

Research Document
Number Plate Recognition

Francois Ribemont

Supervisor: Nigel Whyte

December 16, 2011

Contents

1 Introduction

Number Plate Recognition (NPR) is a software that reads Irish car plate numbers from pictures. The input of the program is an image, and the output of the program is a text string containing the car plate number. By executing a series of algorithms, the program will be able to take an image as an input and generate the number plate in a text format. For the Figure ??, the output would be: 03MH1847.



Figure 1: Irish car plate

This software is usually embedded with video cameras. It is mainly used by the police to recognize stolen vehicles or speeding. If, for instance, a car goes too fast on a motorway, some sensors send a signal to the camera, and then a picture is taken. Then it gives the taken pictures to the NPR system, and NPR output the number plate in a text format.

Irish car plates respect this format: YY-CC-SSSSSS where YY is a double digit for the year of registration, CC represents the two letters from which county the car has been registered in, and finally SSSSSS is the serial number. This serial number starts from 0 every year, and is specific to a county, meaning that 157 in Dublin is different than in Carlow. All the specifications about Irish car plate

regulations, such as the size of characters, thickness of the edges, distances between characters, can be found on the Irish Status Book's website [?].

The software should be able to read car plate number for a range of distances from 5 meters to 15 meters. Because the plate is not always parallel to the ground (if the car is turning to the right or left, or if the ground is not flat for example), the software should identify car plate numbers from 0° to 10° . Another issue could be the dirt on a car plate. If the dirt is light enough and is not located directly on the car plate characters, the software should be still able to read the numbers. We also assume that there will be only one car plate readable on the image.

2 Existing commercial system

We can mainly find NPR on Closed-circuit television (CCTV) and on systems used by the police to recognize stolen vehicles or speeding.

2.1 CCTV Camera Pros

The DWC-LPR650 is a video-camera that takes pictures of car plates. This model is specific to the American cars which have reflective car plates. The distance to get the best results is between 75 and 100 feet (22.86 to 30.48 meters). The video-camera can work in 4 different traffic modes related to the speed of the cars [?]. No information about the embedded software is available. It is priced at €1799.99.

2.2 Spytown

The DWC-LPR650 is a video-camera that takes pictures of car plates. It is said that it can "captur[e] car plate in "any extreme light conditions", and this can capture images "both day and night" [?]. It is priced at €609.00. The product is made by Digital Watchdog. No information is available about the embedded software.

2.3 Surveillance-Video

REG-L1875-XE-B is a video-camera like the previous ones. It embeds a licence plate recognition software. This camera is able to take pictures of vehicles at a speed of 160 km/h. This video-camera is priced at €1575.00 [?].

3 Existing softwares

Roughly, we can say that the NPR software can be split in two parts. The first part is a bunch of mathematical processes to locate the car plate. The second one is what we can call an Optical Character Recognition (OCR).

3.1 Image modification software

GIMP

GNU's Not Unix (GNU) Image Manipulation Program (GIMP) is, as its name says, a free software image manipulation. Its development has started in 1995, and its latest version was released in August 2011. GIMP is available on most Operating System (OS) such as Windows, GNU/Linux and MacOS.

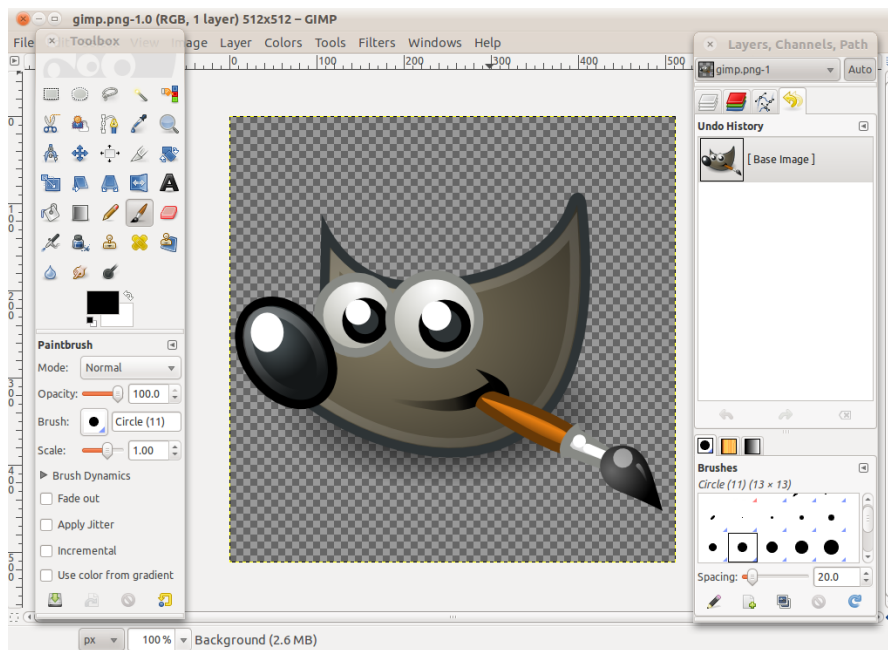


Figure 2: The GIMP interface

GIMP has many different features. It contains a bunch of painting tools such as brushes, pencil, eraser... It supports layers and channels, in particular the alpha channel, which is used for transparency, multiple undo/redo, transformations tools for rotating, scaling shearing, and flipping. It also includes selections tools such as rectangles, ellipses, fuzzy, Bezier, intelligent scissors and free. GIMP supports

many different data types for images including JPEG, GIF, PNG, BMP and even PDF [?].

GIMP can be used in a different way than other image manipulation softwares, some features can be called by other programs. Its interface is tiled, it can surprise at first, but it can be very handy with time. GIMP also has a plug-in system. Plug-ins may be written in Perl, Python or Tcl. These scripts can use the 150 standard effects and filters.

Photoshop

Photoshop is probably the most known image modification software. Photoshop is a proprietary software developed by Adobe. Its development has started in 1987, but the first release under the Photoshop name had been made in 1988.

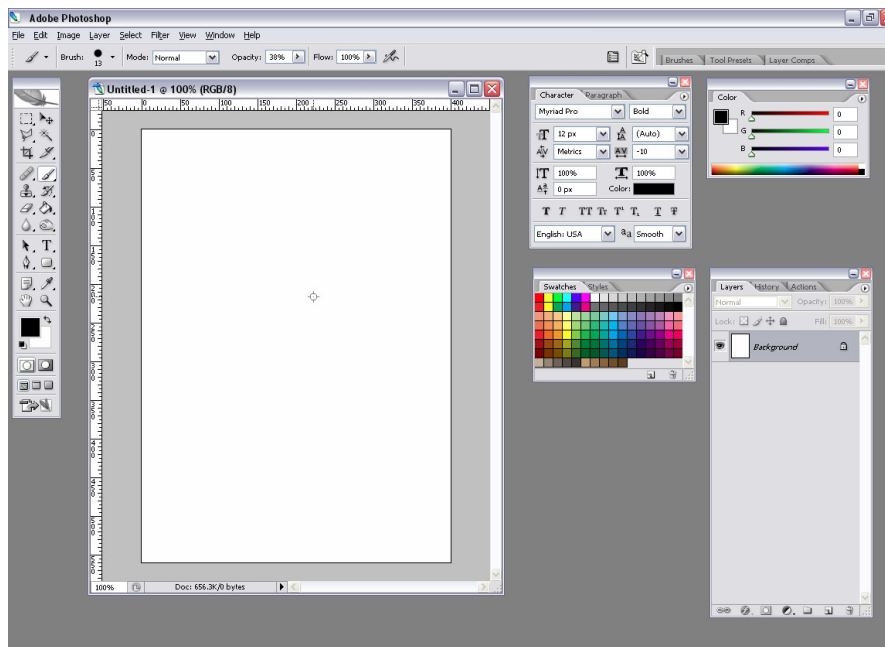


Figure 3: Photoshop interface

Photoshop contains loads of features containing automatic lens correction, straighten image tool, a gradient tool preset for neutral density. We can also find control color and tone features such as High Dynamic Range imaging (HDR) imaging, HDR toning, noise removal, complex selections, color decontamination... A full list of features is available on the Adobe's website [?]. Like GIMP, Photoshop has its plug-in system

Phatch

Photo & Batch (Patch) is a free modification image software. As far as we can go in the Patch's history, there is no release date for the first release called 0.1. The second one called 0.2 was released in September 2009, and the last one has been released in March 2010. So it is a new project, and might not be as thorough as other softwares.

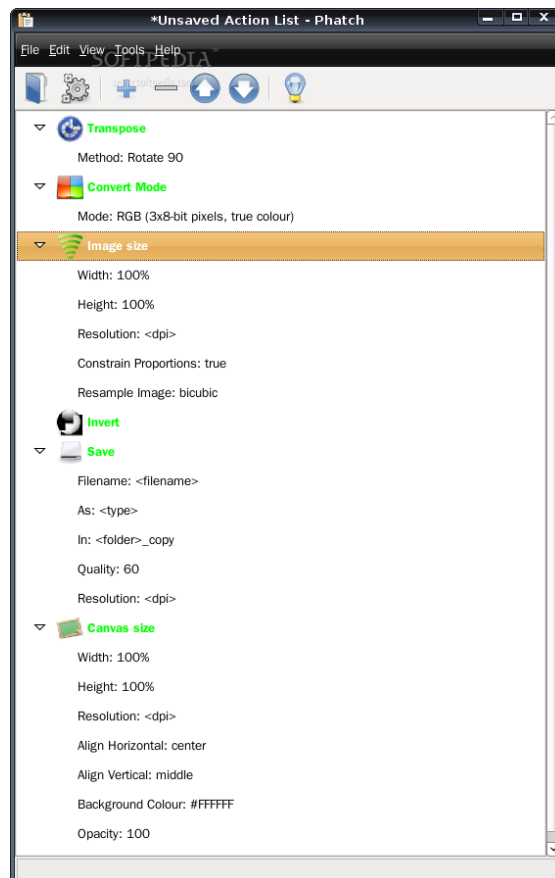


Figure 4: Phatch interface

Such as Image Magick (described below), Patch is different from the usual image modification softwares. Indeed, its approach to image modification is a bit different, Patch will actually deal with bunches of images, and apply modifications set up by the user like resize, apply filters, colorize, fit, relect... A full list is available on the Patch's wiki [?].

Image Magick

Image Magick is a free image modification software, its development has started in 1987. The latest version was released in November 2011¹.



Figure 5: Image Magick logo

Image Magick is not like the other image modification software. Its main characteristic is that there is no Graphical User Interface (GUI), except for the image rendering that uses the X Window GUI. So, we can wonder how it works. Image Magick is composed by a number of commands. Image Magick has a lot of features, such as format conversion, transforms (resize, crop, flip, trim), transparency. It can also draw (add text, or shapes).

Image Magick support over 100 formats, including videos. For a complete list of the available feature, have a look at the Image Magick's website [?]. Because of its interface, Image Magick is used differently than the other softwares, but it does not mean that Image Magick is less powerful. Image Magick is mainly used in Shell scripts. It can then deal with complete folder, just by launching the script.

3.2 Optical Character Recognition

Ocropus

Ocropus is a free as in freedom OCR software. It is developed by the German Research Center for Artificial Intelligence in Kaiserslautern, and is sponsored by Google. Ocropus might be the engine of Google Books to read texts from physical

¹<http://sourceforge.net/projects/imagemagick/files/6.7.3-sources/>

books. But Google did not really talk much about this engine [?, ?]. OCRopus is available on MacOS and GNU/Linux.



Figure 6: OCRopus logo

The code is written in C++ and is well documented, even the design documents are published [?]. [?]. Every component of the software is pluggable, so it is easy to take off some parts and add new ones. Before the release 0.4, OCRopus used the Tesseract engine for the character recognition, but now uses its own one [?].

Tesseract-ocr

Tesseract was initially released in 1985 by Hewlett-Packard (HP) Labs until 1995. Then, only a few changes for the next decade, and finally, HP decided to publish the source code as a free software. Since then, Google took the project over, and is the main maintainer. In 1995, it was in the top 3 performers at the OCR accuracy [?]. Tesseract still has very good performances, in word accuracy or characters accuracy, with results ranging from 0.14% to 6.66% except when there is color in the text, and in that case Tesseract is really bad, with a high failure rate (93.33% and 89.75% for two different texts for the error rate, and 75.14% and 73.57% of error rate for the characters) stil

Tesseract is written in C and C++. The application is available on Windows, GNU/Linux and MacOS. Tesseract can be used to recognize layouts by using OCRopus [?]. Tesseract can recognizes 29 different languages [?], and it is easy to extend this system with other languages. [?].

Microsoft Office Document Imaging

Microsoft Office Document Imaging (MODI) was, as its name says so, developed by Microsoft. It was first included in Office XP and was in some versions including Office 2007. It was used with scanners in order to copy, edit and search in scanned document. MODI is no longer furnished with Office. We can read this

message on the Microsoft's website: "In Office 2010, MODI is fully deprecated. This change also affects the setup tree, which no longer shows the MODI Help, OCR, or Indexing Service Filter nodes on the Tools menu. [...] MODI and all its components are deprecated for 64-bit Office 2010" [?].

Ocrad

Ocrad is the OCR of the GNU project. This software is free, and is written in C++. The development probably started in 2003 [?]. 2007 and the latest release was available in January 2011 [?]. Ocrad is available on Unix-like OS. Like Tesseract and Ocropus, Ocrad has no GUI. It is usable by command-line. Ocrad has an error rate between 20% and 38%, for the word accuracy, and between 5% and 13% for the character accuracy. Ocrad does not seem very performant with italic text "Both Ocrad and GOCR perform very badly on italic text" [?].

4 Languages

4.1 Python



Figure 7: Python logo

Python is an interpreted programming language created in 1991. Its philosophy is to be readable by any programmer because of its syntax. “Python combines remarkable power with very clear syntax” [?]. Python is a multiple programming paradigms meaning that it can be used with object-oriented paradigm or with functional paradigm, or even with procedural, reflective or imperative paradigm. Python was influenced by ABC, ALGOL 68, C, C++, Haskell, Icon, Java, Lisp, Modula-3, Perl. Python has different implementations, but CPython is the most used and this implementation support more features than the others [?]. Python can be install and used on Windows, GNU/Linux, GNU/BSD, MacOS [?] and some other platform like Android [?].

Its libraries is very thorough. “Fans of Python use the phrase “batteries included” to describe the standard library, which covers everything from asynchronous processing to zip files” [?]. Moreover, it is possible as any other good language, to import other libraries written by other programmers. These libraries can be written in C or Python [?].

The built-in types are very powerful as well. Strings, dictionaries, lists and tuples are the commonest, but not least because we can also find unicode, bytearray, buffer, xrange, set and frozenset. Moreover these particular and powerful types, booleans, integers, floats are also available.

```
class MyClass:
    def operation(self, value, value2=1):
        self.data = 2*value + value2

    def display(self):
        print self.data

class SecondClass(FirstClass):
    def display(self):
        print 'Current value = "%s" ' % self.data

if __name__ == '__main__':
    z = SecondClass()
    z.operation(42, 53)
    z.display()
```

Listing 1: Python Sample

4.2 C++

C++ is a programming language invented in 1983. The last standard was published in 2001 [?]. Like Python, C++ is a multiple paradigm language. C++ was influenced by C, Simula, Ada 83, ALGOL 68, CLU, ML.

The built-in types in C++ are the integers, wide characters (for non-ASCII characters), floats, boolean types, void, enumeration (such as C), arrays, pointers strings, structures and classes, unions and functions.

The standard C++ library is a set of 51 headers. These headers contains the list of function names. Each one of them is described in UNIX man pages. The list of headers is available on dinkumware [?].

```

#include <iostream>
using namespace std;

class who
{
    char name;
public:
    who(char c)
    {
        name = c;
    }

    ~who()
    {
        cout << "Destructing who: " << name << endl;
    }
};

who makewho()
{
    who temp('B');
    return temp;
}

int main()
{
    who ob('A');
    makewho();
    return 0;
}

```

Listing 2: C++ Sample

4.3 Java



Figure 8: Java logo

Java is a semi-compiled programming language initially developed by Sun in 1995, and because Sun was bought out by Oracle, Oracle is the actual developer. It is a Object-oriented paradigm. Java was influenced by Ada 83, C++, C#, Delphi Object Pascal, Eiffel, Generic Java, Mesa, Modula-3, Oberon, Objective-C, UCSD Pascal, Smalltalk.

The compilation of a Java program does not make an executable, but a bytecode. This bytecode has the particularity to be executed on any OS which embeds a Java Virtual Machine (JVM). A compiled program can then be executed on any operating system. It also does not depend of the architecture of the machine.

The Java library is pretty thorough as well. As the documentation shows, there are not less than 3793 different classes in the standard library [?]. Java also contains a set of built-in types which are characters and strings, integers, real numbers and booleans. Everything about the equivalent of lists and dictionaries in Python is located in the standard library and is not considered as a built-in type.


```

public class JavaClassExample
{
    private String name;
    public void setName(String n)
    {
        name = n;
    }
    public String getName()
    {
        return name;
    }
    public static void main(String args [])
    {
        JavaClassExample javaClassExample = new JavaClassExample ();
        javaClassExample.setName(" Visitor");
        System.out.println(" Hello " + javaClassExample.getName());
    }
}

```

Listing 3: Java Sample

4.4 C#

C# is a programming language created by Microsoft in 2001. Its syntax has been inspired by Java, C++, Pascal. C# was influenced by Java, C++, Eiffel, Modula-3, Object Pascal. Like Java, C# is semi compiled and run in a virtual machine called Common Language Runtime (CLR). Figure ?? shows the different layers in programs using the .NET framework². C# has the philosophy of being simple, modern, general-purpose, object-oriented programming language.

Different compilers exist for this language. The official one created and maintained by Microsoft is the .NET framework Software Development Kit (SDK). There are two other compilers which are free (as in freedom): Mono and DotGNU. The .NET framework SDK is only available on the Windows OS whereas DotGNU and Mono are available on different platforms such as Windows, GNU/Linux, GNU/BSD, MacOS. DotGNU do not support the last versions of C#, its support was stopped in 2009 [?], and seem to only implement the version 2 of C#. Mono implements the version 4 [?] which is the last one at the moment.

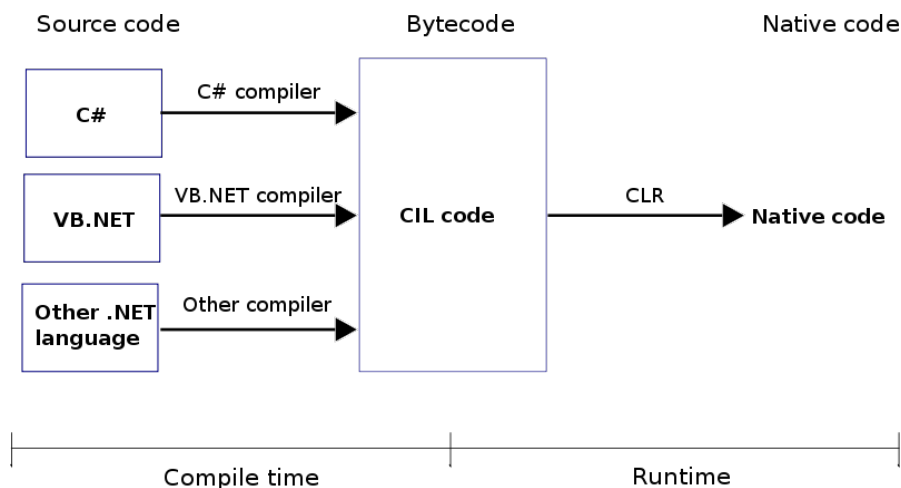


Figure 9: Common Language Runtime

The built-in types are split in two parts. First, there are the built-in types such as the integers, float numbers. . . Then there are the collections for the LinkedLists, Queues, Stacks, Lists. . . . A full list is available on the documentation [?].

²Image from Wikipedia: http://upload.wikimedia.org/wikipedia/commons/6/6f/CLR_diag.svg

```

using System;
using System.IO;

public class WriteFileStuff
{
    public static void Main()
    {
        FileStream fs = new FileStream("c:\\tmp\\WriteFileStuff.txt",
            FileMode.OpenOrCreate, FileAccess.Write);
        StreamWriter sw = new StreamWriter(fs);
        try
        {
            sw.WriteLine("Howdy World.");
        }
        finally
        {
            if (sw != null)
            {
                sw.Close();
            }
        }
    }
}

```

Listing 4: C# Sample

4.5 The language that will be used

Each language has its pros and cons. The executable of a C++ software is not usable on different platforms, a compilation has to be done for every architecture and platform, so it can be an inconvenient if we do not have all the requirements to compile it. C# is mainly used on Windows, and its Mono's implementation is not as good as it is on Windows, and might not exist forever because of some software patenting in United States [?]. Python and Java do not have this issue. And because I know Python better than Java, and because its syntax is much more readable for someone who do not know the language, and its built-in data-types which are incredibly powerful, the language that will be used is going to be Python.

5 The way to proceed

5.1 The principle

In order to create the software, there is a couple of algorithms to implement. Each algorithm, or set of algorithms represents a step. This is an overview of the main algorithm.

- Plate localization
- Plate orientation and sizing
- Character segmentation
- Character recognition
- Syntactical/Geometrical analysis

There are many ways to implement each of these algorithms. A couple of them is presented below.

5.2 Plate localization

The first step of NPR is to localize the plate in the picture. For this, a couple of different algorithms exists and had already been implemented.

Grayscale - Sobel filter - Otsu's method

From 26th January 2005 to 15 February 2005, Scott Douglas and Sean Neubert have worked on an algorithm in order to detect number plates and draw rectangles on the images. This algorithm is available on their website for everyone and had been written in Matlab [?].

Their main algorithm is divided in three algorithms:

- Convert the image in gray scale
- Vertical edge detection with Sobel filter
- Edge map thresholded using Otsu's method:



Figure 10: Grayscale. Before/After

Gray Scale

An image is composed by a triple called Red Green Blue (RGB) of intensities of these colors. Three algorithms made this possible, with three formulas:

Lightness:

$$\frac{\max(R, G, B) + \min(R, G, B)}{2}$$

Luminosity:

$$0.21R + 0.72G + 0.07B$$

Average Brightness:

$$\frac{(R + G + B)}{3}$$

[?]

Sober Filter

The Sobel filter edge detector uses two matrices called Sobel gradient edge detec-

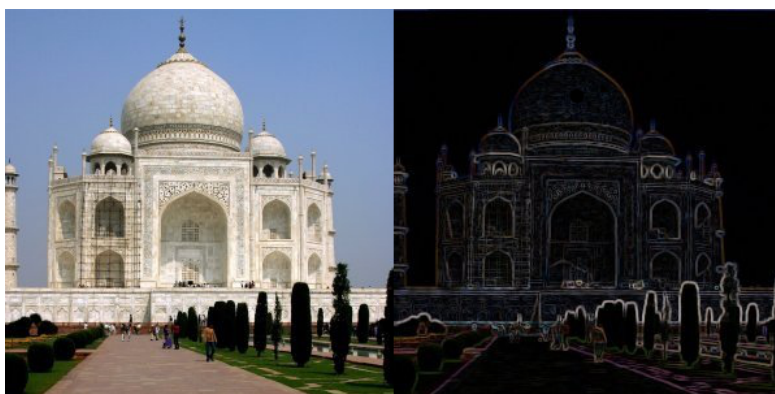


Figure 11: Sobel edge detector. Before/After

tor.

$$\textit{Vertical matrix} = \begin{pmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix}$$

$$\textit{Horizontal matrix} = \begin{pmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{pmatrix}$$

These matrices are applied to every pixels on the gray scaled image.

The Canny edge detector

The Canny edge detector method is another method that aims to get a good detection, a good localization and a minimal response. Six steps for the algorithm:

- Noise reduction
- Finding the intensity gradient of the image
- Non-maximum suppression
- Tracing edges through the image

The noise reduction uses a Gaussian filter which slightly blurs the image. To apply the Gaussian blur, simply apply a Gaussian filter. Here is a 5×5 Gaussian filter.

$$B = \frac{1}{159} \begin{pmatrix} 2 & 4 & 5 & 4 & 2 \\ 4 & 9 & 12 & 9 & 4 \\ 5 & 12 & 15 & 12 & 5 \\ 4 & 9 & 12 & 9 & 4 \\ 2 & 4 & 5 & 4 & 2 \end{pmatrix} \times A$$

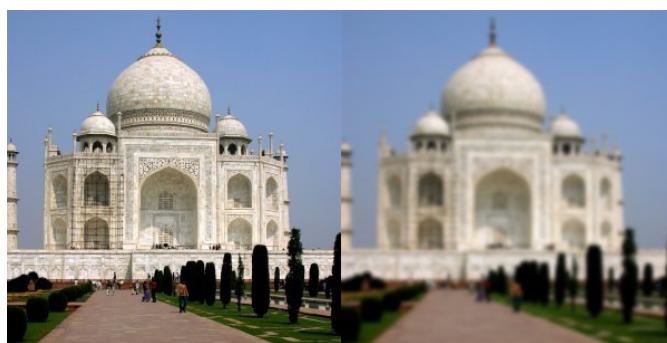


Figure 12: Gaussian blur. Before/After

Finding the intensity gradient of the image uses an edge detection operator such as Sobel (see above). The returned value will be used for the “for the first derivative in the horizontal direction (G_y) and the vertical direction (G_x). From this the edge gradient and direction can be determined.

$$G = \sqrt{G_x^2 + G_y^2}$$
$$\Theta = \arctan\left(\frac{G_x}{G_y}\right)$$

The edge direction angle is rounded to one of four angles representing vertical, horizontal and the two diagonals (0, 45, 90 and 135 degrees for example)” [?].

The non-maximum suppression is defined as : “The image is scanned along the image gradient direction, and if pixels are not part of the local maxima they are set to zero. This has the effect of suppressing all image information that is not part of local maxima” [?]. An algorithm, written in Java is available on the University of Southampton’s website³.

Tracing edges through the image uses hysteresis thresholding which uses two different kind of thresholding itself: high and low. Hysteresis thresholding is defined as: “The hysteresis mode uses a hysteresis loop to provide a more connected result. Any pixel above the upper threshold is turned white. The surround pixels are then searched recursively. If the values are greater than the lower threshold they are also turned white. The result is that there are many fewer specks of white in the resulting image” [?]. An algorithm has been published on the University of Southampton⁴.

³http://users.ecs.soton.ac.uk/msn/book/new_demo/nonmax/nonmax.java

⁴http://users.ecs.soton.ac.uk/msn/book/new_demo/thresholding/hystThresh.java

5.3 Plate orientation

The first method to orientate the plate is called the Hough transformation. It is used to detect lines in an image. “For each pixel in image space (x_0, x_1) , using transformation, $r = x.\cos\theta + y.\sin\theta$. We get a curve $r = x_0 + y_0.\sin\theta$ in the parameter space (θ, r) . Suppose that there are n points in the image space. After translating them to the parameter space, we obtain n curves in the parameter space. If these curves cross the same points (θ_0, r_0) , then the n points in the image space are on a line. So we can find lines in the image space by searching the cross points in the parameter space” [?].

5.4 Character segmentation

The character segmentation is the action to separate the characters, in order to deal with them one by one. The main method to segment the car plates characters is the vertical and horizontal projection (see Figure ??). A peak corresponds to a space, and between these peaks are the characters we are looking for. The projections are the sum of all the values per row (either vertical or horizontal).

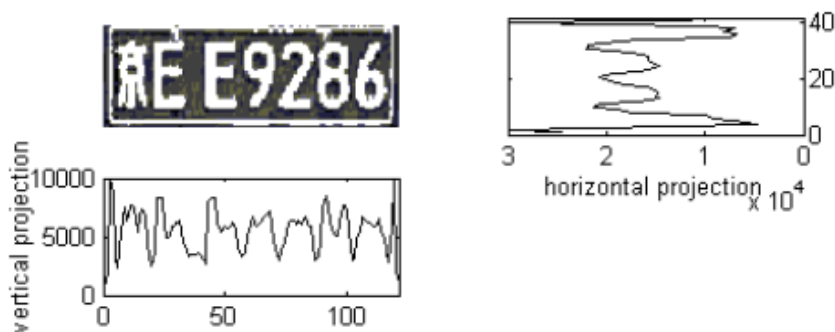


Figure 13: Horizontal and vertical projections

5.5 Character recognition

Two different ways of recognizing characters are possible. The first one is called OCR and the second one is called Template Matching Character Recognition (TMCR).

OCR

The algorithm of an OCR engine is as follow:

- outlines are analysed and stored
- outlines are gathered together as Blobs
- blobs are organised into texts lines
- text lines are broken into words
- First pass of recognition process attempts to recognize each word in turn
- Satisfactory words passed to adaptive trainer
- lessons learned by adaptive trainer employed in a second pass, which attempts recognize the words that were not recognized satisfactory in the first pass
- Fuzzy spaces resolved and text checked for small caps
- digital texts are outputted

[?]

Template Matching Character Recognition

The TMCR is split in two parts: offline and online systems. Online systems are the system we are using: an image where only characters have to be recognize. Offline systems are reading from external sources like a pen writing on a touch screen for example. The second one need a very good algorithm with good performances, because it has more steps, such as localising the pen, and analyse the movement of it as it writes [?].

The algorithm is to use patterns and compare them to the different characters. For this, the characters and the patters has to be at the same size. The pattern who is the best candidate (who match the most) is going to be saved, and we will try to match the next one.

5.6 Syntactical analysis

This is a part where no specific algorithm are required. The plate which had been analyzed, has now an output (since the character recognition). The only thing to do is to check if the plate respects the syntax of the licence plates of the country (Here, Ireland). As said in the introduction, the specifications are available on the Irish Status Book's website [?].

List of Figures