Raspberry Pi Based Security System for Automotive Theft Detection

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Abstract: ***The vehicles are becoming a sign of luxury in human life and changed the life style of a common man. The rate of vehicle theft increases as the number of vehicles increases. Here comes the importance of detection of vehicle theft. . The proposed system is a face recognition based security system with face recognition module loaded in Raspberry Pi . When the driver sits in the driver seat and inserts key in to the key hole, a sensor is activated and a hidden camera captures the image of the driver which is then sent to the Raspberry Pi through an RS-232 cable. The captured image is pre-processed using histogram equalization.The face recognition system using back propagation neural network for classifying frontal grey scale images .The system uses voronoi diagram properties in image segmentation. The face blob is extracted from the segmented image and represented by using sobel gradient operator. Face to be recognized is correlated with images in the training set by calculating the matching scores obtained from its edge responses. The edge gradient representation using sobel gradient operator is found to be a good image representation method. Good classification results are achieved by this technique and it has found to be invariant against the changes caused due to illumination and facial expression. The software can distinguish between authorized and unauthorized drivers and send email to the owner if the vehicle is driven by an unauthorized person.***

Keywords: Raspberry Pi B+ , Histogram Equalization, voronoi diagram , sobel gradient operator,image representation, back propagation neural network, peak to side lobe ratio

1. Introduction

Building up of a security mechanism that is incorporated inside an automotive is a novel idea. The proposed system is having great relevance in detecting theft of a vehicle when the owner parks his vehicle in a parking lot or anywhere. The idea of authenticating a vehicle using face recognition system incorporated inside Raspberry Pi is a novel one. The main advantage of face recognition among other biometric methods is that it does not require the active co-operation of a person and can be used in cases where people are unknown about the presence of face recognition system.

Here we used Raspberry Pi B+ as the microcomputer in which the face recognition module is loaded. It is a small, low cost computer developed by Raspberry Pi foundation ,UK. It is a single board computer which is capable of doing any work a desktop can do and can be placed anywhere inside the vehicle.

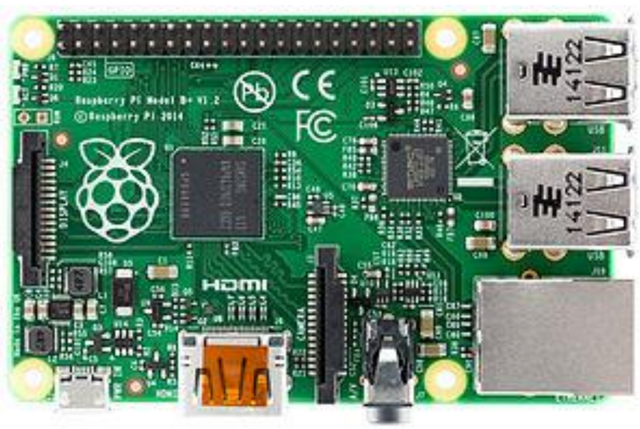


Figure 1: Raspberry Pi B+

2. Block Diagram

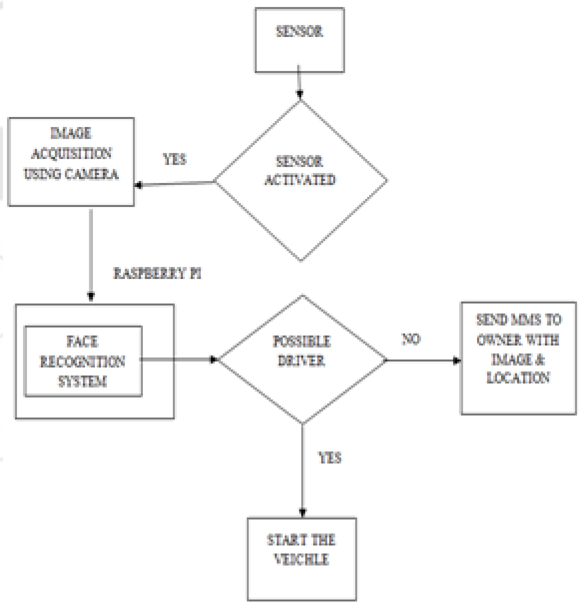


Figure 2: Block Diagram

The image of the driver, captured using a camera is passed to the face recognition system loaded into the Raspberry Pi. The face recognition system detects the face portion in the image and compares it with the images of possible drivers in the training set. If a mismatch is found, the owner is informed of the vehicle theft by sending an mms containing the acquired image of the driver as well as the current location of the vehicle.

3. Module Description

The software has three modules.

- Image Acquisition Module
- Face recognition Module
- Owner Module

3.1 Image Acquisition Module

When a person enters into the vehicle and put the key into the key hole a sensor will be activated which in turn activates a hidden camera in the vehicle. The camera will capture the image of the driver and pass it to the microcomputer through an RS-232 cable for further processing.

3.2 Face Recognition Module

The face recognition module is loaded into the Raspberry Pi B+ for processing of the captured image. The captured image is preprocessed using histogram equalization to better adjust the intensity values on the histogram. It is then passed to the face recognition module. The module comprises processes such as face detection and face recognition.

Face detection is the first stage of an automatic face recognition system, since a face has to be located in the input image before it is recognized.. Usually, face detection is a two-step procedure:

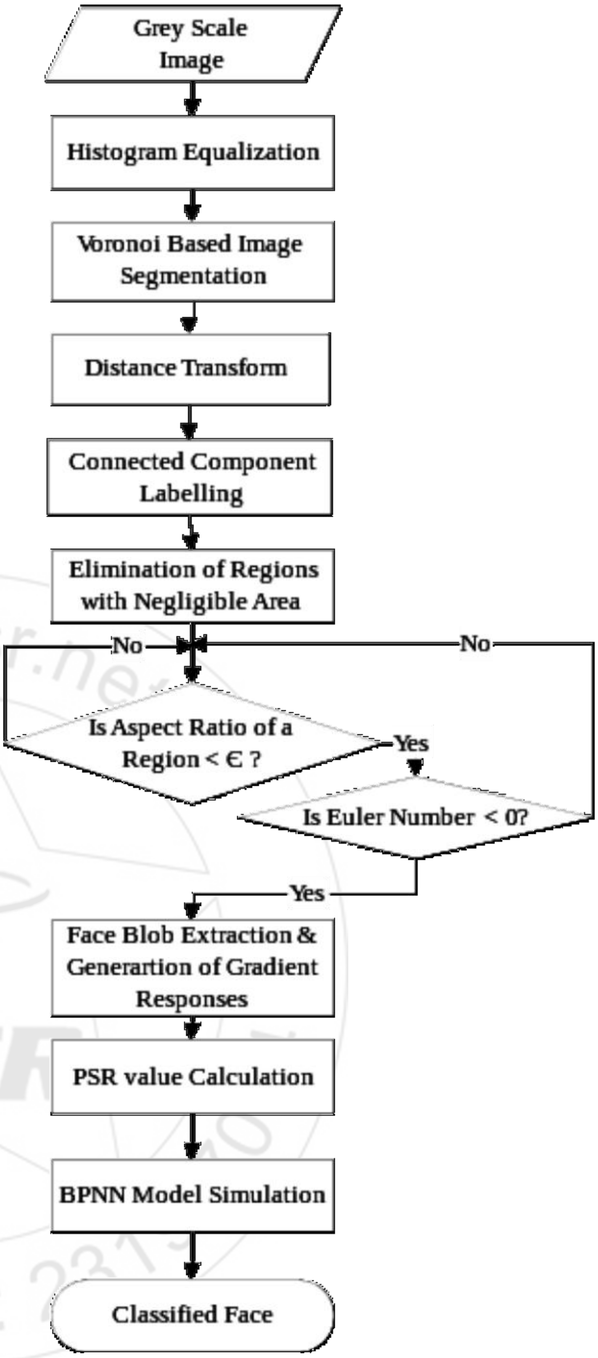
a) Finding a region that is identified as face.
b) Localization of its exact position

Face detection is mostly concerned with finding the face blob in images with complex background and the localization procedure emphasizes spatial accuracy.

A. Face Segmentation

Face segmentation is considered to be a key process in face detection. It is the process of grouping regions in an image based on similarities. The regions thus obtained have pixels that are similar with respect to some characteristics such as color, intensity or texture.

For segmenting the image, we use the concept of voronoi tessellations. The first step in segmentation is the generation of a feature vector which corresponds to some grey value steps needed for segmentation. For that, Voronoi Diagram (VD) is created from grey intensity frequencies obtained from the histogram of the image. VD is used to construct Delaunay Triangulations (DT) .From the DT list of vertices, we consider only the vertices pertaining to the outer boundary of DT called the convex hull. These vertices correspond to feature vector for segmentation. The top two vertices in the DT list of vertices corresponds to top two peaks (global maxima) in the histogram. We also include minima points in the feature vector. To determine the global minima, VD/DT is again applied on the histogram after excluding the intensity values not falling in the range of global maxima. The resulting feature vector is sorted and each pair value dictates a homogeneous range of data.Then we segment the image by giving a particular intensity value to the pixel intensities of the image if they fall between each pair of feature vector.



B. Face Localization

The result of image segmentation is a group of regions. After image segmentation, the next step is to find a region that corresponds to face. It is very difficult to extract the face blob from its background if there is a small difference between the pixel intensities of face region and background . To encounter with this situation we have used Distance Transformation (DisT) to separate the face region from its background by setting up a suitable threshold value for the DisT. The function operates on the Euclidean distance between two given points (x1, y1) and (x2, y2), where:

$$\text{DistT}= \sqrt{(x1-x2)^2+(y1-y2)^2} \qquad (1)$$

For the selection of a probable face candidate, the resultant image is converted to binary. Connected Component labeling is carried out to mark different regions. Next, we eliminated regions of negligible area as they may not form a face area .We used two criterion simultaneously for selecting the face region

- *Aspect ratio of the major and minor axes*: It has been empirically noted that the aspect ratio of faces will be less than a tolerance factor
- *Euler number*: A binarized face region will normally expose face features as holes because of their low intensity. This helps in identifying a probable face region in terms of its Euler number. Therefore, it is safe to say that a face would consist of at least two holes.

4. Face Recognition Process

The success of the face recognition system depends on the method used for classifying the images. Image representation using sobel edge gradient operator and classification using BPNN forms the core of the recognition process.

A. Image Representation

An edge gradient based image representation is used in this work. Gradient refers to the change in the image. We used sobel gradient operator for computing the gradient of the image. The Sobel operator is based on convolving the image with a small, separable, and integer valued filter in horizontal and vertical direction and is therefore relatively inexpensive in terms of computations The operator calculates the *gradient* of the image intensity at each point, giving the direction of the largest possible increase from light to dark and the rate of change in that direction. The result therefore shows how abruptly or smoothly the image changes at that point

Mathematically, the operator uses two 3×3 kernels which are convolved with the original image to calculate approximations of the derivatives - one for horizontal changes, and one for vertical. If we define **A** as the source image, and $\mathbf{G}_x$ and $\mathbf{G}_y$ are two images which at each point contain the horizontal and vertical derivative approximations, the computations are as follows:

$$\mathbf{G}_y = \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} * \mathbf{A} \quad \text{and} \quad \mathbf{G}_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * \mathbf{A} \qquad (2)$$

where * here denotes the 2-dimensional convolution operation. The *x*-coordinate increases in the right-direction, and *y*-coordinate increases in the down-direction.

We took the horizontal and vertical edge responses of the sobel gradient operator and formed a two dimensional gradient vector

B. Correlation Based Template Matching

Face verification is achieved through correlation based template matching [21] and BPNN. Let r(x, y) and i(x, y) be the reference face image and the test face image respectively. Then correlation between them is computed as follows:

$$C(\tau_x, \tau_y) = i(x,y) \square r(x,y)$$

$$= \iint i(x,y) r(x+\tau_x, y+\tau_y) dxdy$$

$$= \iint I^*(u,v) R(u,v) \exp(j2\pi(u\tau_x + v\tau_y)) dudv \quad (3)$$

where I(u, v) and R(u,v) are the Fourier transforms of i(x, y) and r(x, y), respectively, and □ denotes the correlation operator. If the test and reference face images are similar, then the correlation between them $C(\tau_x, \tau_y)$ will produce a high value at the origin and if they are not similar, then the correlation output will produce a low value at the origin. Here, the origin refers to the center of the correlation output

To quantify the correlation output we used, peak-to-side lobe ratio (PSR) measure . The PSR measures the sharpness of the highest peak in the correlation output. If the test and reference face images are similar, the peak will be high and sharp and will be low and blunt in the opposite case. PSR (P) is defined as:

$$P = (\rho - \mu) / \sigma \qquad (4)$$

where ρ is the value of the maximum peak in the correlation output , μ is the mean of the correlation output around the peak and σ is the standard deviation of the values.

C. Classification using Back propagation Neural Network

BPNN is found to be very effective in pattern classification. For correct classification of images sufficient training is required. Here we designed BPNNs with three layers namely input, hidden and output layer. We used *Hyperbolic tangent sigmoid* and *Linear* transfer functions at the hidden and output layer respectively.

The Back propagation learning process works in small iterative steps: one of the example cases is applied to the network, and the network produces some output based on the current state of it's synaptic weights (initially, the output will be random). This output is compared to the known-good output, and a mean-squared error signal is calculated. The error value is then propagated backwards through the network, and small changes are made to the weights in each layer. The weight changes are calculated to reduce the error signal for the example case chosen. The whole process is repeated for each of the example cases, then back to the first case again, and so on. The cycle is repeated until the overall error value drops below some pre-determined threshold. At this point we say that the network has learned the problem well enough.

3.3. Owner Module

The owner module comprises the process of sending mms to the owner when an unauthorized person tries to drive the vehicle. The output of face recognition module is used for this purpose. When a person who is not authorized tries to drive the vehicle, an mms containing the image of the person and the current location of the vehicle is sent to the owner. The owner can then inform the police about the theft with a solid proof.

5. Results

The training set consists of four different frontal images of two possible drives authorized to drive the vehicle as shown in Fig-6 .This is fed to the face recognition system and it is trained to identify the possible drivers.

Figure 6: The training set

The system very well identifies the possible drivers if they enter in to the vehicle. If an unknown person such as shown in Fig-7 enters in to the vehicle, face recognition system recognizes him as a thief and informs the owner about the vehicle theft.

(a) (b)

Figure 7: (a) Image of an unauthorized person (b) Recognized Face

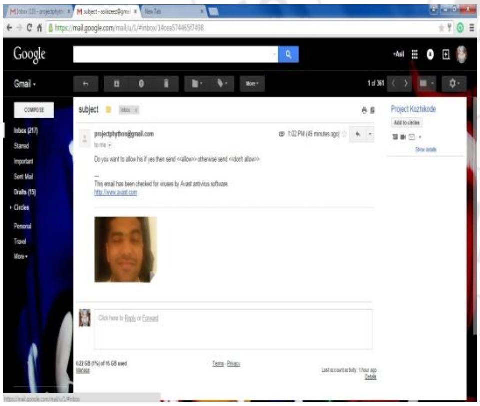


Figure 8: Screen shot of the email sent to owner

6. Conclusion

The proposed system is a novel idea that enables the manufacturer of a vehicle to embed the security system inside the vehicle at the time of manufacturing. Face detection is performed efficiently by voronoi image segmentation and face selection criteria . Face recognition is achieved through correlation based template matching and BPNNs. The use of sobel gradient operator for generating edge responses exposed better classification results. The use of BPNN successfully classified images as authorized and unauthorized and email is sent to the owner when the person is unauthorized.

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