License plate detection for preserving privacy using Haar classifiers

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Abstract. *This paper deals with the issue of the preservation of privacy on surveillance cameras recordings. Increase in the number of surveillance cameras has lead to a reduction of privacy. In order to preserve privacy, a special .XML file which will be used in the algorithm was created. This research presents the method for creating an XML function through Haar classifiers which aims to detect licence plates of vehicles and blur the licence plate in order to preserve citizens privacy*.

Keywords. licence plates, privacy, Haar-like features

1 Introduction

In the last 20 years computer power has extremely increased and prices declined. Computers have become available to everyone. Increase in the availability of computers has increased the emergence of computer crime. Traditionally, people protect their sensitive data with passwords and PINs. But these protection method are becoming less secure as computing power increases. This is the main reason why biometric features for preserving data are introduced. Breaking the password or PIN, or something that a person knows is far easier than stealing something that a person is. Biometric technologies are becoming increasingly popular, more accepted and less expensive.

Video surveillance on the roads is a new concept. With video surveillance the number of traffic accidents and possible traffic jams are reduced, and if an accident occurs, it can be determined who is responsible for it. The goal of this research is to ensure the privacy of citizens along the roads in cars. The main goal is to create an algorithm which, in real time, detects and blurs license plates and makes them unreadable. The license plate is somenting that uniquely identifies the vehicle and the vehicle owner.

The algorithm has to be fast, but simple enough that existing computers in traffic control centers can run it. In this way the cost of intoducing the algortihm in everyday use is reduced.

2 License plate detection

This research intertwines two terms - license plate and privacy. Each state has a defined appearance of the license plate and it represents an official document, together with the vehicle documents. License plate is unique and there are no two of the same. Because of this uniqueness, the vehicle owners can be clearly identified. Registration number belongs to a single owner in a certain time period. This is the reason why a license plate represents private information.

Another major concept of this work is a term privacy. "The word privacy translates as confidentiality, trust, hidden, peace [1]." Every person has a right to privacy. "It represents an elementary human right, as internationally, and the constitutional right of public-law character and personal right of a civil-law importance as one of the indispensable elements of human existence that protects a man of excessive encroachment of state government, the public and other individuals in the decisive individual's mental, spatial and informational privacy [2]."

The title of this paper, and the basic functionality of the algorithm, is the word *detection*. There are many papers on this subject using different methods and their title contains the word *recognition*. The detection of license plates indicates the ability of a computer to classify license plates differently from other objects in the image. Recognizing the license plate often involves identifying the content with the help of OCR (Optical Character Recognition). In this paper only license plate detection is used, because the goal is to make the license plate unreadable and it is much less complex and less time consuming to mathematically describe the license plate than all possible characters on it.

3 Previous work

Other authors used the complex algorithms and advanced mathematical methods to determine the portion of the image containing the area of interest, in this case the license plate. Also, their primary goal was reading the characters of the license plates, or OCR. Papers using similar methods to manipulate the image in order to detect license plates will be described. The first paper is by Ondrej Martinsky [8]. He describes the construction of recognition systems based on vehicle license plate and the paper gives a mathematical background. His work is based on the segmentation of images, and presents the algorithm implemented in the Java programming language. The paper is mainly concerned with character recognition (OCR), but it is necessary to detect the licence plate to detect charactrs. Among other things, in human natural language license plate is defined as "a small plastic or metal plate on the vehicle used for official identification" [8] while the computer does not understand such a definition. For a computer, registration plate is "rectangular area with a distinctive appearance of horizontal and vertical edges" [8]. Convolution matrix and Sobel filter are used for edge detection. The program achieved great accuracy and under different camera angles, but the author states that there is room for improvement.

Other paper presented uses similar methods to those used in this work [9]. The author describes the software implementation of Haar's classifiers, which are the basis of the algorithm presented in this paper. The author states the method of Viola and Jones, underpinning Haar's classifiers, and says that their primary purpose is face detection, but can be trained to find any kind of object, because it uses machine learning algorithms. The author describes the construction and reliability measurement of linear cascade and tree cascades. She trains the cascades on a set of 2100 positive examples, or images that contain a subject that wants to be detected, and 711 negative examples, or images that contain anything other than the object that wants to be detected. At the end, she tested the cascade with 918 pictures that were not used during the function training.

During a short comparison of these two works, it is easy to see that the first paper, which uses mathematical image analysis and segmentation of images is far more demanding and more difficult to explain. Nevertheless, it achieves great results, which are far better than the results achieved by using a cascade in the second paper.

4 License plate detection algorithm

The aim of this research is to develop an algorithm that will, with sufficient accuracy and in real time, detect an object of interest, in this case that is the license plate. The paper will use the Viola-Jones algorithm [11] that was developed by Paul Viola and Michael Jones. This algorithm can be used for detection of any object. When designed, it was used for detection of faces in an image, but today it is used for any object. The selected algorithm is one of the machine learning algorithms, and these algorithms operate on the principle of training or learning.

An additional advantage of this algorithm is, according to Stojanec [3], that its implementation in the OpenCV library functions as a black box.

4.1 Database

The algorithm is based on one XML file which contains the entire knowledge. This file is an output parameter of process caller *training the function* [10].

In the beginning, it was necessary to collect a large number of images. The images are divided into two categories, positives and negatives. Positive images are those images which contain the object of interest, in this case the license plates. These images are taken from publicly available databases of the Faculty of Electrical Engineering and Computing [4]. A total number of downloaded images was 510 positive images. On the other hand, it was also necessary to collect the negative images, or images that do not contain an object of interest. These images were collected from various sources on the Internet and there were 1987 pictures.

After downloading the images, it was necessary to prepare them for further processing. Each area of interest on the image was manually tagged. The area of interest is an area in which the license plate is located. Coordinates of obtained rectangles are stored in a separate text file that will serve as a source of information in the training process. This process is time consuming and laborious, and requires a lot of attention. It is necessary to accurately mark all license plates in images.

In Croatia, there are two types of license plates - rectangular and square. In order to get a function that will recognize both types of license plates, it is necessary to have images of both forms in database.

Some images from the database were not adequate so they were dropped from further use, so the final result was a sample of 475 marked license plates. Images that were not adequate were images taken in the dark or license plates that were dirty.

4.2 Haar Classifier

As mentioned earlier, Viola-Jones algorithm will be used. Viola and Jones devised the concept of integral images so the algorithm could work faster. Integrated image is a mathematical representation of the initial, realistic images [11].

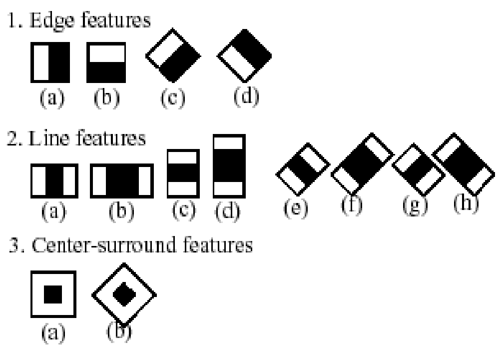

Figure 1: Viola-Jones features [7]

Figure 1 shows the Viola-Jones features. In the first row under a) and b) the original Haar's features are shown. Other features were designed and implemented by Viola and Jones to further speed up the algorithm. Each rectangle in the original size is 24x24 pixels because this is the optimum size when it detects a human face, and the original algorithm has been designed for this purpose [11].

Integrated image is calculated by summing up the values of image elements in the white part of the square and the black part of the square, and then the two values are subtracted. "Each picture element in the integrated picture S_i you get by calculating the sum of all image elements of the original image with the left and above the desired image elements, including required [5]." The sum of the values of integral elements of the image is expressed by the formula as follows:

$$S_i\,(x,y) = \sum_{x' \leq x, y' \leq y} S(x',y') \quad [5]$$

Although this method gives good results in a short period of time, it can be further accelerated. It is possible to get the value of all image elements with a single pass through the image. It takes the sum of all image elements with the column above the required element, and a new formulas for the calculation are:

$$S_S(x,y) = Ss\,(x, y-1) + S(x,y) \quad [5]$$

$$S_i(x,y) = S_s(x,y) + S_i(x-1,y) \quad [5]$$

It is possible that it is not necessary to count the value of rectangular features. With shapes that calculated the value of rectangular areas there are features that calculated the value of rotated areas.

In this case a new formula for calculating the value of integral image has to be used:

$$AR[x,y] = \sum_{x' \leq x, x' \leq x-|y-y'|} A(x',y') \quad [6]$$

In this case AR is equal to S_i but different authors use different notation.

Each of the displayed features can be represented as a single weak classifier. The process of calculating the strong classifiers lasted too long to be executed in real time, so multiple weak classifiers need to be calculated and they can be calculated easily and quickly. The values of weak classifiers need to hook into a strong classifier. This is done by using the AdaBoost algorithm [9].

"Boosting is the meta-algorithm of machine learning, which from a set of weak classifiers builds a strong classifier [7]."

The method of calculation of the weak classifier is extremely time-consuming process. It is necessary to determine the optimal feature for each image. Since there is no logical way, Viola and Jones have proposed a simple brute-force method. This means that each feature must be checked in every case to learn how to detect it with the best performance. This is a method for determination of only one weak classifier. A single image usually has about 180 000 samples [4]. It is easy to see that the process of checking each sample for each of the images in the training sample should be carried out many times. That is why the process of building the tool may take several days.

The first classifier in the series has the lowest accuracy, and every additional increasing accuracy. To make algorithm work quickly the whole picture is taken as an input only in the first classifier with the lowest accuracy. Areas that the classifier highlighted as potentially positive areas or areas which may contain the object of interest, are input to the next classifier. Every next classifier has less areas that should be checked, and it does not waste time to check areas that earlier, simpler and quicker classifiers rejected [9].

XML file is built by layer. As a rule, the more levels there are to the function, the accuracy is higher.

This research implements the process of training with 10 levels and it lasted for more than 4 days on a personal computer and Wndows operating system. Some authors state that the process is faster running on Linux operating system. It is recommended to build a function with at least 20 levels, but it was estimated that it would take too long. The process of training requires a considerable amount of RAM. 1 GB of memory was used for training a classifier. Reliability or warning error of each classifier specifies the starting parameter of training. This research defined it to 0.4 which means 0.4^{10} or 0,000105. This means that 1 cascades (with multiple classifiers) are trained as long as its classifiers have not achieved the level of false recognition of 0.4^{10}. That means that the total number of incorrectly identified objects will be only 0.000105 which is an extremely small number and an affordable solution.

As a boost algorithm Real AdaBoost is used because it proved the fastest. To build a classifier using another boost algorithm 8-10 features were needed. When Real AdaBoost was used, that number has been reduced to only 3-5, which saved time.

When the device is accessed and the image acquired, it is necessary to convert the RGB color space to the 8-bit grayscale. There may be some additional image transformations, such as histogram equalization of the image, focus adjustment and blur or a number of other parameters. It is better to have less transformations on image to unburden the processor and for the execution of the algorithm in real time. Each additional transformation on the image requires a certain amount of processing time and slows down the performance.

One feature which allows to further speed up the process of detection with Haar's classifier is to set the minimum size of the rectangle that searches an object of interest. Thus, it is ensured that all areas that have dimensions less than the default will not even be observed.

5 Results

In order to validate the created XML file it is necessary to test the algorithm. The algorithm is validated on a sample of 35 files that were not present in the original sample. License plate successfully identified the 26 photos or 74.28% of the sample for testing. False recognized license plates was 6 or 17.14% while falsely denied or unrecognized license plate was 3 or 8.57%.

Figure 3: Final results

This XML function does not contain sufficient knowledge to work under all circumstances. The problem is an image recording at an angle. The rectangle that indicates the found areas of interest can not rotate on the z-axis. Therefore it creates more rectangles, so that the algorithm covers the highest possible area of license plates. This leads to the appearance of multiple false recognition. Another problem are the areas that morphologically resemble to license plate. These are areas that are bordered by a higher-contrast colors and contain a sign. An example of such false recognition of the surface is shown in Figure 4.

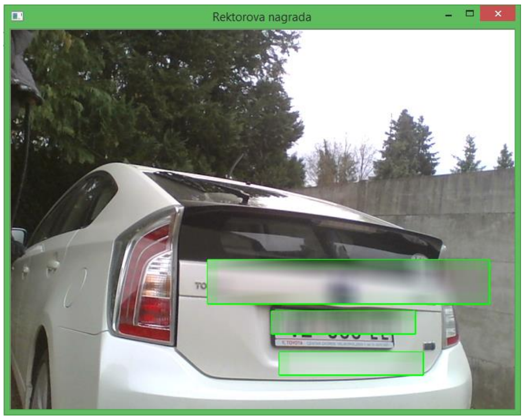

Figure 4: Multiple false recognition

These problems are solvable. It is necessary to collect a larger amount of images at the beginning of the development process. In this case 475 images were used. Recommendations by various authors are to use more than 2,000 positive images. It takes images that are taken from different angles and at different brightness levels. Also the training process was done on 10 levels. Some authors state that is advisable to conduct training on 20 or more levels.

6 Conclusion

The goal that was set at the beginning of the work has been successfully accomplished. A function that detects license plates and makes them unreadable was created. Some progress in preserving the privacy of all drivers has been made, and on the other hand the road safety has not been reduced because the algorithm does not affect the original recording. Also, the desire to create an algorithm that performs its task in real time is achieved. Image manipulation is minimized, rejection areas that are not of interest were recorded in the classifier but also within the algorithm itself, and processing all recorded images in real time has been achieved.

Once again it should be noted that this function does not represent the final solution. This is just a prototype. The observed defects and ideas for elimination of this defects have been proposed, which leads to better and more reliable end product.

It is important to become aware of the fact that we are observed and in most cases we do not know it. Maybe at first it looks like license plates have no significance for the detection of somebody's identity or invasion of privacy because it is the object that each participant in traffic sees. But the roads are becoming more covered with different types of cameras, and a reconstruction of somebody's movement becomes an almost trivial task. Certainly not pleasant to live with the knowledge that anyone at any time can know the exact location and time of movement of a person. In this way someone's lifestyle habits can be traced. The centers that store these data, which can be called big data, are not guarded by special protections and operators who work there.

That is why it is necessary to provide the citizens a certain level of security and prevent the possibility to be tracked by inadequately trained staff.

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