

**VEHICLE IDENTIFICATION SYSTEM
BASED ON
SINGULAR VALUE DECOMPOSITION**

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M.C.Tech.

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ABSTRACT

Document Images are important in everyday lives. Document Image Recognition is required for information retrieving, searching, editing, and reporting of image text. There are several kinds of document images such as text, image, figure, signature, Certificate, type of ID card, car license plate, chassis number and so on. This thesis focuses to develop the Vehicle Identification System by using Vehicle Identification Number (VIN) images. The proposed system will provide to extract the detailed information to support decision making system for the Myanmar Customs Department.

There have no two vehicles in real world have the same VIN. So, it can be used to identify the specific automobile as the unit ID like the fingerprint in human being. In this thesis, we propose Vehicle Identification System based on Singular Value Decomposition. This system includes five major steps: preprocessing, segmentation, or text area (VIN area) extraction, character segmentation, feature extraction and recognition. In the preprocessing step, Median filter is used to remove noises that can be in VIN image acquisition step. Average filter is also used to solve problems relating with contrast situation. As a second step, Canny edge detection algorithm and morphological processing are applied for possible VIN area extraction. Physical features such as size, shape, and ratio of width and height are considered for choosing final VIN (text) area extraction. In the next step, each character in the VIN area is segmented by histogram method. In the last step, for all the segmented characters, Singular Value Decomposition (SVD) features are calculated to recognize each character as recognition process. Finally, by combining the recognized characters, this work can easily give required information of a vehicle which belongs to detected VIN. Microsoft Access Database system is also used for VIN information system which can be used on ground because of working on real data. The system is implemented by C# and the result shows that the recognition method is feasible and easy to use in real world, so it can be put into practice. It can be easily extended to the real time vehicle examination and identification system by using mobile device thought over the network.

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CHAPTER 1

INTRODUCTION

As the importation of vehicles in Myanmar has increased, it has become difficult to manually identify the vehicles valued at the customs duty. An automated and effective vehicle identification system is needed to easily identify a vehicle. Many developing countries are required the robust vehicle examining and identification system for vehicle administrative tasks such as license registration, vehicle valuation assessment, traffic violation cases and so on.

Vehicle Identification System based on Singular Value Decomposition (SVD) is proposed in this thesis. The image of Vehicle Identification Number (VIN) of a vehicle is detected to classify the information of the vehicle. A VIN is also called car's chassis number and it is a unique code, including a serial number of automotive industries. The information about the vehicle can be retrieved from the VIN number. There are some related thesis works of chassis number recognition systems and optical character recognition systems (OCR). Parul Shah et al., [26] proposed the OCR based Chassis-Number Recognition system using Artificial Neural Networks. ZechengKuang [37] discussed about the application of Singular Value Decomposition. Chaitanya R.et. al., implemented the review of text detection and recognition [5].

The 17 characters of digits and capital letters are included in a VIN. In some vehicle identification systems, it is needed to type the 17 characters manually for checking with the database. If any typing error occurs, the identification system will give the incorrect information. In proposed vehicle identification system, the VIN document images are used directly to overcome this problem. The proposed Vehicle Identification System based on Singular Value Decomposition will be developed to be able to accurately identify cars wherever needed.

1.1 VIN and Locations

For car manufacture, VIN is a unique for each vehicle. The most common place for the chassis number (VIN) written on bulkhead of the car and found on the left side of the center column (Driver's side door jamb).

The information of a vehicle can be extracted from VIN. This number distinguishes one vehicle from the other, which is useful especially for brand, model, country of origin, manufacture, vehicle type, engine capacity and body type of each vehicle. An automated system can be implemented to identify the VIN of a vehicle and extract the characters from the VIN document image.

The VIN is fixed throughout the life of the car as a human eye. Each VIN is A to Z; Combined with 17 possible letters from 0 to 9. However, to avoid confusion with the three numbers (0, 1 and 9), the letter O, I and Q are not used in 17-letter characters of VIN. Figure.1.1 illustrates the possible locations of VIN number in a car and detailed explanation of the VIN number is also shown in Figure 1.2 respectively.

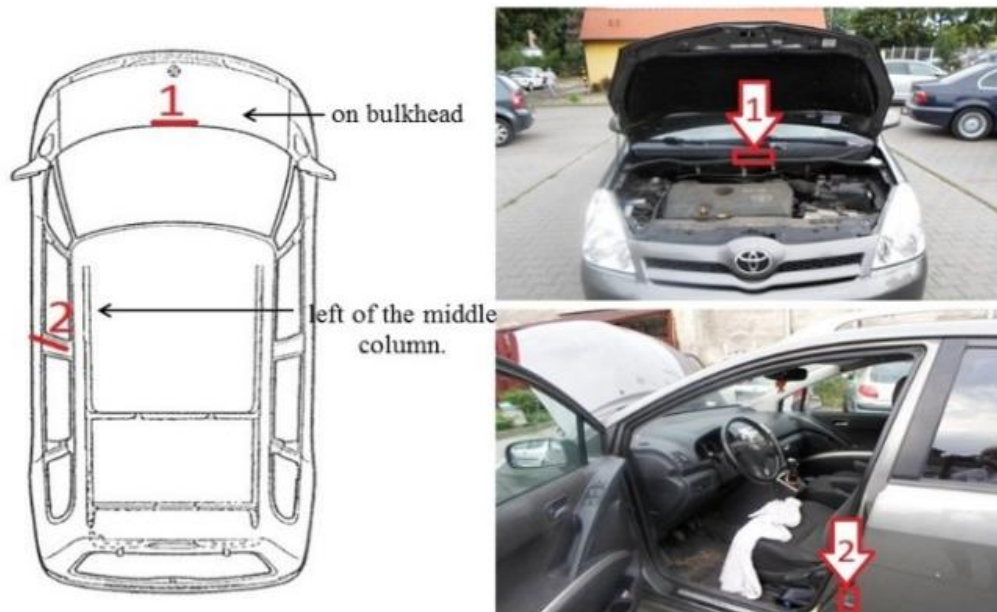


Figure 1.1: Location of VIN Numbers

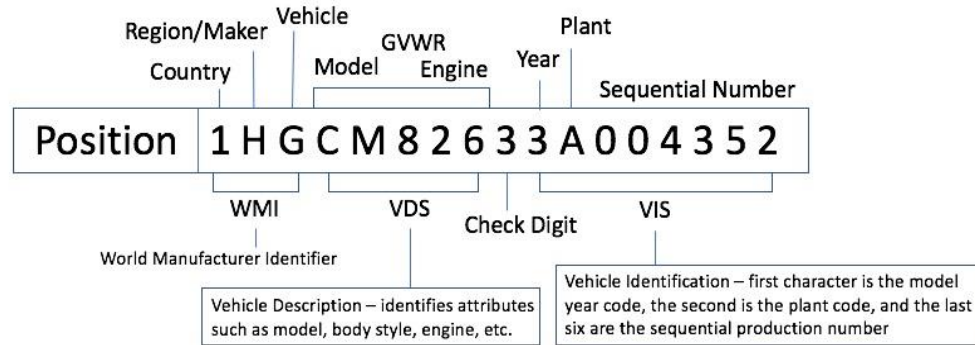


Figure 1.2: The details of Vehicle Identification Number (VIN)

1.2 Image Processing Technique

An image processing system has several basic steps. These include Image acquisition, Filtering and enhancement of images, Image restoration, Color image processing. The main steps are Wavelength processing and Multiple resolutions processing, Compression, Morphological processing, Segmentation, Representation and Object recognition.

1.2.1 Image Processing Application

Image processing techniques are nowadays used in almost everywhere. Example applications which use imaging are demonstrated below in Figure 1.3.

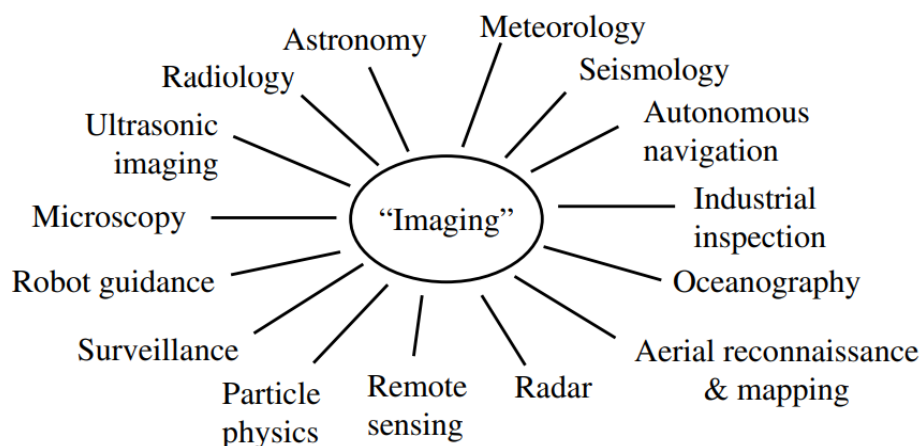


Figure 1.3: Part of the Universe of Image Processing Applications

Image processing is the application of signal processing techniques to an image domain that actually displays two-dimensional signals.

1.2.2 Image Processing Steps

In general, the image acquisition phase is the first step in imaging which includes pretreatment such as scaling. But, in this system, already taken images are saved in digital format and they will be used as input images.

Image preprocessing is the second step taken to format images before they are used in subsequent processing step. This includes, but is not limited to, noise removing, image enhancement, resizing, orienting, color corrections, binarization.

Image segmentation is the third step in the process of creating a digital image that emphasizes the segmentation of an image into different parts according to its features and properties. In image segmentation, an image is divided into different parts with the same properties. The parts that separate the images are called Image Objects.

Feature selection involves extracting the ability to generate interesting quantitative data or extracting basic attributes to differentiate one class from one class of objects to another.

Feature extraction involves reducing the number of resources needed to display the data set. The extracted features are expected to contain relevant information from the input so that the desired operation can be performed using this reduced representation instead of the complete initial data.

Recognition is the process of assigning labels to objects based on descriptors. Image recognition is the ability of software to recognize the objects, places, people, writing and actions in images. Computers can use visual technology combined with camera and artificial intelligence software to gain image recognition.

1.3 VIN Identification

Every VIN is unique and used to identify the produced vehicles. It is one to many searching technology. The Vehicle Registration Number is an identifying code for a specific vehicle. The VIN acts as the car's fingerprint; The VIN is made up of 17 letters (numbers and capital letters) that act as a unique symbol for the vehicle. The VIN is a unique feature of the car, and it describes specifications and manufacturer. The VIN can be used to track recalls, registrations, theft, and insurance coverage.

1.4 Objectives

This study has aimed to achieve the following objectives:

- ❖ To design an efficient Document Image Recognition System for Vehicle Identification based on Singular Value Decomposition (SVD) approach.
- ❖ To provide a practical solution to document image recognition problem.
- ❖ To achieve good accuracy in character classification and recognition process in vehicle identification.
- ❖ To reduce time duration in vehicle identification process and to be cost effective.

1.5 Motivation

Governmental organization and departments in Myanmar are working VIN identification process just manually. Up to now, no such thesis on VIN identification has been done in Myanmar. Researchers and experts from academic should pay extensive attention in this area.

1.6 Contribution

The automated identification system using VIN is developed for easy and rapid checking of the vehicle information in Myanmar. The VIN area extraction and choosing number of closing step can be the contribution of this thesis.

1.7 Problem Definition

VIN will be input and the proposed system must do the following:

- ❖ Find the VIN area in the input image
- ❖ Extract this area
- ❖ Extract all the characters from the segmented VIN text area
- ❖ Calculate the Singular Value Decomposition (SVD) features for each character

- ❖ Save these features to Database or input these features to Character Identification system which calculates distance between input vector and stored vectors to define a character
- ❖ Combine all resulted characters and Output the VIN information regarding with those combined characters (VIN)

1.8 Chapter Summary

There are five chapters in this thesis. The Chapter 1 introduces the VIN identification system and the motivation behind the present work, thesis objectives and problem definition are briefly described. Chapter 2 contains the literature review and theory background of this thesis work. All the required technologies regarding with preprocessing and processing of image, classification are studied in details. In Chapter 3, the Design and Implementation of the thesis work are described. Overall system design, and step by step implementation are explained in this chapter. Chapter 4 shows experimental thesis results and analysis of the results. Analysis of edge detectors and morphological closing method analysis are also done. Finally, Chapter 5 concludes with the detailed discussion and further extension of this thesis.

CHAPTER 2

BACKGROUND THEORY

In this chapter, all necessary technical theories and studied literature, previous works regarding to the research of VIN identification are discussed. Some main topics expressed in this chapter are the overview steps of image processing systems, automated VIN identification, recognition process, database management system and development tool.

2.1 Digital Image Processing

Image processing is referred to digital image processing in this thesis work. A digital image can be defined as $f(x, y)$ where x and y are spatial or cartesian coordinate. And amplitude of f is finite and discrete value at any pair of coordinates (x, y) and is called intensity or gray level of the image at that point of (x, y) [28]. The fundamental steps of digital image processing and some applications are described in [28]. It also covers the process from extracting attributes from an image to recognizing each object. They also provide examples of character recognition systems to clarify the steps involved in digital imaging in their book.

		Column					
		1	2	<i>j</i>	n
row	1	f_{11}	f_{12}	f_{1n}
	2	f_{21}	f_{22}		.		f_{2n}

	<i>i</i>	.			f_{ij}		.
.	.			.		.	
.	.			.		.	
.	.			.		.	
n	f_{n1}				.		f_{nn}

Figure 2.1: Mathematical Notation for Digital Image

A digital image is denoted as a 2 dimensional Mathematical notation. C.A Glasbey and G. W Horgan [2] simply and clearly shows understandable 2 dimensional Mathematical notation of a digital image as in Figure 2.1. A type of signal function contains certain characteristics or features associated with the image.

In fact, image processing field is composed of many other areas and Gaurav Sharma [9] describes that the field of digital color Imaging. The field of digital color rendering is focused on Physics, Visual science, Chemistry, Psychological, Computational algorithms, Systems engineering and Mathematical optimization.

The primitive operation of the image processing is the noise reducing, contrast stretching, Image sharpening and so on. The major steps of character recognition system are described by K.Karthick [18] as follow:

- ❖ Preprocessing
- ❖ Feature Extraction
- ❖ Recognition
- ❖ Post processing

The figure 2.2 illustrated the steps involved in text recognition system.

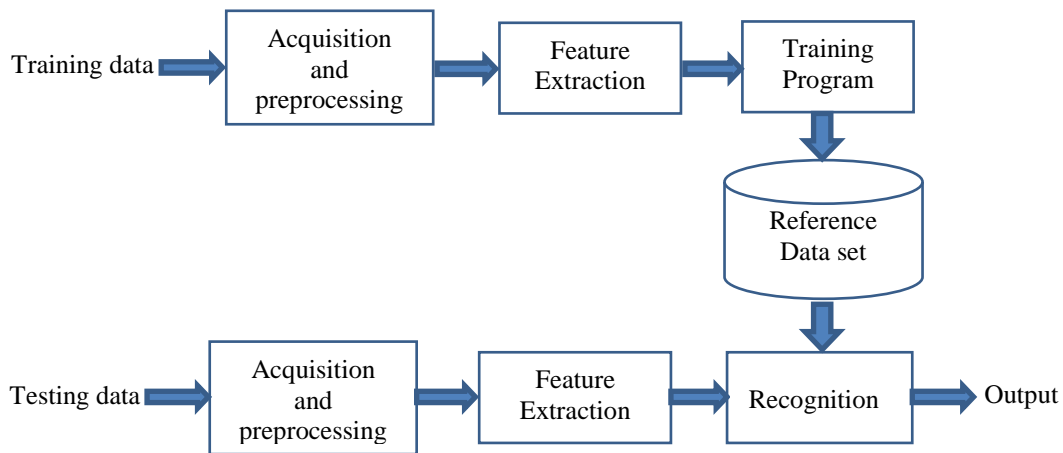


Figure 2.2: Steps Involved in Text Recognition [18]

In addition to the above steps, the process of recognizing segmentation and morphology process is also involved before the feature extraction process.

The image processing steps are almost similarly described in most of the literature books. But in a famous digital image processing book, Rafael C Gonzalez and Richard E. Woods define the fundamental steps of digital image processing as the following [28]-

- (a) Image Acquisition
- (b) Image Enhancement
- (c) Image Restoration
- (d) Color Image Processing
- (e) Wavelets
- (f) Compression
- (g) Morphological Processing
- (h) Segmentation
- (i) Representation and description
- (j) Recognition

2.1.1 Image Preprocessing

Image preprocessing are the steps taken to perform before they are processed. This steps may differ according to the application. Most common steps are color transformation, noise removing, binarization and so on. But in [28], the four different types of Image preprocessing techniques are described as follows:

- ❖ Pixel brightness transformations or Brightness corrections.
- ❖ Geometric Transformations.
- ❖ Image Filtering and Segmentation.
- ❖ Fourier transform and Image restoration.

Color quantization is the complex work in image acquisition step and preprocessing steps are commonly used to reduce data processing by quantization algorithms[9]. The main techniques used to reduce the data are prequantization and histogram calculation, which reduces the range of each coordinate in the color space and allows manage the color scheme more efficiently. Image acquisition can be a simple process that provides a digital image. Generally image acquisition stage involves preprocessing such as scaling.

But in [36] an example approach of texture segmentation is given by William K. Pratt. The process requires calculating some texture coarseness measure at each pixel per image and then knowing the coarseness changes in the texture measurement. For subsequent amplitude segmentation, the original image is pre-configured to convert the texture to an amplitude scale [36].

Image enhancement and image restoration are the important processes in the image preprocessing. The processing stages are not fixed for image enhancement. Improving the image visualization is the image enhancement where as improving the image appearance is the image restoration. The image restoration is to recover an image that has been degradation in some way.

2.1.1.1 Gray Scale Transformation

In case no special usage of color image processing, gray scale image is useful to reduce computational complexity in image processing. There is an easy way of transformation color image (Red, Green, Blue color space) to 256 gray scale image which is used in this thesis work. Among the some gray scale transformation methods this is the weighted method. It is also called luminosity method. The formula is as follows:

$$I_{\text{Gray}} = (0.299 * I_{\text{Red}}) + (0.587 * I_{\text{Green}}) + (0.114 * I_{\text{Blue}}) \quad 2.1$$

2.1.1.2 Binarization

Binarization is an important part of preprocessing steps, and it is converting a color image to binary image. The binarized image can be used in subsequent processing such as dilation, erosion, labeling and character segmentation. That image has exactly two colors, usually black and white. Each pixel of the image is stored as a single bit- i.e., 0 or 1. It is differentiating background and foreground. The method replaces each pixel in an image with a black pixel if the image intensity $I_{i,j}$ is less than some fixed constant T (that is, $I_{i,j} < T$), or a white pixel if the image intensity is greater than that constant T . Example black and white binary image is shown in Figure 2.3 which has only 2 types of intensity level: 0 and 255. Threshold value 127 is used in this example binarization process. This is also called thresholding method in image processing term. By another word, Binarization steps are:

1. Select initial threshold value T , for example 127.
2. Obtain two portions by dividing an original image.
 - If Pixel values that are less than or equal to the T :
Then background (0).
 - If Pixel values greater than the T :
Then foreground (255).



Figure 2.3: Example - Binary Image Using Threshold Value 127

2.1.1.3 Filtering Method

The most popular noise removing filters such as Median filter and Average filter are used in the thesis work.

- ❖ Median filtering is a nonlinear method used to remove noise from images.
- ❖ It is widely used for removing pepper noise while preserving edges.
- ❖ The median filter works by moving through the image pixel by pixel, replacing each value with the median value of neighboring pixels.
- ❖ The pattern of neighbors is called the “window”, which slides, pixel by pixel, over the entire image.
- ❖ The median value is calculated by sorting all the pixel values in the window into numerical order and then substituting the considered pixel with the middle (median) pixel value.

In the following Figure 2.4, median value “9” is replaced at the place of “8”. In this way, all the pixels in the image are replaced by the median value of the neighboring pixels.

Average filter, on the other hand, calculates average intensity value of neighbor pixels and set that average value into the current place. The formulation of average filter as follows:

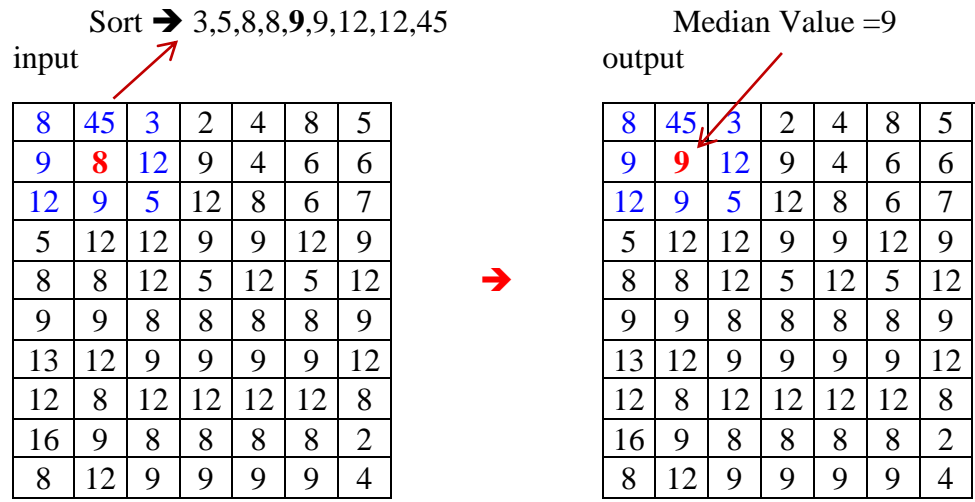


Figure 2.4: Median Filter Demonstration

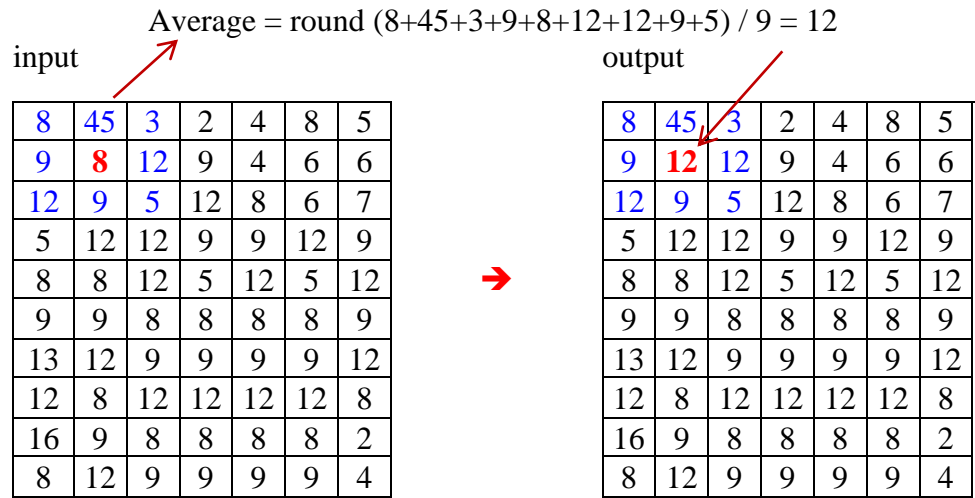


Figure 2.5: Average(mean) Filter Demonstration

$$I(x,y) = \text{average} \{k(s,t)\} \quad \text{where } (s,t) \in S_{xy} \quad 2.2$$

where, S_{xy} is the image coordinate in a rectangular window which has center at (x, y) . $I(x,y)$ is the restored image and $k(s,t)$ is 3 x 3 moving window on the $I(x,y)$.

A mean filter or average filter is a linear convolution window filters that smooth an image. The filter works as a low pass filter.

2.1.2 Auto Skewing

Before preprocessing, in this work, auto skewing or auto rotating of input image is carried out for better text area extraction. Gradient values are used to calculate the average direction of some lines along the horizontal direction of input image. Firstly some lines are drawn horizontally by desired interval value. Average direction is calculated summing up all the direction in each pixel location along all the lines drawn.

$$\text{Average direction of an image} = \sum_{i=1}^h \sum_{j=1}^w A_{i+interval,j} \quad 2.3$$

where

h and w are the height and width of input image,

$A_{i+interval,j}$ = direction at the position $i+interval$ and j in the image direction is calculated using gradient values of each pixel

Desired angle is calculated by the average direction, and finally rotation process is easily in the C# by using the built-in GDI+ mechanism. Following function is used to do that work:

RotateTransform(angle)

To get perfect quality of the result image, following interpolation parameter should be used in GDI+ class:

InterpolationMode.HighQualityBicubic

2.2 Image Segmentation

In text recognition, character segmentation is the vey important stage. The two main types of segmentation are external and internal [18]. External segmentation divides page layout into logical units. It is an integral part of text analysis as it is an essential step before off-line text recognition. It extracts the paragraph, sentence or words. Internal segmentation splits an image of a set of text into fragments images. It provides to extract the word, especially, in cursive written words. Some edge detection methods are superior to others in all testing methods [18].

Image segmentation techniques are compared in different papers and actually it is hard to say whether which method has the best performance. It depends just on the type of the application in which they are used. The primary types of image segmentation techniques are as follows [27]:

- ❖ Thresholding-Based Segmentation.
- ❖ Edge-Based Segmentation.
- ❖ Region-Based Segmentation.
- ❖ Watershed Segmentation.
- ❖ Clustering-Based Segmentation Algorithms.
- ❖ Neural Networks for Segmentation.

Above methods are well known and can be used for different purposes. Thresholding Based Segmentation is the most common and easiest way to do segmentation using threshold value. Edge-based segmentation uses edge detection technology to detect color-changing areas in space [19]. Most applications use edge detectors to detect edges. Region-Based Segmentation is dividing the region by neighbouring properties. These three segmentation methods are detailed for VIN identification system.

General autonomous segmentation is the most difficult task in digital image processing [28]. Segmentation procedures are the process of dividing an image into its constituent parts or objects. Weak or incorrect segmentation algorithms almost always guarantee failure in the end. Generally the success of recognition much depends on the more accurate result of segmentation.

C A GLASBEY describes that segmentation divides an image into parts that belong to different parts or objects by classifying all the pixels [2]. The purpose of segmentation is to identify the pixel aggregation associated with which cells as in Figure 2.6.

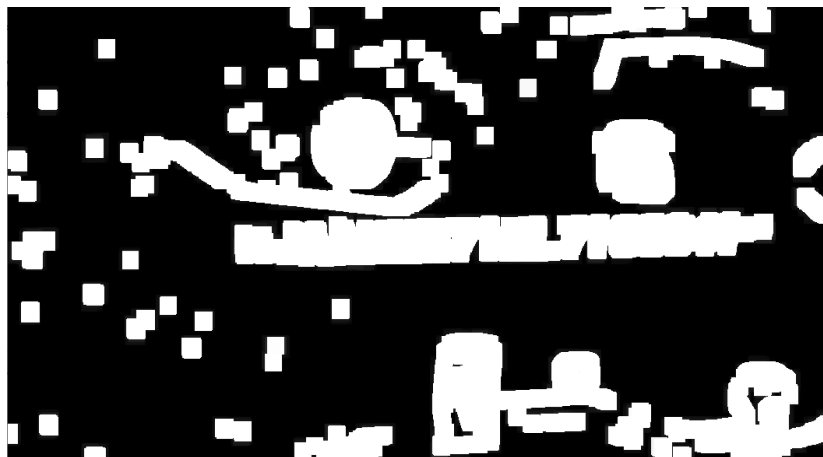


Figure 2.6: Binary Image to do Segmentation

2.2.1 Thresholding Segmentation

Thresholding segmentation is a type of image segmentation. Changes the pixels of an image to make it easier to analyze an image. An image is converted from a color or gray scale to a binary image, that means plain black and white. Thresholding is a very popular segmentation technique, used for separating an object from its background.

A simple global threshold method is used when the intensity distribution between the foreground and the background objects is very different. Only one single threshold value is needed to distinguish between the background and foreground. Here the most important thing is defining the threshold value. Otsu's algorithm is a common and good technology to find the overall threshold. Unlike the global thresholding technique, local thresholding select different threshold values for different areas in the image based on an application. Otsu's threshold value is also used in this thesis work. Its algorithm finds threshold value T in the image $I_{i,j}$ having intensity frequency histogram. Its calculation depends on the two mean values m_1 and m_2 for the intervals in the histogram. Threshold value calculation algorithm is as below Figure 2.7.

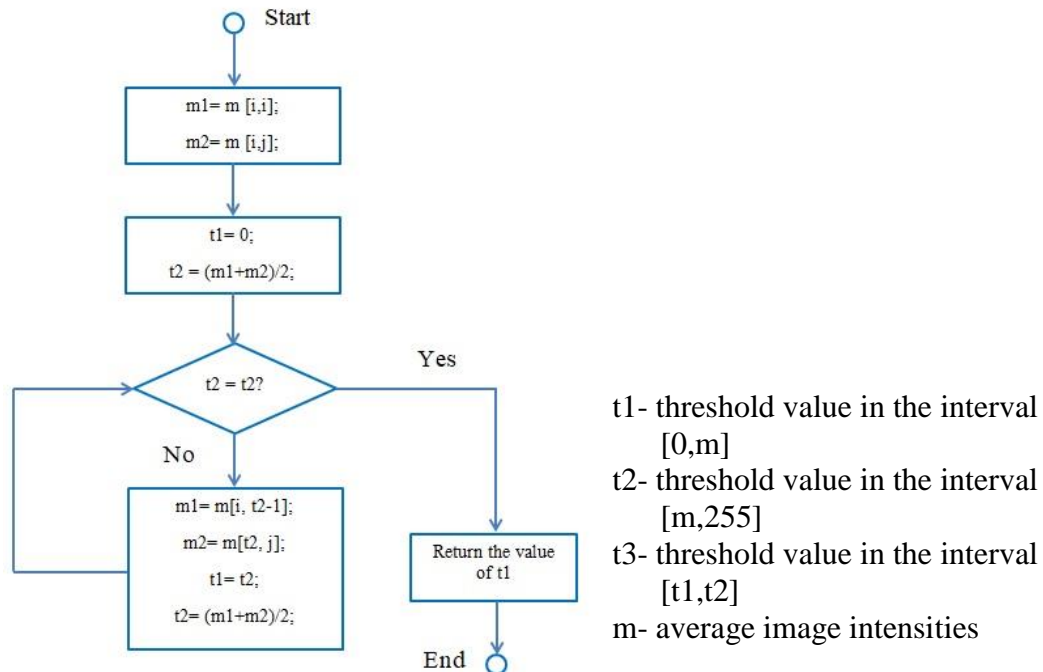


Figure 2.7: Diagram of Otsu Threshold Value Calculation

2.2.2 Edge Based Segmentation

Edge detection is a very useful tool for object detection and object extraction from an image [17]. It is used in this work to find the VIN area. The discrete approximations will be used to the image linear partial derivatives, $f_x = \frac{df}{dx}$, $f_y = \frac{df}{dy}$ by convolving the digital image f .

Gradient values are useful to find edges. In this thesis work, to get approximation gradient values, Prewitt and Sobel convolution masks are tested to decide whether they should be used or not. They are first-order image derivatives.

2.2.2.1 Prewitt Operator

By using the central difference and noise reduction in the orthogonal direction, the Prewitt edge gradient operator completes differentiation in one coordinate direction. Because the central difference is used instead of the first difference, there is less edge-location bias. The Prewitt operator has two convolution masks for horizontal and vertical direction. They are defined as the following-

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \quad 2.4$$

2.2.2.2 Sobel Operator

Sobel edge detection operator is the most commonly used gradient edge detector [7]. Sobel operator has also two convolution masks for horizontal and vertical direction. They are defined as the following-

$$\begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} \quad \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad 2.5$$

Approximation of horizontal gradient values is computed for the image I as the following equations:

$$I_x = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * I, \quad I_y = \begin{bmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{bmatrix} * I \quad 2.6$$

2.2.2.3 Canny Edge Detector

To detect a wide range of edges in images, the Canny edge detection operator uses a multi-stage algorithm. Canny's method uses the concepts of the first and second derivatives in a very effective way [4].

The process of the Canny edge detection algorithm can be divided into five stages:

1. Use the "Gaussian filter" to smooth the image and eliminate noise.
2. Compute the intensity gradients of the image.
3. Use gradient magnitude thresholding or lower bound cut-off suppression.
4. Use double threshold to determine possible edges.
5. Track the edges with "hysteresis" - Finish the discovery of the edges by suppressing on all the other weak edges without connecting to the strong edges.

Canny also demonstrated that this filter was well predicted by the Gaussians's first order. He also introduced the concept of non-maximum repression, which means that given the pre-smoothing filters, edge points are defined as the point where the gradient magnitude assumes the local maximum point in the gradient direction. In this thesis, canny edge detector is mainly used for VIN images.

2.2.3 Region-Based Segmentation

The region-based segmentation method is a localization method and it looks for similarities between adjacent pixels in an image. That is to say, pixels containing similar attributes are grouped into separate regions. The similarity between pixels is in intensity and color. In this segmentation, there are some predefined rules that a pixel must obey to classify them into similar pixel areas. For a noisy image, region-based methods are preferred over edge-based methods.

Region-based segmentation methods are preferred over edge-based segmentation methods in case of a noisy image. Region-based technologies are divided into two categories based on the Region growing method and Region splitting and merging method [16].

2.3 Object Detection

Object detection is involved in finding objects in the background of an image. Objects can be extracted from the background. The purpose of object detection is to identify all instances of objects such as people, cars or faces in an image. It is used in VIN identification at the labeling process. Methods for detection on objects are generally related to neural networks or non-neural approaches. For non-neural approaches, it is necessary to first define the features using one of the following methods, then use technology such as support vector machine (SVM) for classification. Neural technique is typically based on convolutional neural networks (CNN) and it can detect end-to-end objects without specifying features. This feature requires a feature calculation process, as it uses a non-neural approach to detect objects in this research. A feature is a piece of information about the subject matter of an image. Usually there are certain properties in certain areas of the image. Morphological operation is applied for object detection.

Morphological image processing is a collection of non-conforming functions related to the shape or form of a feature in an image. According to Wikipedia, morphological operations rely not on their numerical values but on a system that compares pixel values. Therefore, it is especially suitable for processing of binary images[15].

In VIN identification system, it is used to close or connect detected characters in the VIN image after binarization process. The two most basic morphological operations are dilation and erosion. Morphological openings and closing are simply combine different basic morphological functions [23].

A structural element is a small binary image and small matrix of pixel, each with a value zero or one value. The matrix dimensions determine the size of a structuring element. The pattern of ones and zeros determines the shape of the structuring element. Although the origin of a structural element is usually one of its pixels, in general, the original may be outside the structural element.

2.3.1 Dilation

The dilation of an image f is denoted as $f \oplus s$, where s is a structuring element. It produces a new binary image $g = f \oplus s$ with ones in all locations (x,y) of a structuring element's origin at which that structuring element s hits the input image f .

$$\begin{aligned} \text{i.e. } g(x,y) &= 1 \text{ if } s \text{ hits } f \text{ and} \\ &= 0 \text{ otherwise, repeating for all pixel coordinates } (x,y). \end{aligned}$$

In fact, the dilation process adds pixels to the boundaries of an object in an image [24].

2.3.2 Erosion

The erosion of a binary image f is denoted $f \ominus s$ by a structuring element s . It produces a new binary image $g = f \ominus s$ with ones in all locations (x,y) of a structuring element's origin at which that structuring element s fits the input image f .

$$\begin{aligned} \text{i.e. } g(x,y) &= 1 \text{ if } s \text{ fits } f \text{ and} \\ &= 0 \text{ otherwise, repeating for all pixel coordinates } (x,y). \end{aligned}$$

The erosion process removes pixels from the object boundaries of an image and makes the object smaller.

2.3.3 Opening Operation

Opening operation is useful for removing small objects (inside large objects) from an image while maintaining the shape and size of large objects in the image. The opening function uses the same structural element for both functions to erodes an image and then dilates the eroded image. In short, Opening is Dilation after Erosion. The opening of an image f is denoted as $f \bullet s$ by a structuring element.

$$f \bullet s = (f \ominus s) \oplus s \tag{2.7}$$

2.3.4 Closing Operation

The order is the reverse of opening. Closing fills in narrow black regions or holes in the image. The closing function uses the same structural element for both functions to dilate an image and erodes the dilated image. This is done by first dilating and eroding the image. The closing of an image f is denoted as $f \blacklozenge s$ by a structuring element s . It is performed erosion after dilation.

$$f \bullet S = (f \oplus_{S_{rot}}) \ominus_{S_{rot}} \quad 2.8$$

Research work uses closing technique to connect and thicker texts firstly and secondly thinner the connected texts.

2.3.5 Labeling (Segmentation)

Labeling of the connected parts of an image is one of the basic steps involved in recognizing an object [20]. As shown in Figure 2.8, the pixels owned by the same connected component are grouped together and indexed with a unique label.

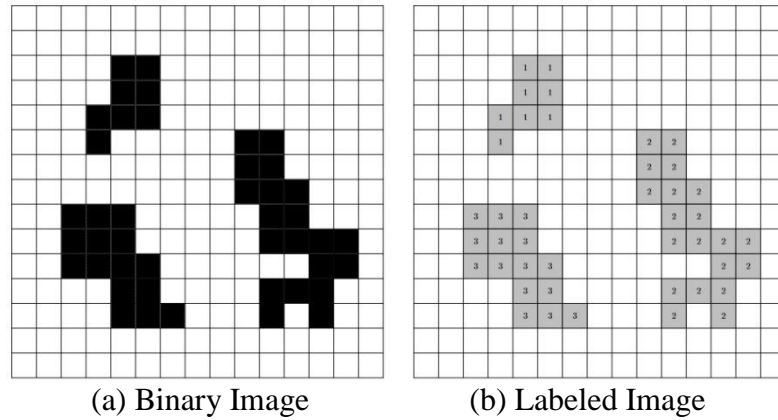


Figure 2.8: Demonstration of Labeling [7]

Image Labeling is the actually segmentation of image to produce set of separated objects (regions) or sub-images. Segmented object from an image can be expressed by the following function given in the equation below.

$$O_i = \{ (I_{ij}), j = \overline{1, N} \}, \quad 2.9$$

Where,

$i = \overline{1, k}$, k – number of object,

N_i – number of pixel i^{th} object,

I_{ij} – intensity of j^{th} pixel in i^{th} object,

O_i – set of pixels, defining i^{th} object.

Each object has its own pixels which can be used to calculate a set of feature by the properties of each pixel in the i^{th} object O_i .

2.4 Feature Extraction

An image feature is the original character or attribute of an image [36]. Some features are defined by the visual appearance of an image, so some features are natural and some are not. Other artificial features come from the unique manipulations of an image. Natural features include the brightness and grayscale texture of a pixel regions. Image display histograms and spatial frequency spectra are examples of artificial features. Image features play a key role in separating common property areas (images) and their subsequent identification or labeling (image classification) of such regions.

Features help to identify parts or shapes of an object in an image. For example, a square has four squares and four edges, which can be called a square shape, and they help us define a rectangle. Features include the corners, edges, regions of interest points, ridges, etc.

Actually, matching two images is the matching features of each image, not matching pixel by pixel. There are many kinds of feature types such as statistical, structural, etc. Usually the features are points, they can be distinctive structures in the image, such as edges or objects. Here in this thesis, for the each object ($O_i, i=N$), the features of object size, the value of x-min, x-max, y-min, y-max and ratio of width and height are calculated. These features are used both in the VIN area extraction, character segmentation, and character recognition process.

2.5 Recognition and Classification

Image classification is a method used to classify or predict the classification of a particular object in an image. The purpose of this technology is to identify the features of an image. Image classification belongs to the field of computer vision and describes the process of labeling an image according to its visual content. A classifier is an algorithm that maps the input data to a specific category. There are some different types of well-known classifiers such as Perceptron, Naive Bayes, Decision Tree, Logistic Regression, K-Nearest Neighbor, Artificial Neural Networks/Deep Learning, Support Vector Machine and so on.

An artificial neural network receives an input signal from the external world in a vector format [26]. Each input is then multiplied by its respective weights (these are the

details that neurons use to solve certain problems). In the writing of GIS-Geography [12], many classification algorithms are expressed as the following:

- ❖ Maximum likelihood
- ❖ Minimum-distance
- ❖ Principal components
- ❖ Support Vector Machine (SVM)
- ❖ Iso cluster

In VIN number identification system, features are extracted and constructed as a feature vector. And then this is saved in the database. To find the class of input vector, distances or similarity must be calculated. Current research work uses euclidean distance for calculating the distance between two rows of data (vector) that have numerical values [21].

2.6 Statistical Feature

Mean, variance, dispersion, mean square value or average energy, entropy, skewness and kurtosis are included in statistical features. Images can be represented by advanced statistical constraints calculated from co-occurrence or short-term matrices or frequent approaches.

SVD is a linear matrix transformation used to compress images [1].

SVD can be thought of as a way of programming data into m -columns (features) as a way of programming to a subdivision of m or a few columns while maintaining the essence of the original data. Using SVD an image matrix is represented as the product of three matrices U , S , and V where S is a diagonal matrix whose diagonal entries are singular values of matrix A . The image A can represent singular values in small numbers; Therefore, it can display the necessary features of an image while compressing it.

2.7 VIN Identification System

Vehicle Number Plate Recognition (VNPR) is a digital imaging technology widely used in vehicle transportation systems to identify vehicle number plates. However, this is a very challenging issue due to the different scales and the availability of light during image acquisition [8]. In the case of stolen vehicles and / or vehicles used to

commit insurance fraud, their vehicle registration number is often changed to conceal the identity of the stolen vehicle or to declare it declared a rescue vehicle.

Changed VNPR can be accomplished by checking the files frequently (less than 15 minutes) and checking available documents. The “identity” inspection can be incorporated into any routine, visual inspection of the vehicle [25].

Vehicle Registration Number, also known as chassis number or frame number is a unique and, including serial number, used by the automotive industry to identify individual motor vehicles, towed vehicles, motorcycles, scooters and mopeds, as defined in ISO 3779 and ISO 4030 [25]. VINs were introduced in the United States in 1954. There was no accepted standard for these numbers from 1954 to 1981, the VIN format is different among the manufacturers.

The US Automobile Manufacturers and Automobile Manufacturers Association (VAMA) was involved in the creation of a standardized vehicle numbering system named the Vehicle Identification Number (VIN) with an agreed upon digit sequence and concealed chassis markings of this VIN, in 1954.

In 1981, United States National Highway Traffic Safety Administration standardized the format of the 17-character VIN, which does not contain the letters O(0), I (i) and Q (q), to avoid confusing numbers (0, 1, and 9) . Modern VINs are standardized based on two related standards ISO 3779 and ISO 3780, issued in 1979 and 1980: respectively [29].

The first three characters uniquely identify the manufacturer of the vehicle using the world manufacturer identifier or WMI code.

The manufacturer of the vehicle can be identified by the first three characters (WMI code) of VIN. The vehicle descriptor section or VDS can be detected using fourth to ninth positions in the VIN [31].

This is the Vehicle Descriptor Section or VDS. This VDS is used according to local regulations, to identify the vehicle type, the model, and the body style. To identify the engine type, some manufacturers used the eighth digit. The 10th to 17th positions are used as the Vehicle Identifier Section or VIS. This is used by the manufacturer to identify the individual vehicle in question. This may include information

on options installed or engine and transmission choices, but often is a simple sequential number.

One of the common elements of VIS is the 10 digits required worldwide to encode the vehicle model year. In addition to the three characters not allowed in VIN (I, O and Q), U and Z and 0 are not used for the two model codes. The year code is the model year for the vehicle.

Some 1980s manufacturers; In particular, General Motors and Chrysler codenamed "A" (the 17-digit VIN was mandatory until 1981); "A" or zero is included in the manufacturer's VIN placement before 1981. Ford and AMC still use zero for 1980. The "Y" represents the year 2000, with the later letters allowed. From 2001 to 2009 the numbers are encoded as 1 to 9 and the following years are encoded as "A", "B", "C" etc.

2.8 Database System

A database is a collection of structured information data in table form. They are usually stored electronically on a computer system [6]. There are several Database Management Systems (DBMS) including tables. Actually a database system is often called just database. A database management system (DBMS) controlled a database[3]. Microsoft Access is the most common DBMS system which is included all the versions of Microsoft Office. Another open-source well-known DBMS is MySQL. MS Access works only on Windows whereas MySQL works on almost all platforms. Actually there is no comparison between MySQL as a real commercial heavy duty database, and MS Access which is typically a local use, giveaway in Microsoft Office. It is no good for remote access, its' connection system is not solid. It is generally useless for multiple user purposes. And you are far better using a web based interface for MySQL[30].

Since database is a collection of related data in the tabular form and can be created a text or binary file to store them. People have been using databases since before the computer age. Before the advent of computers a database can be a Rolodex computer system with the phone numbers of important people you know or it may be a folder containing company records of employees. Today, databases are computer-based and are ubiquitous. From the desktop database of your archive to the web-based databases run by

large corporations. Databases come in all shapes and sizes. Due to this, the database industry grew as fast as the rest of the computer industry [11].

This work is the identification system not the verification system. The system verifies the authenticity of the system by comparing the feature set with the default input feature in the system. It makes comparisons with each other to determine if the evidence requested by each individual is correct. The verification system rejects or accepts the claim of the submitted evidence.

On the other hand, an identification system recognizes an individual by searching the entire template database for a match. It makes comparisons with each other to identify the individual.

Authentication \approx verification

Recognition = verification and identification.

a template = a compact but expressive representation.

Although more disk space is needed in using Microsoft Access database management system, it is the easy way to use with C# development tool to create VIN identification system. SQL language can easily be used in this DBMS.

2.9 Developing Tools

There are many artistic tools available for research on image processing. Some of them are Matlab image processing tool, OpenCV in different programming languages, C# and Python programming languages [34]. C# and Python are some of the more popular programming languages because they can be easy to learn, simple to use and offer quality performance and fast development. Both C# and Python revolve around object-oriented programming concepts that aim to make them useful for real-world applications.

Generally, C# is a multi-paradigm programming language. And it can be widely used to develop for desktop applications, web applications and web services. Furthermore, it can be used in game development and Microsoft application at a large scale [13].

Python is a programming language that many IT professionals and developers use for data visualization, web development and machine learning. Like C#, Python can be portable, easy to learn and has high-level capabilities. Python combines various features

of other programming languages, like its ability to perform type-checking at runtime. Because of its dynamic language capabilities, Python can be useful if you need to change an existing outdated system. It is also common one of the first languages programmers learn because of its broad applications, accessibility and widespread use within the software development industry [3].

ImageProcessor is a collection of lightweight imaging libraries built using C#. ImageProcessor allows users to quickly and easily edit and manipulate images on both desktop and mobile applications [14].

Visual Studio is a tool-rich Windows programming environment with the functionality needed to create large or small C# projects running on Windows. To create easily user interface, Microsoft Visual C# supports all the necessary tools. Besides one of class library, GDI+ can make the basics of graphics programming in Windows more easier than other programming languages.

GDI+ is the next-generation graphics tool interface defined in "System.Drawing" in C# and its sub namespaces. GDI+ allows programmers to use printers, a library that provides an interface that allows you to write Windows and web graphics applications that interact with graphics devices, such as monitors or files.

Microsoft's managed GDI+ documentation divides its functionality into three categories: 2D vector graphics, imaging, and typography. Some useful GDI+ function contained two more additional categories as printing and design [10].

Well-known image processing tools OpenCV is available in both C# and Python. But experimental research is carried out, not using OpenCV so as to make the own library for the department.

2.10 Chapter Summary

This chapter presents the background theory of image processing, necessary technical theories such as gray scale transformation, binarization, filtering and auto skewing. And the studied literature of some existing works of image segmentation are described which contains the character segmentation, edge-based segmentation, region-based segmentation, thresholding-based Segmentation, watershed segmentation, clustering-based segmentation, Neural Networks and so on. Also, the morphological

operations such as dilation, erosion, opening, closing, labeling process are discussed for object detection and feature extraction.

Furthermore, the statistical feature of singular value decomposition (SVD) is represented for Vehicle Identification Number (VIN) recognition and classification. The detail history of the vehicle identification number is expressed. The last discussion is the databased management system and developing tool which are applied in this thesis.

CHAPTER 3

THE SYSTEM IMPLEMENTATION

This section has described about the overview of the proposed (VIN) identification system. There are five main steps for the proposed system such as pre-processing, detecting the text region, segmentation, chassis number (VIN) recognition and vehicle identification. First, the camera captures the image of the Vehicle Identification Number (VIN). There is no limit to the types of imaging devices that can be used. Then, the possible VIN area is extracted from input image. The text region is detected by using Canny edge detection algorithm from the input VIN image. Morphological dilation is used to detect the text region and segment the character according to histogram methods. Then the features of each letter of the VIN / Chassis number is computed based on the Singular Value Decomposition (SVD) approach. SVD matching process is performed for character recognition. Finally, the system will display the information of vehicle according to the recognized characters. The system overview is shown in Figure 3.1. The system is developed in the C # programming language, and as a result the authentication method is user friendly and easy to use.

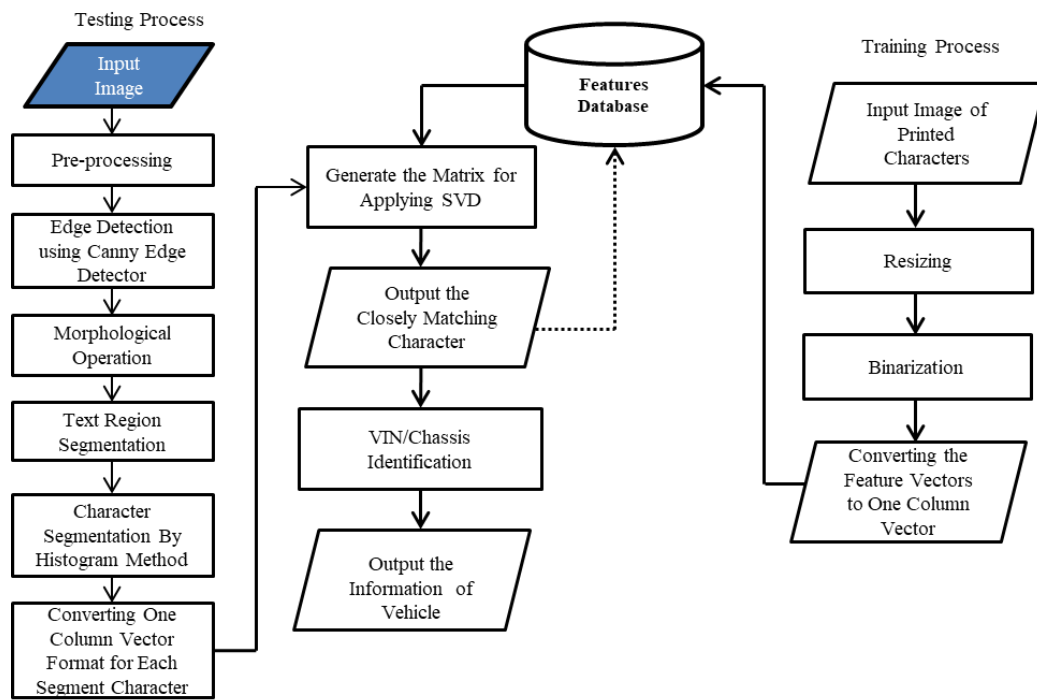


Figure 3.1: Overview of the Proposed Vehicle Identification System.

3.1 Preprocessing

The image preprocessing stage is essentially required for each image before post processing. In the image acquisition, there are so many factors which degrade the quality of taken image. Robustness of the segmentation quality much depends on the quality of input image. These may be clear contrast, color, light, focus, range, etc. Enhancing input image is the required task for the digital image of VIN number of a vehicle. In this step, noise removal and contrast adjustments are carried out for the better segmentation. VIN auto rotation is done if necessary for the better VIN area cropping. Binarization is also done as a preprocessing step to differentiate objects and background. Figure 3.2 is the preprocessing steps.

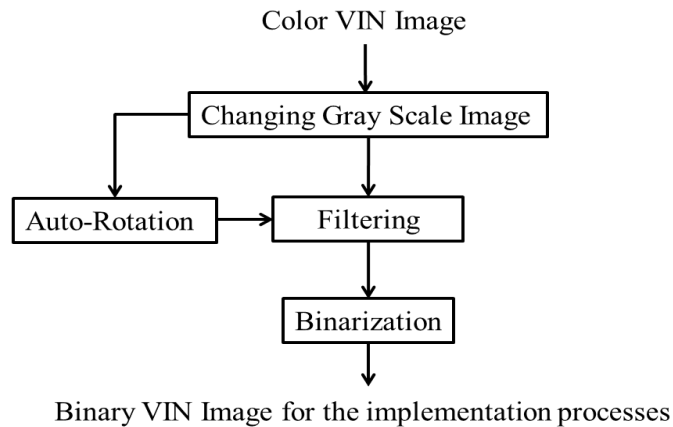


Figure 3.2: Preprocessing Steps

3.2 Text Area (VIN area) Extraction

After preprocessing step, VIN area will be extracted from the input image. Firstly, object detection is carried out by using Canny Edge detector followed by the morphological methods. No doubt, many objects are detected. In this case, real VIN area must be extracted among the possible candidate VIN area. That is extraction region of interest (ROI), here VIN area.

3.2.1 Canny edge detecting, Dialing and Eroding

Input of this step comes from the previous preprocessing step which passes binary image containing objects and background. Another method of objection is carried out by using canny detector which extracts edges of input image from background.

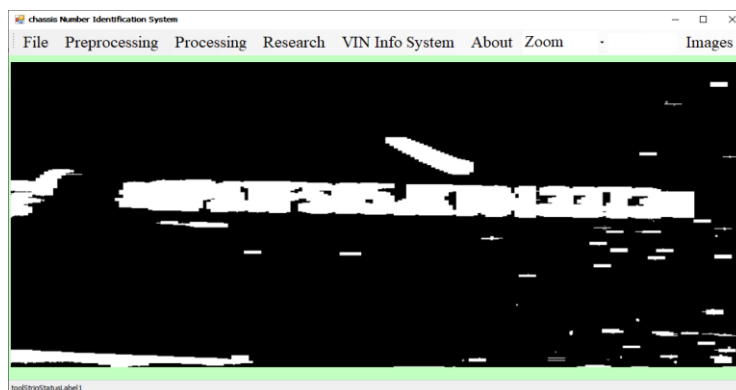
Image with the detected objects having only their edges has many disconnected edges of each object. Each character is also located as isolated objects in the edge image. To identify and extract VIN area, obvious useful features such as: size, ratio of width and height are considered to identify the VIN area. Each character is also located separately each other. So, dilation process is carried out only horizontally to get the connected characters as a long-flat possible VIN area. In this case, edges of detected objects are thicker horizontally and connected.



(a) Input Image



(b) The Result Image after Edge detection by Canny Method



(c) The Result Image after Dilation

Figure 3.3: The Result of VIN Area Detection

Likewise, all the characters are also connected at the border side of both end of VIN area. Finally, we can get back original size of VIN area by re-cutting the extra area of both ends. This process can be easily done by eroding horizontally. In contract, before extraction of VIN, do merging characters first and eroding to get back original size without re-separating connected characters. The result of dilation is described in Figure 3.3.

3.2.2 Labeling Operation

Dilating process followed by the eroding process along the horizontally will give the candidate separated objects as shown in Figure 3.3. Labeling to each object can give the valuable information of each detected object in the input image. This method is actually finding objects which have adjacent object pixel intensity (here 255). After labeling all the objected, size of object, shape, ratio of width and height can be considered valuable features or information to define or find or choose VIN area and crop it for next steps. During labeling process, unwanted small-enough objects can be defined as the noise and should be removed. Unwanted small-enough objects may have some predefined number of pixels. Figure 3.4 described the result of labeling process. Each label (object) is presented with label number and different colors for more visual view.

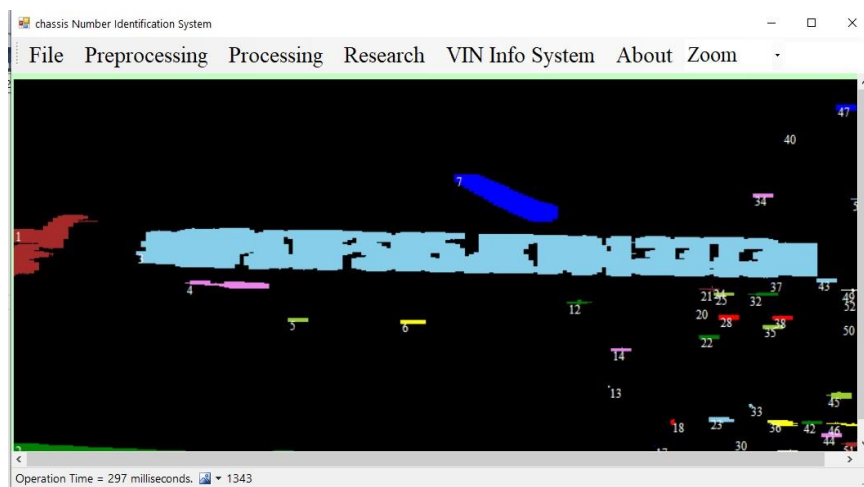


Figure 3.4: Result of Labeling

3.2.3 Removing the Small Parts

As shown in Figure 3.4, each label has their own properties or features such as: ratio of object size and image size, ratio of width and length, shape, position of each pixel in each label. Firstly, unwanted or impossible label are removed. And finally, among the rest objects, the most possible object is selected as a VIN area to extract for next step.

After the most possible label is selected, this label area is cropped as a sub image from the input one. As mentioned above, each label has all the coordinate positions of each interior pixel. Top-Left point is easily defined by the minimum “x” and minimum “y” of among the pixel coordinates. Right-Bottom point can also be defined by the maximum “x” and minimum “y” of among the pixel coordinates.

3.3 Character Segmentation

After labeling process, unwanted regions are removed, and the word of VIN region is extracted by using Left-Top and Bottom-Right point features. And then binarization is performed for cropped image to distinguish background and text objects. Each character is easily segmented by using object (white pixels) count histogram along the width illustrated in Figure 3.5. As shown in such figure, white pixel (character area) count frequency along the image width is created. Quality of character segmentation process is important to get real characters in the image.

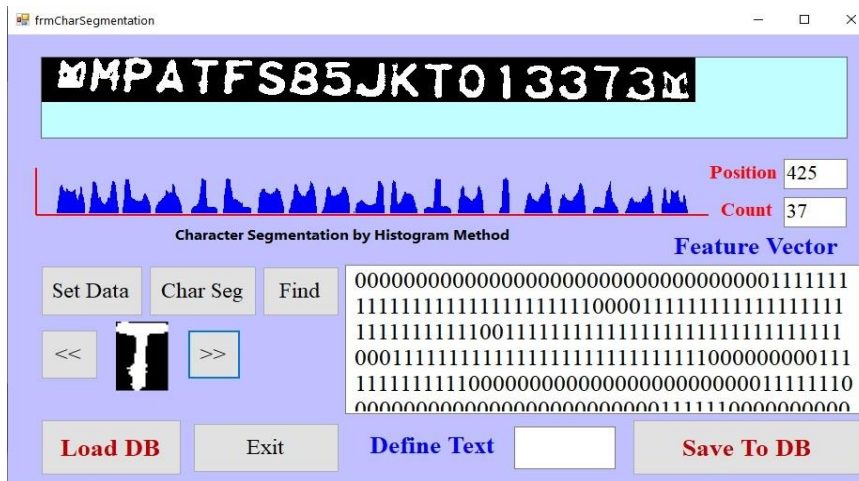


Figure 3.5: Illustration of the Character Segmentation

Histogram gives the border points of each characters. Height of each character is considered here same as the input labeled image. By using these points each character area is segmented as image and save them for feature extraction and recognition processes. The detail of character segmentation processing stages is as follow:

- ❖ Load cropped text area image
- ❖ Binarization of load VIN image
- ❖ Count the created objects by the histogram along the width of the image (White Pixels)
- ❖ Find the start and end points of each non-adjacent area (Border area)
- ❖ Crop each character as a result of Step 4.
- ❖ Save these cropped character images temporally.

3.4 Feature Extraction based on SVD Method

Singular Value Decomposition feature is computed for each segmented character image. The segmented character image is normalized to 32 x 32 size images to get (1024 x 1) vector size.

A special feature of SVD can operate on any real (m, n) matrix.

For any matrix A ($m \times n$), to find matrices U , Σ , and V such that

$$A = U \Sigma V^T \quad 3.1$$

Where $U = [u_1, u_2, \dots, u_r, u_{r+1}, \dots, u_m]$ is an $m \times m$ orthogonal matrix, Column vectors u_i , for $i=1, 2, \dots, m$, form an orthonormal set:

$$u_i^T u_j = \delta_{ij} = \begin{cases} 1, & i=j \\ 0, & i \neq j \end{cases} \quad 3.2$$

Matrix $V = [v_1, v_2, \dots, v_r, v_{r+1}, \dots, v_n]$ is an $n \times n$ orthogonal matrix, Column vectors v_i , for $i=1, 2, \dots, n$, form an orthonormal set:

$$v_i^T v_j = \delta_{ij} = \begin{cases} 1, & i=j \\ 0, & i \neq j \end{cases} \quad 3.3$$

The matrix Σ is a diagonal matrix with Singular Value (SV) on the diagonal and its size is an $m \times n$. For computational simplicity, the following flow diagram shows calculation of feature vector. Firstly, each segmented character is normalize to the (32 x 32) pixel in size.

All the feature vectors are recorded (trained) with a character description in the feature table in Database. Example segment of feature vector table is also shown in the below Figure 3.7. In fact, actual feature vector database contains 3 tables as shown in Figure 3.8. In the system not only the feature table but other two (Brand Code and Country Code) tables exist.

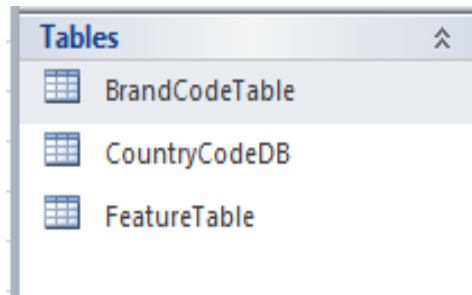


Figure 3.8: Tables in Feature Vector Database

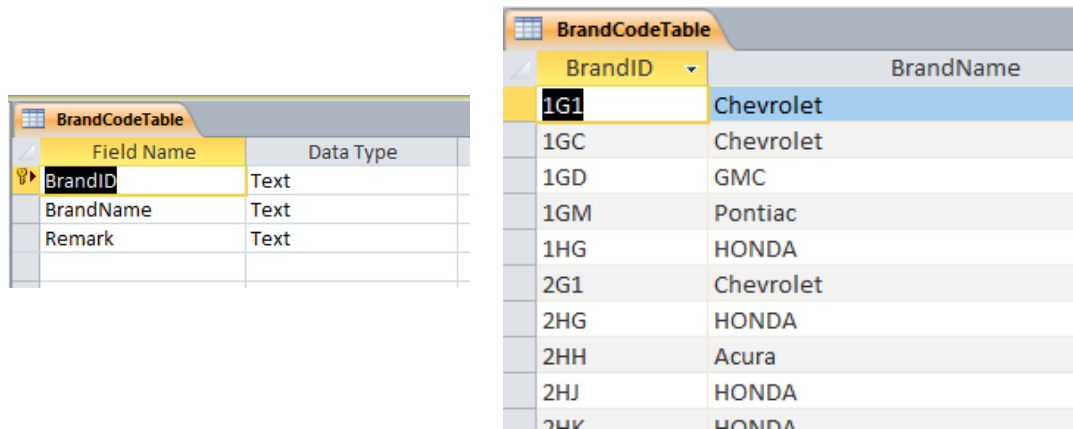


Figure 3.9: Brand Table and Example Segment

Other two tables are used for VIN information management system. Detailed fields and example segment of each tables are shown in the Figure 3.9, Figure. 3.10. Brand code and Country code searching tools and VIN identification system tool are also created.

Field Name	Data Type
IdCode	Text
CountryName	Text
Remark	Text

IdCode	CountryName
1B	United State
1C	United State
1F	United State
1G	United State
1H	United State
1J	United State
1L	United State
1M	United State
1N	United State
2G	Canada
2H	Canada

Figure 3.10: Country Code Table and Example Segment

For two points $p = (p_1, p_2)$ and $q = (q_1, q_2)$, the Euclidean distance $d(p, q)$ is defined by the two-dimensional geometry as:

$$d_{(p,q)} = \sqrt{\sum_i^n (q_i - p_i)^2} \quad 3.4$$

The distance “ d_i ” is selected as the most probable of all the characters in the database. This is the position where the minimum “ d_i ” value is made into i between the features spaces, where $i=1, N = \text{Total feature vectors in DB}$.

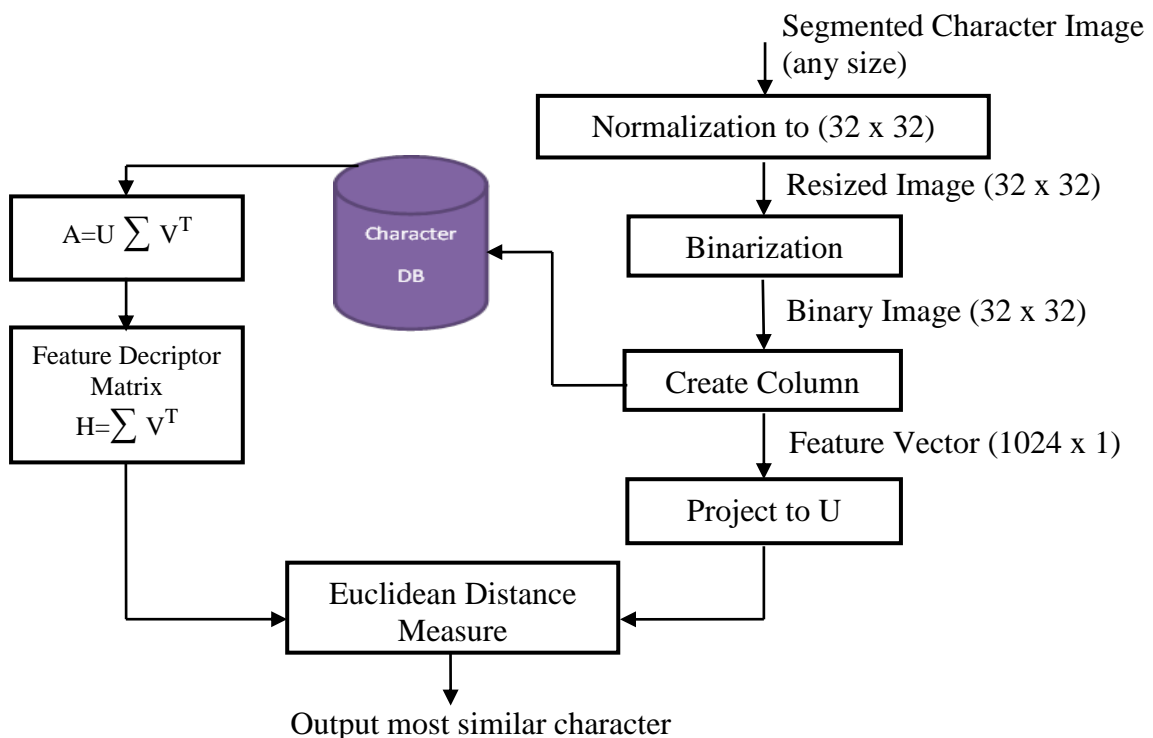


Figure 3.11: Recognition by SVD feature

The computing SVD and recognition operation procedure is listed as follows [4, 5] and recognition steps are also demonstrated in Figure 3.11:

- ❖ Generate a data matrix ‘ A ’
- ❖ Use *SVD* method to A , $A = U \Sigma V^T$
- ❖ Compute feature descriptor matrix, $H = \Sigma V^T$
- ❖ Get a test vector ‘ a ’ and compute $a^T U$
- ❖ Repeat computing $a^T U$ to match the dimension of $H = \Sigma V^T$
- ❖ Find the minimum variance of $\| \text{ repmat}(a^T U, \text{size}(H,2)) - H \|_2$ to obtain the desired class.

Output of the result is the Unicode character Alphabets (A to Z) and Numbers (0 to 9). In real work, input is the VIN containing picture taken a camera and output is the Unicode sequence representing the actual VIN number.

3.6 Training and Testing VIN image Feature

Actually there are vast amount of real VIN images stored in the current system. Since this thesis work is intended to use in real ground, real features are extracted. Feature database is formed by the feature vector of the standard alphabet and numeric data with their related information. Three kinds of font images such as, Times New Roman, Century, and Arial are used as training images. Font size does not restrict and any size is available. Column vector of the image is extracted after the pre and post processing of a font image. The related information of a character also added to Feature Database. More than 280 images are grabbed by various kinds of image acquisition devices as phone, camera and so on. All acquired images are testing images. It is also available to add the features of matched character of VIN image.

3.7 Searching Brand Code and Country Code

If user input “*code*”, the system can give the Brand Name as a output. To do that very simple SQL code is used to find both Brand and Country code as shown below. The word “*name*” in italic is the variable user input.

```
("Select Nmae From BrandCodeTable Where BrandID='{0}''", name);
("Select Name From CountryCodeDB Where IdCode='{0}''", name)
```


In fact, the searching tool can give the set of Code while typing each word of Brand or Country Name using “Like” SQL command.

3.8 Chapter Summary

This chapter presents about the overview of the proposed (VIN) identification system and the detail discussion of its stages with some experimental results. The main five stages such as the pre-processing, detecting the text region, text region segmentation, VIN recognition and vehicle identification are described. The gray scale converting, scaling, auto skewing and noise filtering are performed in pre-processing stage. The morphological processing, canny edge detection, dilation, erosion and labeling operations are used for detecting the text region in VIN image. After removing the unwanted parts in VIN image, the text region of VIN is extracted by using Left-Top and Bottom-Right point features.

The histogram process is applied for the character segmentation for the extracted text region image. The fundamental matrix is generated by the features of the segmented character image and standard character images in database. The Singular Value Decomposition (SVD) process is performed for recognizing the segmented characters. In this thesis, about 300 images are grabbed by various kinds of image acquisition devices and all acquired images are testing images. The feature database is formed by the feature vector of the standard alphabet and numeric data with their related information codes such as brand code, country code and so on. Three kinds of font images such as, Times New Roman, Century, and Arial are used as training images. Column vector of the image is extracted after the pre and post processing of a font image. The related information of a character also added to Feature Database. It is also available to add the features of matched character of VIN image. Some example code tables are explained by table in this chapter.

CHAPTER 4

EXPERIMENTAL RESULTS AND ANALYSIS

In this section experimental results are carried in the experiment for edge detectors for VIN Image, the experiment for normal and bad quality input images, the experiment for Dilation Process, the experiment for Labeling, the experiment for Cropping, the experiment for Character Segmentation and the experiment for Overall Accuracy Result. About 280 VIN images have been already analyzed and so more than 2000 feature vectors have already been trained.

4.1 Edge Detector Analysis

This work is actually intended just to use practically in a Governmental Department. The best accuracy and reliable results are enough regardless of detailed analysis. Accuracy and quality of this work strongly depend on the object detection in another word, on the reliable character segmentation. For the best result of character segmentation, text area extraction is also important process to get the real VIN area. Finally, choosing a reliable edge detection method merely leads to the good VIN text area extraction. In real world process of VIN number identification, taking VIN number or VIN acquisition may not always accomplished properly. Although there is no problems for the quality input VIN image, there will be a great problem for the bad quality VIN input image which has non uniform brightness, bad color distribution, etc. Due to lack of modern high quality instrument, lack of expert, image acquisition state may be very poor.

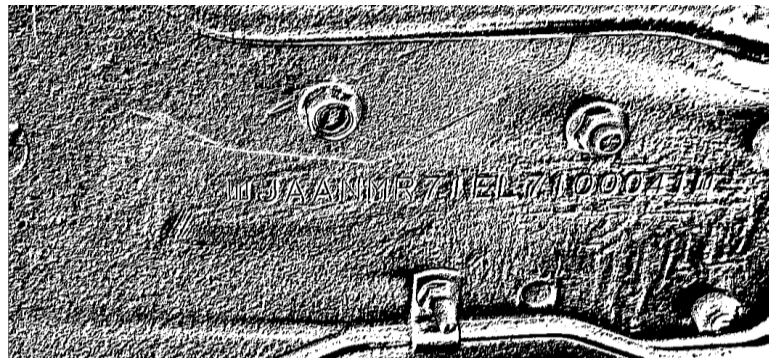
Edge detector analysis for the bad quality VIN image is carried out to choose the best edge detector. The various edge detection methods are tested for bad quality VIN image and these results are shown in Figure 4.1. As the result, Prewitt and Sobel edge detectors give the rather unpleasant output than Canny Edge Detector for the bad quality and non-uniform brightness image. The quality analysis of edge detectors shows that the best choice is “Canny Edge Detector”.



(a) Input image with bad color and brightness



(b) Experimental Result of Prewitt Edge Detector



(c) Experimental Result of Sobal Edge Detector



(d) Experimental Result of Canny Edge Detector

Figure 4.1: Experimental Result of Edge Detectors for VIN Image

4.2 Analysis of Dilation Process

VIN area (Text area) extraction is done by closing morphological method which is the process of dilation after erosion operation. For the best closing result, the number of dilation is the most important consideration task. The more number of dilation times, the more and more thicker objects. In fact, only optimal times of dilation is required. Extra times of dilation will result undesired connection of objects in the labeled VIN image.

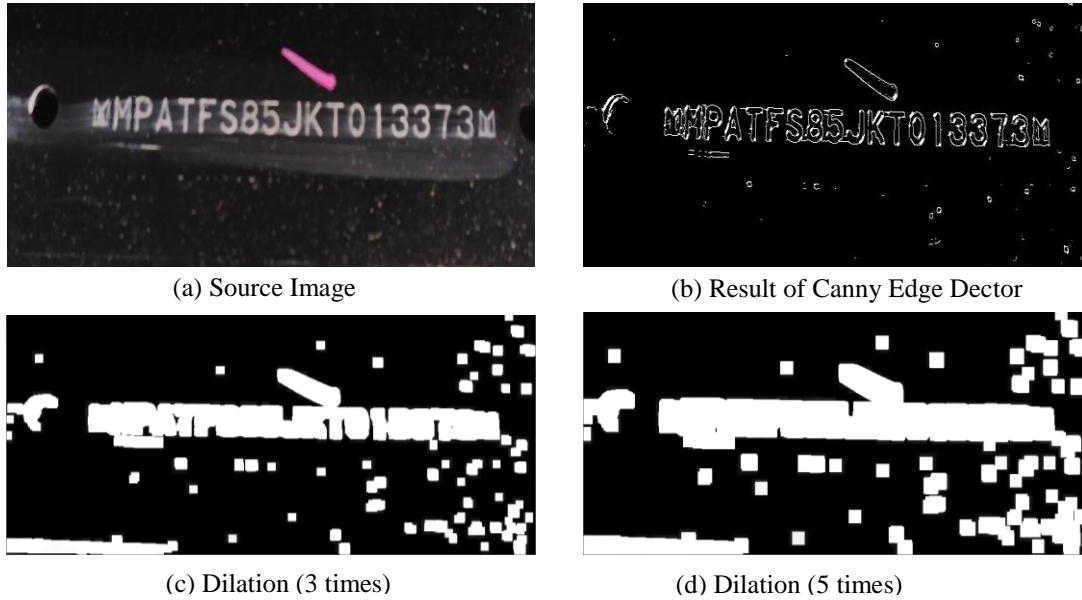


Figure 4.2: Experimental Result of Dilation for VIN Image

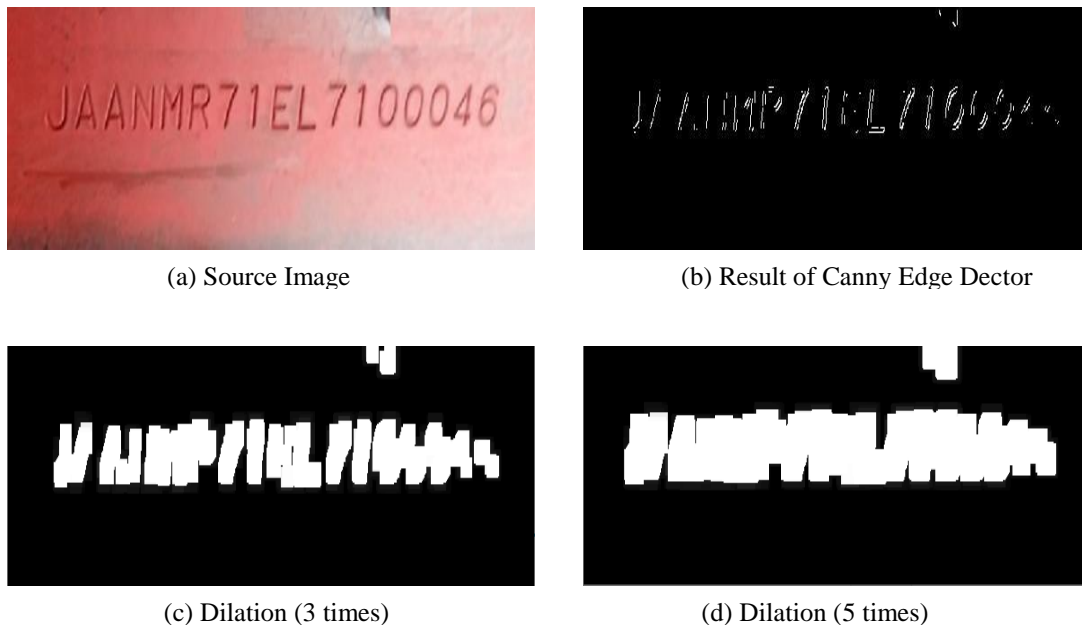


Figure 4.3: Experimental Result of Dilation for VIN Image(With Unbalance Brightness)

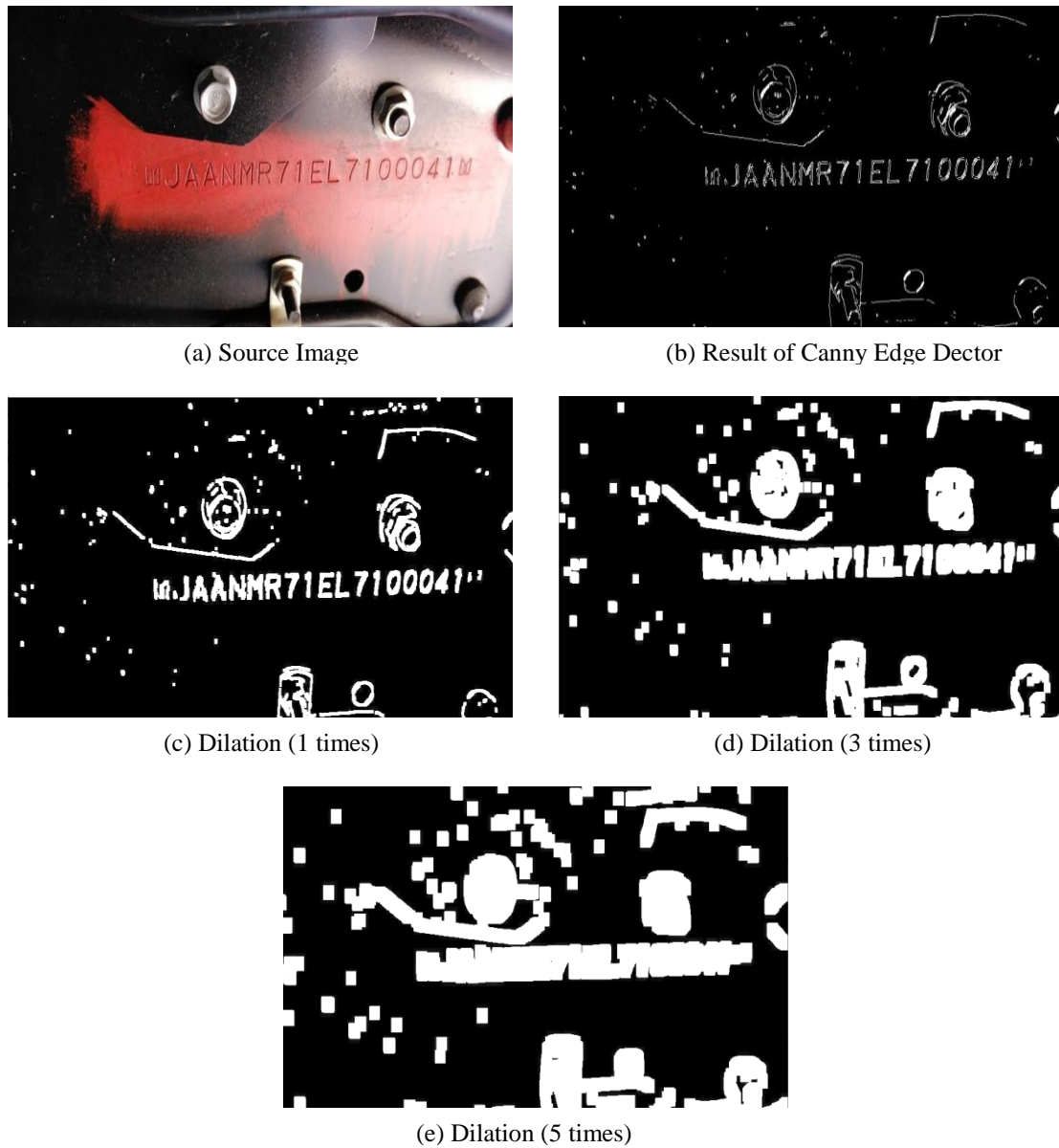


Figure 4.4: Experimental Result of Dilation for VIN Image (with bad brightness)

Figure 4.2, Figure 4.3 and Figure 4.4 illustrated the result of various dilations on the different image qualities, respectively. According to empirical tested results, the proposed system is robust in 3 times of dilation process. But for the worst quality image, the more number of dilation is needed.

4.3 Experimental Results

In this research, Edge detection, Closing, Labeling experiments are done in both normal VIN images and bad quality VIN images. And also experiments of the text area cropping, the character segmentation and the feature extraction processes are done and the results of experiments are shown in the below sections.

4.3.1 Result of Edge Detection, Closing and Labeling

As mentioned in 4.1, canny detector is the most suitable for VIN image. Example result is shown in the Figure 4.5(a). Obviously the better input VIN and the better result of edge. The result shows that so much noise and brightness/contrast problems do not disturb edge detection process in VIN image.



(a) Source Image



(b) Result of Canny Edge Dector

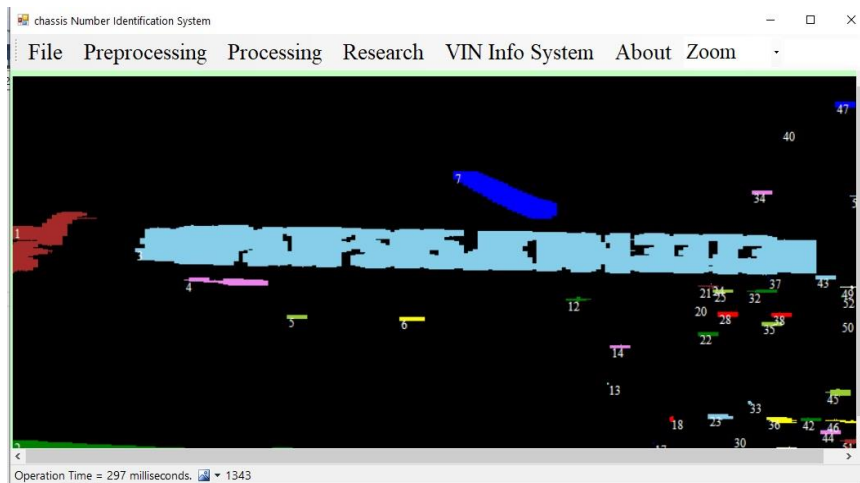
Figure 4.5: The Results of Edge Detection

In order to extract all the text in VIN area as a one connected unit, closing morphological idea is applied in the VIN image. Closing means dilation process of objects followed by the erosion process on the dilated objects.

After closing, all the texts inside VIN area in the image is connected as one unit. In Figure 4.6(a), 2 times closing result demonstrates that it is enough and robust dilation-erosion pair process.



(a) Closing Result (Dilation followed by erosion)(2 times)



(b) Labeling Result

Figure 4.6: Results of Closing and Labeling

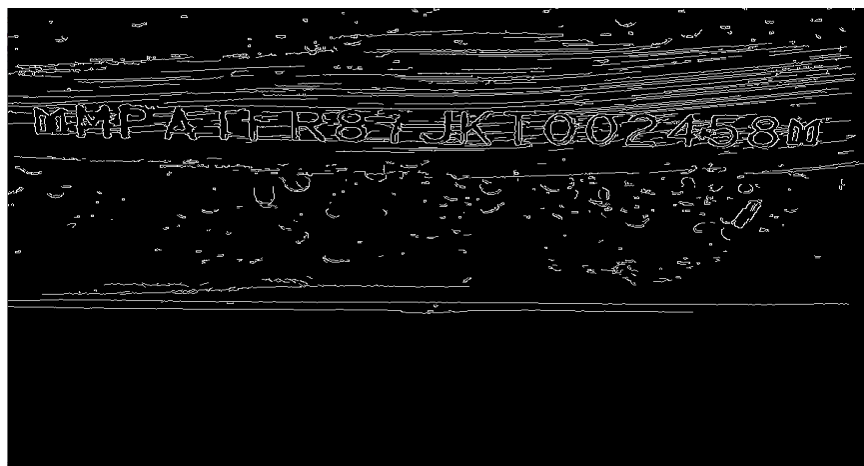
Result of labeling method is the a set of segmented objects which have properties of their own such as size, shape, position, etc. Acceptable result can be seen in the example output Figure 4.6(b).

4.3.2 Experimental Result of Bad Quality Input VIN Images

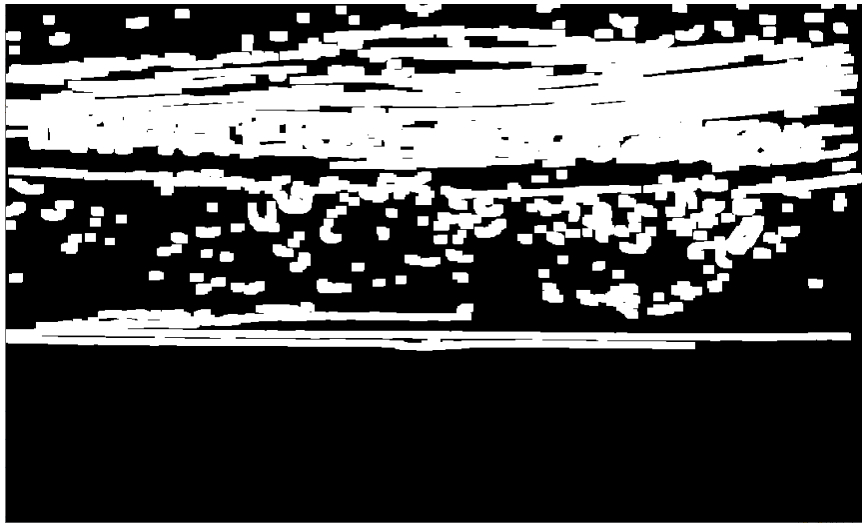
When the numbers and characters are not clearly visible in the taken image, it may lead to poor VIN area extraction and segmentation results. This can be seen in the following Figure 4.7.



(a) Bad quality input image



(b) Result of Canny Edge detector



(c) The result of image (b) by dilation (2 times)

Figure 4.7: Bad Quality Input Image and Bad Output

Bad quality input image produces only bad quality output. Figure 4.8 is another example of bad VIN image for automatic VIN number recognition system. That will reduce the accuracy of character recognition.



(a) Bad quality input image



(b) Result of Canny Edge detector



(c) Result of dilation (2 times)

Figure 4.8: Bad Quality Input Image and Bad Output

Apart from the bad quality input VIN image, there is another problem in developing labeling process using C# platform. Labeling algorithm of this thesis is done by recursively checking neighbor pixels to denote one label. In this situation, very big size image containing also big objects can lead to stack overflow problem. Custom stack size can, of course, be set by the developer, it is really not the easy work in C# environment. This stack overflows error is occurred because labeling function contains too many nested method calls.

4.3.3 The Text Area Cropping

The most possible object to represent VIN area can clearly be seen with bare eyes as in Figure 4.10(a). But text area (VIN area) algorithm must take into account all the candidate labels to define the VIN area. Selecting the right object can be done by using the properties of each object. Obviously, small object, for example, in yellow, blue and red color of that result image definitely cannot be the desired objects.

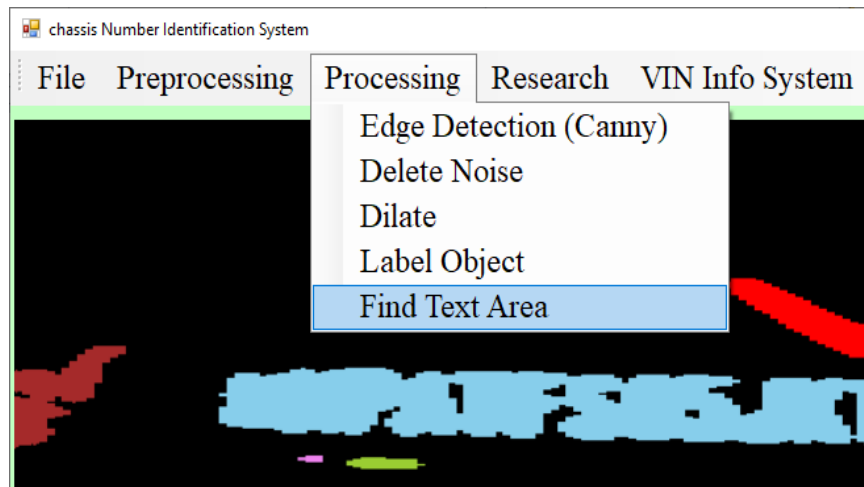
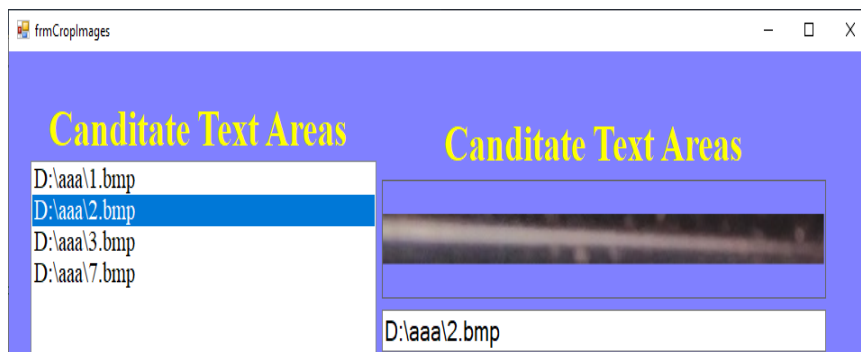
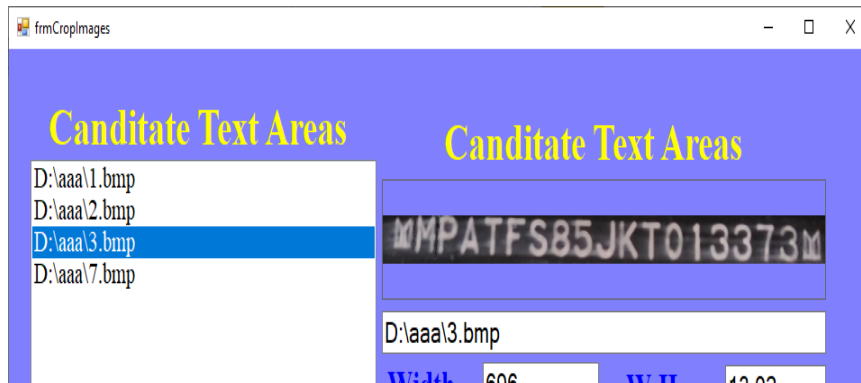


Figure 4.9: User Interface Menu

The user interface Menu is illustrated in Figure 4.9. As a preprocessing stage of object selection process, impossible objects are neglected. Figure 4.10 (a) is selecting the acquired image, and Figure 4.10 (b) and Figure 4.10 (c) are shown the selected images. VIN area is extract by using criteria mentioned in section (2.2)(2.3) and it is shown in Figure 4.10(d).



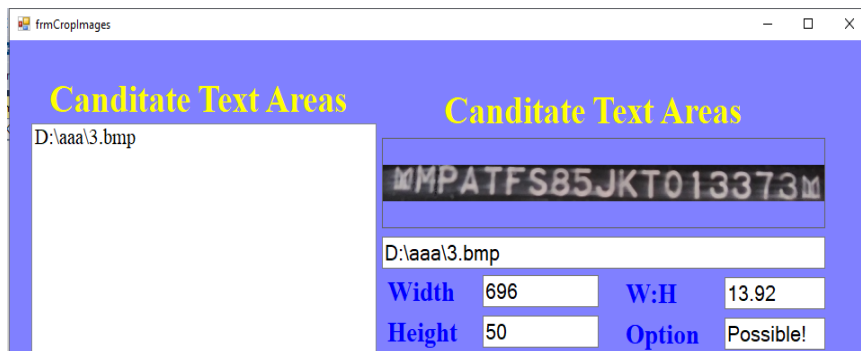
(a)



(b)



(c)



(d)

Figure 4.10: The Cropping Result of the Text Area from VIN Image.

They may be small or big enough in size, may not be in reasonable width and height ratio. After removing impossible object, final selected image is cropped as (VIN) area.

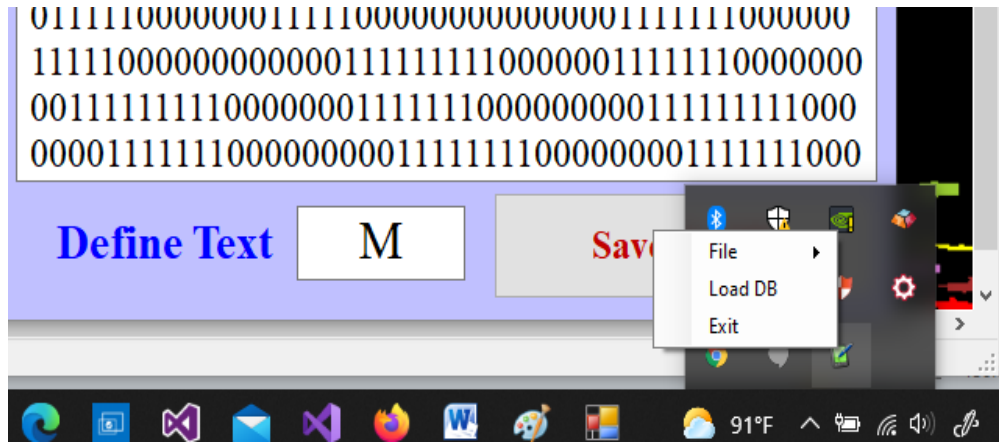


Figure 4.12: Setting Database Location

4.4 Recognition Accuracy Analysis using Testing tool

After saving feature vector to database, experiment for accuracy testing can be carried out separately apart from main system using the following application tool. Testing can be done in two ways: loading input character and own drawing with mouse pointer as shown in picture below. “Find” button do the finding the distances between the feature vector of input character and feature vectors in database. Vector with minimum distance from input is the most similar and corresponding character will be output as a result.

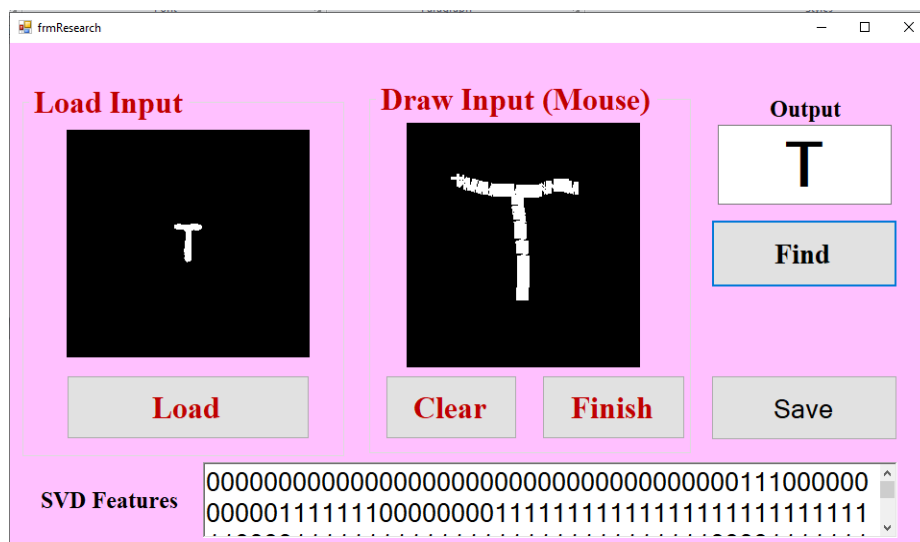


Figure 4.13: Accuracy Analysis

This accuracy analysis can be easily done one character by another (character wise). But in the main research work, all the characters are output at the same time and are input directly to VIN number identification system. Truly or falsely recognition result can be used in the system accuracy analysis process.

4.5 VIN Information System

As mentioned in the introduction section, each character in VIN represents its own meaning. Actual Country code and brand code are already stored in corresponding tables, and can be used or tested separately from main research system. VIN Information System (VinIS) is created as a supporting tool to test thesis work. Users can input real VIN directly and the system will response real country name, brand type and model year according to the input VIN. Thinking in mind, this thesis is actually intended to use on ground, so some supporting tools have been created while doing thesis work. VIN information system can be used as a stand alone decision support system. “More” button in the VinIS (as shown in Figure 4.15) is intended to find Country code and brand code (searching system) while inputting some remember words. It is really useful tool in related department. Example results of information system and searching system are demonstrated in the following pictures Figure 4.14 and Figure 4.16.

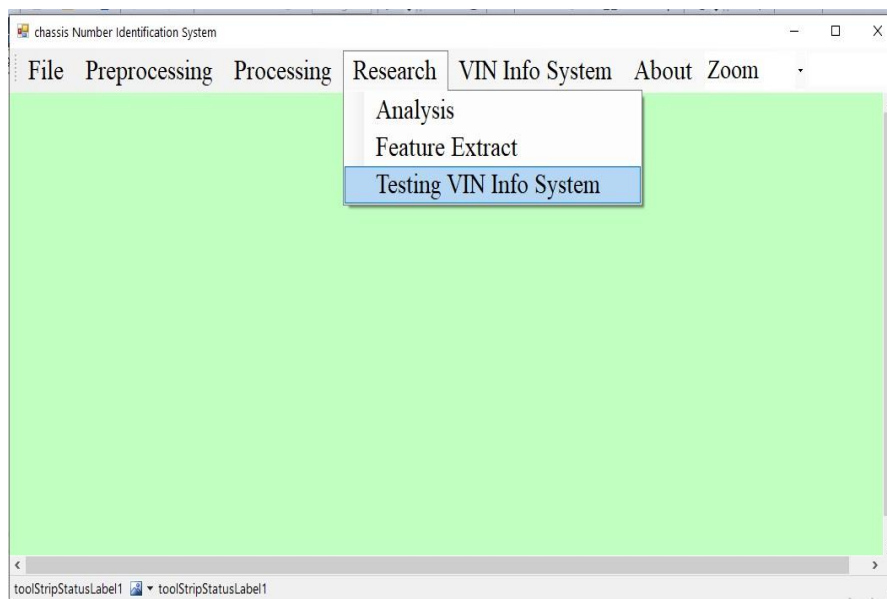


Figure 4.14: Testing VIN Information System Menu (VinIS)



Figure 4.15: Real VIN Information for Real VIN Number Image



Figure 4.16: Real VIN Information for Country and Brand Code

Standard real Brand Codes and Country Code used all round the world are stored in MS Access Database and the segments of these two tables are shown in the picture Figure 4.16. Above these tools are tested with the real data and result of this application segment is definitely 100% correct. Example Brand Code and Country Code database is shown in Figure 4.17.

BrandID	BrandName
1G1	Chevrolet
1GC	Chevrolet
1GD	GMC
1GM	Pontiac
1HG	HONDA
2G1	Chevrolet
2HG	HONDA
2HH	Acura
2HJ	HONDA
2HK	HONDA
2HM	Hyundai
2LN	Lincoln
3HG	HONDA
3HM	HONDA
3VW	Volkswagen
4S3	Subaru
4S4	Subaru
4S6	HONDA
4US	BMW
5FN	HONDA

IdCode	CountryName
3N	Mexico
3V	Mexico
4F	United State
4J	United State
4M	United State
4S	United State
4T	United State
4U	United State
55	United State
5F	United State
5J	United State
5L	United State
5N	United State
5T	United State
5U	United State
5X	United State
5Y	United State
6T	Australia
6U	Australia
7A	New Zealand
82	Bolivia
8A	Argentina
8B	Argentina

Figure 4.17: Example Brand Code and Country Code database

4.6 Experimental Result of Accuracy Analysis

According to the result of extracted characters in VIN number image, VIN information is given as the real result of this system. As this work is intended to used in real ground, about total 2040 VIN character image's features are already collected in feature database. While testing current research work, feature vectors have being added day by day. So feature database is getting increased for time. The results of region extraction, character extraction, segmentation and matching have been expressed in previous sections. The testing result of a VIN number information for the input image Figure 4.18 is also shown in the Table 4.1 for the required decision making processes.



Figure 4.18: Source Image

Table 4.1: The Result of Actual VIN Information

1	Brand	ISUZU
2	Vehicle Type	Double Cab
3	Model Year	2019
4	Country of Origin	Thailand

Experimental research is carried out to know accuracy of the recognition of the proposed system. Results show that almost all the characters are recognized correctly for the input character image. But in very rare case, for example number “8” and character “B”, system may give wrong result. Testing is carried out on the way to research target. So when small amount of feature vectors are in database, there is some wrong output. But more and more vectors are saved, more exact results are given by the system. Step by step research work is demonstrated in the following Table 4.2.

Table 4.2: Experimental Result of Accuracy

	Number of Features in DB	Accuracy
1	50 features	95.5%
2	100 features	99.7%
3	200 features	99.9%
4	500 features	More than 99.9%
5	1000 features	More than 99.9%

Table 4.3: Result of Overall Accuracy

Number of VIN Images	True Result	Accuracy
280	270	96.4%

Obviously the result shows that 500 feature vectors is good enough to get the accurate and the best result from the system. All the test images are taken by various types of phone camera in real work places area.

Overall Accuracy just depends on the (VIN) number text area Extraction step (Segmentation). Segmentation process is related with the input VIN image quality. If text area is accurately segmented, the system can give almost 100% true results. Table 4.3 shows the overall accuracy result testing for all the mix of (normal and bad) VIN images taken from department.

4.7 Chapter Summary

This Chapter implements the experiments and results by testing the proposed Vehicle Identification system based on the Singular Value Decomposition (SVD). The several images of Vehicle Identification Number (VIN) are applied for these experiments. The user interface-menu is created for this proposed identification system. The character segmentation and feature extraction are performed by histogram approach. Morphological operation is provided to reduce the noise and remove the unwanted part from scan image. The experimental results are described for all operation steps of noise reducing, edge detection, and morphological operation as opening, closing and labeling. Histogram method is applied for character segmentation and VIN information is extracted by SVD matching approach. The proposed system will provide to extract the detailed information to support decision making system for the Myanmar Customs Department (VIN Code checking Section).

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 Discussion

VinIS works well with reasonable or acceptable input image which is properly taken by appropriate camera. Regarding with the input image, developed research system VinIS will have the problems when input image is:

- (1) Input image is very big and taken rather far from the VIN. In another word, VIN number in that image is very small.
- (2) The most important and evil thing is that there is no VIN number in the input image. Input image without VIN number may cause the VinIS system produce unpredictable result.
- (3) Input image has very high brightness, very low brightness or unbalanced brightness.
- (4) VIN number text is not in horizontal direction. Auto rotation of the VinIS can only rotate slightly slopping image.
- (5) There is a defective mark in the area of VIN characters. It will lead less number of segmented characters because two or more characters may be connected as one character in the character segmentation process.
- (6) Input image is very bad quality.

Most of the above input images of quality and acquisition problems are rather difficult to be solved.

Database system used in this thesis program for storing feature vector is a commercial database software which need privacy license. Another fact to be considered about used database is unnecessarily occupation of disk place. This is used just for convenience and that there is no need to consider for errors. Actually feature vectors can be saved just in binary file for faster processing and lesser size.

5.2 Conclusion

In Myanmar, There is still lack of technology to access the visual content of documents stored in different media. In this study, valuable information retrieving from VIN image is introduced to the corresponding departments to use it in decision making of daily routine. It is the first research work in Myanmar and honestly needs further and thorough studies in different ways and in different technologies. Besides, the discussion about used technologies and their results are needed.

VIN certification system developed for real needs in Myanmar. According to the implementation and results, it can be say that the system can actually crop the required VIN area of the input and well segmented each character in that area. So accuracy of proposed method can be considered very high and good enough.

All the necessary steps of automatic vehicle number identification process have been thoroughly examined though the thesis work. A lot of experiments in each step give the acceptable and reliable results and we can conclude that reliable and robust parts of main process produces promising results in main VIN identification thesis work.

Through out the thesis, VIN Identification System (VinIS) is successfully developed. This system contains VIN identification tasks, VIN information management system which can retrieve desire information and can search country cade and brand code on demand.

Recognition is easy and clearly done by using simple and effective classifier, Euclidean method which finds the differences between two feature vectors. Another conclusion that can be made is that easy-to-use user interface is created for thesis work.

5.3 Future Work

Recognition processes is also robust to use in real world. Real-time vehicle inspection and identification should be done using available network and webcams. Additionally, car information management system can be easily integrated into VinIS for more information about the vehicle being inspected. The type of Web application and mobile application for VinIS needs to be created to use everywhere in all round the country. There is an online license plate identification android application which needs

manual input of plate number. Developing an automated system for VIN identification remains a challenge for Myanmar researchers.

Nowadays there are so many technologies which are developing day by day. Among them Python is the best one which supports image processing and neural networks technologies. It is gaining popularity as a scientific programming language and many free image processing tools are available in its ecosystem for free. For more appropriate processing time, some Image-Processing Python Libraries such as: OpenCV, Scikit-Image, PIL (Python Imaging Library) should be used in future.

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