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This is to certify that Dr./Mr./Ms. Arun Kumar Shukla

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Anomaly Detection and Monitoring System for Elderly Citizens

A. K. Shukla[a], A. Sharma[a], H. Saini[a], R. K. Ratnesh[a*]

[a]*Department of Electronics & Communication Engineering, Meerut Institute of Engineering & Technology, Meerut, UP, 250005, India*

[*]Corresponding author:
E-mail: ratnes123@gmail.com ; ratneshwar.ratnesh@miet.ac.in

***Abstract*— Anomaly detection is crucial for identifying unusual activities within daily routines, and the Internet of Things (IoT) has emerged as a pivotal tool in this realm. This study focuses on using IoT to remotely monitor and detect anomalies in the daily lives of elderly individuals, enhancing their demographic supervision and overall well-being. Our research aims to develop a remote monitoring system for elderly individuals at home or in rehabilitation, centering on their daily routines. In cases of delayed routines or lack of response, our proposed system, utilizing the cost-effective ESP32-CAM module, will capture video and images of their daily activities to identify anomalies like falls or wandering. Machine learning algorithms will further analyze face images to alert caregivers or family members when anomalies are detected. This IoT-based approach will provide vital demographic information and improve the safety and quality of life for elderly individuals.**

***Keywords*—Anamoly behaviour detection, IoT based monitoring, Data collection by ESP32-CAM based system.**

I. Introduction

There are various ways through which we can stay in contact with object of interest (Elder Citizens) back at home/specified location, while we are working away from them such as - calls, WhatsApp, Facebook, and other social media handles. The problem arises when they are not in condition of picking up the call and then next possible way to reach them would be to call neighbours but what if they do not respond to door bells either? Then the next solution that come to mind is to call the cops to break the door and let us know, what has happened. So, we designed a solution which will help us to avoid such situations. This project is mainly useful for an elderly citizen living alone who had difficulty to remember to take their medications on time [1]. An anomaly detection and monitoring system using ESP32 Cam can be programmed to detect when medication or such routines are not performed at the predefined time, and send an alert to the care person or monitoring family member [2]. This allows for prompt intervention, ensuring that the elderly citizen receives their medication on time and reducing the risk of adverse health outcomes. This project proposal is to make sure that people can watch their elderly persons in rehabilitation space any time. If they are moving to different rooms, the robot that we made will be able to reach/ follow them in room where they are presently available. In order to make robot learn the path between different rooms we will create mapping corresponding to each room's distance from charging station of robot. By doing this anyone can customize the distance according to their home. A robot made of ESP32-CAM module is a low-cost and efficient solution for monitoring and securing indoor environments. This paper presents the development and evaluation of such a monitoring robot, which integrates an ESP32 microcontroller and a camera module to capture and transmit video and images wirelessly. The robot's architecture and functionality are described, and its performance is evaluated in terms of image and video quality, transmission range, battery life, and object detection.

Other studies have explored the use of ESP32-CAM module-based systems for detecting and monitoring anomalies in the home environment of elder citizens. An ESP32-CAM module-based system was used for monitoring the indoor air quality of the elder citizen's home. The system was able to detect anomalies such as high levels of carbon monoxide, which could be harmful to the elder citizen's health [3][4].

However, further research is needed to explore the full potential of ESP32-CAM-based systems for anomaly detection and monitoring for elder citizens and to develop more advanced applications and features.

II. Tool and Techniques

A. Software tools

Arduino IDE, short for Arduino Integrated Development Environment, is a software platform designed specifically for programming Arduino boards. It serves as the official programming software provided by Arduino for developing projects using their microcontroller-based boards. At its core, Arduino IDE provides a user-friendly interface that allows users to write, compile, and upload code to Arduino boards. It simplifies the process of creating and uploading code, making it accessible to both beginners and experienced developers. One of the main features of Arduino IDE is its code editor. The editor provides a text-based environment where users can write their Arduino code. It offers syntax highlighting, auto-indentation, and code completion, which help improve code readability and productivity [5][6].

B. Hardware tools

The ESP32-CAM module is based on the ESP32 microcontroller, which is a powerful and feature-rich Wi-Fi and Bluetooth enabled chip. The module incorporates a camera sensor along with supporting circuitry to capture and process images or videos. The ESP32-CAM module features an OV2640 camera sensor, which is capable of capturing images with a resolution of up to 2 megapixels. The camera sensor supports various image formats, including JPEG and BMP, and can also record video in formats such as AVI and MJPEG. One of the standout features of the ESP32-CAM module is its support for wireless connectivity. The underlying ESP32 microcontroller provides built-in Wi-Fi and Bluetooth capabilities, enabling seamless integration with IoT networks [7] and communication with other devices [8].

The L298N motor driver is a highly versatile and widely used integrated circuit (IC) designed to control and drive DC motors [9]. It offers a comprehensive solution for controlling the direction and speed of motors in a variety of robotics, automation, and electronic projects. The L298N motor driver incorporates two H-bridge circuits, allowing it to independently control two DC motors. Each H-bridge consists of four transistors that can be controlled to drive the motor in either direction, enabling forward and reverse motion. This bidirectional control is crucial for many applications, including robot navigation, motorized vehicles, and motor-driven mechanisms.

The SG90 servo motor is a popular and widely used miniature servo motor known for its compact size, affordability, and versatility in various hobbyist and robotics applications. It is a rotary actuator that converts electrical signals into precise mechanical movement. The SG90 is a type of small-sized servo motor commonly used in projects. It is a 9-gram micro servo that can rotate approximately 180 degrees, making it suitable for controlling small mechanisms that require precise angular positioning [10]. The SG90 operates on a pulse-width modulation (PWM) signal, which means that the servo receives a series of electrical pulses that determine the position it should move to. The servo has three wires: red for power (typically 5V), brown for ground, and orange for signal.

The CP2102 is a USB to UART bridge controller that provides a simple way to connect microcontrollers and other embedded systems to a host computer through a USB port. It is commonly used in Arduino and other development boards to enable communication between the board and the computer [11]. The CP2102 module is a small board that contains the CP2102 chip and the necessary components for USB communication. It typically has a USB Type-A connector on one side and a set of pins on the other side for connecting to the microcontroller or other device. The CP2102 module supports full-speed USB (12 Mbps) and provides a standard UART interface with baud rates from 300 to 1.5 Mbps. It also supports various flow control modes, such as hardware flow control and the XON/XOFF software flow control. The CP2102 module is easy to use and requires no external programming or driver installation. It has a compatibility with a wide range of operating systems, including Windows, Linux, and Mac OS X. The module can be easily integrated into a variety of projects, such as data loggers, GPS receivers, and wireless modules. The CP2102 module is a simple and reliable solution for adding USB connectivity to microcontroller-based projects. It provides a standard UART interface and supports various flow control modes.

11.1V lithium polymer batteries are rechargeable batteries that are commonly used in remote control vehicles, drones, and other hobbyist applications. They are also known as 3S (three-cell) LiPo batteries, as they consist of three individual lithium polymer cells connected in series, with each cell providing a nominal voltage of 3.7V. Lithium Polymer (Lipo) batteries are now used in many consumer electronics devices. They have been gaining popularity in the radio-controlled device’s industries over the last few years and are the most popular choice for anyone looking for long run times and high-power output. When fully charged, an 11.1V lithium polymer battery has a voltage of around 12.6V, and its capacity is usually measured in milliampere-hours (mAh). The capacity of an 11.1V lithium polymer battery can range from a few hundred mAh to several thousand mAh, depending on the specific model. It is important to handle and use lithium polymer batteries with care, as they can be dangerous if mishandled or improperly charged. The complete schematic diagram of anomaly detection robot is shown in fig.1

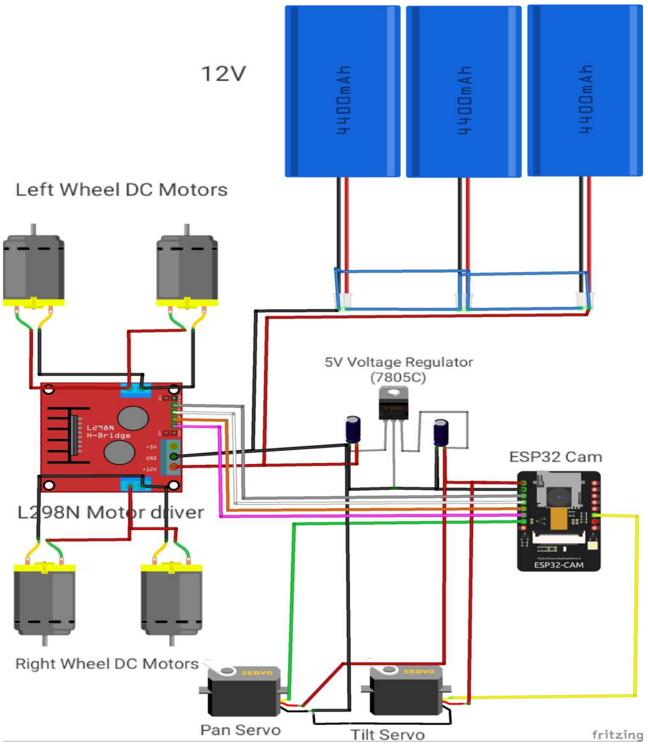

Fig. 1 show the schematic representation of anomaly detection robot.

C. Robot's architecture and functionality

The live streaming HTTP server for anomaly detection and monitoring system for elderly citizens using an ESP32 Cam module allows real-time video streaming [12] of the robot's camera feed to connected clients over a network. The system starts by initializing the ESP32 Cam module and establishes a connection to a Wi-Fi network. The necessary libraries are imported to support the server implementation as shown in fig. 2.

An HTTP server is created using the ESPAsync WebServer library. This server listens for incoming HTTP requests and defines routes to handle different types of requests. The camera module is initialized with specific settings such as resolution and frame rate using the appropriate camera library for the ESP32 Cam module. A dedicated route is set up within the server to handle the video streaming request. This route acts as the endpoint for clients to access the live video feed [13]. The camera continuously captures video frames according to the specified frame rate

Each captured frame is encoded into a suitable format, typically JPEG or MJPEG, for efficient streaming. Compression techniques are applied to reduce the data size while preserving acceptable image quality. When a client sends a request to the designated route, a connection is established between the client and the server.

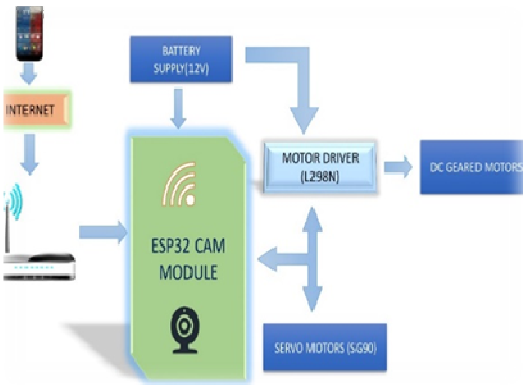

Fig 2: show the working model of anomaly detection robot [14][15].

The client can be a web browser or a specialized video player application. As new video frames are captured and encoded, they are sent over the network to the connected clients. The server transmits the frames as a continuous stream of data, typically in chunks or packets. The data transmission follows the HTTP response mechanism, utilizing the "multipart/x-mixed-replace" content type. On the client side, the received video stream is decoded and rendered using appropriate methods or libraries. The client application interprets the incoming data and displays it as a live video stream, allowing users to monitor the surveillance footage in real-time. The process of capturing, encoding, and transmitting video frames continues in a loop to maintain the live streaming functionality. The server keeps sending new frames to the connected clients, ensuring an up-to-date video feed. By implementing this live streaming HTTP server, the anomaly detection and monitoring system for elderly citizens with the ESP32 Cam module enables users to remotely monitor the robot's camera feed, providing a real-time view of the robot's surroundings [16].

III. Result and Discussion

The performance evaluation of a monitoring system typically involves assessing its capabilities in several areas, including image and video quality, transmission range, and battery life, to determine its effectiveness in carrying out its intended monitoring system tasks.

A. Image and Video Quality

To evaluate the image and video quality of a monitoring system robot, it is important to assess the resolution, clarity, and color accuracy of the camera(s) used by the robot. This can be done by capturing footage in different lighting conditions and assessing the quality of the resulting images and videos. Image and video processing algorithms, such as image stabilization and noise reduction, can also be evaluated to determine their effectiveness in improving image and video quality.

B. Transmission Range

The transmission range of a monitoring system robot refers to the maximum distance over which it can transmit data, such as images and videos, to a remote location. This can be evaluated by testing the robot's ability to transmit data in various environments and assessing the quality of the transmitted data at different distances. Factors that can affect transmission range include the strength of the robot's wireless signal, the presence of obstacles or interference, and the quality of the receiving equipment.

C. Battery Life

The battery life of a monitoring system robot is an important factor to consider, as it determines how long the robot can operate before needing to be recharged or have its batteries replaced. To evaluate battery life, the robot can be tested in various operating conditions and the duration of its operation recorded. Factors that can affect battery life include the robot's power consumption, the type of batteries used, and the efficiency of the robot's power management system.

D. Performance

The performance of monitoring system and camera modules can vary depending on several factors, such as their hardware, software, and application environment. Here are some comparisons of the performance of monitoring system robot with other monitoring system and camera modules:

Performance of monitoring system robot compared to other monitoring system robots:

Monitoring system robots can vary widely in their capabilities and performance depending on the specific model and application. Some factors that can affect their performance include the quality of their sensors, the effectiveness of their algorithms, and the reliability of their mobility systems. When compared to other monitoring system robots, the performance of a given robot can be evaluated based on factors such as its range of motion, coverage area, image, and video quality, and tracking and detection accuracy.

Performance of Monitoring system Robots Compared to Camera Modules:

While both monitoring system and camera modules are used for monitoring purposes, they have different capabilities and limitations. Camera modules are typically fixed in place, providing a limited coverage area, and require additional equipment for remote control and data transmission. In contrast, monitoring system robots are mobile, providing wider coverage and the ability to navigate challenging environments. However, the mobility and additional functionality of monitoring system robots often come at a higher cost compared to camera modules. The performance of monitoring system robots and camera modules can be evaluated based on their specific capabilities and limitations, as well as the demands of the monitoring system application. It is important to carefully consider factors such as range of motion, coverage area, image, and video quality, and tracking and detection accuracy when choosing between different monitoring system options.

E. Angular Change in Servo Motors

In servo motors, PWM signals can be used to control the angles and speed of rotation of camera. The duty cycle of the PWM signal helps to determine the position of the servo motors. As we analyze the duty cycles of PWM signal using DSO (Digital Signal Oscilloscope). By analyzing the PWM signals for varying duty cycles of 5% and 29%, we find deflection in mobility of camera in the terms of live video angular variation of camera which are corresponding to said duty cycle. The image of the varying duty cycle is as shown in fig.3.

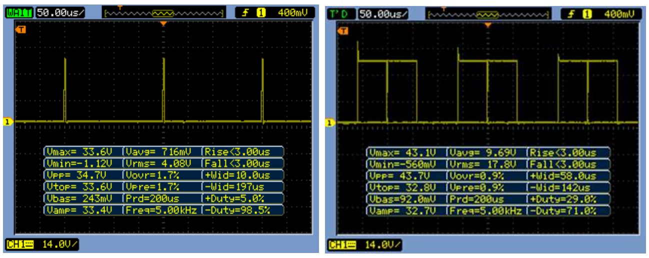

Fig. 3 shows the angular change from 13.5 & 36.45 corresponding to duty cycle 5% and 29%.

F. Flash Brightness Change

In anomaly detection and monitoring system for elderly citizens using ESP32 Cam, brightness plays important role in proper visibility and detection of object of interest. As PWM signals, can also be used to control the brightness of the flash. The duty cycle of the PWM signal determines the intensity of the flash light. By analyzing the PWM signals using DSO, the brightness of the flash can be monitored to ensure optimal lighting conditions for image and video capture. The PWM signals on 19.5 % and 55.5% duty cycle are as follows which indicate a variation in brightness of flash are shown in fig. 4.

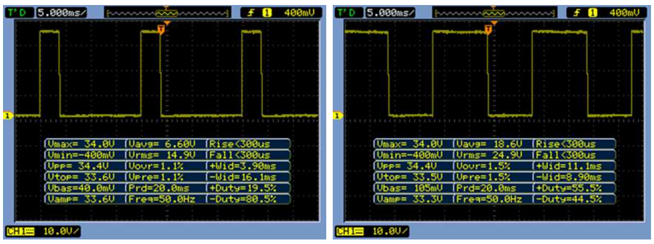

Fig. 4 shows the approx. intensity variation of flash from 0.26 & 0.80 corresponding to duty cycle 19.5% and 55.5%.

IV. STRENGTH & LIMITATIONS

The monitoring system robot made of ESP32 Cam module has several strengths and limitations that are worth discussing.

A. Strengths

1) Low cost: ESP32 Cam module is a low-cost development board that can be easily integrated into a monitoring system robot, making it an affordable option for many applications.
2) Real-time monitoring: The monitoring system provides real-time monitoring of the environment and the elder citizen's health, allowing for timely response in case of an emergency.
3) Anomaly detection: The system is capable of detecting anomalies such as falls, wandering, and abnormal behaviour. This can help prevent accidents and provide early intervention for health issues.
4) Low-cost: The ESP32-CAM module is a low-cost solution for monitoring elder citizens' health and wellbeing, making it an affordable option for many families.
5) Customizable: The system is highly customizable, allowing for the addition of sensors and other components as needed.

B. Limitations

1) Limited range: The ESP32-CAM module has a limited range for wireless transmission. This means that the robot must be within range of a Wi-Fi network to transmit data.
2) Limited battery life: The robot's battery life is limited and will need to be recharged regularly. This could be a limitation if the robot is needed for continuous monitoring.
3) Limited functionality: The monitoring system is limited in its functionality, and cannot provide physical assistance to the elder citizen or perform tasks such as cleaning or cooking.
4) False alarms: The anomaly detection system may generate false alarms in case of sensor malfunctions or misinterpretation of sensor data.
5) Based on the strengths and limitations discussed above, there are several suggestions for further improvements and future research directions for the monitoring system robot made of ESP32 Cam module:
6) Mobility: To improve the mobility of the monitoring system robot, it can be equipped with motors or wheels, allowing it to move around more easily. This can increase its range of applications and make it more suitable for outdoor monitoring system or monitoring of large areas.
7) Power supply: To address the short battery life limitation, the monitoring system robot can be equipped with a more powerful battery or a charging station that allows it to recharge its battery while in operation. This can increase its operating time and allow it to operate for longer periods of time without the need for external power.
8) Processing power: To address the limitation of limited processing power, more powerful microcontrollers or processors can be used to improve the speed and accuracy of the monitoring system robot's detection and tracking capabilities.
9) Range: To address the limitation of limited range, alternative communication methods such as cellular or satellite can be used to enable the monitoring system robot to transmit data over longer distances.
10) Additional functionalities: To address the limitation of limited functionality, additional sensors or modules can be added to the monitoring system robot to increase its

range of capabilities, such as infrared sensors for night vision or obstacle avoidance sensors.

11) Artificial intelligence: Future research can focus on incorporating artificial intelligence algorithms into the monitoring system robot to improve its detection and tracking capabilities. This can involve the use of deep learning or computer vision techniques to improve the accuracy and reliability of object detection and tracking.

V. Conclusion

The interpretation of results from monitoring system robots or camera modules has significant implications for monitoring system applications. Accuracy, reliability, and effectiveness in object detection and tracking, as well as system coverage, are critical factors impacting safety and security. If robot tests demonstrate accurate detection and tracking in various environments, the robot is deemed suitable for accurate and reliable monitoring applications like security or border control. Conversely, low accuracy or frequent false alarms indicate ineffectiveness, prompting the exploration of alternative monitoring options. Similarly, camera module tests reveal image and video quality, coverage range, and object detection capabilities. These results inform the camera module's suitability for specific monitoring system applications, such as security or safety monitoring in a designated area. The careful evaluation and consideration of these results are essential for selecting the most appropriate monitoring system solution for a given environment and application.

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