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Automatic Number Plate Recognition System Based on Deep Learning

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Abstract**—**In the last few years, Automatic Number Plate Recognition (ANPR) systems have become widely used in the safety, the security, and the commercial aspects. Forethought, several methods and techniques are computing to achieve the better levels in terms of accuracy and real time execution. This paper proposed a computer vision algorithm of Number Plate Localization (NPL) and Characters Segmentation (CS). In addition, it proposed an improved method in Optical Character Recognition (OCR) based on Deep Learning (DL) techniques. In order to identify the number of detected plate after NPL and CS steps, the Convolutional Neural Network (CNN) algorithm is proposed. A DL model is developed using four convolution layers, two layers of Maxpooling, and six layers of fully connected. The model was trained by number image database on the Jetson TX2 NVIDIA target. The accuracy result has achieved 95.84%.

Keywords**—**Automatic number plate recognition, character segmentation, convolutional neural network, CNN, deep learning, number plate localization.

I. Introduction

THE ANPR systems become more and more used in intelligent transportation systems since they meet several needs, especially when they solve security issues and improve safety [1]. The ANPR is also exploited for the tracking [2] applications and the commercial aspect like parking control access for management or feeing and so on. The first ANPR system was generated in 1976 by the UK police scientific development office to read vehicles registration plates [3]. And since then, the evolution of these ANPR systems has not stopped. Several techniques and approaches are exploited to improve the systems accuracy. In addition, each vehicle in the world has its own license number identification that is printed on its plate and fixed on vehicle body at the back and at the front of the vehicle [3]. In fact, the license plate of any vehicle contains a number of numeric characters that can be recognized by computer. Each country or group of countries has specific characteristics of the license plate. In this paper, a new ANPR system conception is proposed to automatically detect and identify the Tunisian number plate. It is based on new computer vision algorithms of both number plate detection and plate CS. For OCR step, the newest technique of recognition in images is used: the DL.

This paper is organized as follows: the second section presents a survey of the state of art by citing some related works. The third section is reserved to explain the proposed ANPR algorithms in three subsections: the NPL algorithm, the CS algorithm and the OCR DL model. Implementation results and a comparison with the stat of the art works are then shown in Section IV. Finally, Section V gives the conclusion and the future works.

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II. Related Works

There are a lot of studies and works that are already done on automatic vehicle identification by the detection and recognition of license plate number. Researchers are using different methodologies and algorithms depending on the plate characteristics of each nation. Several research publications were consulted to find relevant information about ANPR systems. Following is a brief description of some of them:

Tawfeeqet and Tabra [4] developed a particular ANPR system to control private vehicle access applications. The algorithm is applied on the new Iraqi license plate. The accuracy achieved 93.33% of performance result.

The ANPR system in [5] worked on Indian number plates. The paper proposes a method of localization and recognition using MATLAB. In fact, the proposed software module starts by analyzing the input image, then identifying the location of the plate. The segmentation step of the character is then applied to finally recognize characters. A summary of the ANPR systems related works where the accuracy results were between 85% and 97.19% is described. But, no results are mentioned for the proposed ANPR system.

Puranic et al. [6] worked also on ANPR of Indian plate using MATLAB tools. They proposed a system that detect plate number and track it. In addition, the system detects the type of vehicles. The particularity of this work is on the OCR step that uses Template Matching method. It consists of comparing characters of the detected plate, with a template from static images database. An average accuracy of 80.8% was obtained.

Kurdi and Elzein [7] introduced an approach of ANPR with neural network optical character recognition (NNOCR). This technology allows recognizing of Lebanese license plates with day and night time images. The proposed technique measures accuracy about 96 % of the system.

An ANPR system for Ghanian plate is proposed in [8]. It uses OpenCV library in C++ language. The algorithm uses edge detection and feature detection techniques combined with mathematical morphology for the plate localization. For the OCR phase, it applied Tesseract method to identify the detected characters on the plate.

In [9], the proposed algorithm of the NPL is called

Secondary Positioning (SP). It is applied on New Zealand license plate and it is based on Hue Saturation Value (HSV) color space. First stage is founding the red light regions in HSV color space, and then an accurate position of the plate number is localized by finding out vertical edge of the plate number. For recognizing step, a template matching is implemented. It incorporates a correction coefficient that is calculated between the templates and testing images. Accuracies, obtained from the plate number localization and the recognition, are above 75% and 70% respectively.

Based on the state-of-art study which is made with the cited works and others, an ANPR system is defined with new approach in each proceeding step. First, specific plate detection and CS algorithms, adapted to Tunisian license plates, are defined. In fact the study of Tunisian plate characteristics leads to new algorithms to separate and detect characters. It can be also used for many other plate nations that are similar to Tunisian one. Second, a newest technique of recognition, which is DL, is used. Those two major particularities create the innovation of this work.

III. Proposed ANPR System

The whole ANPR system is based on three main stages [1]: The NPL includes the image preprocessing and the computer vision algorithm to detect and localize the license plate. The CS consists of the separation of characters in the detected plate. The OCR uses DL method to identify the plate number. The following subsections present the details of each step.

A. The NPL Algorithm

The proposed algorithm of NPL is given by Fig. 1. It starts by an image prepossessing. It consists of blurring image by the bilateral filter [10] in order to remove noise that is caused by capture or transfer. A comparative study of many other filters was done before implementing the selected filter. Using a personal image database, the parameters of bilateral filter were empirically fixed. The blurred image is then gray scaled using the functions of OpenCV libraries.

The next step of the proposed algorithm is the contours detection of the gray image to isolate the region of interest, which is the license plate. Many filters are used in the literature [11]. Some of them were tested in this work, to finally select the threshold filtering method because of its simplicity and its efficiency in this images case. The threshold filter [12] consists of replacing each pixel in the gray input image with a black pixel if its intensity is less than the fixed threshold value, or a white pixel if the image intensity is greater than the threshold value.

Depending on the choice of the fixed threshold value, sudden changes in contrast can be then detected by an OpenCv function. In fact, possible number plate areas can be identified by observing detected contours. The remaining areas in the image are filtered out. However, not all detected contours represent a plate number. Hence, the proposed algorithm has defined two constraints to select the right contours and eliminate all false ones. The adopted constraints are given by the two tests in Fig. 1.

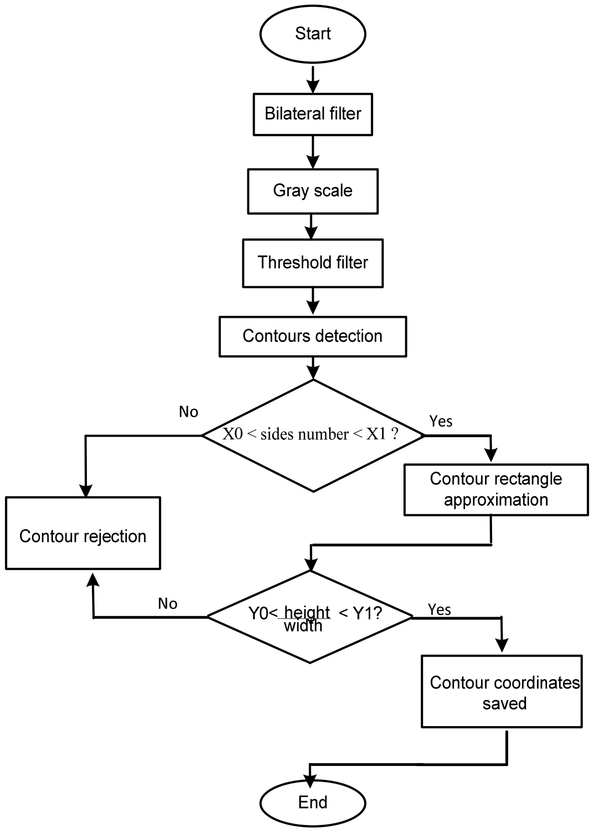

Fig. 1 NPL algorithm

The first one is based on contours shape since the standard Tunisian plate is rectangular. Thus, only contours that have between X0 = 4 and X1 = 6 sides are considered. All others are rejected. This simple test eliminates more than the half of contours. After that, the resulting contours are approximated to rectangular shape to be ready for the next test.

The second constraint consists of comparing the plate width by the plate height. The idea is inspired by the fact that the actual Tunisian number plates have almost the same proportions of dimension. A slight variation is considered because of the angle of image capture or the brand of the vehicle itself. It fixed between empirical values (Y1 and Y2).

A test image in different NPL steps is shown in Fig. 2. The first image is the original one. The second is the gray scaled image with bluer effect. Image (c) is given after threshold filter. Image (d) presents all detected contours. The final image presents only selected contours that present license plate number.

The localized plate is the resulting of the NPL algorithm. It is extracted then filtered before starting CS steps as presented in Fig. 3.

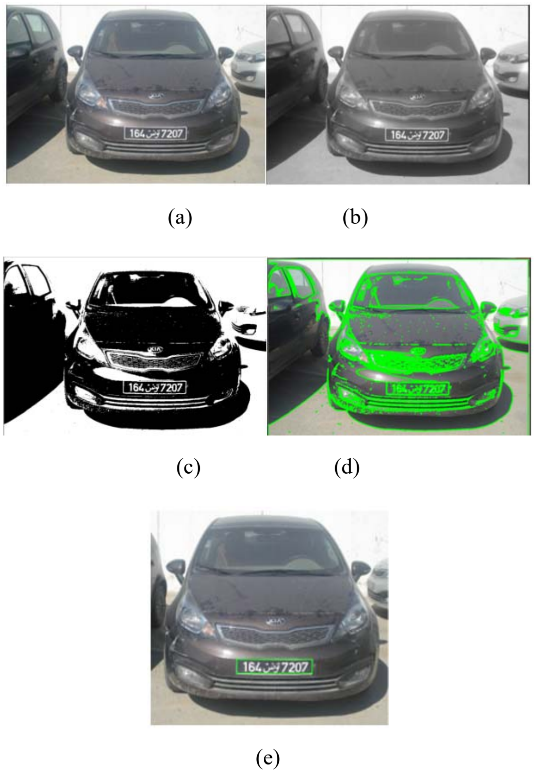

Fig. 2 A test image NPL and detection steps: (a) Original image. (b) Gray scaled image with blurred effect. (c) Threshold image. (d) Contours detection. (e) The final selected contours

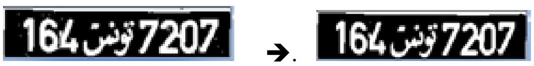

Fig. 3 Plate extraction and filtering

B. The CS Algorithm

The CS is applied on the extracted plate from the NPL image. Algorithm details are given by Fig. 4. It consists of the determination of the plate components. In fact, the Tunisian plate is composed of two field of number separated by the word "Tunisia" in Arabic language as presented in the plate example of Fig. 3. The proposed algorithm is based on only number detection. The space reserved for the Arabic word is deducted by its size after all number determination.

The proposed algorithm is applied on gray extracted image which is resized before contours detection process. The size normalization is used because the selection of detected contours is especially based on the area criteria. Therefore, plate should be resized to have almost the same character size in all plate case. Therefore, the selected contours should be in range which was fixed empirically. In addition, the CS is less time consuming than the plate localization because of difference in the input image sizes. Therefore, the overall possible threshold values between 100 and 255 were tested to guarantee the detection of all plates in the frame. The discounted line in Fig. 4 limits repetitive steps for each threshold value.

After detection and selection of contours, a character ordering step is done using contours coordinates, as presented in Fig. 5. At times, the same character can be detected twice or more. To solve this issue, the X coordinate of each character is compared to others. If a difference of 5 pixels or less is between two characters, it means that is the same one. In this case, only one character is saved, the others are rejected.

This test is presented by the condition "Character already exists" in Fig. 4. Finally, the resulting characters are resizing and saved in order to be ready for the OCR stage.

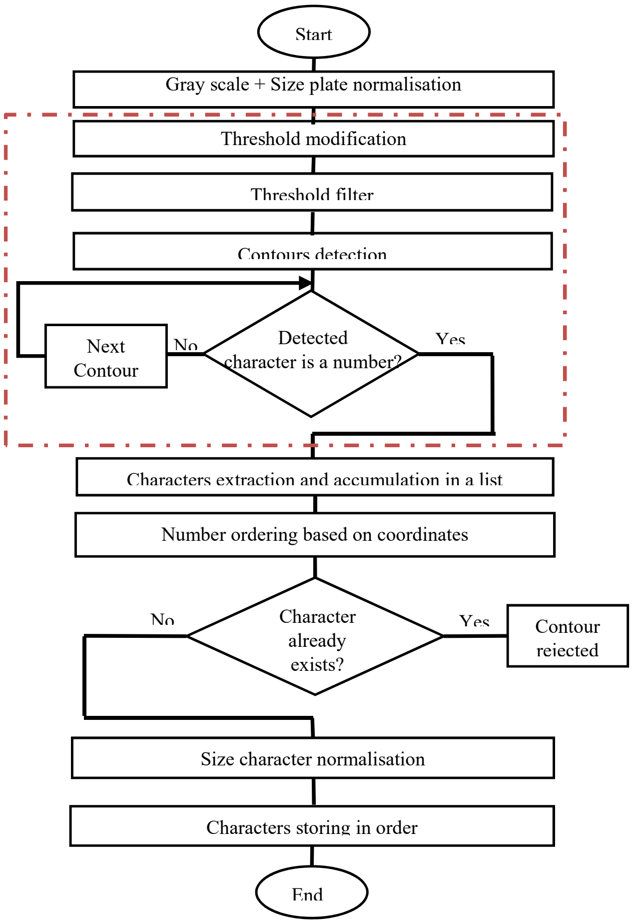

Fig. 4 CS algorithm

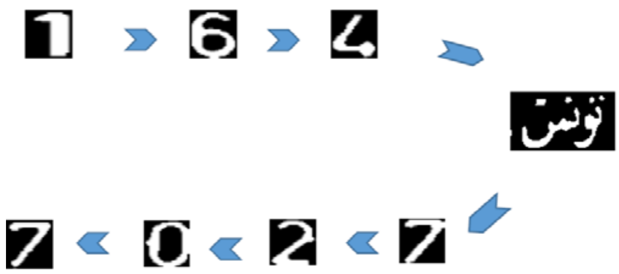

Fig. 5 Final ordering Tunisian plate characters

C. Character Recognition based on DL Model

The OCR stage is the identification step of an ANPR system. The proposed algorithm is a DL model proceeding by

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a pretreatment process, as presented in Fig. 6. The pretreatment starts with a Gauss filter 5x5 to bluer image and eliminate noise. Then, the character is resized to 28x28 pixels in order to be compatible with test database. Finally, the binarization of character is done.

(a) (b) (c) (d)

Fig. 6 Pretreatment steps: (a)original character (b) Blurred character by Gauss filter (c) Resized character (d) character biniarization.

The proposed OCR algorithm is based on the CNN model because the CNN has achieved outstanding performance especially in the fields of visual recognition in the last recent years. It is the network that has advanced furthest among different types of neural network. A CNN includes convolutional layers, pooling layers and fully- connected layers. And through locally connected neural net and sharing parameters, the CNN can efficiently decrease the number of parameters. The proposed CNN algorithm has the following characteristics, as detailed in Fig. 7:

- Four convolution layers,
- Two layers of Maxpooling,
- Six layers of fully connected.

The input image size is 28 * 28. The image goes to the first convolution layer which is composed of 32 filters sized 3 * 3. The activation function ReLU is used. It forces the neurons to return positive values. After this convolution, 32 features are created to be the input of the following convolution layer which is also composed of 32 filters. The ReLU activation function is applied on this layer. The Maxpooling is applied afterwards to reduce the size of the image. In the end, the dropout regularization technique is applied with a value of 0.25 to avoid falling into the problem of over learning. At the exit of this layer, 32 feature maps of size 14*14 are given. The next step is the third and the fourth convolution layers which are composed of 64 filters. The ReLU activation function is always applied on each convolution. A layer of Maxpooling is applied after convolution layer four with a dropout of 0.25.

At the end of this layer, 64 feature maps of size 7*7 are presented. The feature vector resulting from the convolutions has a size of 3136. The six fully connected layers are then applied as follows where the activation function used is ReLU:

- The first layer is composed of 392 neurons with a dropout of 0.5.
- The layer 2 has 196 neurons with a dropout of 0.5.
- The layer 3 has 98 neurons with a dropout of 0.5.
- The layer 4 has 49 neurons with a dropout of 0.5.
- The layer 5 has 24 neurons with a dropout of 0.5.
- The last layer uses the softmax function which allows calculating the probability distribution of the 10 classes (0-9 numbers).

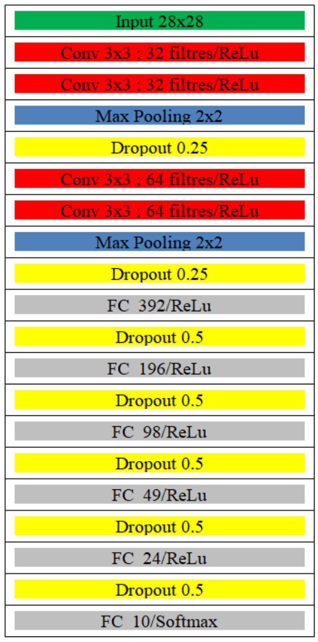

Fig. 7 The proposed CNN model

IV. Results of Implementation

The proposed algorithms constitute an ANPR system to detect and identify Tunisian license plate. All proposed algorithms were done using python language with several libraries. Most important ones are Open Cv, Tenserflow and Kerras.

The first one is used especially in the NPL and CS stages. The second ones are used for CNN algorithm which is applied in OCR phase. The system was implemented on an embedded system: the NVIDIA Jetson TX2 target. It is pre-flashed with a Linux development environment and supports libraries for DL and computer vision. The NVIDIA Jeston TX2 was used especially for the DL algorithm training. The proposed CNN model is trained to perform particular operation by adjusting the values of the connections between function elements, called weights. The basic procedure of training the CNN network is by giving particular input to get definite model. The training needs several images to obtain greater accuracy. The MNIST database [13] was used. It is composed of 60,000 images of number figures where 10,000 images of them are used for testing and 50,000 images for training. Several tests were done by varying the Epoch value to observe the change of accuracy. Fig. 8 presents a curve of the accuracy precision according to the Epoch.

A comparison of training implementation on Jetson TX2 and a Personal Computer is given by Table I, which obviously shows that TX2 is faster in terms of execution time.

The accuracy is 95.84% that presents acceptable value compared to related woks. A result comparison study is given by Table II. It presents accuracy of proposed algorithm on

TX2 compared to referenced stat of art in related work section.

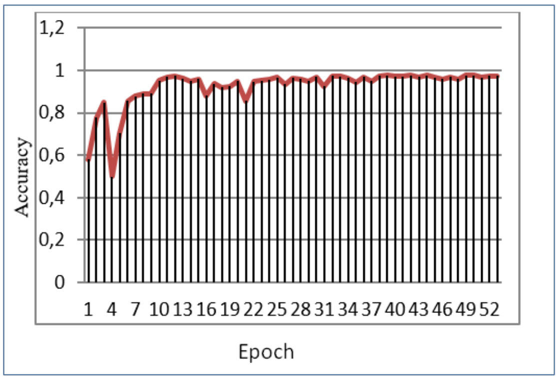

Fig. 8 Model precision analyses

TABLE I
TRAINING IMPLEMENTATION CHARACTERISTICS

	NVIDIA Jetson TX2	Intel Personal Computer
CPU	HMP Dual Denver 2/2 MB L2 + Quad ARM® A57/2 MB L2	Intel Core i5-4440 (3.1 GHz)
GPU	NVIDIA Pascal™, 256 cores CUDA	AMD Radeon (TM) 530 4GB
RAM	8 GB 128 bit LPDDR4 59.7 GB/s	8GB
Training execution time (sec)	2906.67139316	10116.6237640380
Test execution time (sec)	0.0045	1.7458

TABLE II
COMPARISON RESULTS WITH STAT OF THE ART

Works	Accuracy (%)
[4]	93.33%
[5]	Above 85% and 97.19%
[6]	80.8%
[7]	96 %
[8]	60%
[9]	Above 75% and 70%
Proposed	95.84%

V. CONCLUSION

This work proposed an algorithm for ANPR system. For plate localization algorithm, the contours selection is based on the shape and the plate size. The CS algorithm is based on area of selected contours since plate size is normalized. The third algorithm of number recognition uses a CNN algorithm which is defined and trained on Jetson TX2 board. The accuracy is achieving 0.9584.

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