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Intelligent Integrated Home Security System Using Raspberry Pi

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***Abstract*---- Security, be it of a small apartment or of a sophisticated, gigantic institute is of arrant concern. In metro cities in India, for a housing complex/small apartment, security personnel are generally employed for the said purpose, who may not be that efficient especially at night. This paper intends to build an "Intelligent Home Security System" based on Digital Image Processing and Speech Processing, using a Raspberry Pi. The system is divided into two sub- systems.**

1. Allowing/Disallowing vehicles based on Number Plate Recognition

2. Allowing/Disallowing human beings based on Face Detection and Recognition and Speech Recognition

A database of the residents of the building is prepared. It consists of a pre-recorded security code word and an image of the resident. A separate vehicular database containing the number plates of the cars is also stored in the memory.

The Raspberry Pi used in the above system houses an onboard camera which captures the image of the number plate of the car. It is then processed, recognized, compared with the list of cars stored in the memory of the Raspberry Pi and accordingly the car is allowed/ disallowed to enter the premises of the building.

For permitting human beings to enter the premises of the building, the intruder says a pre- assigned security code number which is recorded and the face captured. Again the processing is done, the image of the concerned person is recognized, and stored in the memory. The code number is then processed, compared with the one stored in the database and the matching image found. If both the images match (the one obtained by face recognition and the other by speech recognition), then a decision jointly approved by both the sub-systems is taken. If one sub-system fails to give an output, then the other sub-system complements it. Thus, the system as a whole never fails.

***Keywords*---- Intelligent Home Security System, Number Plate Recognition, Speech Recognition, Face Recognition, Raspberry Pi.**

I. INTRODUCTION

Crime rates in India is rising and according to reports, a burglary occurs every 14 seconds! As such, strong emphasis should be laid on adopting appropriate security measures to prevent the same. Two of the possible solutions of the above problem are:

1. Employing highly skilled security personnel
2. Installing automated, computer based or biometric security systems.

Biometric security systems are the ones which are based on automated detection of physiological or behavioral characteristics of an individual to authenticate his/her identity. Common ones include fingerprint recognition, iris recognition, face detection and recognition. These systems provide high level of security and can be used to prevent fraudulent activities. In India, in various research and development institutes, defence in particular, where data is classified, this technology is widely used. Even in the banking sector, developing such sophisticated systems is a dire necessity since a huge amount of money of many thousands of people needs to be kept safe and secure.

Implementing these technologies on such a vast scale requires a large amount of memory for storing huge amounts of data, complex hardware and software and will thus be extremely expensive. There will in fact be a trade-off between the cost and the efficiency of the system. For eg: Iris recognition is an extremely efficient technique, but is costly. Next in consideration are the size issues eg: Hand geometry identification requires a device of a large size to be implemented. Consequently when it comes to the security of small apartments, especially in India, such technologies are generally not adopted. Instead security personnel are employed who allow people to enter the building premises after checking their identity cards. Now this kind of security system is extremely unreliable as the guards can easily be fooled or spoofed!

II. PROPOSED METHOD

To overcome the above problem, a cheap, ready to use, automated security system [2] using Raspberry Pi [1] is intended to be developed. The system uses the following three technologies:

1. Number Plate Recognition
2. Face Detection and Recognition
3. Speech Recognition

The major advantage of this system is that it is extremely cheap and requires a one-time investment. The hardware components to be used, with their estimated price are as follows:

TABLE 1: BILL OF MATERIALS

Sl No.	Component Name	Cost (INR)
1	Raspberry Pi Model B+	2502.67
2	Raspberry Pi Camera Module	1876.22
3	8GB micro-SD card with NOOBS 1.3.9	748.61
4	Wolfson Audio Card	2189.44
5	L293D(Motor Driver)	55.00
6	PiTFT-TFT+touchscreen	2189.44
7	External Flash	500.00

The total manufacturing cost is estimated to be around 10000 INR.

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Reasons for selecting Raspberry Pi:

Implementing three of the above mentioned technologies in a single device requires a lot of processing and hence arises the need of a bigger RAM.

Possible devices with a good RAM:

- Laptop or Desktop Computer
- BeagleBone Black
- FPGA Boards
- Raspberry Pi

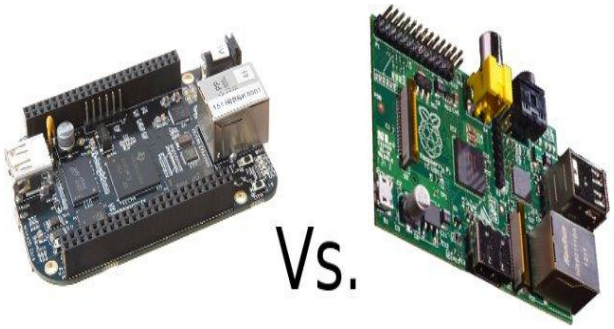


Figure 1: Beaglebone Black vs Raspberry Pi

However, not all of these options are viable. The processing requirements of the system demands the functionalities of a desktop computer but of a feasible size. Thus, taking size and processing capabilities into consideration Raspberry Pi is the best possible option for implementing the security system since BeagleBone Black and FPGA boards will be far more expensive than it. Also, Raspberry Pi has an established community behind its large number of products which BeagleBone Black does not have.

Other hardware requirements

- PI CAMERA MODULE: This camera module has a lot of advantages. The camera board size is extremely small(25mm x 20mm x 9mm),thus taking into account the size considerations of the system. It has a 5MP (2592×1944 pixels) Omnivision 5647 sensor in a fixed focus module. It also supports 1080p30, 720p60 and 640x480p60/90 video record. As such, it is extremely efficient.
- WOLFSON AUDIO CARD: This is by far the best suited add-on for audio processing applications. It has 2 on-board high quality MEMS microphone for audio capture and a separate 3.5mm jack for microphone input. It also has phono jacks for S/PDIF digital stereo audio input and output. It consumes extremely low power and has very high efficiency class D power amplifier.

III. Details Of The Proposed System

As mentioned previously, the system centers around three technologies namely, Number Plate Recognition, Face Detection and Recognition and Speech Recognition. Details of each of the three technologies are as under:

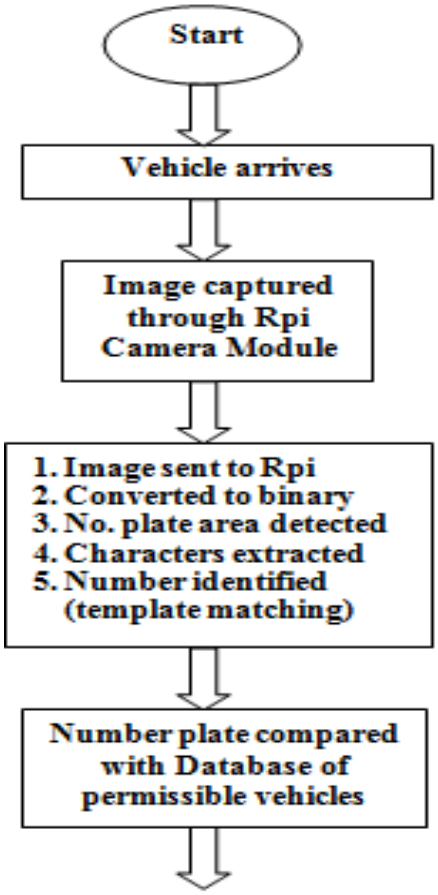
Number Plate Recognition

Introduction

Started in late 2009, this technology is widely used by patrolling cars in New South Wales. It makes use of 3 cameras,2 on the rooftop and 1 sideways. There is an LCD inside the car which beeps when the number plate of a suspected car is scanned. Unfortunately this technology is yet to be popularized in India.

Details of the procedure

An image of the vehicle is captured through the Raspberry Pi Camera module. The captured image is converted to grayscale. It is then dilated and the brightness and contrast of the image are adjusted accordingly. This is done using Contrast Limited Adaptive Histogram Equalisation [5]. This is followed by median filtering of the image to smoothen the background inhomogeneties. Next, the Number Plate Area is detected. This is done by edge detection [4] of the rectangular box in which the numbers lie. The image is now converted to binary**.** Characters are segmented and extracted using bounding box technique. Numbers are then identified using template matching technique. Finally the Number Plate is compared with the database of permissible vehicles. If a matching image is found, then an appropriate signal is sent to the GPIO, servo motors are activated and the door is opened. Otherwise an error message is displayed.



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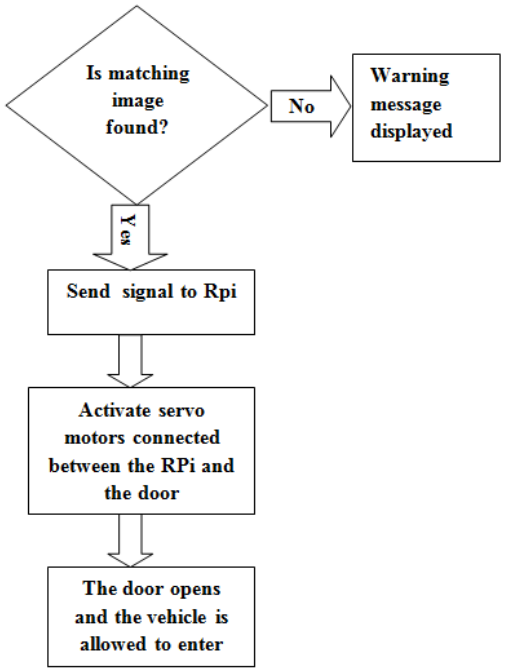

Figure 2: Flowchart for Automatic Number Plate Recognition Sub-system

Hardware implementation details

- The camera needs to be placed at an appropriate height so as to take a proper image of the number plate
- Proper lighting conditions is a must; a flash is provided for the same
- On successful recognition, an appropriate signal is sent to the GPIO
- The GPIOs are connected to a servo motor, powered externally
- Servo motors are activated on receipt of a positive response from the GPIO

Face Detection and Recognition

Introduction

Given an image, face detection software answers the question whether a human face exists or not and face recognition is concerned with the identity of the concerned person. There are multiple approaches to face detection:

- Knowledge-based methods
- Feature invariant approaches
- Template matching
- Appearance based methods

Popular face Recognition techniques include:

- Eigen faces
- Feature Analysis
- Neural Networks
- Automatic Face Processing

Details of the Procedure

An image of the face is captured through the Raspberry Pi Camera module. The captured image is converted to grayscale. It is then dilated and the brightness and contrast of the image are adjusted accordingly. This is done using Contrast Limited Adaptive Histogram Equalisation. This is followed by median filtering of the image to smoothen the background in homogeneties. After all the pre-processing tasks, a detector object is created using Viola-Jones [3] algorithm and a human face is detected. Face Recognition is done by Eigen Face Detection using Principal Component Analysis. The algorithm [7] utilizes the two dimensional global grayscale images representing distinctive characteristics. Using the above algorithms a face is detected and finally recognized.

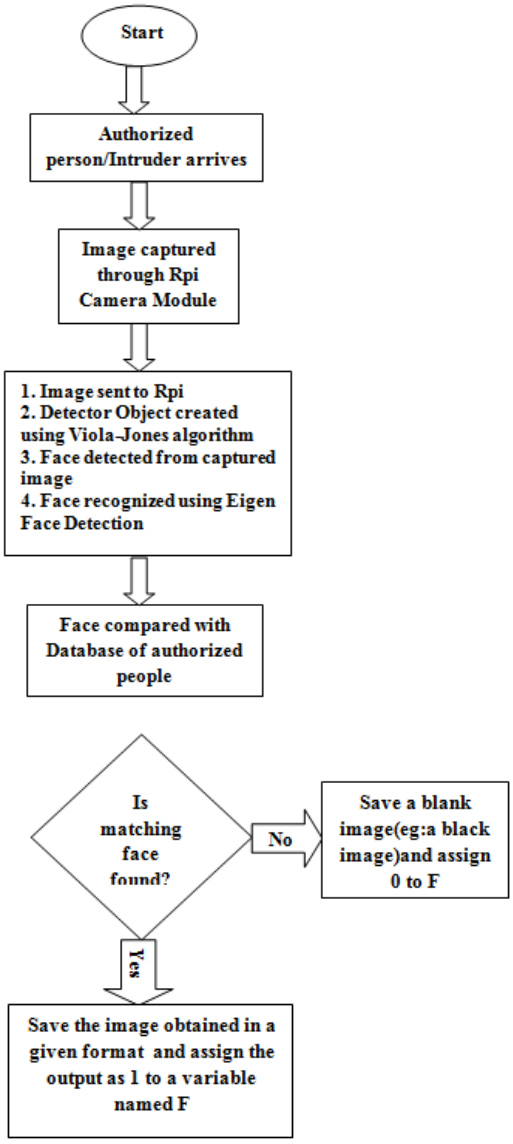

Figure 3: Flowchart for Face Detection and Recognition Sub-System

Hardware implementation details

- The camera needs to be placed at a strategic location so as to take a proper image of the face
- Proper lighting conditions is a must; a flash is provided for the same
- An external push switch will be provided which will trigger the PI Camera module to capture the image of the face

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Speech Recognition

Introduction

There are three main approaches for Speech Recognition Systems:

1. Hidden Markov modeling
   i. Based on statistical methods
   ii. Requires a large amount of training data
   iii. Gives most accurate results
2. Neural Networks
   i. Small set of words can be recognized very easily with some simplified models
1. Pattern Recognition
   i. Appropriate for less vocabulary speaker dependent systems
   ii. Easy to implement

Details of the Procedure

The technology adopted in the above system is Pattern Recognition. The first step involves filtering of the unvoiced part of speech. This is done by passing the input speech through a low-pass filter. Next, time alignment and amplitude normalization algorithms are applied. And then feature extraction of each frame of the input signal is done using normalization of absolute value of Fourier Transform [6]. Finally Pattern matching is done in which the input speech is compared with the database of stored voice samples and an array of errors is created. Minimum error object detected is considered as recognized voice.

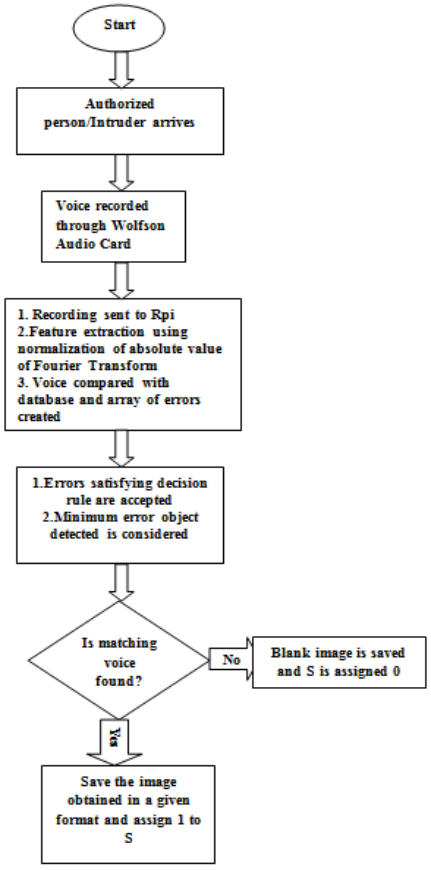

Figure 4: Flowchart for Speech Recognition Sub-system

Hardware implementation details

- Input speech is recorded using on-board MEMS microphone
- For commercial purposes, a separate microphone is used
- Voice processing is done by the programmable DSP embedded in the audio card

Overall Details of the System

On successful recognition of a face, 1 is assigned to a variable named 'F' else 0 is assigned. Similarly on successful recognition of a voice, 1 is assigned to a variable named 'S' else 0 is assigned. The outputs of the two systems are fed to the following circuit based on the following truth table:

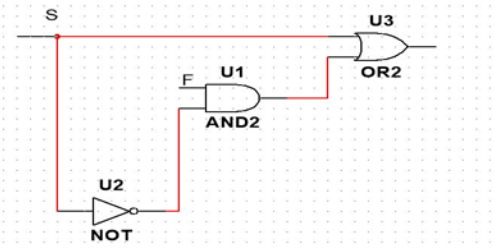

Figure 5: Circuit Diagram of overall system

TABLE 2: TRUTH TABLE OF DECISION MAKING CIRCUIT OF THE OVERALL SYSTEM

F	S	D
0	0	0
0	1	1
1	0	1
1	1	1

D=S+FS'

If the value of output 'D' is 1,then an appropriate signal will be sent to the Raspberry Pi, the servo motors will be activated, the door will be opened and the person will be allowed to enter the building complex.

IV. PRACTICAL APPLICATIONS

The above system has a lot of practical applications. Since it is very cheap, ready to use, portable, it can easily be bought and carried anywhere to monitor the security of the place. In contrast to the bulky, complex, face-recognition systems, it occupies a very small amount of space and is thus highly acceptable to the society. In addition it also eliminates the need to employ security personnel and pay them heavily. We can thus sleep peacefully at night without being worried about our belongings!

The sectors where this system can work are:

- Local Banking Institutions
- Small apartments/Housing Complexes
- Small office buildings(containing about 200-300 people)

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V. FUTURE SCOPE

The system however, has a few limitations. Situations might arise when:

1. The face-recognition system incorrectly recognizes face i.e. It recognizes person 'a' as person 'b'.
2. The voice recognition system incorrectly recognizes a voice.
3. The number plate recognition system fails to recognize the characters of the plate because it might be written in regional languages.

Overcoming these limitations can help improve the efficiency, authentication and reliability of the system a lot more.

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