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Design and Implementation of a Low-Cost Ultrasonic Radar System using an Arduino Microcontroller

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Abstract:

In this paper, a low-cost ultrasonic radar system based on Arduino microcontroller was developed. It utilizes ultrasonic sensors to detect the object in range and passes the information to the Arduino microcontroller. When an object is detected, two sets of alarms are triggered. Graphical display on a computer screen was used to illustrate this design. The graphical display uses the position of the detected object on the computer screen to send visual alarm on LED (Light Emitting Diode) screen. Sound alarm can also be sent via an audio buzzer. Adjusting the rotation of a servo motor allows the sensor to detect objects in range between $\mathbf{0}$ and $\mathbf{150}^{\circ}$. Objects up to $\mathbf{40}\ \boldsymbol{cm}$ away from the ultrasonic sensor can be detected. The prototype of the design was implemented and coding for Arduino microcontroller was developed. Experimental results show that the system can detect objects with the specified range ($\mathbf{40}\ \boldsymbol{cm}$ away from the ultrasonic sensor) and alarm was successfully triggered.

Keywords **—Low-cost, Ultrasonic radar, Arduino microcontroller, Servo motor**

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I. INTRODUCTION

Radar detection system can be a means for preventing or reducing the rate of accident occurrence on high ways and major roads. Accident and collision of vehicles can be caused by the following; high speed, carelessness, drowsiness, alcohol consumption which are major problem of most drivers. In an automobile (e.g. a car), there is need for the vehicle to be monitored on a regular basis to check for incoming vehicles and objects to avoid collision.

The installation of a low-cost ultrasonic radar detection system in an automobile can prevent and reduce collision or accidents by alarming the driver at a specific distance good enough to avoid the collision. In recent times, as technology advances, radar systems have been efficiently used in traffic control, radar, astronomy, air-defense systems, antimissile systems; marine radars to locate landmarks and other ships; aircraft anti-collision systems, ocean surveillance systems,outer space surveillance and rendezvous system, meteorological precipitation monitoring, altimetry and flight control precipitation monitoring, altimetry and flight control systems, guided missile target locating systems and ground penetrating radar for geological observations. High tech radar systems are associated with digital signal processing and can extract useful information from very high noise levels.

The history ofradar (Radio Detection and Ranging) started with experiments by Heinrich Hertz in the late 19th century that showed that radio waves were reflected by metallic objects. This possibility was suggested in James Clerk Maxwell's seminal work on electromagnetism. However, it was not until the early 20th century that systems able to use these principles were becoming widely available, and it was German inventor Christian Hülsmeyer who first used them to build a simple ship detection device intended to help avoid collisions in fog. Numerous similar systems, which provided directional information to objects over short ranges, were developed over the next two decades.

The development of systems able to produce short pulses of radio energy was the key advance that allowed modern radar systems to come into existence. By timing the pulse on an oscilloscope, the range could be determined and the direction of the antenna revealed the angular location of the targets. The two, combined, produced a "fix", locating the target relative to the antenna. In the year 1934–1939,eight nations developed radar independently,and in great secrecy. These nations were; the United Kingdom, Germany, USSR, Japan, Netherlands, France and Italy.

In addition, Britain shared their information with the United States and four commonwealth countries: Australia, Canada, New Zealand, and South Africa.These countries also developed their own radar systems. During the war, Hungary was added to this list [1]. The term *RADAR* was coined in 1939 by the United States Signal Corps as it worked on these systems for the US Navy [2].

Progress during the war was rapid and of great importance, probably one of the decisive factors for the victory of the Allies. A key development was the magnetron in the UK [3], which allowed the creation of relatively small systems with sub-meter resolution. At the end of hostilities, Britain, Germany, the United States, the USSR, and Japan had a wide variety of land and sea-based radars as well as small airborne systems. After the war, radar use was widened to numerous fields including: civil aviation, marine navigation, radar guns for police, meteorology andeven medicine. Key developments in the post-war period include the travelling wave tube as a way to produce large quantities of coherent microwaves, the development of signal delay systems that led to phased array radars, and ever-increasing frequencies that allow higher resolutions. Increase in signal processing capability due to the introduction of solid-state computers has also had a large impact on radar use.

The scope of this study is within security systems. We design and implement a low-cost ultrasonic radar detection system with a programmable microcontroller. The system was fabricated on a single prototype board with an ultrasonic sensor controlled by an Arduino microcontroller with a servo motor to rotate the ultrasonic sensor from 0 degree to 180 degrees and vice versa, a processing IDE to display the angle and direction if an object is been detected.

II. MATERIALS AND METHODS

This section focuses on the design of the system, its working principle and the description of the parts for the design.

OVERVIEW OF LOW-COST ULTRASONIC RADAR SYSTEM

This system consists of a microcontroller, an ultrasonic sensor, an alarm unit. The microcontroller is an Arduino Uno which controls the system by sending and receiving signals for the system to perform a task. The ultrasonic sensor sends signals and when the signal is interrupted by an object, it bounces back to the ultrasonic sensor [4].

The software processing is an application which is used to view the angle and distance of the object detected by the ultrasonic sensor.

The alarm unit consists of two LEDs and a buzzer which is triggered once an object is been detected due to a specific distance.

COMPONENTS AND REQUIREMENTS FOR DESIGN

For the design of the system, software and hardware components are required.

Hardware Components

The following are the hardware components required for the design of the system.

- Arduino Uno.

- Ultrasonic Sensor.
- Servo motor
- Breadboard.
- Jumper Wires.
- Buzzer.
- LED
- A Switch

Arduino Uno

The Arduino Uno is an open source microcontroller. It is built with an 8-bit ATmega328P microcontroller chip mounted on a board. It consists of 14 digital I/O pins, 6 analog I/O pins, serial ports, USB power in port, 7-12volts DC power jack port, 16MHz Crystal oscillator, a reset button and other components.

Pin Description

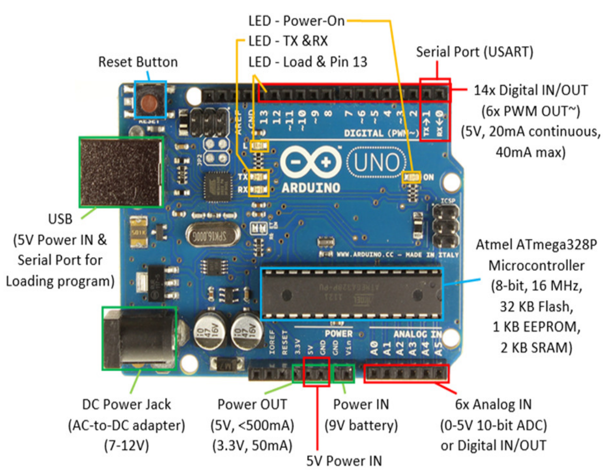

Fig. 1 Arduino microcontroller [21]

Arduino Uno Specifications

- Microcontroller: ATmega328
- Operating Voltage: 5V
- Input Voltage (recommended):7-12V
- Input Voltage (limits): 6-20V
- Digital I/O Pins: 14 (of which 6 provide PWM output)
- Analog Input Pins: 6
- DC Current per I/O Pin: 40mA
- DC Current for 3.3V Pin: 50mA
- Flash Memory: 32 KB (ATmega328)
- SRAM: 2 KB (ATmega328)
- EEPROM: 1 KB (ATmega328)
- Clock Speed: 16 MHz

Ultrasonic Sensor

The ultrasonic sensor works on the principle of SONAR and RADAR system which is used to determine the distance to an object.

An ultrasonic sensor generates the high-frequency sound (ultrasound) waves. When this ultrasound hits the object, it reflects as echo which is sensed by the receiver as shown in below Fig .2[5].

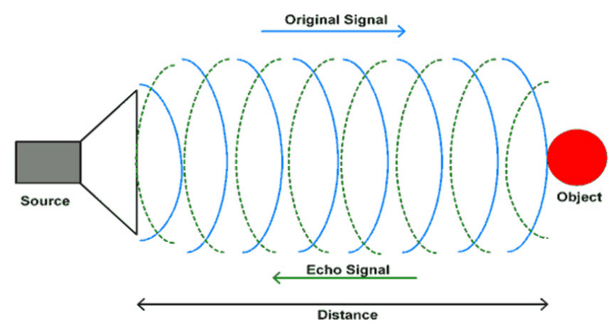

Fig 2 Transmitting and receiving reflected echo from object.

HC-SR04 Pin Description

Fig. 3 HC-SR04

VCC: +5 V supply

TRIG: Trigger input of sensor. Microcontroller applies 10 µ*s* trigger pulse to the HC-SR04 ultrasonic module.

ECHO: Echo output of sensor. Microcontroller reads/monitors this pin to detect the obstacle or to find the distance.
GND: Ground

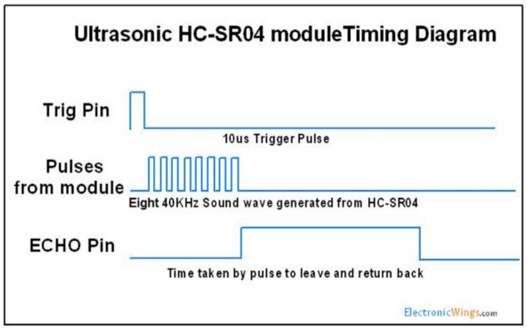

Fig.4 Ultrasonic Hc-SR04 module timing diagram

1. We need to transmit trigger pulse of at least 10 µs to the HC-SR04 Trig Pin as shown in Fig 4.
2. Then the HC-SR04 automatically sends Eight 40 kHz sound wave and wait for rising edge output at Echo pin.
3. When the rising edge capture occurs at Echo pin, start the Timer and wait for falling edge on Echo pin.
4. As soon as the falling edge is captured at the Echo pin, read the count of the Timer. This time count is the time required by the sensor to detect an object and return back from an object.

Now how to calculate distance?

$$Distance = speed \times time$$

The speed of sound waves is 343 m/s.
So,

$$Total\ Distance = 343 \times time\ of\ high(echo)/2$$

Total distance is divided by 2 because signal travels from HC-SR04 to object and returns to the module HC-SR-04.

Servo Motor

Fig.4 Servo Motor

- Servo motor is an electrical device which can be used to rotate objects (like robotic arm) precisely.
- Servo motor consists of DC motor with error sensing negative feedback mechanism. This allows precise control over angular velocity and position of motor. In some cases, AC motors are used.
- It is a closed loop system where it uses negative feedback to control motion and final position of the shaft.
- It is not used for continuous rotation like conventional AC/DC motors.
- It has rotation angle that varies from 0° to 180°.

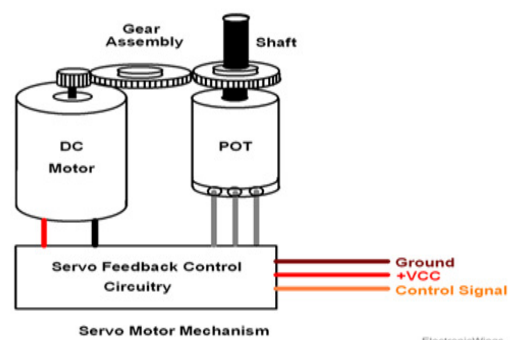

Fig.5 Servo Motor Mechanism

As shown in Fig. 5 Servo motor has three pins for its operation.

- **+VCC (RED)**

Connect +VCC supply to this pin. For SG90 Micro Servo it is 4.8 V (~5V).

- **Ground (BROWN)**

Connect Ground to this pin.

- **Control Signal (ORANGE)**

Connect PWM of 20ms (50 Hz) period to this pin.

Software Requirements

a. Arduino Software

This is the application software used in programming the Arduino microcontroller. It is an open source platform. It was downloaded from the Arduinosoftware website (Fig. 10).

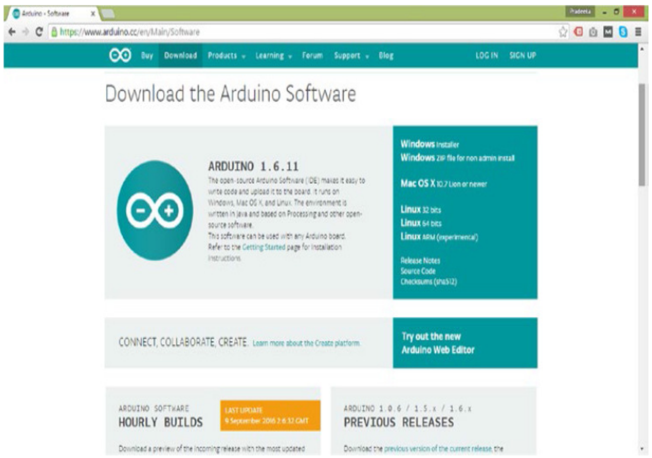

Fig.10 Arduino Software Download Page.

b. The Arduino IDE

After download has been completed, extract the downloaded ZIP file (i.e., arduino-1.6.11-windows.zip) using the **WinZip** or **7-Zip** compression software.The download contains a folder named arduino-1.6.11. The folder contains an executable file named Arduino, which is an application type file. Simply double-click on the icon to start the Arduino IDE.

If it prompts you with a Windows Security Alert. Just click on the Allow Access button to proceed. The IDE is loaded with a default sketch (Fig.11). The menu bar and toolbar provide a host of options and configurations to work with Arduino boards [7].

Fig. 11 Arduino IDE

c. Processing Software

Processing is an open-source graphical library and integrated development environment (IDE) built for the electronic arts, new media art, and visual design communities with the purpose of teaching non-programmers the fundamentals of computer programming in a visual context.

Processing uses the Java language, with additional simplifications such as additional classes and aliased mathematical functions and operations. It also provides a graphical user interface for simplifying the compilation and execution stage [6].

Design of the System

This section describes the design of the system using the various system components that have been stated in subsequent section. The design of the system is given in Fig. 13.

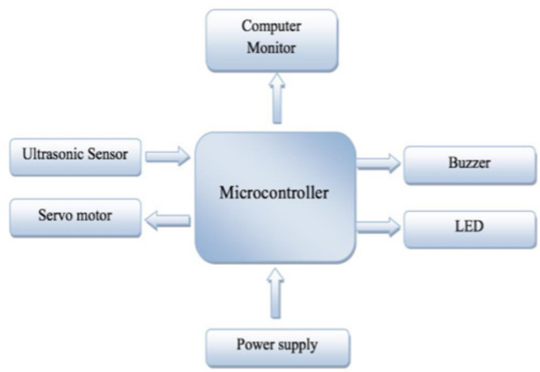

Fig.13 System block diagram

PROCEDURE ON HOW TO SETUP THE LOW-COST ULTRASONIC RADAR SYSTEM

1. Connect +5V power supply from the Arduino board via breadboard to the VCC pin on the ultrasonic sensor.
2. Connect the trigger pin from the ultrasonic sensor to pin 10 on the Arduino board.
3. Connect the echo pin from the ultrasonic sensor to pin 11 on the Arduino board.
4. Connect GND pin on the ultrasonic sensor to the GND pin on the Arduino board via breadboard.
5. Connect +5V power supply from the Arduino board via breadboard to the VCC pin on the servo motor.
6. Connect the control signal pin from the servo motor to pin 9 on the Arduino board.
7. Connect GND pin on the servo motor to the GND pin on the Arduino board via breadboard.
8. Connect pins 3 and 4 to the +5V pins of two different LEDs.
9. Connect the shorter leg of the two LEDs to GND pin via the breadboard.
10. Connect positive pin of buzzer to pin 6 on the Arduino board via breadboard.
11. Connect negative pin of buzzer to Ground on the breadboard.
12. Connect the Arduino board via USB cable to the computer [8].

13. Right-click on the **"Start"** icon and select **"Device Manager"**.
14. Double-click "Ports (COM & LPT)" to expand.
15. Note the **port** to which the Arduino board has been connected specified in the parenthesis to the board name.
16. Open the Arduino software.
17. On the tab menu, click on **tools**.
18. Go to **boards**and click on **Arduino/Genuino Uno** to select the board type.
19. After selecting the board type, go back to **tools.**
20. Hover on **"Port"** and select the COM from the list of "serial ports" to which your Arduino board is connected.
21. Click on **New** to create a new sketch.
22. Write the code to control the hardware.
23. Save, verify and upload the code to the Arduino board.
24. Open processing software
25. Copy the processing code, paste and run it [9].

Hardware Design

This include the design and construction of the system using the component parts listed in subsequent section. The hardware design implements a circuit diagram which is given in Fig. 14.

Circuit Diagram

Proteus was used to give out the schematic diagram of the hardware design.

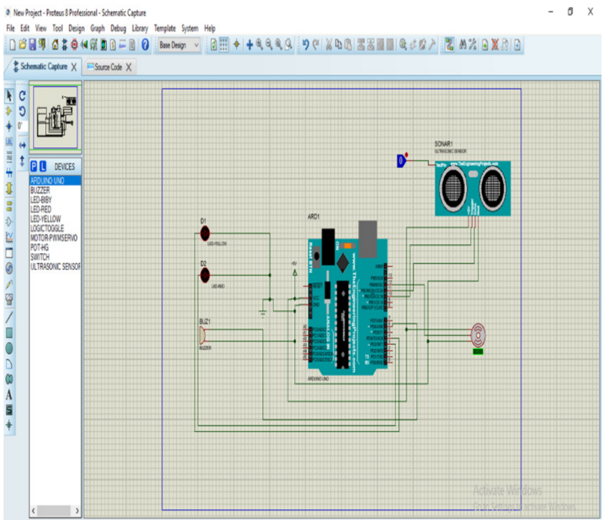

Fig.14Circuit Diagram low- cost ultrasonic radar system

III. RESULTS AND DISCUSSION

The proposed design for low-cost ultrasonic radar system has been successfully implementedand shows good performance. The ultrasonic radar detects an object and send the right signal to the Arduino board and the Arduino communicates with the processing software so that the angle, position of the object is calculated successfully. Buzzer and LEDs were also used to give an alarm if a car is detected at a specific distance.The results of implementation are shown in Fig. 15 and 16.

The ultrasonic radar can actually detect an object of about 400cm awaybut a specific distance was chosen in this research for the alarm system to be triggered.

An LED remain high indicating that no car is close to colliding with another car if the position of the other car or object is greater than 40cm, but if it is less than 40cm then the Arduino will trigger the alarm system to come up with a buzzer and another LED indicating that the car is close to colliding with another car. Fig. 15 below shows that a car or object is not close to colliding with another car therefore the blue LED remains ON.

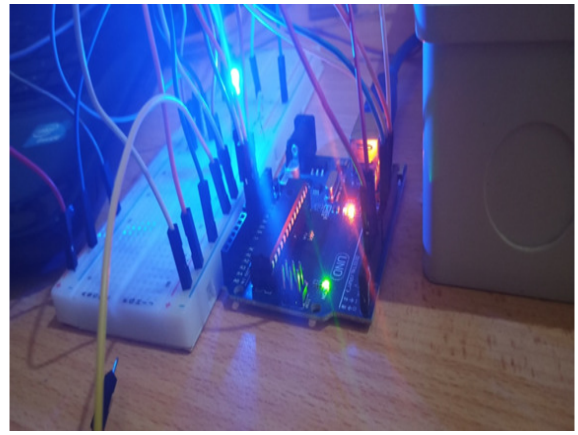

Fig.15Safe mode

Fig. 16 below shows that a car or object is close to colliding with another car.Hence,the blue LED goes off while the yellow LED and the buzzer comes ON.

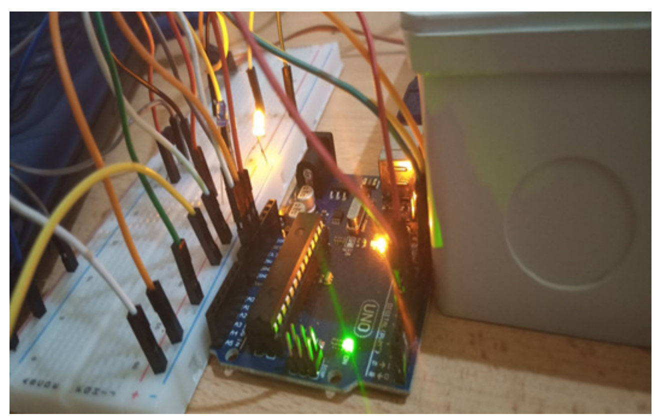

Figure 16.Unsafe mode

IV. CONCLUSIONS

The ideal security system for ultrasonic radar application is yet to be achieved. However, in this paper, a design of low-cost but effective security system for ultrasonic radar was implemented. This system has been designed to deliver a reasonable level of efficiency and simplicity, providing a standard real time user experience. The system has also been designed to provide efficient security and monitoring using computer vision with limited setup required.

In this article, an ultrasonic radar system was designed and implemented experimentally for distance measurements purposes to be used in various applications. An Arduino Uno device was used as a controller in the design beside other requirements such as servomotor, ultrasonic sensor and computer for distance calculation of objects or obstacles placed at different angles (from 0 to 180 degrees) within the range up to 40 centimeters.

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