CHAPTER 1

INTRODUCTION

1.1 ENTHUSIASM AND AIMS

Transformation invariant pattern recognition plays an essential role in the field of computer vision, pattern recognition, document analysis, image understanding and medical imaging. Since the system works well for the invariant real-time transformation distortions, it turns into an efficient recognition or identification system. In addition, features extracted from the identical sources should be classified as the same kind of classes in diverse illumination and other deformation. An invariant pattern recognition system is capable of adjusting to any exterior artefacts and produces minimum false positives for the patterns that are obtained from the intraclasses. The aim of this thesis is to suggest transformation invariant pattern recognition that improves the performance of recognition system. The proposed algorithms have been tested on Iris Recognition System (IRS) and License Plate Recognition System (LPRS).

IRS is a difficult problem in computer vision to recognise a person in non-invasive manner, for instance, from a short distance. It provides high security in any public domain application such as E-election, bank transactions, network login and other automatic person identification systems. The IRS algorithm can be categorised into four types such as Quadrature-phasor encoded, Texture analysis, Zero-crossing and Local variation methods suggested by Daugman (2004), Li ma et al (2003), Boles and Boashash
(1998) and Li ma et al (2004) respectively. However, these methods have limitations such as masking bits for occlusion avoidance, shifting of feature bits and several templates required to make a system as rotation invariant.

Recognising iris from eye images and license plate from natural scene are complicated processes that include localisation, segmentation, feature extraction and recognition. LPRS is of substantial interest in the field of machine vision because of its applications to areas such as cross border security, law enforcement and various other automation applications. Many methods have been suggested in the current literature (Shyang et al 2004, Yali Amit et al 2004, Park et al 1999 and Hegt et al 1998). These methods used plate specific details such as aspect ratio, colour or dimensions of the plate in the complex task of plate localisation. Most of these techniques put a lot of constraints on the size and colour of the plate, the size of the characters, position of the vehicle, stationary backgrounds and fixed illumination.

The main objective of this thesis work is to reduce inaccurate localisation, false reject rates and deploy the transformation invariant pattern recognition in the IRS and LPRS. The challenge is to investigate an effective approach to localise the region of interest (ROI). In addition, this thesis aims to employ the iris patterns in the cryptography system.

1.2 THESIS ORGANISATION

The research work carried out in this thesis is mainly related with real time images acquired in the Indian environments. The work of weight-based localisation is performed on the vehicle and eye images to efficiently isolate ROI. The transformation system is developed to resolve the issue of invariant pattern recognition. The wavelet and optimised Gabor filters are employed for feature extraction of both the IRS and LPRS. The iris patterns
are deployed in present cryptosystem to confine key management and repudiation issues. The entire work reported in this thesis is divided into 7 chapters.

Chapter 1 describes the role of transformation invariant analysis in pattern recognition. It mainly presents the various issues related with LPRS and IRS. An overview of LPRS and the different approaches like colour histogram, aspect ratio, TDNN, dynamic range, fuzzy map and coarse-to-fine strategy are explained. An overview of IRS with various approaches in the literature such as quadrature-phasor encoding, texture analysis, local sharp variations and zerocrossing are described.

Chapter 2 describes the process of acquiring vehicles and eye images in real time conditions, which assist to process patterns in transformation invariant manner. The anti-spoofing phase is proposed to prevent artificial sources by verifying the system. The quality frame phase is suggested to choose the best one from the sequence of frames by the Fourier feature descriptors and support vector machines. The image status checking is used to verify the status of the eye images in diverse illuminations and artefacts. Finally, the various luminance levels of the acquired images are estimated to obtain the adaptive optimum threshold values to do the processes such as binarisation and localisation. These methods are executed with the real time images and results are obtained.

In Chapter 3, localisation of region of interest is discussed. The localisation is based on the weight based density map, which forms density area on the region of interest and isolate the most relevant part from the other region of the image. Two methods have been proposed for performing this operation, straight-line map, which isolates LP from the natural scene of vehicle image and circular map that is used to localise iris from the real time
eye image. In both the approaches translation invariant is achieved efficiently, which assists to make the system as invariant pattern recognition. The results of these approaches in applying LPRS and IRS are illustrated.

The orientation estimation of real time patterns is represented in Chapter 4. It reports the estimation of rotation angle of real time license plates and iris images. The estimated angles are used to correct the images to its original position and then wavelets are applied to extract the features from the iris patterns. Gabor filter optimisation is used for efficient selection of the filter parameter values and subsequently to achieve better accuracy in the rotation-invariant pattern analysis. The experimental results of transformation invariant analysis are reported for both LPRS and IRS.

The statistical analysis of IRS and LPRS are given in Chapter 5. The performance of Euclidean norm distance measures, weighted distance and Hamming neural network classifiers were studied a classification of iris images and the results are reported. These methods intend to discriminate subjects’ iris pattern as independent of statistical hypothesis. In LPRS, classification of ambiguous LP characters is a main issue, which shrinks the efficacy of the system. This problem has been resolved by optimised Gabor features and HNN classifier design. The results of statistical analysis are reported.

Chapter 6 explains the new avenue of research related with fusion of biometric and cryptography system. The various issues of biometric cryptosystem are described based on the iris patterns and encryption/decryption processes. The SIC and NRIC approaches have been proposed for fabricating iris pattern in the cryptography system. The issues of repudiation and key management are resolved by these approaches. However, the uncertainty of iris keys can be determined by autocorrelators and
heterocorrelators that exemplify the iris key and can directly be used as cryptography key in the enciphering and deciphering processes.

Chapter 7 summarises the fact findings from this research work and the ideas for extension of this work. The open discussion creates a new possibility for further research in the field of invariant pattern recognition and biometric cryptosystem.

1.3 TRANSFORMATION BASICS

The basic geometric transformations are usually employed in computer graphics and visualisation, and are often executed in image analysis, pattern recognition and image understanding as well (Milan Sonka et al 1999). They allow exclusion of image deformations that occur when images are captured in an on-line criterion. If one strives to match two different images of the same subject, an image transformation should be required to compensate their changes in orientation, size and shapes. For example, if one is trying to capture and match a remotely sensed eye or vehicle images from the same area even after a minute, the recent image will not match exactly with the previous image due to factors such as position, scale, rotation and changes in the illuminations. To examine these alterations, it is necessary to execute an image transformation and then recognise the images. In the LPRS, license plates skew occur while capturing images with an obvious orientation at the diverse angles. These variations may be very tiny, but can be critical if the orientation is demoralised in subsequent processing. This is normally a problem in computer vision applications such as character, iris and license plate recognition.

The basic transformation is a vector function $T$ that maps the pixel $(x,y)$ to a new position $(x',y')$ as described in Equation(1.1)
\[ x' = T_x(x, y) \quad y' = T_y(x, y) \quad (1.1) \]

where \( T_x \) and \( T_y \) are transformation equations.

It transforms pixels in point-to-point basis. The commonly used transformations in recognition systems are pixel coordinate and brightness transformation. Pixel coordinate transformation is used to map the coordinate points of input pixel to a point in the output image. Figure 1.1 illustrates pixel coordinate transformation.

\[ \text{Figure 1.1 Transformation on an image plane} \]

Equation (1.1) is usually approximated by the polynomial (Milan Sonka et al 1999) as shown in Equation (1.2)
\[ x' = \sum_{r=0}^{m} \sum_{k=0}^{m-r} a_{rk}x^ry^k, \quad y' = \sum_{r=0}^{m} \sum_{k=0}^{m-r} b_{rk}x^ry^k \]  

(1.2)

where \( a_{rk}, b_{rk} \) are linear coefficients, \((x,y)\) is the known point and \((x',y')\) is the transformed point in the output image. It is possible to determine \( a_{rk}, b_{rk} \) by solving the linear equations, if both coordinate points are known. When the geometric transform does not change rapidly depending on the position in the image lower order approximation polynomials (\(m=2\) or \(3\)) are used with 6-10 pairs of corresponding points. These points should be distributed in the image in such a way that it can articulate the geometric transformation. Typically corresponding points are spread uniformly. When the geometric transform is sensitive to the distribution of corresponding points in the input, higher degree of approximating polynomials are used. Equation (1.1) is approximately with four pairs of corresponding points by the bilinear transform as shown in Equation (1.3).

\[
\begin{align*}
x' &= a_0 + a_1x + a_2y + a_3xy \\
y' &= b_0 + b_1x + b_2y + b_3xy
\end{align*}
\]  

(1.3)

The affine transformation requires three pairs of corresponding points to find the coefficients as in Equation (1.4). The affine transform includes geometric transformation such as rotation, translation, scaling and skewing.

\[
\begin{align*}
x' &= a_0 + a_1x + a_2y \\
y' &= b_0 + b_1x + b_2y
\end{align*}
\]  

(1.4)

A transformation applied to the entire image may alter the coordinate system. Jacobian \( J \) provides information about how the coordinates are modified due to the transformations. This is represented in Equation (1.5).
\[
J = \begin{vmatrix}
\frac{\partial x'}{\partial x} & \frac{\partial x'}{\partial y} \\
\frac{\partial y'}{\partial x} & \frac{\partial y'}{\partial y}
\end{vmatrix}
\]  
(1.5)

If transformation is singular J = 0. If the area of an image is invariant under the transformation then J = 1. The Jacobian for the bilinear and affine transform is described in Equations (1.6) and (1.7), respectively.

\[
J = a_1b_2 - a_2b_1 + (a_1b_3 - a_3b_1)x + (a_3b_2 - a_2b_3)y 
\]  
(1.6)

\[
J = a_1b_2 - a_2b_1 
\]  
(1.7)

Table 1.1 describes the various geometric transformations.

**Table 1.1 Transformation functions**

<table>
<thead>
<tr>
<th>No.</th>
<th>Transformation Types</th>
<th>Transformation Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rotation through an angle ( \phi ) about the origin in clockwise direction</td>
<td>( x' = x \cos \phi + y \sin \phi ) ( y' = x \sin \phi + y \cos \phi )</td>
</tr>
<tr>
<td>2</td>
<td>Rotation through the angle ( \phi ) about the origin in anticlockwise direction</td>
<td>( x' = x \cos \phi - y \sin \phi ) ( y' = x \sin \phi + y \cos \phi )</td>
</tr>
<tr>
<td>3</td>
<td>Rotation through the angle ( \phi ) about rotation point ((x_r,y_r)) in anticlockwise direction</td>
<td>( x' = x_r + (x - x_r) \cos \varphi - (y - y_r) \sin \varphi ) ( y' = y_r + (x - x_r) \sin \varphi + (y - y_r) \cos \varphi )</td>
</tr>
<tr>
<td>4</td>
<td>Scaling a in x-axis and b in y-axis</td>
<td>( x' = ax ) ( y' = bx )</td>
</tr>
<tr>
<td>5</td>
<td>Fixed point scale</td>
<td>( x' = x_f + (x - x_f)a ) ( y' = y_f + (y - y_f)b )</td>
</tr>
<tr>
<td>6</td>
<td>Skew by the angle ( \phi )</td>
<td>( x' = x + y \tan \phi ) ( y' = y )</td>
</tr>
<tr>
<td>7</td>
<td>Translation</td>
<td>( x' = x + t_x ) ( y' = y + t_y )</td>
</tr>
</tbody>
</table>
Any complex distortion can be approximated by partitioning an image into smaller rectangular sub-images. Image distortion is estimated on the corresponding pair of pixels by using affine or bilinear method and then repairing each sub-image separately. An optical camera is a passive sensor, which offers more affordable non-linearities in raster scanning and a non-constant sampling period in capturing any moving object. There are some distortions that must be tackled in remote sensing. The main source of rotation, skew, scale, translation and non-linearity distortions are due to the wrong position or orientation of the camera or sensor with respect to the object or diverse way of acquiring an object. Figure 1.2 shows some of the distortions that occur while capturing an object by any type of passive sensor.

![Figure 1.2 Types of distortions](Image)

Figure 1.2 Types of distortions

- (a) Line non-linearity Distortion
- (b) Panoramic Distortion
- (c) Skew Distortion
- (d) Shear Distortion
- (e) Change-of-scale Distortion
- (f) Perspective Distortion

Line non-linearity distortion is caused by variable distance of the object from the camera mirror as shown in Figure 1.2a. Camera mirror rotating at constant speed causes panoramic distortion that is shown in Figure 1.2b. The rotation or shake of an object during image capturing produces skew distortion as shown in Figure 1.2c. The shear distortion is represented in Figure 1.2d. The variation of distance between the object and
camera provokes change-of-scale distortion as shown in Figure 1.2e. Figure 1.2f shows the perspective distortions.

The pixel coordinate transformation generates a new co-ordinate point (x’,y’) which does not fit the discrete raster of the resultant image. The set of transformed pixels give the samples of the resultant image with non-integer coordinates. The system needs values in an integer space, which is done by evaluating brightness interpolation from some of the neighbouring pixels that are having non-integer samples. The three most popular interpolation methods commonly used for brightness transformation are nearest neighbour, linear and bi-cubic interpolation methods. Table 1.2 defines these transformations.

**Table 1.2 Brightness transformation function**

<table>
<thead>
<tr>
<th>No.</th>
<th>Transformation Types</th>
<th>Transformation Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nearest neighbour</td>
<td>( f_n(x, y) = g(\text{round}(x), \text{round}(y)) )</td>
</tr>
<tr>
<td>2</td>
<td>Linear interpolation</td>
<td>( f_n(x, y) = (1-a)(1-b)g(l,k) + a(1-b)g(l+1,k) + b(1-a)g(l,k+1) + abg(l+1,k+1) )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( l = \text{round}(x), \quad a = x - l )</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( k = \text{round}(y), \quad b = y - k )</td>
</tr>
<tr>
<td>3</td>
<td>Bi-cubic interpolation</td>
<td>( f_n(x, y) = \sum_{l=-\infty}^{\infty} \sum_{k=-\infty}^{\infty} g(l\Delta x, k\Delta y) h_n(x-l\Delta x, y-k\Delta y) )</td>
</tr>
</tbody>
</table>
|     |                              | \( h_n = \begin{cases} 
1-2|x|^3 + |x|^2 & \text{for } 0 \leq |x| < 1 \\
4-8|x|^3 + 5|x|^2 - |x| & \text{for } 1 \leq |x| < 2 \\
0 & \text{otherwise} 
\end{cases} \) |
|     |                              | where \( h \) is the interpolation kernel and \( g(\ldots) \) is the sampled version of input image. |
1.4 IRIS RECOGNITION SYSTEM (IRS)

Very high security is an essential goal for any public domain application. Impostors can enter into any protected area by breaking passwords or physical keys. Biometric key can help us create a shield to prohibit cheaters from entering into secure areas. This type of bio-keys can be generated based on human metrics like palm, retina, gait, face, fingerprint, iris and voiceprints. Among them iris is a stable pattern over the human lifetime and its well-distributed pigments are not often affected by exterior energies. Iris biological features consist of crypts, radial furrows, pigment frill, papillary area, ciliary area, zigzag collarette arching ligaments and freckles (Daughman 2004). These biological features can be captured by NIR (Near Infrared) wavelengths in a distance up to one-meter. Even dark coloured iris features can be imaged in a prosperous manner by NIR. This method can work from 17 to 36 inches distance between sensor and eye acquisition position, i.e., there is no direct contact between eye and iris acquisition camera. The eye images are captured without cooperation of subjects in short distance variations. This type of approach opens a new epoch in iris recognition system to capture a person’s iris distantly. In the process of iris recognition, it is essential to convert an acquired iris image into a suitable encoding feature that can be easily manipulated for iris verification and recognition processes. In accordance with iris feature extraction, iris recognition algorithm can be classified into four approaches as reviewed in the current literature: Quadrature-phasor encoding, Texture analysis, Zero-crossing analysis and Local sharp variation. However these systems require efficient solution for various problems such as localisation of iris portion from eye image, distance of iris capturing, anti-spoofing, estimation of iris pattern orientation, rotation-invariant features and less false reject rates. Hence this thesis aims to resolve these problems and provide efficient solution. The following topics depict various methods reviewed from current literature.
1.4.1 Quadrature-phasor Encoding

In (Daugman (2004, 1993), Daugman et al (2001)), recognition algorithms have been tested on images collected in Britain, USA and Japan. This algorithm was tested with 2150 different iris images acquired from 70 eyes. It compares pair of iris images by excluding the duplicates, double-counting pairs and not including the same eyes. The total number of unique pairing between different eye images whose Hamming distance (HD) could be compared i.e., total of 2,307,025 comparisons were made to test the algorithm. In addition to that it provides 244 degree-of-freedom with discrimination mean of 0.499 and standard deviation was 0.032. It used complex valued multi scale quadrature wavelets to extract phase structure information of the iris and 2,048-bit (256 bytes) iris codes were extracted from each subject in order to discriminate from others. These codes were compared based on HD. In most of the trails, imaging was done by passive sensor like pan/tilt CCD camera. However, users have to give their full cooperation with the focusing system in order to image iris patterns impressively. Focus measurement was carried out in real-time acquisition by computing 2D Fourier spectrum of its high-frequency power in order to capture minimum focusing images. This is interactively done by moving active lens or audio feedback to subjects in sense to adjust pan or tilt angle of their head positions accordingly. Finally the eye images having a minimum focus criterion were taken for recognition process. For that, first iris was localised using a CTF strategy, which estimated a single-pixel precision of centre coordinates and radius of both the iris and pupil. An integrodifferential operator was used to localise the iris in CTF method. However, rotation-invariant of this system was achieved by maintaining 7 relative orientation of feature template for each subject.
1.4.2 Texture Analysis

The research work proposed by Li ma et al (2003) uses spatial filters to extract feature information. This filter is based on Gabor filters but it is based on circular symmetric sinusoidal function. It used 1536 feature vectors for recognising a person and tested with 213 Subjects eye images. The system includes iris imaging, image quality assessment and recognition. Iris imaging was performed using a specifically designed sensor.

The iris detection is an essential process to detect subject iris from fake, photography or video playback eye inputs. However, liveness detection researches are still limited though it is highly desirable. Image quality assessment is performed to assess image quality by analysing the frequency distribution of the iris image. The images of poor quality can be categorised into three classes, namely, defocused, motion blurred and severely occluded eyelids/eyelashes images. These artefacts occur frequently in a non-invasive system. Moreover, if a system needs to capture images without cooperation of subjects then it would produce more amounts of artefacts in the imaging.

Robust representation for pattern recognition must be invariant to changes in the size, position and orientation of the patterns. In (Li ma et al 2003), translation and scale invariant are achieved by iris normalisation process but rotation invariance by unwrapping the iris ring at different initial angles. The system to acquire eye images in long distance i.e., full-fledged non-invasive system requires the estimation process to exactly finding an orientation angle of real time acquisition patterns. As the degree of rotation may not be large in practical cases in the work of Li ma et al (2003), predefined values -9, -6, -3,0,3,6 and 9 degrees were used to denote templates of seven rotation angles for each iris subject in the iris database. When matching the input features with the templates of an iris class, the minimum
of the seven scores is taken as the final matching distance. However, this process brings overburden to the application domain and it would fail when orientation of iris images were rapidly varied.

Li ma et al (2002) proposed an IRS based on the Multi-channel Gabor filters with weighted Euclidean distance. Circular symmetric filters were used to extract iris features in (Li ma et al 2002a) and classification was based on nearest feature line method.

In the work of Shinyoung et al (2001), Haar mother wavelets were used for extracting compact features from the iris images. This was obtained by decomposing the 450 by 60 iris patterns into 28 by 3 sub-images by high and low pass filters. After employing four level decomposition, a feature vector of 84 features of fourth high pass filter and average of the three remaining high pass values were taken for recognition process, i.e., totally 87 feature vectors were collected for recognising a person. The competitive learning method called linear vector quantisation was employed for the identification and verification. However, the work did not address the issue of rotation invariance and also the features of low frequency components were considered for recognition. It may produce false positives when images are acquired with combination of low, middle and high frequencies.

1.4.3 Local Sharp Variations

Li ma et al (2004) proposed a system to extract iris features from an appearing or vanishing important image structure. The feature collection process was done by dyadic wavelet transform that records a position sequence of 660 local sharp variation points. The iris matching was based on HD exclusive-OR operation. Localisation of iris portion is carried out by edge detection and Hough transforms. But due to localisation problem, false non-
matching of 57.7% was reported. This is because of overstuffing eyelids and eyelashes in the iris portion. Moreover, due to inaccurate localisation, 21.4% of false positives were documented. This problem arises in the occluded images, as the eyelids and eyelashes increase some edge noises and decrease localisation accuracy. In order to achieve position, rotation, scale invariant system the iris normalisation process was carried out. However, under the extreme conditions, i.e., iris portion is excessively compressed by pupil, the iris after normalisation still has many differences with normal state. Due to pupil changes, 10.7% of false non-matches were reported. This study also states that normalisation is a common problem in all iris recognition methods. The other factors that produce false positives include spectacle reflection or eyeglasses, poorly focused images and motion-blurred images. This approach did not give any idea to measure the acquisition of iris images and there was no documentation related with rotation-invariant approach, since these factors are relevant to non-invasive iris imaging.

1.4.4 Zerocrossing

The work of Boles and Boashash (1998), zerocrossing of dyadic wavelet transform at various resolution levels were calculated for extracting iris features and the matching process is based on dissimilarity functions. This system is designed to handle noisy conditions, variations in illuminations and camera-to-face distances as well. In the localisation process, choosing the centroid as the reference point ensures that the representation is translation invariant. In order to achieve size variation, the virtual circles were used to extract iris portion in the eye images. The dimensions of the irises in the images were scaled to have the same constant diameter regardless of the original size in the image.

Other methods were proposed in (Wildes 1997, Sanchez-Reilo and Sanchez-Avila 2001). However, these methods faced with various issues in
real time conditions and certain open problems related with IRS, as discussed in the following section demand efficient transformation invariant IRS.

1.5 DESIGN ISSUES IN IRS

The issues in the design of IRS such as liveness detection during image acquisition, image quality measure and tilted iris patterns have been addressed in the work to achieve rotation-invariant recognition system.

1.5.1 Liveness Detection

The liveness detection is required to determine, if the biometric sample presented to a system is coming from a live human being or not. One of the vulnerable points in the system is the user data capture interface that should ensure the signals are actually coming from the genuine subject or not and negate artificial sources such as image, spurious eyes, video clips and any kind of objects like eyes. This thesis proposes a challenge-response test that ensures the pupil diameter variations in the imaging. It monitors the diameter of eye images under diverse lighting conditions that enables the system to prohibit artificial sources.

1.5.2 Image Quality Assessment

Eye images can be acquired in widely varied illuminations under dark or bright lightings or in twilight or sunlight environments. Moreover, eye images might be truncated due to pan/tilt of subjects’ head movements, closed eyelashes/eyelids may be portrayed on the iris portion, spectacle reflection may occur in the iris area and glare images may be acquired due to reflection of fortifications colours. To resolve these problems, image quality must be assessed.
1.5.3 Distance Variation in Capturing

The current research includes identification of persons by their irises even as they are walking around the place. Currently, iris recognition technologies identify a person who stands in front of a scanner and shows his/her eye properly. This is because iris pigments are not explicitly sharp enough to be scanned by the passive scanners in non-invasive manner. However, iris technology is more reliable than face recognition but it requires cooperation of subjects who will stand in front of the scanner and line up his/her eye properly. Thus, this thesis analysed iris patterns’ variations by varying its capturing distances. Remote iris recognition (RIR) is a value added solution to the IRS for the public if it is capable of recognising the persons by their iris while moving at a distance. However it requires a high-resolution camera to capture the subjects’ eye images without their full cooperation. Thus this thesis aims to suggest some technical contribution related to the remote iris recognition system (RIRS).

1.5.4 Orientation-invariant Patterns

Most traditional approaches used a set of predefined rotation parameters to match the iris scores. For example, -9, -6, -3,0,3,6 and 9 degrees were employed by Li ma et al (2003), Li ma et al (2004) and seven left and right shifts were carried out by Daugman (2004). But during the runtime these predefined degrees may not be enough to estimate the rotation angle of iris patterns and hence produce false positives while pan/tilt angles of head positioning are rapidly varied. This thesis estimates the rotation angle of iris patterns during imaging. By using the estimation angle, pattern’s rotation is corrected to its principal direction and then applies the feature extraction to encode the iris features. Thus, transformation invariant iris pattern recognition has been achieved efficiently by the system.
Machine vision is an automated method of analysing visual inputs. License plate (LP) recognition is one of the challenges concerning machine vision in which a complex natural input of a vehicle is processed to identify the registration details of the vehicle. Moreover, recognising the LP of a vehicle from a natural image involves the detection of LP and the recognition of characters on the plate. In addition, natural scenes endow with many multiclass objects and different types of poses, from which localising the LP is the more challenging process. Computer vision has been one of the challenges that computer scientists have been working to overcome for decades as it still remains as an unconquered challenge. This is due to the difference between the way machines deal with data and the way humans do. The human way of interpreting visual data is inherently based on patterns in the data than independent data entities as in the case of machines. The biological neural network enables us to extract the patterns in the data. Although developments in the field of artificial neural networks have been substantial, they are still nowhere near the efficiency offered by the biological neural networks, when operated on today’s hardware technology. This has forced many of the machine vision challenges to be dealt with in conventional computational means, limiting the role played by neural networks.

License plate recognition requires analysing a complex image containing a vehicle, extracting the license plate region, and then recognising the LP characters. LPs have been localised by looking for rectangular edges in the image edge map. The prerequisite for this method is that the LP should exhibit sharp rectangular edges. However, if the colour of the car and the license plate are almost the same and the transition from car body to the LP is not very distinguishable, the rectangular edges of the license plate will not be
visible. Therefore, LP localisation using only the edge map is not very robust. This section describes various approaches of LPRS.

1.6.1 Colour Histogram

Colour histograms are used to locate the Korean license plate (Eun et al 1994). This approach consists of two major modules, one to extract plate region and another to recognize characters. Candidate colours of a plate are extracted from an input image of 256 colours using neural network. Candidate plate regions are extracted by using colour histogram and a fixed HV (horizontal to vertical) ratio of a plate consists of three steps. Histogram of a character-colour is used to extract each character. Template matching is used for character recognition and character dictionary is done for post processing. There are three types of Korean license plate according to the use of car. Though the colour of a license plate is fixed, an input 256-colour image of a plate is not consistent because of light condition and fading of colour. This technique fails under different lighting conditions when the actual colour of the LP differs from the colour reflected by it. This problem was overcome by the use of a neural network to first classify the colour. Still the system would fail when the colour of the license plate is the same as other parts of the car and produce a similar histogram.

1.6.2 Aspect Ratio

In (Ahmed et al 2003), Saudi Arabian license plate recognition system was proposed. It employed the width to height ratio of license plate to match the vertical edges for finding the regions where there is high probability of a plate. They have used standard ratio that range from 1.75: 1 to 2.25:1. This system used template-matching approach to recognise license characters. In (Dong Su Kim et al 2001), scan line based generalised symmetry transform (GST) is used to extract the region of license plate.
Finally, a verifier for license plate candidate module was designed with image warping and neural network approach to check whether the extracted portion has a valid license plate or not. Adaptive threshold approach was proposed to extract plate region with some prior knowledge of the plate (Guangzhi Cao et al 2003). In (Gyu-Dong Lee et al 1999), a new local variance maxima method was used to locate license plate region. However the vertical edges’ lengths are between 18 and 48 pixels may be those of license plate, i.e., height of license plate is about 100 pixels. It used four parameters, two of them represented the minimum and maximum length of the vertical edge and the rest are used for width and height of the license plate. These methods are represented with plate specific parameters such as plate aspect ratio or even exact plate measurements are used to locate correct candidate region. They would fail when the aspect ratios vary drastically as observed in Indian license plates. This is illustrated in Figure 1.3.

![Sample sets of license plates in various aspect ratios](image)

**Figure 1.3** Sample sets of license plates in various aspect ratios

### 1.6.3 Two-time delay neural network

Two-time delay neural network (TDNN) is employed to analyse horizontal and vertical cross-sections of the image. The two neural network based filters are applied to Hue saturation and intensity (HIS) colour image
and then it uses a post-processor to combine the two filter images in order to locate license plates (Park et al 1999). Each neural network examines small windows of an image and decides whether each window contains a license plate.

1.6.4 Dynamic Range

In (Takashi Naito et al 2000), a dynamic range-sensing device has been developed to avert blurring of images and TV camera shutter speed was controlled in accordance with the external environment (brightness or illumination). The sensing system utilised for license plate recognition under outside environment has to be capable of capturing fine images under various illumination conditions, i.e., from low brightness at twilight up to high brightness at noon and simultaneously of capturing non-blurring images for fast passing vehicles. Fusion of vehicle images is performed with two CCD (Charged coupled device) cameras at the same time and under different exposure conditions, an image with a wide dynamic range and without blurring would be acquired. From the configuration of the sensor (e.g. a focal length) and the range of the distance between the sensor and vehicle, the size of license plate characters observed in the images can be estimated in advance. However this system may produce false positives if estimated distance is rapidly varied.

1.6.5 Fuzzy Edge Map

Fuzzy edge method was reported by Shyang-lih et al (2004). A license plate locating module characterised by fuzzy disciplines attempts to extract the plate from an input image. This approach was performed in two different ways, the first one was to perform colour edge detection and the next one was to convert RGB colour of input image to HSI values, i.e., totally 4
parameters were used such as edge map, hue, saturation and intensity. These parameters were employed for fuzzification and fuzzy aggregation is formed to detect exact plate location. However this method suffers to locate license plate when vehicle bodies and plate have similar colour.

1.6.5 **Coarse-to-fine Strategy**

The study reported in (Yali Amit et al 2004) multiclass shape detection and localising shapes in cluttered gray-level vehicle images were experimented. The multiclass searching is based on successive approximations to likelihood ratio tests arising by a simple naive Bayes statistical model for the edge maps extracted from the original image. Detecting Region of interest (ROI) from the multiple classes and organising poses by means of indexing is called as coarse-to-fine (CTF) strategy. The hypothesis to detect license plate from multiclass and poses are performed by local ORing operation. This method of detecting license plate is based on invariant features specifically invariant to position, scale and orientation.

The other method in (Hegt et al 1998) is aimed at relaxing the constraints on the complexity of the images that have been successful in achieving lesser false detection rates. But the system remains to be improved further. Thus many effective techniques have been proposed and claim to be able to work with other kinds of license plates without making any major design changes. But as elaborated above, Indian license plate recognition requires an approach that is suited to a wide variation of plate parameters such as colour, font size, style and plate dimensions. Moreover, LPRS requires a solution in position, scale and rotation invariant manner, which is essential for locating different dimension of plates in widely varying location in the image.
1.7 DESIGN ISSUES IN LPRS

The design issues in LPRS include relaxation of plate dimension, capturing of non-blurred images recognition in high-speed vehicles, widely varying pan/tilt angles of the camera, widely varied illuminations and assorted character size/fonts.

1.7.1 Relaxing Plate Dimension

Most traditional LPRS use the dimensions such as aspect ratio of the plate. It is suitable when prior knowledge of plate dimension is available. The approach used in this work relaxes this constraint and could read license plates of any dimension.

1.7.2 Capturing Non-blurred Images

One of the design issues is to capture non-blurred images from the high-speed vehicles. This can be achieved either by increasing the capability of the sensing system or by the motion-blur correction.

1.7.3 Pan and Tilt Angles

The shape of license plate depends on relative placement of the camera and vehicles. The horizontal and vertical distortions of the plate are encountered due to varied pan/tilt angles of the camera position and in the direction of passing vehicles.

1.7.4 Illuminations

The widely varied illumination conditions due to factors such as dull light, raining seasons and capable of capturing fine images from hot
sunlight to twilight variations may affect the performance of the system. Hence an adaptive threshold analysis method is required to find the optimum thresholds for recognising plate in various illuminations.

1.7.5 LP Characters Size and Fonts

In countries like India, there is no predefined dimension or font size of the character in the license plate. The characters may be either machine printed or hand drawn. Hence, the system requires an approach to recognise characters, which is independent of character size and fonts.

1.8 CONTRIBUTION OF THE THESIS

A transformation invariant pattern analysis is suggested to get efficient solution for the pattern recognition problems. In order to make recognition, rotation-invariant projection of two-dimensional images is mapped to a set of line integrals from single and multiple sources. This computation estimates a rotation angle of the object from single or parallel paths/beams in a certain direction. The performance of these two approaches is studied in applying real-time natural images of eye and vehicles. After rotation correction, these patterns are used to extract a set of feature vectors that are able to discriminate from each other, achieving more accuracy in pattern classifications.

In the two domains such as LPRS and IRS the location of finding ROI is an important problem in real time acquisition. Hence Weight based density map (WBDM) is suggested to efficiently localise ROI of natural vehicle and eye images in relaxing constrains such as aspect ratio, colour of the plate, size of the irises, position and scaling factors of ROIs. In IRS, the method locates Cartesian coordinate of flash and pupil boundaries of eye image in order to isolate the iris portion. In LPRS, coordinates of plate region
are curbed to detach a license plate from the complicated natural vehicle images.

In the iris recognition, liveness checking is carried out by challenge-response test (CRT) that is capable of detecting human beings in various illumination conditions. It observes the diameter variation of pupil boundary from the same distance between the subject and camera. In the Iris feature extraction, sub band analysis is employed to encode features of middle and high frequencies from the wavelet coefficients, which are capable of discriminating subjects in large population. Therefore it is a way to improve class discrimination in rotation invariant patterns as well.

Gabor parameter optimisation is a process to essentially select a breed of features in the rotation invariant pattern analysis. It is a critical issue when designing any pattern classification system that efficiently discriminates inter and intra class variability from the minimum set of feature vectors. Hence this thesis aims to build set of Gabor filters that are able to produce efficient features from the iris and plate characters, thus improving the intra and inter class discrimination.

Finally this thesis aims to utilize iris patterns in cryptography system, which confines the crucial issue of maintaining and sharing lengthy, random keys in enciphering and deciphering process. A new approach is described for generating a crypto key, which is acquired from a person’s iris pattern. It intends to resolve the repudiation and key management problems in traditional cryptography system. Results were analysed in both symmetric iris cryptography system (SIC) and non-repudiation iris cryptography system (NRIC). The autocorrelators and heterocorrelators are used to recall original bits from the partially corrupted bits produced by the decryption process.