Comparative Study of Obstacle Distance Measurement with Ultrasonic Sensor using Internet of Things Development Boards

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Abstract— Navigational systems are becoming more challenging as the detection of obstacles ahead is to be predicted in advance with greater accuracy to take corrective actions. This becomes even more challenging in the case of unmanned aerial vehicles. It is the requirement of the day to device a predictive vehicle collision avoidance system in order to safe guard the vehicle from occurrence of fatal accidents. Fortunately, with the emergence of Internet of Things (IoT), detection of object has become much easier. In the present work, one such application of IoT has been taken under considerations in which ultrasonic sensor has been used to measure distance of obstacle using different IoT development boards. The obstacle distance has been measured using Raspberry Pi, Arduino Uno board and ATMEGA 328 controller. Their performance have been compared in terms of the error percentage. The obstacle material for all the measurement has been taken as white paper sheet. It has been observed that the measurement using Raspberry Pi gives lowest error than the Arduino Uno board and AVR ATMEGA 328 controller. The value of error increases with increase in the distance measured.

Keywords— *Internet of Things, ultrasound sensor, obstacle avoidance, distance measurement*

I. INTRODUCTION

The emergence of Internet of Things (IoT) have made decision making capabilities more accurate and has reduced the percentage error in automatic measurement [1]. This has been possible owing to making the things (devices) smart by introducing in them the computing, communicating and sensing capabilities. Now using IoT things can see, hear and talk to each other without any human intervention. In the case of autonomous vehicles, unmanned aerial vehicle, etc. the navigational systems are more challenging as the detection of obstacles ahead is to be predicted in advance with greater accuracy to take corrective actions [2]. It is the requirement of the day to device a predictive vehicle collision avoidance system in order to safe guard the vehicle from occurrence of fatal accidents. The detection of object has become easier due to advancement in technology. In the present work, one such application of IoT has been taken under consideration in which ultrasonic sensor has been used to measure obstacle distance using different development boards [3]. The obstacle distance has been measured using Raspberry Pi, Arduino Uno board and ATMEGA 328 controller. Their performance have been compared in terms of the error percentage. The obvious reason to select these development boards are compactness, low cost, higher efficiency and user popularity. Arduino Uno board has become a common name in the field of robotics and automation [4]. Comparatively Raspberry Pi is costlier than Arduino Uno board, but is much more efficient and versatile and is considered to be a mini computer in itself. When the cost of the project is to be reduced by many fold, then the stand alone controllers are much ahead of the development boards with almost comparable performance parameter. This has been one of the major factor to include AVR ATMEGA 328 controller under the present work. It's per unit cost is much lesser than the other two boards under study [5].

II. ULTRASONIC SENSOR

The ultrasonic sensor shown in Fig. 1 works on the principle of transmitting a 40 KHz signal of 10 μs (micro second) pulse duration from the transmitter unit of the sensor. The transmitted signal has 8 bursts of 10 μs TTL (transistor-transistor logic) signal [6]. It travels toward the obstacle, whose distance is to be measured and the reflected echo (signal) is received back by the receiver unit of the sensor [7].

Figure 1. Ultra-Sonic Sensor HC-SR 04.

The distance to be measured is calculated by the time taken by signal to travel from the transmitter unit to the obstacle and arriving back (echo) at the receiver of the sensor. Since the speed of the signal is approximately 340 m/s, equal to speed of sound, the distance can be calculated from the formula, velocity = distance/time, or distance = velocity x time [8]. The timing diagram of ultrasonic sensor is depicted in Fig. 2.

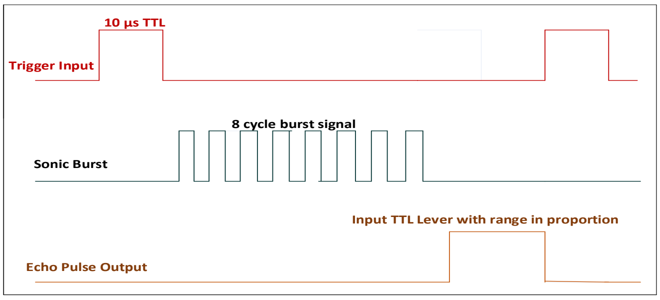

Figure 2. Timing Diagram of Ultra-Sonic Sensor

The calculated distance value has to be further divided by 2 (two), to calculate the one way distance of obstacle from the sensor to the object whose distance has to be measured [9]. In this study HC-SR 04 ultrasonic sensor has been used. It works with 5 volt DC input voltage, 15 mA DC current, at 40 Hz frequency. It can measure minimum distance of 2 cm and maximum distance 4 meter with resolution of 0.3 cm and measuring angle of 15 degree. It generates trigger input signal of 10 µs TTL pulse [10]. The working principle of ultrasonic sensor is shown in Fig. 3.

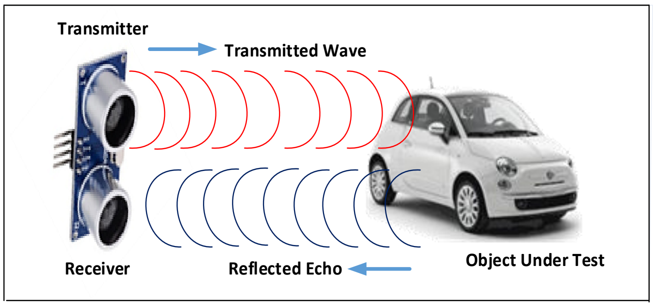

Figure 3. Working Principle of Ultrasonic Sensor

The obstacle material for all the measurement has been taken as white paper sheet [11].

III. LCD DISPLAY UNIT

The distance measured using Arduino Uno board and AVR ATMEGA328 microcontroller have been displayed on RG1602A, 16X2 LCD display unit as depicted in Fig. 4. It is having green back light with 4/8 bit MPU interface and a built-in HD44780 LCD driver [12].

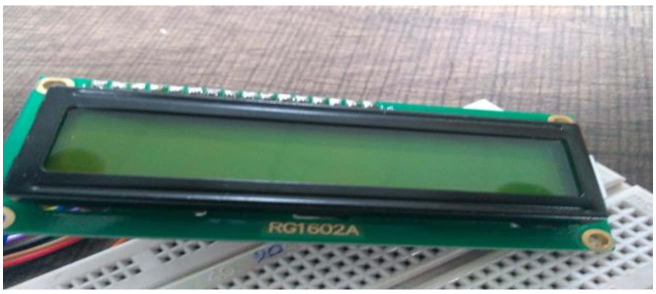

Figure 4. RG1602A, 16X2 LCD display unit

It is a 16 character by 2 line display module and operates with 5 volts DC voltage.

IV. INTERNET OF THINGS DEVELOPMENT BOARDS

There are many development boards available for IoT prototype development which include Arduino Uno, Microduino, Intel Galileo, Intel Edison, Beagle Board, Raspberry Pi, standalone microprocessors and microcontrollers, etc. In this work, we have used Raspberry Pi 3 model B +, Arduino Uno R3 and standalone AVR ATMEGA328 microcontroller for measurement of object distance using ultrasonic HC-SR 04 sensor [13]. The details of the development boards used are explained in the following paragraph.

A. *Raspberry Pi Board*

In this work Raspberry Pi 3 B + model has been used which is shown in the Fig. 5.

Figure 5. Raspberry Pi 3 B + model

It has a 64-bit system on chip (SoC) broadcom BCM2837B0, Cortex–A53 quad core processor with operating frequency of 1.4 GHz. It has 40 pin general purpose input output (GPIO) pins which can be configured through the python programming code for connecting as either input or output pins [14]. It has connectivity to dual band IEEE 802.11.b/g/n/ac wireless LAN in the industrial, scientific and medicine (ISM) band of 2.4 GHz and 5.0 GHz frequency range, Bluetooth 4.2 BLE, and gigabit Ethernet over USB 2.0. It has 1 GB LPDDR2 SDRAM memory unit, it support video and sound through HDMI port and multimedia. For loading operating system and for data storage, we have used 16 GB micro SD card. The input power requirement is 5 volt/ 2.5 amps DC through micro USB connector. Ethernet port is used for connecting to the internet. It works with the Raspbian, an open source operating system which is installed through new out of box software (NOOBS) on the micro SD card [15]. The program codes are written in python for the execution of tasks through the Cortex controller A53 [16].

After inserting the micro SD card and installing the Raspbian software, mouse and keyboard are connected through USB cable [17]. Then the monitor/projector is connected through the HDMI port and Ethernet cable is used to connect it with internet. Finally a micro USB power supply is plugged in to connect it to the power port, a red LED lights up to indicate that power is connected to the board [18].

B. Arduino Uno Board

Arduino Uno R3 Board is one of the most commonly IoT development board used for the development of basic automatic projects in the field of IoT or robotics. It is an open-source platform which is based on the principle of easy to use hardware and software [19]. It works with the suitable Arduino integrated development environment (IDE) software installed in the personal computer/ laptop. The computer codes written in the simple version of C++ are uploaded on the physical board which works in synchronization with Arduino IDE software. It does not require any extra programmer (hardware) in order to upload a new computer code onto the board. All the board functions can be controlled with the help of set of instructions to the microcontroller using the installed (IDE) software [20].

Major essential electronics chips and devices required for small IoT projects are embedded on the printed circuit board itself constituting the development board. In figure 6 Arduino Uno board model R3 is shown in Fig. 6.

Figure 6. Arduino Uno R3 Board

This board uses 8 bit microcontroller, AVR ATmega328, at 16 MHz clock frequency. It has the provision of a USB, power jack, ICSP header and also has one onboard reset button. It requires 5 Volt DC power supply for its operation. It has many general purpose input-output pins including 14 digital input-output pins, 6 analog input pins, 32 KB flash memory, 2 KB SRAM and 1 KB EEPROM [21].

C. The AVR ATMEGA328 Microcontroller

The AVR ATMEGA328 Microcontroller shown in Fig. 7 can be used as a standalone controller for implementation of any IoT project.

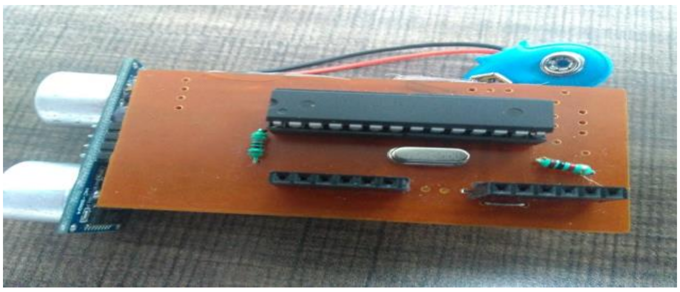

Figure 7. AVR ATMEGA328 Microcontroller

It is a family of high performance 8-bit RISC controller with 32 KB in system programming (ISP) flash memory with having capabilities of read while write [22]. It has 1 KB EEPROM, 2 KB SRAM, 23 GPIO lines and 32 general purpose registers. It has 3 timers, external as well as internal interrupts, serial interface, serial programmable USART, 6 channel, 10-bit Analog to Digital Converter (ADC), SPI serial port and 6 pulse width modulation (PWM) pins. It comes with 28 pin configuration. The controller is designed to operate with 1.8 to 5.5 DC volts with features of software operated power saving modes. The main advantage of this controller are: high performance, cost efficiency, less power requirement, real timer counter with separate oscillator, fully static operation, on chip analog comparator, advanced RISC architecture etc. Because of these features the Arduino Uno development board also uses the AVR ATMEGA328 Microcontroller [23].

V. MEASUREMENT OF OBSTACLE DISTANCE

In the present study obstacle distance has been measured using Raspberry Pi, Arduino Uno board and ATMEGA 328 controller. Their performance have been compared in terms of the error percentage. The obstacle material for all the measurement has been taken as white paper sheet.

A. Obstacle Distance Measurement using Raspberry Pi 3 B+ Board

The laboratory set up for obstacle distance measurement is shown in the Fig. 8.

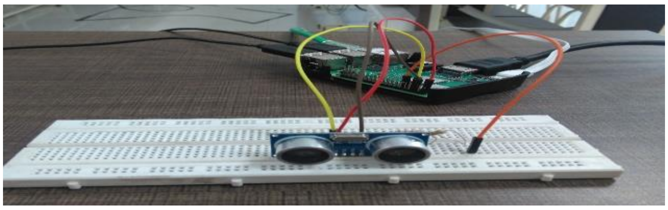

Figure 8. Laboratory setup with Raspberry Pi

After making necessary connections with keyboard, mouse, power supply, monitor, etc. the computer code written in python programming language has been run with Raspbian software installed in the micro SD card inserted in the slot provided in the Raspberry Pi board and measurement has been displayed on projector/monitor [24].

The distance measurement working principle has been explained in the ultrasonic sensor section. The measured distance has been reflected in the table -1. Fig. 9 depicts the computer code and the measured distance displayed on the projector screen.

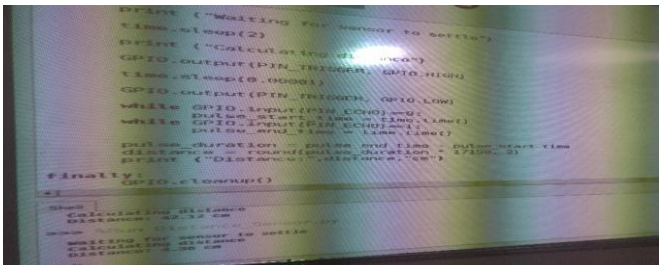

Figure 9. Distance measurement with Python code for Raspberry Pi

B. *Obstacle Distance Measurement using Arduino Uno R3 Board*

The distance measurement using Arduino Uno R3 board is shown in Fig. 10.

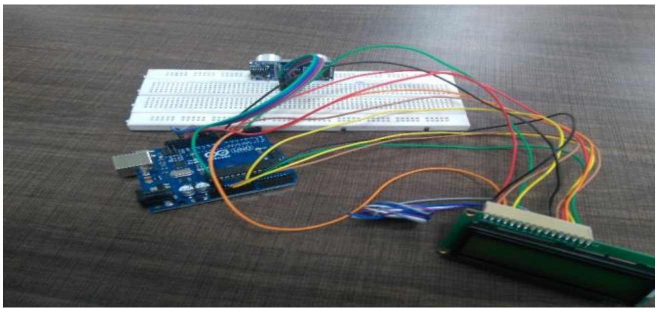

Figure 10. Laboratory setup with Arduino Board

After making the necessary connections the computer code written in C++ programing language has been run in the personal computer installed with suitable Arduino integrated development environment (IDE) software. The distance measured is displayed on the 16X2 LCD display unit. The values obtained are shown in the table - 1.

C. *Obstacle Distance Measurement using AVR ATMEGA 32 Controller*

In order to compare the performance of development boards with a standalone microcontroller, we have used AVR ATMEGA 328 controller [25]. The laboratory setup diagram is shown the Fig. 11.

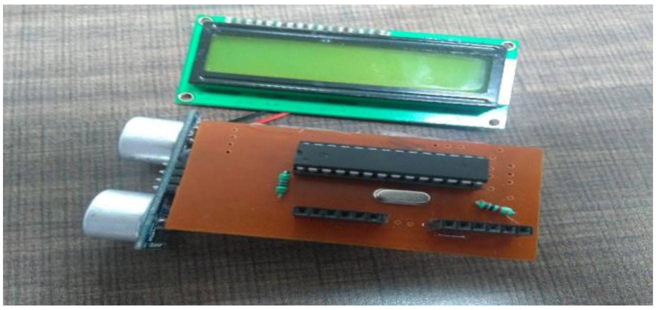

Figure 11. Measurement using AVR Controller

The measured distance has once again been displayed on 16X2 LCD display unit shown in Fig.12 and measured values are reflected in the table -1.

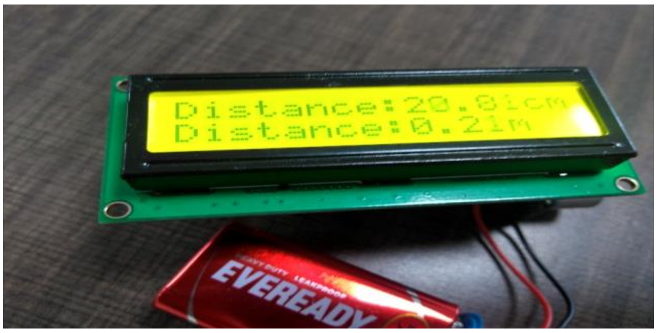

Figure12. Distance Measurement Display on LCD

VI. RESULT AND DISCUSSIONS

The results obtained with three different IoT development boards are shown in Table-1.

TABLE 1. VALUE OF DISTANCE MEASURED

Sl. No.	*Actual Distance (cm)*	**Distance Measured (cm)**		
		Raspberry Pi	***Arduino Uno***	***ATMEGA 328***
1	10	10.02	10.03	10.04
2	12	12.03	12.04	12.05
3	14	14.04	14.05	14.06
4	16	16.06	16.07	16.08
5	18	18.07	18.08	18.10
6	20	20.08	20.10	20.12

From the table-1 it is evident that the measurement using Raspberry Pi gives lowest error than the Arduino Uno board and ATMEGA 328 controller. The value of error increases with increase in distance measured. Similarly Fig.13 depicts the error percentage for all three different boards.

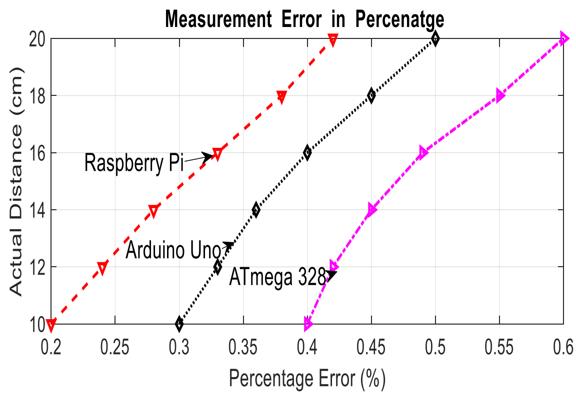

Figure13. Measurement Error in Percentage

It is once again revealed that measurement taken in the case of Raspberry Pi is lowest in terms of percentage than the other two boards used in the study. When response time in the distance measurement is compared among the three development boards, the maximum time is taken by ATMEGA 328 controller and the minimum by Raspberry Pi. The response time of Arduino Uno board is greater than Raspberry Pi but smaller than ATMEGA 328. When the cost of the project is to be reduced by many fold, then the stand alone controllers are much ahead of the development boards with almost comparable performance parameter. This has been one of the factor to include AVR ATMEGA 328 controller under the present work. It's per unit cost is much less than the two boards under study.

VII. CONCLUSIONS

In order to safe guard the vehicle from occurrence of fatal accidents, it has become necessary to device a predictive vehicle collision avoidance system. In the present work, ultrasonic sensor has been used to measure obstacle distance using Raspberry Pi, Arduino Uno board and ATMEGA 328 controller. Their performance have been compared in terms of the error percentage. The results obtained reveals that the obstacle distance measurement using Raspberry Pi gives lowest error than the Arduino Uno board and AVR ATMEGA 328 controller. The obstacle material for all the measurement has been taken as white paper sheet. The value of error increases with increase in obstacle distance measured.

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