AUTHENTICATED VEHICLE PARKING SYSTEM BY THE METHOD OF NUMBER PLATE RECOGNITION AND IRIS PATTERN MATCHING OF THE DRIVER OF THAT PARTICULAR VEHICLE

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by

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DECLARATION

We declare that the work presented in this report titled "**Authenticated Vehicle Parking System by The Method of Number Plate Recognition and Iris Pattern Matching of The Driver of that Particular Vehicle**", submitted to the Computer Science & Engineering Department, National Institute of Technology Agartala, for the award of the ***Bachelor of Technology*** degree in ***Computer Science & Engineering***, represents our ideas in our own words and where others' ideas or words have been included, We have adequately cited and referenced the original sources. We also declare that We have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE

It is certified that the work contained in the report titled "**Authenticated Vehicle Parking System by The Method of Number Plate Recognition and Iris Pattern Matching of The Driver of that Particular Vehicle**", has been carried out by *Nirupam Chakrabarti* bearing Enrolment Number *11UCS035*, *Chumki Acharya* bearing Enrolment Number *11UCS019*, *Abir Dutta* bearing Enrolment Number *11UCS003*, *Pratham Kar* bearing Enrolment Number *11UCS038* and *Anirban Datta* bearing Enrolment Number *11UCS009* under my supervision and this work has not been submitted elsewhere for a degree.

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Dedicated to

To our loving families for their kind love & support.
To our project supervisor Asst. Prof. Parthasarathi De for sharing his valuable knowledge, encouragement & showing his confidence on us all the time.

“I believe in evidence, I believe in ovservation, measurement, and reasoning, confirmed by independent observers. I’ll believe anything, no matter how wild and ridiculous, if there is evidence for it. The wilder and more ridiculous something is, however, the firmer and more solid the evidence will have to be.”

- Isaac Asimov

Abstract

The issue of security is very paramount in any organization, especially whenever the growth of the organization is directly related to the customer satisfaction and trust. Therefore we intend to aid the security system of a vehicle parking area by bringing in a typical authentication by the method of vehicle number plate recognition and Iris pattern matching of the driver of that particular car. In our prescribed project the system is going to be implemented in such a manner that whenever any car will be entering into the parking lot the registration number of the car and the digital template of the iris of the driver will be stored. The moment the car will be leaving the parking lot the registration number and the iris of the driver will once again be compared with the previously stored template. If both the images match with the corresponding templates (created and stored at the time of entry) only then the car will be allowed to be driven out of the lot. From this project we hope to build an alternative but more enhanced security system for the vehicle parking lots that ensures only the authenticated person to drive the car out of the parking bay it was parked into.

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Chapter 1

Introduction

1.1 Motivation

When the computing era started, we had little to feed to those electronic machines to help us. But as time passed by, we had more and more problems that were being taken care of by computers. And as it stands, we use computers for almost everything. With changing technology and emphatically increasing technological requirements of the world, we are realizing the need for a much more dynamic structure which will provide us the elasticity, robustness and scalability to keep on providing the computing resources we need.

Iris detection is one one of the most accurate and secure means of biometric identification while also being one of the least invasive. Fingerprints of a person can be faked–dead people can come to life by using a severed thumb. Thieves can don a nifty mask to fool a simple face recognition program. The iris has many properties which make it the ideal biometric recognition component.

The iris has the unique characteristic of very little variation over a life's period yet a multitude of variation between individuals. Irises not only differ between identical twins, but also between the left and right eye. Because of the hundreds of degrees of freedom the iris gives and the ability to accurately measure the textured iris, the false accept probability can be estimated at 1 in 10^{31}. Another characteristic which makes the iris difficult to fake is its responsive nature. Comparisons of measurements taken a few seconds apart will detect a change in iris area if the light is adjusted - whereas a contact lens or picture will exhibit zero change and flag a false input.

Whereas, automatic license plate recognition could be used to automatically open a gate or barrier into a secured area for authorised members. This could replace or assist security guards at the gates or barriers of premises. Again if a vehicle is stolen, it could be marked in the license plate recognition system as so. If at any point the stolen vehicle happens to pass a camera on the roadside that belongs to the license plate recognition system analarm is set off to alert a guard.

We are willing to encapsulate this two highly entertained features in the field of security to build up a typical security system that claims to be more enhanced in the aspect of securing the premise.

1.2 Objective

1. Merge two different image processing techniques to establish a secured authentication system.
2. Learning image processing fundamentals, iris and number plate recognition technologies by hands-on practice.
3. Build an alternative but more enhanced security system for the vehicle parking lots that ensures only the authenticated person to drive the car out of the parking bay it was parked into.

1.3 History

Although John Daugman developed and patented the first actual algorithms to perform iris recognition, published the first papers about it and gave the first live demonstrations, the concept behind his invention has a much longer history.

In 1953, in a clinical textbook, F. H. Adler wrote : "*In fact, the markings of the iris are so* *distinctive that it has been proposed to use photographs as a means of identification, instead of fingerprints.*" [1] Apparently Adler referred to comments made by the British ophthalmologist J.H. Doggart, who in 1949 had written that: "*Just as every human being has different fingerprints, so does the minute architecture of the iris exhibit variations in every subject examined. [Its features] represent a series of variable factors whose conceivable permutations and combinations are almost infinite.*"[2] Much later in the 1980's two American ophthalmologists, L. Flom and A. Safir managed to patent Adler's and Doggart's conjecture that the iris could serve as a human identifier, but they had no actual algorithm or implementation to perform it and so the patent was conjecture. The roots of the conjecture stretch back even further: in 1892 the Frenchman A. Bertillon had documented nuances in "*Tableau de l'iris humain*".

The core theoretical idea in Daugman's algorithms is that the failure of a test of statistical independence could be a very strong basis for pattern recognition, if there is sufficiently high entropy (enough degrees-of-freedom of random variation) among samples from different classes. In 1994 he patented this basis for iris recognition and its underlying Computer Vision algorithms for image processing, feature extraction, and matching, and published a paper in `IEEE Transactions`.[3] Those original algorithms became widely licensed through a series of companies like IriScan, Iridian, Sarnoff, Sensar, LG-Iris, Panasonic, Oki, BI2, IrisGuard, Unisys, Sagem, Enschede, Securimetrics etc. With various improvements over the years, these algorithms remain today the basis of all significant public deployments of iris recognition.

On the other hand, Automatic Number Plate Recognition (ANPR) was invented in 1976 at the Police Scientific Development Branch in the UK. Prototype systems were working by 1979, and contracts were let to produce industrial systems, first at EMI Electronics, and then at Computer Recognition Systems in Wokingham, UK. Early trial systems were deployed on the A1 road and at the Dartford Tunnel. However it did not become widely used until new developments in cheaper and easier to use software was pioneered during the 1990s. The first arrest through detection of a stolen car was made in 1981.

Until the early 2000s, ANPR systems consisted of a camera, usually with an illuminator, and a computer running ANPR software. In 2003 PIPS Technology introduced the P372, the first fully integrated ANPR camera with all of these functions in a single small housing.

[1] Chapter VI, Physiology of the Eye - F. H. Adler

[2] Page 27, Ocular Signs in Slit-Lamp Microscopy - J. H. Doggart

[3] Daugman (1993) High confidence visual recognition of persons by a test of statistical independence. IEEE Pattern Analysis Machine Intelligence 15: 1148 1161

1.4 Concept behind Recognition Systems

The main technology behind our system is digital image processing. In iris recognition, the identification process is carried out by gathering one or more detailed images of the eye with a sophisticated, high-resolution digital camera at visible or infrared (IR) wavelengths, and then using a specialized computer program called a matching engine to compare the subject's iris pattern with images stored in a database. The matching engine can compare millions of images per second with a level of precision comparable to conventional fingerprinting or digital fingerscanning.

Automatic Number Plate Recognition (ANPR) is a challenging area of research that deals with artificial intelligence, neural networks and machine vision to construct an ANPR system.this is done by using mathematical principles and algorithms.

1.5 Advantages of Iris Recognition

Biometrics makes use of the physiological or behavioral characteristics of subjects for personal identification. By using biometrics it is possible to establish an identity based on who a person is, rather than by what that person possess, such as an ID card, or what that person knows, such as a password. Although a number of biometric modalities may be used for identity authentication, there are significant differences between them in terms of identification performance metrics such as accuracy, scalability, robustness, usability, and security. In 2001, the UK National Physics Laboratory conducted a comprehensive comparative study on popular biometric modalities such as face, fingerprint, iris, hand geometry and voice, and iris recognition was found to be the most accurate bio-metrics technology. As a relatively new member in the biometrics family, iris recognition has attracted growing attention from academia, industry and government due to its highly desirable properties for personal identification.

- Uniqueness: The uniqueness of iris pattern comes from the richness of texture details in iris images, such as freckles, coronas, stripes and furrows. Even twins have totally different iris details. The randomly distributed and irregularly shaped microstructures of iris patterns make the human iris one of the most informative and reliable biometric traits.

- Stability: Iris texture is formed during gestation and the main structures of iris are shaped after 8 months. It has also been shown that the iris is essentially stable across ones lifetime.

- Non-invasiveness: Since the iris is an internal organ as well as externally visible, iris images can be taken at a distance from the user. Non-invasiveness not only makes the procedure of iris recognition more hygeian than touch needed biometric modalities such as fingerprint recognition, but also enables iris recognition to be applicable to passive or covert personal identification, which is of great importance for public security applications.

- Scalability: Images of the iris region can be normalized into rectangle regions of fixed size so that binary feature codes of fixed length can be extracted for extremely fast feature matching based on simple XOR operation. Therefore iris recognition is well suited to large-scale personal identification applications.

- Security: Security of biometric systems has been a bottleneck to the wide deployment of biometrics. Compared with most biometric modalities, iris recognition is more secure simply because of the difficulty of live iris forgery. Iris is small in size and active near infrared illumination is required to capture detailed iris textures in most cases. So it is difficult to collect clear iris images of others without their awareness. In addition, human iris has many special optical and physiological characteristics which can be exploited to defend against possible spoofing. So it is non-trivial if at all possible to forge an iris with similar dynamic characteristics to live human irises.

1.6 Disadvantages of Iris Recognition

- Cost : One of the main reasons of slow adaptation of iris recognition technology is the cost associated with installation and maintenance of iris scanning systems. It is, however, expected that as industry matures and iris recognition becomes more wide-spread, the cost will come down significantly.

- Acceptability: Users do not generally like the unfamiliar. People are slow to adopt new technologies especially when they see them violating their privacy and confidentiality.

- Security: No system is 100% accurate that includes biometrics. From research conducted it is highlighted that there is a False Acceptance Rate where the wrong person is accepted and False Rejection Rate where the system rejects the right person. The levels of these errors are deemed to be well under acceptable level.

- Technical Issues:
  - Small target (1 cm) to acquire from a distance (1 m).
  - Moving target.
  - Located behind a curved, wet, reflecting surface
  - Obscured by eyelashes, lenses, reflections
  - Partially occluded by eyelids, often drooping.
  - Deforms non-elastically as pupil changes size
  - Illumination should not be visible or bright

Chapter 2

Fundamentals Of Image Processing

An image is used to convey useful information in avisible format. An image is nothing but an arrangement of tiny elements in a two-dimensional plane. These tiny elements are called Pixels. A large number of pixels combine together to form an image, whether small or large.

Each pixel represents certain information about the image, like color, light intensity and luminance. A large number of such pixels combine together to form an image. Pixel is the basic element used to describe an image. Mostly, each pixel in an image is represented in either RGB (Red Green Blue)format or YCbCr format. In case of an RGB image, all the three components, namely R, Gand B combine together to convey information about the color and brightness of a single pixel. Each component consumes certain memory space during image processing.

In case of a YCbCr image, each pixel in an image is represented as a combination of Y and Cb/Cr values. Here, Y stands for luminance, which describes light intensity, and Cb/Cr stands for chroma component, which describes color information for an image. Over the time, it has been found that YCbCr components of an image convey sufficient amount of information compared to its counter partsRGB, with less amount of memory space. This is a major advantage nowadays, as most of the applications require sufficient information at very high speed and less storage.

2.1 RGB Format

In case of an RGB image, each pixel is represented by three different components R, G and B. Each of these components requires at least 8 bits for their storage. In general, a single pixel may require upto 8 * 3 bits for its storage. An example of a representation of single pixel in RGB format is shown below.

R	G	B	R	G	B

Figure 2.1: Representation of pixels in RGB format.

The value of R, G and B each ranges from 0-255. A value of (0, 0, 0) represents a black pixel, (255, 0, 0) represents a red pixel and(0, 255, 0) represents a green pixel. So, 8 bits are required to store value for a single component.

2.2 YCbCr Format

In contrast to RGB format, the YCbCr format is available with various kind of interleaving. For example, a 4:2:2 YCbCr format suggests that a single pixel is represented by two components, Y and C. Cb and Cr components are interleaved among the pixels. So if one pixel is represented by a combination of Y and Cb, the adjacent pixel will be represented by a combination of Y and Cr. Even if the Cb and Cr components are interleaved, its effect is not visible to human eye.

Y	Cb	Y	Cr	Y	Cb

Figure 2.2: Representation of pixels in YCbCr format.

Values for Y, Cb and Cr vary from 0-255. Thus, to store a single pixel, the amount of storage required is 8 * 2 bits, which is less compared to that required by RGB format. For this project, Texas Instruments EVM320DM6437 kit is to be used for license plate detection. The kit contains internal buffers to store the incoming frames of video. The format for the type of storage is shown below.

Cb	Y	Cr	Y
Cb	Y	Cr	Y
Cb	Y	Cr	Y

Figure 2.3: A part of frame buffer storage for input video frames.

From the above image, it is seen that the storage of frame starts with a C component and then a Y component. Therefore, at the 0th location, one can find the C component while at the 1st and alternate locations of Frame Buffer, one can find the Y component.

2.3 Gray-Scale Image

Grayscale is a range of monochromatic shades from black to white. Therefore, a grayscale image contains only shades of gray and no color.

While digital images can be saved as grayscale (or black and white) images, even color images contain grayscale information. This is because each pixel has a luminance value, regardless of its color. Luminance can also be described as brightness or intensity, which can be measured on a scale from black (zero intensity) to white (full intensity). Most image file formats support a minimum of 8-bit grayscale, which provides 2^8 or 256 levels of luminance per pixel. Some formats support 16-bit grayscale, which provides 2^{16} or 65,536 levels of luminance.

2.4 NTSC and PAL Standards

NTSC and PAL are the two most commonly used standards used for broadcasting. NTSC stands for National Television System Committee. This standard is being used in most parts of Northern America and countries like South Korea, Japan, and etcetera. Videos broadcasted using NTSC standard contains a sequence of images with resolution of 720 * 480 pixels. The video is displayed at the frame rate of 30 frames per second.

PAL stands for Phase Alternate Line. PAL Standard is used mainly in countries like India, China, United Kingdom, and etcetera. This standard supports the video resolution of 720 * 576 pixels at the frame rate of 25 frames per second.

Chapter 3

Underlying Technologies

3.1 Image Segmentation

Segmentation partitions an image into distinct regions containing each pixels with similar attributes. To be meaningful and useful for image analysis and interpretation, the regions should strongly relate to depicted objects or features of interest. Meaningful segmentation is the first step from low-level image processing transforming a greyscale or colour image into one or more other images to high-level image description in terms of features, objects, and scenes. The success of image analysis depends on reliability of segmentation, but an accurate partitioning of an image is generally a very challenging problem.

Segmentation techniques are either contextual or non-contextual. The latter take no account of spatial relationships between features in an image and group pixels together on the basis of some global attribute, e.g. grey level or colour. Contextual techniques additionally exploit these relationships, e.g. group together pixels with similar grey levels and close spatial locations.

3.1.1 Edge Detection Techniques for Image Segmentation

Edge detection provides rich information about the scene being observed. Many researchers have been taking advantage of edge detection information to improve the segmentation of range images by integrating edge detection with other different segmentation techniques. Few most frequently used edge detection techniques are:

Roberts Edge Detection

The Roberts Cross operator performs a simple, quick to compute, 2-D spatial gradient measurement on an image. It thus highlights regions of high spatial frequency which often correspond to edges. In its most common usage, the input to the operator is a grayscale image, as is the output. Pixel values at each point in the output represent the estimated absolute magnitude of the spatial gradient of the input image at that point.

+1	0
0	-1

Gx

0	+1
-1	0

Gy

Figure 3.1: Robert Mask

For example, if a 2x2 window is used as such

p1	p2
p3	p4

where the filter is centered on p1 with p2 being pixel[x+1][y] and p3 being pixel[x][y+1], etc. then the forumla to calculate the resulting new p1 pixel is pixel = abs(p1-p4)+abs(p2-p3) which is them clamped to the 0-255 range.

Sobel Edge Detection

The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradientmagnitude at each point in an input grayscale image. In theory at least, the operator consists of a pair of 3x3 convolution kernels. One kernel is simply the other rotated by 90o.This is very similar to the Roberts Cross operator. The convolution masks of the Sobel detector are given below.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

+1	+2	+1
0	0	0
-1	-2	-1

Gy

Figure 3.2: Sobel Mask

Prewitt Edge Detection

The prewitt edge detector is an appropriate way to estimate the magnitude and orientation of an edge. Although differential gradient edge detection needs a rather time consuming calculation to estimate the orientation from the magnitudes in the x- and y-directions, the compass edge detection obtains the orientation directly from the kernel with the maximum response. The prewitt operatoris limited to 8 possible orientations, however experience shows that most direct orientation estimates are not much more accurate. This gradient based edge detector is estimated in the 3x3 neighbourhood for eight directions. All the eight convolution masks are calculated. One convolution mask is then selected, namely that with the largest module

-1	+1	+1
-1	-2	+1
-1	+1	+1

0°

+1	+1	+1
-1	-2	+1
-1	-1	+1

45°

Figure 3.3: Prewitt Mask

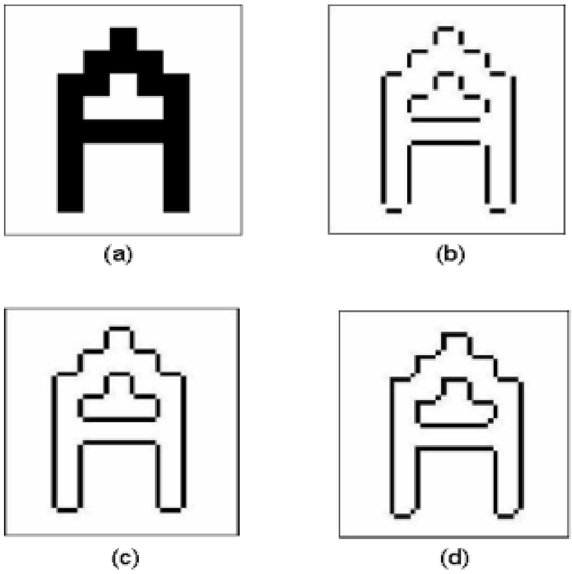

Figure 3.4: The comparison of the edge detections for the example image. (a) Original Image (b) using Prewitt Edge Detection (c) using Roberts Edge Detection (d) using Sobel Edge Detection

Canny Edge Detection

The Canny operator was designed to be an optimal edge detector (according to particular criteria — there are other detectors around that also claim to be optimal with respect to slightly different criteria). It takes as input a gray scale image, and produces as output an image showing the positions of tracked intensity discontinuities. The Canny operator works in a multi-stage process. First of all the image is smoothed by Gaussian convolution. Then a simple 2-D first derivative operator (somewhat like the Roberts Cross) is applied to the smoothed image to highlight regions of the image with high first spatial derivatives. Edges give rise to ridges in the gradient magnitude image. The algorithm then tracks along the top of these ridges and sets to zero all pixels that are not actually on the ridge top so as to give a thin line in the output, a process known as non-maximal suppression. The tracking process exhibits hysteresis controlled by two thresholds: T1 and T2, with T1 ¿ T2. Tracking can only begin at a point on a ridge higher than T1. Tracking then continues in both directions out from that point until the height of the ridge falls below T2. This hysteresis helps to ensure that noisy edges are not broken up into multiple edge fragments.

3.2 Normalization

In image processing, normalization is a process that changes the range of pixel intensity values. Applications include photographs with poor contrast due to glare, for example. Normalization is sometimes called contrast stretching or histogram stretching. In more general fields of data processing, such as digital signal processing, it is referred to as `dynamic range expansion`. [1]

Normalization transforms an n-dimensional grayscale image

$$I : \{\mathbb{X} \subseteq \mathbb{R}^n\} \rightarrow \{\text{Min,..,Max}\}$$

with intensity values in the range (Min,Max), into a new image

$$I_N : \{\mathbb{X} \subseteq \mathbb{R}^n\} \rightarrow \{\text{newMin,..,newMax}\}$$

with intensity values in the range (newMin,newMax).

3.3 Filters

3.3.1 Gabor Filter

Gabor filters are bandpass filters which are used in image processing for feature extraction, texture analysis, and stereo disparity estimation. The impulse response of these filters is created by multiplying an Gaussian envelope function with a complex oscillation. Gabor showed that these elementary functions minimize the space (time)-uncertainty product. By extending these functions to two dimensions it is possible to create filters which are selective for orientation. Under certain conditions the phase of the response of Gabor filters is approximately linear. This property is exploited by stereo approaches which use the phase-difference of the left and right filter responses to estimate the disparity in the stereo images. It was shown by several researchers that the profile of simple-cell receptive fields in the mammalian cortex can by discribed by oriented

[1] Rafael C. Gonzlez, Richard Eugene Woods (2007). Digital Image Processing. Prentice Hall. p. 85. ISBN 0-13-168728-X.

two-dimensional Gabor functions. Let x = [x1 x2]. T be the image coordinates. The impulse response of a Gabor filter g(x) is then given by:

$$g_{mn}(x) = \frac{1}{2\pi a_n b_n} e^{-\frac{x^T A_{mn}}{2}} e^{j k_{0mn}{}^T x}$$

3.3.2 Gaussian Filter

A Gaussian filter is a filter whose impulse response is a Gaussian function (or an approximation to it). Gaussian filters have the properties of having no overshoot to a step function input while minimizing the rise and fall time. This behavior is closely connected to the fact that the Gaussian filter has the minimum possible group delay. It is considered the ideal time domain filter, just as the sinc is the ideal frequency domain filter.

Mathematically, a Gaussian filter modifies the input signal by convolution with a Gaussian function; this transformation is also known as the Weierstrass transform.

The one-dimensional Gaussian filter has an impulse response given by

$$g(x) = \sqrt{\frac{a}{\pi}} \cdot e^{-a \cdot x^2}$$

and the frequency response is given by the Fourier transform

$$\hat{g}(f) = e^{-\frac{\pi^2 f^2}{a}}$$

with f the ordinary frequency. These equations can also be expressed with the standard deviation as parameter

$$g(x) = \frac{1}{\sqrt{2\pi} \cdot \sigma} \cdot e^{-\frac{x^2}{2\sigma^2}}$$

and the frequency response is given by

$$\hat{g}(f) = e^{-\frac{f^2}{2\sigma_f^2}}$$

By writing a as a function of σ with the two equations for g(x) and as a function of σ_f with the two equations for $\hat{g}(f)$ it can be shown that the product of the standard deviation and the standard deviation in the frequency domain is given by

$$\sigma \cdot \sigma_f = \tfrac{1}{2\pi},$$

where the standard deviations are expressed in their physical units, e.g. in the case of time and frequency in seconds and Hertz.

In two dimensions, it is the product of two such Gaussians, one per direction:

$$g(x, y) = \tfrac{1}{2\pi\sigma^2} \cdot e^{-\frac{x^2+y^2}{2\sigma^2}}$$

where x is the distance from the origin in the horizontal axis, y is the distance from the origin in the vertical axis, and is the standard deviation of the Gaussian distribution.

3.4 Character Segmentation

The character segmentation process acts as a bridge between the license plate localization and optical character recognition modules. Its main function is to segment the characters in the selected candidate region (extracted license plate) such that each character can be sent to the optical character recognition module individually for recognition. Normalised or standardized license plates are important criteria for efficient segmentation because if numbers are of a fancy format the conditions of the license plate as as required may not hold true. This is the main reason why in India, where license plates are not normalised we do not have widespread license plate recognition system to date.

Once the license plate is localized we proceed to obtain the individual characters. A license plate has high intensity variation regions (due to alternating white and black regions).This forms the basis for character segmentation. Sometimes it is observed that along with the license numbers, various texts may be present (indicating state names etc.), which have to be removed. By various observations we observed that for the license plate regions the amount of white (number or text) on black (background region) or vice versa, is specific for the number regions and falls within a certain range. We ignore those regions which are out of range to isolate the number regions[5]. Morpho logical techniques are used to remove small white areas which escape range corrections (certain shadows or text which show similar patterns to numbers).Finally individual char acters are extracted to pass on through the optical character recognition (OCR) system. Segmentation is one of the most important processes in the automatic number plate recognition, because all further steps rely on it. If the segmentation fails, a character can be improperly divided into two pieces, or two characters can be wrongly merged together which would lead to the failure of following stages of recognition. We can use a horizontal projection of a number plate for segmentation. If we assume only one-row plates, the segmentation is a process of finding horizontal boundaries between characters. The second phase of the segmentation is an enhancement of segments. The segment of a plate contains besides the character also undesirable elements such as noise due to shadows or defects in camera equipment as well as redundant space on the sides of character[!]. There is a need to eliminate these elements and extract only the individual characters.

Pre Processing Stage

Before we can proceed with the segmentation stage, we must ensure that the plate obtained is cleared off most of the unwanted characters or graphics like state name or flags etc. We proceed to do so by scanning the plate vertically and horizontally and ignoring those rows and columns which have too much white or black. This is justified as those areas containing the numbers have black areas which lie in a particular range. This range by experiments was found to lie between 0.2 and 0.8 times the number of pixels horizontally and vertically.

The character segmentation process takes the extracted license plate region from the preceding module as the input. The input is a colored JPEG image. For our process we work with only binary images and thus the first part of segmentation is binarisation of the image.

The binary image thus obtained has certain unwanted areas which need not be considered during the OCR process and may even hamper the detection process. For example in the above figure we have screw marks and country code written on the plate which are of no relevance to the recognition of authentic license numbers. Thus these regions have to be filtered out.

We use the concept oi oonnected components to filter small areas out of the plate region. Componentst with pixels lower than a particular threshold are converted to background and thus iguored. We thus obtain a relatively clear binarised plate region suitable for segmentation and relatively free of noise and redundant region.

Segmentation of plate using a horizontal projection

We compute a horizontal projection px(x) of the plate f (x, y) . We use this projection to determine horizontal boundaries between segmented characters. These boundaries correspond to peaks in the graph of the horizontal projection. The goal of the segmentation algorithm is to find peak, which correspond to the spaces between characters.

The aim of this step is to find the boundaries between two consecutive character on the number plate. By obtaining the horizontal projection we can consider only those peaks which are greater than a certain threshold value as these boundaries.

The last step of the phase of character segmentation is to obtain the individual character. This is fulfilled by using the above obtained boundary values. These individual characters are then fed to the next step of analysis which is the final step called the Optical character recognition.

3.5 Optical Character Recognition

Optical character recognition (OCR) is the mechanical or electronic conversion of images of typewritten or printed text into machine-encoded text. It is widely used as a form of data entry from printed paper data records, whether passport documents, invoices, bank statement, receipts, business card, mail, or other documents. It is a common method of digitizing printed texts so that it can be electronically edited, searched, stored more compactly, displayed on-line, and used in machine processes such as machine translation, text-to-speech, key data and text mining.

There are two basic types of core OCR algorithm, which may produce a ranked list of candidate characters.

Matrix matching involves comparing an image to a stored glyph on a pixel-by-pixel basis; it is also known as “pattern matching”, “pattern recognition”, or “image correlation”. This relies on the input glyph being correctly isolated from the rest of the image, and on the stored glyph being in a similar font and at the same scale. This technique works best with typewritten text and does not work well when new fonts are encountered. This is the technique the early physical photocell-based OCR implemented, rather directly.

Feature extraction decomposes glyphs into “features” like lines, closed loops, line direction, and line intersections. These are compared with an abstract vector-like representation of a character, which might reduce to one or more glyph prototypes. General techniques of feature detection in computer vision are applicable to this type of OCR, which is commonly seen in “intelligent” handwriting recognition and indeed most modern OCR software. Nearest neighbour classifiers such as the k-nearest neighbors algorithm are used to compare image features with stored glyph features and choose the nearest match.

3.6 What we have used

- **Roberts Edge Detection**

  The Roberts Edge filter is use to detect edges based applying a horizontal and verticle filter in sequence. Both filters are applied to the image and summed to form the final result. The Roberts Edge detector is fast since the filter is small but it is also subject to interference by noise. If edges are not very sharp the filter will tend not to detect the edge. See Prewitt or Sobel filters instead which are larger and less sensative to noise.

- **Canny Edge Detection**

  Since edge detection is the early step in object recognition, it is significant to know the differences between edge detection techniques. Representing an image by its edges has the advantage of reducing the amount of data required to be stored while retaining most of the image information. Transmitting of the edge pixels in an image would result in a great deal of compression and there exists very reliable algorithms to reconstruct the entire image based on the edge map. From various researches it have been observed that that the Canny edge detection algorithm produces higher accuracy in detection of edges and execution time compared with Sobel edge detection `algorithm.`[2]

- **Hough Transform**

  The Hough transform is a standard computer vision algorithm that can be used to determine the parameters of simple geometric objects, such as lines and circles, present in an image. The circular Hough transform can be employed to deduce the radius and centre coordinates of the pupil and iris regions.There are a number of problems with the Hough transform method. First of all, it requires threshold values to be chosen for edge

[2]Dr.S.Vijayarani, Mrs.M.Vinupriya - Performance Analysis of Canny and Sobel Edge Detection Algorithms in Image Mining , IJIRCCE - Vol 1, Issue 8, October 2013

detection, and this may result in critical edge points being removed, resulting in failure to detect circles/arcs. Secondly, the Hough transform is computationally intensive due to its brute-force approach, and thus may not be suitable for real time applications. The methods all apply an edge detector to the iris image followed by searching for the best inner and outer circular boundaries for the iris using the Hough transform. The edge detectors used vary between the methods, and in the case of the method proposed in also between detection of the outer and inner boundaries of the iris. These methods all rely on good threshold parameters for the edge detection step,making them sensitive to varying imaging conditions

- **Daugman's Integro-differential Operator**

  Daugman makes use of an integro-differential operator for locating the circular iris and pupil regions, and also the arcs of the upper and lower eyelids. It works with raw derivative information, so it does not suffer from the thresholding problems of the Hough transform. However, the algorithm can fail where there is noise in the eye image, such as from reflections, since it works only on a local scale.

  This method is based on his integro-differential operator, defined in equation 2.0 which searches for the best fitting circles for the inner and outer boundaries of the iris. The operator is used twice, once for the inner boundary and once for the outer boundary searching iteratively for the best centre coordinates $(x0, y0)$ in the image.I. This is done by looking for the max value of the derivative in the radius dimension of the result of a circular contour integration. This search is performed iteratively from a coarse scale down to pixel level through convolution with a Gaussian kernel function, G_r with decreasing size.

- **Daugman's Rubber Sheet Model**

  The homogeneous rubber sheet model devised by Daugman remaps each point within the iris region to a pair of polar coordinates $(r,)$ where r is on the interval [0,1] and is angle $[0, 2\pi]$. Even though the homogeneous rubber sheet model accounts for pupil dilation, imaging distance and non-concentric pupil displacement, it does not compensate for rotational inconsistencies. In the Daugman system, rotation is accounted for during matching by shifting the iris templates in the direction until two iris templates are aligned.

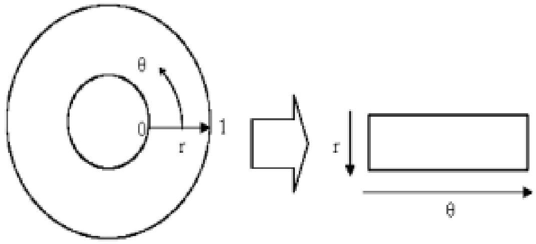

Figure 3.5: Daugman's Rubber Sheet Model

- **Feature encoding**

  The significant features of the iris must be encoded so that comparisons between templates can be made. Most iris recognition systems make use of a band pass decomposition of the iris image to create a biometric template.The encoding, or feature extraction, aims to extract as many discriminating features as possible from the iris and results in an iris signature, or template, containing these features. The matching process between two templates aims to maximize the probability of a true match for authentic identification tries and minimize false matches for impostors. In other words, images of the same iris taken at different times should be identified as being from the same person and images from different irises should be marked as coming from different persons

- **Gabor Filter**

  Gabor filters are able to provide optimum conjoint representation of a signal in space and spatial frequency. A Gabor filter is constructed by modulating a sine/cosine wave with am Gaussian. This is able to provide the optimum conjoint localisation in both space and frequency, since a sine wave is perfectly localised in frequency, but not localised in space. Daugman makes uses of a 2D version of Gabor filters in order to encode iris pattern data.

- **Matching Algorithm - Hamming Distance**

  The Hamming distance gives a measure of how many bits are the same between two bit patterns. Using the Hamming distance of two bit patterns, a decision can be made as to whether the two patterns were generated from different irises or from the same one.Matching is performed, using the normalized Hamming distance measure defined in equation 2.4, taking into account the occluded regions defined as masks by not comparing the feature points extracted from these regions. The result is the number of bits that are different between the binary codes in the non-occluded regions, divided by the number of bits compared.

$$HD = \frac{\text{codeA} \oplus \text{codeB} \wedge \text{maskA} \wedge \text{maskB}}{\text{maskA} \wedge \text{maskB}}$$

If the iris images would not be subject to noise and segmentation errors would not occur,the Hamming distance between two pictures taken of the same iris would be 0, however even at the most perfect conditions for imaging this is not the case. Daugman reports that the mean Hamming distance between two iris templates of the same iris, imagined at different occasions and under near perfect conditions is 0.11.

The theoretical Hamming distance between two different irises results in a Bernoulli trial,or coin toss test, Pp(m—N), where p is the probability that two bits are equal, m is the number of equal bits and N is the total number of bits compared. For uncorrelated iris codes p = 0.5. The fractional function associated with the binomial distribution is defined in equation 4.8 where x = N/m is the normalized hamming distance spanning from 0 to 1.

$$f(x) = \frac{N!}{m!(N-m)!} p^m (1-p)^{N-m}$$

- **Back Propagation Network Algorithm**

  A Back Propagation network learns by example. Various sets of datasets are provided as input .The various input provided helps the network to calculate and recalculate the networks weight value so that when the network is trained it can give the required output.

  The network is initialized by first setting random weights which generally have very small value such as values between -1 and 1. There are two passes in the Back Propagation algorithm. After the network is set up with the random weights the output is calculated and this is called the forward pass. The result obtained in the forward pass may not be equal to the required result or the target and so the error is calculated far each neuron which is, Target- Actual Output .The error calculated for each neuron is then mathematically used to change the weights so that in the next time the forward pass will have minimum error. So, the output of each neuron will get closer to its target. This is called the reverse pass. This process is repeated again and again to minimize the error.

  The Character is recognised after training the network with various datasets of that particu1ar character to get maximum accuracy and minimum error.

Chapter 4

Flowcharts & Implementation

4.1 Proposed Architecture

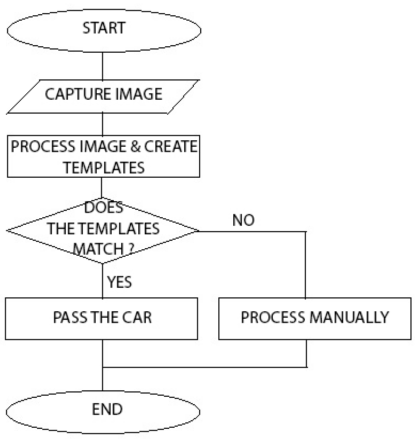

Figure 4.1: Flowchart of the process

4.2 Implementation

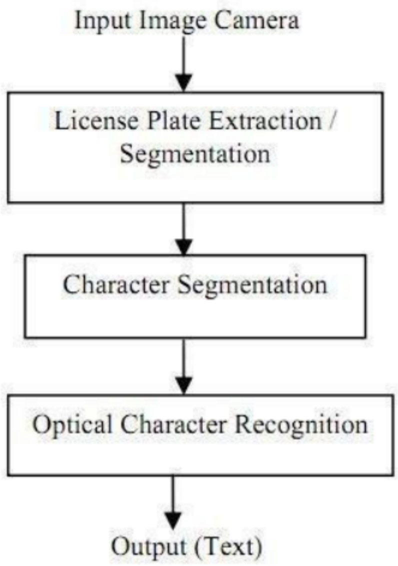

Figure 4.2: Steps followed in number plate recognition

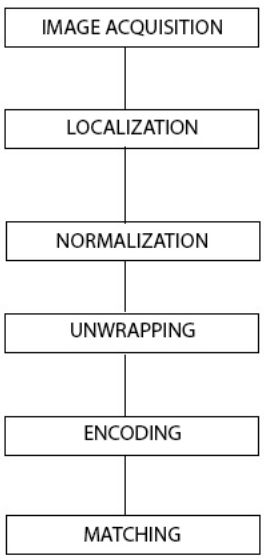

Figure 4.3: Steps followed in iris recognition

4.2.1 Number Plate Recognition

Conversion To Gray-Scale Image

The algorithm described here is independent of the type of colors in image and relies mainly on the gray level of an image for processing and extracting the required information. Color components like Red, Green and Blue value are not used throughout this algorithm. So, if the input image is a colored image represented by 3-dimensional array in MATLAB, it is converted to a 2-dimensional gray image before further processing.

Dilation of The Image

Dilation is a process of improvising given image by filling holes in an image, sharpen the edges of objects in an image, and join the broken lines and increase the brightness of an image. Using dilation, the noise with-in an image can also be removed. By making the edges sharper, the difference of grayvalue between neighboring pixels at the edge of an object can be increased. This enhances the edge detection. In Number Plate Detection, the image of a car platemay not always contain the same brightness and shades. Therefore, the given image has to be converted from RGB to gray form. However, during this conversion, certain important parameters like difference in color, lighter edges of object, etc. may get lost. The process of dilation will help to nullify such losses.

Horizontal & Vertical Edge Processing

Histogram is a graph representing the values of a variable quantity over a given range. In this Number Plate Detection algorithm, the writer has used horizontal and vertical histogram, which represents the column-wise and row-wise histogram respectively. These histograms represent the sum ofdifferences of gray values between neighboring pixels of an image, column-wise and row-wise.

In the above step, first the horizontal histogram is calculated. To find a horizontal histogram, the algorithm traverses through each column of an image. In each column, the algorithm starts with the second pixel from the top. The difference between second and first pixel is calculated.

If the difference exceeds certain threshold, it is added to total sum of differences. Then, algorithm will move downwards to calculate the difference between the third and second pixels. So on, it moves until the end of a column and calculate the total sum of differences between neighboring pixels. At the end, an array containing the column-wise sum is created. The same process is carried out to find the vertical histogram. In this case, rows are processed instead of columns

Passing Histograms through a Low Pass Digital Filter

Referring to the figures, one can see that the histogram values changes drastically between consecutive columns androws. Therefore, to prevent loss of important information in upcoming steps, it is advisable to smooth out such drastic changes in values of histogram. For the same, the histogram is passed through a low-pass digital filter. While performing this step, each histogram value is averaged out considering the values on it right-hand side and left-hand side. This step is performed on both the horizontal histogram as well as the vertical histogram. Below are the figures showing the histogram before passing through a low-pass digital filter and after passing through a low-pass digital filter.

Filtering out Unwanted Regions in an Image

Once the histograms are passed through a low-pass digital filter, a filter is applied to remove unwanted areas from an image. In this case, the unwanted areas are the rows and columns with low histogram values. A low histogram value indicates that the part of image contains very little variations among neighboring pixels. Since a region with a license plate contains a plain background with alphanumeric characters in it, the difference in the neighboring pixels, especially atthe edges of characters and number plate, will be very high. This results in a high histogram value for such part of an image. Therefore, a region with probable license plate hasa high horizontal and vertical histogram values. Areas with less value are thus not required anymore. Such areas are removed from an image by applying a dynamic threshold. In this algorithm, the dynamic threshold is equal to the average value of a histogram. Both horizontal and vertical histograms are passed through a filter with this dynamic threshold. The output of this process is histogram showing regions having high probability of containing a number plate.

Segmentation

The next step is to find all the regions in an image that has high probability of containing a license plate. Co-ordinates of all such probable regions are stored in an array.

Region of Interest Extraction

The output of segmentation process is all the regions that have maximum probability of containing a license plate. Out of these regions, the one with the maximum histogram value is considered as the most probable candidate for number plate. All the regions are processed row-wise and column-wise to find a common region having maximum horizontal and vertical histogram value. This is the region having highest probability of containing a license plate.

Optical Character Recognition

The output of the last phase is the area containing a license plate. This image is sent to the next phase where all the characters are segmented and extracted. Each character is appended to form the string which represents the number plate of the car.

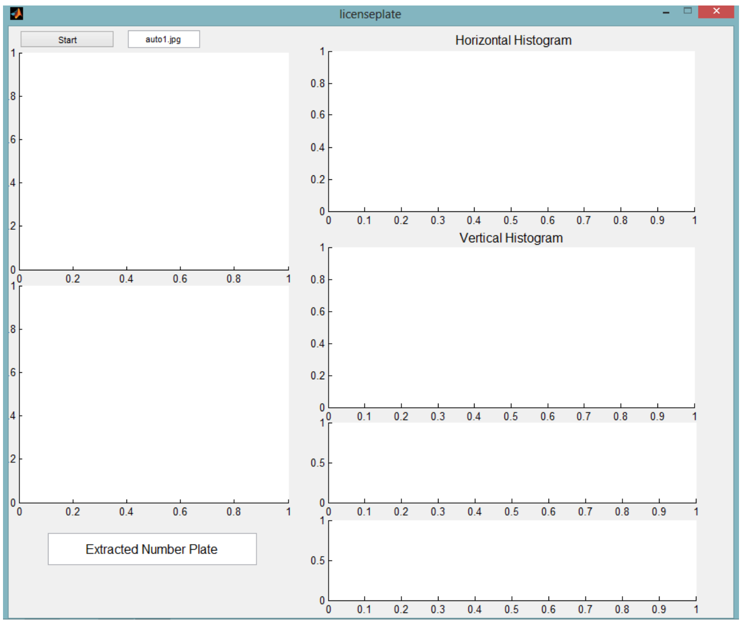

Figure 4.4: Working Window of the System

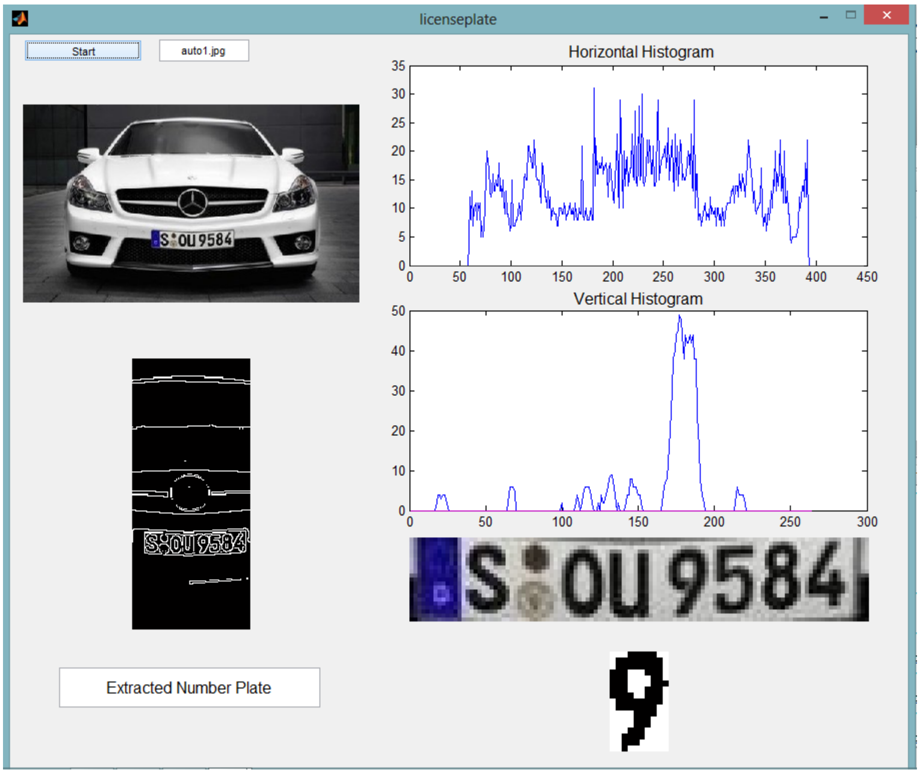

Figure 4.5: Recognition Process in Progress

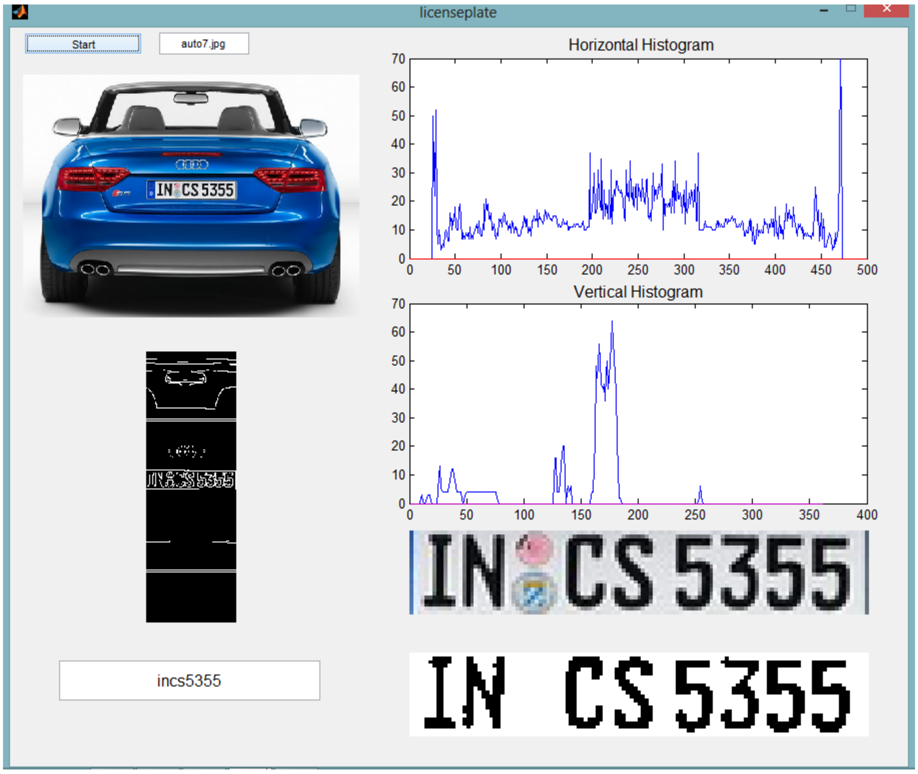

Figure 4.6: Window After the Process is Completed

4.2.2 Iris Recognition

Iris Location

When locating the iris there are two potential options. The software could require the user to select points on the image, which is both reliable and fairly accurate, however it is also time consuming and implausible for any real-world application. The other option is for the software to auto-detect the iris within the image. This process is computationally complex and introduces a source of error due to the inherent complexities of computer vision. However, as the software will then require less user interaction it is a major step towards producing a system which is suitable for real-world deployment, and thus became a priority for extending the program specification. Locating the iris is not a trivial task since its intensity is close to that of the `sclera` [1] and is often obscured by eyelashes and eyelids. However the pupil, due to its regular size and uniform dark shade, is relatively easy to locate. The pupil and iris can be

[1]The white part of the eye

approximated as concentric and this provides a reliable entry point for auto detection.

Pupil

The pupil's intensity and location are fairly consistent in most images and so it lends itself well to auto-detection. Detection of the pupil can be carried out by: removing noise by applying a median blur, thresholding the image to obtain the pupil, performing edge detection to obtain the pupil boundary and then identifying circles. A median filter is a kernel based, convolution filter which blurs an image by setting a pixel value to the median of itself with its neighbours. A native approach to applying a median filter would be to simply find the median for a given area around each pixel by sorting an array and finding the median to replace the current pixel with. This could be implemented with a sorting algorithm which would have runtime O(n log n) on average. However, since the software requires several median blurs on different images a more eficient solution is required. For an improved algorithm we consult `Perreault's paper`[2], which describes an algorithm to create a median filter in linear time.

The overall effect of the median blur is to reduce the noise and pixel intensity complexity of the iris image without perturbing the edge fidelity of the original image. This results in a stronger clustering of pixel values in the resultant pixel data histogram; this permits a largely noise-free, dynamic analysis of features which occupy discrete pixel ranges, such as the pupil. Upon application of a dynamic threshold to our median blurred image the leftmost image is obtained. The location of the pupil is well defined, and edge detection can extract this information to form a single bit depth image which can be searched for circles.

[2]S. Perreault and P. Hebert. Median Filtering in Constant Time. IEEE Transactions on Image Processing, 16(9):2389{2394, 2007.}

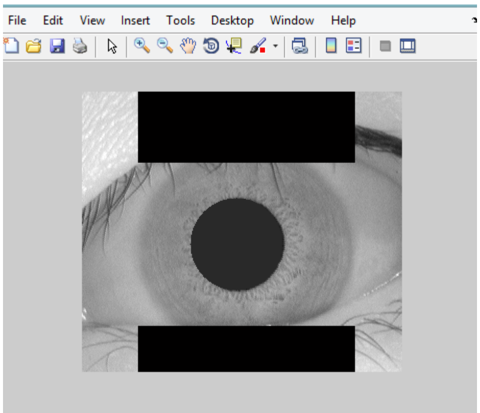

Figure 4.7: Segmented Iris Image

Iris Translation

Having acquired an approximate radius, a small pad of this value should produce a circle centered on the pupil which contains the entire iris. Furthermore, with the perimeter of the pupil known, an annulus may be formed which should have the majority of it's area filled by the iris. This annulus can then be unrolled into cartestian coordinates through a straight discretized transformation. $(r - - > y, - - > x)$.

If the iris is perfectly centered on the pupil, the unrolled image should have a perfectly straight line along its top. However, if the iris is off center even a little this line will be wavy. The line represents the overall distance the iris is at from the pupil center. It is this line which will help to determine the iris' center and radius. Consequently, an edge detection algorith m must be run on the strip in order to determine the line's exact location. Once again canny edge detection is used. However, before the edge detection can be run the image should undergo some simple pre-processing to increase the contrast of the line. This will allow for a higher thresholding on the edge detection to eliminate extraneous data.

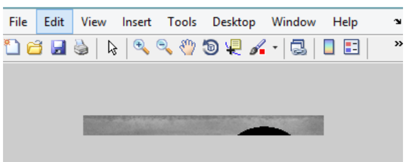

Figure 4.8: Translated Iris

Iris Information Extraction

In order to extrapolate the iris center and radius, two chords of the actual iris through the pupil must be found. This can be easily accomplished with the information gained in the previous step. By examining points with x values on the strip offset by half of the length of the strip a chord of the iris is formed through the pupil center. It is important to pick the vectors for these chords so they are both maximally independent of each other, while also being far from areas where eyelids or eyelashes may interfere.

Iris Unwrapping

Although the pupil and iris circles appear to be perfectly concentric, they rarely are. In fact, the pupil and iris regions each have their own bounding circle radius and center location. This means that the unwrapped region between the pupil and iris bounding does not map perfectly to a rectangle. This is easily taken care of with a little trigonometry. There is also the matter of the pupil, which grows and contracts its area to control the amount of light entering the eye. Between any two images of the same person's eye, the pupil will likely have a different radius. When the pupil radius changes, the iris stretches with it like a rubber sheet. Luckily, this stretching is almost linear, and can be compensated back to a standard dimension before further processing.

Iris Comparision

The problem of comparing iris codes arises when we want to authenticate a new user. The user's eye is photographed and the iris code produced from the image. It would be nice to be able to compare the new code to a database stored codes to see if this user is allowed or to see who they are. To perform this task, we'll attempt to measure the Hamming distance between two iris codes. The Hamming distance between any two equal length binary vectors is simply the number of bit positions in which they differ divided by the length of the vectors. This way, two identical vectors have distance 0 while two completely different vectors have distance 1. Its worth noting that on average two random vectors will differ in half their bits giving a Hamming distance of 0.5. The Hamming distance is mathematically defined in this equation: $D = \mathrm{A} \oplus \mathrm{B}$ In theory, two iris codes independently generated from the same iris will be exactly the same. In reality though, this doesn't happen vary often for reasons such as imperfect cameras, lighting or small rotational errors. To account for these slight inconsistencies, two iris codes are compared and if the distance between them is below a certain threshold we'll call them a match. This is based on the idea of statistical independance. The iris is random enough such that iris codes from different eyes will be statistically independent (ie: have a distance larger than the threshold) and therefore only iris codes of the same eye will fail the test of statisical independance. Empirical studies with millions of images have supported this assertion.

Iris Database

Since we are able to generate the code and the iris mask directly, these are the only two items that are required to be stored in a database, the image bitmaps themselves are no longer required.

We are currently using a basic text

le as our database as this was simple to implement and for the small number of eyes we have as test subjects this is perfectly adequate and proves to be able to compare iris bitcodes extremely fast.

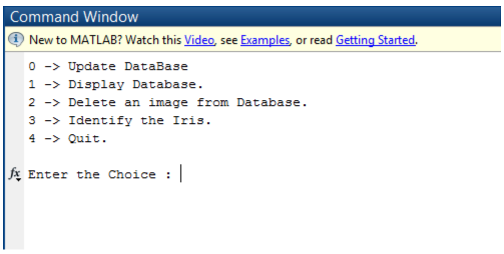

Figure 4.9: Working View of Iris Recognition/ Detection

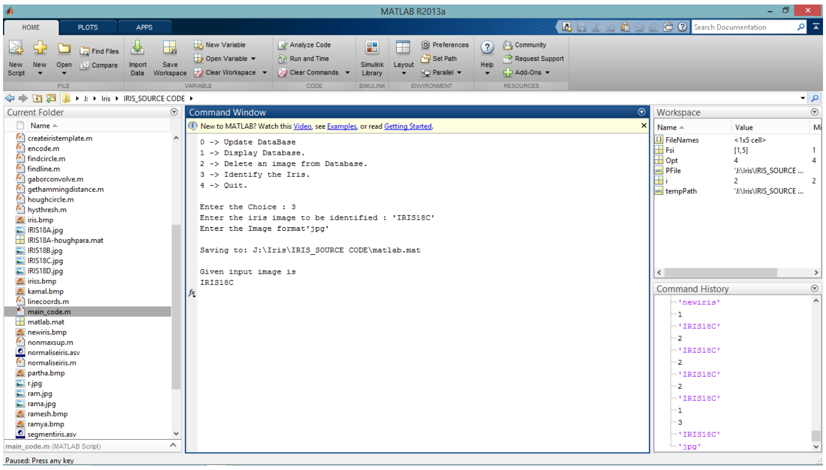

Figure 4.10: Result of Recognition System : Iris Identified

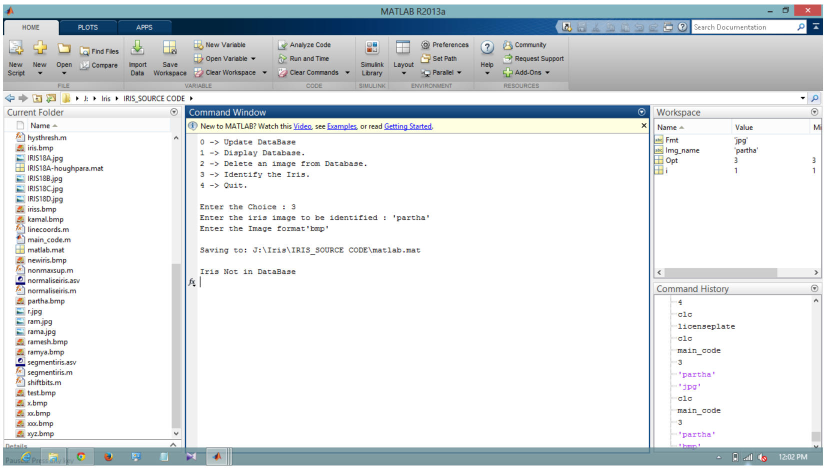

Figure 4.11: Result of Recognition System : Iris Denied

Issues:

To physically implement our build up system, someone has to satisfy the following conditions:

- The person who has driven the car has to drive the car out.
- The parking bay should be spacious enough to accommodate two tier checking systems: one for regular scenarios and the other for exceptions.

Chapter 5

Conclusion

5.1 Final Product

The final product can read in an 8-bit indexed, grayscale image and will attempt to automatically best-fit parameters for the location of the pupil, iris and eyelids with consideration for specular highlights and padding for eyelash interference. The entire auto-detection process takes a matter of milliseconds. The user may choose to manually enter points to specify all of these locations; if the user does, he or she will receive appropriate visual feedback cues for repositioning elements in a manner intuitive to any casual computer user.

From this point, the user input is complete and the application will process the image data, unwrap the iris using polar co-ordinates and mask appropriate regions of the unwrapped iris based on the auto-detection sequence or user input. This information is then extracted using Gabor wavelet convolution filters and the final output is a 2048-bit iris code containing phase information of the valid iris pixel data.

5.2 Auto Detection

Pupil detection in the application works to a very high degree of accuracy in every seen case. The pupil has a fairly unique shade in comparison to the rest of the eye and its surrounding area; this enables an intelligent threshold to be carried out with information from the image histogram to isolate the pupil. This, unfortunately, is not a property shared by the iris, making it significantly more difficult to isolate than the pupil. Currently the prototype makes an estimation of the location of the iris based on con-centricity (a potential source of error) with the pupil, and assumes a detectable gradient ramp between the iris and the sclera. The prototype manages to detect the top edge of the eyelids in the vast majority of cases. With the small amount of padding added to accommodate the thickness of the top eyelid, it can be seen that, although not perfect, a very reasonable estimate of the eyelid boundary is found automatically.

5.3 Critical Lookup

Where our project cannot work

1. For localization of the license plate there should be proper edge in between the license plate boundary and the car.
2. The camera should be present at a particular distance so that the range of pixels in which the number plate lies remains constant.
3. For character segmentation, if there is no clear boundary/peaks between each character, segmentation cannot be carried out successfully.
4. Fancy fonts used in the number plate creates hindrance to successful segmentation of the characters.
5. If the number plate consists of two rows of texts, our algorithm fails.

References

[1] Wisam Al Faqheri and Syamsiah Mashohor, “A Real-Time Malaysian Automatic License Plate Recognition (M-ALPR) using Hybrid Fuzzy” ,IJCSNS International Journal of Computer Science and Network Security, VOL.9 No.2, February 2009.

[2] Saeed Rastegar, Reza Ghaderi, Gholamreza Ardeshipr & Nima Asadi, “An intelligent control system using an efficient License Plate Location and Recognition Approach”, International Journal of Image Processing (IJIP) Volume(3), Issue(5) 252, 2009.

[3] V. Ganapathy and W.L.D. Lui, “A Malaysian Vehicle License Plate Localization and Recognition System”, Journal of Systemics, Cybernetics and Informatics, Vol. 6, No. 1, 2008.

[4] Pramod Kapadia, Car License Plate Recognition Using Template Matching Algorithm, Master Project Report, California StateUniversity, Sacramento, Fall 2010.

[5] Dr.S.Vijayarani, Mrs.M.Vinupriya - “Performance Analysis of Canny and Sobel Edge Detection Algorithms in Image Mining ”, International Journal of Innovative Research in Computer and Communication Engineering, Vol. 1, Issue 8, October 2013

[6] “ Physiology of the Eye” - F. H. Adler

[7] “ Ocular Signs in Slit-Lamp Microscopy” - J. H. Doggart

[8] J. Daugman, “High confidence visual recognition of persons by a test of statistical independence.” IEEE Pattern Analysis Machine Intelligence 15: 1148 1161

[9] J. Daugman, “Biometric personal identification system based on iris analysis”. United States Patent, Patent Number: 5,291,560, 1994.

[10] Dibyendu Ghoshal, Parthasarathi De, Bapi Saha “Identification of Tigers for Census by the Method of Tiger Iris Pattern Matching and Recognition International Journal of Computer Applications (0975 8887), Volume 49 No.2, July 2012

[11] G.T. Shrivakshan, “A Comparison of various Edge Detection Techniques used in Image Processing ”, International Journal of Computer Science Issues, Vol. 9, Issue 5, No 1, September 2012

[13] J. Daugman. “How iris recognition works” IEEE Transactions on circuits and systems for video technology, 14(1):2130, 2004.

[13] J. Daugman, “New methods in iris recognition” IEEE Trans. Systems, Man, Cyber-netics B, 37(1):11671175, 2007. `http://homepages.inf.ed.ac.uk/rbf/HIPR2/hough.htm`

[14] Gonzalez R., Woods R.: Digital Image Processing, Prentice Hall, Upper Saddle River, New Jersey, 2002

[15] Edge Detection Tutorial `http://http://dasl.mem.drexel.edu/alumni/bGreen/www.pages.drexel.edu/_weg22/edge.html`