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VEHICLE LICENSE PLATE DETECTION AND RECOGNITION

Master's Thesis

AHMED RAMADAN ALRFAIE

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ABSTRACT

VEHICLE LICENSE PLATE DETECTION AND RECOGNITION

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COMPUTER ENGINEERING

Supervisor: Prof. Tarkan Aydin

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A proposed new license plate detection technique is provided in this thesis, by mixing the main idea of two other techniques, texture based technique and colour based technique. The main work in this thesis is to locate the license plate location within the image, and then by employing OCR algorithm to obtain the license plate numbers and characters.

The proposed technique operates by converting the input coloured image into binary image without converting the image into gray-scale; the target of this conversion is to convert every pixel with dark colour into black and any other colour into white, after this conversion noise reduction technique is applied to eliminate some of the noise. Then the algorithm eliminated unwanted black pixels based on the mass size of the black pixels, large masses are deleted from the image, then projection technique is used to locate the possible location of the license plate, after that object counting technique is applied on every sub image to eliminate any image that doesn't contain a predefined number of edges on it, then another projection technique is applied to eliminate any unwanted parts of sub images to become one sub part of the image that must contain the License plate only . This method was tested on **231** images, to establish the license plate location, and its success of locating the plate on **89.18** present of the image. Then OCR algorithm is engaged to classify the characters and numbers on the detected plate.

Keywords: Computer Vision, License Plate Recognition, Binarization, Image Processing, Edge Detection.

ÖZET

VEHICLE LICENSE PLATE DETECTION AND RECOGNITION

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Mayıs 2016, 40 Sayfa

Bu tezde, yeni tasarlanan plaka algılama tekniği, doku bazlı teknik ve renk temelli tekniğin ana fikrini harmanlayarak sağlanmaktadır. Bu tezde esas çalışma, plaka numaraları ve karakterleri elde etmek için OCR algoritması kullandıktan sonra görüntü içinde plaka konumunun tespit etmektir.

Önerilen teknik, görüntüyü gri skala içine dönüştürmeden, ikili görüntüyü renkli veri görüntüsüne dönüştürerek çalıştırır; bu dönüşümün hedefi, her bir koyu renkli pikseli siyah renge ve herhangi diğer bir rengi de beyaza dönüştürüp, sonrasında, paraziti ortadan kaldırmak için ses redüksiyon tekniği uygulamaktır. Sonrasında algoritma, kütle boyutuna dayalı, istenmeyen siyah pikselleri ortadan kaldırır, iri kütleler görüntüden silindikten sonra, projeksiyon tekniği kullanılarak plakanın olası konumu yerleştirilir ve ondan sonra her alt görüntüye, üzerinde önceden tanımlanmış kenarların sayısı kadar herhangi bir görüntüyü ortadan kaldırmak için cisim sayma tekniği uygulanır. Bunun akabinde de, herhangi bir istenmeyen alt görüntünün kısımlarını, sadece lisans plakasını içermesi gereken tek bir alt görüntü parçası haline gelmesini ortadan kaldırmak için başka bir projeksiyon tekniği uygulanır.

Bu yöntem, plakanın konumunu ve görüntünün 89.18’nin plaka üzerine başarı ile yerleştirilmesini saptadığı için, 231 görüntü üzerinde test edilmiştir. Sonrasında da, saptanmış plakanın üzerindeki sayıları ve karakterleri sınıflandırmak için OCR algoritması devreye girer.

Keywords: Computer Vision, License Plate Recognition, Binarization, Image Processing, Edge Detection.

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ABBREVIATIONS

ALPR	:	Automatic License plate Recognition
ANN	:	Artificial Neural Network
CCA	:	Connected Component Analysis
CV	:	Computer Vision
HMM	:	Hidden Markov Model
HT	:	Houge Transform
LPD	:	License Plate Detection
LPR	:	License Plate Recognition
NN	:	Neural Network
OCR	:	Optical Character Recognition
RGB	:	Red, Green, Blue
SCW	:	Sliding Concentric Windows
SVM	:	Support Vector Machine

1. INTRODUCTION

License plate recognition is a technology related to computer vision field, it’s used to identify vehicles by their license plate , and it’s one of the important intelligent Transportation system methods, and it’s become popular in today’s world , because it’s used in a lot of fields like road traffic monitoring, automatic payment of tolls on highways or bridges, detection of stolen vehicles, driver navigation support and parking access control ,on all of those one of the main parts is being able to recognize the license plate, and read the plate number then compare this number by pre defined numbers or register it, with this system it becomes very complicated due to the number of the vehicles and the amount of surveillance the aim is to conduct this on vehicles in more than one location, humans can’t perform this type of work efficiently and quickly we need a machine to perform this task and make it possible to work 24 hour per day, that’s one of the main reasons why the License Plate Recognition systems is needed, to detect and recognize the plate numbers then compare the numbers with pre-defined numbers or just register it.

Any License plate recognition system consists of three main phases:

I. Determine the license plate location on the input image.

II. The Segmentation of the characters and numbers to start recognition phase.

III. Recognition and classification of the segmented characters and numbers.

Generally there are two types of License plate recognition systems:

I. Stationary License plate recognition system:

In this type of system the system uses stationary camera mounted to street lights or buildings or any stationary object.

II. Mobile License plate recognition system:

With this type of system it may consist of multiple or single cameras attached to police car or any other vehicle, and while the car is moving the cameras start taking the images of other cars around it.

This thesis is only interested in Stationary License plate recognition systems, and the goal is to deal with the problem of detecting and recognizing the license plates from images and video in real time.

Most of the existing License plate recognition algorithms can be classified into three categories:

I. Color based algorithms:

   There are some countries which use specific colours in their license plates which allow the number plate to be read by locating their colour on the image.

II. Edge based algorithms.

   License plates usually rectangular in shape, Because of that the license plate can be detected by checking all the rectangular shapes on the image, but this doesn't work in all cases.

III. Texture based algorithms.

   This approach assumes the vehicle license plate characters must be of distinct textural characteristics thus allowing them to be distinguished from the background.

In LPR there are a lot of challenges to deal with, due to the complex scene on the real application, the shadows, other edges and other text it maybe writing on the vehicle itself or on the walls, or maybe the shadows of the clouds or birds, all of this things and other things make the LPR a difficult task.

There are other challenges like image quality because it can be affected by weather conditions, not enough or too much light, blurred image based on the car speed and camera shutter speed and other conditions, like if the license plate is dirty, or if there is something between the camera and license plate that will make it impossible to recognize the license plate.

This type of system named Real time system that means the ability of the system to be able to perform its task within a specific time, and if the system can't do said process within the allowed time that means the system can't be called a real time system.

To produce a Real time license plate recognition system, it must be able to process every image within the time of taking the images and developing the image, if the system gives correct data but after the specific deadline time that is not a real time system; the real time system should give instantaneous data.

There are some problems with existing algorithms, most of the existing algorithms work based on edge detection by searching for rectangular shape around the license plate, but there are a lot of license plates which don't have this rectangular shape surrounding them, and the plate colour is the same as the car colour, in this case all existing algorithms using the rectangular shape system which possibly might not work properly, and maybe It will not work at all.

Other types of algorithms work based on the color of the characters on the plate, but this is not good all the time because of real life conditions it maybe there is other text written in black or dirty number plate and that makes it difficult or impossible to detect the plate .

In the proposed method of trying to mix two types of algorithms one of which depends on the colour and the second depends on the texture to become a new method, it must be able to work fast and be more reliable.

The first phase is converting the image into a binary image based on unique selection of threshold value to obtain a black and white image, then because license plate colour is different from the text that is written on it, and because the font size of the characters and digits it can be assumed on specific size range, then it's possible to start phase two by deleting the large black area and small black area from the image, after that it will be possible to search the image for the areas that contain a lot of black edges, then crop the image into sub images based on concentration of the black pixels, then by applying some segmentation technique the characters and digits can be detected, based on the distance between the characters and digits that characters and digits so far from the center are deleted, then due to the fact of characters and digits areas must be nearly close to each other, the characters and digits with outlier areas are eliminated, that gives a much better.

Detecting the license plate location is one of the hardest tasks for License plate recognition systems, and this task starts by converting the image to black and white, then applying a custom smooth filter to decrease the noise, this filter works by changing the very small Black pixels within the white areas into white and changing very small white pixels inside black areas into black, then the large and very small black areas are converted to white leaving only black areas of a specific mass the reason for this is that generally characters on plates are of this size, after this process the algorithm then searches for concentrated areas of black pixels , this is done by vertical and horizontal reading of the picture, the next step is to read the horizontal lines to find a concentration of pixels that could be a possible plate , from this process it can create one or more sub images which may consist of a plate, then by counting the number of objects within the sub image it's possible to eliminate some of the sub images, from the sub images with a predetermined number of objects. The algorithm will look for the highest concentration of pixels within each sub image and eliminate the parts of the sub image with the lowest concentration of pixels, from this it's possible to start to segment and dissect the image to commence classification of the characters within the image thus leading to the recognition of the characters on the plate.

The rest of the thesis is organized as follows:

In Chapter 2 talks about Literature of technologies and algorithms that used ALPR systems, then In Chapter 3, within this chapter various techniques and algorithms will be presented due to the fact they are used within the stages of this thesis of ALPR system, then In chapter 4 thesis method with a set of phases to develop a comprehensive ALPR system for the license plates are described, then in Chapter 5 presents the experimental results of thesis method, then and finally, in chapter 6 some concluding remarks and suggestions for possible future development are provided.

2. LITERATURE REVIEW

Most of the License plate recognition systems consist of three main steps detection, segmentation, and classification of the characters to recognize the License plate data. Due to this fact many techniques are implemented to perform these steps, this chapter focuses on these techniques.

2.1 LOCATING THE LICENSE PALTE

In order to begin the process of detecting the location of the plate on the, Input image can be colour, grey or possibly binary; there are many algorithms that have been implemented to perform this task. This chapter will cover some of them.

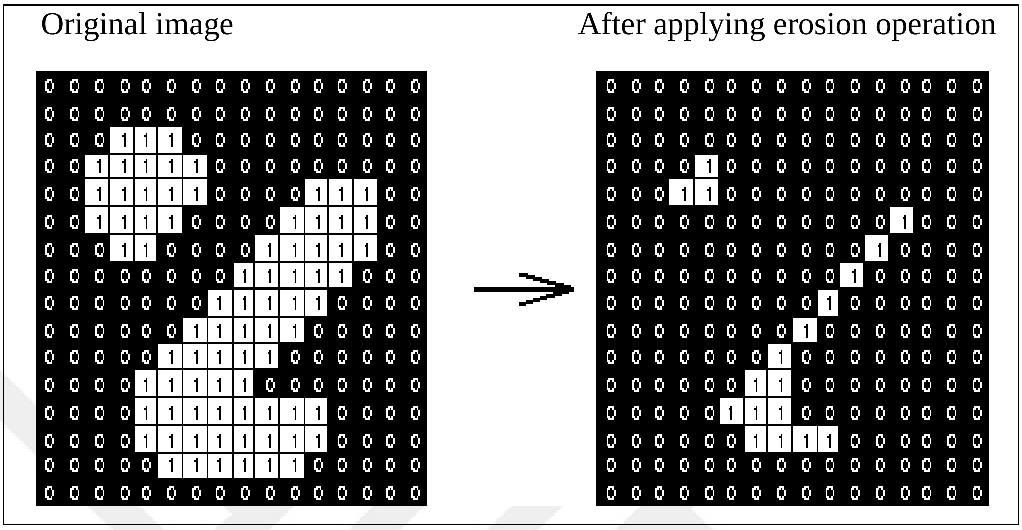
2.1.1 Algorithms Performing the Detection of License Plates on Binary Images

Morphological analysis, edge statistic and connected component analysis are commonly used in binary image possessing techniques; those techniques are used as a part of some license plate detection algorithms.

2.1.1.1 Edge statistics and morphological analysis

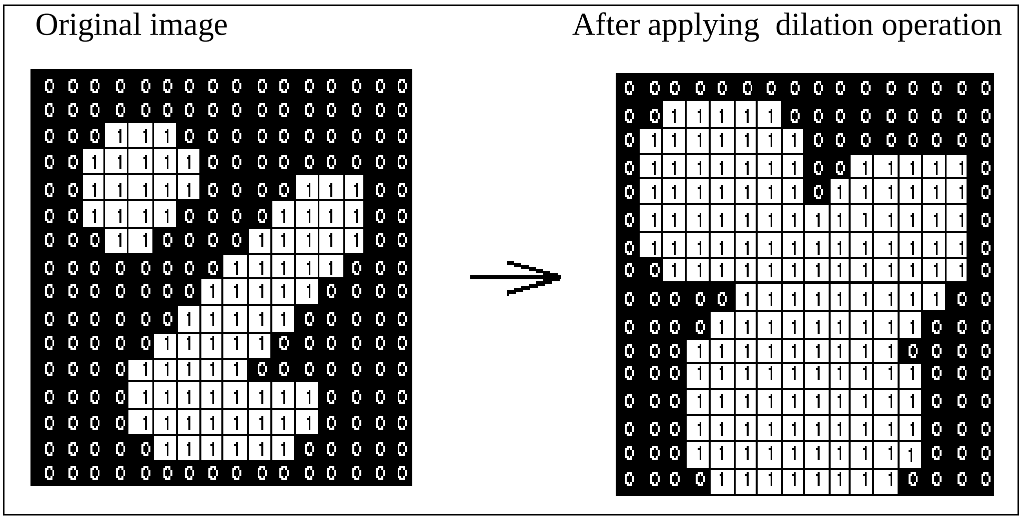
Some research works [3, 4, 6] incorporated edge statistics and mathematical morphology together. Brightness in the area of the license plate region varies more than any other part of the image. Due to this factor it can be used and has been used as a baseline property to establish the position of the license plate. The disparity of the edges of an image is computed. Using the disparity of the edges enables license plate to be detectable. In images that contain a complex background. A consequence of this is that with complex images edge statistics, variance and local mean obtaining a good result is very difficult. To prevent this from occurring mathematical morphology in conjunction with edge statistics are used to remove unfavorable edges from the final image. This enables the detection of license plate to be conducted at a relatively faster rate. Mainly there are two morphological analysis which are used, Erosion and dilation, Erosion operation is used to disconnect connected characters or any connected objects by erosion the edges of every object by moving a window over the whole image and if this window consist for example of only one black pixel it converts it into white, the Figure 2.1 shows how its works

Figure 2.1: Show erosion operation



Dilation operation works exactly the contrary of the erosion operation, it’s used to enlarge the small objects on the image and it can fix some disconnected parts of the same object some times, the next figure 2.2 shows how Dilation operation works.

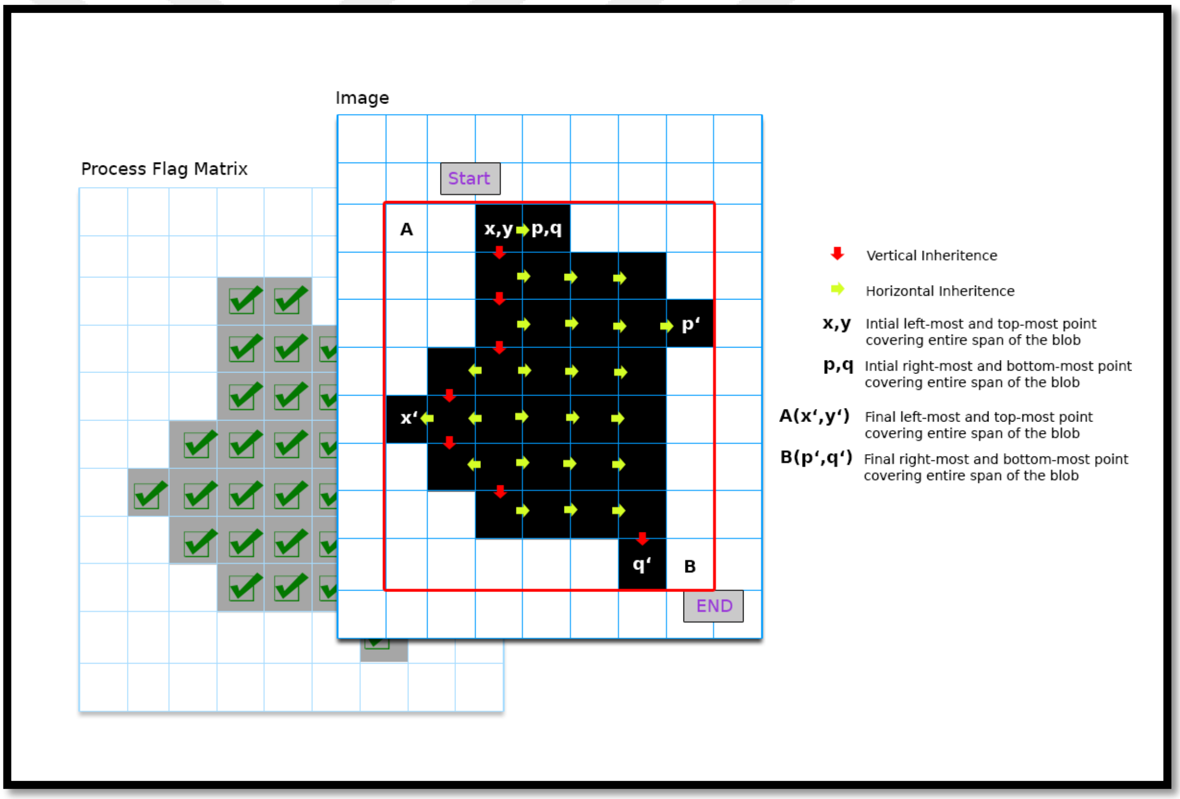
Figure 2.2: Show dilation operation



2.1.1.2 Connected component analysis

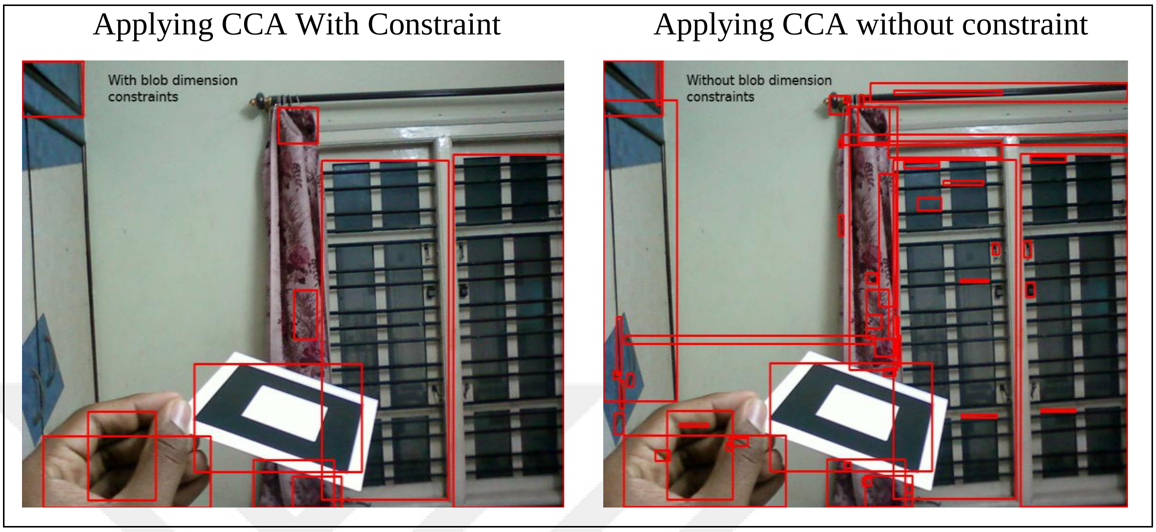
Connected component algorithm [7] is very significant within the processing of the Binary images. Once a binary image has been skimmed by CCA its tags pixels based on pixels connectivity. Dissecting and tagging of connected and disconnected objects within the image is generally used to evaluate position, mass, and aspect ratio which are the main measurements within a binary object. During the segmentation stage CCA is applied to eliminate background noise, to enable only characters to be classified on the binary image after the segmentation stage. Next figure 2.3 shows how this algorithm works to detect the objects.

Figure 2.3: Shows how CCA is works



This algorithm can work with coloured images as well, and it can be implemented with some constraint about the size of the edges or without any constraints, when it's used without any constraints its produce too many objects, especially if the scene is complex due to this fact in most of the cases special constraint must be used for each and every individual case, the next figure 2.4 shows the difference between when CCA is applied with size constraint and when its applied without this constraint.

Figure 2.4: Shows different between applying the CCA with size constraint and without it



2.1.2 Algorithms Performing the Detection of License Plates on Grey Scale Image

Grey scale image processing techniques have been used on research work to locate the license plate [1, 9, 10, 22], there are various different methods used with grey scale image processing, image transformation [9] region segmentation [1, 10], edge counting [23] block counting [22].

2.1.2.1 Image transformation

For license plate detection image transformation is used. The reason being that with image transformation straight lines, edges, or borders are relatively easily found on the input image. Gabor filter method is used in [9] along with the spatial measurements, such as size, and aspect ratio to locate the license plate. The Gabor Filter becomes more usable because that filter performs very similarly to the human visual system in frequency and the orientation. Additionally this algorithm performs well in texture segmentation problem because of its ability to choose the optimal properties in spatial and frequency domains. This algorithm is used on many applications such as image coding, image representation, edge detection, document analysis and for License plate recognition systems; the unique property of this algorithm is the ability to analysis texture in an unlimited number of directions and scales. But the worst drawback within this algorithm is the performance unfortunately it is very slow, and expensive especially if the image size is rather large. Houge Transform (HT) is used in literature [2] to detect the outlines of the license plate. This algorithm uses voting prouder to determine the features of the objects within a specific class of shapes. The original algorithm was implemented to identify the lines within the images, but after that the algorithm has been updated to be able to identify the location of the shapes, waves or circles. In this literature they assume the license plate was surrounded by the rectangular shape, and they use (HT) to detect the vertical and horizontal lines of that rectangle, but always the image contains other rectangular shapes, due to this fact they need to do more work to detect which one contains the correct license plate.

2.1.2.2 Region segmentation

Sliding Concentric Windows (SCW) is proposed in literature [10], this algorithm has also been implemented and operates on reliance due to local characteristic like mean and variance in the given image, this technique uses two concentric windows A and B, the size of the window A must not be equal to the size of the window B and the dimension of the A must be bigger than the dimension of the window B.

The idea behind SCW is to move the created window over the entire image to search for the region which may hold the plate, the size of the window affecting the output of the algorithm due to that maybe many window sizes created to catch the objects the system searches for them, and the step size is very effective to the system performance, if the step size is too large that mean the windows maybe skip the objects without catching them, but on other hand if the step size is very small that means the running cost will be high, especially if the image dimensions are large.

2.1.2.3 Edge counting

Edge counting is used to locate the license plate in [23], this algorithm searches the image horizontally on X-rows and counts the number of objects in that row, in case the number of objects is more than some predefined number the algorithm assumes the plate is in this row, if the number of the objects in that row is less than the predefined number its assumes that there is no plate in this row, but when the scene is very complex this algorithm doesn’t perform well, even if the row contains some single black pixels on the same row specially if edge detection technique like canny edge detection is used without eliminating the noise, maybe some other operations can be used like calculating the edge size before counting it, because of all of that this algorithm is used in this thesis but only as a supporting algorithm.

2.1.2.4 Block based

Some algorithms use Block Based grey scale processing technique to locate the license plate as mentioned in [22], the idea of this technique is to split the image into blocks based on high edge magnitude or high variance to locate the license plate location, with this type the majority of blocks are not the license plate, according to that some other steps must be performed to identify the correct block as a License Plate, such as area and aspect ratio, the result of this process doesn't give a good estimation, with in most of these blocks, if the image contains a complex background it's difficult to locate a plate, for that reason this algorithm fails with images that consist of a complex background.

The block size selection is not an easy task, and it effects the total number of blocks, the block size must be fit to locate the plate and it must be compatible with the image size because if it's very small that will cost to much and it maybe not be catching the license plate location, and if it's very big it might include a lot of noise inside the license plate block.

There are many other techniques which are used on colored image processing to locate license plate [5].

2.1.2.5 Canny edge detection

This algorithm is used in many applications of computer vision field and image processing to detect the objects on the image [20], this algorithm sometimes known as optimal edge detector. This algorithm was developed by John F. Canny in 1986, there are many steps in this technique and it has the ability to detect many types of objects that may have different shapes, this algorithm was designed to have three main advantages first one is to give low error rate, That means it must detect the correct edges as edges and don't miss any edge and mustn't detect fake edges, second one is localization, that means the distance between the real location of the edge and the detected edge must be minimal, the last important advantage in this algorithm is to take the threshold value as one value for every single edge. This algorithm works very well to detect every single object as an edge due to that it has the ability to detect the characters of the license plate as objects and that is the reason for using it in some license plate recognition systems, but this advantage is also a disadvantage at the same time when the background is complex, because with this algorithm after applying the edge detection it counts the edges and they assume the area that contains many objects is the license plate, but this is not correct in most of the cases.

2.1.3 Algorithms Performing The Detection of License Plates on Color Image

There are several algorithms dependent on colored image to work; most of them use the properties of the plate color to locate it, these algorithms assume that no other area looks like the plate area within the image, due to the colour of the characters and the colour of the plate background and this conjunction of colours is unique. These algorithms search within the image for the plate based on that assumption, due to this, this algorithm possibly may fail when the brightness of the image changes. In some countries these algorithms perform better than other countries, if the country applies restricted rules for any license plate if it is not clear enough. But due to the brightness changing on the image this algorithm may fail.

2.1.3.1 Machine learning to detect license plate

One of the most active research areas on machine learning and neural networks is a deep learning, it's a new technique work based on hierarchical learning or deep structured learning, and it's defined as a high-level definition as: deep learning characterized by learning extracting the features automatically from many layers of non-linear functional units, every layer are uses the output of many or just one of the previous layers. High level features are learned based on low level features which from hierarchical representation for supervised or unsupervised feature transformation and extraction, and for classification, analysis and pattern recognition. The Learning stages are learned based on data and modeling the complex relationships among the data.

Deep learning techniques works depending on distributed representation of data. The main assumption of deep learning is that the data is generated by the interactions of many different parameters on different levels of hierarchy. Deep learning assumes that these parameters are organized into numerous levels, corresponding to various levels of abstraction or composition. The number of layers and sizes of layers can be varied and various levels of abstraction. Some of the reasons for the increase in usage of deep learning in current research are due to the high performance graphical processing units, advances in machine learning research and the availability of big data for training and testing.

2.2 LICENSE PLATE SEGMENTATION ALGORITHS

After locating the license plate based on any one of previous algorithms and techniques the next step is to segment the objects on the image, this step must be done before commencing to classifying the characters and digits, because the output of this step is the input for the classifying process. There are many methods is used in segmentation in literature some of them in gray scale image such as projection, Mathematical Morphology [5, 12, 13], and some of them in binary image like Local and Adaptive threshold [13, 14].

2.2.1 Projection

Computing the projection of the pixels vertically and horizontally are used widely to segment the characters because it's a simple and useful technique [5, 12, 13], vertically and horizontally projection technique is used with binary image, the main idea is to find the minimum values and segment the image based on this value, this method allows to segment the image vertically and horizontally if the license plate contains two rows it allows to split every row based on vertical projection, then it's used to split every character based on horizontal projection.

2.2.2 Mathematical Morphology

In literature [13] mathematical morphology is used to build an algorithm which enables to segment the characters, this technique starts by eliminating the noise using morphological operations, like pruning and thickening, Thickening technique is used to discover the boundaries between interfered objects, the output of this process is used in pruning technique, pruning technique is used to clean unwanted objects from this image, after finishing these steps of noise reduction, the next step is to determined the vertical projection then based on the minimum values the segmentation process can done, but some characters maybe divided into two or more parts, and maybe two or more characters segments as one character, due to this fact another merging technique is used, based on the prior knowledge of the maximum quantity of the segments and the width of the characters they decide to merge some parts or divide others.

2.2.3 Local or Adaptive Threshold with Connected Component Analysis

In literature [15] This technique is used to segment the image and it's starts by converting the image into binary image based on global or local threshold value, global threshold value means one threshold value used in the binarization of the whole image by converting the values upper than this value into white, and convert all values lower than this value into black, one of these algorithms is described in the next chapter within this thesis. Local threshold value means the threshold value for each region within the image calculated based on the some parameters which are taken from that region, this type of algorithm is generally complicated more than the previous one but they are used widely, especially with images with low brightness in some regions and more brightness in other regions. Mainly there are two types of local threshold binarization algorithm the first one works by dividing the image into a set of regions with specific size and then calculate the threshold for every single region; the second local threshold binarization algorithm calculates the threshold for every single pixel not for regions. There are some local-threshold algorithms described in the following chapter. After applying local or adaptive threshold to binarization the image CCA is used to label every character, after that there are some techniques are used to take decision about every labeled character based on the character size and other parameters, very small characters maybe eliminated because they are not recognizable, and very large characters eliminated too, because the distance between the camera and the car makes the biggest range size of the characters known, then applying directional projection to segment every character.

2.3 LICENSE PLATE RECOGNITION

The Last step of License plate recognition systems is to recognize the characters, there are so many algorithms are used in recognition stage such as Hidden Markov Model (HMM), Artificial Neural Network (ANN), Support Victor machine (SVM) [18, 8, 11, 19, 21, 23], and template or pattern matching technique [16, 17] all of those techniques and more are used in recognizing the segmented characters.

2.3.1 Neural Network

In literature [11, 19, 21, 23] Neural networks are used to recognize the segmented characters and digits, this type of classification starts by training phase, the training dataset samples quantity and quality are very important to enable a good output, because the training data is used to learn how to classify the output, another important factor is the number of hidden layers and the number of neural on the every layer. The other important factor is the activation function and this function should be selected based on trial and error technique to achieve good results, all of these parameters are affecting the output a lot.

2.3.2 Support Vector Machine

In literature [8] support vector machine are used to recognize the characters of License plate, this Algorithm is categorized as supervised learning algorithm. Because it's analyses the data and defines the pattern of it, this algorithm needs to learn the pattern of the data then classify the segmented characters and digits.

2.3.3 Template Matching

In case the font type and size is known, and no rotation within the image. It's possible to use template matching algorithms to recognize the characters, in literature [17] it's used in license plate recognition. The idea behind this technique is to search within the image to find parts within the image matching some predefined templates. For every character and digit it must create a template then search the whole image and try to find the most matching objects, based on mean-squared-error classify the characters to the best matching template with the lowest mean-squared-error, if the size of the segmented characters is not the same as the templates, the segmented characters must be resized to be matched to the size of the templates, the resizing process can solve the problem of the size differential between the segmented images and the templates but there is no way to solve the different font type problem, due to this fact, for every different font type specific templates must be created, or if the country uses just only one font type for all license plates that enables this algorithm to work better with one type of templates.

3. BACKGROUND OF SUPPORTING ALGORITHMD AND TECHNIQUES

There are some algorithms which are used in this implementation such as image binarization, edge detection, smoothing filter, and OCR algorithms, in this chapter a brief description of these algorithms is explained, mainly there are three types of algorithms are used as a supporting for the method this algorithms is binarization, edge detection, and projection.

3.1 EDGE DETECTION

This technique is used in many computer vision applications and image processing applications, the main target of this technique is to detect the objects on the images based on the sharp brightness changes within the images, this brightness change happens when there is a object or some part of the same object with different colors, and the output of the algorithm must give the outline of any object within that image, defining the boundaries of the object, and the output of this algorithm is always a binary image (black and white) it shows the outline in black or white, there are many existing algorithms of edge detection such as canny edge detection, Roberts cross, Prewitt operator, Sobel operator and there are more.

3.1.1 Roberts Cross

This algorithm is used in many applications in image processing and computer vision field to detection the edges within the image. And it's from one of the oldest edge detector algorithms and it was proposed at first by Lawrence Roberts in 1963. [1] and this algorithms works as a differential operator, the main idea of Roberts cross operator is to approximate the gradient of an image through discrete variance which is done by calculating the summation of the squares of the variance between diagonally neighbor pixels.

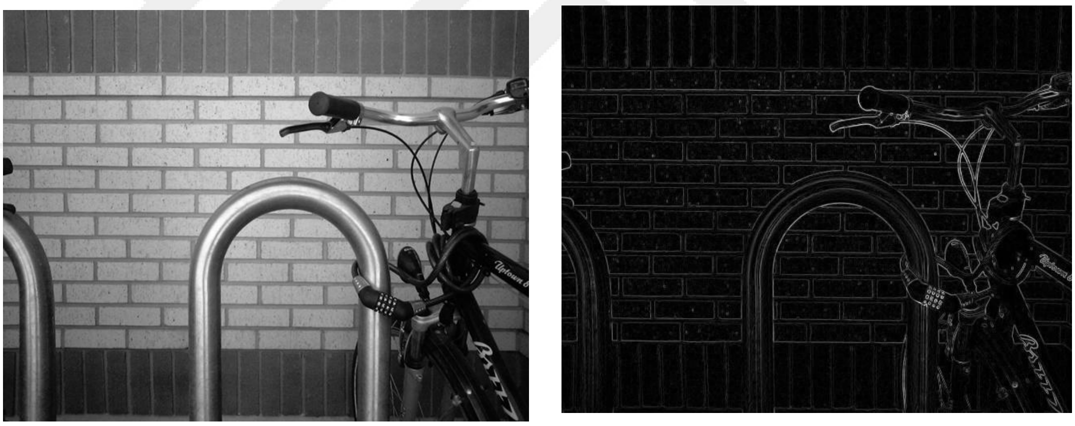
The operator is performed by applying a pair of 2*2 convolution kernels, one of them make the computing vertically and the other one is horizontally and those kernels are shown in equation 3.1

$$R_x = \begin{matrix} 1 & 0 \\ 0 & -1 \end{matrix} \qquad R_y = \begin{matrix} 0 & 1 \\ -1 & 0 \end{matrix} \tag{3.1}$$

This calculation of Rx and Ry was followed by the calculation of the gradient magnitude by equation 3.2

$$|R| = \sqrt{R_x^2 + R_y^2} \tag{3.2}$$

Figure 3.1 show the output of Roberts cross algorithm



Orginal image | Edge detection using Roberts cross

3.1.2 Prewitt Operator

This algorithm works based on the intensity change, by calculating the gradient of the image brightness for each pixel, based on the direction of the largest possible rise from bright to murky and the rate of change in that direction . The result of that shows how "sharp" or "soft" the image variation at that point and it will show how likely it is that part of the image represents an edge, and it shows the edge orientation. And this operation works by applying the kernel filters as shown in Equation 3.3 to detect the edges vertically and horizontally.

$$P_x = \begin{matrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{matrix}$$

$$P_y = \begin{matrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{matrix} \tag{3.3}$$

Figure 3.2 show the output of Prewitt operator algorithm

Orginal image   Edge detection using Prewitt operator

3.1.3 Sobel Operator

The Sobel operation, Sobel technique, or sometimes referred to as Sobel-filter, it's is used in some image processing applications for edge detection where it creates an image assurance edges. This filter uses 3*3 kernels and those kernels are shown in equation 3.4

$$s_x = \begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix}$$

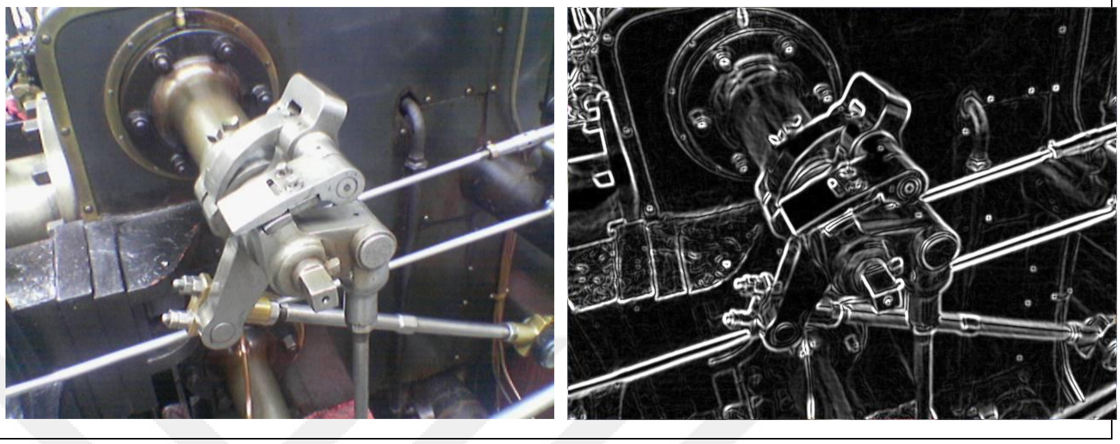
$$s_y = \begin{matrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{matrix} \tag{3.4}$$

Then the other equation is used to calculate the value of each pixel and this equation is shown in 3.5

$$|s| = \sqrt{s_x^2 + s_y^2} \tag{3.5}$$

The example of the output of this operation is shown in figure 3.3

Figure 3.3: Show the output of Sobel operator



3.2 BINARIZATION

Image binarization is a very important technique used in this thesis , the ultimate goal of this algorithm is to simplify the image complexity from about 16,777,216 Possible colours on a colored image on every pixel, or 256 possible colours on every pixel on grayscale images to convert them into (Black and white) with just two possible colours on every pixel, the most popular and easiest way to achieve that is by converting the image by choosing a global threshold value, and to classify all pixels with this value, any number more than this number will convert to White (255) and every number less than this number will convert to Black (0), but because the amount of light in every environment is not the same, that makes some images brighter than others and that will make the choosing of the threshold value quiet difficult , threshold values for every image has to be different due to this fact to achieve a good results . There are some algorithms that works using local threshold values, like Sauvola Algorithm, and Otsu Algorithm; those algorithms use a different threshold value for every region on the image, that makes them work very well even if the brightness is low or high, the output of those algorithms in some cases looks like the output of edge detection algorithms, this is due to the change of the threshold value.

3.2.1 Sauvola Image Binarization Algorithm

This algorithm operates by using the calculation of the threshold value for each pixel, that value is dependent on local statistics like range, variance, and other local data, it's used to obtain a different threshold value more suitable for every region on the image, the threshold T(x,y) is defined as a function of the current pixel (x,y) , by using standard deviation on the windows with a size of [A x A]. The threshold value at pixel (x,y) calculated by the equation

$$T(x,y) \quad = m(x,y) + \left(1 + k\left[\frac{\sigma(x,y)}{R} - 1\right]\right) \tag{3.6}$$

Where m(x, y) and σ(x, y) are the local sample mean and standard deviation respectively, this algorithm defines the value of K=0.5, R=128, and b = 10, the use of standard deviation makes the binarization process perform better and adaptively, that makes the threshold value low if that region of the image has low brightness, and it makes it higher if the brightness is higher, to make the binary image represented as

$$\text{BinaryImage}(x, y) = \begin{cases} 1\,, if\ I(x,y) \geq T(x,y) \\ 0\,, if\ I(x,y) \leq T(x,y) \end{cases} \tag{3.7}$$

3.2.2 Otsu Image Binarization Algorithm

This Algorithm is used for the selected optimal Threshold value for every given image by maximizing discriminate criterion, like the disunity of the resultant classes in grey levels, it assumes that the grey levels of the given image ranges will be confined in a specific range {0, 1, 3, 10,., N-1}, N is the total number of grey levels on the given image, then it commences a search for an optimal value of the threshold within that range, to achieve its maximum. It's defined as

$$J(T) \quad = \frac{P1(T)P2(T)[m1(T) - m2(T)]}{\sigma^2} \tag{3.8}$$

Sauvola algorithm is widely used for the binarization of the images of documents and it's doesn't perform as good as Otsu's in the binarization of license plate images,

Images that consist of black background, and of varying brightness levels like in License plate images.

3.2.3 Median Based Method For Image Binarization

These techniques start by defining the size of the window size n by n, then by calculating the median value for every window its determined the threshold value for that window, then its moves the windows over the image starting from top left hand corner until right hand button, and repeating the same process after every movement.

3.2.4 Gaussian Based Method for Image Binarization

Gaussian binarization technique works using the same technique as Median binarization Technique but the deferent it's calculates the threshold value based on the summation of the window size not based on the median values, that makes the output of this technique a little bit different from previous one.

3.3 Vertical and Horizontal Projection

Vertical and Horizontal projection is applied to the binary image using equations 3.9 and 3.10 one after the other, this helps to locate the plate location within the image, and it's used in plate segmentation phase.

$$fv(i) = \sum_{j=1}^{w} b(i, j) \quad (3.9)$$

$$fh(j) = \sum_{j=1}^{w} b(i, j) \quad (3.10)$$

Several algorithms and techniques are described in this chapter like edge detection algorithm, image binarization, and projection. Horizontal and vertical edge detection algorithms are used in this thesis to detect the objects on the images. Image Binarization techniques are used to simplify the image complexity, plate locating process, and segmentation of the characters to classify them. Vertical and Horizontal Projection are used to locate the plate on the input image.

3.4 NOISE REDUCTION

There are many algorithms for noise reduction from the image; one of the most popular ones is Median filtering, this algorithm is a nonlinear signal processing technique it works based on statistics. The idea behind it is to replace the noisy value of the input image with median value of the closest pixels based on the calculation of median on predefined mask size of pixels. All of the pixels of the mask are used to calculate the median, and then it used to replace the pixel value with this median value. The output of median filter effects are based on two things: the selection of mask size, and the noise distribution within the image, when the size of the mask is selected with a large size it's eliminating too much noise but at the same time it's eliminating to many details from the image, and when the distance between the noisy pixels is much closer to each other the output become worse.

3.5 APPLYING COUNTRIES LICENSE PLATE FORMAT CHECK

For every Country there are special styles of license plate, for example some countries design their license plate to start with numbers of two digits followed by two characters then two or more numbers, other Countries style maybe completely different, due to this fact this style can be used to eliminate any wrong results and to enhance the output of the license plate system.

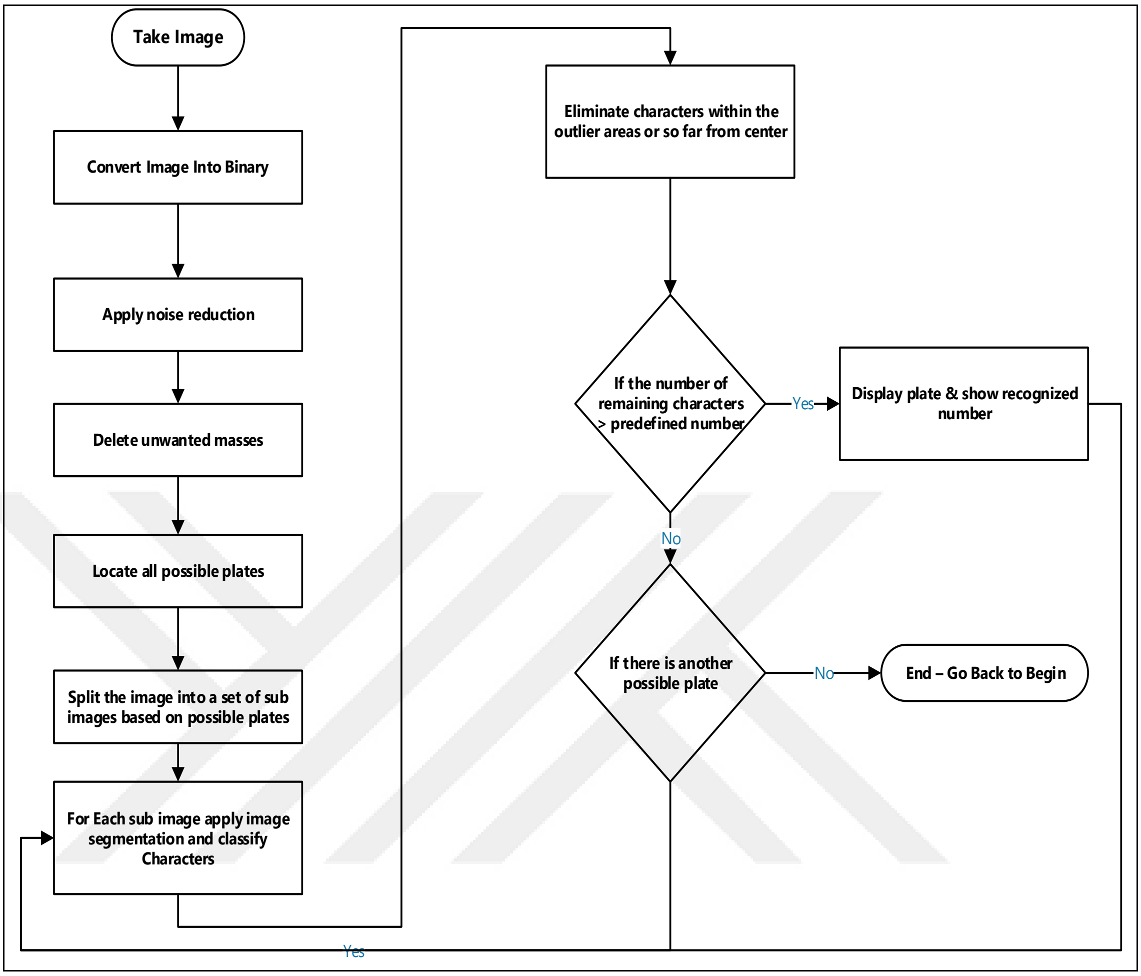
4. METHOD

There are many License plate recognition systems that have been developed over a long period of time, every one of them has its advantages and disadvantages, they perform well in specific conditions but fail to perform as they are suppose to in other conditions, This method is mixing the main idea of two algorithms to perform more efficiently, using the main idea from one of the algorithms works based on texture and the other algorithm works based on colour, There are several other supporting techniques which are also introduced in this chapter, The main job of this thesis is to locate the license plate location, because after locating the plate location there are many algorithms which are very efficient in detecting the characters.

This method mainly consist of these steps, First it starts by converting the image into binary image, then applying noise reduction to eliminate the noise, then delete all unwanted object from the image, then applying projection technique to locate the plate location, after that crop the image and extract all possible plates into new sub images to start segmentation and classifying steps, every sub image not contains of some predefined number of edges will be eliminated after applying edge counting technique, because the license plate must contain at least some characters and digits. The classification stage is followed by eliminating incorrect classified characters based on elimination strategy it is applied to eliminate incorrect characters based on the location of the character and the character size and this strategy is described in this chapter.

After all of these steps the output will be the license plate characters and number with lowest error rate. The next flowchart shows the main steps of this method.

Figure 4.1 shows the method flowchart



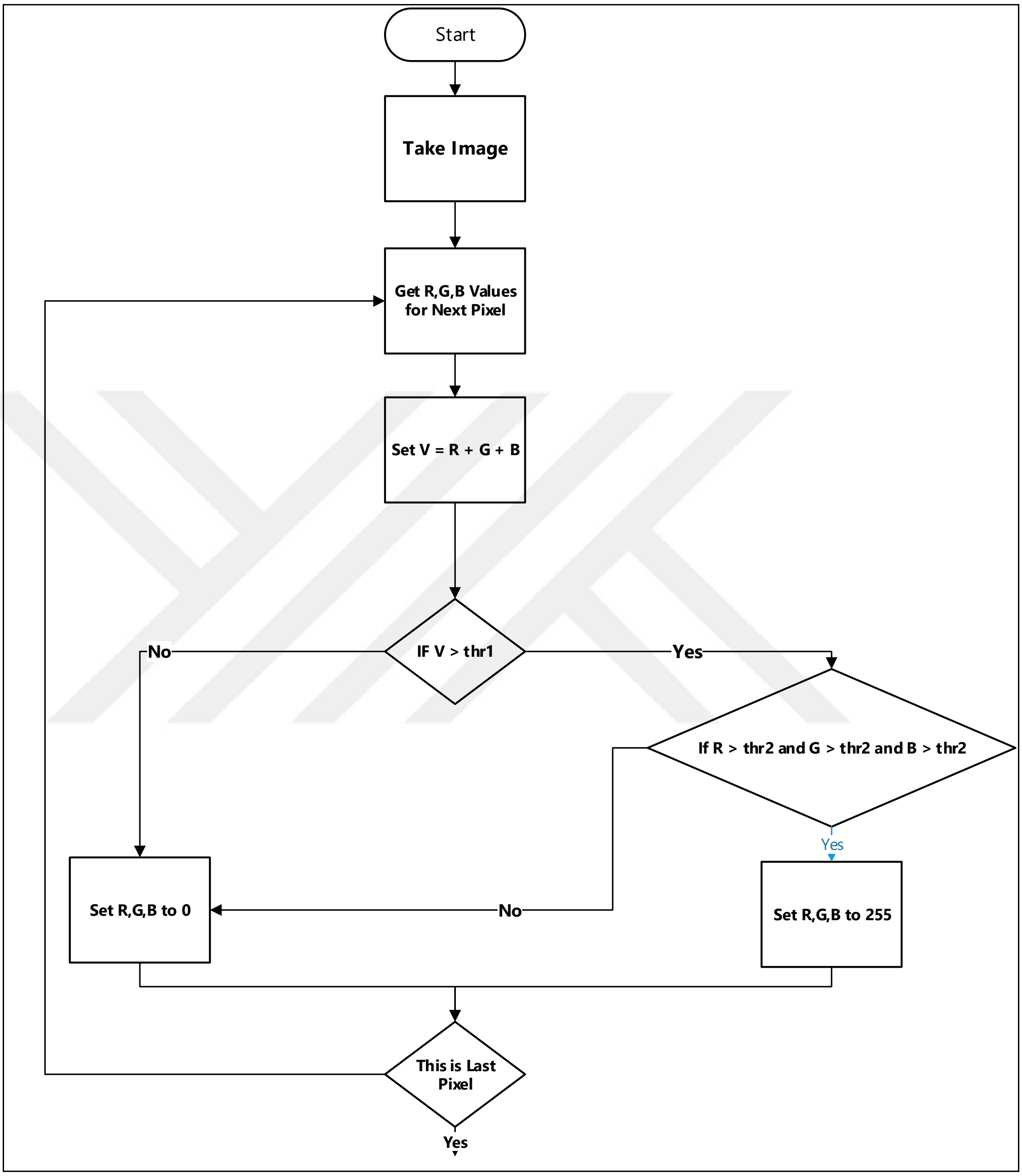
4.1 DETECTION OF THE LICENSE PLATE

The input image is coloured, if the input image size is bigger that 600 pixel in width its automatically resized to be 500 width and 320 pixels on height, then the first operation is to convert the image into a binary image, as mentioned before the selection of the threshold value is very complicated, but to archive this goal some unique technique is used, due to the fact that the input image was not converted into a gray-scale image, the image still contains the original values for Red, Green and Blue on every pixel, this technique enables classifying the color as black if the summation of R, G and B be less than threshold value 1, this threshold value calculated based on the average of the image brightness , and the value for any one of R, G and B must be less than threshold value 2, the value of threshold value 1 it can be 150 up to 250, but in this case 200 works fine with most of the images, and the value of the threshold value 2 can be between 40 and 100 but the selected threshold value 2 in this case is 70, these values have been selected by trying different values many times over, to achieve positive results with the greatest number of images, these values have been found to give the best results (Figure 4.1 shows the result of the binarization technique). In a completely different environment these values may need some slight positive or negative adjustment due to prevailing conditions, those values look like global threshold value was used, but actually due to technique using them, they work somehow like adaptive threshold based on the condition of comparing the summation of the RGB values with threshold value 1 then comparing every one of them by threshold value 2.

Figure 4.2 shows the result of the binarization technique

The next flowchart shows the steps of binarization technique.

Figure 4.3 shows the binarization technique flowchart

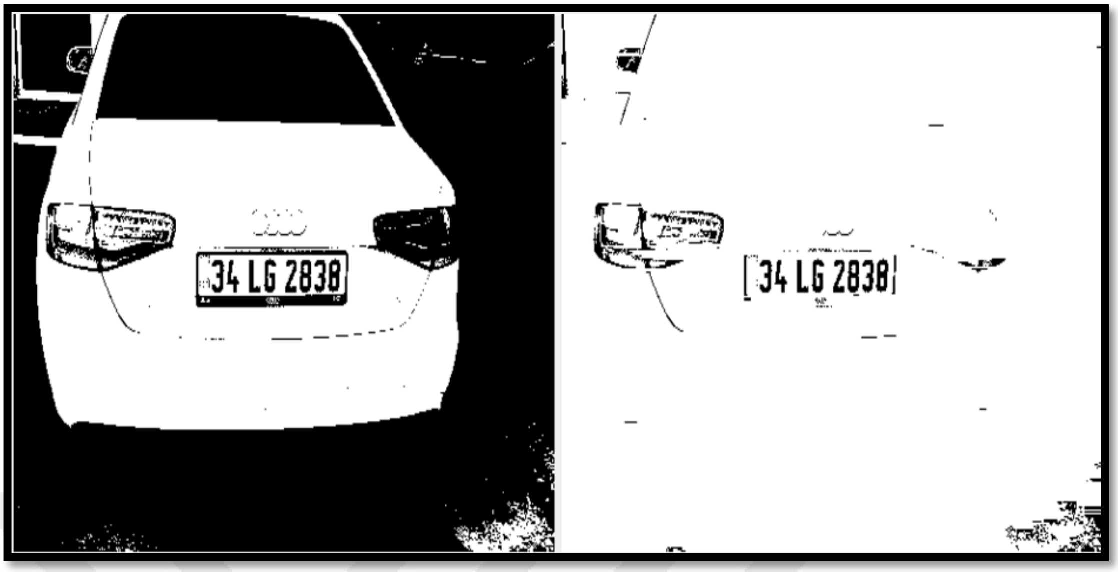


Within the noise reduction algorithm Noise is eliminated by way of creating a window of 3x3 pixels, this window then commences from the upper left corner of the image, and then moves across the image from left to right, from top to bottom, whilst performing this operation should any black pixel be found surrounded by white pixels the black pixel will be converted into white, and the same is said to happen when a white pixel is found surrounded by black pixels. This enables the next step to be completed with better results. (Figure 4.4 shows the result of noise reduction technique)

Figure 4.4 shows the result of noise reduction technique

Deleting large black areas, this process is performed in a similar way to the noise reduction with some major differences, unlike noise reduction which uses a window of 3x3, this process searches each horizontal row of pixels individually as it is searching each row the number of black pixels is calculated upon reaching a predetermined minimum number of black pixels and or a predetermined maximum number of black pixels that segment of the row can be eliminated, the predetermined minimum or maximum is derived from the size of a character on a plate. (Figure 4.5 shows the result of deleting large black areas technique)

Figure 4.5 shows the result of Deleting large black areas technique



Commencing the search to locate areas containing a number of pixels which could be part of a plate, this process is performed in two stages firstly by searching each vertical row of pixels and each horizontal column of pixels individually, as each row of vertical pixels is searched should a predetermined minimum number of pixels not be attained, this row will not be contained within the statistics and it will be deleted from the image as shown in Figure 4.6, and the same can be said for each and every horizontal column. Secondly, in order to be able to divide the image into sub images based on the concentration of the black pixels from statistics taken from the first stage. Figure 4.7 shows the cropping of the image into sub image. This process may not succeed to eliminate some black masses even if they are not characters, because their size is close to characters size, this will produce some noise on some parts of the images they may look like plate for algorithm in this step, because of that there are other steps are implemented like eliminating the edges with very small area or too far from the center of the license plate, and edge counting to eliminate the sub images if they don't contain some predefined number.

Figure 4.6 shows the result of deleting some unwanted data from the image.

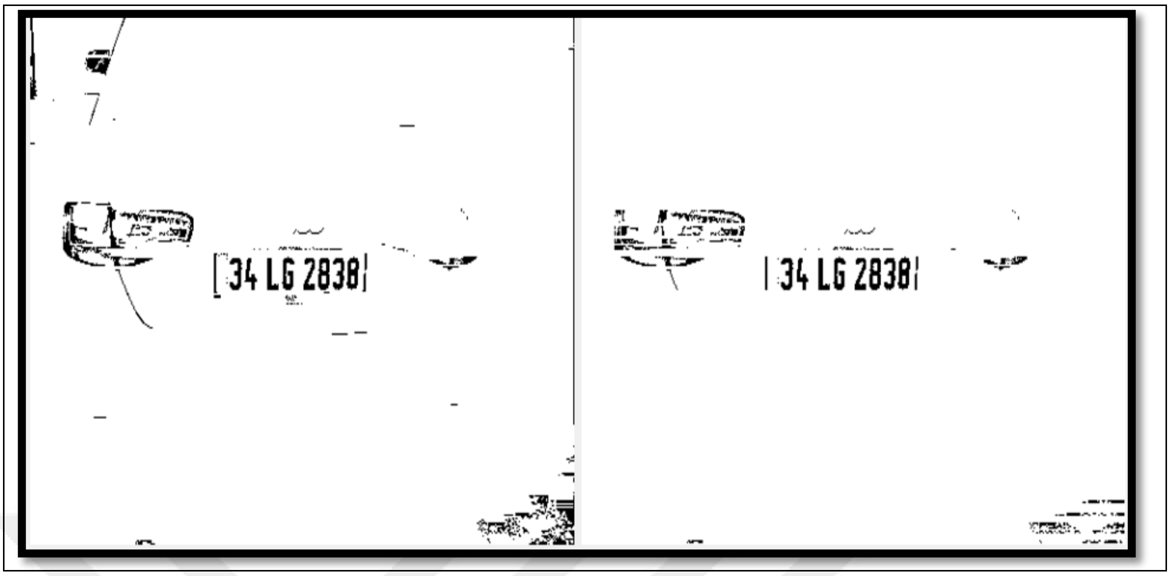
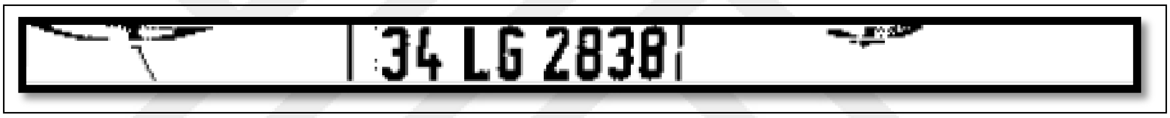


Figure 4.7: shows the cropped image.



In order to be able to discount some of the sub images edge counting technique is applied to the sub images, and should any sub image contain less than a predefined minimum number of objects that said sub image or images can be discounted.

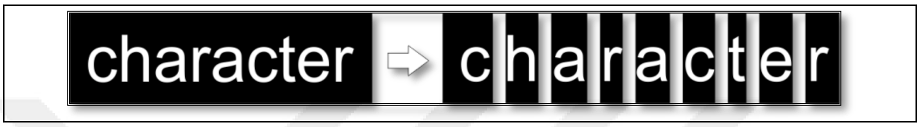
With each sub image that has not been discounted, each image is then searched one more time to locate the exact position of the plate, this is performed by searching each and every column individually, during this process a predetermined number of black pixels must be discovered in each column, once an area has been located where the concentration of columns containing this predetermined of black pixels that can be said to be the area of where the plate can be found. (As it's shown on the fig 4.8), then when the process of locating of the license plate is complete, the Segmentation stage can start.

Figure 4.8: shows the detected plate

4.2 SEGMENTATION

The aim of segmentation process is to split every character of digit from others to allow classification step to start, there are many techniques can be used to perform this task, must popular one is the projection, by applying vertical and horizontal projection, horizontal projection is used to split the image into rows, and vertical projection is used to split the character as shown in figure 4.9

Figure 4.9 show the result of vertical projection



4.3 CLASSIFICATION

The classification commences by taking the segmented character as binary image of N x N size, and tries to find the most similar character and classify it as that character, the classifier techniques work by taking an image and then extracting number of attributes from it. Then create an array which contains these attributes as a vector. This vector has a dimension defined by the number of the extracted attributes from the image. By comparing the output of this process for every single one of the segmented characters and the pre labeled characters and by applying some nearest neighbor technique the classifier gives the characters a class label as a character or digit.

4.4 LEIMINATING INCORRECT CLASSIFIED CHARACTETRS AND DIGTIS

After applying any segmentation technique there is some noise will be classified as characters or digits In spite of this they are not characters or digits they are just noise and this will affect the output of the system due to that after applying the segmentation, mathematical technique to detect outlier size of characters is applied, this technique is simple and very efficient, the idea behind it, is to arrange the numbers starting from smallest number until biggest number then split them into two parts then take the middle value of the first part as Q1 and take the middle value of the second part as Q2, then Calculate X and Y as shown in equations 4.1 and 4.2 , then if the value is bigger than X or less than Y its labeled as outlier value and its eliminated from the output. This technique is used to eliminate the characters with outlier size or outlier location if it's far from center of the image.

$$X = Q2 + 1.5 * (Q2 - Q1) \quad (4.1)$$
$$Y = Q1 - 1.5 * (Q2 - Q1) \quad (4.2)$$

The method discussed in this chapter, consists of Image binarization technique as the first step, then noise reduction is discussed To eliminate detectable noise, to allow for the large object deletion stage to perform as well as possible, after deleting the unwanted objects from the image the algorithm starts searching vertically and horizontally to locate parts that consist of as many black pixels, then split them into set of sub images, to discount the number of sub images Edge counting technique is employed to eliminate any image that contains a number of objects less than a predefined number, then the projection technique is used to crop the image by performing voting of black pixels to locate the exact plate location within the sub image, that allows OCR algorithm to perform better.

5. EXPERIMENTAL RESULTS

The new proposed license plate recognition technique is provided and described in chapter 4, to detect the license plate location within the input image. OCR algorithm is then applied to detect the plate characters and digits; this algorithm is implemented using Visual Basic.Net as programming language and Microsoft "Visual Studio 2015 Community edition" as a development environment. Nearly all of this implementation was written from scratch, there are no other libraries being used in this implementation for detecting the license plate location, just for character recognition Tesseract Library is used, Tesseract is free and open source, it was developed initially by HP then they made it open source which the code to be available to everyone under Apache License. This algorithm has been tested on **231** coloured images as input with different brightness situations.

This method has been tested to locate the license plate location and its success in locating the correct license plate location on **89.18** percent that mean its success in **206** images is over **231** images.

Most of the cases that the method failed to detect the location of the license plate within the image was because the car distance far from the camera location that made the license plate text undiscoverable because it's too small, the other reason is blur image. And the very thin font of the text on the license plate, and when the license plate is dirty or the colour of the digits and characters was faded to be close to white.

5.1 IMAGES DATABASE

Throughout the stages of testing the algorithm, images database ware was in use, it's downloaded from the internet and it's available for free to download on this link: http://www.zemris.fer.hr/projects/LicensePlates/english/baza_slika.zip all of these pictures were taken by digital camera model of this camera is OLYMPUS CAMEDIA C-2040-ZOOM.

Figure 5.1 shows sample images of used database

5.2 METHOD OUTPUT

As mentioned before the input image is coloured and the first step is converting the image into binary image then applying noise reduction and delete unwanted masses of pixels this steps output is shown in figure 5.2

Figure 5.2: Shows the output of first steps of the method

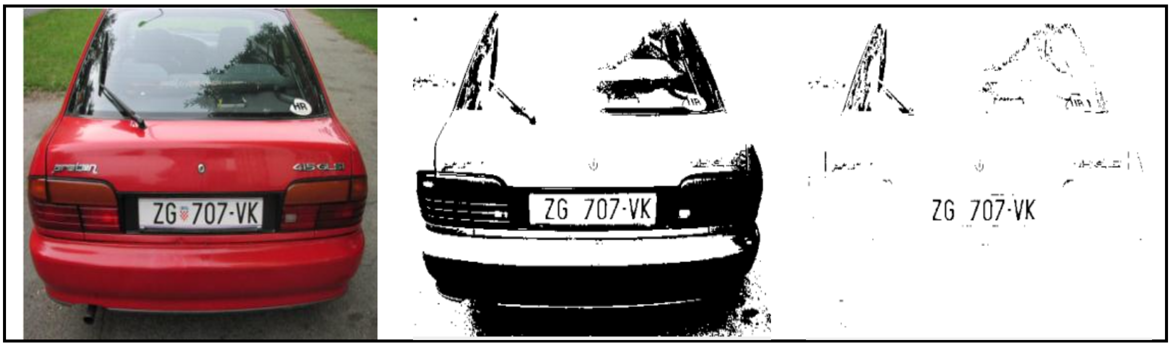
The next step is applying the projection operation to detect the possible location of the license plate, this operation are used to crop the image into sub image as shown in figure 5.3.

Figure 5.3: Show the cropped image after applying projection operation

This cropped image is used to classify the characters after applying projection technique to split the characters, and then the elimination operation is applied to eliminate any outlier characters, this elimination process is described in 4.4

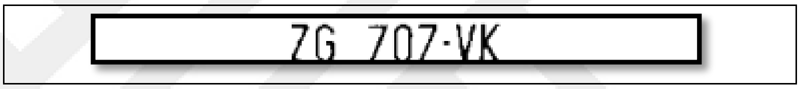
The next figure 5.4 shows other example of the previous steps, and figure 5.5 shows the output after applying the projection technique as a cropped image contains the exact license plate without any other noise in this case.

Figure 5.4: Shows the output of the first steps of method



The next figure 5.5 shows the output after applying the projection technique to the previous image and the output contains the exact license plate after applying noise reduction technique

Figure 5.5: Shows the exact license plate after applying noise reduction.

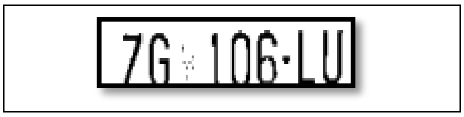


Other Example for the output of the method are shown in Figure 5.6

Figure 5.6: Shows the output of the first steps of method

The output after applying the projection and noise reduction techniques to previous images is shown in figure 5.7 and it shows the exact license plate.

Figure 5.7: Show the exact license plate after applying Noise reduction.

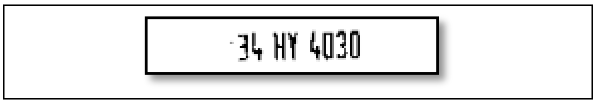


The method was tested in low light condition images and it provides a good result as well, the output of applying the method in image with low brightness is shown in figures 5.8 and 5.9

Figure 5.8: Shows the output in low light conditions

Because of the low brightness the noise of unwanted masses become less that allows the projection technique to give better output as well, the output of projection is shown in figure 5.9

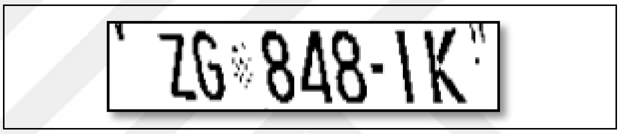
Figure 5.9: Show the output of projection in low light case



The method was tested on some images that were taken from different angles and gives a good output in some cases as shown in figures 5.10 and 5.11 , when the input image is skewed.

Figure 5.10: Show the output of method for skewed image

Figure 5.11: Show the output projection in skewed image



5.3 DISCUSS THE FAILURE TO IDENTIFY THE LOCATION

In some cases the algorithm failure to locate the license plate within the image, the most popular case was when the car was far away from the camera, when the car is far from the camera the text on license plate becomes unclear very small and difficult to reads, the output of the binarization process is shown in figure 5.12, as mentioned before in chapter 4 the next step after binarization is deleting unwanted masses from the image, this process will delete the noise but when the car is far away it will delete some characters as well because they are very small and undetectable, as shown in figure 5.13

Figure 5.12: The binarization of the image contains a car far from the camera

This issue is not a big problem or unsolvable because the camera must be configured to catch the image from specific range and the method will succeed in detecting the license plate when the car comes within the detection area.

Figure 5.13: Show the characters was deleted because they are very small

When the font is thin the size of characters become undiscoverable, the output of this case is shown in figure 5.14

Figure 5.14: Show the characters was deleted because they are very thin

The second failure reason of failure is blur image, most of the binarization techniques fail to binaries the blur image, two binarization methods are applied for blur image as shown in figures 5.15 and 5.16 the first binarization technique is described in chapter 4, and the output of this method shown in figure 5.15, and the second binarization method is adaptive technique using Gaussian binarization algorithm which is shown in figure 5.16, the characters can't be detected using both of these techniques.

Figure 5.15: Shows the method binarization for blur image

Within a very blur image the RGB values of any pixels on the same region become very close to each other, that makes Gaussian binarization technique fail and gives output like that was shown in the figure 5.16.

Figure 5.16: Shows the Gaussian binarization for blur image

5.4 RUNNING TIME

The running time with current configuration takes from about 740 milliseconds up to 1800 milliseconds based on the size of the image, because if the input image size is bigger than 600 by 600 pixel it's resized into a smaller size, and this process takes some time, this issue it can be solved by setting the camera to take the images of the cars with a reduced size to avoid the resizing process and decreasing the running time. Due to the fact that all of the code of locating the plate was written using vb.net language without using any supporting library and without focusing too much on running time that makes the running time longer than it must be. The performance can be improved by applying some programming enhancement, such as LockBits Method, this method takes approximate 18% of the running time comparing to working with image as two dimensional arrays. LockBits Method is used only in binarization phase, if it’s applied to the rest parts of this implementation it will make the running time less.

6. CONCLUSTION AND FUTURE WORK SUGGESTION

Within this thesis, a set of three algorithms used for the detection, recognition of license plate numbers written in the English alphabet, using three standard stages of processing, with each stage each algorithm and technique used for the implementation for binarization, detection and recognition are all new for this thesis. During the first operation the object is to change the input image from colour to binary image, not using gray-scale, to attain this new technique is used which is able to distinguish black colour very effectively. Also within this thesis a proposed technique of taking the main ideas of two different algorithms and applying them together, one based on texture and the other based on colour, several other supplementary techniques which help with the main idea, have also been introduced. The primary topic is how to locate the license plate, after that using OCR technique to recognize the characters on the plate.

With the Proposed algorithm some work is needed to improve the performance especially with noise reduction, before the algorithm commences the locating phase of the license plate, because during the deleting of unwanted black masses from the image the process doesn't work as well as it could, noise makes some parts of the image that do not contain the License Plate appear like they contain it, due to the number of objects in the image sometimes the compatibly described by the predefined rules, those objects should be deleted during the noise reduction process.

There are some other improvements that can made to the proposed algorithm to enable the algorithm to operate more efficiently, the threshold value selection within this algorithm is fixed, should the threshold value be variable for the binarization of the image, there is a strong possibility it may improve to allow the algorithm to work better if the image brightness is very High or extremely low, because this algorithm sometimes in these light conditions does not perform as well as expected.

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