VISION BASED OF TACTILE PAVING DETECTION METHOD IN NAVIGATION SYSTEM FOR BLIND PERSON

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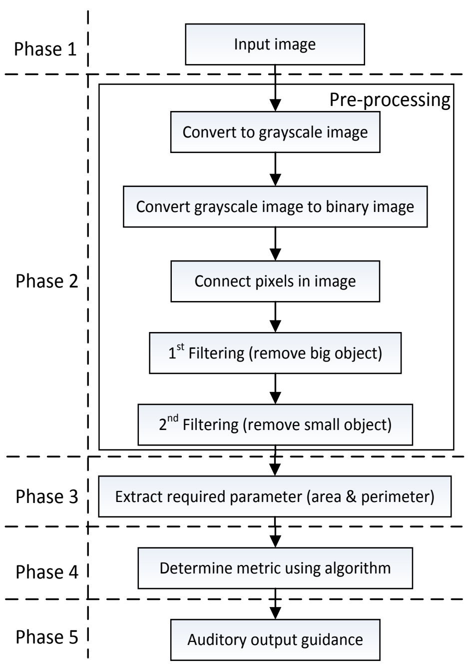
Graphical abstract



Abstract

In general, a blind person is relying on guide canes in order to walk outside besides depending only on a tactile pavement as warning and directional tools in order for avoiding any obstructions or hazardous situation. However, there still need a lot of training in order to recognize the tactile pattern and it's quite difficult for new blind person. This paper describes the development and evaluation of vision based on the tactile paving detection method for blind person. The developed tactile paving detection system can be used by blind person for blind navigation purpose. Experiments will be conducted on how it works to detect the tactile pavement. In this experiment, we propose the vision based method by using MATLAB including Arduino platform and speaker as warning tools. There are two types of tactile pattern need to recognize which are circle acts as warning tactile and bar acts as directional tactile. Output of this system will be based on the result found from the tactile detection in MATLAB, then produces auditory output and notifies the blind about the type of tactile detected. As a result of this project, it will definitely help the blind by easing their mobility.

Keywords: Tactile pavement, vision based, blind person

1.0 INTRODUCTION

In early 2014, the United Nations (UN) released the statistic that people with disabilities (PWDs) in the world are estimated more than 1 billion people or 15 percent of the world's population. Moreover, 80 percent of these disabled people are located in developing countries. This number has increased due to increment of aging populations, chronic health conditions and more accessibility to facilities. In Malaysia, the population is around 28 million people. However, until February 2014, the number of disabled people in Malaysia which was registered was only 500,000 people instead of the 2.8 million people which are estimated. This total number does not reflect the real situation of disabled people in this country. This is because people of disabilities still remain invisible in the majority of development agendas and processes.

The accurate data on people with disabilities cannot be regularly obtained or recorded. This shows the clear image of the lack of connections between disability and country development which mostly occurred in developing countries. The collected data is inaccurate and show the shortage of acceptable measurable statistics and the complications faced in gathering correct data [1, 2].

According to the Convention on the Rights of Disabled Association of the United Nations, disabled people should be given priority and need more attention from the government in order to build a high income country. However, the disabled people in some developed country are not considered well and usually ignored in the country development. The convention guarantees that the disabled people enjoy equal opportunities with those efforts as well as full and effective participation in society in all aspects of life - accessibility, mobility, health, education, employment, rehabilitation and participation in the political, economic and socio-cultural. On the other hand, the disabled people can be categorized in some classes such as deaf, blind, physically disability and etc. However, of all disabled people who are involved in dangerous situations are almost always blind people. There are also multiple sensory problems such as deaf-blind person. It is more severe than a single sensory problem [3].

Conventionally, the blind people rely on white canes or guide dogs to assist them in order to reach their desired destination safely. However, the conventional method is beneficial if only the path to the destination is already familiar or known. It becomes difficult if the destination is new especially where the environment is not designed for blind people. They do not know where to go and cannot recognize their surroundings. It is very hard for them to travel independently from one destination to another without the proper navigation tools. Additionally, the disadvantage of the white cane is that the obstacles can only be detected by contact. This problem will expose the users to dangerous situations when the blind person is very close to obstacles. Hence, there is a lot of research that has been actively conducted in regards to a supporting device for blind people. The machines that have been researched are electric wheel chair [4], NavBelt [5], and electronic guide canes [6], My 2nd Eye [7], Robotic mobility aids [8] and Smart EYE [9, 10].

However, the decision maker of the system is a controller which controls the motor at the wheel to turn or go straight for researched machines. Consequently, it will give hidden damage to the user's brain where their brain cannot actively use it as a decision maker. The main requirements of the assistive device for blind person are safety, practicability, portability and convenience. Safety is the basic requirement to judge whether an assistive device is reliable or not. The most important task for the blind person is to gain information on the circumstances of the road and the location of obstacle. By using the collected information, the deaf-blind person needs to arrive at their destinations avoiding unexpected obstacles. Recently, an intelligent white cane has been developed by implementing the infrared sensor in order to detect the obstacle around the user. However, the developed intelligent white cane cannot directly replace the conventional white cane because the blind person needs time to familiarize themselves with the intelligent white cane before replacing the conventional white cane [11, 12].

Moreover, almost of the studied travel aids are normally used to help the user to detect the obstacles by touching the obstructions directly. Tactile pavement system is one of many kinds of aid and assisting tools for the blind person. It can be found almost at anywhere near the streets or roadside where there are heavy traffic or pedestrian areas. It is used as travel aids for the blind person to move from places to places despite being highly inconvenient due to their lack of vision, and thus the presence of danger in the environment could not be sense. Besides, there still need a lot of training in order to recognize the tactile pattern and it's quite difficult for new blind person for navigation purpose [13, 14].

The meaning of "tactile paving detection using visual method" does not mean that the blind have to actually see the tactile to realize its presence. A video/image input device, which could be a camera or a webcam, is representing the blind person to "detect" the tactile, and the output of this aiding system would be in audio, which is auditory output. This project is developed on the basis of the needs for implementing more advanced method of detecting the tactile pavement and helping the blind as much as possible. In short, the video/image input device is the 3rd eye for the blind which will aid them in detecting the types of tactile pavement on the road, and the auditory output system will enlighten the system's user about the possible type of the tactile depends on the detection [15, 16].

This paper describes the development and evaluation of vision based of tactile paving detection method for blind person. The developed tactile paving detection system can be used by blind person for blind navigation purpose. Experiments will be conducted on how it works to detect the tactile pavement. In this experiment, we propose the vision based method by using MATLAB including Arduino platform and speaker as warning tools. There are two types of tactile pattern need to recognize which are circle acts as warning tactile and bar acts as directional tactile. Output of this system will be based on the result found from the tactile detection in MATLAB, then produces auditory output and notifies the blind about the type of tactile detected. As a result of this project, it will definitely help the blind by easing their mobility.

2.0 HARDWARE CONFIGURATION

Figure 1 shows the system configuration between personal computer including with MATLAB, web camera, Arduino UNO board, XBee transceiver, voice module WTS020 and speaker in order to give auditory warning to blind person after implementation of vision base tactile detection method. After a coding has been inserted into the Arduino UNO microcontroller, it will be ready to receive signals from MATLAB, and then send commands to the voice module to play selected audio file. In order to produce auditory output, a voice module will be used to play the required audio file when commands are executed. Figure 2 shows the actual hardware which has been developed in order to validate the performances of the proposed vision based tactile pavement detection system.

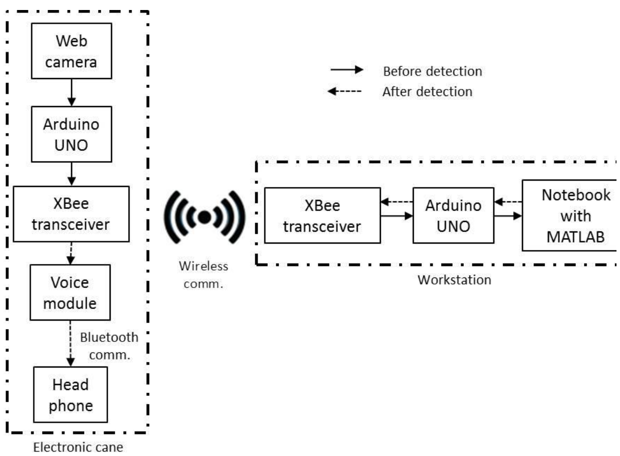


Figure 1 System configurations for developed tactile paving detection system

From illustration which is shown in Figure 2, a web camera is mounted on the centre of electronic cane. A distance between the web cameras to the tactile paving is about 50 cm. The web camera is connected to the personal computer which has been installed with the MATLAB software through XBee wireless communication. The personal computer will process the image which has been captured through web camera by using the proposed tactile pavement detection system which will be explained in next section. After the shape of the tactile pavement have been successfully determined by the proposed tactile pavement detection system, two type of voice guide will be given which are "WARNING" and "DIRECTION" through speakers which is wore at the head of the user. The result of the detection will be sent through XBee transceiver to the guide cane`s transceiver in order to activate the voice module. The voice guidance will be given through Bluetooth wireless communication.

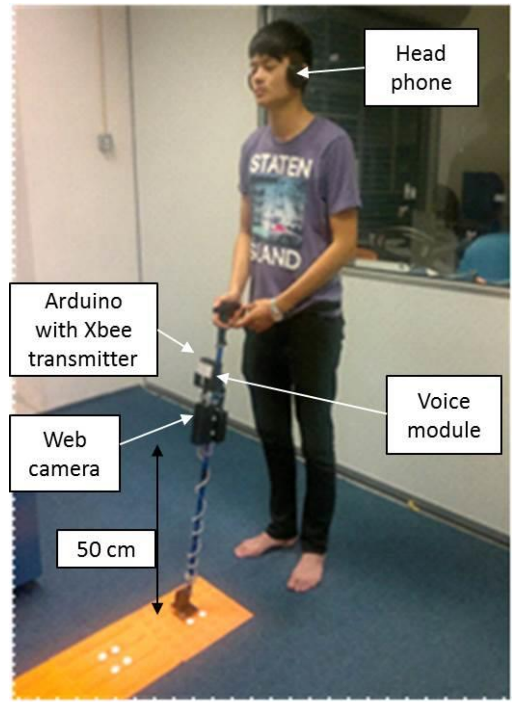


Figure 2 Actual hardware of developed tactile paving detection system

3.0 PROPOSED VISION BASED TACTILE PAVEMENT DETECTION SYSTEM

This project consists of five main phases. The first part is to input the image containing the tactile pavement including the warning tactile and directional tactile. The second part is the pre-processing of the input images, which includes the filtering of the noises for the tactile detection in the image. The third part is to extract and determine the area and perimeter of the connected components detected in the image. The fourth part is to determine the metric for the connected components, by using the area calculation algorithm of the detected components. The last part is to produce the accurate audio output to the blind. A process flow chart regarding the overall process of this project is shown in Figure 3.

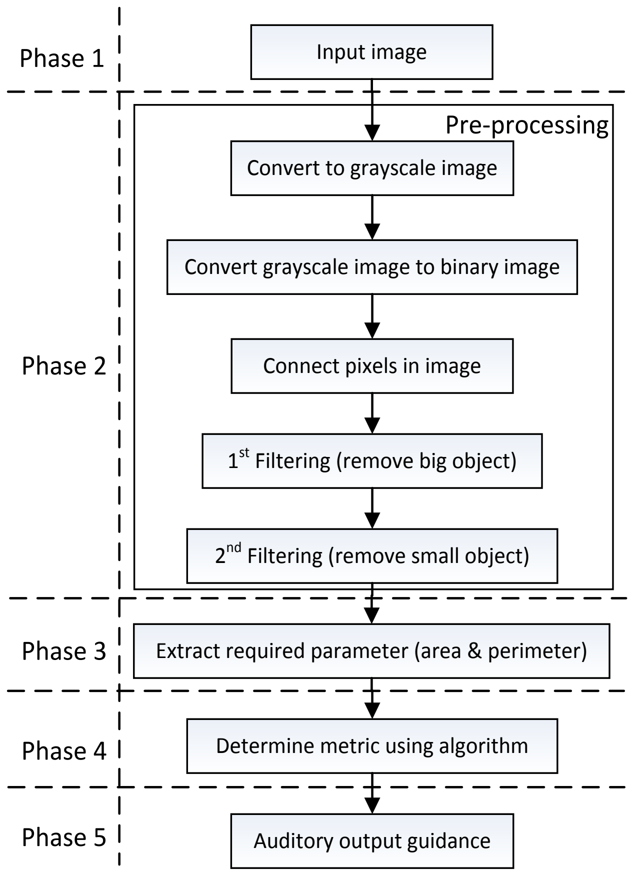
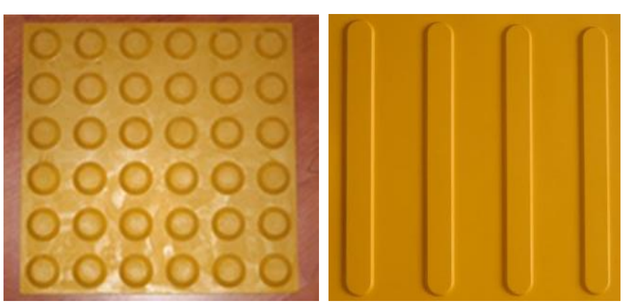


Figure 3 Overall process flowchart of vision based blind guide system

3.1 Input Image

A webcam/camera will be used to capture the image that contain the pattern of tactile pavement, it will be loaded into MATLAB for further pre-processing required for MATLAB to successfully detect any possible tactile shapes. Figures 4(a) and 4(b) show the images of tactile paving which are warning tactile and directional tactile.



(a) Warning tactile (b) Directional tactile

Figure 4 Input tactile image

3.2 Pre-processing

This phase of the whole process is to filter the image of what is actually required to be detected in MATLAB. There are several steps that are shown in Figure 4 in pre-processing that are important to achieve the goal of this project.

3.2.1 Color Image to Grayscale Image

The previous image is a RGB image, which is a colored image. The brightness levels of the red (R), green (G) and blue (B) components are each represented as a number from decimal 0 to 255. Therefore, the RGB image has to be converted to black and white image for the ease of processing. The lightness of the grey is directly proportional to the number representing the brightness levels of the primary colors. Black is represented by R = G = B = 0 and white represented by R = G = B = 1. The converted grayscale image is shown in Figure 5.

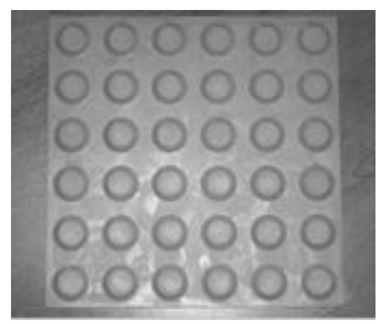


Figure 5 Grayscale image

3.2.2 Grayscale Image to Binary Image

This process will change the grayscale image to a binary image, which is an image with only black and white pixels in it. The pixel value that exists in this format of image is only 0, which is black in color, and 1, which is white in color. Figure 6 shows the result image of binary image after it has been through thresholding method when the threshold has been set to value of 0.5.

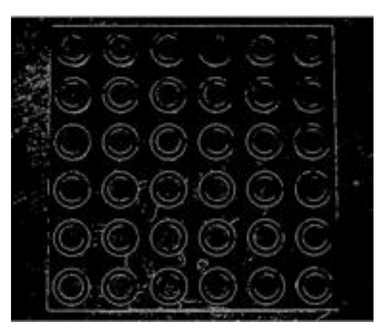
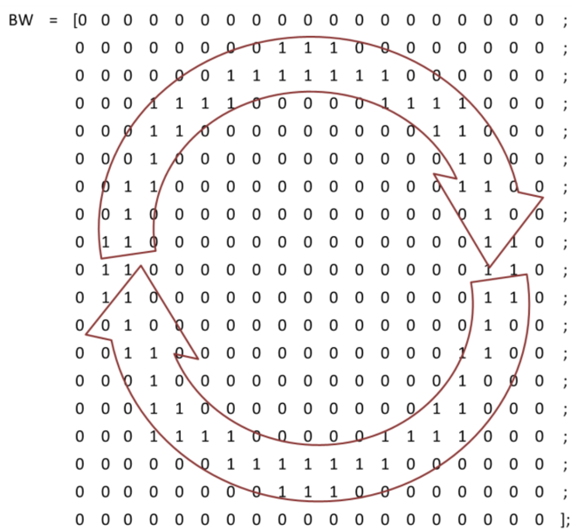


Figure 6 Binary image

3.2.3 Connecting Pixels in Image

In this phase, the pre-processing is used to identify the connected components inside the binary image. Figure 7 shows the connected components algorithm which is applied in order to identify the connected components by using group of binary symbols. After the connected components have been identified, the next process to fill the "holes" inside any connected pixels in the image automatically using MATLAB, in attempt to make the connected pixels looks more obvious. Therefore, further detecting process for the tactile shapes could be performed easier. The processed image which has been filled 'holes' with white color is shown in Figure 8.



```
BW = [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ;
      0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 ;
      0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0 ;
      0 0 0 1 1 1 1 0 0 0 0 0 1 1 1 1 0 0 0 ;
      0 0 0 1 1 0 0 0 0 0 0 0 0 0 1 1 0 0 0 ;
      0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 ;
      0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 ;
      0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 ;
      0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 ;
      0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 ;
      0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 ;
      0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 ;
      0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 ;
      0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 ;
      0 0 0 1 1 0 0 0 0 0 0 0 0 0 1 1 0 0 0 ;
      0 0 0 1 1 1 1 0 0 0 0 0 1 1 1 1 0 0 0 ;
      0 0 0 0 0 0 1 1 1 1 1 1 1 0 0 0 0 0 0 ;
      0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 0 ;
      0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 ];
```

Figure 7 Connected components algorithm

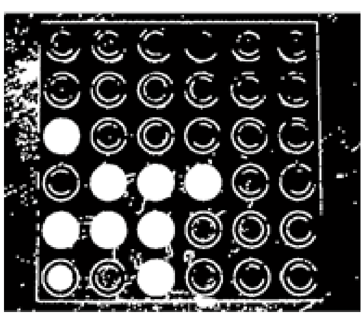


Figure 8 Image with filled 'holes' inside connected components

3.2.4 1st Round Image Filtering

This process has been implemented to remove all objects that are connected to the edge, in which these noises could cause problems for the tactile detection in the image. Furthermore, pixels that are connected to the edge are more than likely be useless in gaining any information that is required, therefore removing them would work as filtering. Figure 9 shows the image with cleared border.

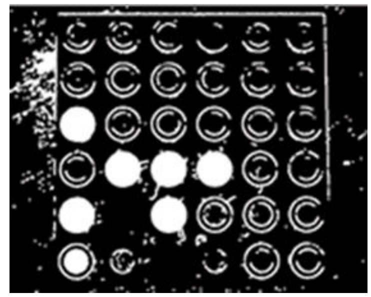


Figure 9 1st round filtered image

3.2.5 2nd Round Image Filtering

As it is shown in Figure 8, there are still far too many noises in presence in the image, even after the 1st round of image filtering. Therefore, another method has been implemented to filter the image off the noises even more. This method is to set a threshold value for the pixel size, and anything that has a pixel value below the threshold value, it will be removed. Figure 10 shows the image after it has removed all components that have pixel value less than 1000 $pixel^2$.

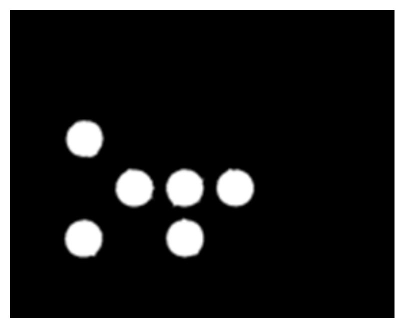


Figure 10 2nd round filtered image

3.3 Extract Required Parameters from Connected Components

In this phase, after the image is done filtered by the pre-processing process, some parameters are required from the connected pixels/components that are left. The parameters required by the tactile detection algorithm are area and perimeter of the left image. A function in MATLAB will be used to determine these required parameters. Figure 11 shows the pieces of area which is recognised and each of the parameters found by the function on the connected pixels is shown in Tables 1 to 6.

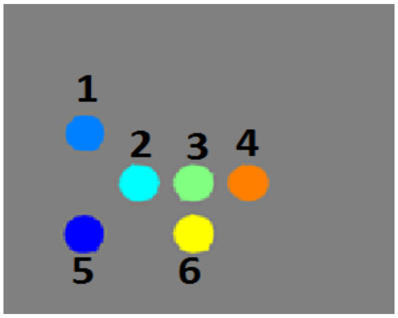


Figure 11 Parameters (area, perimeter, centroid) of the connected pixels

Table 1 Parameter for no.1

Area	1919
Centroid	[146.1730,176.4815]
Perimeter	163.7317

Table 2 Parameter for no.2

Area	1980
Centroid	[213.070,242.8086]
Perimeter	173.8234

Table 3 Parameter for no.3

Area	1988
Centroid	[280.6459,242.7938]
Perimeter	177.6812

Table 4 Parameter for no.4

Area	1951
Centroid	[348.2952,242.4567]
Perimeter	165.6812

Table 5 Parameter for no.5

Area	1984
Centroid	[144.9057,311.9995]
Perimeter	170.6102

Table 6 Parameter for no.6

Area	1993
Centroid	[280.9910,310.4752]
Perimeter	173.0955

3.4 Determining the Metric

This phase will be the main part that will decided whether the connected components/pixels in the image are a potential image containing tactile or not. The metric is determined by using the Equation 1.

$$m = \frac{4\pi A}{r^2} \qquad \text{(Eq. 1)}$$

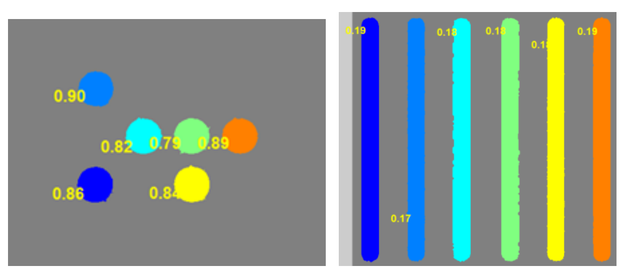
where, m indicates for metric, A indicates for area and p indicates for perimeter. Therefore, it is important to obtain the required parameters, which is area and perimeter of the connected pixels before this phase. MATLAB will calculate the metric from the parameters obtained earlier using the Eq. 1. Table 7 shows the result of the metrics of the connected components/pixels.

Table 7 Calculation results of metric for each area

Area	1	2	3	4	5	6
Metric	0.899	0.823	0.791	0.893	0.857	0.836

3.5 Producing Auditory Output based on Metric

After the metric for each connected component/pixels has been calculated, the 'shape' for each will be determined. An analysis has been done, which will be shown in the Section 4. In the results, it has proved that the connected pixels which has metric value in the range of 0.85 – 1.0 will most likely be a circle, representing the warning tactile. In contrast, the connected pixels that has metric value in the range of 0.15 – 0.30 will most likely be a bar, which represents the directional tactile. Figures 12(a) and 12(b) shows the metric results of warning tactile image and directional tactile image. After the result of metric values have been calculated, the system will then send a signal to the auditory output system, and notify the blind person about what have been detected.



(a) Warning tactile (b) Directional tactile

Figure 12 Final image results

Figure 13 shows the overall system hardware process flow for the auditory output. In this case, when the warning tactile has been detected (metric value in range from 0.85 – 1.0) in MATLAB, MATLAB will send a signal to the voice module to have an auditory output saying 'WARNING' via Arduino UNO. And if the directional tactile has been detected (metric value in range from 0.15 – 0.30), the auditory output would be 'DIRECTION'. Prior to sending signal to the voice module from MATLAB via Arduino, a serial communication between MATLAB and Arduino must first be made. After the serial communication has established, then only will Arduino be able to receive any signals from MATLAB when the command is being given to MATLAB.

For this project, after the metric has been determined, a certain signal will be send to the Arduino UNO, where coding are already uploaded to the Arduino UNO board before hand through the Arduino IO interface. There are three cases, where the metric values are of range 0.15 to 0.30, 0.85 to 1.0 and all the other metric range out of the two before. For example, when the metric values of range 0.15 to 0.30 are found, MATLAB will send a signal 'a' indicates 'DIRECTION', and Arduino UNO will receive it, and execute the next command. It is the same for two other cases, where 'b' will be sent if metric values of range 0.85 to 1.0 indicates 'WARNING' are found and 'c' will be sent if none of this two metric range are determined.

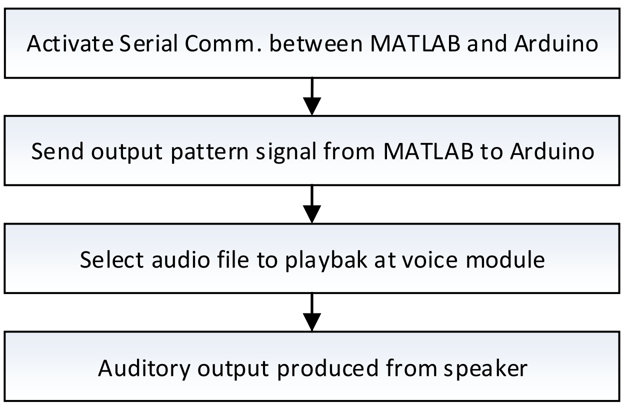
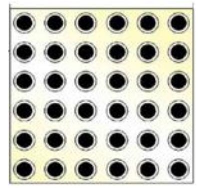
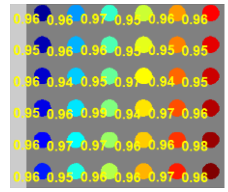
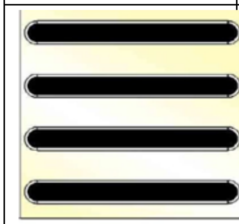
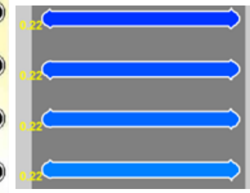
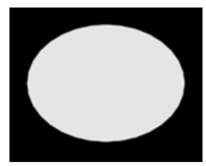
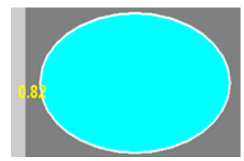
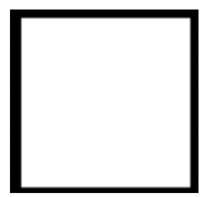
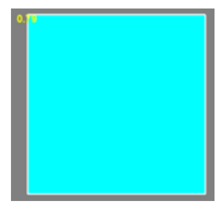
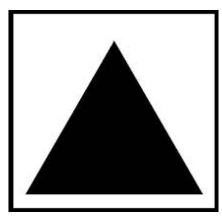
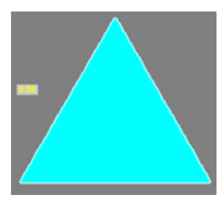
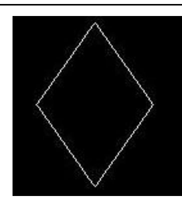
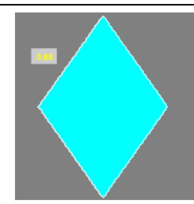


Figure 13 System hardware flowchart

4.0 RESULTS AND DISCUSSION

In order to validate the effectiveness of developed vision based tactile detection method, an experiment is conducted to recognize variety of shape by using the proposed tactile paving detection method. In this experiment, the proposed tactile paving detection method will be used to compare six different shapes such as circle, bar, eclipse, square, triangle and diamond. Some shapes have been captured through web camera and also downloaded from internet. A metric calculation will be used to detect the shapes. The metric in the coding works by calculating any connected component's area and perimeter in a binary image after preprocessing, and then compute it using Eq. 1. After the metric has worked on the connected components, it will give a certain range of values for different shapes detected. Table 8 shows the detection results of variety of shapes by using proposed tactile detection algorithm.

Table 8 Detection results of variety shapes

Tactile image	Detection	Result
		Circle (0.9-1.0)
		Bar (0.15-0.3)
		Eclipse (0.82)
		Square (0.79)
		Triangle (0.58)
		Diamond (0.68)

From Table 8 results, the rage of the metric value for each shape is confirmed by using the vision based tactile detection algorithm. These metric values will be a benchmark value for each shape in order to differentiate the image shape. However, there are some shapes which are having similar metric values such as circle, eclipse and square. These analysis results will be used to improvise the current detection algorithm, making the system better and more robust to different types of detection environment of the tactile paving.

5.0 CONCLUSION

In this paper, the performance of a developed vision base tactile detection algorithm which was used to recognize the shape of tactile pavement for navigation purpose was evaluated. The vision based tactile detection algorithm was proposed and the experimental study on effectiveness of the detection algorithm by using five phase of process which are load image, preprocessing, parameters extraction, metric calculation and auditory output was conducted. The proposed vision based tactile paving detection system was also confirmed to be functioned in order to differentiate variety types of shape such as circle, bar, eclipse, square, triangle and diamond. All the metric values could be suggested as benchmark metric values for next step of development of blind navigation system.

In the future, this system can be improved and developed into a system that could handle the uncertainty that occurs in the natural world, for example, the shadow and illumination case that has always affected the result of many system using image processing algorithms. Furthermore, obstacle detection can also be implemented as it has proven to be an effective tool in aiding the blind people too. If possible, the output can both be in auditory and tactile display, which will display the Braille code, which is the international language for the blind. Portability is important for high mobility, therefore the computer system can be replaced with FPGA (Field-Programmable Gate Array) or DSP (Digital Signal Processor) to enable the entire system to be portable.

Acknowledgement

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