https://doi.org/10.24867/GRID-2022-p52 Original Scietific Paper

NUMBER PLATE RECOGNITION USING TEMPLATE MATCHING TECHNIQUE

Andrea Gutai, Andraš Anderla, Nina Kozma, Anđela Milićević, Sara Havzi
University of Novi Sad, Faculty of Technical Sciences, Industrial Engineering and Engineering Management, Novi Sad, Serbia

Abstract: *The purpose of this study is to propose an approach to number plate recognition using digital image processing techniques in Matlab. The template matching method serves as the foundation for the suggested methodology that is thoroughly discussed and illustrated within a graphical user interface. A few limitations are mentioned along with the application of the methodology. Finally, suggestions are made for future research and methodology enhancement.*

Key words: Number Plate Recognition (NPR), Optical Character Recognition (OCR), Template Matching, Digital Image Processing, MATLAB

1. INTRODUCTION

The leading factor for the development of digital image processing in the last few decades is the need to extract information from images and interpret certain content from images. Systems using image processing techniques may be affected by camera resolution, low visibility, environmental and weather factors while recognizing objects. Therefore, there is a necessity to create a system capable of providing user-relevant information based on digital images that are used as input in different methodologies, especially in the field of license plate recognition.

The main goal of this paper is to present automated license plate extraction and character recognition that are subsequently written into a text file. The characters on license plates, which are easily readable by humans but not by algorithms, are typically used to uniquely identify vehicles. In addition, the methodology for license plate character recognition is presented by using MATLAB, which supports digital image processing techniques. License plate recognition technology works based on converting image data from the camera into a character format that enables further processing in a specific application area.

In this paper, the emphasis is on the recognition of the characters of license plates in the Republic of Serbia. The proposed methodology is presented, textually described and visually presented with a real example. After a thorough review and testing of the proposed methodology, the observed limitations were addressed, and at the end, based on the presented and analysed work, the conclusion was drawn along with directions for future work and improvement are provided.

2. THEORETICAL FOUNDATIONS

Digital image processing in the last couple of decades has been improved by implementing operations on the image to obtain an enhanced image or extract required information. The MATLAB development environment was utilized in this research due to the fact that solutions in the field of digital image processing, in general, require experimental work that includes simulation and testing with large sets of sample images (Gonzalez, Woods & Eddins, 2009). Different approaches which has been implemented in Matlab, used different image formats as an input in approaches accomplished with numerous techniques for eliminating certain parts of image that provide easier classification (Anderla, Culibrk & Delso, 2013).

The image, in general, can be defined as a two-dimensional function $f(x, y)$, where x and y represent the spatial coordinates, the pixel positions, and the amplitude f that is in the pair of coordinates (x, y) is called the intensity or grey level. An image is referred to as a digital image when its x, y, and amplitude values f are all finite (Gonzalez, Woods & Eddins, 2009). In other words, a digital image is a representation of a two-dimensional image using a finite number of dots, commonly called picture elements or pixels (Marques, 2011). Enhancing the visibility of the characters used for the future identification of the vehicle is the primary goal of applying digital image processing in the field of license plate recognition.

This paper represents the use of MATLAB as a development environment that uses digital images as input parameters for methodology. MATLAB stores digital images in the form of a matrix, where each pixel in

the image corresponds to one element of the matrix. Consequently, an image can be defined by a two-dimensional array separately arranged in rows and columns (Goyal, 2010).
Number Plate Recognition (NPR) is a technology that uses Optical Character Recognition (OCR) on digital images to recognize license plate characters based on input image. License plate recognition can be configured to save camera images for license plate text, and others can additionally include driver photos in the case of need. The systems typically use infrared illumination to allow the camera to take pictures and videos at any time of the day or night and in different weather conditions. Licenses are recognized with the aid of optical character recognition, which processes input images into textual format. Optical character recognition represents a technology for converting handwritten, typed, scanned text or text within images into machine-readable text (Ashraf, Arafat & Iqbal, 2019). The basic process of OCR involves scanning the text of a document or image and translating the characters into a code that can be used later to process the data. The process of optical character recognition consists of three necessary steps - image preprocessing, character recognition and post-processing. The results of optical character recognition strongly depend on the quality of the input data, notably in the field of digital image processing the results depend on the quality of the input image.
The first step involves the acquisition, which is responsible for acquiring one or more images of a vehicle containing a license plate. The next preprocessing step involves improving the quality of the image obtained from the previous step. The next step involves segmentation, which is responsible for dividing the image into its two main components, the relevant object and the background. Extracting feature is the following step, which aims to create algorithms responsible for encoding image content. The last step is classification, assigning a label to each character, and creating a string (or ASCII file) on the output, containing the license plate (Marques, 2011). Template matching is used for classification and represents an important topic in the field of Artificial Intelligence (AI) due to the fact it represents an approach that involves locating regions of interest. The original image represents the image in which we expect to find a match to the template, while the template image presents the image that will be compared to the original image. Simple template matching involves comparing the template image to the source image in a pixel-by-pixel shift. The template image is shifted one pixel at a time from left to right or top to bottom to allow the numerical similarity of the template to the overlapping image to be calculated. Both images are converted to binary images or black and white, and then template-matching techniques such as utilizing cross-correlation or the sum of absolute differences are applied (Swaroop & Sharma, 2016). This approach involves the use of a database that consists of numerous characters or templates. In order to achieve recognition, the input character is compared with each template and if an exact match is found, the result is obtained (Swaroop & Sharma, 2016). After identifying the characters, the character is converted to the American Standard Code for Information Interchange (ASCII) code, which computer systems can use for further use and manipulation of the text. Before saving a specific document for later use, users can resolve simple inaccuracies, proofread, and make sure that text is accurately identified.

3. OVERVIEW OF METHODOLOGIES FOR AUTOMATIC VEHICLE REGISTRATION NUMBER RECOGNITION

In the automatic license plate recognition system, license plates are extracted from the original images of the vehicle, which later serve as the basis for recognizing numbers and letters. The characters on license plates are used to uniquely identify vehicles in the majority of cases. For machines, a license plate is just an object in the image that has a certain intensity and brightness and for whose identification is necessary to create a methodology. Therefore, it is necessary to design a system capable of extracting relevant areas of the image, which are subsequently converted into the different formats with the aid of character recognition methods. The subsequent sections of this chapter will discuss and give an outline of the methodologies that have been proposed in the last decade.
The importance of the license plate recognition system, especially optical character recognition methods is affected by the need to reduce the human factor in this process, achieving a higher level of vehicle access control in a specific area, parking billing solutions, and automatic calculation of the time and money required for using specific services that are integrated with software. In the field of software engineering, the use of a systematic literature review is recommended in order to represent prior techniques in the field in an indisputable form and to eliminate subjectivity from that process (Stefanovic

et al., 2021). As a result of systematic literature review done in the field of number plate recognition, the most frequently used method for the optical character recognition step is the template matching technique, followed by the subcategory of neural network methods (Gutai et al., 2021). Subsequently, two approaches that stated high overall recognition rates were approaches (Shaikh et al., 2013) and (Mutholib et al., 2013) that used template-matching techniques.

The automatic license plate recognition system proposed by Xie et al. (Xie & Wu, 2014) consists of a series of steps. The first step is image acquisition, followed by image preprocessing, which includes edge detection, noise removal, and other operations. The next step involves the segmentation of each character. Character recognition is provided through a template-matching technique. The previously mentioned steps are shown on the GUI interface with the help of MATLAB and the printout of the license plate mark is printed with the help of the message box.

Bhat et al. (Bhat & Mehandia, 2014) proposed a license plate recognition methodology using MATLAB to help detect authorized and unauthorized license plates. The first step is image input, after which a series of morphological operations are used to detect the desired area and the threshold value is calculated using the Sobel operator. The removal of merged objects is the next step, while the segmentation of the license plate is provided by multiplying the previously processed image with a black-and-white image. The bounding box technique was used to retrieve the properties of a certain region and to segment each character, which is subsequently compared with the templates with the help of template matching. The result of the methodology is printed in a text file, which contains the license as well as the date it was read.

The methodology developed in the work (Sutar & Shah, 2014) as the first step involves the acquisition of the image of the vehicle. The license plate of the vehicle is extracted using image segmentation, after which the optical character recognition technology is used. The resulting data is then used to compare against patterns in the database that is followed by a signal which is given to the microcontroller to control the system. If the entered number plate mark contains an authorized character, then the green indicator light will turn on, while in the opposite case, the red light will turn on.

The following automatic license plate recognition system proposal (Tiwari et al., 2016) is implemented using MATLAB. After inserting the colour image in the MATLAB development environment, the user is subsequently asked to manually mark the license plate region from the colour image and crop it. Converting the image from RGB to HSV (*Hue Saturation Value*) and analysing hues, saturations and values is the next step. Image enhancement is provided using a histogram, followed by segmentation of each character from the image, and finally displaying the results in MATLAB.

The next approach (Dias & Ashan, 2016.) is based on vehicle detection, license plate region extraction and optical character recognition. The vehicle detection phase accepts a video as input, where a certain mask is applied and thus identifies a moving vehicle while the result of this phase is an image that is passed to the next phase. A series of image processing operations are performed within this phase, and the area containing the license plate is selected. The final stage involves optical character recognition, initial noise reduction and segmentation of each character as well as sizing and template matching.

Another approach to automatic license plate recognition presented in the paper (Pagad et al., 2017) was created to help specific institutions to identify unregistered vehicles. If the recognized license plate is found to be unauthorized, the vehicle number identified as unauthorized is sent as a text message to the designated authority, along with the current date and time.

The proposal of Stefanović et al. (Stefanović et al., 2017) for license plate feature extraction suggests an algorithm that includes image pre-processing, noise removal, a series of corrections, additional filtering in the case of difficult detection conditions, as well as additional processing in the case of distorted image region. Based on the segmented characters, using a free online tool for optical character recognition, a result was obtained in a specific format chosen by the user.

In the next approach by Tejas et al. (Tejas et al., 2017), a combination of digital image processing and the Internet of Things (IoT) was proposed. The documented efficiency of the proposed methodology is approximately 97.89%. After applying the methodology using MATLAB, the license plate of the vehicle is written and saved in a Notepad file. The information written in the file is constantly deleted and new information is transferred to the cloud using the automatic FTP data transfer protocol. The results of the read license plates are forwarded to the cloud for further interpretation and manipulation of the obtained data. It is stored within the tables, which provide vehicle tracking, while the administrator can also access the date, time and location data of a specific vehicle. The database facilitates modifications

and makes it easier to track specific vehicles assuming that all cameras of a specific geographic area are connected to the same server. The main goal of the search module is to know the registration number of the vehicle, then the entered number is searched in the database and all data from the database of that vehicle can be accessed by the authorized administrator in different locations.
Surekha et al. (2018) proposed a methodology whose main purpose was to provide support for parking services. As a result, it was necessary to record the time and date when the vehicle entered a certain parking area, as well as the details of the vehicle's license plate. The proposed license plate character recognition system uses a sensor network to activate the camera and a graphical user interface (GUI) to allow the user to control the complete process.
In the approach presented by Srinu et al. (2018), a license plate recognition system was proposed for recognizing and accessing vehicle data for surveillance purposes. It consists of three main steps of the methodology: image acquisition via a mobile application, a graphic user interface for tag recognition and a web page with vehicle information.
Based on a review of the literature and the previously proposed approaches, it was determined that methods connected to cameras that enable image acquisition make the methodology simpler to use because the images should be similar in terms of quality and size. The definition of success for any information system is rather subjective, because it depends on how quickly it responds to user requests and how well it increases user productivity (Stefanovic et al., 2020). In some approaches, the methodology was implemented and further processed with the aid of a graphical user interface, which is preferable to methodologies that simply list necessary steps without visual representation in a form of interface and make it considerably more difficult for the end user to use the proposed methodology. The proposed methodology within this work addressed these constraints by development of a methodology that will be represented in a form of GUI and custom developed for license plates in the Republic of Serbia.

4. PROPOSED METHODOLOGY

The methodology proposed for the automatic recognition of license plate characters based on an image is presented in this chapter, as well as the graphical user interface to support the mentioned system, which was developed in the MATLAB development environment with the help of techniques for digital image processing and optical character recognition, which will be described in detail. Experimental work was carried out on license plates of the Republic of Serbia, to identify improvements that can be proposed for the methodology in future iterations.
License plates that are primarily used within the proposed application are white, while the border is marked in black. On the left side of the plate, on a blue background, the abbreviation of the Republic of Serbia - SRB is written in white letters, which is excluded from the recognition process. The registration number of the vehicle is represented by a series of marks, at the beginning, the mark of the registration area is written in black letters, after that, the digits representing the registration number are separated with the help of the sign "-" from the letters in the two last positions (Figure 1).

Figure 1: License plate of the Republic of Serbia

Recognition of the Latin letter on the vehicle license plate consists of a combination of numbers from 0 to 9 and all the letters of the Latin alphabet and three additional alphabetic letters, namely "X", "Y" and "W". The first two marks in the series of registration marks are letters, after that there are digits in three or four positions, depending on the registration area, and finally, there is a combination of letters in the last two positions.

The objectives of the proposed methodology are:

- ensuring the exact location of the license plate area in the image, successful recognition of each character located within the previously recognized region and
- printing recognized characters in a text file for further data manipulation.

4.1 Methodology

The algorithm for extracting license plate features implemented in this paper requires an input image, followed by image preprocessing operations, localization of the position of the plate in the image, as well as segmentation of the identified plate. Aforementioned phases are followed by segmentation of special characters that are subsequently read with the help of optical character recognition, while at the end of the process, it prints the output of the process - the registration number written in a text file. A visual representation of the phases for the proposed methodology is shown in Figure 2.

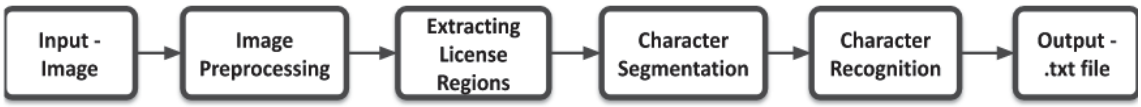

Figure 2: Phases of the proposed methodology

4.1.1 Input Image

The first step is providing an input image that serves as the basis for further steps. The input image may have light or dark image tones, low contrast images, blurred images, or noisy images. As it is not possible to claim with certainty that the input image is always of adequate format and quality, a series of pre-processing operations are carried out to ensure the highest level of character recognition success. Figure 3 shows the input image of the vehicle that was used to demonstrate the functionality of the methodology through a series of iterations.

Figure 3: Input image

4.1.2 Image Preprocessing

The main goal of preprocessing is to improve the contrast of the input image, reduce the noise in the image and minimize the image processing time. A colour image is converted to a greyscale image before image processing, and after noise removal and contrast adjustment, the image is converted to a binary image. After that, the operation of edge detection, dilation to remove small elements in the image, then filling of holes, and finally the erosion operation is performed. The remaining paragraphs of this chapter will discuss each of the aforementioned phases of image processing.

The first step of image preprocessing involves sharpening the image. Sharpening is achieved by subtracting the blurred version of the image from itself. Contrast is increased along the edges where different colours border, improving the visual impression. Image sharpening is followed by the conversion of the image into shades of grey. By converting the input image to a greyscale image, brightness reduction is achieved. It improves image noise reduction to a certain extent and also facilitates further image processing. Image noise mostly occurs during image acquisition or transmission. In order to remove noise, a filter is used that takes into account each pixel in the image and its surrounding pixels and replaces the pixel with the median of the surrounding values.

Adjusting the image contrast is the next phase, and contrast is defined as the difference between the lowest and highest intensity levels. The contrast of the greyscale image is transformed using adaptive histogram equalization. In the binarization step, the image is converted to black and white format, and the purpose of applying colour conversion is to reduce the number of colour scale ranges from the range of 0 to 255 to the range of 0 to 1. The resulting image contains white pixels against the background and letters that are represented by black pixels.

The following phase includes edge detection. The goal of edge detection is the identification of certain objects in the image, where the basic step is dividing the image into regions corresponding to different objects in the image. In most cases, it is followed by dilation which represents a type of morphological operation that adds pixels around an object in an image. It helps to fill in any unnecessary holes in the image, which will benefit in higher accuracy and also to enhance the borders of the subject by filling in the broken lines of the images. Hole filling is then applied to binary images where a hole is defined as a group of background pixels. One of the fundamental techniques for removing unnecessary elements from a binary image is erosion. The morphological erosion operation is used to discover the candidate license plate area and its results, and it also reduces the size of the object and exclude unwanted details from digital image that will aid license plate extraction.

Figure 4 shows a concrete example of the application of the mentioned steps on the input image from Figure 3.

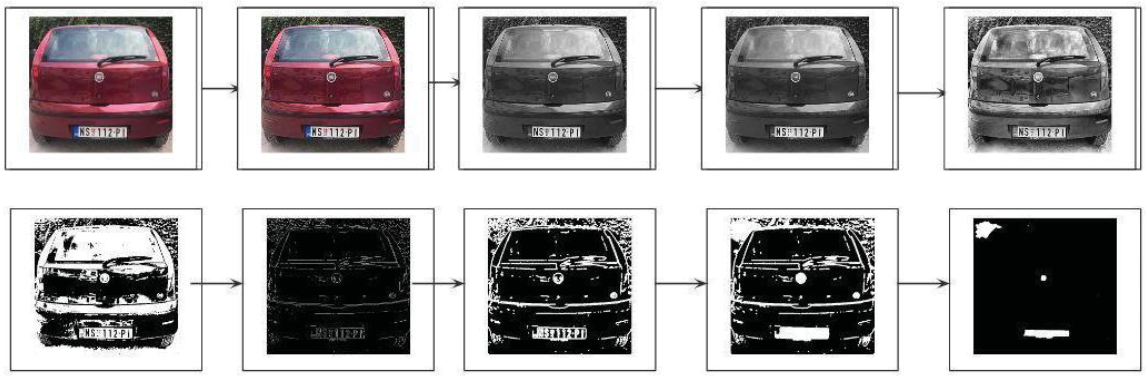

Figure 4: Image preprocessing

4.1.3 Extracting license plate regions

Segmentation of the license plate from the original input image is a crucial process in automatic license plate recognition because all subsequent steps depend on this step. The function used returns a set of properties for each connected component in the binary image. Based on a set of properties, segmentation operations were applied to the processed image and the representation of the segmented license plate is shown in Figure 5.

In addition, the removal of connected components from the binary image that have a value smaller than the defined pixel is performed, and thus the components that have a value smaller than the specified pixel are classified as non-digital components and are removed from the binary image. In this way, it is certain to find only numbers and letters on the segmented license plate without unnecessary elements such as the sign coat of arms or the SRB mark located on the left side.

Figure 5: Segmented license plate

4.1.4 Character Segmentation

The extracted region serves as the basis for adding a bounding box, which was used to mark the characters with a yellow line in Figure 6.

Figure 6: Bounding box around each character

In this phase, the characters in the license plate area are separated into individual images. In the proposed approach, character segmentation is performed using bounding box analysis (BBA). Marked characters are segmented by analysis into a certain number of sub-images that contain digits or letters. The display of character segmentation results and seven sub-images are presented in Figure 7.

Figure 7: Image of segmented characters

4.1.5 Character Recognition

Following phase is related to character recognition that is implemented by using template matching technique that recognizes a number or letter by comparing two images, the segmented character from the previous step, and the patterns created and saved in database within this step.

The establishment of a template database, which is made specifically for the demands of the methodology, is the first stage in the template-matching process. The base of 42 patterns contains the digits 0 to 9, the Serbian Latin alphabet with the exclusion of "LJ" and "NJ" and the addition of the "X", "Y", "Q", and "W" letters, as well as the sign coat of arms. The font used in the templates has been customized for the license plate used in the Republic of Serbia. Templates are binary files in the .BMP format that are 42x24 pixels in size and include all of the letters and numbers described previously and are shown in Figure 8.

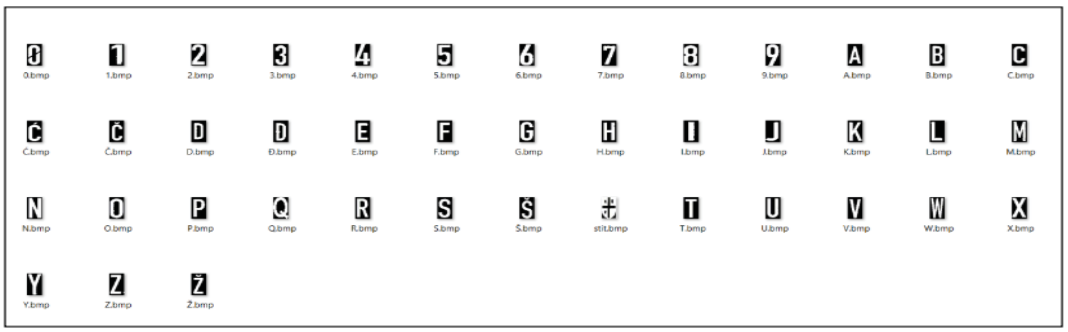

Figure 8: Template base

After creating database, the next step is to resize the image of the segmented character from the previous step to 42x24 pixels to ensure a comparison with the template images. A pixel-by-pixel comparison of the image and the template is performed for each possible position, sliding pixel by pixel.
In order to recognize a particular character, the input segmented character from the previous step is compared to each pattern to find an exact match or pattern with the closest representation of the input character. It is necessary to find the highest level of correlation, which can be defined as the degree of similarity between the segmented character and the template. When the highest level of degree of similarity is found, the character is written into a special matrix intended for saving the character. The procedure is repeated for each segmented character.

4.1.6 Output

The result of the previous series of steps and the result and output from the methodology is shown in Figure 9. The value of the license plate is written to the text file, which can then be saved for further manipulation of the data.

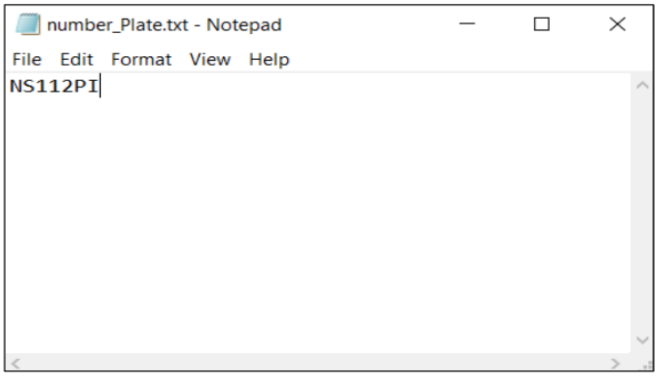

Figure 9: Printing of methodology results in a .txt file

4.2 Graphical User Interface (GUI)

The methodology will be presented to the end user in a graphical representation that was created with within the MATLAB. An interface that requires an image as input and converts it into a textual format using the previously mentioned image processing methods has been designed to facilitate the usage of the methodology. The end user just receives the final outcome of the methodology in a form of textual file, while the phases of image processing are not displayed within the GUI in order to retain transparency. A simple layout of the developed GUI application is presented in Figure 10.

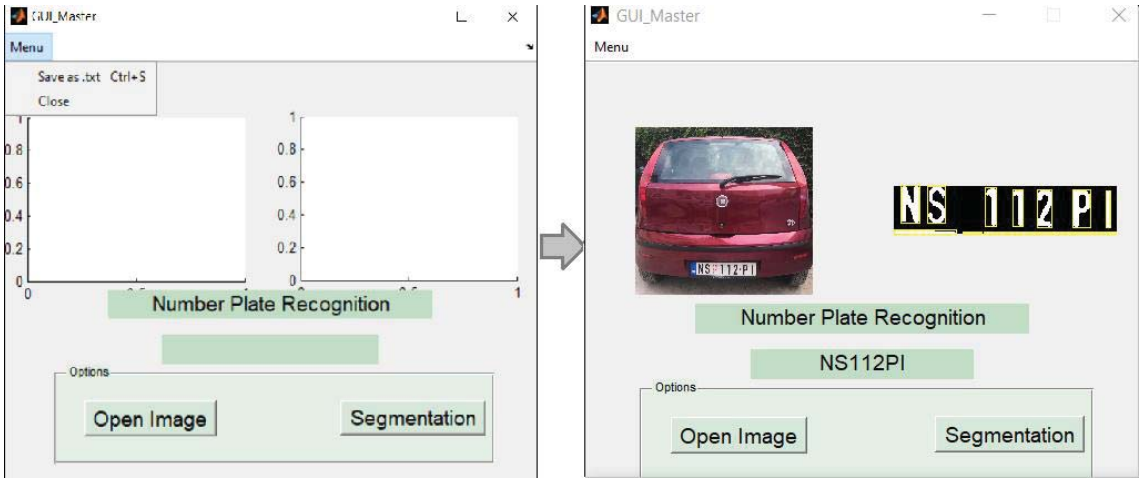

Figure 10: Graphical user interface

5. DISCUSSION

Limitations of the methodology were identified after testing the application through a series of iterations. Defining the limitations of the methodology serves as a basis for further improvements of the current version of the methodology and potential solutions to currently observed shortcomings. In order to draw conclusions and directions for future work, it is necessary to test the application on a larger set of different images.

Based on testing phase, it ca be concluded that the segmentation step was adequately performed in most examples, as well as the segmentation of all individual characters and the creation of sub-images. However, difficulties arise at the last step - character recognition, where the search for the highest level of correlation occurs, in some cases lead to the mismatch of letter and number characters as well as between letters. Due to the use of the application, it was established that certain numbers and letters are mixed up, specifically "O" and "0" or "B" and "8" or "6". A potential solution that arises is to define specific positions of letters and numbers within the license plate. If the license plates of the Republic of Serbia are observed, a template can be created by defining in which positions either a letter or a number can occur. The first two positions always contain letters, while the next three or four fields (depending on the region where the vehicle is registered) contain numbers, and the last two positions of the plate again contain letters. This method would eliminate the possibility of misreading similar characters, in the specific case of digits and letters.

The difficulty that occurs when reading the characters of license plates from the Republic of Serbia is also mixing the letter "C" with "Č" or "Ć" in conditions of poor visibility or low image quality. Also for letter designations "Z" with "Ž" and "S" with "Š", however, by applying a series of operations to improve image quality and correct the imaging angle, these difficulties could be overcome.

The proposed methodology is sensitive to pattern mismatch when the segmented character does not contain the same font as the patterns. Changes in the structure of the input characters have a negative impact and the matches of certain characters are not found in their corresponding letter or digit patterns. Different fonts and the lack of a universal font used by all countries would make character recognition considerably simpler with the aid of the template matching technique. Depending on the regulations of the country in which license plates were issued, they possess different characters, letters, digits, fonts, and background colours. Vehicles from different countries or states can use the same font, but the arrangements on their license plates may differ. It would require a considerable amount of time to make this methodology global, not just for license plates registered in the Republic of Serbia, because the current database of templates would need to be enhanced with all potential fonts, digits, and characters.

6. CONCLUSIONS

The importance of license plate recognition systems integrated with optical character recognition techniques, is influenced by the need to minimize the human element in this process, achieve a higher level of vehicle access control in a particular area, for example in parking billing solutions, and automatically determine how much time vehicle has spent in certain area and charges that are needed to be paid after the use of specific services. If the proposed methodology is used in monitoring the parking lot, then it is necessary to provide a connection with a database where the time of entry to the parking lot of a certain license plate and the time when someone should exit it would be automatically entered. By calculating the time spent in the parking lot, monetary compensation would also be calculated. A similar example is the possibility of use in the parking service, where it is possible, based on an image and characters, to check in a certain database whether parking has been paid for a certain region or not and for what period of time. If it is a matter of vehicle registration, a database of registered vehicles is also necessary, with which every result of the methodology would be compared, and if there is no such record in the database, the conclusion is reached that the car with certain license plates is not registered.

Based on the aforementioned potential fields of use, this methodology offers a broad spectrum of applications, and future research will be concentrated on enhancing it. The direction of future development can be focused on the elimination of the limitation of optical character recognition, which is reflected in the mixing of letter and number marks within the license plates of the Republic of Serbia. A potential solution to the problem is the definition of specific positions where you can expect a letter mark

and where a numerical one. Consequently, the success of recognizing the registration number of a certain license plate would be increased. In the future, it would be important to apply the methodology to a larger set of images in order to accomplish and demonstrate the level of success of the methodology, as well as provide more relevant data related to the overall accuracy of the methodology. In the matter of digital image processing, if a universal camera was used for the acquisition of images that serve as an input parameter in the proposed methodology, the problems of different image quality, lighting, contrast and other external factors that greatly affect optical character recognition could be solved.

7. REFERENCES

Anderla, A., Culibrk, D. & Delso, G. (2013) Metal Artifact Reduction from CT Images Using Complementary MR Images. In: *11th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services, TELSIKS, 16-19 October 2013, Niš, Serbia.* Piscataway, IEEE. pp. 337-340. Available from: doi: 10.1109/TELSKS.2013.6704943

Ashraf, N., Arafat, Y. S. & Iqbal, J. (2019) An Analysis of Optical Character Recognition (OCR) Methods. *International Journal of Computational Linguistics Research*. 10, 81-91. Available from: doi: 10.6025/jcl/2019/10/3/81-91

Bhat, R. & Mehandia, B. (2014) Recognition of Vehicle Number Plate using MATLAB. *International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering*. 2 (8), 1899-1903.

Dias, N. J. & Ashan, M. B. (2016) Recognition of Vehicle Licence Plates using MATLAB. *European International Journal of Science and Technology.* 5 (6), 91-101.

Gonzalez, R., Woods, R. & Eddins, S. (2009) *Digital Image Processing Using MATLAB*. Gatesmark Publishing.

Goyal, P. (2010) Image Processing using Matlab. In: *National Conference on Advance Computing and Communication Technology, NCACCT-2010*, *Ghaziabad, India.* pp. A48-A51.

Gutai, A., Havzi, S., Stefanovic, D., Anderla, A. & Sladojevic, S. (2021) Optical Character Recognition Methods for Number Plate Recognition: A Systematic Literature Review. In: *Proceedings of the 32nd International DAAAM Virtual Symposium "Intelligent Manufacturing & Automation", 28-29 October 2021, Vienna, Austria.* Vienna, DAAAM International. pp. 692-700. Available from: doi: 10.2507/32nd.daaam.proceedings.097

Marques, O. (2011) *Practical Image and Video Processing Using MATLAB*. Hoboken, John Wiley & Sons.

Mutholib, A., Gunawan, T. S., Chebil, J., & Kartiwi, M. (2013). Optimization of ANPR Algorithm on Android Mobile Phone. In: *2013 International Conference on Smart Instrumentation, Measurement and Applications, ICSIMA, 25-27 November 2013, Kuala Lumpur, Malaysia*. Piscataway, IEEE. pp. 1-5. Available from: doi: 10.1109/ICSIMA.2013.6717950

Pagad, N. S., Shetty, B. S., Sharada, N. K. & Kulkarni, S. M. (2017) Automatic Vehicle Recognition System for Enforcing Security in Restricted Places using MATLAB. *International Journal of Scientific Development and Research*. 2 (6), 529-533.

Shaikh, S., Lahiri, B., Bhatt, G. & Raja, N. (2013) A novel approach for automatic number plate recognition. In: *2013 International Conference on Intelligent Systems and Signal Processing*, *ISSP*, *1-2 March 2013, Vallabh Vidyanagar, India.* Piscataway, IEEE. pp. 375-380. Available from: doi: 10.1109/ISSP.2013.6526938

Srinu, V., Morla, V. R., Baditha, K. V., Varakumari, S. & Maddimsetti, S. (2018) License Plate Recognition System Using Matlab GUI For Surveillance. *International Journal of Engineering & Technology*. 7 (2.7), 1008-1016. Available from: doi: 10.14419/ijet.v7i2.7.11676

Stefanovic, D., Havzi, S., Nikolic, D., Dakic, D. & Lolic, T. (2021) Analysis of the tools to support systematic literature review in software engineering. In: *IOP Conference Series: Materials Science and Engineering,*

Volume 1163, The 9th International Conference on Engineering and Technology, ICET-2021, 27th May 2021, Hat Yai, Thailan. Philadelphia, IOP Publishing. Available from: doi: 10.1088/1757-899X/1163/1/012013

Stefanovic, D., Spasojevic, I., Havzi, S., Lolic, T. & Ristic, S. (2020) Information systems success models in the e-learning context: A systematic literature review. In: *Proceedings of the 31st International DAAAM Virtual Symposium "Intelligent Manufacturing & Automation", 21-24 October 2020, Mostar, Bosnia & Herzegovina.* Vienna, DAAAM International. Pp. 0555-0564. Available from: doi: 10.2507/31st.daaam.proceedings.077

Stefanović, H., Veselinović, R., Bjelobaba, G. & Savić, A. (2017) Optimizacija algoritamskih rešenja za izdavanje obeležja registraskih tablica u osnovima otežane detekcije. *Info M*. 16 (64), 33-37.

Surekha, P., Gurudath, P., Prithvi, R. & Ritesh Ananth, V. G. (2018) Automatic License Plate Recognition using Image Processing and Neural Network. *ICTACT Journal on Image and Video Processing.* 8, 1786-1792. Available from: doi: 10.21917/ijivp.2018.0251

Sutar, G. T. & Shah, A. V. (2014) Number Plate Recognition Using an Improved Segmentation. *International Journal of Innovative Research in Science, Engineering and Technology*. 3 (5), 12360-12368.

Swaroop, P. & Sharma, N. (2016) An Overview of Various Template Matching Methodologies in Image Processing. *International Journal of Computer Applications*. 153 (10), 8-14.

Tejas, K., Ashok, R. K., Pradeep, R. D. & Rajesh, M. (2017) Efficient Licence Plate Detection By Unique Edge Detection Algorithm and Smarter Interpretation Through IoT. In: *7th international conference on soft computing and problem solving*, *SocProS 2017, 23-24 December 2017, Bhubaneswar, India*.

Tiwari, B., Sharma, A., Singh, M. G. & Rathi, B. (2016) Automatic Vehicle Number Plate Recognition System using Matlab. *IOSR Journal of Electronics and Communication Engineering*. 11 (4), 2278-2834. Available from: doi: 10.9790/2834-1104021016

Xie, W. & Wu, Y. (2014) Licence Plate Automatic Recognition System Based on MATLAB-GUI. *The Open Automation and Control Systems Journal*. 6 (1), 497-502. Available from: doi: 10.2174/1874444301406010497