Design and Application of BatBot: Distance Measuring and Obstacle Sensing Mobile Robot

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Abstract

This paper revolves around a mobile robot that can sense its distance from a certain obstacle. This project makes use of the PIC16F877A microcontroller for it to function. The read length measurement is programmed to exhibit continuously onto a liquid crystal display (LCD). The movement of the robot's motor is controlled by the use of a L293D integrated circuit. The mobile robot (MOBOT) embedded system's overall purpose is similar and could be compared to a bat's echolocation skills.

***Keywords* — Microcontroller, MOBOT, ultrasonic sensor, PWM, echolocation**

I. INTRODUCTION

The general idea of creating a "BatBot" is derived and inspired by the echolocation skills of the webbed wings mammals that are the bats. According to Merriam-Webster, echolocation is a process of locating objects by sound waves reflected to the emitter from the objects [1]. Figure 1 shows how echolocation works. To show a comparison, echolocation works in a similar way to a sonar. For bats, echolocation is very important. It is crucial to a bat's survival since they use it for hunting their prey in the dark [2]. They also use it to navigate while flying and to avoid crashing into any upcoming obstacle that may be blocking their path. This is done by the bats by emitting high frequency signals. For humans, these frequencies are too high to hear since the hearing range for humans is 20 Hz to 20,000 Hz [3].

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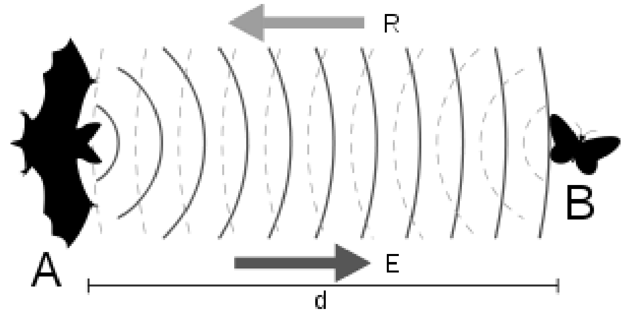

Fig 1. A bat using echolocation to detect animals and objects [4]

The future is here and is fast improving and it is noticeable in the world of robotics. In unpublished work written by Khanal (2014), he defines robotics as "the branch of technology that deals with the design, construction, operation, and application of robots." [11] One variation of the robot invention that showcases the enhanced skills and knowledge of human beings is the MOBOT or mobile robot. Robotics engineers are those who study, design, and find ways to further develop the uses of robots and widen their capabilities to help mankind. A robot in motion is already a big help in various applications needed in the industry of manufacturing, agriculture, aerospace, mining, and medicine. These may be jobs that the robots can do that humans cannot such as those that may cause danger or cannot be easily accessed by the human body and thus people would resort to small-sized machines.

Mobile robots cannot simply work on their own. It needs a brain or a set of instruction in order to work. This could be done by programming the robot. The robotics engineer is in charge of designing the process and writing the lines of code that would be read in a sequential manner understood by the robot. [12] A certain programming language must be used as well as a microcontroller. A robot basically operates by the manipulation of a program. The output of the robot and how it'll work would depend on the skill of the robotics engineer.

The two (2) main parts of a robot and its operation are the hardware and software element. The robot itself and its chassis are basically the hardware component. As for the software component, a specifically designed code is needed. As mentioned earlier, a microcontroller is a vital instrument for the programming of a robot's function. The integration of the software application and hardware operation is called an embedded system. [11] If we compare the system to the human being, the hardware component could be considered as the body of the person and the software being the brain. In mechanical terms, the hardware would consist of the microcontrollers and microprocessors and other solid components while the software comprises of the programming language to operate the hardware the way it is coded.

A distance sensor works the same way bats use sound waves in order to navigate their way through obstacles since they are known as nocturnal animals. The mammals release sounds of high frequency that eventually bounce back when there is a block in the path. These returned signals are heard by the animal and serve as a sign for them to change direction so as to not to collide with what may be in the way. The ultrasonic distance sensor performs similarly. Although it may not be heard by the human ear, a high frequency sound is also being emitted by one of the sensors of the device that triggers the sound waves. Furthermore, the other sensor receives the echo of the sound wave that is bounced back. The distance can be determined by measuring the time it takes for the sound waves to return [13]. In a study that focuses on the distance measurement of robotics mentions one strategy of knowing the length between two points called the Time-Difference-of-Arrival (TDOA) [14]. The method makes use of two (2) different varieties of signals which are commonly the radio and acoustic. This technique considers the two following factors which are the distance and speed. Another way to measure distance is with the use of infrared (IR) sensors. In comparison to the ultrasonic sensor, this kind of device uses light which travels much faster than sound waves. The distance is measured through the parameter which is the intensity of the light. A similar study uses advanced techniques to further widen the use of a distance measuring robot. The project done by Saint-Raymond (2012) mainly focuses on the obstacle avoiding characteristic of the robot. [15] As mentioned earlier, the ultrasonic sensor transmits sound waves and receives them in order to know if there is a certain wall or object blocking its path. This particular study concentrates on the direction changing capabilities of the MOBOT as it integrates the use of omni-directional wheels that offer easier rotation of the robot.

The main objective of this study is to design and apply the mobile robot in distance measuring and obstacle detection.

The robot also has its own significance to the real world. The fact that these robots could be made into any size such as a portable type, it can be used for jobs that are impossible and risky for the human body to do. One example is reaching into tight enclosures. A robot can be controlled to navigate its way towards a specific path whilst avoiding obstacles. Moreover, devices other than the ultrasonic sensor can be used and integrated onto the robot for it to perform more complex and highly technical tasks.

II. Methodology

The goal of "BatBot" to measure how far it is from a solid object. The measurement was done by integrating an ultrasonic sensor that can transmit and receive sound waves as shown in Figure 2. These sound waves are inaudible to the human ear. After transmitting and receiving the reflected sound waves, or echoing, that bounces off a solid object, the "BatBot" would then be able to calculate the distance in between the object and itself and display the measured distance through the LCD output display [5]. The integration of the ability of a bat to sense an obstruction onto the design project basically implies and stresses how this kind of operation can be done mechanically and electronically with the help of a PIC microcontroller.

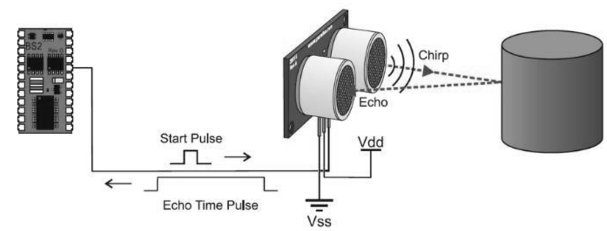

Fig 2. Working Principle of an Ultrasonic Sensor in a Batbot [6]

B. Hardware Design

The device made use of the PIC16F877A microcontroller which is considered as the brain of the BatBot. It is the main component that houses the instructions of the mobile robot in the form of a highly descriptive code. The code was programmed and designed in a way that it would control the whole movement and the operations of the individual components. A quadruple half-H driver L293D IC was used to operate the motors of the mobile robot. A Liquid Crystal Display (LCD) was also used to monitor the output. The component that completes the whole robot is the ultrasonic sensor. Other than the main components, the circuit design consists of a crystal oscillator, capacitors, resistors, and a push button. To refrain from encountering errors in the final design, the components were first connected and properly placed in a breadboard. All these materials each had their own significance in the process of implementing the MOBOT.

C. Microcontroller

The PIC16F877 is a powerful CMOS FLASH-based 8-bit microcontroller. It has 40 pins that are inclusive of input and output pins and each pin has its own importance and designated function. This device was used for its feature that is it being easy to program due to the fact that it only 35 single word instructions. It was basically used in the project to stock the important instructions that would control the movement of the robot and its individual components. It was chosen because it is ideal for automotive applications and real-time monitoring. The PIC16F877 could also be considered to be an extremely fragile material as it can easily malfunction when connected to a circuit with shorts or errors. [7]

D. Pulse-Width Modulation

The PWM or pulse-width modulation circuit connection plays a vital role in the MOBOT's operation. A single L293D integrated circuit or quadruple half-H driver was used for its ability to conduct the pulse-width modulation needed to control the high current demanding DC motor's speed and direction whether to drive it in clockwise or counterclockwise. For the BatBot's purpose, it turns towards the right whenever it senses an obstacle in its path. Table 1 shows the motion to be done by the robot with the corresponding wheel rotation.

Table I.
MOVEMENT OF THE ROBOT WITH CORRESPONDING MOTION OF THE WHEELS

Motion	Left Wheel	Right Wheel
Forward	Counterclockwise	Clockwise
Backward	Clockwise	Counterclockwise
Right	Counterclockwise	Counterclockwise

E. Liquid Crystal Display (LCD)

The LCD goes hand in hand with the ultrasonic sensor. Without the sensor, it would be of no use as there would be no read distance measurements to display. The LCD is activated by electric current passing through its liquid crystal components. [8] The kind of LCD that was used for the robot is a two-liner which shows the distance label in the first row then the length value in centimeters on the second row.

F. Ultrasonic Sensor

The HSR04 Ultrasonic Distance Sensor used is the ideal sensing device for distance measurement that requires no contact with the object. It measures the distance in centimeters which is just right for its application to the robot. It is inclusive of four (4) pins which are VCC, TRIG, ECHO, and GND. The VCC and GND are to be connected to the positive and negative ends of the power supply, respectively. As for the Trigger and Echo pin, they were connected to the microcontroller at Port B in order to receive and transmit instructions and data. The 2 sensors seen on the front of the device serve as the transmitter and receiver. One acts like a speaker by transmitting ultrasonic waves while the other functions like a microphone as it receives the returned ultrasonic waves. [9]

The ultrasonic sensor measures the distance by using a specific mathematical formula which is:

$$D = {}^{(time)(speed\ of\ sound)} / 2 \tag{1}$$

It is the transmitted and received sound pulse that defines the distance measured.

G. Power Supply

These two voltage sources have the measurements of 5 volts (V) and 9 volts. One is connected to the Vss pin of the PIC16F877A microcontroller while the other is provides power to the Vs pin at the L293D driver. The reason why two (2) power sources were used is because a 5 V source doesn't exceed the maximum input voltage of the fragile microcontroller and therefore could be directly connected to it but it is not enough to power the motors at an appropriate speed. On the other hand, the 9V power supply exceeds the PIC16F877A's maximum input voltage of 6V which would cause the destruction of the integrated circuit and would lead it to malfunction; however, the measurement is just right for the motors to move smoothly at pulse-width modulation circuit when directly connected to the L293D driver.

H. Rolling Chassis

The chassis or the underpart of the MOBOT consists of the frame of the robot and the wheels. It acts as the base where all the components are attached. This includes the printed circuit board, the gears, and the ultrasonic distance sensor. The body of the robot is designed in a way that it would resemble a bat complete with the wings, ears, and tail. The two sensors at the front would be considered as the bat's eyes.

I. Program

The distance measuring and obstacle sensing MOBOT was able to function by following a list of instructions which was executed using the C programming language. The MikroC compiler program was where the code was written.

The code follows the motion of needed to do by the robot with the corresponding wheel rotation as stated in Table 1.

The other two remaining components require their own list of commands because they differ in output, yet they still work together to function the MOBOT as a whole. The element that bring these two together is the distance measured output the code consists of directions for the LCD output and another set of information for the motor output.

The code starts off with the initialization of the LCD module connections with the PIC's Port D. Once that is done, another initialization should be set as a default and this is the distance measured as an integer. Before the main part of the program, an interrupt function is first called to make sure that PORTB is the On-Change Interrupt. If it is, it will be disabled in order to start the timer if the ECHO input in the ultrasonic sensor is high. If the input is low, the timer should stop and calculate the distance using the initial values of the timer at high and low. [10]

The ultrasonic sensor has the capability of sensing a distance of up to 400 centimeters (cm). As soon as the sensor reads a value in between 2 cm to 400 cm, another output is displayed onto the LCD. This would say "Distance: cm". A space is left in the middle of the two words for the display value.

A series of IF, ELSE, and ELSE IF commands are used in order for the BatBot to know which direction it should go. The first condition is that if the MOBOT approaches an obstacle that is in the range of 6 cm to 16 cm from it, it turns its left motor counterclockwise as well as its right motor. This changes the direction of the robot to turn to the right. This is accompanied by an LCD output which states "Turning Right…" If the first condition is not satisfied, the robot moves on to the next which is the distance of a nearing obstacle is less than 6 cm, the MOBOT is programmed to back up. The left motor would now turn clockwise while the right motor is moving counterclockwise and the LCD displays the phrase, "Backing up". The program code ends with the default condition which is for the MOBOT to move forward with the left motor rotating counterclockwise while the right motor rotates clockwise. The default output on the LCD is "Straight Ahead!"

IV. Results and Discussions

Table 2 shows the result of the experiment conducted on the obstacle detection of the prototype. Ten (10) obstacles were placed in the path. The MOBOT can detect the obstacle using the echolocation technique. It can be observed also that the robot can perfectly detect the obstacle in its path.

Table II.
Obstacle Detection

Obstacle No.	Expected	Actual
1	Detected	Detected
2	Detected	Detected
3	Detected	Detected
4	Detected	Detected
5	Detected	Detected
6	Detected	Detected
7	Detected	Detected
8	Detected	Detected
9	Detected	Detected
10	Detected	Detected

Moreover, the distance measuring capability of the prototype was tested. The obstacles were placed in unequal distances. The MOBOT has able to identify the distance of the each obstacle. Table 3 shows the summary of the results of distance measurement of the MOBOT.

Table III.
Distance Measurement

Obstacle		Expected Distance (in.)	Actual Distance (in.)
1	2	6	5.94
2	3	14	14.05
3	4	23	22.67
4	5	17	17
5	6	8	8.33
6	7	20	21.01
7	8	22	22
8	9	12	12.20
9	10	9	8.89
10	11	11	10.99

It can be observed that the design MOBOT based on the Batbot characteristics is a successful study. It was able to perform the target objectives of this study.

IV. CONCLUSION

Based on the results, the designed robot was able to achieve its goal. It was accomplished with the help of the PIC16F877A microcontroller to house the code instructions, the L293D to complete the pulse width modulation circuit that controls the motors, the H-SR04 Ultrasonic Sensor that transmits and receives signals to measure the distance, and the Liquid Crystal Display or LCD that exhibits the final outputs needed in this project. Along with the intricately designed and programmed code, the MOBOT was able to function the way it was expected to and is therefore considered a successfully accomplished task performed.

REFERENCES

[1] Echolocation. (n.d.) In Merriam-Webster's collegiate dictionary.

[2] Retrieved from http://www.merriam-webster.com/dictionary/echolocation

[3] "Echolocation." Internet: http://pages/ echolocation.html, 2016 [February 23, 2016].

[4] Tom Harris. "How Bats Work." Internet: http://animals.howstuffworks. com/mammals/bat2.htm, June 1, 2001 [February 23, 2016].

[5] "Engineering Acoustics/Echolocation in Bats and Dolphins." Internet: https://en.wikibooks.org/wiki/Engineering_Acoustics/Echolocation_in_ Bats_and_Dolphins, June 26, 2015 [February 23, 2016].

[6] "Robot Obstacle Detection and Avoidance with the Devantech SRF05 Ultrasonic Range Finder." Internet: http://picaxe.hobbizine.com/srf05.html, [February 23, 2016].

[7] Bang Bot. "Arduino Sensors." Internet: http://arduinosensors.com/index.php/arduino-ultrasonic-distance-sensor/, May 1, 2014 [February 23, 2016].

[8] "PIC16F877." Internet: http://www.microchip.com/wwwproducts/en/PIC16F877, 2016 [April 8, 2016].

[9] "Liquid Crystal Dispay (LCD)." Internet: http://www.madehow.com/Volume-1/Liquid-Crystal-Display-LCD.html, 2016 [April 8, 2016].

[10] "Ultrasonic Distance Sensor." Internet: http://arduinoinfo.wikispaces.com/Ultrasonic+Distance+Sensor/, 2014 [April 8, 2016].

[11] Ligo George. "Interfacing HC-SR04 Ultrasonic Sensor with PIC Microcontroller." Internet: https://electrosome.com/hc-sr04-ultrasonicsensor-pic/, (n.d.) [April 8, 2016].

[12] Lok Prasad Khanal. "Obstacle-Avoiding Robot." Information Technology, Turku University of Applied Sciences, Finland, 2013.

[13] "Distance Sensor." Internet: http://www.vexrobotics.com/2283011.html, 2016 [April 8, 2016].

[14] "Mobile Robotics." Internet: https://www.worldskills.org/what/career/skills-explained/manufacturingand-engineering-technology/mobile-robotics/, 2016 [April 8, 2016].

[15] Mihai V. Micea, Andrei Stancovici and Sînziana Indreica (2011). Distance Measurement for Indoor Robotic Collectives, Mobile Robots - Control Architectures, Bio-Interfacing, Navigation, Multi Robot Motion Planning and Operator Training, Dr. Janusz Będkowski (Ed.), ISBN: 978-953-307-842-7, InTech, Available from: http://www.intechopen.com/books/mobile-robots-control-architecturesbio-interfacing-navigation-multi-robotmotion-planning-and-operatortraining/distance-measurement-for-indoor-robotic-collectives

[16] Louis Saint-Raymond. "Building of a mobile robot: Sensing or Moving, Time and Energy." Simon Fraser University, Canada, 2012.