

AI-Based Patrolling Robot

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Abstract: The development of this AI-based patrolling robot is presented along with design details and how this patrolling robot will improve campus safety/security and provide better surveillance of the campus than traditional security solutions (CCTV and/or manual patrol) due to the lack of real-time interaction or ability to make decisions. The integration of IoT, AI, and robotics will enable the patrolling robot to autonomously patrol the campus and respond in an emergency. The proposed autonomous patrolling robot will utilize a Raspberry Pi (RPi) platform that has a camera module (for human recognition), ultrasonic sensors (for navigating), and motor drivers (for mobility). Computer vision techniques and machine learning algorithms will allow the robot to detect humans and evaluate the human's posture in order to identify standing alone or falling. If there is a possible emergency situation the robot will communicate verbally using speech recognition and text-to-speech systems with the individual that it has recognized. If a request for help is made or no response is received, the robot will send an alert with the GPS location (with timestamp) plus any images captured during the communication to the appropriate authorities using IoT based communication protocol. In summary, the proposed autonomous patrolling robot will provide a continuous 24 hour/day, 7 days/week patrol (monitoring function), reduce the reliance on human patrols, and increase the speed of responding to an emergency situation.

Key Words: Artificial Intelligence, Internet of Things (IoT), Patrolling Robot, Computer Vision, Human Detection, Autonomous Navigation, Surveillance System, Raspberry Pi.

I.INTRODUCTION

In today's educational settings, whether it is day or night and a human being is present to supervise or not, safety and security are critical to any educational institution or facility. Often, campuses are open spaces and vulnerable to being broken into, stolen from or experiencing any type of emergency with students or faculty while they are present on campus.

Traditional forms of monitoring a campus, such as CCTV and manual patrols/crossing guards represent passive forms of monitoring that tend not to provide immediate feedback, intelligent decision-making or immediate response capability.

To combat these issues, there is now a significant need for autonomous, intelligent systems capable of providing 24/7 monitoring as well as proactive response to whatever the need may be at any given time. With the use of new technologies in the areas of Artificial Intelligence (AI), the Internet of Things (IoT) and robotics, many new smart surveillance products are now available to monitor a campus autonomously without the need for constant human interaction.

This paper will discuss the design and development of a smart campus surveillance robot that uses AI-powered computer vision along with IoT-based communication and autonomous navigation to provide real-time monitoring within a defined perimeter. The robot is based on the Raspberry Pi platform, will use a camera module for acquiring video images, will utilize ultrasonic sensors to detect obstacles and will be able to control its movement using motor drivers.

The system proposed by the AI-based patrol robot will employ various machine learning algorithms to detect the presence of humans and analyse the posture of the person (i.e., standing, sitting or lying down) to identify situations that may be critical. Once a critical situation is identified, the robot will use voice interaction and a combination of voice recognition and text-to-speech technologies in order to determine the status of the individual.

If the individual requests assistance or does not respond to the robot's questions, the system will generate an automated alert containing all necessary information, including location, timestamp and images taken by the robot. This information will be sent out to the appropriate authorities via IoT communication protocols to allow for timely assistance to be provided. By utilizing intelligent perception, communication and autonomous navigation, the proposed system will provide improved situational awareness and allow for rapid response to emergencies.

Additionally, there are not any integrated systems that combine autonomous mobility, intelligent perception and communication functions. Most of today’s solutions are designed to work independently of each other, such as an image detection system without means to move, or an IoT situation alert system without means to detect a situation in real time. The fragmentation of these different products reduces the overall effectiveness of surveillance and emergency response solutions.

II. MATERIAL AND METHODS

An AI-powered robot designed for surveillance will use an integrated approach to implement the main components of the patrolling system: autonomous navigation, real-time visual processing capabilities, human interaction, and communication via the Internet of Things. The plan will accomplish these tasks through various stages of methodology, all supporting the main function of the Overall System.

A. Initialization and Pathway/pathway Design

The system will utilize a Raspberry Pi computer as the main processing component for the overall system. The navigation waypoint will be defined and pre-programmed in order to initiate and automatically patrol. The DC motors will be subject to control from motor drivers that allow the robot to move into forward, backward or directional modes through a combination of these motor controls. This engineering will enable successful and stable navigation and travel of the robot through its designated area.

B. Autonomous Navigation and Obstacle Detection & Avoidance

The mobile robot will patrol around all pre-programmed navigation way points while continually monitoring for any objects located in its surroundings by means of real-time sensor analysis of the environment generated by ultrasonic sensor modules. If it detects any obstacles in its path, the mobile robot will automatically modify its direction of travel to avoid colliding with other objects. This is the second way of ensuring the robot operates in a safe manner, indoors or outdoors.

C. Real-time Image Capture

Real-time visual images from a video camera mounted parallel to the surface of the Raspberry Pi will be captured to create a continuous visual feed from the camera to the computer vision system for processing. The computer will process these series of images through a sequential frame capturing process to allow for real-time monitoring of environmental conditions.

D. Human Detection with AI Technology

To identify if a person is present in real time using computer vision, each video frame captured will be processed and analysed. The processing will be performed on an OpenCV and TensorFlow Lite framework by using a low power machine learning model deployed on a Raspberry Pi. Each frame will be analysed for feature(s) and a bounding box with a confidence score will be created for each feature found. This means that even in low resource constrained environments, detection can be accomplished.

E. Posture Recognition and Analysis

After identifying a person through detection, the system will then perform a gesture analysis to determine their current positioning (standing, sitting, or lying). Gesture analysis will be accomplished using image classification and pose estimation techniques.

As such, the posture recognition module is critical for determining when a potential emergency situation may exist by identifying a potential fall or someone has been motionless for an extended period.

III. LITERATURE SURVEY

Ref.	Author & Year	Focus Area	Key Feature	Gap/How Our Work Differs
[1]	Sharma et al. (2019)	AI Surveillance Robot for Security	Raspberry Pi + OpenCV, face detection, motion tracking	No voice interaction or IoT alerting; our system adds voice communication and real-time GPS alert dispatch.
[2]	Kumar & Rajan (2020)	IoT-Based Smart Surveillance	Multi-node cameras, cloud alerts, MQTT protocol	Static camera nodes with no mobility; our robot patrols autonomously and interacts with detected individuals.
[3]	Zhang & Park (2018)	Autonomous Navigation via Sensor Fusion	Ultrasonic + IR + GPS fusion for collision-free movement	Pure navigation study without AI detection or alerting; our work integrates these navigation techniques with full AI and IoT capabilities.

[4]	Singh & Kaur (2021)	Human Detection using Deep Learning	CNN-based posture classification, 95%+ accuracy	Detection only, no autonomous response; our system acts on detections by interacting via voice and sending emergency alerts.
[5]	Bansal & Lee (2017)	Voice-Interactive Robots	Speech recognition + TTS for human-robot interaction	Voice interaction explored in isolation; our work embeds voice interaction within a full patrolling and alerting system.
[6]	Ahmed & Noor (2022)	Vision-based Fall Detection Outdoors	Pose estimation + optical flow, works in low light	Fall detection without autonomous action or alerting; our robot detects falls and immediately dispatches alerts to authorities.

IV. PROCEDURE METHODOLOGY

The procedure methodology consists of five main modules:

A. Human Detection Module

The Human Detection Module is designed to recognize human presence and to analyse human posture. Real-time video images from a camera module will be processed by computer vision techniques, allowing for the detection of human figures and classification of the posture of each figure (i.e., standing, sitting, and lying down). One important function of this module is to detect abnormal situations (e.g., when a person has fallen or needs help).

B. Navigation Module

The Navigation Module is responsible for controlling the movement of the robot by using DC motors, which are powered by L298N motor drivers and allow for moves in different directions (i.e., forward, backward, or to turn left or right). The Navigation Module has ultrasonic sensors integrated to detect obstacles and, therefore, allow the robot to navigate safely and autonomously on established patrol routes.

C. Voice Interaction Module Describe the Voice Interaction Module that enables communication between man and robot. This includes a microphone for receiving voice input, however, also includes a speaker that generates text-to-speech audio output. When someone is detected, the voice interaction module will ask, “Do you need help?” then will then use a speech recognition to process the answer.

D. IoT Alert Module Describe the IoT Alert Module enabling alerts to be sent to the monitoring system or authorities. The IoT Alert module will allow the ability to transmit alerts by Wi-Fi to send real-time notifications of important events occurring such as the event being detected; image taken; and the time that elapsed since that event occurred, thus creating immediate communication in emergency situations.

E. Monitoring and Control Module Describe the Monitoring and control module; this module will provide the user with an interface to monitor and control the robot. As part of this will be the ability to provide live video feeds as well as provide a control interface or logger to allow security personnel to view robots in use; view and respond to alerts; and take manual control when needed, and provide historical logging for future reference and analysis of events monitored.

V. BLOCK DIAGRAM

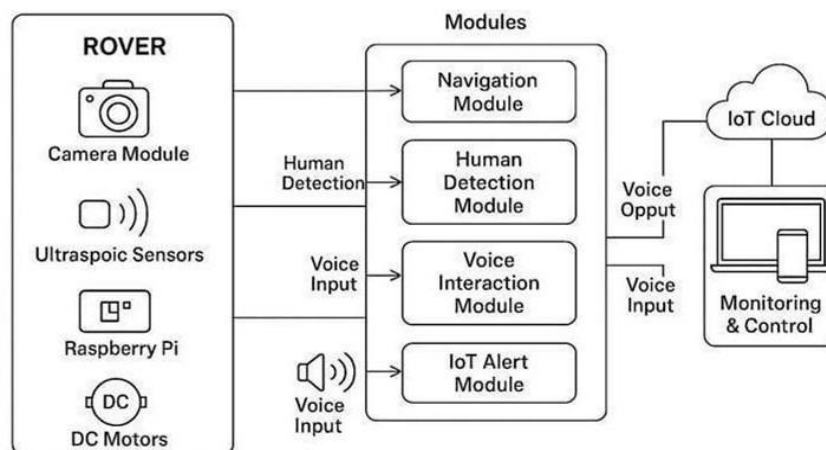


Fig 1: Block Diagram of various modules

VI.RESULT

The AI Based Patrolling Robot Prototype was designed and constructed, and then successfully integrated into a prototype system where all components were tested from a physical and functional perspective in real time.

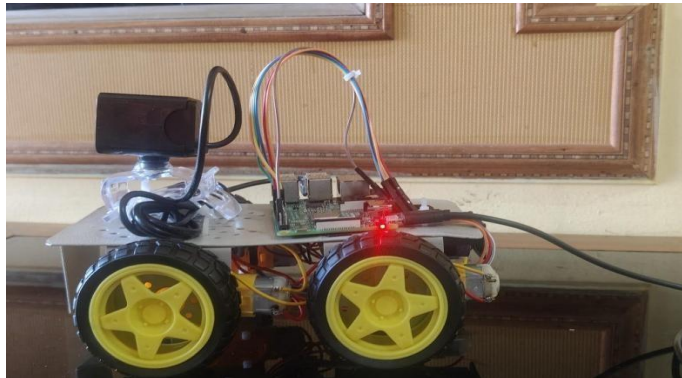


Fig. 2. Side view of AI-based patrolling robot showing Raspberry Pi, motor connections, and hardware setup.

For the four-wheel robot chassis, a Raspberry Pi was used to provide the computational power, a camera module, motor drivers, and a power source. An example of the robot from the top view perspective is shown in the first snapshot.

The Raspberry Pi used its GPIO pins to interface with the external components. Using DC motors, the robot moved smoothly, and the on-board camera module was used for live video feed. The robot performed autonomously, moving, and through basic movement control. The final integration of hardware components modelled a compact yet fully functional unit suitable for patrolling.

The second snapshot of the robot is shown from the front view. The camera module was mounted on the chassis and allowed the robot to take forward-facing still shots to detect humans and to analyse their posture. The camera module successfully sent continuous video frames to the Raspberry Pi, which were processed by the computer vision algorithms to detect human presence.

Results have shown that the design of the system does provide the necessary functionality of performing surveillance, detection, and engagement of individuals. It has also validated the potential to successfully combine AI, IoT, and robotics for real-time security Applications.

However, there were challenges with the performance of the vision system due to low light or a challenging background. The accuracy of navigation will be affected by sensor calibration and environmental condition. Improvements can be made in the future by using enhanced sensors, new and improved algorithms, and/or improved hardware configurations.

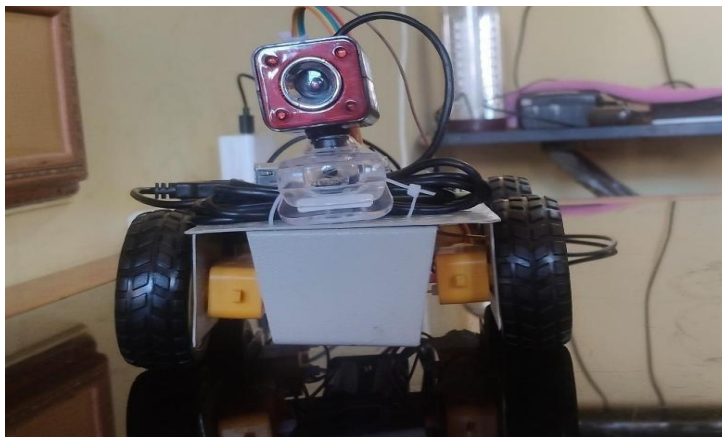


Fig.3. Front view of patrolling robot with camera module for real-time human detection and surveillance.

To summarize, the results from testing demonstrate that an AI based patrol robot provides a reliable and efficient solution for automated surveillance through the ability to monitor activities in real-time, reduce the need for human intervention, and serve as a platform to support future improvements of intelligent security systems.

VII.DISCUSSION

The goal of this research was to design and build an AI driven patrolling robot to improve safety and tracking of public and campus places. This robot uses integration of Artificial Intelligence, Internet of Things (IoT) Technologies and Robotics to develop an intelligent, independent way to monitor.

The way this robot navigates and monitors is by autonomously traveling along a specified path while continually monitoring through live video processing. With the ability of the robot to detect human presence and evaluate their position using computer vision and machine learning, it can assess an individual's state of being (in general terms) and identify a possible emergency situation.

In particular, this research included the development of an Internet of Things (IoT) alert system that provides immediate contact with authorities and emergency responders. When the robot detects a possible emergency, it will communicate to the authorities via the IoT alert system and send detailed information about the location, time/date, and an image of the situation using the cellular data network to expedite any necessary first response.

Ultimately, the work provided in this report reduces the amount of time needed to complete a manual surveillance and therefore decreases the probability that first responders will take longer than necessary to provide assistance in an emergency situation.

The new system has many benefits, such as 24-hour around-the-clock monitoring capabilities, less human effort than other systems, a greater accuracy level when detecting events and providing faster response times for emergencies. This new system's modular and scalable design give it the ability to be tailored to many different applications, including campus settings, industrial sites, healthcare facilities, public gathering locations, and smart city applications.

AI robotic patrols provide an effective, reliable, and smart solution for existing types of surveillance systems. They also represent a transition from being passive observers to being able to engage through active intervention, therefore helping to provide safer/smarter spaces as well. Future upgrades of AI robotic patrols include continuing to develop deep learning models, improved navigation algorithms, and upgraded cloud-based analytic capabilities that will enhance both the performance and scale of the solution.

VIII.CONCLUSION

The AI-based patrolling robot provides an intelligent, autonomous, and cost-effective surveillance solution by integrating AI, IoT, and robotics to enhance real-time security monitoring and emergency response.

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