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Microcontroller based Radar System

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***Abstract*— Microcontroller-based radar systems represent a significant advancement in the field of embedded systems and sensor technology, leveraging the capabilities of microcontrollers to enhance radar functionality while reducing costs and complexity. These systems employ microcontrollers to process radar signals, enabling applications in various domains including automotive safety, industrial automation, and environmental monitoring. Use of radar system has been developed greatly specially in field of navigation. In this research we study about existing navigation technologies and proposed an Arduino based radar system. It has advantage over other radar system as kit reduces power consumption and connect programmer to wide range or Arduino programmers and open source code. The system consist a basic ultrasonic sensor placed upon a servo motor which rotates at a certain an gleand speed. This ultrasonic sensor is connected to Arduino digital input output pins and servo motor also connected to digital input output pins.**

Keywords: Microcontroller, Radar, Industrial Automation.

I. INTRODUCTION

Radar technology has long been a cornerstone of various applications, ranging from military and defense to civilian uses such as air traffic control, weather monitoring, and automotive safety. Traditional radar systems, however, are often complex and expensive, typically requiring specialized hardware and extensive processing capabilities. The advent of microcontroller-based radar systems has introduced a paradigm shift, offering a more accessible and cost-effective approach to radar technology.

Microcontrollers are compact integrated circuits designed to govern a specific operation in an embedded system. They have evolved to become powerful enough to handle tasks traditionally reserved for larger, more expensive processors. By integrating microcontrollers into radar systems, it is possible to streamline the design, reduce costs, and maintain or even enhance functionality.

Microcontroller-based radar systems are particularly advantageous in applications where size, power consumption, and cost are critical factors. For instance, in automotive applications, radar systems are used for collision avoidance, adaptive cruise control, and parking assistance. These applications demand compact, efficient, and reliable radar solutions. Microcontroller-based systems meet these requirements by providing high processing power in a small footprint, enabling advanced features such as real-time signal processing and data analysis.

The core components of a microcontroller-based radar system include the antenna, transceiver, microcontroller, and signal processing unit. The antenna is responsible for transmitting and receiving electromagnetic waves, while the transceiver converts these waves into electrical signals. The microcontroller processes these signals, extracting relevant information such as the distance and speed of objects. Advanced signal processing algorithms are employed to enhance accuracy and reliability, allowing the system to differentiate between multiple targets and mitigate the effects of noise and interference.

One of the critical challenges in the development of microcontroller-based radar systems is the implementation of efficient signal processing algorithms within the limited computational resources of a microcontroller. Techniques such as Fast Fourier Transform (FFT), Constant False Alarm Rate (CFAR) detection, and Doppler processing are essential for extracting meaningful data from radar signals. Optimizing these algorithms to run on microcontrollers without compromising performance is a significant focus of current research and development.

Another important consideration is the integration of the radar system with other sensors and systems. For example, in an autonomous vehicle, the radar system must work seamlessly with cameras, lidar, and ultrasonic sensors to provide a comprehensive understanding of the vehicle's surroundings. This requires sophisticated data fusion techniques and robust communication protocols to ensure real-time operation and decision-making.

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This paper provides a comprehensive overview of microcontroller-based radar systems, detailing the design and implementation of a prototype system. The design considerations for selecting appropriate microcontrollers and other components are discussed, along with the methodologies for integrating and optimizing signal processing algorithms. Experimental results are presented to demonstrate the system's performance in various scenarios, highlighting its potential applications and benefits.

Microcontroller-based radar systems represent a promising advancement in radar technology, offering a viable alternative to traditional systems. Their compact size, low cost, and high performance make them suitable for a wide range of applications, from automotive safety to industrial automation and environmental monitoring. The continued development and refinement of these systems will likely lead to even more innovative and efficient radar solutions in the future.

II. LITERATURE SURVEY

T. K. T. Mach et al.,[1] presented an exploration of the advancements in ultrawideband (UWB) radar technology applied to people counting in the Internet of Things (IoT) applications. We introduce a novel lightweight convolutional neural network (CNN) model specifically designed for implementation on microcontrollers with low power consumption. Our proposed model successfully overcomes the limitations of existing methods, achieving an impressive accuracy rate of 99.38% for counting to ten people while randomly walking in a small area of 5×5 m. In addition, its lightweight architecture enables effortless integration with resource-constrained microcontrollers, enabling efficient execution of intelligent IoT tasks. Notably, our method maintains the accuracy even after quantization, with the model retaining 98.22% accuracy while reducing its size by more than half. Benchmarking results demonstrate the model’s efficiency, with inference times of less than 48 ms on a wide range of STM32 microcontrollers. Furthermore, the model with the most compact size specification achieves a remarkable inference time of only 3.8 ms per prediction on an STM32 microcontroller.

M. Rajeswari et al.,[2] Radar technology has been a cornerstone of numerous applications, from aviation to meteorology, offering invaluable capabilities for object detection and tracking. Traditional radar systems, while powerful, often come with significant costs and complexities, limiting their accessibility in various fields. In response to these limitations, this research endeavors to design and implement a radar system using Arduino microcontrollers and ultrasonic sensors. This innovative approach leverages the flexibility and affordability of the Arduino platform and the distance measurement precision of ultrasonic sensors to create a radar-like system. The research encompasses the development of the hardware, data acquisition, signal processing, and real-time visualization, providing an accessible and cost-effective alternative for radar-based applications. The study explores the integration of Arduino technology and ultrasonic sensors into radar systems, with a focus on simplicity, affordability, and practicality. By bridging the gap between traditional radar systems and DIY electronics, this research aims to democratize radar technology and open doors for applications in robotics, smart cities, industrial automation, and education.

J. Verastegui et al.,[3] operates several radars for different applications, from the main radar, an incoherent scatter radar used mainly for ionospheric activity observations, to ionosondes and wind profilers. Most of these radars use a centralized modular control system that commands all the radar sequences that require the radar modules, these tasks and sequences are controlled by pulsed digital signals. The device responsible for this operation is called the Radar Controller. A large number of customized Radar Controller versions were developed and built at JRO for decades, since the utilization of its first acquisition system. The current version of the Radar Controller is based on an RTL design written on VHDL language that implements a custom arbitrary waveform generator connected to an SRAM memory that stores all the data a given waveform needs.

P. Kaniewski et al.,[4] presented a concept of a high-accuracy positioning system, using ultrawideband (UWB) radio modules. The system is dedicated for supporting operation of a handheld ground-penetrating radar (GPR), as the use of information about the antenna coordinates at the moments of scanning enables correction of the radar signals and facilitates creation of high-resolution subsurface images. The presented system is self-contained and easy-deployable; it has centimeter-level accuracy and provides positioning data with high repeatability. The system's structure, mathematical model, positioning algorithm and chosen simulation results are presented in the paper.

F. Sickinger et al.,[5] An automotive radar sensor for cocoon functions or automated parking requires very small dimensions to access new mounting positions like B-pillar and side skirts. To minimize the dimensions of radar sensors, new concepts are necessary. A new system approach for radar sensors is presented. The new radar sensor system is divided

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in two major units. The sensor unit consists of a small serializer board and Low Temperature Cofired Ceramic (LTCC) miniature frontend. The external radar Electrical Control Unit (ECU) provides the signal processing performance and the power supply for the sensor unit. For the automotive radar band (76-81 GHz), RX- and TX antennas have been simulated, manufactured and the radiation pattern has been measured and a full prototype has been built.

X. Quan et al.,[6] The impulse radio ultra-wideband (IR-UWB) radar technology is attracted strong attention for various applications such as crowdedness measurement, building energy management system, vital sign monitoring, and counting the number of inbound and outbound people. In this paper, we propose a shopping store management system based on IR-UWB radar sensors. In order to manage a shopping store, checking the number of entered customers and sweet spot of a store is necessary. Here, sweet spot means the average residence time of customers in one hour. To get these two information, two applications of IR-UWB radar sensor are required. One is counting the number of inbound and outbound people, and the other one is crowdedness measurement. To validate this system, we install this system in a real shopping store. The performance of the shopping store management system is given in this paper, and the results show that our system is applicable.

III. PROPOSED METHODOLOGY

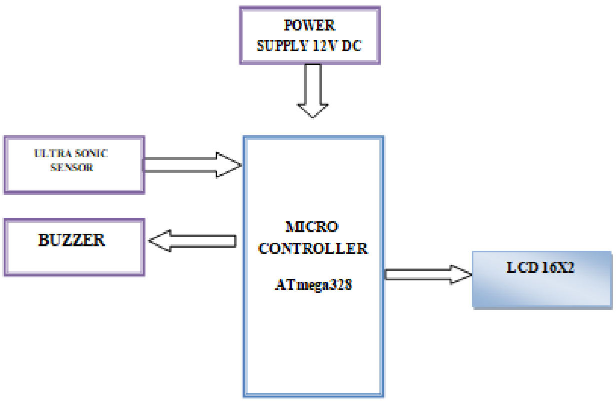

Figure 1: Block Diagram

Here's a description of the block diagram of an electronic notice board system:

- Power Supply (12V DC): This block supplies power to all the other blocks in the system
- Buzzer: This block generates audible tones
- Microcontroller (ATmega328): The brains of the system, it controls the entire operation of the board. The ATmega328 is a commonly used microcontroller from Microchip
- LCD 16x2: This refers to a 16 character by 2 line Liquid Crystal Display. This is the display that shows the information on the board.

1. **Power Supply (Input: AC Mains, Output: Regulated DC Voltage):**
   - Takes alternating current (AC) from the mains power outlet and converts it to a stable direct current (DC) voltage level required by the other components. This often involves a transformer to step down the voltage, a rectifier to convert AC to DC, and a voltage regulator to ensure a steady DC output.
2. **Microcontroller (MCU):**
   - The central processing unit (CPU) of the system, responsible for controlling all operations. It fetches, decodes, and executes instructions from memory, manages data flow, and interacts with other components. Common choices include Arduino boards, Raspberry Pi, or other single-board computers.
3. **Memory:**

- Stores program code (firmware) that defines the system's functionality and data (content to be displayed).

- **Program Memory (Flash/ROM):** Stores the non-volatile firmware that controls the system. This memory retains data even when the power is off.
- **Data Memory (RAM):** Stores temporary data used during operation, like the current message being displayed. RAM loses its contents when the power is off.

- Additional storage (Optional): An SD card or USB drive can be used to store a large library of messages or multimedia content (images, videos).

4. **User Interface (UI):**

- Provides a way for authorized users to interact with the system and update content. This might include:
  - **Physical Buttons:** Simple buttons for basic operations like scrolling through messages or selecting content.
  - **Keyboard:** Allows for text input for creating new messages or editing existing ones.
  - **Touchscreen (Optional):** Provides a more intuitive and user-friendly way to interact with the system.

5. **Communication Module (Optional):**

- Enables wireless communication for features like:
  - **Wi-Fi:** Allows for remote content updates from a computer or web interface.
  - **Bluetooth:** Enables content updates from a mobile device or for displaying information from sensors.
  - **GSM/Cellular (Advanced):** Enables remote updates or content scheduling via SMS messages (text messages).

6. **Real-Time Clock (RTC) (Optional):**

- Maintains accurate time even during power outages. Useful for:
  - Scheduling message displays at specific times.
  - Displaying time and date alongside the notice board content.

7. **Display Driver:**

- An integrated circuit that translates the digital signals from the microcontroller into a format understandable by the display. This allows the microcontroller to control what appears on the display.

8. **Display Panel:**

- The physical screen where the information is shown. This could be:
  - **LCD (Liquid Crystal Display):** Most common type, offers good readability and power efficiency. Available in various sizes and resolutions (character count and number of lines).
  - **LED (Light-Emitting Diode):** Provides brighter and more vibrant displays, often used for outdoor applications.

9. **Power Management (Optional):**

- Includes features to optimize power consumption, especially if the system is battery-powered. This might involve:
  - **Low-power modes for the microcontroller** to reduce power usage during standby periods.
  - **Light sensors** to automatically adjust display brightness based on ambient light conditions.

Connections:

- The power supply provides regulated DC voltage to the microcontroller and other components.
- The microcontroller connects to memory, the UI elements, communication modules (if present), the RTC (if present), and the display driver.
- The display driver connects to the display panel.

Functionality:

- The microcontroller fetches content (text, images, etc.) from memory or receives it through a communication module.
- It processes the content and sends control signals to the display driver.
- The display driver translates these signals into a format that the display panel understands, and the information is shown on the screen.
- The user interface allows authorized users to interact with the system and update content.

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IV. RESULTS AND DISCUSSION

Software Use for Circuit Design:

1:-PROTEUS

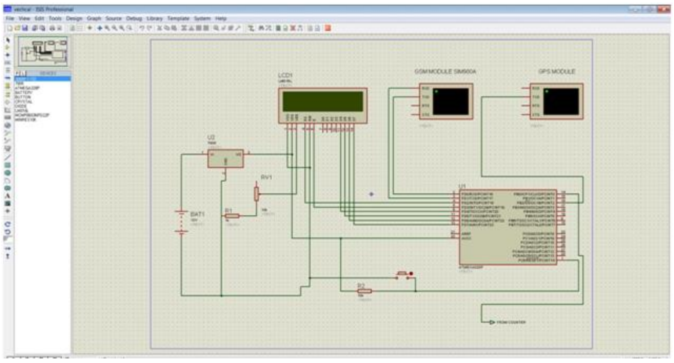

Figure 2: Circuit

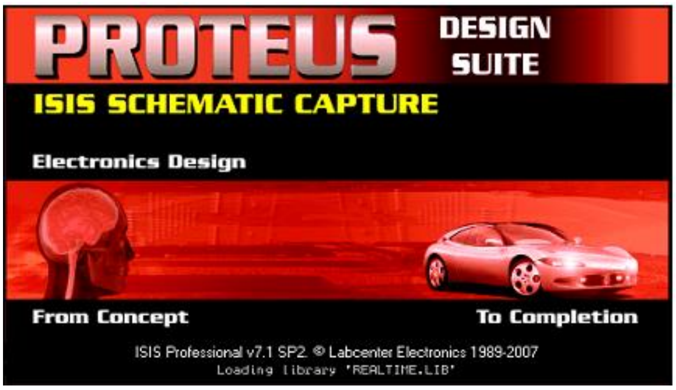

Figure 3: Software

Software Use for PCB Layout Design:

1:-CIRCUIT WIZARD

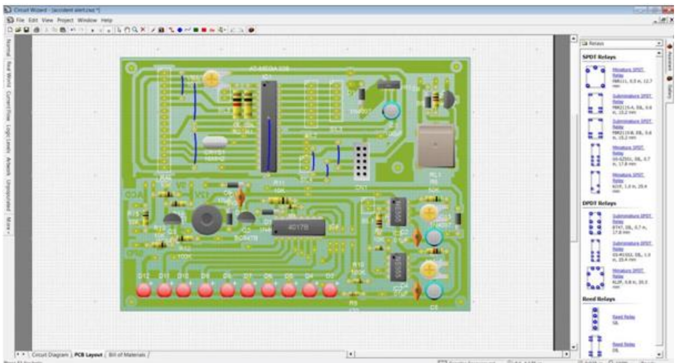

Figure 4: Circuit wizard

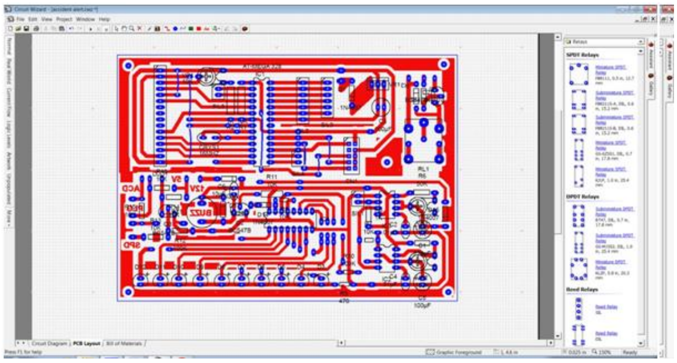

Figure 5: PCB Layout

Atmega328

ATmega-328 is basically an Advanced Virtual RISC (AVR) micro-controller. It supports the data up to eight (8) bits. ATmega-328 has 32KB internal builtin memory. This micro-controller has a lot of other characteristics. You should also have a look at Introduction to PIC16F877a (it's a PIC Microcontroller) and then compare functions of these two Microcontrollers.

ATmega 328 has 1KB Electrically Erasable Programmable Read Only Memory (EEPROM). This property shows if the electric supply supplied to the micro-controller is removed, even then it can store the data and can provide results after providing it with the electric supply. Moreover, ATmega-328 has 2KB Static Random Access Memory (SRAM). Other characteristics will be explained later. ATmega 328 has several different features which make it the most popular device in today's market. These features consist of advanced RISC architecture, good performance, low power consumption, real timer counter having separate oscillator, 6 PWM pins, programmable Serial USART, programming lock for software security, throughput up to 20 MIPS etc. ATmega-328 is mostly used in Arduino.

The further details about ATmega 328 is given followings-

- ATmega328 is an 8-bit and 28 Pins AVR Microcontroller, manufactured by Microchip, follows RISC Architecure and has a flash type program memory of 32KB.
- It has an EEPROM memory of 1KB and its SRAM memory is of 2KB.
  - It has 8 Pin for ADC operations, which all combines to form PortA (PA0 – PA7).
  - It also has 3 builtin Timers, two of them are 8 Bit timers while the third one is 16-Bit Timer.
  - You must have heard of Arduino UNO, UNO is based on atmega328 Microcontroller. It's

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UNO's heart.

- It operates ranging from 3.3V to 5.5V but normally we use 5V as a standard.
- Its excellent features include the cost efficiency, low power dissipation, programming lock for security purposes, real timer counter with separate oscillator.
- It's normally used in Embedded Systems applications. You should have a look at these Real Life Examples of Embedded Systems, we can design all of them using this Microcontroller.
- The following table shows the complete features of ATmega328:

16×2 character LCD

An LCD is an electronic display module which uses liquid crystal to produce a visible image. The 16×2 LCD display is a very basic module commonly used in DIYs and circuits. The 16×2 translates o a display 16 characters per line in 2 such lines. In this LCD each character is displayed in a 5×7 pixel matrix.

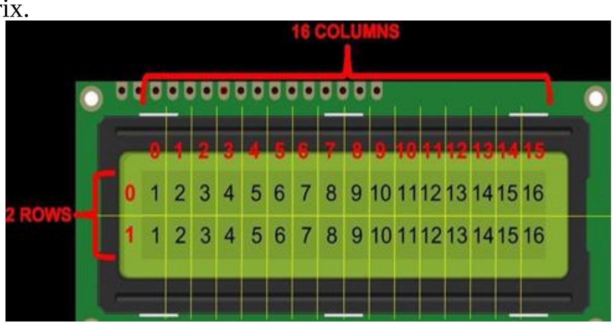

Figure 6: 16×2 character LCD

V. CONCLUSION

This paper presents the radar system which is designed with the help of Arduino, servomotor and ultrasonic sensor which can detect the position, distance of obstacle which comes in its way and converts it into visually represent able form. This system can be used in robotics for object detection and avoidance system or can also be used for intrusion detection for location sizes. Range of the system depends upon type of ultra-sonic sensor used. We used HC-SR04sensor which range from 2 to 40 cm.

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