# AUTOMATIC LICENSE PLATE READING USING MATHEMATICAL MORPHOLOGY

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**ABSTRACT**
This paper describes the application of mathematical morphology to the problem of extracting the characters from a license plate in order to automatically read it. No apriori assumption on the background is made. The key idea is to use as many features of license plates as needed so as to have a low probability than other structures in the input image fulfill all the requirements. The proposed algorithm works in real time on a personal computer. To achieve this, new morphological operators have been defined and are described in this paper.

**KEY WORDS**
Morphology, License Plate, Automatic Reading.

## 1 Introduction

Automatic reading of vehicles' license plates is a technology with many potential applications. In central London a system has been set up that monitors which vehicles enter the central districts. In Italy, motorways have a permanent systems that read plates in an effort to locate stolen vehicles. However, most of these commercial systems use proprietary technology which is not public and performance results of these systems is often unknown. Previous work on the use of morphology to process car plate images can be found at [1]

Although, we can say that this technology has reached a level of maturity where industrial applications are feasible, further research on automatic plate reading is still necessary. For instance, many systems are restricted to particular environments with 'favorable' conditions such as indoors (controlled illumination) parkings.

At the Technical University of Valencia, we are currently developing a License Plate Reader (LPR) with the following characteristics:

- It should have as few restrictions as possible. It should accept monochrome or color standard video as input. Natural or artificial illumination

- It should be fast. Ideally it should process all input frames in real time (25 imgs/s with PAL resolution).

- The system should work in many completely different environments, with the minimal adjustements (parameter tuning) made by non-expert personnel.

- It should be robust in the sense that large deviations in size, orientation, state of preservation of the plate, etc.

- Although possibly tuned for a specific country plate layout, it should be possible to easily modify the algorithm parameters to allow for different layouts.

As explained in next section, our system consists of three diferent blocks. In this paper, we will focus on the morphological image processing tools used in the first block.

The rest of the paper is organized as follows. In section 2 we present the main blocks that build our LPR. Section 3 introduces the new morphological operators that we have created for our LPR. In section 4 we will describe the image processing algorithms that take as input an image containing a car plate and give a binary image containing only the characters. This will be the input to the OCR system. Finally, some conclusions and future work will be drawn.

## 2 System Overview

The block diagram of the whole LPR system is depicted in figure 1. Next subsections will describe each block in greater detail.

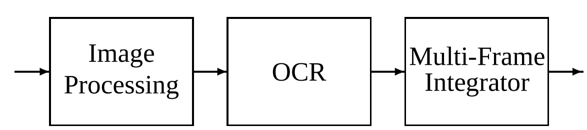


Figure 1. LPR Block Diagram

### 2.1 Input Images

Currently, we are using standard PAL video signals as input, although other image sources such as digital photography images could be used. The use of standard video imposes some limitations on the system (specially on the resolution). For instance, in the case of reading plates of vehicles in motion, only one field of the video signal should be

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used (to avoid the interlacing effect). This gives 768×288 images with pixel aspect ratio of 1:2. Considering a character thickness of 10 mm (at least for Spanish plates), a minimum number of two pixels in the character line to fullfill the Nyquist Sampling Theorem, and that the limiting resolution is the vertical one, we get that the width of the field of view should be smaller than 3.84 m (approximately twice the width of a car)

The previous results have important practical consequences. Roughly speaking we can say that we need at least one camera per lane, with some overlap in the fields of view. This restriction is important for plate detection in multi-lane roads.

## 2.2 Image Processing

We can say that this block is the core of the system and the one with a higher computational burden by far. It receives input images as described above and produces *candidate regions* possibly containing a car plate. The algorithms used in this block will be described in detail below. For now, it is sufficient to say that it locates and extracts regions of the images that fulfill some criteria in terms of contrast, size, number of characters, alignment, etc.. This binary sub-images will be passed to the Optical Character Recognition (OCR) Block.

## 2.3 The OCR

This block takes as input small binary images with the plate candidate regions. For each candidate two different outputs are possible. The first one is *no valid plate is found in current image*, if no car plate could be read in any candidate (in some sense the OCR is used to validate the candidate regions). The second one is the plate reading. The plate reading is consists of a string of characters and a vector that represents the confidence for each character (a number in the 0.0-1.0 range).

## 2.4 Multiframe integrator

At a frame rate of 25 fps, it is usually possible to obtain multiple images from the same vehicle. Ideally, all the readings should be identical for the same car. In practice, differences may appear due to errors in the OCR. Thus, the objective of the multi-frame integrator is to provide a global hypothesis of the plate reading taking as input the characters and confidences produced by the OCR.

As metioned in the introduction, next sections we will focus only with the image processing block.

# 3 Morphological Operators

Morphological operators are a class of non-linear procedures that operate on images and are based on the idea of supremum and infimum [2]. These operators have several advantages over other image operators for the application that we are pursuing:

- Efficient software implementations allow as low as 3 operations per/pixel even for large kernels.
- The filter parameters have clear physical meaning, which makes easier the parameter tuning. For instance, it is pretty straihgtforward to select thin dark objects with a minimum height of $h_1$ and a maximum height of $h_2$.

Morphological operators are usually better understood when applied to binary images. For this reason, we describe our new operators for this type of images only. However, it is important to emphasize that any morphological operator designed for binary images can be easily extended to gray-scale images. For details about how this extension can be performed the reader is referred to [2]. Although, binary operators are easier to undestand, any binarisation is a loss of information that should be avoided (or delayed) as much as possible, therefore the morphological operators described in this section are applied always to gray-scale images.

## 3.1 Bounding Box Connected Opening

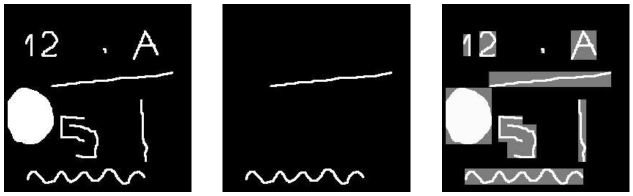
Conected operators are a special group of the morphological operators with the special property of completely preserve or eliminate connected components. For more details about connected operators see [3]. The decision of preserve or eliminate a connected component is based on some criteria that the connected component has to fulfill such us size, orientation, etc.

Different connected operators have been proposed in the literature [3, 4]; among them the most popular ones are conventional openings followed by reconstruction [5], and area openings. The first ones preserve the connected components in which the structuring element may fit anywhere on the connected component. Area connected opening preserves those components with an area above a certain threshold.

In this paper we propose a new connected opening based on the size of the bounding box of the connected component. A connected component will be preserved if the vertical size is greater than a threshold $U_v$ and/or the horizontal size is larger than a second threshold $U_h$.

It is interesting to pay attention that this operator opens new possibilities in order to select objects, when compared with traditional reconstruction openings and area openings. In section 4 we will show how and why we use it to extract characters in a plate.

The extension of the above ideas to gray-scale images is straightforward with the ideas of presented in [2]. However, it is important to notice that the implementation of Bounding Box Connected Opening by decomposing into binary and recombining the result, as in [2] is not be the fastest way of implementation of this operator. However,




(a) (b) (c)

Figure 2. Morphological operators: (a) Original Image. (b) Result of BB Connected Openning. (c) Result of BB Closing.

it is beyond the scope of this paper to describe implementation details. It is sufficient to say here that they can be implemented efficiently in a similar manner to area openings [6] (obviously, the results are independent of the particular implementation).

### 3.2 Bounding Box Closing

The second operator that we are introducing is a closing in the sense that it is extensive (the result has more foreground pixels than the input). However, strictly speaking it is not a closing in the sense of [2], since it is easy to see that it is not idempotent. However, if it is iterated, it becomes idempotent after a few iterations. This operator is easily explained for binary images. The purpose of this operator is to create for each connected component the smallest rectangle that includes the connected component. Notice that this operator is not connected (the shape of the contours may change) and that the rectangles coming from two unconnected objects may merge into a single connected component (see figure 2). This is what causes that this operator is not idempotent.

Figure 2-c) shows what this operator does. White pixels represent the original foreground, gray ones are those that are added to the foreground by this operator and black pixels are the background.

Let's remind again that we have used the grayscale version of this operators to extract the plate characters.

## 4 Character extraction

In this section we describe in detail all the steps needed to locate the regions in the image that with a high probability correspond to plates. Our idea is to apply different morphological operators in order to select the regions that fulfill some simple intuitive criteria. Our system has been tested on Spanish license plates only, however, the ideas presented are general enough to be extended to other plate layouts from different countries.

First of all the image is converted from color to grayscale.

1. Since plate characters are thin dark structures, the first step performs the residue of closing with a horizontal structuring element (SE) larger than the maximum expected width of a character. It could be argued that a more isotropic SE (like a square) could be a better choice. However, it takes twice the time to compute and we have observed no improvement in performance. Figure 3-(b) shows the result of this step.

2. The characters have a minimum width and height. This can be done using the Bounding connected opening width parameters minimum expected width and height. The result of this step can be seen in 3-(c).

3. Also the characters have a maximum width and height. This can be done using the residue of Bounding connected opening width parameters maximum expected width and height. The result of this step can be seen in 3-(d). Notice that only thin objects which were darker than background in the original image and with a size approximately the same of the expected characters have been preserved.

4. Next, we exploit the fact that characters have other adjacent characters:

   (a) Obtain the BB closing (fig. 3-(e)).

   (b) Make a dilation with a horizontal SE of the maximum expected inter-character gap size.(fig. 3-(f))

   (c) Apply the Connected BB opening with the minimum expected plate dimensions as parameters. This leaves only rectangles of the right size that have been built by joining individual characters. Normally only one of such rectangles is found in images containing a license plate. If more than one rectangle is found, all candidates are passed to OCR to be read, (fig. 3-g).

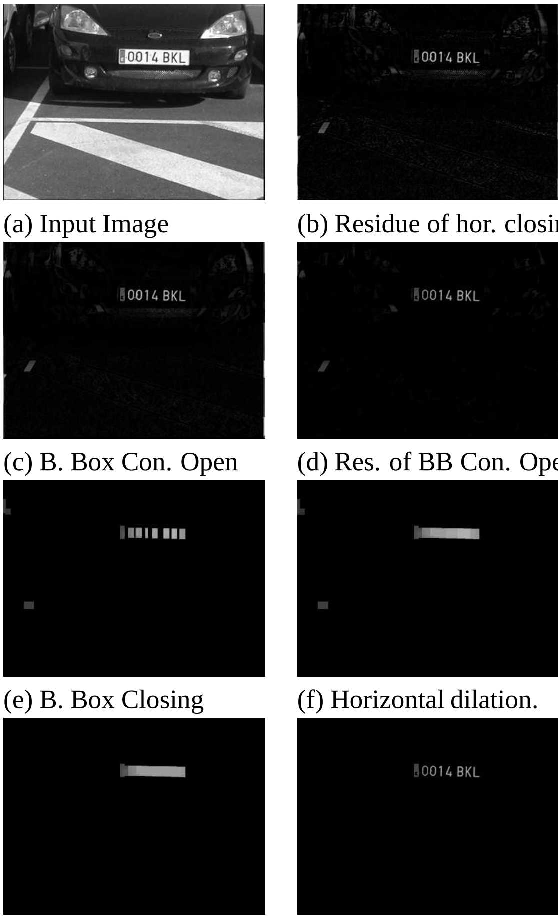
5. In order to obtain the characters it suffices to take the pixel-wise minimum between Minimum of fig. 3-(d) and fig. 3-(g) obtaining the result shown in fig. 3-(h)

A simple threshold on image fig. 3-(h) constitutes the input to the OCR. It is interesting to note the complexity of the original input image and how the proposed algorithm performs a fast (less than 1/25 seconds) and effective extraction of the plate characters.

Figure 4 shows samples of different images where the plate is located using the algorithm described in this paper. Notice the differences in illumination, size, background, presence of shades, sun reflections, etc. among the images.

## 5 Conclusions

This paper describes an algorithm that allows the location of vehicles' license plates using morphological algorithms. The main advantages of the technique that we propose are the computational efficiency and the easy configuration of




(a) Input Image (b) Residue of hor. closing.

(c) B. Box Con. Open (d) Res. of BB Con. Open.

(e) B. Box Closing (f) Horizontal dilation.

(g) Connected BB open (h) Plate characters.

Figure 3. Steps of license plate extraction. All operators are gray-scale.

the algorithm parameters in terms of minimum and maximum sizes of characters and plates. The algorithm makes use of many features that distinguish a car plate from other structures in general video.

The system has been tested in real urban environments with natural illumination conditions obtaining a plate detection rate of more than 99%. Currently a commercial product using the technology presented in this paper is under development in order to monitor parked cars on the streets in order to locate stolen vehicles.


Figure 4. Gallery of images.

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