Automatic and Secure Electronic Gate System Using Fusion of License Plate, Car Make Recognition and Face Detection

Ghaida Saadouli, Maha Ibrahim Elburdani, Razan Mohammed Al-Qatouni, Suchithra Kunhoth, Somaya Al- Maadeed
Department of Computer Science and Engineering
Qatar University
Doha, Qatar
gs1104577@student.qu.edu.qa, me1105251@student.qu.edu.qa, ra1203107@student.qu.edu.qa, suchithra@qu.edu.qa, S_alali@qu.edu.qa

***Abstract*— In this paper, we propose an automatic electronic gate system with authenticity confirmation from 3 individual modules, viz., car make and model, license plate and face detection. The ultrasonic sensor detects the stopped cars and initiate the camera to capture the car image. Connected Components identification and Optical Character Recognition (OCR) algorithms are performed to recognize the characters and numbers in the car plate. The car make and model detection algorithm uses feature extraction algorithms based on Difference of Gaussians (DoG) detector and Scale Invariant Feature Transform (SIFT) descriptor. The Euclidian distance measure identifies the suitable match for a query image with the one in database to determine the car make and model. The face detection of driver is carried out to ensure the security of intended premise of the system deployment. It is based on the Viola Jones algorithm. In the final stage, matching algorithms are applied to decide whether the image of the car plate, make and model and the face does not conflict with the details stored in the database. The smart electronic gate will open and let the car enter when the authenticity is confirmed. The system is evaluated by building a prototype electronic smart gate using Logitech C920 HD pro webcam, Toy car and LEGO NXT Motor Controlled Gate. Moreover we built a preliminary database from the images captured by surveillance cameras for make and model recognition of Qatar cars. Experimental evaluation on this dataset delivered an accuracy of 75%.**

Keywords—car make and model, face detection, license plate recognition, SIFT, LEGO NXT

I. INTRODUCTION

Security is a major concern that should be managed diligently when it comes to the matter of accessing certain restricted premises. Surveillance cameras are widely implemented which allows maintaining a digital record of persons and cars entering the concerned location. Computer vision and image processing approaches provide an automated system for analyzing these images and videos. Since the number of vehicles are increasing day by day, these technologies can provide easier and faster solutions in such scenarios.

Automatic license plate recognition (ANPR) systems [1] have become a very useful technology to identify traffic offenses and thereby control it to a limited extent. Additional benefits such as theft control or prevention, access control management etc. can ensure the safety of persons as well as cars. Nowadays ANPR systems are common in many public areas such as parks, shopping malls etc. However, ANPR may not be enough to recognize a car in certain instances, because it can be easily forged [2]. For example, if the thief wants to enter a secured area and his car is pawned, he can simply replace the license plate of his car by another plate number. Hence we cannot solely depend on the ANPR systems in more secured areas such as military compounds, governmental organizations such as ministry offices. The recognition of car make and model complements the ANPR to build a bit more secure system. It serve as an effective aid for police forces in the investigation of criminal offenses involving vehicles. Moreover, this can also be used to track employees in some secured areas like airports and military buildings. The identification of face of the driver can add further confirmation to indicate the real identity of the vehicle. An automatic gate control system with a multi-level authentication schema built on combining multiple cues from the vehicle can thus control unauthorized entry.

In this work, we propose a smart secure electronic gate based on the functionalities of license plate, car make and model, and face detection. An ultrasonic sensor is utilized to detect the event of the cars being stopped at the gate. The three subsequent modules takes the image of captured car and perform the respective analysis. Once we have the information of number plate, car make and model and the driver, we can confirm the entry based on a matching with the details stored in a database. In the situations of data mismatch, a security guard can turn up to provide the required assistance.

Figure 1. Smart gate equipped with computer vision based authentication techinques

This paper is organized as follows. Section II provides a brief review of the related researches carried out in the past years. Section III looks into the significant benefits of such a system and Section IV describes the methodology of our system. The description and testing of our prototype is provided in section V and VI. The details of our car dataset and the corresponding experimental results are added in section VII. Finally concludes the paper with section VIII.

II. Related Work

There are several research works available in the Intelligent transportation systems (ITS) field involving the ANPR and Automatic vehicle Make and model recognition (AVMMR) techniques. They are summarized here under specific subsections, along with the researches related to face detection.

A. ANPR techniques

Scale invariant feature transform (SIFT) describing local image features are widely used in pattern recognition tasks [3]. The work in [4] is based on SIFT features. However background objects, poor illumination, blurring are found to affect the recognition rate. A different approach based on the SIFT algorithm was proposed in [5] for the localization of the license plates. It finds keypoint features in the images, which were used in the matching process between input images and characters templates. The recognition was based on the peculiarities in transition among pixels of characters. The behavior of these transitions which is unique to each character helps in their classification. An experimentation of two sets of 60 brazilian License Plate images each yielded an accuracy of 88.33% and 70%. Another work [6] used SIFT based template matching technique for localization of Jordanian number plates. The characters were further recognized on application of OCR in the segmented license plates.

Localisation of blue color areas in HSV color space was performed as an intial step in the license plate recognition method proposed by Azad et al. [7]. The method focused on the detection of standard Iranian plates. Color and the geometric aspects served as the cues to localize the license plates in the HSV image which is subdivided into numerous blocks. Any tilts in the located license plate was managed utilizing the features of pixel arrangements and yielded a good result of about 45 degrees. Normal factoring with a similarity measure was used in the character recognition stage and the resultant accuracy was 97%. An ANPR system focused on Indian license plates in [8] uses the template matching technique for character recognition. Segmentation stage suggests the use of rectangular projection of number plate or an alternative method of template matching. However, testing was conducted only in a very small set of 8 images with various shape, illumination, view-angle, distance etc.

ANPR system in [9] makes use of the Fourier transform to detect inherent spatial frequency of the characters in a license plate. Once the plates are localized using fourier analysis, characters are segmented based on connected components and recognized using Support Vector Machines (SVM). The character recognition method in [10] also uses SVM on providing the extracted normalized character subimages as the feature vectors to perform the recognition.

The license plate recognition task is addressed using a You only look once (YOLO) deep learning framework in [11]. Using 7 convolutional layers, the system exhibited approximately 98.22% and 78% accuracy for license plate detection and recognition respectively. ANPR was commonly implemented in a PC based platform to enable the processing of high quality images in a shorter period of time. But nowadays mobile based platforms are also being considered for performing the automatic number plate recognition. The work in [12] reviews several researches that have implemented ALPR in the mobile-based platform.

B. AVMMR techniques

Zafar et. al [13] proposed a 2D Linear Discriminant analysis(LDA) based approach for car make and model recognition. Experiments demonstrated that 2D LDA performed better than the Principal Component Analysis (PCA). A hierarchical classifier was designed in [14] that determine the class of vehicle at first and then proceed to recognize vehicle make and model in a smaller group. The algorithm produced 96% accuracy on a dataset of over 280 back view images of vehicles. Moreover, robustness to illumination and weather conditions were guaranteed. Vehicle model recognition in [15] used the geometry and appearance of car emblems in the captured rear view images. Using linear SVM binary classifier with HOG features, an accuracy of 93.75% was obtained on a dataset of 1342 images of 8 car make and 28 different car models. A smart camera equipped with ANPR, AVMMR as well as color recognition capabilities are described in [16].

The make and model recognition uses scalable vocabulary tree (SVT) which is built on the Speeded Up Robust Feature (SURF) descriptors [16]. The ANPR methodology follows a series of steps such as otsu binarization, canny edge detection, contour extraction, and the usage of an OCR Reader. The developed iCamera system had processing speed of 10 fps. Two specific methodologies for MMR are proposed in [17]. The real time system relies on SURF and SVM for the make and model recognition. The visual content classification approach for a non- real time scenario make use of the Edge Histogram, SURF and SIFT descriptors. The latter method yielded higher classification accuracy. The work in [18] studied the effectiveness of combining several local feature point detectors with the SIFT descriptor. The experimental results on four databases was analyzed to report the comparatively higher recognition rates resulting from the SIFT- DoG, SIFT- Multiscale Hessian, SIFT- Multiscale Harris combinations.

The recent work in [19] used frontal view of the vehicle images with a SqueezeNet deep learning architecture for the realization of an AVMMR system. Experiments on over 291,602 images comprising 766 classes yielded an accuracy of 96.33 %.

C. Face Detection techniques

Face detection and Face recognition methodologies are commonly used for biometric authentication purposes [20]. Viola- Jones proposed a major approach for face detection which ensures faster detection along with high detection rate [21]. The classifier was built on the AdaBoost algorithm, which enables to select a small number of critical visual features from enormous potential features. The cascading of classifiers served to reduce the computation time as well. Face detection based on skin color likelihood utilizes a stochastic model to compute the similarity between skin and non-skin like regions [22]. Local Binary Patterns (LBP), Haar like features was used to build the cascaded classifier. The concept of snakes, which is contour or deformable curve was also used for face detection. The application of color information in the snake models led to the facial feature extraction algorithm in [23].

Apart from the feature based approaches, statistical as well as neural network based methods were also found for face detection. Reference [24] proposed a hierarchical face detection system. The eigenface algorithm was used to select the possible face candidates which are further examined by a neural network. The template based face verification schema was used to confirm each face region from the output of the neural network. Multi-order statistical descriptors capable of object classification and face recognition was introduced in [25]. Dimensionality reduction of descriptors using multiple linear discriminant analysis and kernel linear discriminant analysis makes it a faster algorithm suitable for potential application in real time object classification including faces.

The method proposed in [26] was able to detect faces from different angles and can handle occlusion to some extent. It is a deep dense face detector based on deep convolutional neural network. Another deep learning framework for face detection can be found in [27]. It is an extension of the faster Region based CNN framework for generic object detection. Several strategies for adapting the technique for resolving face detection tasks were proposed, including feature concatenation, multi-scale training, hard negative mining etc.

III. SIGNIFICANCE OF THE SECURE AUTOMATIC GATE SYSTEM

An automatic gate was proposed in [28] for controlling the entry to a building gate. The system relies on a patch based matching process wherein a patch of the entering vehicle image is matched with the vehicle images of database. The gate control system in [29] utilizes the license plate information for the authorization purpose. The automatic parking management and fee collection system [30] depends solely on the license plate recognition for the access control. Similar work is reported in [31] by the implementation of an intelligent secure garage system based on the license plate recognition technique. A recent work [32] was also found to rely merely on the license plate recognition for realizing an automated gate. The automated security gate attendant [33] capture both the visitor face and the license plates. The authentication is based on the name entered by the visitor in the interface as well as the license plate number. The security cannot be assured completely since the name entered by a visitor cannot be considered as a valid information. The system proposed in [34] includes automatic license plate recognition, vehicle make and model detection and under-vehicle inspection. The combination of these methods was suggested to minimize the limitations of each individual technique and increase security in vehicle inspection.

The fusion of three techniques; License plate recognition, vehicle make and model recognition as well as face detection can obviously strengthen the security level and can build a highly secure automatic gate at the entrance of restricted areas. We aims to perform the recognition of Qatari car plates with a design suitable for replacing the traditional security gates in Qatar University. The potential benefits of the system include:

(1) We will have an opportunity to acquire more information about the persons entering the campus which in turn enhances the security in the premises

(2) The waiting times due to the screening procedures such as manual checking of the identity card can be reduced

(3) The categorized information on the incoming faculty, staff, students and guests can be utilized in managing the parking spaces to be allotted for each of them

(4) A statistical data can be collected with respect to the type of visitors as well as the model of car used

IV. PROPOSED METHOD

The Proposed methodology for the secure automatic gate system is depicted in the Figure 2.

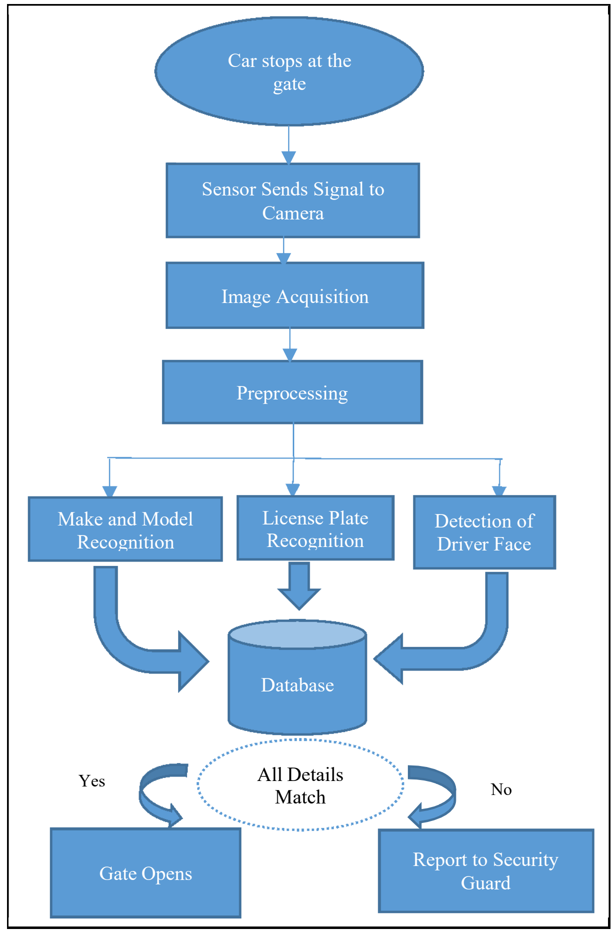

Figure 2. Proposed framework for the secure automatic gate

A. Pre-processing and extraction of region of interest (ROI)

Database of toys cars is used in the implementation of our prototype. The database consists of 10 cars of different make and model. The pre-processing of the captured real time image involves conversion to grayscale and noise removal by median filtering. Binarization and the connected component labelling serves to identify the target license plates based on their specific structural properties (Figure 3). The corresponding regions of interest (ROI) extraction identifies the area around the headlights, upper and bottom grills. This region contains the discriminating information capable of recognizing the car makes and models. The ROI selected from a sample image is shown in the Figure 4.

Figure 3. Extracted License Plate

Figure 4. ROI selection for make and model recognition

B. Make and Model Recognition

The AVMMR system follows the algorithm in [18], where the interest points are detected using DoG and feature extraction from those keypoints are done using SIFT descriptors. The training part computes the SIFT features from various images of different car make-models. A euclidean distance based matching between the query descriptor and all the prestored descriptors from the training image points out the closest match for the test image. The best match identified by the smallest distance determines the make and model of the car.

C. Face Detection

The Face Detection algorithm was implemented using Viola Jone's method [35].

D. Number Plate Recognition

This module accepts the cropped license plates from the preprocessing stage. Following the segmentation and character recognition, it provides the plate numbers as text data. First, a dilation operation is applied to the binarized image to split the characters from each other if the characters are close. Second, a horizontal and vertical line scanning are performed to find each character region. Then, each character is cropped out based on the start and end point information in the horizontal direction.

The next step is to normalize the cropped characters by making sure that there are no extra white spaces and they are equal in size and matches the size of character images stored in the database. The character image is compared with the ones in the database using template matching and the best similar character is sorted out to recognize the target character.

V. Building the Prototype

The hardware and software aspects in the design of prototype are described in the subsequent sections.

A. Hardware Design

Logitech C920 HD pro webcam was used to capture the frontal view images of the stopped car. An ultrasonic sensor senses the event of stopping the car. LEGO Mindstorms NXT, the programmable robotics kit with sensor, motors was used to build the robot to control gate movement. Toy cars of apparently big size are used in this work since they have a convenient size, which help to detect and recognize the plate number.A street prototype is also prepared to setup the demo.

B. Software Design

The software requirements include MATLAB R2013a or above with Image Processing and Computer Vision Toolbox, and VLFeat Library. NXT Lego Software needs to be installed and integrated with MATLAB. The LEGO Mindstorms NXT is used as the electronic gate system in this design.

VI. Testing the Prototype

The system testing was done by simulating different scenarios wherein different toy cars was prompted to enter the gate. Figure 5 shows the interface of our application with the corresponding results. The sensor detected the stopped car, which is a Ferrari toy car. The program was able to recognize its make and model successfully. Then, it recognizes the plate number which is 12889. All the results including the detected driver's face are displayed on the screen. Finally, the car is granted permission by enabling the opening of gate.

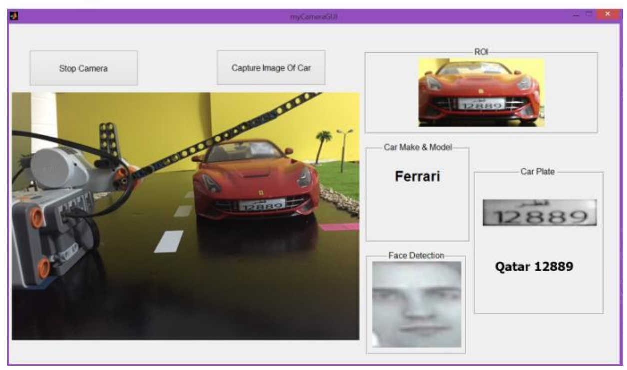

Figure 5. Interface of our system with the test results

The test results on the dataset demonstrated 100% accuracy in recognizing the make and model of the car. However there was one wrong detection for license plate and two wrong detections for face which can be due to light reflections on the windshield.

More accurate algorithms can be experimented for the recognition phases which helps to implement the system in a real scenario apart from this prototype. As far as the prototype is concerned, the recognition and detection takes only 2 seconds. Optimized algorithms serve to deliver comparable processing times, which turns out to be a promising concept. The assured security is really helpful in areas such as international airport where we are safe to leave our cars especially for long term parking. The instances of car thefts can be ruled out. Military premises can guarantee the authorized vehicle entries without a security personnel. These systems tend to be more secure and unbiased.

VII. Car Make and Model Recognition on Qatar University Surveillance Data

There is no publicly available dataset for make and model recognition of Qatar vehicles. We built a dataset for the same utilizing the images captured by surveillance cameras at the university gates. The dataset is comprised of 225 images in total constituting 24 different make-models (Table 1).

TABLE 1. DETAILS OF QU CAR DATASET

SL. No	Car Make Types	Number of Models used
1	Chevrolet	1
2	GMC	2
3	Honda	3
4	Lexus	2
5	Mitsubishi	3
6	Nissan	4
7	Toyota	9

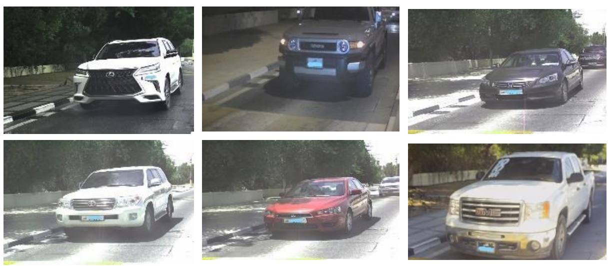

Figure 1. Sample images from our database

The variability of dataset is attributed to the different natural lighting conditions and the security gates from which the images are taken. Compared to the existing datasets, the images are taken while the vehicles are in motion which may result in some blurry images as well.

Experiments were carried out on our raw dataset for the car make and model recognition. The Region of interest is identified as the frontal region containing headlights and grills. It is cropped out manually and used for recognizing the make and model of car. All the images are further resized to 1024x512 to have uniform dimensions. The experimental results for car make and model recognition using the approach in [18] is indicated in the Table 2. The SIFT descriptor is combined with the various detectors and the comparitive analysis indicate that SIFT- DoG and SIFT- Hessian combination delivers the maximum accuracy of 74.63%.

TABLE 2. MAKE- MODEL RECOGNITION ACCURACIES

Method	Accuracy (%)
DoG	74.63
Hessian	74.63
Harris Laplace	68.66
Hessian Laplace	65.67
Multiscale Harris	71.64
Multiscale Hessian	73.13

VIII. CONCLUSION AND FUTURE WORK

We proposed a real time automatic gate with the fusion of car make and model recognition, license plate recognition as well as face detection. The deployment of such a gate can minimize the human effort and increase the level of security in the intended premise. The faster authentication approach can reduce the traffic blocks that may arise as a result of manual screening or the installed card reader. The system tests conducted with the help of our prototype demonstrated the feasibility of real time implementation. Another contribution of the work is the dataset for Qatar car make and model recognition, which is built on real surveillance images. The preliminary results are promising and we intend to extend and build a complete dataset to include the different types of vehicles currently in use in the state of Qatar. In addition, the ROI selection can be automated.

ACKNOWLEDGMENT

This publication was supported by Qatar University Collaborative High Impact Grant QUHI-CENG-18/19-1. The findings achieved herein are solely the responsibility of the authors. The contents of this publication are solely the responsibility of the authors and do not necessarily represent the official views of the Qatar University.

REFERENCES

[1] National Police Chief's Council. "Automatic Number Plate Recognition (ANPR)". [Online]. Available: https://www.npcc.police.uk/FreedomofInformation/ANPR.aspx.[Accessed: Nov 28, 2019].

[2] C. Parker. (2 December 2018). "Warning to Brits over fake number plates as simple tips could stop YOU becoming a victim". [Online]. Available: https://www.thesun.co.uk/uncategorized/7879382/warning-brits-fake-number-plates/.[Accessed: Nov 28, 2019].

[3] S. Almaadeed, A. Bouridane, D. Crookes, O. Nibouche, "Partial shoeprint retrieval using multiple point-of-interest detectors and SIFT descriptors," Integrated Computer-Aided Engineering, vol. 22, (1), pp. 41-58, 2015.

[4] M. Zahedi and S. M. Salehi, "License plate recognition system based on SIFT features," Procedia Computer Science, vol. 3, pp. 998-1002, 2011.

[5] F. A. da Silva, A. O. Artero, M. S. V. de Paiva, and R. L. Barbosa. (2013), "ALPRs-A new approach for license plate recognition using the SIFT algorithm". [Online]. Available: https://arxiv.org/abs/1303.1667. [Accessed: Nov 28, 2019].

[6] K. M. A. Yousef, M. Al-Tabanjah, E. Hudaib, and M. Ikrai, "SIFT based automatic number plate recognition," in 2015 6th International Conference on Information and Communication Systems (ICICS), 2015, pp. 124-129.

[7] R. Azad, F. Davami and B. Azad, "A novel and robust method for automatic license plate recognition system based on pattern recognition," Advances in Computer Science: An International Journal, vol. 2, (3), pp. 64-70, 2013.

[8] K. Bhosale, J. Jadav, S. Kalyankar, R. Bhambare, "Number Plate Recognition System for Toll Collection," International Journal of Emerging Technology and Advanced Engineering, vol. 4, (4), pp. 729-732, 2014.

[9] G. Lekhana and R. Srikantaswamy, "Real time license plate recognition system," International Journal of Advanced Technology & Engineering Research, vol. 2, (4), pp. 5-9, 2012.

[10] A. Kaur, S. Jindal and R. Jindal, "License plate recognition using support vector machine (SVM)," International Journal of Advanced Research in Computer Science and Software Engineering, vol. 2, (7), 2012.

[11] R. Chen, "Automatic License Plate Recognition via sliding-window darknet-YOLO deep learning," Image Vision Comput., vol. 87, pp. 47-56, 2019.

[12] L. Connie, C. K. On and A. Patricia, "A Review of Automatic License Plate Recognition System in Mobile based Platform," Journal of Telecommunication, Electronic and Computer Engineering (JTEC), vol. 10, (3-2), pp. 77-82, 2018.

[13] I. Zafar, E. A. Edirisinghe, S. Acar, H. E. Bez, "Two-dimensional statistical linear discriminant analysis for real-time robust vehicle-type recognition," in Real-Time Image Processing, 2007, pp. 649602.

[14] H. Emami, M. Fathi and K. Raahemifar, "Real time vehicle make and model recognition based on hierarchical classification," International Journal of Machine Learning and Computing, vol. 4, (2), pp. 142, 2014.

[15] D. F. Llorca, D. Colás, I. Daza, I. Parra, M. A. Sotelo, "Vehicle model recognition using geometry and appearance of car emblems from rear view images," in 17th International IEEE Conference on Intelligent Transportation Systems (ITSC), 2014, pp. 3094-3099.

[16] R. Baran, T. Rusc and P. Fornalski, "A smart camera for the surveillance of vehicles in intelligent transportation systems," Multimedia Tools Appl, vol. 75, (17), pp. 10471-10493, 2016.

[17] R. Baran, A. Glowacz and A. Matiolanski, "The efficient real-and non-real-time make and model recognition of cars," Multimedia Tools Appl, vol. 74, (12), pp. 4269-4288, 2015.

[18] S. Al-Maadeed, R. Boubezari, S. Kunhoth, A. Bouridane, "Robust feature point detectors for car make recognition," Comput. Ind., vol. 100, pp. 129-136, 2018.

[19] H. J. Lee, I. Ullah, W. Wan, Y. Gao, Z. Fang , "Real-time vehicle make and model recognition with the residual SqueezeNet architecture," Sensors, vol. 19, (5), pp. 982, 2019.

[20] S. Al-Maadeed, M. Bourif, A. Bouridane, R. Jiang, "Low-quality facial biometric verification via dictionary-based random pooling," Pattern Recognit, vol. 52, pp. 238-248, 2016.

[21] P. Viola and M. J. Jones, "Robust real-time face detection," International Journal of Computer Vision, vol. 57, (2), pp. 137-154, 2004.

[22] Y. Ban, S. K. Kim, S. Kim, K. A. Toh, S. Lee, "Face detection based on skin color likelihood," Pattern Recognit, vol. 47, (4), pp. 1573-1585, 2014.

[23] K. Seo, W. Kim, C. Oh, J.-J. Lee, "Face detection and facial feature extraction using color snake," in Proceedings of the 2002 IEEE International Symposium on Industrial Electronics, L'Aquila, Italy, 2002, pp. 457-462.

[24] C. Tsai, W.C. Cheng, J.S. Taur and C.W. Tao, "Face detection using eigenface and neural network," in 2006 IEEE International Conference on Systems, Man and Cybernetics, 2006, pp. 4343-4347.

[25] A. Mahmood, M. Uzair and S. Al-Maadeed, "Multi-order statistical descriptors for real-time face recognition and object classification," IEEE Access, vol. 6, pp. 12993-13004, 2018.

[26] S. S. Farfade, M. J. Saberian and L. Li, "Multi-view face detection using deep convolutional neural networks," in Proceedings of the 5th ACM on International Conference on Multimedia Retrieval, 2015, pp. 643-650.

[27] X. Sun, P. Wu and S. C. Hoi, "Face detection using deep learning: An improved faster RCNN approach," Neurocomputing, vol. 299, pp. 42-50, 2018.

[28] K. Sundus and S. Mamare, "Using Digital Image Processing to Make an Intelligent Gate," (IJACSA) International Journal of Advanced Computer Science and Applications, vol. 5, (5), 2014.

[29] M. M. Aziz, "Ishik University Gate Control based on Kurdistan License Plat," International Journal of Enhanced Research in Science, Technology & Engineering (2319-7463), vol. 5, (1), pp. 34-38, 2016.

[30] M. M. Rashid, A. Musa, M. A. Rahman, N. Farahana, and A. Farhana, "Automatic parking management system and parking fee collection based on number plate recognition," International Journal of Machine Learning and Computing, vol. 2, (2), pp. 94, 2012.

[31] A. U. Ahmed, T. M. Masum and M. M. Rahman, "Design of an automated secure garage system using license plate recognition technique," International Journal of Intelligent Systems and Applications, vol. 6, (2), pp. 22, 2014.

[32] L. T. A. Al-Mahbashi, N.A. Yusof, S. Shaharum, M. S. Karim, A. A. Faudzi, "Development of automated gate using automatic license plate recognition system," in Proceedings of the 10th National Technical Seminar on Underwater System Technology, 2019, pp. 459-466.

[33] P. Bongard, Automated Security Gate Attendant, United States patent US 8,254,631. Aug 28 2012.

[34] C. Anagnostopoulos, I. Giannoukos, T. Alexandropoulos, A Psyllos, V. Loumos, and E. Kayafas , "Integrated vehicle recognition and inspection system to improve security in restricted access areas," in 13th International IEEE Conference on Intelligent Transportation Systems, 2010, pp. 1893-1898.

[35] Mathworks, Vision Cascade Object Detector. [Online]. Available: https://www.mathworks.com/help/vision/ref/vision.cascadeobjectdetector-system-object.html [Accessed: Nov 28, 2019]