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Autonomous Night Patrol Robot with Real-Time Monitoring using Raspberry Pi

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Abstract—This paper introduces a fully autonomous security patrolling robot designed to enhance premises security using night vision cameras and sound sensors. The robot navigates a predefined path using an IR-based line-following system, stopping at set points along the route. When it detects a sound after hours, the robot proceeds along its path toward the source, using its 360-degree rotating HD camera to scan the surroundings for intrusions. If human faces or suspicious sounds are detected, the robot captures and transmits images immediately. These images are sent over a Local Area Network (LAN) to alert users, accompanied by an audible alarm. By continuously patrolling large areas without human intervention, the robot provides real-time monitoring and alerts, adding an extra layer of security to the facility. It offers tireless surveillance, ensuring comprehensive protection of the premises. This intelligent patrolling system effectively combines IoT technology, sound detection, and facial recognition to deliver reliable, autonomous security.

Index Terms—Patrolling, IOT, Raspberry pi module, Noob software

I. INTRODUCTION

In today's world, the need for efficient and reliable security systems has never been greater. Facilities such as warehouses, offices, and large industrial sites require constant surveillance, which is often impractical to achieve with human personnel alone. To address this need, the concept of a Night Vision Patrolling Robot using Raspberry Pi has been developed. This research aims to introduce an autonomous security robot designed to patrol designated areas, equipped with advanced features like night vision and sound detection to enhance the safety and monitoring capabilities of any facility [1].

The primary objective of this robotic system is to secure the entire area by responding immediately to any suspicious sounds detected within its range. The robot is programmed to automatically move toward the location of the sound, capture real-time images, and send them to the user for review. Any unusual sound triggers the system to investigate, allowing for prompt surveillance of potential threats. At the core of this system lies the Raspberry Pi, which, connected to the camera, enables the robot to operate independently and respond dynamically, making it an essential part of this fully automated security solution[2].

With advancements in technology, robotics has evolved to become a transformative field that impacts daily life by automating complex tasks and reducing human effort. This system exemplifies these advancements, as the robot operates continuously and autonomously, requiring no direct human intervention. Designed to function similarly to a computer, the robot can be operated remotely, making it versatile for various applications. By combining real-time image capture with automation, the robot reliably monitors assigned areas, providing a comprehensive security solution [3].

The robot is also capable of 360-degree image capture, allowing it to record its surroundings from all angles. The captured images are immediately transmitted to the user in real time, enabling quick analysis and response to any observed security issues. The system uses advanced algorithms to enhance image quality and optimize transmission. The user can then assess the situation remotely and decide on necessary actions if a problem is detected. This Night Vision Patrolling Robot integrates robotics and IoT technologies to create an advanced, efficient, and autonomous patrolling system that enhances the security of large areas without the limitations of human surveillance [4].

II. RELATED WORK

J. Ghanem Osman Elhaj Abdalla implemented a surveillance system utilizing a spy robot powered by a

Raspberry Pi module and connected through internet protocol. This system is particularly relevant for border surveillance, where night patrolling is essential for detecting intrusions that may otherwise go unnoticed in the dark. Abdalla's design, which incorporates a night vision camera and sensors, allows for remote monitoring of activities near the border and relays the information to nearby security units through a web server, making it available for real-time surveillance on a webpage [5].

Takato Saito and Yoji Kuroda explored the use of GPS for tracking mobile robots with a place recognition system. This study emphasizes the importance of GPS in accurately localizing mobile robots, especially in terms of tracking their position in various environments. The authors noted that signal stability and accuracy are significant challenges, particularly in congested or out-of-coverage areas where GPS signals may be lost. To address these issues, they utilized a dual-observation approach with GPS data and place recognition, thus improving tracking reliability and minimizing the risk of losing the robot's position [6].

Cheng Tang, Qunqun Xie, Guolai Jiang, and Yongsheng Ou developed a road-monitoring model based on planar reflection to enhance nighttime surveillance. Their system classifies road pixels using infrared imaging, allowing for the detection of pedestrian activity and other anomalies. Although previous designs primarily focused on daytime monitoring, this model adapts to nighttime conditions by classifying road pixels using infrared reflections. However, challenges such as distinguishing between road surfaces and other objects, like birds or vehicles, can complicate detection, as the model solely depends on pixel classification to determine the road [7].

In 2017, Kirk MacTavish, Michael Paton, and Timothy D. Barfoot proposed the "Night Rider" system, a visual odometry technique for mobile robots using headlights as a lighting source. Their system estimates a robot's movement by processing a sequence of images captured by a stereo camera. Since cameras are low-cost yet data-intensive sensors, they are highly suitable for mobile robots, though they require external power sources. Headlights serve as alternative light sources, enabling visibility in low-light environments. This research tackled challenges like limited visibility range and intensity control, investigating how lighting conditions affect visual odometry during extended nighttime operations [8].

A study titled "Design and Implementation of Security Patrol Robot using Android Application" was presented at the 2017 IEE Asia Modeling Symposium. This work highlights the development of an autonomous and reconfigurable security robot that integrates multiple sensors, suitable for various applications, including home and office security. The robot's design focuses on using an Android application to control and monitor the robot's functions, demonstrating the potential for flexible and mobile security solutions through multi-sensor arrays.

In 2015, Q. Yu, T. Zhang, and X. He developed a patrol robot system that uses an ultrasonic sensor to improve obstacle detection and avoidance. The study highlights the use of sensors for effective navigation in unknown environments, where obstacles may impede the robot's path. Their approach involves combining sensor data to detect objects in the robot's vicinity, enabling it to adjust its route dynamically. This method is particularly useful for patrolling in complex environments, where static path-following would be insufficient for complete coverage and safety [9].

S. Ramesh and M. Venkatesh proposed a night vision robot for military surveillance, which operates on a pre-set route to monitor and capture real-time video in restricted or sensitive areas. Their system is designed with a night vision camera and transmits live footage to a remote-control room, allowing for instant monitoring of intrusions. This approach highlights the importance of night vision technology for critical applications, especially in military settings where visibility is often limited. The authors emphasize how such systems can enhance situational awareness, enabling quick responses in cases of intrusion or unexpected movement [10].

A. Kumar and P. Mehta researched an IoT-based surveillance robot with face detection capabilities in 2018. Their work involves using a camera linked to IoT networks to transmit video data to a remote location. The robot integrates facial recognition algorithms, allowing it to identify and track potential intruders autonomously. By implementing IoT, this design enables remote control and monitoring, which enhances the security and management of larger facilities. The study demonstrates how IoT and artificial intelligence can together improve the adaptability and functionality of autonomous robots in surveillance applications [11].

III. PROPOSED METHODOLOGY

Basic design flow of this project is shown in the figure. It consists of Raspberry pi module, Camera, Sound sensor, Wi-Fi module, Camera direction control unit, Robotic motor driver board, Motors and power supply. Robot will be move in predefined path by using predefined commands from pc or laptop/ Smart Phone Sound sensor is used to detect the sound and whenever sound detected raspberry pi module turn on the camera to capture images. 360-degree camera direction control unit is designed here to move the camera in all direction [4]. Through the Wi-Fi module captured images are transmitted to remote monitoring section. Robotic motor drive is used to run the robotic motors

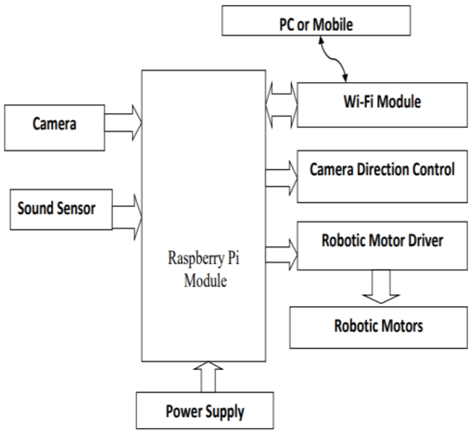

Figure 3.1. Block Diagram of proposed system

3.1 Raspberry Pi

The Raspberry Pi, introduced in 2012, is a versatile, low-cost computer designed to promote programming and development in a compact form factor roughly the size of a credit card. Over the years, various generations of Raspberry Pi boards have been released, each building on the foundation's mission of accessibility and affordability. Early models like the Raspberry Pi 1 Model B and Model A established this platform's core, followed by improved models such as the B+ and A+, which offered enhanced features for a similar price. The Raspberry Pi Zero, released in 2015 for just $5, provided a smaller form factor and reduced I/O capabilities, making it ideal for compact projects. More advanced models, such as the Raspberry Pi 2 and Raspberry Pi 3, introduced increased RAM, integrated Wi-Fi, and Bluetooth, further expanding the possibilities for both beginners and developers in IoT and embedded systems.

All Raspberry Pi models are powered by a Broadcom SoC that includes an ARM-based CPU and VideoCore IV GPU, with CPU speeds ranging from 700 MHz to 1.2 GHz and memory capacities from 256 MB to 1 GB of RAM. These devices rely on SD cards for storage and program memory, and most models feature one to four USB ports, HDMI output, composite video, and a 3.5 mm audio jack. GPIO pins provide low-level interfacing for protocols like I²C, enabling custom electronics integration. While the B-models include Ethernet ports, the Raspberry Pi 3 and Zero W models add onboard 802.11n Wi-Fi and Bluetooth, broadening the scope for wireless applications. The Raspberry Pi Foundation offers "Raspbian," a Debian-based Linux distribution, as the primary OS, with additional support for Ubuntu, Windows 10 IoT Core, and other specialized distributions, enabling users to work in various programming languages like Python and Scratch[12].

3.2 Processor and its performance

The Raspberry Pi series has significantly improved in processing power across generations. The original Pi used a 700 MHz ARM11 CPU, delivering 0.041 GFLOPS, with a GPU offering 1 Gpixel/s and 1.5 Gtexel/s, similar to an Xbox (2001). The Pi 2 upgraded to a 900 MHz quad-core ARM Cortex-A7, improving performance by 4-6 times, and up to 14 times faster in parallel tasks. The Pi 3, with a 1.2 GHz quad-core ARM Cortex-A53, offers 10 times the performance of the Pi 1, with a notable 1.14 GFLOPS achieved in the "Iridis-Pi" cluster at 216 watts[13].

3.3 Over clocking

The first and second-generation Raspberry Pi boards generally didn't require cooling unless overclocked, with overclocking options reaching around 800 MHz, and up to 1000 MHz in some cases. The Raspberry Pi 2 could be overclocked to 1500 MHz under extreme conditions, but this could void the warranty and risk damaging the chip without sufficient cooling. Overclocking is manageable via the "sudo raspi-config" command in Raspbian, with the system automatically throttling performance or shutting down overclocking if the chip exceeds 85°C. Newer firmware versions provide five "turbo" presets that dynamically adjust clock speeds and voltage to optimize performance and lifespan, with presets like none (700 MHz ARM), modest (800 MHz ARM), medium (900 MHz ARM), high (950 MHz ARM), and turbo (1000 MHz ARM, up to 1 GHz). The Pi 3 supports 1100 MHz ARM with additional over-voltage, and the Pi 2 and Raspberry Pi Zero also offer overclocking options. In high and medium settings, adjustments to core clock and SDRAM speeds, such as 600 MHz SDRAM, help prevent SD card corruption[14].

3.4 Development Noob software and python

NOOBS (New Out Of Box Software) is an easy-to-use operating system installer for the Raspberry Pi. To install NOOBS, simply format an 8GB or larger SD card as FAT, download and extract the NOOBS files, then copy them to the SD card. On first boot, NOOBS will resize the "RECOVERY" partition and display available OSes to install. It automatically ensures the latest version of each OS is installed. For formatting the SD card, Windows users can use the SD Association's Formatting Tool, while Mac and Linux users can use their respective built-in utilities. NOOBS simplifies OS installation, offering a user-friendly interface for selecting and installing operating systems, with easy reinstallation options via the SHIFT key on subsequent boots[15].

3.5 Flow chart

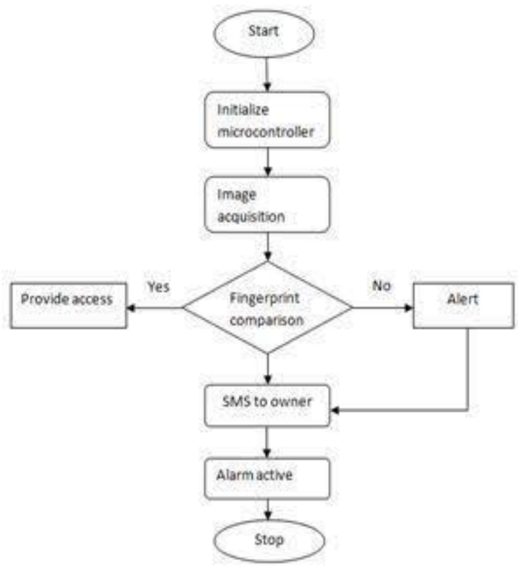

Figure 3.2. Flow chart

IV. RESULTS AND DISCUSSIONS

The paper deals with a security patrolling robot that uses night vision camera for securing any premises. The robotic vehicle moves at particular intervals and is equipped with night vision camera and sound sensors. It uses a predefined line to follow its path while patrolling. It stops at particular points and moves to next points if sound is detected. The system uses IR based path following system for patrolling assigned area. It monitors each area to detect any intrusion using 360degree rotating HD camera. It has the ability to monitor sound in the premises. Any sound after company is closed and it starts moving towards the sound on its predefined path. It then scans the area using its camera to detect any human faces detected. It captures and starts transmitting the images of the situation immediately on sound or human face detection. Here we use IOT gecko for receiving transmitted images and displaying them to user with alert sounds. Thus we put forward a fully autonomous security robot that operates tirelessly and patrols large areas on its own to secure the facility.

4.1 Images of Model

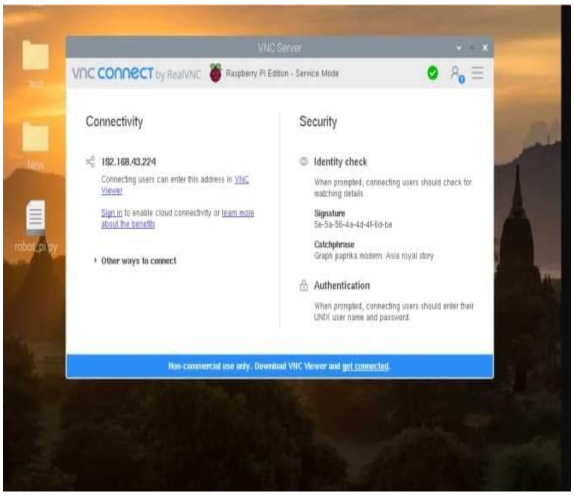

Figure 4.1: VNC server

Figure 4.2: Project model

Figure 4.3: Images captured by the model

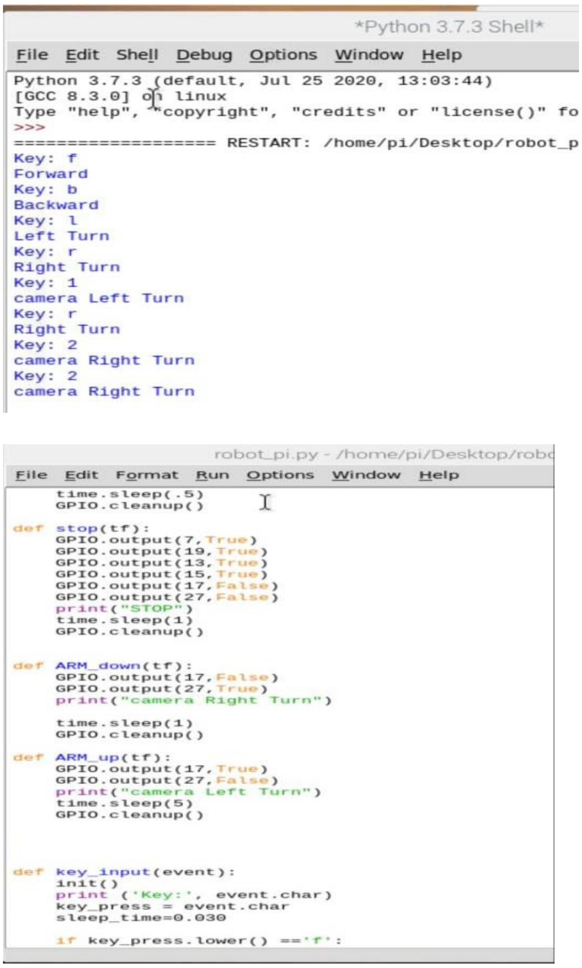

Figure 4.4: Coding

V. CONCLUSION

The robot is equipped with multiple sensors to navigate and monitor its environment efficiently. It utilizes two infrared sensors on both sides to detect obstacles in its path, allowing it to change direction when an obstruction is detected. A microphone is integrated into the system to pick up real-time sounds in the surroundings, transmitting this data to the monitoring system for immediate action. Additionally, a vision camera captures live images and videos, providing valuable visual feedback for the controller.

The movement of the robot is powered by two motors, which are controlled with a specific amount of input current to prevent excessive power from damaging the Raspberry Pi model. With minimal gears in the motors, the robot experiences lower power consumption, optimizing energy efficiency. The project ultimately results in a security robot designed for patrolling, equipped with a night vision camera for enhanced visibility in low-light conditions. The robot follows a predetermined path, capturing and sending real-time images to a control room for monitoring and timely intervention.

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