Chapter 1

Introduction

1.1 General

During last few decades techniques to read text automatically have been developed. First technique out were the banks that used magnetic ink to speed up cheque processing. The interest for optical character recognition (OCR) has grown with the development of better scanners and the gain in computer based systems. Today there exist very advanced OCR programs that can read almost all written text [1]. The possibility to read structured text in documents has turned the interest to the ability to read texts and symbols in other areas. One such area is VNPR, using a camera to take photos of passing vehicles to make it possible to identify them automatically. VNPR is a computer vision method used to identify vehicles by their license plates. VNPR is defined as a *'surveillance capability that uses mobile and fixed road-side sensors to read vehicle number plates and instantaneously cross-match them with information and intelligence held on the Police National Computer and linked systems'* [2]. VNPR has gained much interest during the last decade along with the improvement of digital cameras and the gain in computational capacity.

The significant motivation for VNPR is the security against the increase of terrorist activities around the world. The demand for security related services has now become higher than ever before, and there is a great need to find new way to protect ourselves or improve the existing methods by using latest information technology. One area of interest has been automated surveillance systems controlled

by computers that could work independently with minimal human intervention. An automated system that could identify suspect vehicles passing though and issue alerts or report such incidence to corresponding authorities immediately. This will speed up response time and can save lives.

In parking, number plates are used to calculate duration of the parking. When a vehicle enters an input gate, number plate is automatically recognized and stored in database. When a vehicle later exits the parking area through an output gate, number plate is recognized again and compaired with the first-one stored in the database. The difference in time is used to calculate the parking fee. Vehicular number plate recognition systems can be used in access control. For example, this technology is used by many companies to grant access only to vehicles of authorized personnel. In some countries, VNPR systems installed on country borders automatically detect and monitor the vehicles crossing the border. Each vehicle can be registered in a central database and compared to a black list of stolen vehicles. In traffic control, vehicles can be directed to different lanes to have a better control on congestion in busy urban communications during the rush hours.

A typical VNPR system is composed of many hardware and software components, as shown in figure 1.1.

When a vehicle enters the secured or toll area, the installed vehicle sensor senses the vehicle and sends signals to VNPR system. The installed camera takes pictures of the front and rear portion of the vehicle, where the license plate is located. A hardware device, known as frame grabber, reads the image, which is being analyzed through image processing software algorithms. VNPR system enhances the captured images, locates the plate, and read the license numbers using character segmentation algorithms.

Hence, in general there are four steps for VNPR. In the first step, the images of the vehicles are captured using camera. Camera can vary from low-speed to high-speed, or are specifically designed depending on the application. The CCTV system usually captures and records moving images of pedestrians, bikes, cars etc, while VNPR captures only still images of the vehicle and its number plate and records the number plate data in the form of a text. In the second step, these

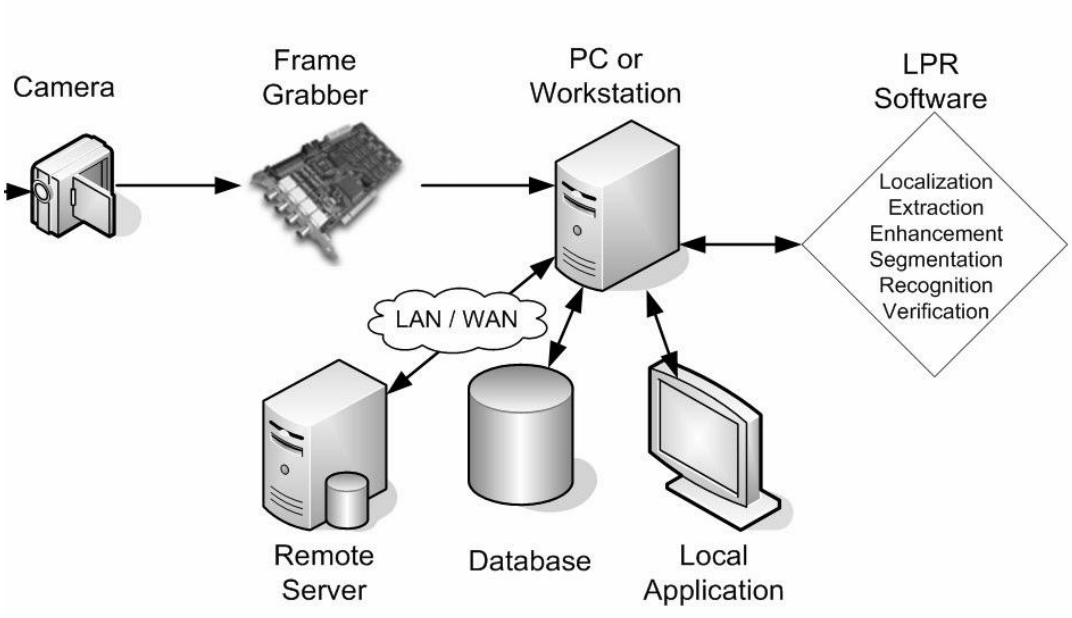

Figure 1.1: A VNPR System.

images are being processed by the system to identify the license plate number of the vehicle. In the third step, the extracted license plate is segmented for character recognition and finally in the fourth step the license plate number is recognized. Each of the above steps is a field of research. Some VNPR also stores the retrieved identity and the original image for review purposes. VNPR systems produce two types of data, 'read' data and 'hit' data. 'Read' data contains all number plates identified and recorded by the system; 'hit' data contains number plates that have a hit against one of these databases. For the fast retrieval, the information of interest can be indexed at the time of storing. Now a day's VNPR system has become fully automated to process the above mentioned steps.

1.2 Need for VNPR

During recent years, VNPR system have been widely used as a core technology for security or traffic applications such as in traffic surveillance, parking lot access control, and information management [3,4]. The various areas, where VNPR is desirable are:

(i) **Security of research facilities**

Generally, the terrorists target to destroy the research facility centres of the countries. More than a decade after the 9/11 attacks [5], security at research centres remains an important concern. There is a possibility of destroying the research facility premises using vehicle bomb. Therefore, there is a requirement to prevent the unauthorized vehicles into such premises, for which VNPR systems are being used.

(ii) **Parking**

VNPR is used for parking automation and parking security: ticketless parking fee management, parking access automation, vehicle location guidance, car theft prevention, and "lost ticket" fraud, fraud by changing tickets, simplified, partially or fully automated payment process, amongst many others [6, 7, 8].

(iii) **Access Control**

Access control in general is a mechanism for limiting access to areas and resources based on users' identities and their membership in various predefined groups. Access to limited zones, however, may also be managed based on the accessing vehicles alone or together with personal identity. License plate recognition brings automation of vehicle access control management in some manner, providing increased security, car pool management for logistics, security guide assistance, event logging, event management, keeping access diary, possibilities for analysis and data mining [6].

(iv) **Motorway Road Tolling**

Road Tolling means, that motorists pay directly for the usage of particular segment of road infrastructure. Tolls are a common way of funding the improvements of highways, motorways, roads and bridges: toll fees are taken for providing better services. Efficient road tolling increases the level of related road services by reducing travel time overhead, congestion and improve roadways quality. Also, efficient road tolling reduces fraud related to non-payment, makes charging effective, reduces required manpower to process events of exceptions. License plate recognition is mostly used as a very efficient enforcement tool, while there are road tolling systems based solely on

license plate recognition too [6].

(v) **Border Control**

Border Control is an established state-coordinated effort to achieve operational control on the country's state border with the priority mission of supporting the homeland's security against terrorism, illegal cross border traffic, smuggling and criminal activities. Efficient border control system significantly decreases the rate of violent crime and increases the society's security. Vehicular number plate recognition adds significant value by event logging, establishing investigate-able databases of border crossings, alarming on suspicious passing's, and many more [6].

(vi) **Journey Time Measurement**

Journey Time Measurement is a very efficient and widely usable method of understanding traffic, detecting conspicuous situations and events, etc. A computer vision based system has its well known downfalls in Journey Time Measurement, while Vehicular number plate Recognition has provided its viability: vehicle journey times can be measured reliably by Vehicular number plate recognition-based systems. Data collected by license plate recognition systems can be used in many ways after processing: feeding back information to road users to increase traffic security, helping efficient law enforcement, optimizing traffic routes, reducing costs and time, etc [6].

(vii) **Law Enforcement**

Vehicular number plate recognition is an ideal technology to be used for law enforcement purposes. It helps to automatically identify stolen cars based on the up-to date blacklist. Other very common law enforcement applications are red-light enforcement and over speed charging and lane control [6].

(viii) **Police Department**

Vehicular number plate Recognition was implemented by police forces in their efforts to control crime and maintain public order. VNPR is typically used in the hope that it will help to detect and determine document offences and acquisitive crime, as well as more serious incidents such as kidnapping

and murder etc. This also helps in improving the public confidence and reassurance.

1.3 Challenges involved in VNPR

Many challenges are involved in building VNPR for vehicle identification in the same way as human can identify. License plates vary in size, character format, base material, color and patterns, throughout the world. In most of the license plates, the color contrast of the printed characters and the background is high. But in some countries, the license plates can contain texture and images, which introduces complexity in localization and extraction of license number. The varying font size and style of the characters further increase the recognition complexity. The challenges involved in VNPR are summarized as follows.

1. Number Plate variations:
   (a) locations: The location of the plates may differ;
   (b) quantity: There could be a possibility that an image may contain no or many plates;
   (c) size: The size of plates image may differ because of the camera distance, orientation and the zoom factor;
   (d) color: plates may have various characters and background colors due to different plate types or capturing devices;
   (e) texture: plates may have various textures;
   (f) font: plates of different nations may be written in different fonts and languages;
   (g) standard versus vanity: for example, some letters are written in left side and some are on right side;
   (h) occlusion: plates may be obscured by dirt;
   (i) inclination: plates may be tilted;
   (j) other: in addition to characters, a plate may contain frames and screws.

2. Environment variations:

   (a) illumination: input images may have different types of illumination, mainly due to environmental lightings and vehicle headlights;

   (b) background: the image background may contain patterns similar to plates, such as numbers stamped on a vehicle, bumper with vertical patterns, and textured floors.

   (c) Motion: Vehicles may be in static position or moving; the speed may differ.

Indian license plates are rectangular in shape and are placed on front and back of the vehicle. Plates for private car and two-wheeler owners have black lettering on a white background (e.g., MH-07 8765). Commercial vehicles such as taxis and trucks have a yellow background and black text. Vehicles belonging to foreign consulates have white lettering on a light blue background. The current format of the registration index consists of 3 parts, they are

- The first two letters indicate the state to which the vehicle is registered.
- The next two digit numbers are the sequential number of a district. Due to heavy volume of vehicle registration, the numbers were given to the RTO offices of registration as well.
- The third part is a 4 digit number unique to each plate. A letter(s) is prefixed when the 4 digit number runs out and then two letters and so on.

Generally, the first two parts are written on the upper line and the third part is written in the down line. In some states (such as the state of Delhi, Gujarat and Bihar) the initial 0 of the district code is omitted; thus Delhi district 2 numbers appear as DL 2 not DL 02.

Human is capable to distinguish and recognize these different pattern and contents by visual examination of a digital image [9]. Our eyes and brain are trained to work together to quickly locate the target area on an image by filtering out backgrounds, and process only the desired information. Even if we are presented with an image with high level of noise or some type of distortion, we can still recognize with little effort.

The challenge is involved in all the four steps of VNPR system that are mentioned in section 1.1. The challenge in the first step is to capture the clear image of the vehicle, so that it can easily be processed for information (license plate number) retrieval. There must be appropriate cameras to capture the image of the vehicle under varying light conditions, speed of the vehicle, weather conditions, location of the license plate or the conditions of the license plate. There is no generic VNPR that works for all the varying conditions. Appropriate lighting condition is needed in order to obtain clear images, poor lightening conditions can result into inadequate exposure distorting the color and creating shades obfuscating the real object. In the recent VNPR system, cameras have infrared capabilities for reading license plates and taking clear photograph under poor lighting conditions. However camera location is another important factor, since narrow angle will result into distorted license plate image with content all clustered and difficult to distinguish. Also, the VNPR must recognize the plate number for moving vehicles also, then camera speed must be high enough to avoid unnecessary blurring. Computer programs hardly know how to adjust to distortions, or imperfections in the input image, as it will directly affect the outcome of the recognition process. Image resolution is another factor to consider, lower resolution images can be difficult to recognize, and even though higher resolution images will provide much more information helping recognition rate, the resolution increase will translate directly into longer processing times. These are mostly external issues that require a hardware solution, but they do need some considerations during software design.

The challenge in the second step is to process the vehicle images for localizing the license plates because of the varying patterns of the license plate as described above in this section. Even after acceptable input images are obtained, there is no guarantee of success. Computers are excellent at performing millions of calculations at high speed, but they fail to establish simple co-relationship between objects. The task of identifying a car out of a background might be simple enough that a little kid can do, but it is hardly trivial for a computer. Digital images are represented just as a big numerical matrix in the computer CPU. The VNPR must attempt to "visually" inspect an image by analyzing the number to find some kind of pattern, determine whether these corresponds to a vehicle license plate, and

extract the plate identity. If image capturing process is also automated, there is no guarantee on the exact location where the plate will appear within the image, nor its size, or whether constant lighting condition will be kept. The VNPR system must be able to cope with all these conditions on the fly and produce results at real-time. For plate localization, a heuristic combination of several traditional image processing techniques are used to filter out the background and extract the candidate region enclosing the plate. Techniques such as histogram equalization, edge detection, filtering and component analysis each plays a role in the extraction process.

The challenge in the third step is to segment the license plate properly, as this will be input to the final step for character recognition. Several methodologies exist for segmentation that are based on pixel connectivity, projection profiles, prior knowledge of the characters, character contours or combined features. The output from the plate localization may contain many problems like non-uniformity brightness, orientation of plate, etc.

The challenge in the fourth step is to finally recognize the characters from the license plate. There are several methods available for character recognition, based on support vector machine and artificial neural network. For character segmentation, an algorithm based on information obtained by filtering, adaptive thresholding and clustering is used to extract each individual character. Then, Artificial Neural Network (ANN) is used for the final Optical Character Recognition (OCR). Traditional training methods for ANN are extremely time consuming and often result in sub-optimal configurations. Further, additional factors such as tow-bars, increased reflective properties of the number plate's lettering, dirt could lead to significant levels of misread.

VNPR technology has developed considerably over the last few years, concerning about the accuracy and reliability of VNPR systems, which can be used for at least many types of license plates, if not all types.

1.4 Motivation of Research

After realizing substantial benefits of VNPR systems, several recent approaches have begun to propose methodologies to overcome these challenges. Some of these approaches works well for some phases of VNPR and fails on other, under varying climatic or structural conditions.

In the first phase, the captured image should be of high quality so that it can be well processed in rest of the steps without complexity. It may be possible that the captured image may be blurred or tilted due the improper orientation of the camera. These issues have been addressed in the present research work.

License plate localization is the most time consuming stage of a typical VNPR system. The license plate can be localized by extracting the features. Various authors have used specific features like background color [10, 11], plate border [12], size and symmetry [13], shape [14] and texture [15]. Near-uniform background intensity [16], sign transition of gradient [17] and regular intervals between plate characters [18] are also used for plate localization. More the features that are extracted, more is the accuracy of the localization. In the process, the computational space and time complexity also get increased. The Principal Component Analysis(PCA) is a commonly used technique for feature extraction which helps in identifying patterns in data to highlight their similarities and differences. It is a powerful tool to find the patterns in a data of large dimension. The other advantage of PCA is reduction of dimensions without much loss of information. This fastens the data analysis. However PCA cannot eliminate out noise well enough. Another commonly used technique for feature extraction is wavelet transform. Wavelets are used as an efficient and practical way to represent edges and image information at multiple spatial scales. Image features at a given scale can be directly enhanced by filtering the wavelet coefficients. A robust approach to localize the license plate has been proposed which can deal with these factors.

In the third step segmentation is performed for which numerous techniques have been proposed to deal with the problems of non-uniform brightness, color combination, etc. These techniques are not robust and fail in certain conditions. Some of them fail to extract all the characters, if they are broken. Many of

them fail to work under noise or are limited by prior knowledge. Few of them are computationally complex and hence take more time for processing. All these issues have been taken into consideration in our research work.

In the final step, character recognition is performed. The character recognition system involves many steps that include feature extraction, normalization, thinning and smoothing. Different authors have proposed several methods like projection [12], morphology [15], connected components [11], coloring and labeling. The projection method is effective and less computationally complex and hence we have used this method for identification of the license plate numbers. The limitation of this method is that it is based on an assumption that the orientation of the license plate is known in advance. The connected component technique is also based on an assumption that all the characters are isolated such that they are easy to segment. Further, characters should not touch the number plates. The time complexity of coloring and labeling algorithms is high because of several iterations and hence is not suitable at the places where the frequency of car passing is high. Some license plate numbers are written in the handwritten style, having cursive strokes. The other problem with the existing methods is that they require clean data and narrow strokes. Such limitations have been addressed in the present work.

1.5 Objectives of the present work

The issues related to existing VNPR systems are addressed in this work. The objective of the present work is to address the challenges of the existing VNPR systems up to maximum extent.

1.5.1 Uncertainty in localization of license plate

The challenges involved in localizing the license plate are discussed along with the existing approaches to deal with. The limitations of these approaches are also brought out. There should be a robust approach to deal with such shortcomings, which has been devised in this work.

1.5.2 To deal with orientation problems

As it has been seen that the text may seem to be in tilted position because of the improper orientation of the camera or tilted number plate. The orientation of the camera may not be proper either because of the improper installation or ageing effect of the holding device of camera. The tilted number plate may be because of the missed screw, which holds the license plate in proper position. These orientation problems are dealt in this research work.

1.5.3 Feature based character recognition

Because of the zooming effects of the camera or poor quality of the image, it is a challenging task. The problems that may arise to deal with the character recognition are discussed in the previous section. These issues are addressed in this work.

1.6 Scope of the Research

1. The proposed methodologies are applicable to any kind of vehicles having different color, formats, texture, and shape and the case studies have been focused on Indian car license plate.

2. The technical fault of the camera is not considered, which is a hardware problem.

1.7 Thesis Outline

In this concluding section, a brief outline of the remaining chapters is provided. The works contained in the thesis will focus on the various stages/challenges of VNPR.

Chapter 2 provides the mathematical preliminaries of the topics used in the thesis. We start with the facets of VNPR followed by VNPR process along with the activities being performed in its each phase. Thereafter, we describe the related concepts like SVM, ANN, character recognition methodologies along

with the different existing approaches. The various transforms are also described. Fourier transform and its types, wavelet along with its analysis, construction of the scaling and wavelet functions, the fast wavelet transform and the decomposition and reconstruction processes. 1-dimensional and 2-dimensional wavelet analysis is shown. The signal processing aspect of wavelet analysis is described. A mathematical review of PCA along with its application in reducing the representation of a signal to a smaller number of coordinates is also given along with the geometric manipulation of the images using PCA. A concept of Monte Carlo methods is given, which is used for character recognition in this work. Monte Carlo methods are broad class of computational algorithms that rely on repeated random sampling to obtain numerical results. A short description about the fundamentals of artificial neural network and their applications on pattern recognition is given. Then the features in a license plate and motion analysis along with its representation in (x,y,t) dimension is given. Spatial Temporal impulse responses are explained. Thereafter, the mathematical and physical aspects of license plate recognition systems are given. An overview of character recognition that includes normalization, base line estimation, slant correction, parameterization is described. The existing methods for character segmentation are described. A concept of Snakes and its application for finding strokes is introduced.

Based on the literature survey carried out, certain unavoidable limitations related to the existing VNPR methodologies, are identified. The impractical issues and their planned strategies have been brought out in **Chapter 3**.

In **chapter 4** a complete framework for recognition of vehicular license plate based on wavelet transform, project and selection of the best candidates of the regions is given. All the phases of our devised framework along with its application starting from image capture, license plate localization to number recognition are described. Daubechies wavelet transform is used to address the limitations of the current approaches that are discussed in detail. Experimental validation is also shown.

The existing VNPR system assumes that the license plate text lies in a plane whose angles are normal to the optical axis of the sensor and hence did not consider the tilted situation. In order to extend the application of VNPR into various fields,

it is necessary to consider the tilted plate recognition as well. In **chapter 5**, a methodology is proposed for detection and correction the orientation of the tilted license plate, for its recognition. The Radon Transform is used for this purpose.

In **chapter 6** a methodology to localize the vehicular license plate of a moving vehicle is described. This methodology is based on PCA. The motion analysis to analyze the license plate of the moving cars is also discussed. The methodology contains five steps that include (i) image capturing (ii) Spatio-Temporal filtering (iii) Thresholding (iv) Motion analysis and finally (v) localization of license plate. These steps are explained in detail. The experimental results along with some interesting findings are also shown.

Every alpha-numeric character is unique with respect to its features. They may have some similar features also but for its identification, we must select its distinct feature. Therefore, for the accurate recognition of the license plate characters, there should be a proper extraction of their features. Some authors have proposed several methods for feature extraction but they failed to identify the characters that are written in handwritten style because of broader strokes. In **chapter 7** an approach for feature extraction of characters by using snakes and PCA is shown, which is capable to overcome this limitation.

In **chapter 8**, a new approach for identification of alpha-numeric characters using Monte Carlo method and neural network is described. We call this approach as circle partition approach, which can be used after pre-processing stage. Another new concept for feature extraction known as vector contour is also described. The pros and cons and limitations of this approach are also discussed.

Chapter 9 concludes our research work and discusses the future research perspectives.