Surveillance Robot using Raspberry Pi and IoT

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Abstract— ***remote surveillance and monitoring of our homes has seen a growing need in emerging times. By means of this paper, we put forward a surveillance robot which can be integrated into any kind of household. The base controller of the bot will be the powerful Raspberry Pi 3 Model B. A webcam attached to the Pi monitors the area and sends a notification when any trespassing or obtrusion is detected. The camera also possesses face recognition algorithm which will possess the ability to identify the person responsible for the motion triggering. If it is an authorized personnel, the on board voice assistant will start talking with the person. The notification will be sent only when it's an unauthorized personnel and will contain pictures clicked of the trespasser and also activate live streaming of the webcam feed. The live streaming ability of the Pi allows the camera feed to be analyzed from any location using internet. With such a system, every user will feel more sheltered while they're not at their place of residence or when they've left their children and old ones alone at home.***

Keywords-surveillance, Raspberry Pi 3 Model B, webcam, live stream

I. INTRODUCTION

Traditionally, surveillance systems are installed in every security critical areas. These systems generally consist of high quality cameras, multiple computers for monitoring, servers for storing these videos and many security personnel for monitoring these videos. When considered as a whole, these systems can yield great complexities while installing as well as for their maintenance. The CCTV camera feeds are only visible in certain locations and they also have limited range within which these can be viewed. Above all these, the cost of implementations of these systems is so high that they cannot be installed in every household. .

The traditional systems require continuous monitoring by some dedicated personnel which is not possible in every household. Hiring an unknown person to do so will also raise privacy issues. The CCTV cameras installed these days also have limited vision because they're stationary modules. If an intruder moves away from the field of view of a CCTV camera, it cannot follow or track his motions. The solution to all the above issues is to have a surveillance robot which can monitor the areas where it's installed and send notifications to the owner when an intrusion happens. It also allows the user to login to the Raspberry Pi's webcam from any remote location and view live feed of whatever is happening in his premises. The cost effectiveness and remote control features of the robot allow it to be used easily by every user.

II. RELATED WORK

Several projects and systems have been introduced in developing a robust home security system. With a common motto, they've developed systems using varying processors and features.

In [1], the author discusses a system developed for remote surveillance of homes using an Arduino, IP cam and Team Viewer to monitor the system. A DTMF controlled remote is used to switch on the PC, camera and robot. Once the mobile phone is called and specific set of keys are pressed, corresponding relay switches activate all the components required in the remote surveillance. Then to login to the remote PC, it uses a VNC server and the Windows app built on the PC. The app then sends respective signals to the mobile robot using RF technology. Looking at it from a broader prospective, we use GSM technology to activate the system, Internet to gain access of the remote PC and RF technology to control the robot. The lag between each system has not been considered in the system, which is a very crucial factor. When experimented with a similar setup, the response time between pressing the button on the Windows app and the robot's movement can extend up to even a minute or more. The RF technology used to control the robot requires line of sight communication between the transmitter and receiver module. It also has limited range and cannot be used in long halls. The robot cannot be controlled from another room either. The advantage of using Raspberry Pi 3 Model B is that it has on-board Wi-Fi, allowing it to connect to the home's router. This allows easy movement in every nook and corner of the house without any hassle. The lag is also only dependent on the internet speed, which can be easily upgraded.

The paper in [2] describes a system for smart surveillance of homes using a PC with on-board camera. The image processing algorithm uses background subtraction to detect motion by fixing certain threshold above which it decides that intrusion is detected. It also uses Gaussian blur to smoothen the high frequency noise which may occur while capturing the images using different conditions. Once motion is detected, the Arduino which has a buzzer connected to it. As soon as motion is detected, the buzzer goes on. Simultaneously, the camera clicks pictures and uploads it to the Dropbox. The obvious drawback of this system is that it doesn't send any notifications to the user regarding the intrusion. Uploading the images to Dropbox is a good idea for remote access but not for instant notifications. Moreover, using a PC's camera for motion detection makes it a very bulky system. It cannot be moved around or controlled from a remote location. The another

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disadvantage of using a PC is that it should always be connected to the power supply. It incurs too much of wastage of electricity. The PC is also capable of doing a multitude of tasks and using it solely for surveillance is an under utilization of resources. By doing so, the cost of implementation of the project also increases, making it less suitable for the different kinds of households available.The other advantage of using a microprocessor like Raspberry Pi is that it can be made into a very handy device. This ensures that we can install this system in any position and in any part of the house. The camera mounted on the robot can also be turned in any required direction, in contrast to the stationary one built in the PC. The power consumption is also very less comparatively. Since the Raspberry Pi runs on 5V DC, it can be easily powered from a power bank. That helps us achieve an uninterrupted power supply for the system as a low power consumption rate.

The authors in [3] have developed a surveillance system using Raspberry Pi and the algorithm for detecting motion is written using SimpleCV. The USB camera attached to the Raspbeeri Pi looks out for any motion and once its detected, it switches on the lights of the room and clicks snapshots of the surrounding area. These images are sent over the internet to the user. This project has the feature of switching on the lights of the room as an added feature and uses a low power processor, compared to the others. But it lacks any authentication feature of the detected intrusion. It will send notifications even when an authorized person moves in front of the system. This is also a stationary module which cannot be moved around. The face recognition feature used in our project provides an extra authentication for the system. It avoids unnecessary storage of images or sending of notifications when the user is at home or in motion in front of the camera. It can also be controlled from any remote location over the internet. Since it has a voice assistant in it, it can be easily controlled by the user using simple voice commands when he is at home.

III. SYSTEM OVERVIEW

Figure 1 contains an overview of the system proposed in this paper.

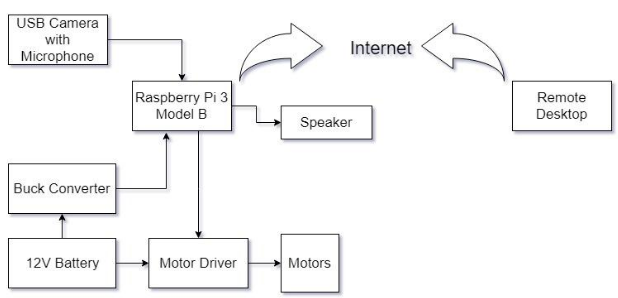

Figure 1. Block Diagram of Proposed System

The main components of the system are:

i. Raspberry Pi 3 Model B

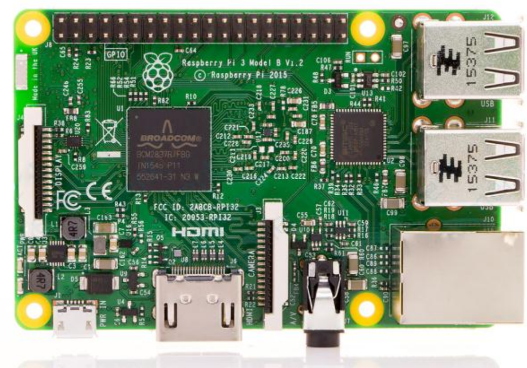

Figure 2. Raspberry Pi 3 Model B

The microprocessor used in the project is the Raspberry Pi 3 Model B. There have been many significant upgrades made in the latest version of the Raspberry Pi board in comparison to the Raspberry Pi 2, which make it more suitable for this project. The SOC in the Raspberry Pi 3 Model B is Broadcomm BCM2837, which is almost 50% faster than the Raspberry Pi 2[4]. The CPU is also faster, at 1.2GHz, in comparison to the 900MHz Quad Cortex A7 in Pi 2.The Graphical Processing Unit is clocked at 400MHz compared to the 250 MHz VideoCore IV in Pi 2. Above all, the Raspberry Pi 3 Model B features an on-board WiFi and Bluetooth 4.0, which makes it easier to use in IoT applications. Apart from all these, there many many other improvisations made in the Raspberry Pi 3, but hardware wise, there has not been any major changes when compared to the Raspberry Pi 2. All the peripherals required in this project are connected to the Raspberry Pi 3 and it also contains the programs required for motion detection, notification alert, controls to move the robot and voice control algorithm. It is the brain of the complete project. The Raspberry Pi features 4 USB 2.0 ports, which are used to connect the different components. The Raspberry Pi is powered using 5V DC supply to the micro USB Power input. It has been upgraded to handle up to 2.5 amperes of current. The MicroSD card slot is inserted with a memory card which contains the OS running on the Raspberry Pi.

ii. USB Camera with Microphone

Figure 3. Logitech C270

The camera is used in this project for motion detection, capturing the image of the intruder when motion is detected, to stream live feed of the intrusion to the user in remote location and also to authenticate the user in case the motion is caused by him or any other authorized personnel. The camera used in this project is the Logitech C270[5]. It can be connected to the Raspberry Pi using the USB port. The live video stream captured by the camera has a resolution of 1280 x 720 pixels. The built-in mic with noise reduction allows background noise cancellation and high quality video capture. The software provided with the camera make it suitable for face tracking and motion detection, the two major components of our project.

iii. Motor Driver

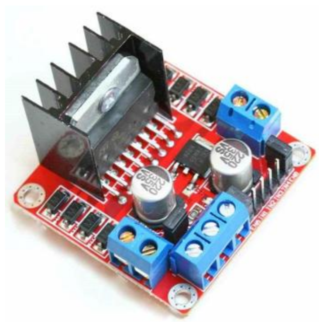

Figure 4. L298N Motor driver

The motor driver contains the H-bridge connection required for bi-directional control of the motor. This is essential for the robot to achieve all directions of locomotion, namely, forward, backward, left and right.The power source for the motors is a 12V battery which is supplied appropriately to the motors using the motor driver. The motor driver is controlled using the actuating signals from the microprocessor. The motor driver used in this project is the L298N. It is a dual motor controller, meaning it can control two motors at the same time[6]. For controlling 4 motors, we need to connect two motors in parallel to the same slot. It can provide up to 2 amperes per channel and it is an inexpensive module to use. This board also features an on-board 12v to 5v regulator, IC 7805, which can be used to power up any board which requires it. This makes it a common choice for hobbyist projects.

iv. Battery

Figure 5. 12v Lead Acid battery

The battery used for powering the system is a 12v Lead acid battery. It is rechargeable and can provide up to 1.3 amperes in an hour. This is ideal for controlling the movement of the 4 DC motors used in the project.

v. Buck Converter

Figure 6. LM2596 Buck Converter

The Buck converter is a DC-DC power step down module, used to regulate higher DC voltage to lower voltages and provide constant DC voltage[7]. In this project, we require a 12V supply for the motors, for which the lead acid battery is used. But the Raspberry Pi requires constant 5V DC for its operations. So the 12V battery is connected to the buck converter, which regulates it into 5V DC which is used to power up the Raspberry Pi. We use LM2596 buck converter module, which can drive loads up to 3 amperes with high efficiency. The high precision potentiometer can be varied to obtain voltages in the range 1.25 to 30V for input voltages between 4 to 35V.

vi. Motors

Figure 7. DC motor

The robot's locomotion is achieved by connecting it to wheels. To run these motors, we require motors. The motors used in this project are 300 rpm DC motors which have ample speed as well as torque to carry the whole weight of all the components that are mounted on the robot [8]. We used 4 motors and wheels to build a 4 wheeled robot which provides stability and proper control of the robot's movements.

vii. Speaker

The speaker is used for the voice assistant. It is connected to the Raspberry Pi's 3.5mm audio jack, which is configured for audio output. The speaker used in this project is the Sony SRS-XB2 which is a portable speaker with a rechargeable battery [9]. This makes it handy to use. It can provide up to 10 hours of battery life for one cycle of complete charge. It is also light weight which allows it to be easily mounted on the robot's base.

IV. FLOWCHART

Figure 9 contains a flowchart explaining the sequence of events taking place in the system.

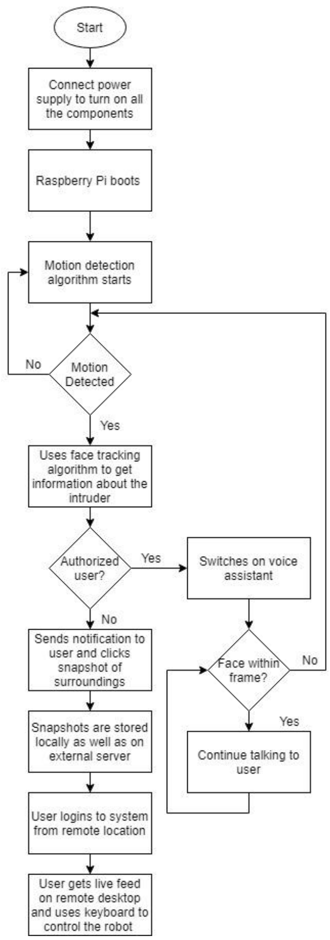

Figure 9. Flowchart of proposed system

V. System Implementation

The system's plot begins by switching in the main switch, which gives power supply from the 12V battery to the entire system. Once switched on, the buck converter regulates it to 5V DC supply and powers the Raspberry Pi. The Pi boots and runs the script written for motion detection using the USB camera feed. The algorithm for motion detection is shown in Figure 10.

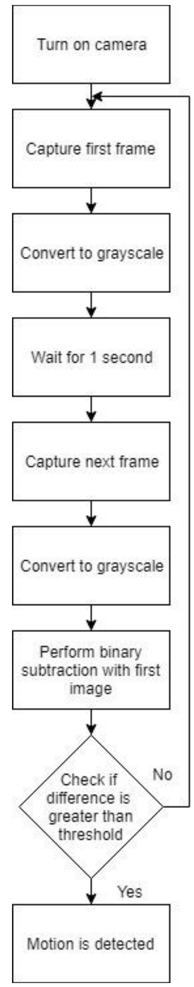

Figure 10. Motion Detection Using SimpleCV

The algorithm for motion detection is based on background subtraction. There are two steps in doing so, namely background initialization and background update [10]. The first step is computation of the background. In our project, this is the reference image we use for determining whether there has been motion or not. The background update is the second operation taking place. For doing so, the second image is captured and the difference between the two images is computed after converting both of them to grayscale. If this difference exceeds a certain threshold, we conclude that there has been motion detected.

Once motion is detected, the camera is triggered to start its face tracking algorithm. If the face detected is an authorized user, the on board voice assistant on the Raspberry Pi switches on and enables the robot to be moved using voice commands. On the other hand, if the face detected is not of an authorized person, it sends a notification to the user through email. It simultaneously starts clicking snapshots of the intruder and stores it locally for future use. It also uploads them to an external FTP server, enabling them to be viewed from a remote location. The Raspberry Pi also begins live video streaming of the camera feed, which can also be viewed from any remote location.To do so, we use VNC viewer to see the video feed and also control the robot over internet from far away places.

VI. RESULTS

Figure 11 shows a snapshot of the motion detection algorithm running on the Raspberry Pi.

Figure 11. Motion detected

Once the motion is detected, an email notification is sent to the user through his registered email address. This is shown in Figure 12.

Figure 12. Email notification

Once the user receives the notification, he can login to the Raspberry Pi by knowing its IP address and using VNC viewer software[11]. For this purpose, the Pi's IP address should be made static, that is, it should not change whenever it reboots and connects to the network again.

Figure 13. VNC login authentication

For logging in to the Raspberry Pi from remote location, we need to enter the right credentials, namely, Username and password which are defined at the time of installation. Once logged in, we can see our desktop from remote location, as shown in Figure 13.

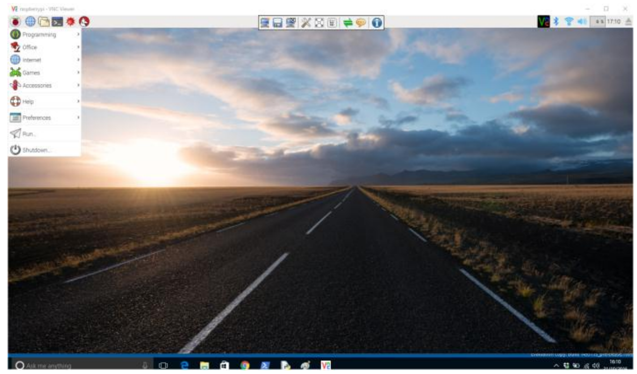

Figure 13. Remote login using VNC Viewer

Once we gain remote access to our Raspberry Pi, we can view live feed from the camera easily using SimpleCV. The live feed obtained is shown in Figure 14.

Figure 14. Live feed from USB Camera

The quality of live feed obtained depends on the resolution of camera used as well as the internet speed at the Raspberry Pi's end (for uploading) as well as the user's end (for video streaming).

The robot's motion is controlled by pressing appropriate keys for performing its various functions. The keys corresponding to these functions is given in Table 1.

Key	Function
W	Robot moves forward
X	Robot moves backward
A	Robot turns left
D	Robot turns right
S	Robot stops moving
Q	Robot rotates left
E	Robot rotates right

Table 1. Keyboard keys and their functions

The control functions for this robot is written using a python script. In this script, we have defined separate functions for each movement. When a key is pressed, an appropriate function is executed and the robot moves in the specified direction. Using Tkinter package, a GUI (Graphical User Interface) can also be built to control the robot easily, instead of using keyboard keys[12]. A buzzer can also be attached to the robot to activate an alarm to scare the intruder away.

The robot can be moved around the house and it can also communicate with any authorized user at home while doing so.

VII. Conclusion

The advantages of installing such a system in every household is that it provides peace of mind to the user about his premises even when he's not present at home. The low power consumption of this system enables it to be installed in any kind of household with ease. It can also be used for a long duration of time by using an appropriate battery. It will allow the system to be under working condition for weeks together. Even if a security camera has already been installed, this system can be added to it so that it can provide extra security. The users will be able to keep an eye on their loved ones at home, even if they are busy working in any other place. It provides safety to old age people and children if they're alone at home.

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