An IoT based Approach to Smart Surveillance System

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***Abstract*—Security is an essential aspect for an individual or an organisation. Public places like institutions, organisations, banks, parks, etc or even homes need to be guarded to prevent theft or an attack. It is impossible for a single guard to man all the probable locations of intrusions at the same time for 24 hours and adding multiple guards will increase operational costs thereby adding financial burden on institutions. CCTVs are a static mode of surveillance as they are immovable and it needs multiple devices to be set up to completely cover an area. We aim to provide a solution by developing an IoT based Smart Surveillance System. This system consists of a robot with wheels attached which makes it mobile in nature and has an ultrasonic sensor mounted for object detection and the components are controlled by Arduino UNO. Also the robot has a camera mounted on top for Face Detection and the camera is controlled by Raspberry Pi. The system displays a live video feed and also notifies the user if a face is detected on the video feed, by raising an alarm and also on registered email along with the last captured frame. Thus, our system will help in safeguarding important places with minimal effort and will provide timely updates.**

Keywords— alert, face detection, obstacle detection, security, surveillance

I. INTRODUCTION

The Internet of Things (IoT) is a network of various components connected together and aiding each other for smooth functioning. These components are various devices like sensors, mechanical or digital machines, objects, etc. Unique Identifiers (UIDs) allow to maintain security of data generated through IoT applications. IoT applications aim to reduce human dependence by lowering human-to-human and human-to-computer interacions. IoT applications help humans leave mundane tasks and concentrate on much important tasks. IoT not just offers smart home automations or individual level automations but also can prove to be a gamechanger for businesses with real-time tracking, monitoring and providing insights about supply chain, stock, etc. [1].

With the growing usage of technology, many conventional practices are being updated to harness and yield better results with the use of technology. CCTVs are installed in both public and organiztional space to get live video feed of a place from a remote location. But, as the time evolves, there is a need to update the existing systems to counter newer challenges. Many studies have shown that an intrusion or a hostage situation on most occasions involves people armed with some kind of weapon which might be harmful to an unarmed human or a first responder to deal with. A mobile robot capable of capturing video and then displaying them will be much more beneficial than CCTVs fixed on the walls. Also the ability to perform face detection and accordingly update the owner or operator through different means is an added advantage. This system not only finds its usage in monitoring and surveillance activities but also with a few added components it can help in search and rescue operations where it might be difficult for a human to reach. This will ensure lesser loss of lives in a disaster or an attack. While our system is intended for indoor use, with some modifications it can be useful in outdoor conditions such as border regions. We are aiming to eradicate human dependence on security through our system that will be cost-effective and much more accurate.

II. RELATED WORK

The study by T. Akilan *et al.* [2] discussed the use of robotics and the Internet of Things (IoT) to monitor people through the use of human surveillance. It used an Arduino UNO microcontroller which was controlled by a smartphone and a computer. The efforts were aimed at creating a spy robotic vehicle that can do continuous surveillance in a dangerous setting. With the aid of a wireless camera, their robot captured real-time streaming throughout both the day and the night. Data was transferred to the Android smartphone that is connected after being monitored while it is live streamed. While the PIR sensor picks up movement while keeping watch over any person or animal in a dangerous area, Android applications can remotely manage the robot's path using WiFi. using the suggestion. It is too complex for a domestic setting. Also it has no alert facility to inform users about any possible breach.

V. Ratna Kumari *et al.* [3] developed a clever and effective mechanical framework, customized to give a stage to observable reason.In order to replace humans in hazardous activities like mining, investigation, watching sensitive areas, and other uses that are at a greater distance from danger.This goal aided in controlling the robot's camera feed that was sent back to their computer. It can be remotely controlled from any remote location using an IP address. They performed continuous object discovery using these video

feeds, allowing them to identify the object. In the recommended architecture that follows, a single camera was mounted on a mobile robot that can move in all directions and take pictures from various vantage points.The use of quick computer processing, high-definition cameras, machine learning, and long-range image sensors is the practical significance of their suggested effort.

The surveillance robot developed by K. RajKumar *et al.* [4] did scale both horizontal and vertical surfaces while automatically regulating surface transitions. It was capable of navigating confined spaces and transmitting live video to distant workstations over wireless channels. Wireless cameras also conveyed real-time video signals that may be viewed on a distant monitor and responded to accordingly. This system used Arduino, which served its purpose as it is good at connectivity. By simply plugging a Wi-Fi dongle into one of its ports, one can control the robot from a remote end, say mobile or laptop, using Wi-Fi and the internet. But the robot lacked human face detection and alert capabilities rendering it less human independent.

Gaja Ashok *et al.* [5] developed a surveillance robot for web data monitoring that may be incorporated for monitoring remote and border areas that are vulnerable. Moreover, there were various obtrusions found as the Pi's live streaming capability enabled the analysis of camera video from any location using the internet. Any user can feel a great deal of protection with such a system as the method here was developed with the help of inexpensive PIR sensing element and smoke sensing element to trace out the intruders and to find the fireplace mishaps by utilizing a field Raspberry Pi that delivers a wireless order that was received on the website controller and exploitation of Raspberry problems.Recently installed CCTV cameras even have limited vision because they are stationary modules, but it is also possible for the user to log into the Raspberry Pi's camera from any remote location and view a live feed of whatever is going on in his premises. The above system is more suitable for home conditions as it lacks key components for outdoor surveillance. Also it lacks human face detection and alert capabilities.

In their paper, Bandi Narasimha Rao *et al.* [6] have suggested usage of a Raspberry Pi and IoT to create a security camera. The photographs were actually taken using a raspicam camera. As it only records video and takes pictures when motion is detected in the monitored area, the proposed surveillance system needed less storage capacity. This software used a database to organise the recorded video. Security is the primary duty of the local government, and the video recorder (in this instance, a mobile phone) receives the encoded signal from the camera over the internet protocol. They can simply integrate raspberry into the camera circuit because of its low power consumption, compact design, and reasonable pricing. They must first connect the raspberry pi to the raspberry camera in order to broadcast live video from the android device and store images and movies with various aspects. As the system only records video and takes pictures when motion is detected, it saves a large amount of capacity. This system needs to be installed at a fixed position and does not provide locomotive luxury and also there are no provisions made for establishing any alert mechanism.

Rahul Muppanagouda Patil *et al.* [7] have offered a cutting-edge surveillance system that uses Raspberry Pi, Amazon Web Services, and Google Drive to deliver results quickly. An economical surveillance system was created using the well-liked background subtraction method to identify motion, according to a report that goes into further detail. Other features were also included into the system using AWS services, such as SES for email notifications to users and AWS RDS for data storage. The system had a three-tier architecture, and it informed the user of pertinent data. This approach needed to be swift and precise because it allowed for real-time decision-making. The system also had a feature that treated motions that happened close together as a single motion. The created method makes it simple to implement efficient monitoring in any room or area of one's home. The system lacks locomotive properties and could have included a buzzer alarm to increase the probability of catching a suspect.

III. Proposed System

To enhance security of an individual and an organization, we have proposed the following system. Below block diagram illustrates all the components involved in working of our system and their respective connections. Also the flowchart explains the flow of processes involved in our system.

A. Block Diagram

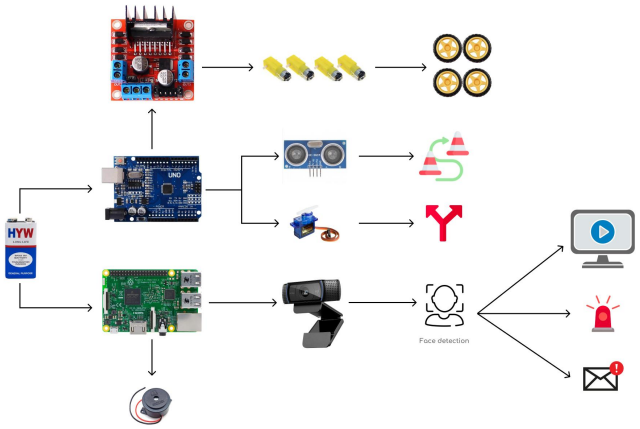

Fig. 1. Block Diagram

As seen in the above block diagram Figure 1, the power supply is connected to both Arduino Uno and Raspberry Pi. While the Arduino Uno is used for obstacle detection and movement of the robot, Raspberry pi facilitates face detection and alert mechanism. The chassis used is a 4WD and its wheels are controlled by DC motors which are operated by L298N Motor Driver. The Ultrasonic sensor is mounted on a servo motor which provides 180° coverage and it is used for obstacle detection. The Raspberry Pi is connected to a USB-camera and a buzzer. The camera will be used for face detection and also for displaying live footage. Once a face is detected, it can be seen in live footage, an alarm is raised and also an email containing the detected face is sent to the registered user. Also the user will be informed if the detected face moves away.

B. Flowchart

The entire surveillance system gets started as we connect both the Raspberry Pi and Arduino Uno to the power supply. Once the power supply is connected, obstacle detection and face detection occur simultaneously and independent of each other. If the ultrasonic sensor detects any obstacle, the DC

motors turn the wheels of the robot which subsequently changes its direction. This is a recurring process and it makes sure that the robot does not collide with any obstacle. On the other hand, if a person approaches the robot, their faces are detected and the users are alerted via an email and an alarm. Also the user gets notified in the live video feed too. This too is a recurring process as it keeps on detecting faces and sending alerts if a face is detected until the power supply is disconnected. The following image Figure 2, depicts the flowchart of the proposed system.

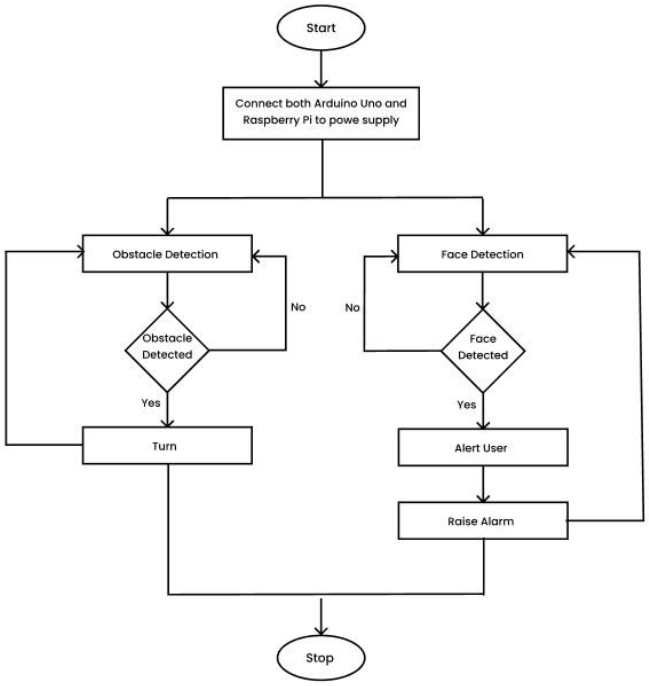

Fig. 2. Flowchart

IV. Hardware and Software Description

A. *Arduino Uno*

Arudino.cc developed an open-source micro-controller board Microchip ATmega328P micro-controller. This board is known as Arduino Uno. The Arduino Uno consists of 14 digital and 6 analog input/output (I/O) pins. These pins can be interfaced to various expansion boards and circuits. An Arduino Uno provides a number of facilities for communication with a computer or another board or even other micro-controllers too [8].

Fig. 3. Arduino Uno

B. *L298N Motor Driver*

An L298N module is a motor driver with characteristics like high voltage, high current, dual full-bridge module. This motor driver module is useful for controlling DC motors and Stepper motors. This modules has an L98N dual-channel H-bridge motor driver IC. For controlling speed and rotation direction of DC motors, two methods are put to use. They are:PWM (for speed control) and H-bridge (for rotation direction control) [9].

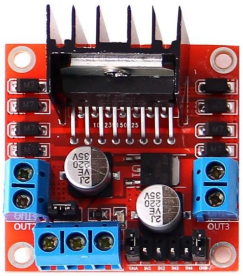

Fig. 4. L298N Motor Driver

C. *DC Motors*

A DC motor is an electric motor that requires direct current power to function. Electromagnetism is the basic concept behind functioning of a electric motor. Magnetic field is generated by a current-carrying conductor and if placed in an external magnetic field, a force will be encountered which would b proportional to current in conductor and also strength of external magnetic field. Its job is conversion of electrical energy to mechanical energy. As discussed above,the force that is encountered causes DC motors to rotate [10].

Fig. 5. DC Motors

D. *HC-SR04 Ultrasonic Sensor*

A device that is capable of measuring distance of a paricular object by emitting ultrasound is called an Ultrasonic sensor. An ultrasonic sensor makes use of a trasnducer to send and recieve pulses which provide information about an object's presence. Ultrasonic waves travel faster than sounds that a human can hear [11].

Fig. 6. HC-SR04 Ultrasonic Sensor

E. *SG90 Servo Motor*

A servo motor has rotational capabilities with great precision. These type of motors usually consist of a circuit that provides information about present position of motor shaft and this allows motors to turn properly. Servo motors are useful for rotatig an object at specific angles or distance [12].

Fig. 7. SG90 Servo Motor

F. *Raspberry Pi*

A Raspberry Pi is a tiny credit card sized single board computer. It can function as a mini computer upon connecting peripheral devices like a display, mouse, keyboard, etc. Also it can be used through remote access

using VNC server or teamviewer. Raspberry Pi finds its application in various areas like real-time Image/Video processing, IoT applications, Robotics, etc. Though slower than a laptop/desktop, still it can provide basic features and applications at absolutely ow power consumption. Also it is a programmable device and requires installation of Raspbian OS to be installed via an SD card which can be inserted in designated port [14].

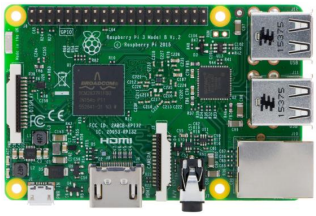

Fig. 8. Raspberry Pi

G. *Raspbian OS*

Raspbian or Raspberry Pi OS is a light-weight operating system based on Linux. While it was initially independently built, the Raspberry Pi foundation optimized and built an operating system exclusively for Raspberry Pi. The Raspbian OS comes with most features and applications that are necessary for normal day-to-day tasks and it can run on most Raspberry Pi boards with a few notable exception like the Raspberry Pi Pico due to smaller form factor and computing power [15].

H. *Python*

Python is high-level, interpreted, object-oriented and dynamically semantic programming language developed by Guido van Rossum. It is one of the most favoured for Rapid Application Development due to its offering of built-in Data Structures and dynamic typing allowances. It is also useful as a scripting language which acts as a glue and binds existing components together [16].

I. *VNC*

Virtual Network Computing (VNC) is a desktop-sharing mechanism which uses Remote Frame Buffer protocol. This protocol allows remote control of one computer via an another computer. VNC transmits graphical-screen updates as well as mouse and keyboard inputs over a network [17]. There are two parts of a VNC mechanism viz. VNC Server and VNC Viewer. VNC server on a device shares the display and updates over a headless server and allows the client to control it. VNC Viewer (client) enables an another user to control and access the display and updates remotely [18].

J. *OpenCV*

OpenCV is a vast open-source library that finds its applications in computer vision, machine learnign and mage processing as well as real-time operaios which requires continuous monitoring. It helps in processing images and videos to identify faces, humans, objects, handwrittings, etc. OpenCV combined with other libraries such as NumPy, comlex projects can be built where image processing is requred [19].

K. *Smtplib*

The Simple Mail Transfer Protocol (SMTP) is an electronic mail transmission communication protocol. SMTP is an Internet standard first defined in 1982 and further updated in 2008 for extended additions. SMTP is used by mail server and agents to send and recieve Emails. The smtplib is a built-in python library for utilizing SMTP features. It abstracts SMTP complexities and offers simple usage [20]

V. IMPLEMENTATION

The following image Figure 9, shows all the primary components that are used in the proposed system

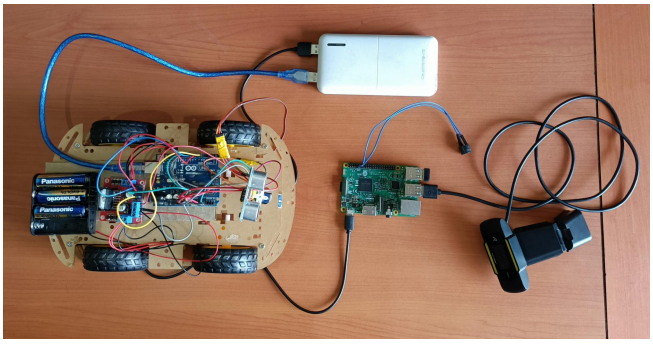

Fig. 9. Components Used

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The following image Figure 10, shows the front view of the Surveillance Robot.

Fig. 10. Front View Robot

The following image Figure 11, shows the side view of the Surveillance Robot.

Fig. 10. Side view of Robot

The following image Figure 12, depicts the desktop of Raspberry Pi which is displayed remotely using VNC Viewer.

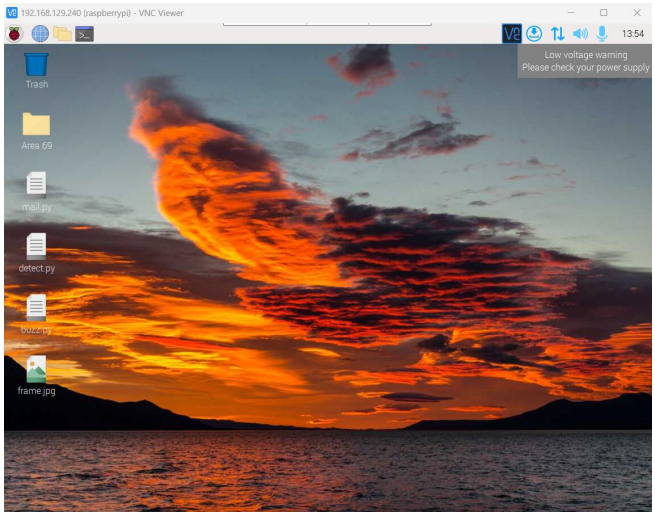

Fig. 12. Raspberry Pi desktop

The following image Figure 13, is a screenshot of the terminal as we start the face detection process by executing the file.

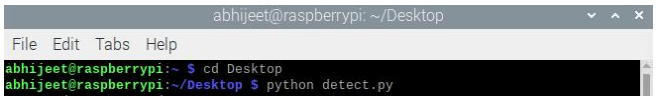

Fig. 13. Starting Face Detection

VI. Results and Discussions

In this research, we created a smart surveillance robot that aims to secure an individual or an organization by detecting faces of a person approaching it. This system is built for an indoor environment. The proposed robot is capable of traversing an area, avoiding obstacles using ultrasonic sensor mounted at the front and detecting faces through a camera mounted on top. Also it enables the user to view live footage. If a face is detected, the system successfully informs the user via an email consisting of the latest frame captured, through a buzzer alarm and also on the live video feed. Although our system is built keeping in mind its usage in indoor environment, as discussed earlier, it will not just allow users to secure their properties and assets but also with few modifications, this system can be extended to various other domains as well such as rescue and search operations in case of a natural disaster or a terrorist attack or even in border areas and mines.

The following image Figure 14, shows the screenshot of live video feed running with the help of VNC Viewer when a Human is detected.

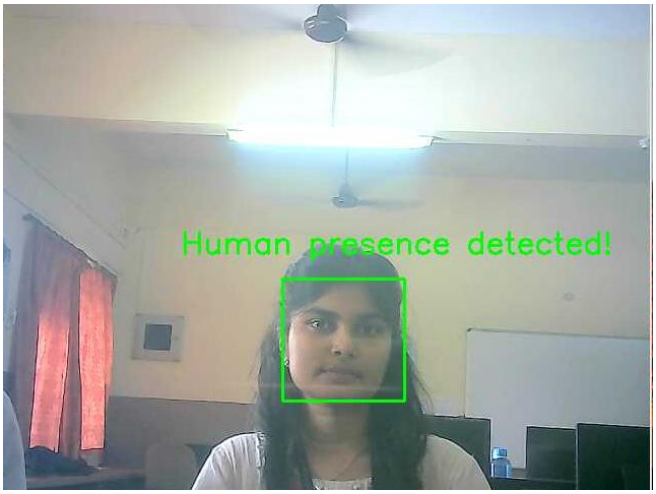

Fig. 14. Face Detected on video feed

The following image Figure 15, shows the screenshot of email alert received as a human face was detected

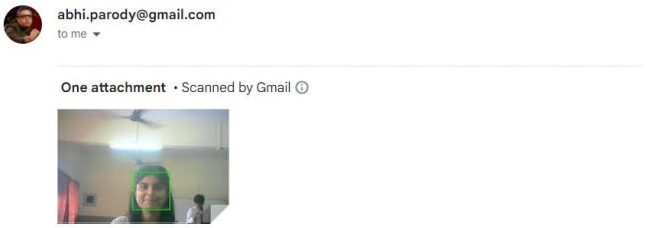

Fig. 15. Email alert of detected face

The following image Figure 16, shows the screenshot of live video feed running with the help of VNC Viewer when no human is detected.

Fig. 16. Video feed when no face is detected

The following image Figure 17, shows the screenshot of email alert received when the detected human moved.

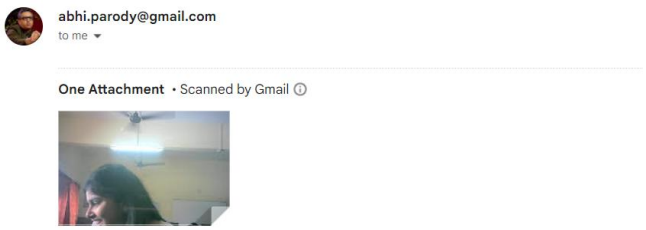

Fig. 17. Email alert when the detected face moves

VII. Conclusion and Future Work

The research was aimed at developing an effective surveillance system which can be easy to operate and can safeguard assets of an individual or an organization. The proposed system successfully performs both obstacle detection as well as face detection. The obstacle detection is carried out using ultrasonic sensor. The ultrasonic sensor is turned using a servo motor. Obstacle detection is carried out by the Arduino Uno whereas face detection is carried out by the Raspberry Pi. If the system detects any human face, it notifies the user along-with the captured frame of individual. The proposed system has solved many issues faced by existing systems. We focused on adding multiple methods to inform the user about a possible breach which was an aspect ignored by most existing systems. Our system informs the user via an email which consists of the last captured frame, buzzer alarm and also on the live video feed. Also being a mobile robot, it has an edge over fixed CCTVs.

In future, this system can be made manually operable to allow users to monitor desired areas of their choice. Also the system can be upgraded to enable face recognition that could clearly differentiate between known and unknown faces and alert the user on detecting unknown faces. The live video feed and controls could be made available on mobile of the user for ease of access and usage.

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