A Low Cost Artificial Vision System for Visually Impaired People

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***Abstract*—A cheap guidance system based on AT89C52 microcontroller is developed for facilitating visually impaired people. Ultrasonic sensors are used to calculate distance of the obstacles around the blind person to guide the user towards the available path. Output is in the form of voice which the blind person can hear e.g., right, left etc. In its advance mode, the system will be able to recognize objects using image processing algorithms. Results are presented to show the validity and performance of the system.**

Keywords-artificial vision;cheap guidance system;visually impaired people;voice output;image processing

I. Introduction

Typical human beings are gifted by the nature with number of senses that make them able to develop a fine perception of the surrounding world. Unfortunately a number of people for different reasons have lost or deprived their visual sense. In any country the number of visually impaired people and those with very low vision are significant. This is an important issue amongst social as well as scientific society to find an adequate solution for this problem. Among the handicapped people, those visually impaired ones are facing more difficulties than others in gathering information. For about 70% information got by human being is through sight. Recent challenges came to the scientific surface with the development of prototype artificial eyes [1], available after 2010. Also, implants for blind people [2, 3, 8] will be available at that time. But these systems will be quite expensive and they will not be affordable by a common person. Though, there are many systems developed to help visually impaired people but the purpose of Artificial Vision System for Blind (AVSB) is to develop such a system which is cheap and easy to use. AVSB's purpose is to help the blind people walk like a normal human being and to identify the objects when it is required. Till now, character recognition is done for object recognition purpose. There are two modes in the system namely WALK mode and CAM mode. In WALK mode, AVSB uses the information acquired with the help of ultrasonic sensors to determine the distance of the obstacle from the user and guide him towards the best possible path thereby avoiding obstacles on the way. CAM mode, in addition to ultrasonic sensors utilizes information from camera for facilitating the blind man in recognizing various objects. In both these modes, user is given information about the path and the object through voice commands. An ear speaker attached to the system makes these voice commands available for the user.

II. Main Parts of System

AVSB contains the following major parts: Microcontroller board, which is the heart of the system and is fed by a 6V battery as a power supply generator, a set of six Ultrasonic Sensors, two EEPROMs, a Digital to Analog Converter, a Vision Camera, a Computer System and an Ear Speaker. The block diagram of the system is shown in Fig. 1 while hardware setup is shown in Fig. 2.

A. Microcontroller

AT89C52 microcontroller is selected as brain of the system because it is low cost and readily available in market. Two such microcontrollers are used. Ultrasonic sensors and computer system are interfaced to microcontroller 1 at ports 1 and 3 respectively while EEPROM is interfaced at ports 0 and 2. Because the voice samples cannot be stored in single EEPROM, another EEPROM is interfaced to second microcontroller at ports 0 and 2. The microcontroller 1 communicates with microcontroller 2 via two bits of port 3.

B. Ultasonic Sensors

Ultrasonic sensors work on a principle similar to radar or sonar which evaluates attributes of a target by interpreting the echoes from radio or sound waves respectively. They generate high frequency sound waves and evaluate the echo which is received back by the sensor. They are used to calculate the time interval between sending the signal and receiving the echo to determine the distance of an object [4]. Four SRF05 sensors are used which are assembled at relative positions on top so as to cover the maximum area in surrounding. These top sensors are assembled on a hat for user's comfort. Another sensor is attached on the belt of the user for detecting ground obstacles.

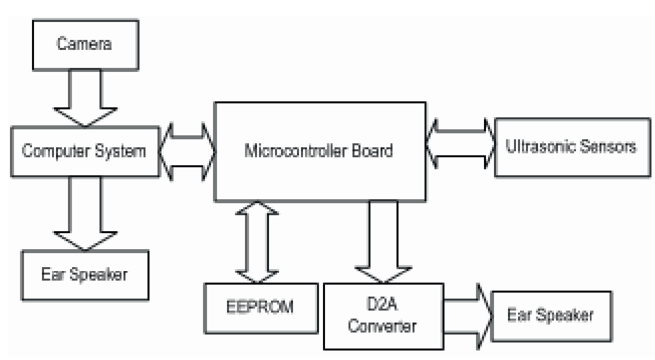

Figure 1. System Block diagram

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Figure 2. Hardware Setup

C. EEPROM

While operating in WALK mode, in order to guide the user, sample values of number of voices such as LEFT, RIGHT, FRONT etc are written on Intel's 28C512 EEPROM (Electrically Erasable Programmable Read Only Memory). The 28C512 is a fast, low power, 5V-only CMOS parallel EEPROM organized as 64K x 8-bits. It requires a simple interface for in-system programming. On-chip address and data latches, self-timed write cycle with auto-clear and VCC power up/down write protection eliminate additional timing and protection hardware [5].

D. Digital to Analog Converter

DAC0808 is used as Digital to Analog converter (D2A) which receives input from EEPROM in digital form, converts it to analog form and then sends to ear speaker.

E. Vision Camera

The vision camera is used to capture image of the surrounding when the user enables CAM mode. It is also mounted on the hat of the user in order to provide a better view of the targeted scene. The camera is high resolution, color, small in size and weight.

F. Portable Computer System

The basic purpose of using a computer system is for object recognition and is not needed in case of walk mode. The cam mode is enabled by a switch available to blind person. The microcontroller then generates an interrupt signal for PC through parallel port. The PC then captures the image with the help of camera and uses image processing algorithms for object recognition.

G. Ear Speaker

AVSB has one ear speaker through which the user receives the description of the surrounding environment.

III. MODES OF OPERATION

AVSB has two modes of operation i.e., walk mode and cam mode. The walk mode is cheap and portable while cam mode is expensive and carries a LAPTOP computer. For the blind man, walk mode is more important than cam mode in order to move safely in real environment. The two modes are discussed separately:

A. WALK Mode

In WALK mode, microcontroller builds a map of environment with the help of ultrasonic sensors and outputs appropriate voice commands to guide the blind man towards hurdle free path.

1) Ultrasonic sensors in function: SRF05 ultrasonic sensors are used for acquiring distance information. The timing diagram of this sensor is shown in Fig. 3 [4]. A short 10uS pulse is applied to the trigger input to start the ranging from controller. The SRF05 sends out an 8 cycle burst of ultrasound at 40 kHz and raise its echo line high (or trigger line). It then listens for an echo, and as soon as it detects one it lowers the echo line again. The echo line is therefore a pulse whose width is proportional to the distance to the object. By timing the pulse the range of a nearby object is calculated. If nothing is detected then the SRF05 will lower its echo line anyway after about 30ms [4]. By calculating the time between the transmission and the reception of the ultrasonic pulse, the distance (d) to the object having reflected the ultrasonic pulse can be calculated as:

$$d=v*t/2 \tag{1}$$

where v = velocity (340m/s) of sound and t = time between the transmission and the reception of ultrasonic pulse.

The range of ultrasonic sensor is set at 2 meter for obstacle detection but it is adjustable. Three sensors are mounted on the head at front side in the form of an assembly. Each sensor covers certain area in the surrounding environment as shown in Fig. 4 [4]. Sensors are positioned accordingly as to cover the maximum area. One sensor is attached on the back of the head whose purpose is to monitor the moving vehicles approaching the blind person from behind. Another sensor is attached to belt for detecting ground obstacles.

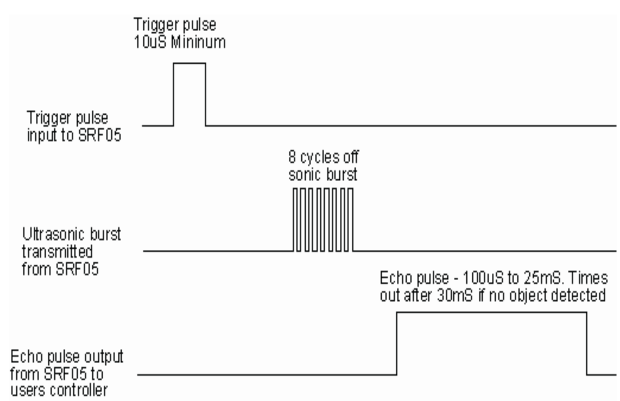

Figure 3. SRF05 Timing Diagram

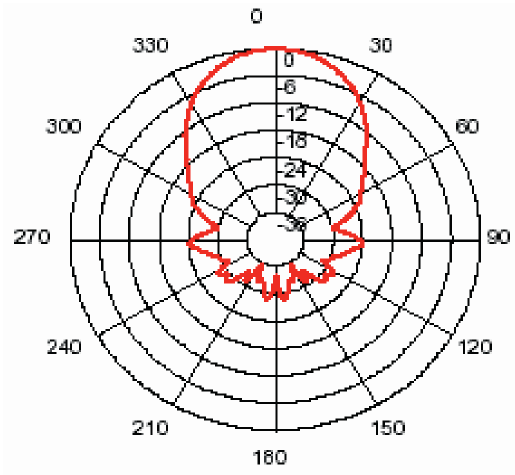

Figure 4. Beam Pattern of SRF05

2) *EEPROM in function:* By using Data Acquisition Toolbox of MATLAB® [6] number of voices are recorded at 8kbps and there sample values are taken. Sample values of voice LEFT are shown in Fig. 5. In this figure sample numbers are taken on x-axis and sample values on y-axis. These sample values are converted in D2A acceptable form by adding a threshold of unity and multiplying with a factor of 128 as shown in table 1. These samples are stored in EEPROM with the help of Super-Pro universal programmer. In the required condition, required sample values are retrieved by controller from their respective addresses and sent to ear speaker through DAC0808.

3) *D2A in function:* Algorithm for AVSB estimates the required voice according to the actual environmental conditions which is then played through ear speaker after conversion into analog form with the help of D2A.

4) *Voice commands via ear speaker:* Fig. 6 shows the five possible conditions that can arise in actual environment. Following voice commands are produced on the required condition to guide the blind man.

a) FRONT: When certain obstacle comes in the range of F sensor than the user will be given a caution, FRONT as shown in Fig. 6(a), so that he can take the right or left turn alternatively.

b) LEFT: If any obstacle comes in the range of F and R sensor simultaneously than the user is given a command, LEFT by ear speaker, shown in Fig. 6(b) so he may follow the path towards left.

c) RIGHT: If any obstacle comes in the range of F and L sensor simultaneously than the user is given a command, RIGHT by ear speaker, so he may follow the path towards right, shown in Fig. 6(c).

d) TURN: When all of the three sensors F, R and L are encountered by obstacles e.g., a wall comes in front of the user then the user will be given a command, TURN shown in Fig. 6(d).

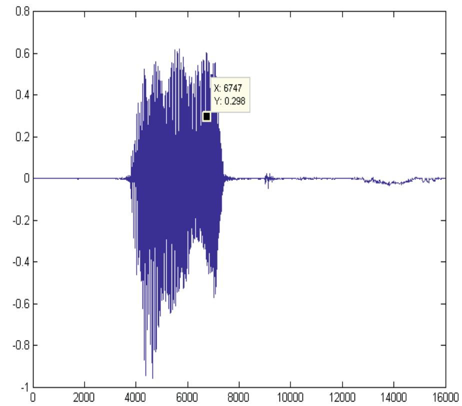

Figure 5. LEFT Voice Spectrum

TABLE I
SAMPLE VALAUES OF VOICE "LEFT"

Extracted from MATLAB	Setting threshold	Converted to digital value
(X)	**(X+1)**	**(X+1)x128**
0.1908	1.1908	152.4224
0.1074	1.1074	141.7472
-0.0259	0.9741	124.6848
-0.1105	0.8895	113.8560
-0.0809	0.9191	117.6448
0.0927	1.0927	139.8656
0.5078	1.5078	192.9984
0.5126	1.5126	193.6128
0.2043	1.2043	154.1504
-0.2096	0.7904	101.1712

e) BACK: The function of the ultrasonic sensor B mounted on the back is to notify any obstacle that may come from the back and to make user aware of anything moving towards him that can harm him. The user is given a caution, BACK when it happens, shown in Fig. 6(e) so that he may move or change his position.

f) DOWN: When the sensor attached on the belt of the user detects hurdle, shown in Fig. 6(f), voice command, DOWN is generated.

g) DIG: Voice command, DIG is given to user in case belt sensor detects a dig on the way as shown in Fig. 6(g).

5) *Algorithm:* WALK mode algorithm is simple and implemented in C language using Keil software. As long as WALK mode is switched on; sensors F, R, L, B and G keep on finding obstacle and user is being guided towards available path, when CAM mode is switched on control is transferred to LAPTOP for object recognition. The complete algorithm for this mode is described below while flow chart is shown in Fig. 7.

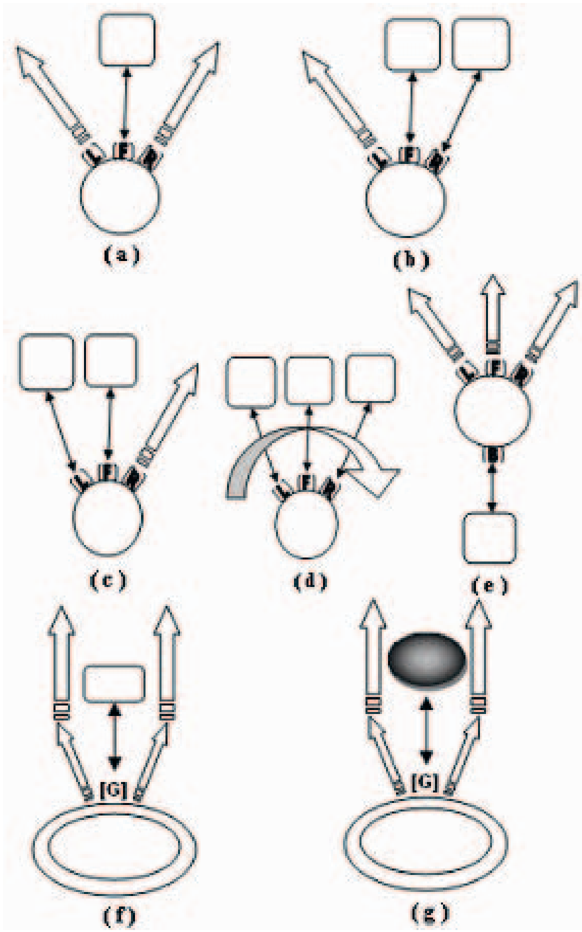

Figure 6. Possible Conditions

```
while True
    do
      if walkmode is on
              if F sensor detects hurdle
                          then speak FRONT
              if F and R sensors detect hurdle
                          then speak LEFT
              if F and L sensors detect hurdle
                          then speak RIGHT
              if F,R and L sensors detect hurdle
                          then speak TURN
              if B sensor detects hurdle
                          then speak BACK
              if G sensor detects hurdle
                          then speak DOWN
              if G sensor detects dig
                          then speak DIG
      else
                call object_recognition( )
```

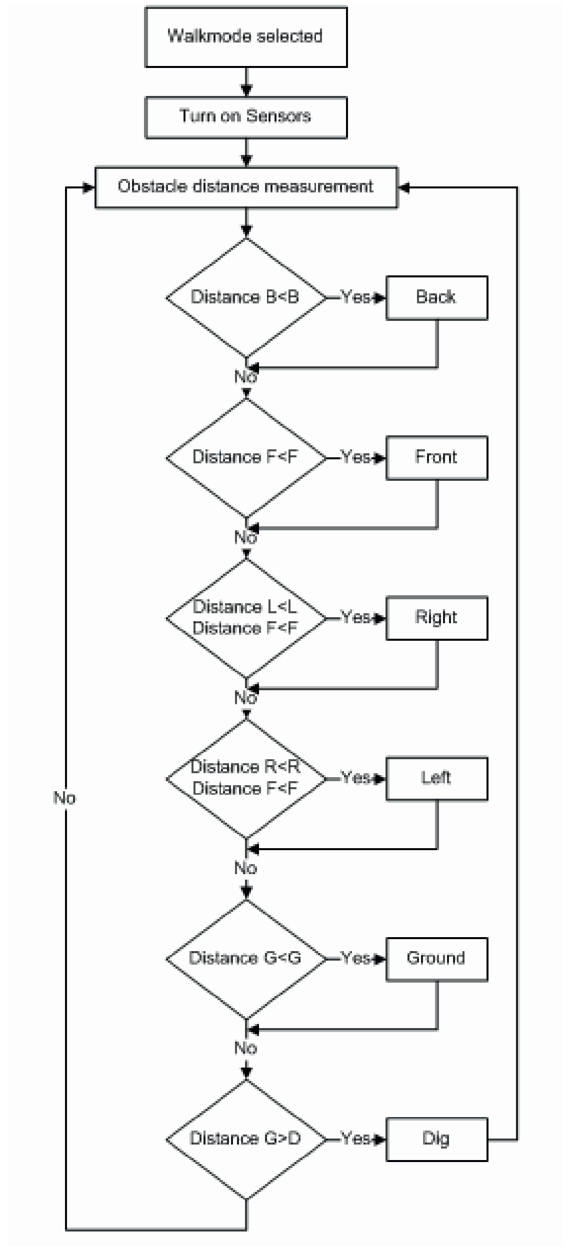

Figure 7. Flow Chart for WALK Mode

B. CAM Mode

CAM mode is developed to help blind person in recognizing objects and text. Recognition of numbers and characters are done till now. Processing on the image taken of a car name plate, shown in Fig. 8, is described below. When user switches the CAM mode ON, control is transferred to computer system where code is developed in MATLAB®. Image acquisition and image processing toolboxes of MATLAB® have been used to develop the software [7].

1) Image Acquisition: Image Acquisition Toolbox of MATLAB® is used to acquire images efficiently from the camera. This toolbox provides a variety of convenient functions to acquire images according to the requirements.

2) Image Processing: Image Processing Toolbox of MATLAB® is used to recognize the alphabets and numbers from the image. The processing technique is described below:

a) Conversion to grayscale: The image acquired from the image acquisition is in RGB format which is a 3-dimensional image. It is not advantageous to process it in 3-dimensional format as the majority of MATLAB® functions deal with 2-dimensional images. So RGB image is converted to grayscale which is a 2-dimensional image.

b) Conversion to binary: The gray scale image is converted into binary format i.e. white and black. Binary image is a 2-dimensional image. It has only two values i.e. 0 and 1. '0' represents black and '1' represents white. Now the converted image is in the form of 1's and 0's as shown in Fig. 9.

$$g(x, y) = T\,[\,f(x, y)\,] \tag{2}$$

$$T(r) = \begin{cases} 1 & r \geq m \\ 0 & r < m \end{cases} \tag{3}$$

c) Refining the image: Binary image is refined by bwareopen() function which removes from a binary image all connected components (objects) that have fewer than P pixels. Firstly, this function is applied on the original binary image than on the inverted binary image. Dots and tiny objects are removed from the image by this function. Further imdilate() function is applied on the binary image to make objects broader or large. Major purpose to apply this function is to combine pieces of an object which is captured in broken form. Functioning is shown in Fig. 10.

d) Clipping the image: The converted binary image is clipped to get the area of the image which is useful to us. The clipped image contains only that part which has something written on it. This is the part of the image which is intended to be processed in order to recognize the object. The clipped image is shown in Fig. 11.

e) Labelling the characters: Labeling function of MATLAB® is used to identify the number of objects (characters) in the image. This function gives the number to each object with the last object getting the highest number. This helps to process the image as the total number of characters in the image to be processed are known in advance.

f) Edge detection: Various edge detection methods are available. The Sobel edge detection method, which returns edges at those points where the gradient of image is maximum [9], is used with the following operators [10]:

$$G_x = (z_7 + 2z_8 + z_9) - (z_1 + 2z_2 + z_3) \tag{4}$$

$$G_y = (z_3 + 2z_6 + z_a) - (z_1 + 2z_4 + z_7) \tag{5}$$

Figure 8. Image of Car's name plate

Figure 9. Binary image

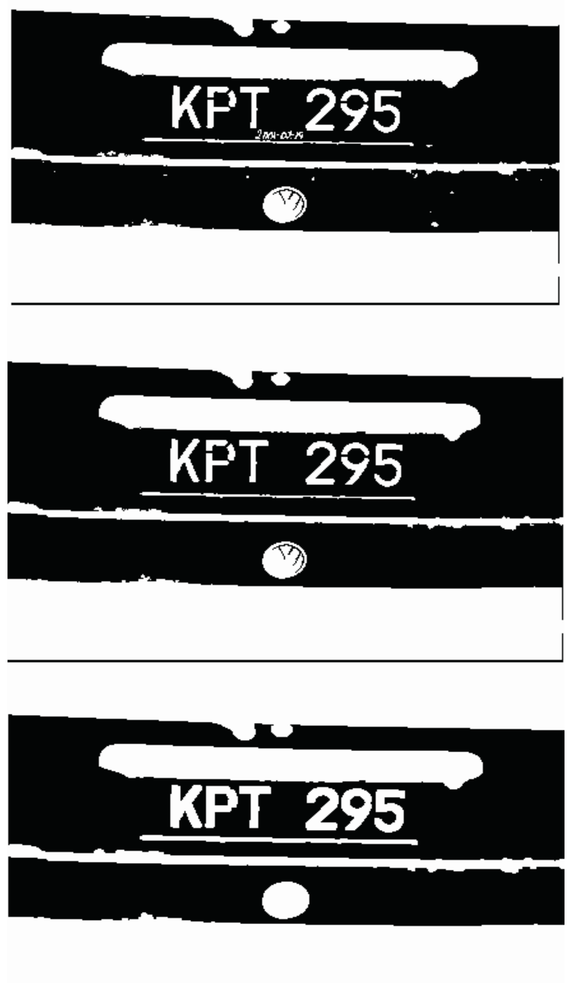

Figure 10. Refining of Image

Figure 11. Clipped image

g) Seperating the characters: After labeling the characters, they can be dealt separately.

h) Character recognition and Information via ear speaker: In order to recognize the characters, cross correlation function is employed [10]:

$$f(x, y) \circ h(x, y) = 1/MN\left(\sum_{m=0}^{M}\sum_{n=0}^{N} f(m, n)\, h(x+m, y+n)\right) \tag{6}$$

The correlation is performed with the sample images present in the database and the result is saved for further implementation. Voices of characters are already stored in database and they are produced after character recognition from ear speaker.

IV. CONCLUSIONS

In this paper, design and development of a low cost artificial vision system for visually impaired people has been discussed. Ultrasonic sensors have been used for environment scanning containing moving and stationary obstacles. Appropriate voice commands are then played by AT89C52 microcontroller stored in EEPROM for guiding the blind people.

V. FUTURE WORK

Future work deals with the improvement and advancement of AVSB. In WALK mode, vibrators can be used instead of voice commands. Because the voice commands can disturb the routinely hearing of blind person, vibrators will be a feasible solution. The blind man can then sense different frequencies corresponding to different environment conditions. In CAM mode, computer system can be replaced with FPGA or DSP processor in order to make the entire system portable. The entire system can also be integrated with GPS to highlight the location of blind person. A mobile phone with GPS software can be used for this purpose. This software will verbally inform the blind man about his location, names of streets and certain buildings through ear speaker and thus will be a useful device for city navigation.

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