Development of Algorithms for Vehicle Plate Recognition

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***Abstract-** Due to the increasing insecurity in public areas such as parking lots, the inclusion of surveillance cameras has been necessary as an effective system for crime prevention [1]. Considering this scenery, this project aim was to develop a program for a commercial high-resolution camera to control access to a parking lot. The project is focused on developing image recognition algorithms that capture the license plates of vehicles, and through a database, the system allows access to the parking lot only to vehicles whose plates are in that base. It has been carried out a study of several possible algorithms to stablish the most ideal for implementing them in the application. The most suitable algorithm is developed in LabVIEW software and its Machine Vision toolkit.*

***Keywords:** plate recognition, computer vision, pattern matching, database, IP camera, access control, Labview, OCR.*

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Abstract- Due to the increasing insecurity in public areas such as parking lots, the inclusion of surveillance cameras has been necessary as an effective system for crime prevention [1]. Considering this scenery, this project aim was to develop a program for a commercial high-resolution camera to control access to a parking lot. The project is focused on developing image recognition algorithms that capture the license plates of vehicles, and through a database, the system allows access to the parking lot only to vehicles whose plates are in that base.

It has been carried out a study of several possible algorithms to stablish the most ideal for implementing them in the application. The most suitable algorithm is developed in LabVIEW software and its Machine Vision toolkit.

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The objective of the system developed is to recognize license plates in vehicles at the entrance of a parking lot by digital image processing through LabVIEW´s machine vision toolkit and an IP high resolution camera.

The software designed is able to locate the license plate within a captured image of a vehicle and recognizes characters and numbers within it. The license plate in the image is located by searching for patterns. For recognition of characters and numbers on the plate, optical character recognition, OCR is used.

Once the text on the vehicle plate has been "read", characters and numbers are compared to a database containing all plates of vehicles that are authorized for entry into the parking lot.

I. HARDWARE DESCRIPTION

The main hardware components of the application are: IP camera, its power supply and a computer.

A. IP Camera

Being an outdoor application, the IP camera must tolerate different weather conditions such as sun, rain and temperature variations.

The IP camera must have high resolution in order to avoid further and unnecessary analysis due to blurred and defective samples caused by low quality images.

The IP camera must be able to offer the same functionality regardless of environmental conditions and the amount of light. Also, it is needed a camera with IR filter that detects the amount of light present in the environment, corrects variations and do not alter its functionality. According to these requirements and conditions, Pelco Sarix camera IX10DN series has been selected as the most appropriate.

The Pelco Sarix 1.3 megapixel day / night model is a network camera. Its live recording can be observed using standard web browsers such as Microsoft Internet Explorer, Mozilla or Firefox. The camera comes with its own software installed, which can be enabled and configured using a web browser [2].

B. Camera power supply WCS1-4.

The multiple power source WCS1-4 is designed for exterior and interior applications. The power source WCS1-4 can supply electrical power to up to four units and can handle the operation of units of horizontal and vertical rotation, heaters, fans and cameras. This power supply is capable of supporting up to 4 amps (100 VA) of total load. [3].

C. Computer

To perform all processing of the images provided by the IP camera and software development in Labview, it is required a computer with at least a Intel® Pentium® 4, 2.0 GHz, Windows 10/8.1/8/7 SP1 (32 or 64 bits), memory: 512 MB RAM or superior, a 100 megabits (or higher) network card, minimum 1024 x 768 resolution color monitor [4]. Also, it is required a web browser: Internet Explorer 9.0 (or higher) or Mozilla®, Firefox® 20.0 (or higher), media player: Pelco's Media Player or QuickTime® for Windows 7 or higher.

For the development of the application software in LabVIEW, it was required LabVIEW´s Report Generation Toolkit for Microsoft Office, Vision Development Module and Microsoft Office.

II. SOFTWARE DEVELOPMENT

Firstly, it was carried out a study of different methods for the vehicle plate detection in an image of the vehicle captured when entering to the parking lot. In this study it was also important to consider the different conditions limiting the application such as the uncontrolled ambient lighting, geometry and orientation of the vehicle plates, text size and determining the type of image for information processing.

From this study, the problem was divided into two parts:

- Location of the license plate within an image.

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– Recognition of the characters of the license plate.

For the first part, in order to locate the license plate within an image, a pattern search was envisioned.

A. *Searching the pattern "ECUADOR" present on license plates.*

For the location of the license plate within an image, it was considered the best alternative to search for the word "ECUADOR", Fig 1, present in all plates of the country.

Fig. 1. Word located in all license plates in the country.

In LabVIEW, pattern search uses a procedure known as Cross Correlation. The basic concept of correlation can be understood by considering a sub-image *w*(x,y) of size K x L within an image *f*(x,y) of size M x N, where K ≤ M and L ≤ N, as shown in Fig. 2.

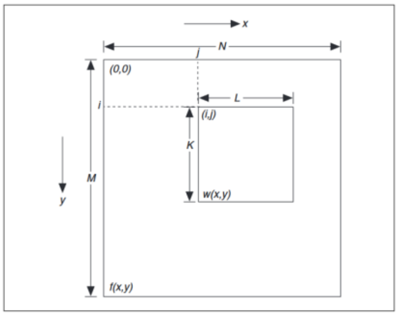

Fig.2 Cross Correlation procedure.

It is assumed that the origin of the image *f* is at the top left corner. Correlation is the process of moving the pattern template or subimage *w* around the total image area and computing the value of correlation C in that area. This involves multiplying each pixel in the pattern template by the image pixel that it overlaps and then summing the results over all the pixels of the template. The maximum value of C indicates the position where *w* best matches *f* [5]. The correlation between w(x,y) and f(x,y) at a point (i, j) is determined as in (1).

$$C(i,j) = \sum_{x=0}^{L-1}\sum_{y=0}^{K-1} w(x,y) * f(x+\mathrm{i},\ y+\mathrm{j}) \quad (1)$$

Where i =0, 1…, M–1, j = 0, 1..., N–1, and the summation is taken over the region in the image where *w* and *f* overlap.

The LabVIEW virtual instrument (VI) that allows an effective search of the "ECUADOR" pattern in an image through cross-correlation is the IMAQ Find Pattern 2 VI, shown in Fig. 3. Using "Find Pattern 2 VI" is possible to develop an image characteristics identification procedure that consists of seeking an image that matches with the template of a smaller image used as a pattern. The process consists of two phases: the learning phase in which the template is processed and the search phase that runs in real time.

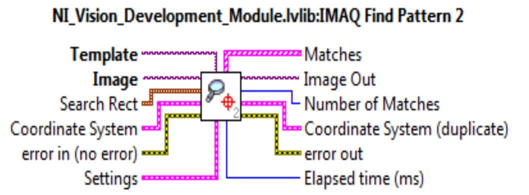

Fig.3 IMAQ Find Pattern 2 VI.

The learning phase involves analyzing the image of the template to find features that can be subsequently used in the search for matches. This strategy provides higher reliability compared to other traditional methods based on using grayscale pattern matching. Traditional methods do not have learning phase, so the pattern template is simply compared with each possible match location within the image. This generates a high computational cost and involves many redundant calculations.

Using "Find Pattern VI", a pattern template must be created and represents the object which must searched for. In this case, this template is the word "ECUADOR" present in all Ecuadorian license plates. The algorithm searches the pattern template in each acquired image and calculates a score for each match using cross correlation.

Find Pattern finds matches regardless of variation of light, noise, and geometric transformations such as size, rotation and shifting.

Another advantage of using the "Find Pattern 2 VI" is that it automatically learns the template image in the same VI and does not require another VIs to configure the learning phase of the pattern template as in other methods.

Finding patterns is the first step in many image processing applications, but this step must be highly reliable when working under very variable environmental conditions. In certain applications, the visual appearance of materials or components under inspection may change due to different factors such as object orientation, size changes or changes in lighting. The usage of IMAQ Find Pattern 2 tool in the algorithm developed has proved to be able to locate reference patterns despite of the before mentioned factors.

After the location of the vehicle plate in an image, the next step was to recognize the characters and numbers within it, in order to transfer them to a database for comparison.

For the recognition of characters within a vehicle plate, the OCR optical character recognition system has been used.

B. *Optical Character Recognition OCR.*

Optical Character Recognition (OCR) is the process that vision software uses to read text and characters from an image.

OCR automatically identifies symbols or characters of a given alphabet in an image, and stores them in the form of data that can be manipulated through a text editor.

OCR algorithms differentiate text in any image in 4 stages:

- Binarization: most OCR algorithms begin their analysis in a binary image, it means, a two colors image. Any color or grayscale image can be converted into a black and white image. In a black and white image, the outlines of characters and symbols are clearly highlighted, in order to isolate the parts of the image where there is text.

- Segmentation: this is the main step before character recognition. The segmentation deals with the detection of the contours of the characters or symbols of the image taking into account its intensity information. In addition, it allows the decomposition of the text into different logical entities sufficiently invariant so as not to depend on the writing style, and may be significant enough to recognize them.

- Thinning of the components: once the contours of the characters are detected, it is necessary to delete the contour points successively so that the typology of the character is maintained. A parallel sweep is made pointing out the pixels that must be erased to eliminate them all at once. Thanks to this it is possible the classification and recognition of characters.

- Comparison with patterns: the characters obtained in the previous step are compared with pattern characters stored in a database.

In LabView, the OCR character recognition process consists of a training phase and the reading or verification phase.

OCR Training Phase

In the training phase, the vision software learns the types of characters, letters or patterns to be detected in the image during the reading phase.

The location of characters in an image is generally related to the segmentation of characters. Character segmentation essentially involves locating and separating characters from the background of the image.

Before training the OCR, it is necessary a configuration phase to determine the segments characteristics of the letters to be used in the training process. Once they have been segmented or separated, character by character, the software is trained by storing the information that will allow the OCR to recognize the same characters in other images.

OCR training consists of giving a character value to each segmented or separated character, creating a unique representation of each segmented character. Then, the characters learned in a set of characters are stored in a file for later use in the reading phase of the OCR.

Training can be a one-time process, or it can result in a repetitive process, which creates some character sets to expand the range of characters that are desired to be detected in the image.

OCR Reading Phase

The character reading phase is the process in which the developed software segments each object in the image and compares it to the elements of the character set created in the training phase.

Optical Character Recognition OCR extracts unique characteristics from each segmented object in the image and compares each object with each character stored in the character set.

The OCR returns the value of the character in the set of characters that best matches the object and returns a score other than zero. If any character in the character set matches the object, the OCR returns a substitution character, such as the character value, in addition to a zero score.

III. Development of the Administration Software

Several screens were developed to manage the application.

- "Presentation" screen (Fig. 4): this screen presents the program itself. It shows the theme of the project and the name of the authors. This screen appears only the first time the program is run.

Fig.4. "Presentation" Screen

- "Home" screen (Fig.5): This screen was designed to enter the name of the shift guard at the entrance to the parking lot. It shows the time and date and it is possible to display a report about the available space for the vehicles and finally to start the system of recognition of vehicular plates. This screen appears only the first time the program is run.

Fig.5 "Home" Screen.

- "Camera" screen (Fig. 6): This screen shows in real time the image of the vehicles at the parking lot entrance. This is where the image of the vehicle is captured by the camera for its analysis. It's possible to go to the next screen only if a vehicle photo has been taken.

Fig.6 "Camera" Screen.

- "Search Pattern" screen (Fig. 7): this screen shows the photograph captured in the previous screen and the software proceeds to locate the vehicle plate inside the image by searching the pattern template "ECUADOR". Once the pattern has been found, a green led lights up on the screen and it automatically goes to the next screen.

Fig.7 "Search Pattern" screen.

- "Result" screen (Fig. 8): this screen automatically displays the image of the vehicle plate. The program reads it and displays the characters and numbers recognized within the plate in a text box. These characters and numbers are sent to a database where they are compared with the information of the vehicles which are allowed to enter to the parking lot.

If the read plate read is indeed within the database, the program displays the message "ACCESS PERMITTED"; otherwise, "ACCESS DENIED" will be displayed. At the end of this process, the program goes to "Camera" screen again.

Fig.8 "Result" screen.

IV. TESTS AND RESULTS

The proper operation of the vehicle plate recognition software is verified in the "Result" screen, where it is possible to verify that characters and numbers of the vehicle plate reading, made by the recognition software, is correct and matches the real characters and numbers of the processed plate image, as shown in Fig. 9.

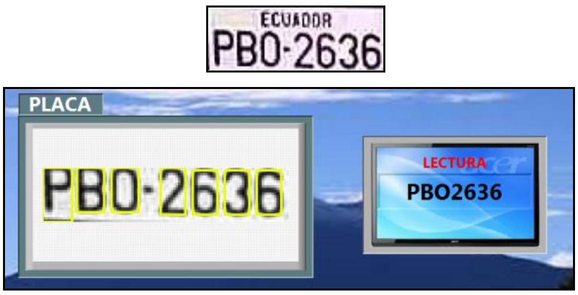

Fig.9 Actual processed plate and "Result"screen.

Performance tests of the developed software were carried out with different vehicles placed at different distances and locations of the pre-established zone, as well as the same vehicle in several times.

The pre-established and considered ideal area is 2.20 meters wide and 1.00 meters long measured at 0.85 meters from the right-hand column of the exit of the parking lot, as shown in Fig.9.

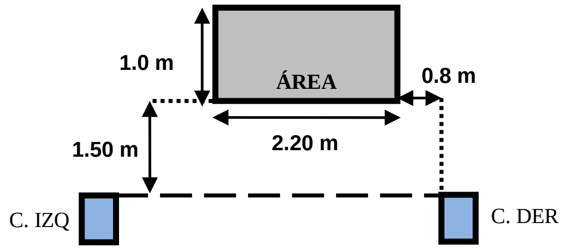

Fig. 9 Diagram of the area established as ideal.

Table I shows the results obtained from the tests performed on the designed software.

TABLE 1. RESULTS OBTAINED BY TESTING THE DESIGNED SOFTWARE

Test type	# tests	Successful Tests	Failed tests	% CONFIAB
Different vehicles	35	33	2	96.41
Same vehicle	10	8	2	97.14

Failures during the tests were primarily due to: wrecked or illegible plates. The tests carried out demonstrated the system to have a high reliability rate of 96.41% success.

Considering that two of the tests performed on the same vehicle were incorrect, because the vehicle was not in correct position at the entrance, a high reliability rate of 97.14% was obtained.

V. CONCLUSIONS

- The use of a high resolution IP camera was really important because the distance between the location of the camera and the place where the vehicle stops was considerable. Likewise, the camera with IR filter proved not to alter its operation exposed to variations of light, climatic changes be it sun, rain or temperature variations.
- The high quality images obtained from the chosen IP camera, allowed to discard the need to apply image filters and corrections to the captured images for the subsequent processing.
- Test results allowed to assert that the algorithm that best adapted to the conditions of the application, turned out to be the search of the "ECUADOR" pattern present in the vehicle plates.
- The distance between the vehicle and the camera is an important factor when looking for patterns. So, an ideal

area was defined, which can be complemented by placing a mechanical barrier, or a mark on the floor where the vehicles must stop when entering to the parking lot.

- The tests performed also allowed to conclude that in order to recognize the characters and numbers within an image, the optical character recognition OCR proved to be the most ideal, since it works on the basis of algorithm training with characters similar to those to be recognized later.
- Despite the fact that plate sizes and plate characters are standardized, notable differences have been found between letter and number sizes which could cause problems in this kind of systems.

VI. FUTURE IMPLEMENTATIONS

- Improve the algorithm developed to reduce any error achieved in initial tests, due to deteriorated or poorly placed plates and somehow eliminate the use of a pre-established area.
- Complement this system in conjunction with the use of a mechanical barrier.

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