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Home Security against Human Intrusion using Raspberry Pi

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Abstract

Technology has changed the world. There is a huge growth in technology connected to almost every field. The pace and diversity of advancement is very rapid. Hence, new technology and techniques are coming up and are put to use as per the need. In such advanced scenario, providing security to home has also become a major point of concern. Presently security cameras can be used for the same. But such cameras may be visible to intruders and there is possibility that cameras may be damaged. Hence, in order to serve the purpose, there is a need to find an alternative secure, accurate and quick method. Hence, an effort is made in this paper to design a home security system using Raspberry Pi. System requires Raspberry Pi, Camera, Touch screen and android mobile as hardware components. Python, Node.js and OpenCV libraries are used for software coding. Usually most of the intrusion detection systems click the photo of intruders as soon as the human is detected. But, such systems fail to click photos, so that the intruder can be identified (Face View Photo) and visible. In proposed system, a proper illustrative method is proposed so that the intrusion detection is accurate and photos thus captured are clear, so that intruder is clearly visible. The proposed system is designed as a smart mirror which will provide both information and home security. The system is developed to accept touch and mobile commands. As soon as the intrusion is detected, an alert message along with the identifiable and clear photo (Face view) of intruder will be sent to the owner's/administrator's mobile. The mirror owner can also see the video of deployed environment through the camera fitted on smart mirror.

Keywords: Smart Mirror; Home Security; Intrusion Detection; Raspberry Pi; Frontal Face Detection ;

1. Introduction

The comfort zone of human beings is increasing, as the facilities are increasing. With the incorporation of many technologies into day today activities, life has become easier. On the other side, as far as the technologies are concerned, it also creates security related issues. For example, we use ATMs for doing banking transactions, the security of device and the working accuracy of device matters a lot. Similarly, with the advancement in technology, it is evident that skills of thieves, robbers also have increased. Hence, it is a great challenge to design a foolproof system. Usually people make use of security cameras in order to secure home. The cameras record the activities that

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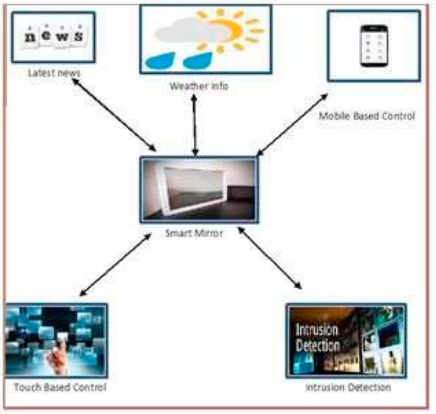


Fig. 1. Features of Smart Mirror

Fig. 2. Smart Mirror.

occurs and store in the storage device. The actions can be taken after video is being analyzed in case of any harmful or suspicious incidents or activities. There is also a possibility that, the cameras can be destroyed during incidents like theft or robbery. Hence, complete security cannot be ensured in such cases. This is the regular security system, that presently exists. But, this system is passive approach. There is an urge for active system, which can take actions as soon as security threat is suspected. Hence, the proposed system, which can provide security during human intrusion in home, is proposed. For this a smart mirror is designed, which not only displays the customized information on the mirror but also does human intrusion detection. The proposed model can be designed using sensors or image processing techniques. PIR sensors like DHT22 or image processing techniques such as frame difference can be used for designing the proposed system. But, the sensors have more false alarm rate and accuracy of image processing techniques for proposed model is also less. Hence, a model is proposed which makes use of machine learning technique like Yolo and Haar cascade classifier of the OpenCV. Using this technique an average accuracy of 96 percent can be achieved. The following figure 1 shows the features that are implemented in the proposed model. The figure 2 shows the prototype designed, which is tested for best possible accuracy.

According to the surveys it is known that, people use mirror while getting ready for office or daily work and use it for at least 20 minutes per day. The proposed smart mirror can be used for grooming up and also to keep the user updated with latest news and weather updates. When owner will not be available at home, the same mirror can be put into intrusion detection mode either by touch or mobile command and make the smart mirror to do Human Intrusion detection. As soon as the intrusion is detected, the face visible photo of the intruder is clicked and sent to registered mobile number. The actions can be taken accordingly. Entire mechanisms take place without the notice of the intruder. The smart mirror which looks like any regular mirror will not catch an attention of the intruder also. So, here is an active security method is proposed to protect the home against intrusion. Major importance has been given for the accuracy of the system and to ensure the clarity of the photos taken during intrusion.

The section 2 explains the existing work taken up in the specified field. The section 3 explains the Issues and Challenges of the proposed system. The section 4 explains the detailed description of the Proposed Model along with necessary block diagrams. The Experimental aspects related to the Human Intrusion Detection are explained in section 5. The details of the Results and Analysis by considering different scenario are explained in section 6. The section 7 briefs about the Conclusion and scope of future work for this paper.

2. Related Work

Already some works have been put up in this field. Smart mirrors so far proposed work as passive devices with very less interactivity. The existing systems fetch the data from the internet using APIs and display them on the mirror display.

In [1], an Intelligent mirror which accepts voice commands via the microphone and which is built with Raspberry Pi microcontroller, LED monitor and acrylic mirror, which displays the weather, time, and location information on the screen, is proposed. The software components of the system are SD formator, Etcher, and the Raspbian OS. It uses VNC viewer for connectivity. In [2], a Smart mirror built with Raspberry Pi, microphone, speaker, LED Monitor, One way mirror and MCU (Multi Control Unit) units to display weather and latest news updates on the screen, is proposed. Humidity and Temperature sensors are used and IoT is implemented using cloud. In [3], a Futuristic multimedia based Smart Mirrors are designed which accept voice commands. The system makes use of Artificial Intelligence

concepts. For example, if it is cold day, it will display a message on the mirror screen saying "Please wear jacket today". In [4], some of the Smart mirrors are having a Webpage based interface which can be customized as per the user needs. These are operated using voice commands. In [5], some mirrors designed which can be used as weight and fitness trackers. The authentication is provided using Face Recognition. GPS navigation, Bluetooth Connectivity and wireless communication are added features. SONUS technology is used for improved communication. In [6], some mirrors designed which use Hermoine 1.0 that is an extension of Magic Mirror. The platform provides the user with easy installation of a Smart Mirror for domestic use. In [7], the system is proposed to work in two modes namely Normal Mode and Smart Mode. System is developed using Python and Javascript programming tools such as Node.js. It is a voice command based smart mirror. In [8], a voice controlled, wall mirror is designed and is named as Magic Mirror. It stores the personalized data for decision making and prediction. In [9], a voice controlled, mirror is developed. Smart Mirror is implemented with Raspberry, LCD monitor, microphone, webcam and SMT32F030CT8T6 microcontroller as core controlling chips. The mirror accepts voice commands and processes them. In [10], smart mirror is having capability of speech recognition. Face recognition is provided for login and authentication purpose. The system wakes up by touch and accepts voice commands.

In [11], smart mirror proposed is having two striking features. It displays the map and architecture of the college. It can be used by the students to see course details and also can be used as register. In [12], a smart mirror is designed for Theft Detection in a home environment. It displays the real time data on the mirror. PIR (Passive Infrared) sensors are used for human motion detection and the camera captures information and stores in drop box. In [13], a comparative study of Smart Mirrors is given and a Voice based Smart mirror is proposed. It is a system which supports Human Gestures and Face Detection. In [14], a smart mirror is proposed to monitor children. The system can be connected to the user's mobile using an android application. In [15], a health monitoring Smart Mirror is designed to detect health related issues. System makes use of a special algorithm called PAA (Posture Analysis Algorithm) to analyze postures of human to find any changes in postures over a period of time. In [16], a smart mirror which can be controlled using the smart phone is proposed. The system allows the user to control the home appliances. In [17], a home and commercial model of the smart mirror is proposed. The mirror can display the real time data by fetching it from the internet. The system can be controlled and operated using the voice commands. It makes use of speech processing techniques to interact with user through verbal commands, functions and to listen and respond user questions. In [18], a smart mirror that acts like a personal assistant is designed. It makes use of artificial intelligence. In [19], a multiuser smart mirror is proposed which can also be used as the commercial product. It works on the basis of the RFID. The employees are allowed to wear RFID based tags. Access is allowed based on the RFID authentication. It is designed to have personalized interface for the specific user. In [20], a smart mirror is proposed to control the lights in the house. The system makes use of SONUS technology. It can accept voice commands and processes them to produce the results.

3. Issues and Challenges

The major challenge is to work with an embedded system. A proper knowledge of hardware is necessary. Raspberry Pi is a device with low processing capacity and storage. The latest version of Raspberry has 1GB RAM only. Hence, designing proposed model with such a low processing device is a major challenge. Another challenge is to provide maximum possible accuracy in human intrusion detection. Most remarkable challenge is to click the clear facial photo of the intruder during the intrusion detection. The other issues related to the proposed system are the cost and durability of the hardware devices used. Sometimes Raspberry heats up and starts rebooting repeatedly.

4. Proposed System

The block diagram of the proposed model is shown in figure 3. The figure 4 shows the block diagram for human intrusion detection. The block diagram depicts the modules used in the proposed work.

The Mirror State is a software component that does the task of a synchronizer. Figure 5 shows the Mirror State. It decides whether any given command can be executed at that instance of time or not. It is because, some previous command may be already under execution. The proposed system is built with hardware components like Raspberry Pi, Touch enabled screen, Camera, Power bank (works in case of Power failure),

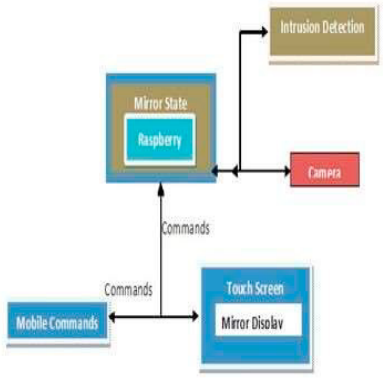


Fig. 3. Block Diagram of Smart Mirror.

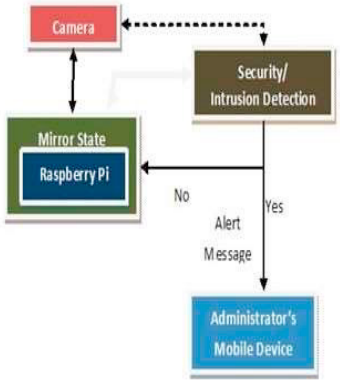


Fig. 4. Block Diagram for Intrusion detection.

android mobile and Wi-Fi connectivity. The software components needed are Python, OpenCV libraries, PythonAnywhere cloud services and SMSLane servers. The Photo of intruder can be uploaded to the Amazon cloud services such as PythonAnywhere. The photo will be converted to base64 format and stored in the database. Such format conversion is necessary for easy storage and retrieval of the photos.

The proposed system works in two modes namely Normal Mode and Triggered mode. In normal mode, it displays the real time information on the mirror. The latest news, weather information, calendar, Indian holidays and greetings are displayed on the screen. The contents displayed on the mirror screen are designed as the webpage are the dynamic content being fetched using the APIs and displayed at the specified locations on mirror using NodeJS and electron. The system can be pushed into triggered mode either by the touch commands or by mobile commands. During triggered mode the system will act as a human intrusion detection system. During this mode of operation, as soon as the human is detected, the system will take a frontal photo of the human and send it to the owner of the Smart Mirror through SMS. Further, the owner can take actions based on the situation.

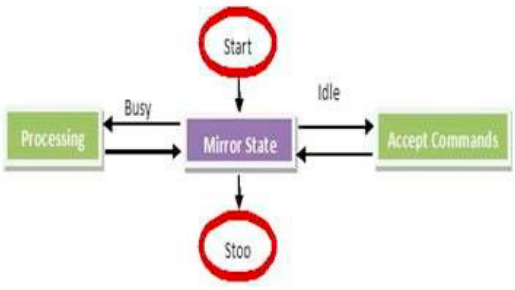


Fig. 5. Mirror State.

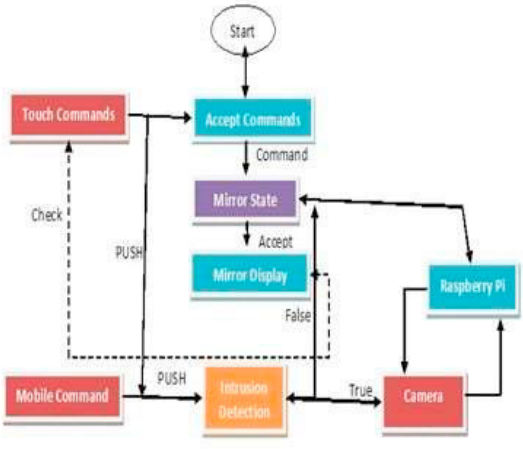


Fig. 6. Types of Inputs.

The system accepts touch and mobile command as input and processes them to produce results. Touch commands can be used when the user is in front of the mirror and mobile commands can be used when user is away from the mirror. The details are shown on figure 6.

5. Experimentation

The main contribution of the work is explained in this section. The mirror is designed for providing information and also to detect human intrusion at deployed environment. During this process the system is specifically concerned about the best possible accuracy of the system and to click the facial photo of the human under surveillance. Section 6 explains the Results and Analysis by considering different cases during human detection process.

5.1 Human Intrusion Detection

The main work during human intrusion detection is the process of detecting human. Initially the human detection is done using Yolo object technique of OpenCV. But the problem with such a system is that, once a human is detected the proposed system has to capture the face image of the intruder. So, that it can be sent to the owner/ administrator of the Smart Mirror. It means that by using Yolo technique it may not be always be possible to get a facial photo of the intruder because Yolo technique can detect human even in side and back angle positions. Hence, the identification of the person will become a problem. If it is possible to capture face images, then the actions can be initiated with proper proof. When the system is pushed to the Intrusion Mode, then the system does human detection. The block diagram of process is shown as in figure 7. The overall method for human detection is shown in figure 8.

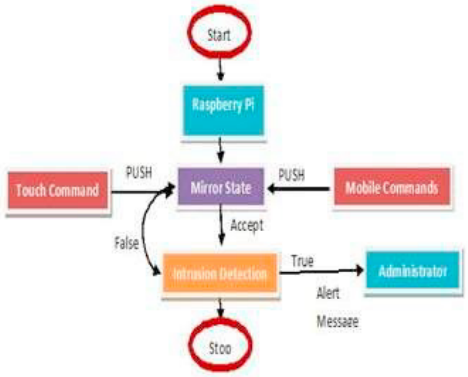


Fig. 7. Intrusion detection process.

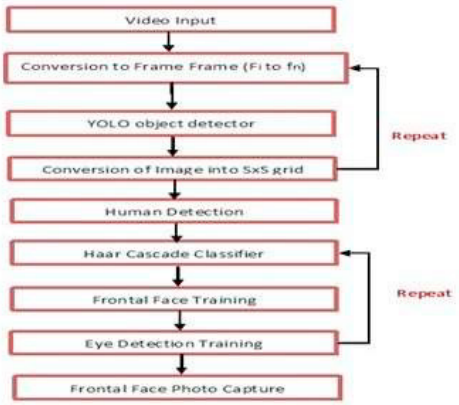


Fig. 8. Method for Intrusion detection.

The first step is human detection. This is done using the Yolo technique which is trained using the COCO data set for human detection. The following figures shows the 9 shows the human detection by the Yolo technique. Next step is to click the front face of the intruder. Soon after Yolo technique detects human, the proposed system immediately apply Haar cascade technique of OpenCV for frontal face and eye detection. The figure 10 shows the details of the Haar cascade classifier technique.

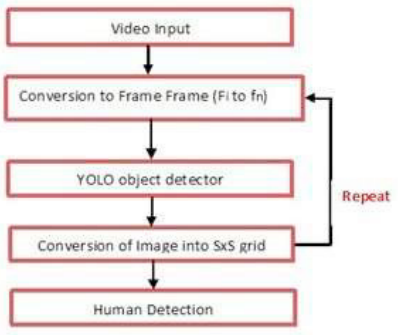
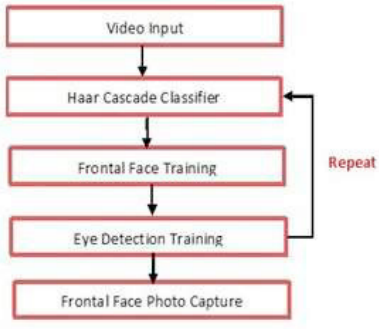


Fig. 9. Yolo Technique.Fig.



10. Haar Cascade Technique.

As soon as face or eyes of intruder are detected, the system clicks the photo of intruder and that photo will be sent to the cloud namely PythonAnywhere. Alert SMS along with the photo of the intruder will be sent to the owner of

mirror with the help of SMSlane services. Now the owner can take action immediately. The intruder will not come to know about all these activities and can be caught with proof and evidence.

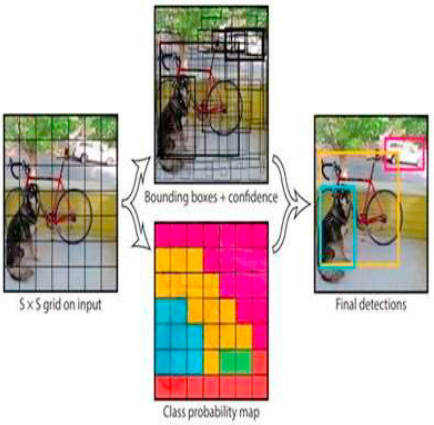


Fig. 11. Grid and Bounding Box Formation.

$$b_x = \sigma(t_x) + c_x$$
$$b_y = \sigma(t_y) + c_y$$
$$b_w = p_w e^{t_w}$$
$$b_h = p_h e^{t_h}$$

Fig. 12. Bounding Box Equations.

In order to work with the Yolo, the system has to convert the video to frames and frame image into SxS grids. Once the grids are formed, proposed system has to create the bounding boxes for identifying the objects. The proposed system makes use of COCO data set for detecting the human. The following figure 11 shows the grid creation and figure 12 shows the formula for creating bounding box.

Where, *bx, by* ⟶ the x,y center co-ordinates,
bw, bh ⟶ the width and height of prediction,
tx, ty, tw and th are network outputs during processing,
cx ,cy are the top-left co-ordinates of the grid,
pw and ph are anchor dimensions for the box.

6. Results and Analysis

6.1 Human Detection

The major work here is to detect human. So, the model is trained to detect human first. During this process it is necessary to consider different possible scenarios. The following cases are taken into consideration during human detection using Yolo technique.

I: Single person with side view (partial and complete)
II: Single person partially face covered by hand and masked
III: Single person with back view
IV: Multiple Persons.

The proposed system detects all the above cases mentioned. The details of the same are shown in figure 13. Different standing positions of humans are tested and found that the system is able to identify humans. The table 1 shows the actual results during human detection with different cases considered. The system is tested by executing 100 different cases, for above categories. It is observed that the accuracy of the trained model is at an average of 95% taking all cases in totality.

In all the mentioned cases the system performed absolutely accurate and gave correct predictions. On left side to each picture there is a related message that shows the “Person found” indication. The accuracy increased to 100% when there are more than two persons. Since detecting only one among the group of people is also sufficient, hence the accuracy is 100%.

6.2 Human Face Detection

Though the accuracy of human detection using Yolo technique is considerably good, the main problem is to identify the intruder during back view or complete side view. Immediately after the human is being detected by the Yolo technique, the system has applied the Haar cascade for face or eye detection. This is done to ensure that the system can capture the frontal face picture of intruder with proper clarity and visibility. So that the intruder can be easily identified.

The details can be divided into two categories. In first category the system is trained for detection of only face of the intruder. In second category the system is trained for detection of face or eyes of the intruder. By doing so it can be ensured that the face of the intruder is facing the camera and it is the right time to click the photo.

Fig. 13. (a) Partial Side view (b) Complete Side view (c) Partially Covered Face (d) Masked Face (e) Back View (f) Multiple Person

Table 1. Human Detection Analysis using Yolo.

Position	No. of Persons (*t*)	Frequency of Execution(*t*)	Accuracy Measured(*t*)
Partial Side View	01	100	98.28
Complete Side View	01	100	96.22
Partially Covered Face	01	100	94.18
Masked Face	01	100	94.12
Back View	01	100	93.67
Multiple Person	≥ 03	100	100

6.3 Face Detection Using Haar cascade classifier

Different cases have to be taken into consideration during face detection process. It is mainly to ensure better accuracy. Pets are also considered during testing to confirm that the system is properly trained to identify humans only. The following cases are considered during the face detection.

I: Only Persons

II:Persons with Pets

The details about the analysis of the same are shown in figure 14. The rectangle covering face in the figure represents the detection of the face. In case of multiple persons, the photo is clicked even if one person is facing frontal face view. Hence, the accuracy of the system increases when the persons are more than four. But it is worth noticing that the system's performance degraded with the use of Haar for detection of face only.

The table 2 shows the actual results during face detection using Haar classifier with different cases being considered. The system is tested by executing 100 different cases, for above categories. Hence, there is a need to increase the accuracy of proposed model.

Table 2. Face Detection Analysis using Haar frontal face.

No. of Persons (*t*)	Frequency of Execution(*t*)	Accuracy Measured(*t*)
01	100	64.20
02	100	69.78
03	100	71.67
04	100	75.89
≥ 05	100	83.22

6.4 Face and Eye Detection Using Haar cascade classifier

In order to increase the accuracy of the proposed model, the Haar classifier is trained to detect either the face or eye of the human under observation. If either of eyes or face is visible then it evident that the intruder is properly facing the camera and a clear photo can be taken. Different cases have to be taken into consideration during detection process.

Hence, the following cases are considered during the face and eye detection.

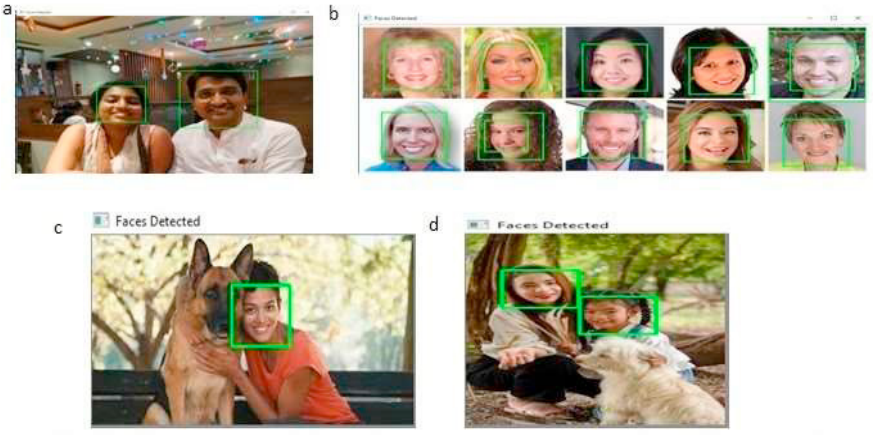


Fig. 14. (a) Two persons (b) More than 2 persons (c)Person with pet (d) Persons with pet

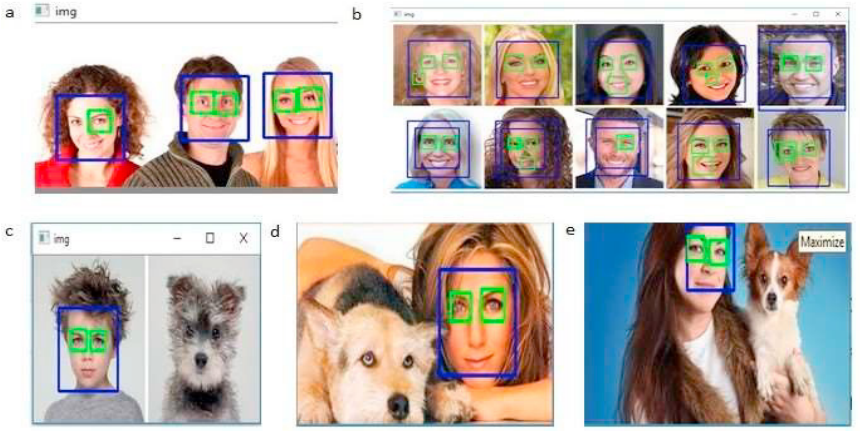


Fig. 15. (a) Three persons (b) Ten Persons (c)A single Person and a pet

I: Face and Eye Detection of persons
II: Face and Eye Detection of persons along with pets

The details of the same are shown in figure 15. The rectangle covering face and eye represents the detection of the face and eye respectively. The table 3 shows the actual results during face or eye detection using Haar classifier with different cases being considered. The system is tested by executing 100 different cases, for above categories.

Table 3. Human Face Detection Analysis using Haar frontal face and eye.

No. of Persons (t)	Frequency of Execution(t)	Accuracy Measured(t)
01	100	88.26
02	100	89.32
03	100	92.53
04	100	93.07
≥ 05	100	96.12

It is worth noticing that the accuracy of the system now increased to an average of 96.12% when either face or eyes of the intruder have to be detected. Even the requirement of clicking the facial photo of the intruder is also satisfied along with increase in accuracy. The accuracy increases as the count of number of people under observation increases.

7. Conclusion and scope for future work

The model is not only an information provider but also an intelligent system, which can provide security in the

deployed environment. The system is trained to detect humans during intrusion. The prime concern is to provide better accuracy and speed during detection process. The proposed system makes use of both Yolo and Haar techniques for human face and eye detection. With the use of Haar classifier for frontal face detection the accuracy of proposed system was measured to be 83%. But, by training the system for face or eyes detection, the accuracy of the system is increased up to 96%. Since the proposed model is using Raspberry Pi as a processing device there is a need for better programming skills to improve the performance of the system. The proposed system is unique because of the speed and accuracy. The system is designed for intrusion detection of humans only. But the same work can be extended to identify whether the person is authentic user of the system or not. The face identification can be done by comparing with the photos stored in database. Here also the challenge of clicking the clear and visible image during, authentication exists.

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