
# ÇANKAYA UNIVERSITY
# FACULTY OF ENGINEERING
# COMPUTER ENGINEERING DEPARTMENT

# Project Report
**Version 1**

# CENG 407
Innovative System Design and Development I

# *<202121>*
# *<LICENCE PLATE RECOGNITION SYSTEM>*

***Mehmet Furkan Turan***

*201726072*

***Arda Kayış***

*201711043*

***Doğukan Tutak***

*201711065*

***Burak Çetin***

*201711015*

***Muhammed Emin Atalık***

*201711003*

**Advisor:** ***Prof. Dr. Ahmet Coşar***

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## Abstract

License Plate Recognition System offers a solution that has been needed in recent years and necessary steps can be taken for the operation of an efficient smart transportation network. Due to the rapid increase in vehicles, it has become a necessity for traffic control management. The main purpose of the License Plate Recognition System is for traffic monitoring and security purposes. License plate recognition uses image processing techniques or OCR techniques and edge detection technology to detect characters on license plates. The model consists of three modules: vehicle detection module, license plate segmentation module and recognition module. License plate recognition system is used in various fields such as police forces, military areas, traffic control and security. It is used in areas such as keeping city entrances and exits under control with the License Plate Recognition System, city security, and the establishment of smart traffic systems. In the License Plate Recognition System project, we aim to detect and read the license plates of vehicles by using image processing and deep learning methods.

**Key words:**

Image Processing, Deep Learning, Licence Plate, Optical Character Recognition (OCR).

## Özet:

Plaka Tanıma Sistemi, verimli bir akıllı ulaşım ağının işletilmesi için son yıllarda ihtiyaç duyulan ve gerekli adımların atılabileceği bir çözüm sunmaktadır. Araçlardaki hızlı artış nedeniyle trafik kontrol yönetimi için bir zorunluluk haline gelmiştir. Plaka Tanıma Sisteminin temel amacı trafik izleme ve güvenlik amaçlıdır. Plaka tanıma, plakalardaki karakterleri algılamak için görüntü işleme tekniklerini veya OCR tekniklerini ve kenar algılama teknolojisini kullanır. Model, araç algılama modülü, plaka segmentasyon modülü ve tanıma modülü olmak üzere üç modülden oluşmaktadır. Plaka tanıma sistemi, polis kuvvetleri, askeri alanlar, trafik kontrolü ve güvenlik gibi çeşitli alanlarda kullanılmaktadır. Plaka Tanıma Sistemi ile şehir giriş çıkışlarının kontrol altında tutulması, şehir güvenliği, akıllı trafik sistemlerinin kurulması gibi alanlarda kullanılmaktadır. Biz de Plaka Tanıma Sistemi projesinde görüntü işleme ve derin öğrenme yöntemlerini kullanarak araçların plakalarının tespitinin yapılması ve plakaların okunmasını sağlamayı amaçlıyoruz.

**Anahtar Kelimeler:**

Görüntü İşleme, Derin Öğrenme, Plaka,  Optik Karakter Tanıma (OKT).

# 1. Introduction

License Plate Identification System is a method that is frequently used in the identification of vehicles, in parking lots, in urban areas and in places where security is important such as road cameras. A license plate identification system is used to uniquely identify a vehicle. License Plate Recognition system plays an important role in many applications such as electronic payment system (toll payment and parking fee payment), stolen car finding, traffic surveillance. For example, in parking, plates are used to calculate the parking time. When a vehicle enters the door, the license plate is automatically recognized and recorded. When leaving, the license plate is re-recognized and compared to the registered license plates. The time difference is used to calculate the parking fee. License Plate Recognition System is a useful and versatile system as it is automatic.

Various researchers have suggested various techniques for each step, and an individual technique has its positives and negatives. The license plate recognition method includes three main steps. This is the zone of removal of interest, removal of license plate numbers and character recognition. Below is the block diagram for the plate system in Figure 1.

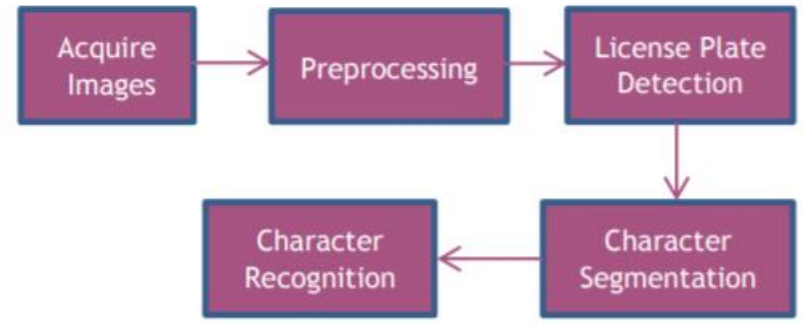



*Figure 1 Block diagram of License Plate Recognition*

License plate recognition is provided through the ANPR instrument program. Images captured using cameras show the printout of the license plate. The basic job of ANPR is to read and open the license plate. ANPR is also called ALPR (Automatic License Plate Recognition). The software of this system creates a record of all license plates which it interprets with all relevant data such as date, time and GPS location. It uses OCR technology to recognize the characters of number plates. License Plate Recognition is an important process of automated parking. It will be a feature expected by industry demand for higher commercial parking management projects in smart city areas.

It has also been used for security purposes in toll collection systems, traffic control, gas stations and many other exploration opportunities. Intelligent Transportation Systems play a leading role in facilitating smart cities due to its many applications such as highway surveillance, city logistics and traffic law enforcement, and more.

With the License Plate Recognition System, our goal is to determine the license plates of vehicles using image processing methods such as character and segmentation. We aim to determine the characteristics such as the type, type, size and color of the vehicles by using the determined plates. In addition, we aim to use the deep learning method using different vehicle images and datasets of the TensorFlow library in order to be accurate and realistic when defining the license plates in the License Plate Identification System.

## 1.1 Problem Statement

In the License Plate Recognition System, our aim is to recognize and determine the license plates by using the deep learning method with the camera, with methods that will increase the accuracy of the result. Thanks to the deep learning method, it is aimed to make license plate recognition faster by shortening the license plate recognition time.

Licence Plate Recognition System is exploited in various applications that involve vehicle identification, such as controlling limited access to restricted areas, automating parking systems and payments, monitoring toll fee payments, controlling state border pass and security measures in countries, traffic management and law enforcement.

Since it is aimed to use deep learning, image optimization, camera adjustment and image processing method, data processing speeds and related delay times can be seen as potential problems. Since license plate recognition will be made with different vehicle images, the teaching time may vary. There can also be issues with the camera, such as lags.

## 1.2 Background or Related Work

Several studies and work has been carried out earlier. In a deep learning model is created to recognize the number plate using the dataset made by them. They used TensorFlow framework with the Keras deep learning library. Since the images were taken from the real time background, they carried out several image processing techniques. After these preparations, the CNN model is trained using the images. In an automatic number plate recognition system using

machine learning approach is developed. They got the input from an Infrared camera followed by contrast enhancement and noise reduction as pre-processing steps.

Then they localized the number plate in the image by finding out the Region of Interest (RoI). After that, contour tracing is applied to get the salient features of the image. Then Edge detection is done to find out the edges of the characters in the number plate. Finally, segmentation is applied to separate the characters. The individual characters are recognized using pattern matching by Artificial Neural Networks (ANN). The basic steps in ANPR include vehicle Image capture, number plate detection, Character segmentation and Character recognition.

For number plate detection the factors such as plate size, plate location, plate background and screw must be considered. It is followed by character recognition which is usually done by Artificial Neural Networks, template matching or Optical Character Recognition (OCR) techniques. [1]

## 1.3 Solution Statement

With more specific algorithms and methods, the license plate recognition system can be made in accordance with speed and time. Thus, problems such as camera optimization can be solved.

## 1.4 Contribution

We aim to make the license plate recognition system that we will build in a similar way to the previous one, but by improving it. While doing the project, we aim to do it by considering features such as deep learning and performance.

## 2. Literature Search

While working on your project, you have compiled a database of literature that supports your work. Literature sources can and should include the following:

### 2.1 History of Licence Plate Recognition System

The History of ANPR is considerably longer than most people realise. Because of its prolific use in more recent years for a broad range application such as traffic studies, access control and parking, many people, if asked, would guess at it being an invention belonging to this millennium. The history of ANPR stretches into the last century as it was invented in 1976 in the UK at what was then known as the Police Scientific Development Branch (PSDB) (now titled Home Office Scientific Development Branch) and early systems were developed for use from 1979. [2]

Earlier prototypes were premature with low accuracy readings and only functioned under restrictive laboratory conditions that made real world application nearly impractical. Moderate improvements were made and working models were implemented a few years later in Wokingham, England. This subsequently led to the successful development of commercial contracts and applications for early adopter usage. While still crude, with an accuracy that averaged below 60%, the technology was state of the art during its time.

Several decades later, the technology has greatly evolved and prior limitations incurred from vehicle speed, light fluctuation, angular skew, character segmentation and recognition have been solved with today's algorithm technology. Additionally, prior cost prohibitive fees have made way for more reasonably priced implementations allowing application to thrive in multiple industries. [3]

### 2.2 Previous Works

Several studies and work has been carried out earlier. In [4], a deep learning model is created to recognize the number plate using the dataset made by them. They used TensorFlow framework with the Keras deep learning library. Since the images were taken from the real time background, they carried out several image processing techniques. After these preparations, the CNN model is trained using the images. In [5], an automatic number plate recognition system using machine learning approach is developed.

They got the input from an Infrared camera followed by contrast enhancement and noise reduction as pre-processing steps.

Then they localized the number plate in the image by finding out the Region of Interest (RoI). After that, contour tracing is applied to get the salient features of the image. Then Edge detection is done to find out the edges of the characters in the number plate. Finally, segmentation is applied to separate the characters. The individual characters are recognized using pattern matching by Artificial Neural Networks (ANN). The basic steps in ANPR include vehicle Image capture, number plate detection, Character segmentation and Character recognition.

For number plate detection the factors such as plate size, plate location, plate background and screw must be considered. It is followed by character recognition which is usually done by Artificial Neural Networks, template matching or Optical Character Recognition (OCR) techniques. [6]

## 2.3 Methods of Licence Plate Recognition System

### 2.3.1 Licence Plate Detection

Computer vision and character recognition, algorithms for license plate recognition play an important role in video analysis of the number plate image. Therefore, they form the core modules in any ANPR system. The system for automatic car license plate recognition includes a camera, a frame grabber, a computer, and custom designed software for image processing, analysis and recognition. Vehicle identification has been an active research for over the last few years. A number of researches have been carried out to identify the type of vehicle such as a car, truck, scooter or motorcycle.

In order to detect a license plate, a definition thatcan be understood by a machine is required. Considering its features, the definition for a license plate can be stated as ‘‘a rectangular area of a vehicle with a high density of horizontal and vertical edges’’ [7]. Based on these features, many algorithms have been put forward to solve the license plate detection task and some of them are rooted in traditional computer vision techniques and some in deep learning. Figure 2 shows a classification of the license plate detection techniques that are used in existing methods.

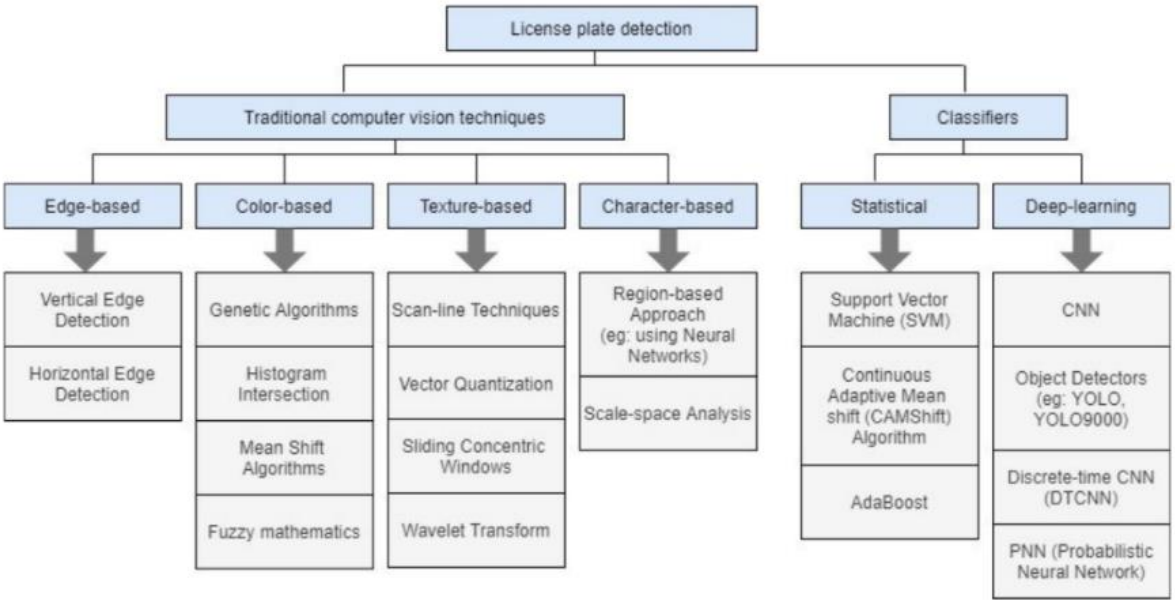



*Figure 2 Classification of Related License Plate Detection Techniques*

### 2.3.1.1 Edge Based Methods

Edge detection is the process of locating edges in an image which is a very important step towards understanding image features. It is believed that edges consist of meaningful features and contains significant information. It significantly reduces the size of the image that will be processed and filters out information that may be regarded as less relevant, preserving and focusing solely on the important structural properties of an image for a business problem.

Edge-based segmentation algorithms work to detect edges in an image, based on various discontinuities in grey level, colour, texture, brightness, saturation, contrast etc. To further enhance the results, supplementary processing steps must follow to concatenate all the edges into edge chains that correspond better with borders in the image. Edge detection algorithms fall primarily into two categories. Gradient based methods and Grey Histograms. Basic edge detection operators like sobel operator, canny, Robert's variable etc. are used in these algorithms. These operators aid in detecting the edge discontinuities and hence mark the edge boundaries. The end goal is to reach at least a partial segmentation using this process, where we group all the local edges into a new binary image where only edge chains that match the required existing objects or image parts are present. [8]

#### 2.3.1.2 Colour - Based Methods

Colour-based methods rely on the fact that the colour of a license plate is different from the background colour of the vehicle. Also, the colour combination of the plate and its characters is nowhere found in the image other than the plate region. The Hue, Lightness, and Saturation (HLS) colour model can be used to classify the pixels in an input image against different illuminations. Unlike the Red, Green, and Blue (RGB) model, the HLS model has classified pixels into many categories.

#### 2.3.1.3 Deep-Learning Techniques

Tactile texture refers to the tangible feel of a surface and visual texture refers to seeing the shape or contents of the image. In image processing, the texture can be defined as a function of spatial variation of the brightness intensity of the pixels. The texture is the main term used to define objects or concepts of a given image. [9]

Texture-based methods use the presence of characters on the license plate as the base for plate detection. Due to the significant colour difference between the plate and its characters, it creates a frequent colour transition on the license plate. Hence, if the image is grey-scaled there is a notable difference between the characters and the plate background. Thus, it creates a unique pixel intensity distribution around the plate region. Moreover, the colour transition makes the plate region to have a high edge density. [10]

#### 2.3.1.4 Character-Based Methods

Examining an image for the presence of characters and locating them is also used for license plate detection. These methods are categorized as character-based methods and consider the region with characters as the possible plate region. A neural network classifier is used to classify those extreme regions and if any linear spatial configuration is found, it is assumed as the possible region with the license plate. This method is claimed to be robust against different illumination conditions and viewpoints and the reported detection accuracy is 95%. [11]

#### 2.3.1.5 Deep-Learning Techniques

According to the recent development in computer vision approaches, most of the statistical methods have been replaced by deep learning neural networks due to their high accuracy in object detection. Embracing this fact, many studies in license plate detection have used different types of neural networks. [12]

### 2.3.2 Licence Plate Recognition

As the second stage in a multi-stage automated license plate recognition pipeline, this stage is responsible for ‘‘reading'' the license plate ones the detection stage has localized it. This is a specific case of optical character recognition that considers certain features in the license plate.

For instance, many countries have strict regulation regarding the font and colour of the license plate and usually, they are selected to be easy to read. However, there are some unique issues associated with the license plates [13]. For instance, since the image is taken outdoors, the system designers have to consider aspects such as variable ambient light, uneven brightness, effect of weather. Despite having a standard license plate, they still could be damaged or rotated. Figure 3 shows the recognition pipeline of a typical ALPR system with possible techniques applicable for each stage. However, some of the tasks can be omitted depending on the selected techniques.

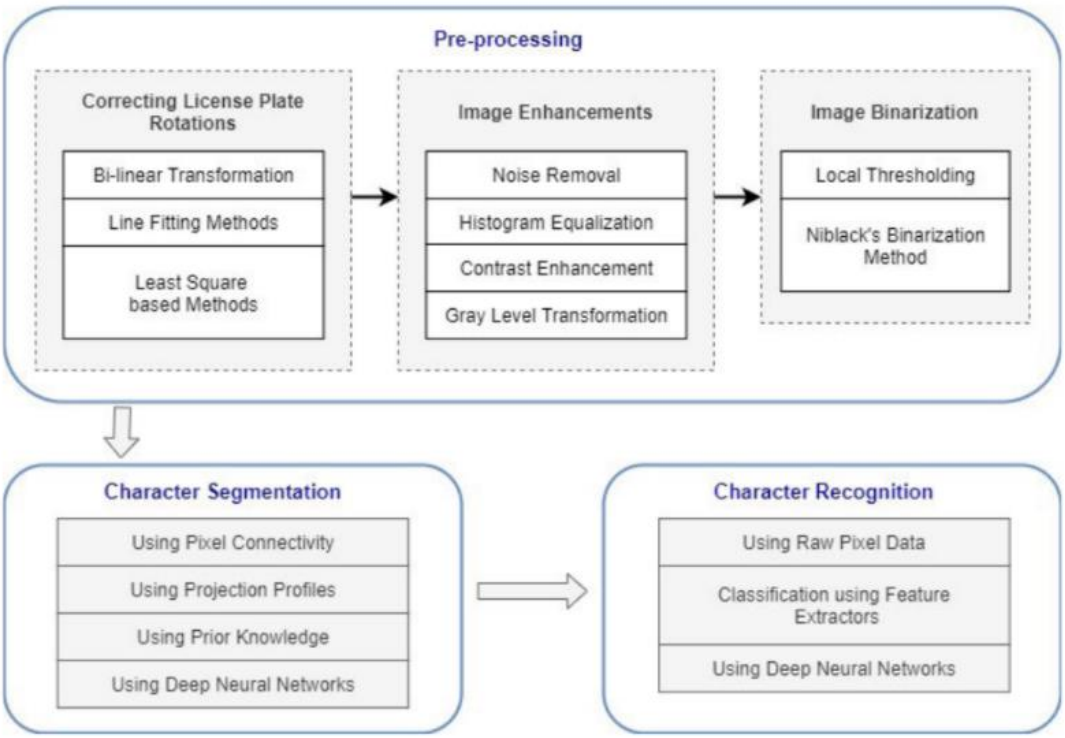



Figure 3 License Plate Recognition Pipeline With Associated Techniques

### 2.3.2.1 Pre-processing Techniques

Several pre-processing tasks performs before the character segmentation and recognition to handle unique challenges in license plate recognition. For example, rotation techniques such as bilinear transformations [14], least square-based methods [15] and line fitting methods [16] have been used in related studies. In many classical machine vision-based techniques for character recognition, the image is binarized before segmentation. The process makes it easier to separate the pixels belong to the characters in the image, compared to grey-scale or colour images. However, the threshold for this binarization must be determined correctly, to avoid the combining of the characters or merging with the license plate frame in the binary image, which makes it difficult to segment [17]. The threshold value can be defined using image enhancement techniques such as noise removal, histogram equalization, contrast enhancement and grey level transformation. However, even with these enhancements, it can be hard to get a single threshold.

### 2.3.2.2 Character Segmentation

In many optical character recognition techniques, the characters are first segmented before the classification. License plate character segmentation techniques consider the attribute of having contrasting colours for the background and characters. Binarization of the image makes this separation easier, as the foreground (character) and background pixels get the opposite ‘‘colours’’ in binarization.

**Character Segmentation Using Pixel Connectivity:**

Pixel connectivity is a simple method for character segmentation. Here, the connected pixels are labelled and if the pixels of the same label for an object of predetermined size or aspect ratio, then they are extracted as a character. One problem with pixel connectivity based methods is that they fail with broken characters or when characters are joined due to binarization threshold selection. However, pixel connectivity based methods are robust against rotated license plates and relatively simple to implement. Lack of need for pre-processing to compensate for license plate rotation further simplifies the license plate recognition pipeline.

**Character Segmentation Using Projection Profiles:**

Projection profiles methods use the fact that having opposite colours for the character and background pixels in the license plate image after image binarization. Typically, vertical projections are used to detect the starting and ending positions of the character and then horizontal projects are used to extract the character. However, project-based techniques are sensitive to image quality and image noise. As a result, a de-noising stage has to be included in the pre-processing stage of the recognition pipeline. Although these methods give low robust values compared to pixel connectivity based methods for rotations, the projection-based methods are still robust to rotations and independent on character positions.

**Character Segmentation Using Prior Knowledge:**

Prior knowledge about the license plate such as the aspect ratio of the characters, the ratio of various coloured pixels in the image is used for character segmentation. Approaches based on prior knowledge tend to be simple to implement; however, these methods are usually specific to the regions where they were designed to operate and do not generalize in other instances.

**Character Segmentation Using Deep Learning:**

Neural network has become a recent approach for character segmentation, which uses CNN (Convolutional Neural Networks) for the task associated with computer vision. A localized license plate is given as the input for the CNN and the bounding boxes of each character are produced as the output. However, depending on the dataset, the CNN execution consumes more time and resources compared to the traditional computer vision-based techniques. In addition, several deep learning-based license plate recognition pipelines have omitted explicit character segmentation in favour of implicit character segmentation in later stages, which leads to reduce the number of parameters and the computational cost. [18]

### 2.3.2.3 Character Recognition

Many classification techniques require fixed-size inputs to the learning model. Since the output from the segmentation stage is vary in size, the input segments are re-scaled before the classification. Because the number of characters, their relative position and possible values are known in most cases, each segment is classified individually to be of one of the possible values. This can be considered in three cases, (A) Com-pare all the pixel values of the raw image data directly with the predefined templates, (B) Use different image processing and machine learning techniques to extract features before classifying the segments, (C) Use deep learning techniques to classify segments.

**A) Template and Pattern Matching Techniques:**

Given that license plate usually have a known font and character size, one popular option is to use template matching techniques to classify characters. Template matching is typically used with binarized images. For each possible character, a predefined template is created and each segment is matched with each template to find the most similar tem-plate. In order to handle the rotations in characters, additional templates have to be stored which further increases computation time and processing memory.

**B) Character Recognition Using Feature Extractors:**

In general, all the pixels are not required to recognize a character. Thus, feature extractors are used to distinct simpler features from the images by reducing the computational costs. Some feature extraction techniques can extract features, which are robust against rotations and image noise. In these methods, a feature vector is generated using a transformation on each segment and then classifies using a machine learning model. Some of the feature extractors techniques are eigenvector transformation, Gabor filter, Kirsch edge detection. Machine learning models are used to classify the extracted features.

**C) Character Recognition Using Deep Learning:**

Advantage of using neural networks is that they can be given the raw pixel data directly and act as both feature extractors and classifiers on their own. Various forms of neural networks ranging from simple multilayer perceptrons to Probabilistic Neural Networks (PNN) [26] and discrete-time cellular networks have been used for this task. However, many recent studies have used CNN (Convolutional Neural Networks), which have shown great potential in many computer vision tasks. Another recent approach is to directly use object detection based technique such as YOLO (real-time vehicle detection using deep learning methods). [19] Although deep learning-based approaches are relatively computationally expensive than the alternative methods like template matching and statistical feature extractors, they provide better accuracy in general.

# 3. Summary

## 3.1 Technology Used

Due to the wide library possibilities such as TensorFlow, OpenCV and Keras, we are considering the use of Python language in the system. During the development of the project software, we aim to use Python supported compilers such as Visual Studio, PyCharm and Spyder.

# 4. Software Requirements Specification

## 4.1 Introduction

### 4.1.1 Purpose

In the License Plate Recognition System, we aim to determine the characteristics such as the type, color and size of the vehicles by using image processing, image detection and recognition methods. In addition to these methods, we aim to ensure that the Plate Recognition System gives accurate results by using the deep learning method with libraries such as TensorFlow and Keras.

### 4.1.2 Scope of Project

License Plate Identification System is a method that is frequently used in the identification of vehicles, in parking lots, in urban areas and in places where security is important such as road cameras. A license plate identification system is used to identify a vehicle.

The license plate recognition system is made by detecting the license plate region of the vehicles with the vehicle image and reading and separating the characters on the plate with image processing. By developing the license plate recognition system with deep learning and image processing, it will be tried to work towards detecting license plate recognition and the type of vehicle whose license plate is recognized.

With the License Plate Recognition System, our goal is to determine the license plates of vehicles using image processing methods such as character recognition and segmentation. We aim to determine the characteristics such as the type, size and color of the vehicles by using the determined plates. OCR (Optical Character Recognition) technology is used to recognize the characters of number plates. In addition, we aim to use the deep learning method using different vehicle images and datasets of some libraries in order to be accurate and realistic when defining the license plates in the License Plate Recognition System.

## 4.2 General Description

### 4.2.1 Glossary (Definitions, Acronyms, and Abbreviations)

| Term | Definition |
|---|---|
| Camera | A device for recording visual images in the form of photographic, film or video signals. |
| Character Recognition | Character recognition is a process which allows computers to recognize written or printed characters such as numbers or letters and to change them into a form that the computer can use. |
| Character Segmentation | Character segmentation is an operation that seeks to decompose an image of a sequence of characters into sub images of individual symbols. It is one of the decision processes in a system for optical character recognition (OCR). |
| Deep Learning | Deep learning is a type of machine learning and artificial intelligence (AI) that imitates the way humans gain certain types of knowledge. While traditional machine learning algorithms are linear, deep learning algorithms are stacked in a hierarchy of increasing complexity and abstraction. |
| Keras | Keras is an open-source software library that provides a Python interface for artificial neural networks. Keras acts as an interface for the TensorFlow. |
| Licence Plate | A license plate is a sign on the front and back of a vehicle that shows its license number. A rectangular, usually metal plate that bears a sequence of numbers, letters, or both and is issued by a government to identify an officially registered vehicle. one of the signs with numbers on it at the front and back of a car. |
| Licence Plate Recognition | License plate recognition system is a type of technology, mainly software, that enables computer |

| | |
|---|---|
| System | systems to read automatically the registration number (license number) of vehicles from digital pictures. |
| Optical Character Recognition (OCR) | Optical character recognition or optical character reader is the electronic or mechanical conversion of images of typed, handwritten or printed text into machine-encoded text, whether from a scanned document, a photo of a document, a scene-photo or from subtitle text superimposed on an image. |
| OpenCV (Open Source Computer Vision Library) | OpenCV is a library of programming functions mainly aimed at real-time computer vision. |
| Python | Python has a standard library in development, and a few for AI. It has an intuitive syntax, basic control flow, and data structures. It also supports interpretive run-time, without standard compiler languages. This makes Python especially useful for prototyping algorithms for AI. |
| Software Requirements Specification | A document that completely describes all of the functions of a proposed system and the constraints under which it must operate. For example, this document. |
| Users | The person using the License Plate Recognition System. |

### 4.2.2 User Characteristics

**Users** are which Persons or institutions that use, operate and observe the License Plate Recognition System.

**Licence Plate Recognition System** is a system that enables to read the license plates of the vehicles by detecting the vehicle according to the color and type of the vehicles. While doing license plate reading, it detects the vehicle, detects the location of the license plate and performs license plate recognition by reading the characters on the plate with OCR.

**Support system manager** is the person who helps the License Plate Recognition System when there is a problem with the system, camera or license plate reading.

### 4.2.3 Product Perspective

In the License Plate Recognition System, the system works by training the license plate position in the photos of the vehicles at different angles and in different frames, using the deep learning method, so that the license plates of the vehicles can be determined easily. For License Plate Recognition System, we prefer Python language to be used in the system due to its wide library possibilities such as TensorFlow, OpenCV and Keras. During the development of the project software, we aim to use Python supported compilers such as Visual Studio, PyCharm and Spyder.

In the License Plate Recognition System, besides the deep learning method, it is also aimed to use image processing and machine learning techniques. The system should be trained and tested using the sources in the license plate recognition system available on the internet, different vehicle images and the TensorFlow library dataset.

In case an external camera such as ESP32 is used as an external camera, images are taken via the ESP32 camera and transferred over Wi-Fi to a sufficiently equipped computer to operate the system. Thus, in the images transferred to the computer, first the location of the plate is determined, then the character cementation is done. Finally, character recognition is done and license plate recognition is done.

### 4.2.4 Overview of Functional Requirements

In the Plate Recognition System, the recognition process of the plates first takes place by finding all the contours in the picture. It happens that each stroke has its bounding rectangle. Then it has to compare and verify the side ratio and area of each bounding rectangle with an average plate. Image segmentation is then applied to the image within the verified contour to find the characters inside the plate. As the last step, the characters on the plate are recognized by using OCR (Optical Character Recognition). In the license plate recognition system, there is also a training phase by using the deep learning method for more recognition of the license plate in the images. Thus, different directions of vehicles and license plate positions can be better detected using multiple images or different sections of a video. In this way, it also provides convenience in terms of accuracy and speed in plate recognition.

### 4.2.5 General Constraints and Assumptions

**Software Conditions:** Since the images and times to be used for teaching using deep learning in the license plate recognition system can vary, it can be seen as the challenging part. Since the type of car will be determined with different vehicle images, the teaching time may vary. Every user shall need a computer and compiler that can run the codes in the software part of the license plate recognition system well.

**Ambient Conditions:** In order for the License Plate Recognition System to work properly, the camera must be in sufficient light and in suitable weather conditions, day or night.

**Hardware Conditions:** In case of using an external camera such as ESP32 other than the normal camera, the video must be at a suitable distance to be sent. Also the videos need to be sent via the Wi-Fi module over the network.

**Security Conditions:** In case of using an external camera such as ESP32, since the camera will be connected via Wi-Fi when connecting to the system, other devices using the same Wi-Fi must not block or access the camera. For this, the security of the camera is provided via Wi-Fi.

It is assumed that the system should be trained and tested using the sources in the license plate recognition system available on the internet, different vehicle images and the libraries such as TensorFlow library dataset.

## 4.3 Specific Requirements

### 4.3.1 Interface Requirements

#### 4.3.1.1 User Interface

Since the users will use more compilers in the License Plate Recognition System, the recognized license plates on the vehicles and their outputs will be displayed here.

**Requirement 1: Running the Compiler**
In this interface, the user can operate the system with the buttons on the compiler and observe the outputs.

#### 4.3.1.2 Hardware Interface

**Requirement 1:** For the License Plate Recognition System, a computer that can train the data in deep learning and that has good enough hardware should be used.

**Requirement 2:** Thanks to the ESP32 camera module as an external camera, video transfer is carried out over Wi-Fi. The video taken from the camera reaches the computer and plate recognition is performed.

#### 4.3.1.3 Software Interfaces

**Requirement 1:** As operating systems, any Windows, Linux and MacOS operating systems with the latest version are chosen as much as possible for the best support and ease of use.

**Requirement 2:** Libraries such as TensorFlow and OpenCV are planned to be used for the license plate recognition system. Therefore, compilers such as Visual Studio, PyCharm and Spyder are used that support these libraries and Python language.

#### 4.3.1.4 Communication Interfaces

**Requirement 1:** In case of using the external camera, the network connection is required to be stable in order to establish the connection properly.

### 4.3.2 Detailed Description of Functional Requirements

By using the deep learning method in the License Plate Recognition System, it provides license plate recognition by training the pictures of the vehicles with their license plates from different angles and frames. Thus, high accuracy results are obtained by minimizing the error rate and false results. In the License Plate Recognition System, a picture is taken first, and the location of the plate is determined in the picture taken. Then, character segmentation is done and finally the process is completed by character recognition.

**Requirement 1:** The user operates and uses the License Plate Recognition System.

**Requirement 2:** Pictures or videos are uploaded to the License Plate Recognition System.

**Requirement 3:** For the License Plate Recognition System, firstly, the defined pictures or videos are trained to detect different angles and frames by deep learning method.

**Requirement 4:** Vehicle image defined in License Plate Recognition System is converted to grayscale format.

**Requirement 5:** The image is binarized to reveal the plate.

**Requirement 6:** In the License Plate Recognition System, all the contours of the vehicle picture are found.

**Requirement 7:** The bounding rectangle of each contour in the vehicle image is found.

**Requirement 8:** In the License Plate Recognition System, a comparison and verification of the side ratio and area of each bounding rectangle with an average plate in the vehicle image is made.

**Requirement 9:** Image segmentation is applied to the image within the verified contour to find the characters in the license plate found in the system.

**Requirement 10:** In the Plate Recognition System, the characters are recognized separately by using OCR (Optic Character Recognition) as the last process.

**Requirement 11:** Users can see the license plates of the defined vehicles as a result of the operations in the License Plate Recognition System.

**Requirement 12:** Support System Manager assists the user and fixes any problem that occurs during the operation of the License Plate Recognition System.

### 4.3.3 Non-Functional Requirements

**Requirement 1: Speed**

In the License Plate Recognition System, it is important that there is a minimum delay in the image source.

**Requirement 2: Size**

According to the size of the images in the Plate Recognition System and the size of the libraries used, it will occupy a certain space on the computer.

**Requirement 3: Performance**

In the License Plate Recognition System, the performance of the recognition process of the license plates may vary depending on the camera or the current operating speed of the computer.

**Requirement 4: Usability**

In order to use the deep learning method in the License Plate Recognition System, certain libraries must be on the computer and the images must be transferred to the computer to be run.

**Requirement 5: Reliability**

If an external camera such as ESP332 is used in the License Plate Recognition System, since the connection of this camera with the computer is done via Wi-Fi, necessary protection measures must be taken over Wi-Fi.

**Requirement 6: Robustness**

License plate recognition shall be done according to changing ambient conditions and ambient light.

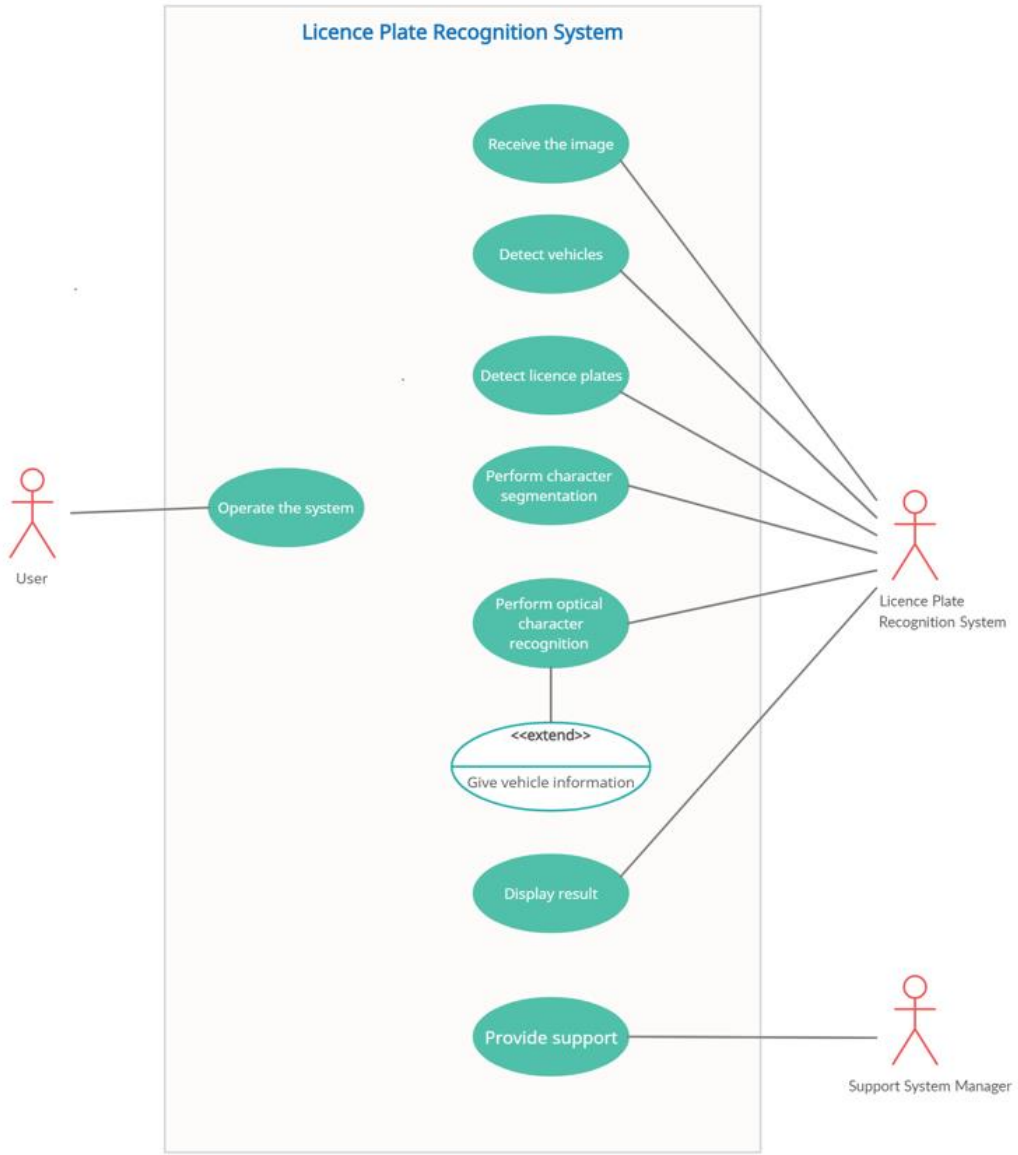
**Requirement 7: Portability**

License Plate Recognition System can be used in any computer environment.

## 4.4. Analysis –UML

### 4.4.1 Use cases

#### 4.4.1.1 Drawing Use Case Diagram



#### 4.4.1.2 Describing Most Use Cases

##### 4.4.1.2.1 Operate The System

| **Use Case Name** | Operate The System |
|---|---|
| **Actor** | Users, Licence Plate Recognition System |
| **Description** | 1. It is necessary to start the software from the compiler. |
| **Trigger** | Compile the program |
| **Preconditions** | Users starts the Licence Plate Recognition System project source code. |
| **Postconditions** | After users start the system, they can observe the results. |

##### 4.4.1.2.2 Receive The Image

| **Use Case Name** | Receive The Image |
|---|---|
| **Actor** | Licence Plate Recognition System |
| **Description** | 1. The system compiles images from vehicle images and video frames in the IDE. |
| **Trigger** | Receiving the image. |
| **Preconditions** | Licence Plate Recognition system gets the image. |
| **Postconditions** | Pictures are made ready to apply the operations by the License Plate Recognition System. |

#### 4.4.1.2.3 Detect Vehicles

| Use Case Name | Detect Vehicles |
|---|---|
| **Actor** | Licence Plate Recognition System |
| **Description** | 1. The processed image is converted to grayscale format and the image is blurred.<br>2. The blurred image has vertical edges.<br>3. The image is binarized to reveal the plate.<br>4. All contours in the picture are found. |
| **Trigger** | Process the image. |
| **Preconditions** | The system detects the vehicle by using software. |
| **Postconditions** | After the vehicle is detected, the license plate recognition phase starts in the License Plate Recognition System. |

#### 4.4.1.2.4 Detect Licence Plates

| Use Case Name | Detect Licence Plates |
|---|---|
| **Actor** | Licence Plate Recognition System |
| **Description** | 1. The transformation is applied to the thresholded image.<br>2. The rectangular white box of the plate is revealed.<br>3. Contours are drawn in the binary and transformed image.<br>4. By drawing all the extracted contours to the original image, the |

| | |
|---|---|
| | boundaries of the license plate and vehicle are determined.<br>5. For the plates, the minimum area rectangle enclosed by each contour is found and the side proportions and area are verified.<br>6. The minimum and maximum area of the plate is defined according to the plate to be used.<br>7. The plate has contours in the verified region, and the lateral proportions and area of the bounding rectangle of the largest contour in that region are verified.<br>8. The found contour is subtracted from the original image and the view of the plate is obtained. |
| **Trigger** | Detection of vehicles |
| **Preconditions** | Determination of the contours of vehicles. |
| **Postconditions** | Character segmentation process is started. |

#### 4.4.1.2.5 Perform Character Segmentation

| Use Case Name | Perform Character Segmentation |
|---|---|
| **Actor** | Licence Plate Recognition System |
| **Description** | 1. To fully recognize the characters on the plate, image segmentation needs to be applied and the value channel is extracted from the HSV format of the plate image.<br>2. Adaptive thresholding is applied to the value channel image of the plate to binarize and reveal characters.<br>3. In order to find the connected components in the image, not bitwise processing is applied on the image.<br>4. A mask is created to display all character components and their contours in the mask. By subtracting the contours, the largest is taken, the bounding rectangle is found, and the side ratios are verified.<br>5. By verifying the lateral proportions, the convex shell of the contour is found and drawn on the character candidate mask.<br>6. All contours in the character candidate mask are found and these contour areas are extracted from the threshold value image of the plate, all characters are taken separately. |

| | |
|---|---|
| **Trigger** | Detect Licence Plates |
| **Preconditions** | Defining the plate perimeter and contour. |
| **Postconditions** | The optical character recognition stage is applied. |

#### 4.4.1.2.6 Perform Optical Character Recognition

| | |
|---|---|
| **Use Case Name** | Perform Optical Character Recognition |
| **Actor** | Licence Plate Recognition System |
| **Description** | 1. Plate texts are obtained from the picture with character segmentation. |
| **Trigger** | Completion of character segmentation. |
| **Preconditions** | Obtaining the characters on the plate separately as a picture. |
| **Postconditions** | Determination of vehicle type and features and recognition of license plate. |

#### 4.4.1.2.7 Give Vehicle Information

| | |
|---|---|
| **Use Case Name** | Give Vehicle Information |
| **Actor** | Licence Plate Recognition System |
| **Description** | 1. Providing vehicle type and features by using plates. |
| **Trigger** | End of Optical Character Recogniton. |
| **Preconditions** | Completion of license plate recognition processes. |
| **Postconditions** | Proceeding to the display stage. |

#### 4.4.1.2.8 Display Result

| Use Case Name | Display Result |
|---|---|
| **Actor** | Licence Plate Recognition System |
| **Description** | 1. After the license plate recognition process is completed, the plate is printed in text format. |
| **Trigger** | End of Optical Character Recognition processes. |
| **Preconditions** | Vehicle information is defined. |
| **Postconditions** | Printing the License Plate Recognition System. |

#### 4.4.1.2.9 Provide Support

| Use Case Name | **Provide Support** |
|---|---|
| **Actor** | Support System Manager, Licence Plate Recognition System |
| **Description** | 1. System problems are addressed and necessary solutions are realized. |
| **Trigger** | Error message. |
| **Preconditions** | Error occurred in the system. |
| **Postconditions** | Support system manager solves the problem. |

# 5. Software Design Description

## 5.1 Introduction

### 5.1.1 Purpose

This software design document describes the License Plate Recognition System architecture and system design. This includes the architectural features of the system which operations each module will perform. The aim is to guide a design that can be easily implemented by any user reading this report. The primary audience for this document is License Plate Recognition System users and developers.

### 5.1.2 Overview

Each chapter contains the following topics in order.
Section 2 introducing the system context and design, and discussion the background to the project.
Section 3.1 is the Architectural Design, which determines the design to perform all functions included in the system. Each of these entities has a brief description concerning the services that it provides to the rest of the system.
Section 3.2 includes the providing decomposition of software components, including the hierarchy and control and data flows.
Section 4 discusses the User Interface Design, and how it can be created with maximum user efficiency and ease of use.

### 5.1.3 Definitions and Acronyms

| Term | Definition |
|---|---|
| Activity Diagram | An activity diagram is a behavioral diagram i.e. it depicts the behavior of a system. An activity diagram portrays the control flow from a start point to a finish point showing the various decision paths that exist while the activity is being executed. |
| Architectural Design | Architectural design is a concept that focuses on components or elements of a structure. An architect is generally the one in charge of the architectural design. They work with space and elements to create a coherent and functional structure. |
| Camera | A device for recording visual images in the form of photographic, film or video signals. |
| Class Diagram | Class diagram is a type of static structure diagram that describes the structure of a system by showing the system's classes, their attributes, operations, and the relationships among objects. |
| Character Recognition | Character recognition is a process which allows computers to recognize written or printed characters such as numbers or letters and to change them into a form that the computer can use. |
| Character Segmentation | Character segmentation is an operation that seeks to decompose an image of a sequence of characters into sub images of individual symbols. It is one of the decision processes in a system for optical character recognition (OCR). |
| Decomposition Diagram | A decomposition diagram shows a complex, process, organization, data subject area, or other type of object broken down into lower level, more detailed components. For example, |

| | |
|---|---|
| | decomposition diagrams may represent organizational structure or functional decomposition into processes. |
| Interface | Interface is a shared boundary across which two or more separate components of a computer system exchange information. |
| Licence Plate | A license plate is a sign on the front and back of a vehicle that shows its license number. A rectangular, usually metal plate that bears a sequence of numbers, letters, or both and is issued by a government to identify an officially registered vehicle. one of the signs with numbers on it at the front and back of a car. |
| Licence Plate Recognition System | License plate recognition system is a type of technology, mainly software, that enables computer systems to read automatically the registration number (license number) of vehicles from digital pictures. |
| Optical Character Recognition (OCR) | Optical character recognition or optical character reader is the electronic or mechanical conversion of images of typed, handwritten or printed text into machine-encoded text, whether from a scanned document, a photo of a document, a scene-photo or from subtitle text superimposed on an image. |
| Software Design Description | A software design description is a representation of a software design that will be used to record design information, address various design concerns, and communicate that information to its design. |
| Support System Manager | Someone who helps the License Plate Recognition System when there is a problem with the system, camera or license plate reading. |
| Users | The person using the License Plate Recognition |

| | |
|---|---|
| | System. |
| User Interface Design | Focuses on anticipating what users might need to do and ensuring that the interface has elements that are easy to access, understand, and use to facilitate those actions. UI brings together concepts from interaction design, visual design, and information architecture. |

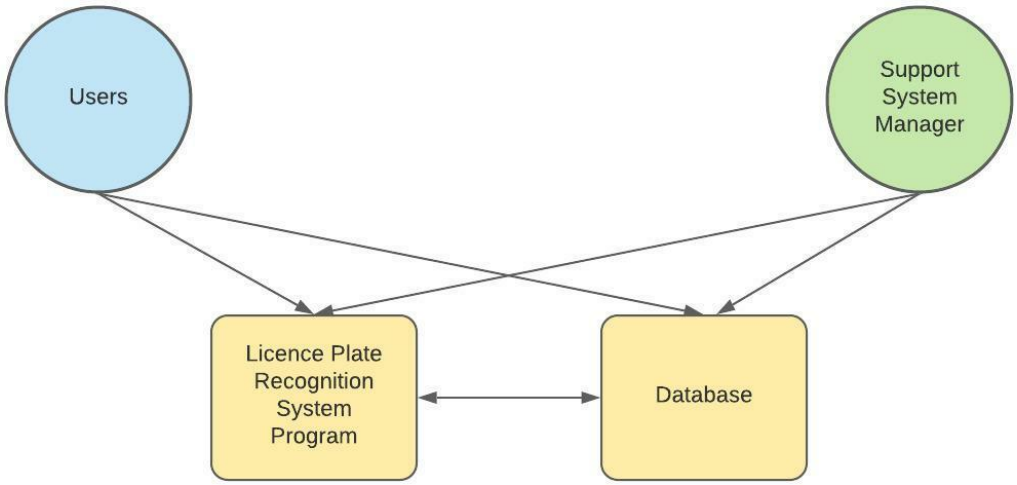
## 5.2. System Overview

The license plate recognition system is made by detecting the license plate region of the vehicles with the vehicle image and reading and separating the characters on the plate with image processing. By developing the license plate recognition system with deep learning and image processing, it will be tried to work towards detecting license plate recognition.

In the Plate Recognition System, the recognition process of the plates first takes place by finding all the contours in the picture. It happens that each stroke has its bounding rectangle. Then it has to compare and verify the side ratio and area of each bounding rectangle with an average plate. Image segmentation is then applied to the image within the verified contour to find the characters inside the plate. As the last step, the characters on the plate are recognized by using OCR (Optical Character Recognition). In the license plate recognition system, there is also a training phase by using the deep learning method for more recognition of the license plate in the images. Thus, different directions of vehicles and license plate positions can be better detected using multiple images or different sections of a video. In this way, it also provides convenience in terms of accuracy and speed in plate recognition.

## 5.3 System Design

### 5.3.1 Architectural Design

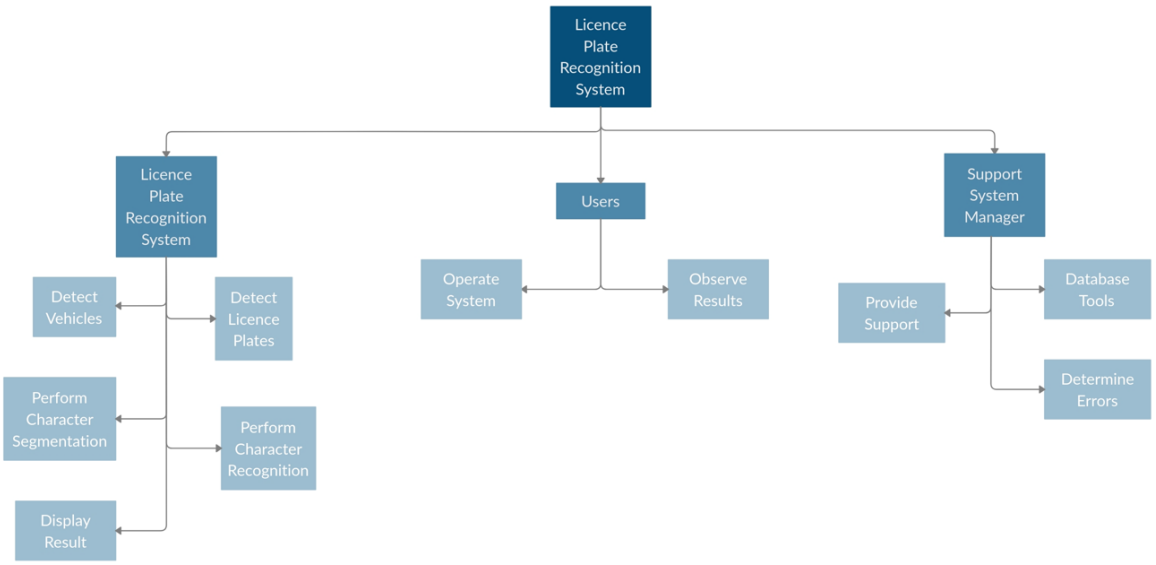



**1. Licence Plate Recognition System Program:** It is the part where the users run the License Plate Recognition System project and the whole project is located.

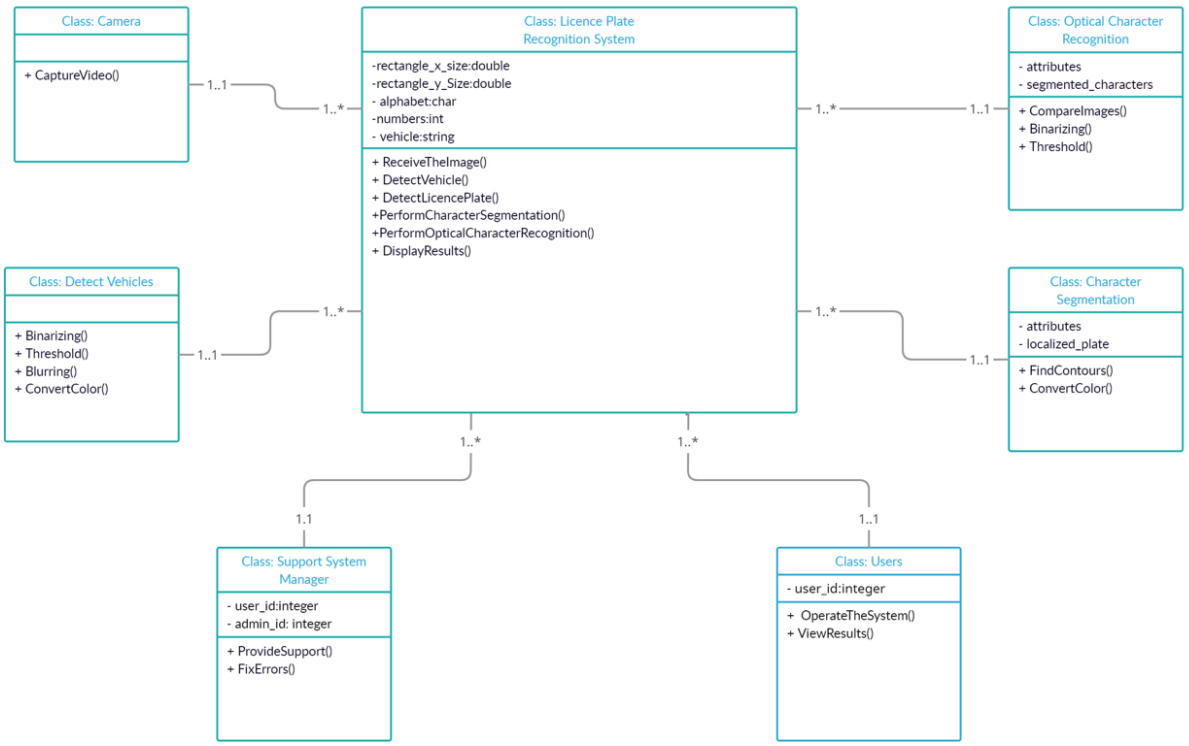
**2. Database:** It is the place where license plate information is stored in the License Plate Recognition System project.

## 5.3.2 Decomposition Description

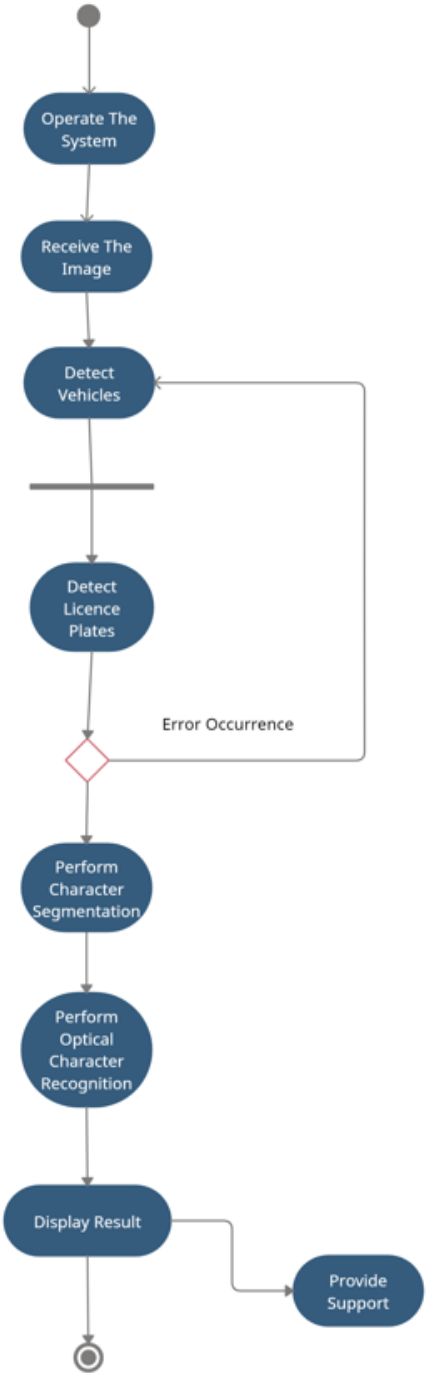
### Decomposition Diagram:




### Class Diagram:

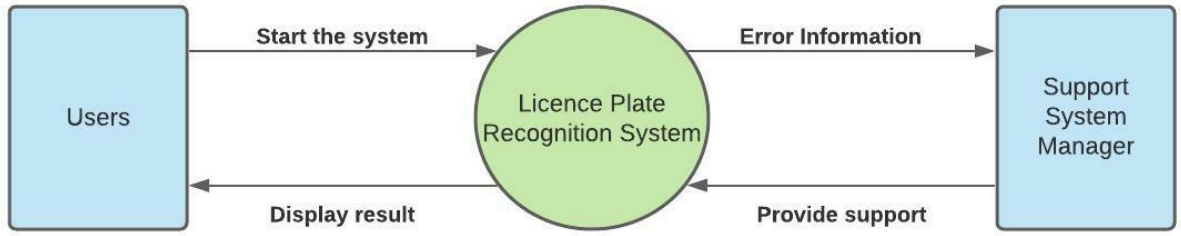


**Activity Diagram:**

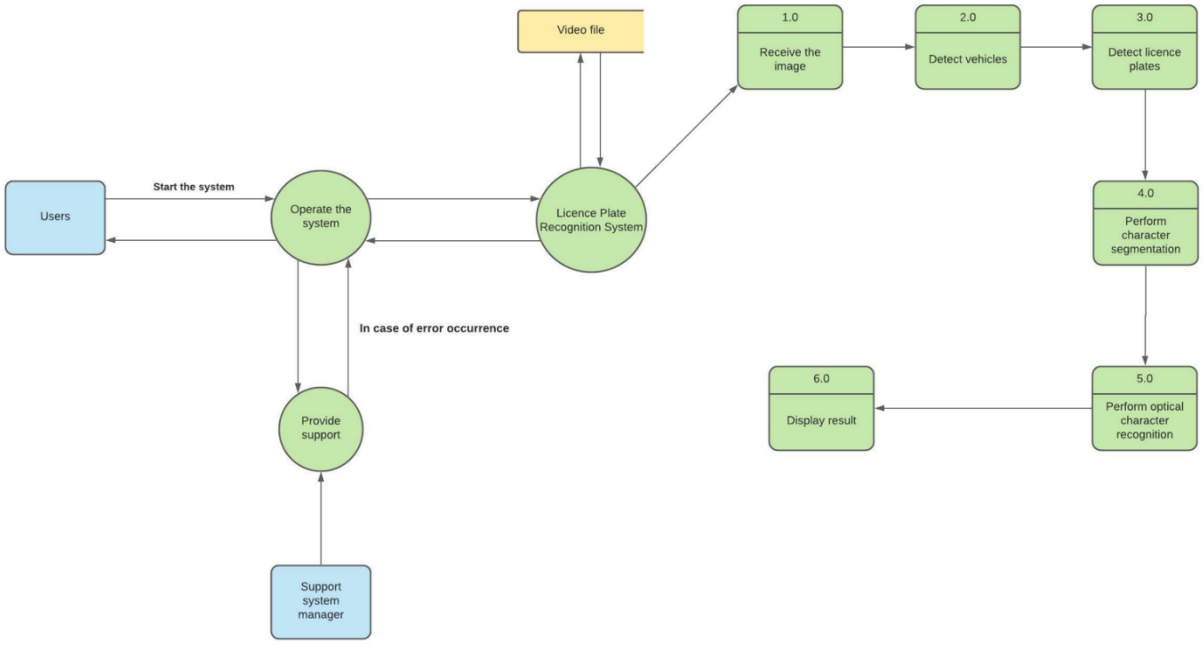


**Data Flow Diagram (DFD):**

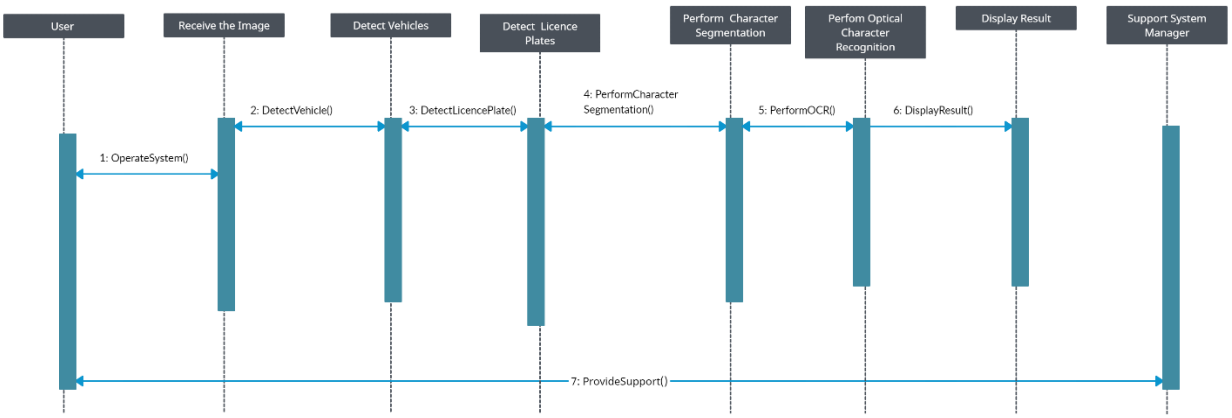
**LEVEL 0:**




**LEVEL 1:**

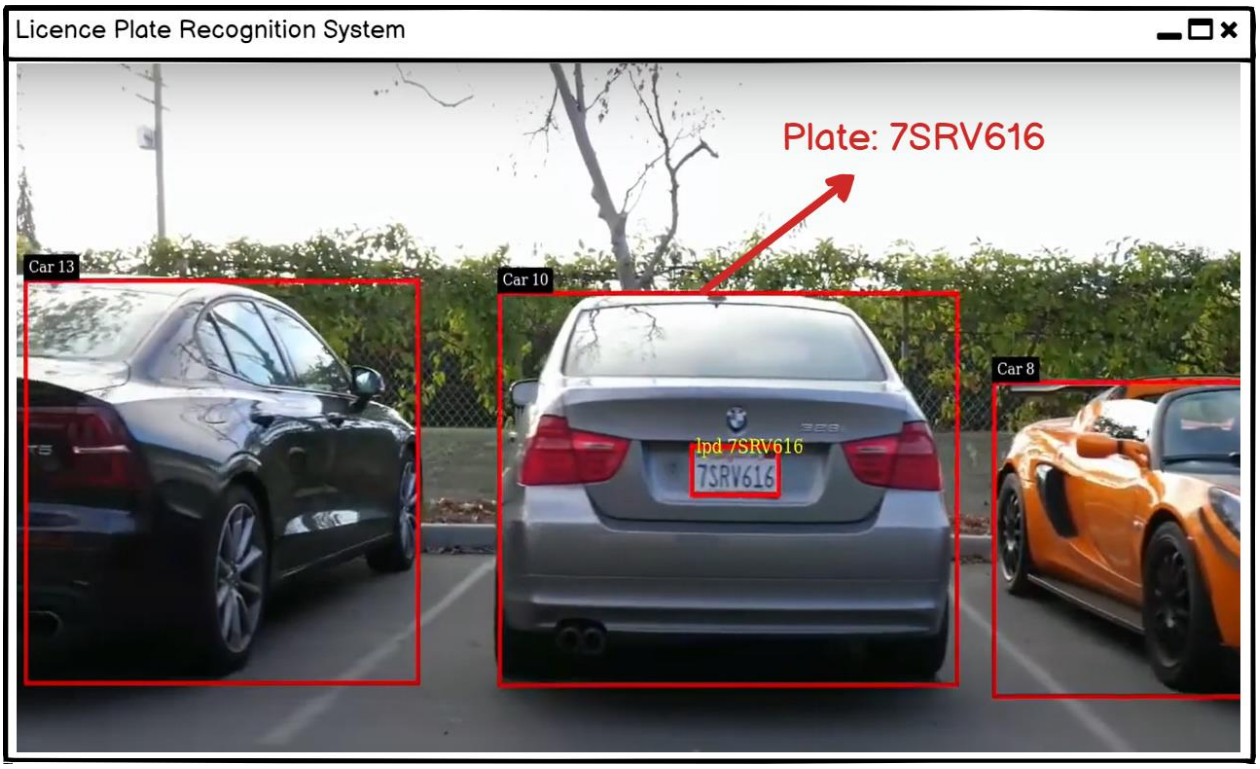


**Sequence Diagram:**



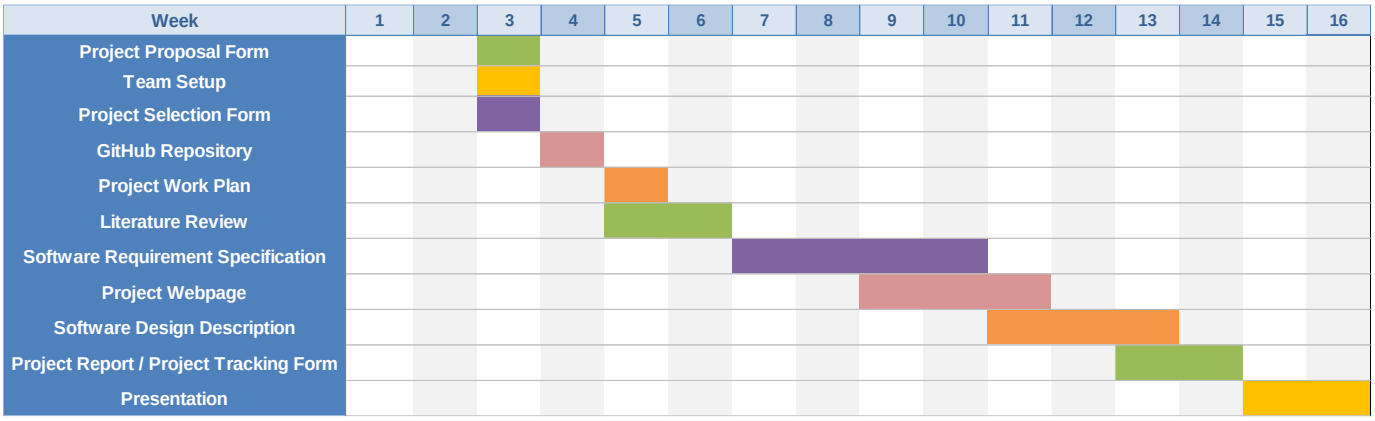

## 5.4. User Interface Design

- **Display Result**




After users run the License Plate Recognition System, the system performs license plate recognition. The license plate of the vehicles is recognized through the image taken from the video. After the users run the program, the result of the license plate recognition process is written on the screen as in the interface. In this way, users can clearly see the result of the license plate recognition process.

## 6. Project Work Plan




## 7. Conclusion & Discussion

The design and development of an automated license plate recognition system requires careful selection of specifications and techniques to work with different operating and hardware constraints. We have briefly summarized the history of the License Plate Recognition System in the Literature Review. Thus, we observed how and why the License Plate Recognition System came from the past to the present. We examined in detail the research and analysis of current approaches and techniques used in the solution of the Plate Recognition System. We have discussed in detail the main methods required for the License Plate Recognition System. We examined these methods in detail under the titles of License Plate Detection and License Plate Recognition. We also explored the open challenges of the License Plate Recognition System and suggested solutions to these challenges.

Based on our research, we aim to determine the features required for the recognition of license plates by using image processing, image detection and recognition methods for the License Plate Recognition System. In addition to these methods, we aim to make the Plate Recognition System by using the deep learning method with libraries such as TensorFlow and Keras.

Since it is intended to use deep learning, image optimization, camera adjustment and image processing, data processing speeds can be seen as potential problems. With more specific algorithms and methods, the license plate recognition system can be made in accordance with speed and time. Thus, we aim to perform the process of recognizing the license plates of the vehicles by taking images from the camera by using the libraries and methods required for the License Plate Recognition System.

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