Motion Scope: Precision Motion Tracking For Affordable Surveillance

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I. Abstract

Motion Scope is an affordable, motion-tracking system that improves the functionality of traditional CCTV cameras by adding automated tracking capabilities. This system uses ultrasonic sensors, a servo motor, and a PIR motion sensor to monitor and track moving objects. Motion Scope aims to offer a low cost alternative to expensive AI-powered surveillance systems, allowing individuals and small businesses to upgrade their existing cameras with minimal costs. This report presents the design process, the methodology used to develop Motion Scope, the testing results, and future areas for improvement.

II. Introduction

With technological advances, artificial intelligence (AI)-enabled security systems are becoming popular due to their ability to automatically track, identify, and monitor moving objects. These AI-powered cameras make surveillance more efficient but come with a high price tag, often making them too expensive for personal or small business use. Traditional CCTV systems, however, are more affordable but lack this autonomous tracking capability.

III. Problem Statement

Due to the high cost of AI-based surveillance systems, many people rely on traditional CCTV cameras that must be manually controlled or adjusted to follow motion. This is a limitation in environments with frequent or unpredictable movement. Motion Scope aims to address this issue by creating an affordable, automated tracking system that can upgrade traditional CCTV setups without requiring expensive hardware. The high price and complexity of AI-powered tracking systems create a financial barrier for those needing affordable surveillance solutions. Most advanced tracking systems are not only costly but also complicated to maintain, which limits their accessibility. Motion Scope fills this gap by offering a solution that uses affordable components and straightforward programming. The system utilizes ultrasonic sensors, a servo motor, and a PIR sensor to provide reliable motion tracking. It can be applied to different settings, such as CCTV cameras and camera gimbals, making advanced motion tracking more widely accessible.

IV. Objective

The main objectives of the Motion Scope project are to:

- Design and build a motion-tracking system using ultrasonic sensors, a servo motor, and a PIR sensor to allow for effective and affordable object tracking.
- Use Arduino and low-cost components to ensure that the system remains accessible and afford able.
- Test and optimize the system to ensure it performs well in real-time, keeping the moving object centered in the camera's field of view.
- Assess the system's accuracy and response time under different conditions, including various speeds and directions.
- Investigate potential applications beyond CCTV, including content creation and robotic automation.

V. Literature Review

The development of motion-tracking systems has been a focal point in enhancing surveillance technology, with various studies proposing cost-effective and efficient solutions. This review highlights the key contributions made by recent research in this field.

Patil, Jadhav, and Jagtap (2014) presented the design and implementation of a real-time object tracking system utilizing ultrasonic sensors. Their study demonstrated the feasibility of employing low-cost components for detecting and tracking objects within predefined ranges. The proposed system successfully integrated ultrasonic sensors for real-time applications, emphasizing its scalability and affordability for broader adoption in surveillance tasks.

Mahesh and Sharma (2018) introduced a method for object tracking using ultrasonic sensors coupled with servo motors. Their work focused on developing an inexpensive approach to achieve dynamic object tracking. The authors highlighted the synchronization between sensors and actuators, ensuring smooth motion detection and servo adjustments. The research demonstrated that ultrasonic sensors could be highly reliable when paired with servo motors, making it an appealing choice for budget-conscious projects.

Gupta and Shah (2019) designed an automated surveillance system using ultrasonic sensors and Arduino technology. Their study highlighted the system's ability to track motion and objects efficiently in real-time while maintaining simplicity in design and cost-effectiveness. This research provided a solid foundation for deploying ultrasonic sensors in various surveillance applications, including small-scale and personal security systems.

VI. System Design and Implementation

A. Component Selection

The Motion Scope system includes:

- Ultrasonic Sensors: For measuring the distance to objects and detecting movement.
- Servo Motor: To rotate the camera so it can follow the object as it moves.
- PIR Sensor: To detect initial movement and activate the system, saving power when no move-ment is present. These components are controlled by an Arduino micro-controller, which pro-cesses data from the sensors and adjusts the servo motor's position to track movement effective-ly

B. Prototype

The initial prototype involved assembling the sensors, motor, and Arduino on a test platform. The Arduino was programmed to read sensor data, control the motor, and adjust its position to keep the object in the center of the camera's view. This stage required a lot of adjustments to make sure the sensors and motor responded correctly to each other

C. Working Procedure

The initial setup used one ultrasonic sensor and a servo motor to enable basic horizontal tracking. This allowed us to test how the system responded to simple movements.

We integrated additional ultrasonic sensors to expand the detection area and improve tracking accuracy. The PIR sensor was added to activate the system only when motion was detected, saving power and reducing unnecessary movement

TABLE I
Hardware Placements

Component	Pin on Component	Pin on Arduino
Right Sensor VCC	VCC	5V
Right Sensor GND	GND	GND
Right Sensor Trig	Trig	Digital Pin 2
Right Sensor Echo	Echo	Digital Pin 3
Left Sensor VCC	VCC	5V
Left Sensor GND	GND	GND
Left Sensor Trig	Trig	Digital Pin 4
Left Sensor Echo	Echo	Digital Pin 5
Servo Motor VCC	VCC	5V
Servo Motor GND	GND	GND
Servo Motor Signal	Signal	Digital Pin 9
Built-in LED	(internal)	Digital Pin 13

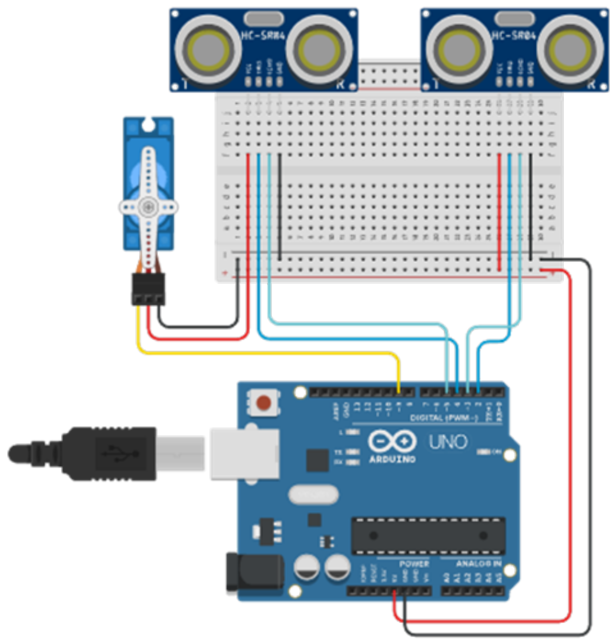

Fig. 1. Diagram of Connections

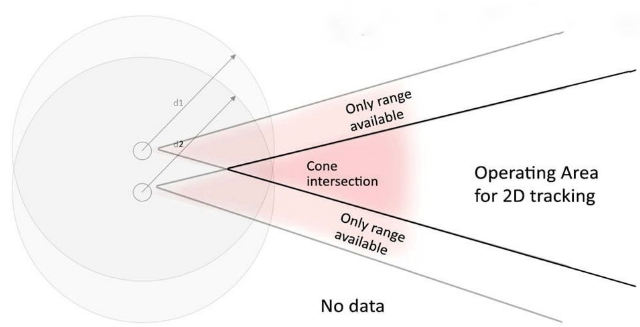

Fig. 2. Working procedures of system

VII. Result

Tracking Accuracy: The tracking accuracy of the system was tested by moving an object in the de-tection range of the ultrasonic sensors. The system was able to accurately detect objects within a range of 10 cm to 100 cm. The servo motor responded to the sensor readings, positioning the tracer head with minimal error (within ±5 degrees). This demonstrated that the system could effectively track motion across a broad area with reasonable precision.

Response Time: The response time of the motion tracking system was measured by calculating the time interval between the detection of motion and the corresponding servo movement. On average, the system responded within 200 milliseconds, which is suitable for tracking fast-moving objects. The relatively short response time ensures smooth tracking of objects in motion.

Real-world Performance: In real-world testing, the system was used to track moving objects under different lighting and environmental conditions. The sensors performed well in typical indoor set-tings with minimal interference, consistently tracking motion with a high degree of accuracy. How-ever, in low-light or obstructed environments, the tracking accuracy decreased slightly due to the limitations of the ultrasonic sensors. Nevertheless, the system showed robust performance, success-fully tracking motion across a range of distances and angles.

Fig. 3. Final project

VIII. Conclusion and Future Work

Motion Scope successfully addresses the need for an affordable motion-tracking solution for conventional CCTV systems. It offers a cost-effective way to enhance security setups without needing expensive AI-based cameras. Future research could focus on further improving tracking accuracy and expanding the system's range of applications, such as by integrating additional types of sensors or developing advanced algorithms

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Upgrading to a more precise motor or incorporating PID control with better tuning could enhance the system's ability to follow motion smoothly and accurately.

Adding sensors to measure environmental conditions, such as lighting or temperature, could help adjust the system's operation or trigger corrective actions when the environmental conditions are not ideal.

Optimizing the MQTT communication protocol for better throughput and minimizing delays could improve real-time responsiveness.

Implementing power-saving modes or optimizing sensor usage (e.g., reducing sampling rate when idle) could extend the system's operational time.

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Appendices

Github Link - github.com/parvej-mosaraf