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AutoSPY: An Autonomous Spy Car for Real-Time Audio Surveillance

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Abstract: This project presents the design and implementation of an autonomous obstacle avoiding robotic car integrated with a Mini A8 voice recorder for real-time audio monitoring. The robotic car uses ultrasonic sensors to detect obstacles in its path. A microcontroller processes the sensor data and controls the motors accordingly. The system automatically changes direction to avoid collisions. This enables smooth and efficient navigation without human intervention. To enhance functionality, a Mini A8 voice recorder is mounted on the car. The device allows real-time audio monitoring through GSM communication. Users can remotely listen to surrounding sounds by calling the SIM card in the recorder. It also supports audio recording for later use. The integration improves surveillance and environmental awareness. The system is built using low-cost and easily available components. It ensures reliability, simplicity, and efficient performance. This project is suitable for indoor surveillance and security applications. It is also useful for educational and robotics learning purposes. Future improvements include adding a camera module, GPS tracking, and IoT-based monitoring.
Index Terms: Autonomous, Robotics, Ultrasonic, Microcontroller, Surveillance, GSM, Audio, Navigation.

I. INTRODUCTION

Surveillance has become an essential part of modern security systems, especially in areas such as industries, institutions, and restricted zones. However, most traditional surveillance methods rely on fixed systems like CCTV cameras or manual monitoring. These approaches are often limited in terms of mobility and flexibility. In many cases, manual surveillance in hazardous or restricted environments can also be risky and inefficient.

With the rapid development of embedded systems and robotics, there is a growing interest in designing intelligent systems that can operate autonomously. Such systems can reduce human effort while improving efficiency and reliability. One of the key advancements in this field is the use of sensors and microcontrollers to enable machines to interact with their environment and make decisions in real time.

In this project, we propose an intelligent spy car that combines autonomous movement with real-time voice surveillance. The system is designed to move independently while detecting obstacles using an ultrasonic sensor. Based on the distance measured, the microcontroller controls the direction of the car to avoid collisions, ensuring smooth and safe navigation.

The proposed system offers a low-cost, portable, and efficient solution for surveillance purposes.

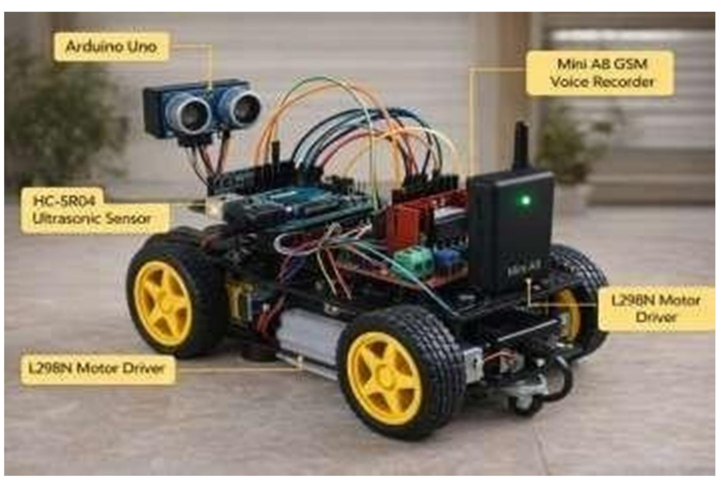

Fig. 1. A general view of Spy Car

In addition to obstacle avoidance, the system is equipped with a Mini A8 voice recorder that enables real-time audio monitoring. The device uses GSM communication, allowing the user to listen to surrounding sounds by simply calling the SIM card inserted in the recorder. This eliminates the need for internet connectivity and makes the system more practical for real-world applications. An intelligent spy car system is being developed that integrates obstacle avoidance and real-time voice surveillance to enhance modern security and monitoring solutions. This innovative system utilizes ultrasonic sensors, a microcontroller, and GSM-based audio communication to enable autonomous navigation and remote environmental monitoring. The primary objective of this project is to create a low-cost, portable, and efficient surveillance system that minimizes the need for manual monitoring, especially in hazardous or restricted areas.

A. System Design and Development

The entire flow of the proposed system is divided into a few steps as follows.

- Autonomous Obstacle Avoidance: design a robotic car that detects obstacles using ultrasonic sensors and navigates autonomously without human intervention, ensuring safe movement and preventing collisions.
- Real-Time Navigation Control: The system aims to process sensor data using a microcontroller and control the movement of motors accordingly. This enables the car to make quick decisions such as moving forward, stopping, or changing direction.

B. Integration of Audio Surveillance

Another key objective is to incorporate a Mini A8 voice recorder into the system to capture surrounding audio. This enhances the surveillance capability by providing real-time environmental awareness.

C. Objectives & Benefits

The main objectives and benefits are as follows.

1) To design and develop an autonomous robotic car with obstacle avoidance capability.
2) To develop a low-cost, portable, and efficient surveillance system.
3) To integrate a Mini A8 voice recorder for real-time audio surveillance.
4) Helps in learning and understanding embedded systems and robotics
5) Provides real-time audio monitoring for better situational awareness.

The rest of the paper is organized as follows: Section II presents a review of existing surveillance systems and their limitations. Section III describes the proposed system design and methodology for obstacle avoidance and real-time voice monitoring. Section IV discusses the implementation details and performance evaluation of the system. Section V presents the results obtained from testing the proposed system. Finally, Section VI concludes the paper and highlights the future scope of the project.

II. RELATED WORK

In recent years, several researchers have explored the development of intelligent surveillance and robotic systems using embedded technologies. Traditional surveillance systems such as CCTV cameras are widely used; however, they are limited by their fixed positioning and lack of mobility, which restricts their effectiveness in dynamic environments.

The work proposed by J. Borenstein and Y. Koren focused on real-time obstacle avoidance techniques for mobile robots, where sensors are used to detect obstacles and navigate safely in unknown environments. Their research laid the foundation for modern autonomous robotic systems by introducing efficient navigation algorithms for real-time applications. Another study by S. R. Kumar and P. K. Singh demonstrated the implementation of an Arduino-based obstacle avoiding robot using ultrasonic sensors. Their system used simple hardware components and showed that low-cost microcontroller-based solutions can effectively perform autonomous navigation tasks.

With the advancement of compact computing platforms, researchers such as S. Rathinamala et al. have implemented embedded systems using Raspberry Pi, enabling more powerful processing and integration of multiple functionalities such as image processing and surveillance. These systems provide better performance but often increase system complexity and cost. In addition, M. R. K. Krishna and S. N. Sivanandam developed a GSM-based surveillance system that allows remote monitoring using mobile networks. Their work highlights the importance of communication technologies in surveillance applications, enabling users to access real- time information without requiring internet connectivity. Research in robotics by S. Thrun et al. and R. Siegwart et al. further emphasizes the importance of autonomous mobile robots in real-world applications. Their work on probabilistic robotics and intelligent navigation systems demonstrates how robots can operate efficiently in uncertain environments using sensor data and decision- making algorithms.

The ultrasonic sensing technique is widely used in obstacle avoidance systems due to its simplicity and fast response. It measures distance using sound waves and is easy to implement with microcontrollers like Arduino. However, its performance can be affected by object angle and surface type. Microcontroller-based systems using Arduino and Raspberry Pi are commonly used for robotic control. Arduino is preferred for its low cost and simplicity, while Raspberry Pi offers higher processing power for advanced applications. However, Raspberry Pi increases system complexity and power consumption. GSM-based communication is also widely used in surveillance systems. Devices like the Mini A8 voice recorder allow real-time audio monitoring through mobile networks without requiring internet connectivity. However, system performance depends on network availability and may face signal delays. Motor control using PWM (Pulse Width Modulation) helps in controlling the speed and direction of the robotic car efficiently. While it ensures smooth movement, improper tuning can affect performance. Overall, the proposed system combines ultrasonic sensing, Arduino-based control, GSM communication, and motor control to provide a simple, low-cost, and effective solution for real- time surveillance and autonomous navigation. Applications using intelligent spy car systems offer several advantages in terms of mobility, real-time monitoring, and cost-effectiveness. However, they also come with certain challenges such as dependency on sensor accuracy, GSM network reliability, and hardware limitations. Factors like obstacle detection errors, signal disturbances, and power management can affect overall system performance.

Therefore, organizations or users planning to implement such systems should carefully consider these limitations and ensure that proper resources, reliable components, and maintenance support are available. A balanced approach between functionality, cost, and system reliability is necessary for effective deployment and long-term usage of the system.

III. METHODOLOGY

Obstacle Detection And Real-Time Audio Surveillance Using Ultrasonic Sensor And Gsm Module

The methodology of the proposed intelligent spy car system focuses on integrating autonomous navigation with real-time audio surveillance using embedded system components.

Fig. 3.1 Overview of detection and recognition process

The system is designed in such a way that it can operate independently without human intervention while continuously monitoring its surroundings. The overall approach involves sensing the environment, processing the acquired data, making decisions based on predefined conditions, and executing actions through motor control. At the same time, the system performs audio surveillance, enabling remote monitoring through GSM communication. This combination of navigation and surveillance makes the system more efficient and practical compared to traditional stationary monitoring systems. To achieve this functionality, the system is divided into different functional modules that work together in a coordinated manner. Each module is responsible for a specific task, and their integration ensures smooth operation of the system.

A. Method-1: Sensing Unit (Obstacle Detection)

The sensing unit is responsible for detecting obstacles in the path of the robotic car. It uses an HC-SR04 ultrasonic sensor, which works on the principle of sound wave reflection. The sensor emits ultrasonic waves that travel through the air, hit an object, and return back to the sensor.

The time taken for the echo to return is measured, and based on this time, the distance between the object and the sensor is calculated.

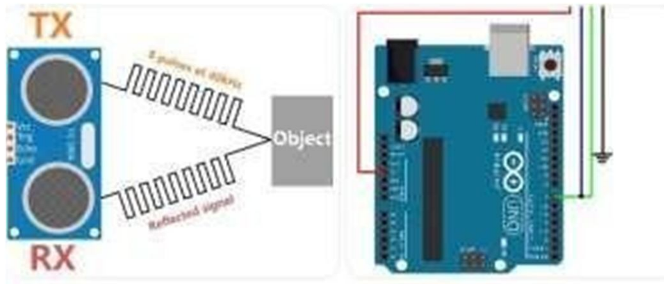

Fig. 3.2 Overview of Arduino and Sensor

The distance is calculated using the following formula:

$$v = d * t/2 \qquad [eq^n \dots 1]$$

Where, d is the distance to the obstacle, v is speed of sound (approximately 343 m/s), t is time taken for the echo to return. The division by 2 is required because the sound travels to the object and then back to the sensor. This continuous sensing allows the system to detect obstacles in real time.

B. Method-2: Processing Unit (Decision Making)

1) The processing unit acts as the brain of the system and is implemented using an Arduino Uno microcontroller. It receives distance data from the ultrasonic sensor and processes it to make decisions regarding the movement of the car.

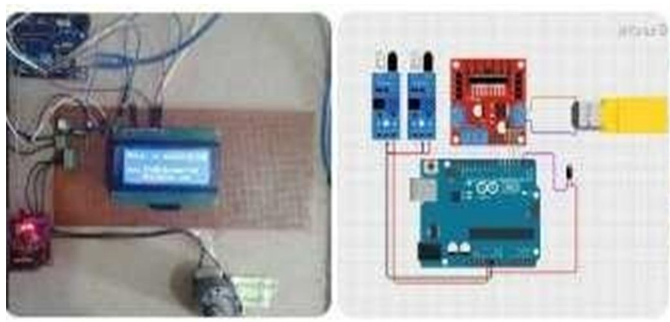

Fig. 3.3 Overview of Circuit Diagram

2) The logic used by the microcontroller is simple but effective:

$$if\ d < dthreshold \rightarrow change\ direction$$

ELSE -> move forward ….$[eq^n \dots 2]$

Here, $dthreshold$ is a predefined safe distance.

If an obstacle is detected within this range, the system automatically changes direction to avoid collision. This decision-making process happens continuously and ensures real time responsiveness of the system.

C. Method-3: Actuation Unit (Motor Control and Movement)

The actuation unit is responsible for controlling the movement of the robotic car. It consists of a motor driver (L298N) and DC motors.

The motor driver acts as an interface between themicrocontroller and the motors. It receives control signals from the Arduino and drives the motors accordingly.

Based on the signals, the car can perform the following movements:

- Move forward
- Move backward
- Turn left
- Turn right

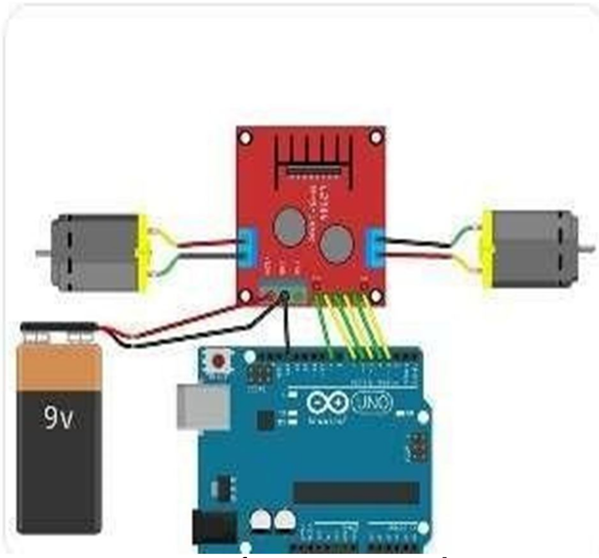

Fig. 3.4 Overview of Motor Driver Architecture

Motor speed control is achieved using Pulse Width Modulation (PWM). The duty cycle of the PWM signal determines the speed of the motor.

$$\text{Duty Cycle} = T_{ON} / T*100 \quad \ldots.[eq^n \ldots 3]$$

Where T_{ON} = time for which the signal is on.

T = total time period.

D. Method-4: Audio Surveillance Unit (GSM-Based Monitoring)

Fig. 3.5 A8 Mini Recorder

The audio surveillance unit enhances the functionality of the system by enabling real-time monitoring of the environment.
This unit uses a Mini A8 voice recorder, which is equipped with GSM capabilities device. This eliminates the need for internet connectivity and makes the system suitable for real-world applications.

IV. CONCLUSION

In conclusion, the intelligent spy car developed in this project successfully integrates obstacle avoidance and real- time voice surveillance into a single system. The use of ultrasonic sensors enable safe navigation, while the Mini A8 voice recorder enhances surveillance capability through GSM- based audio monitoring. The system is low-cost, easy to deploy, and suitable for various applications such as indoor surveillance, security monitoring, and educational demonstrations. This project highlights the potential of technologies for developing efficient surveillance systems.

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