Volume 7, Issue 1
February 2018

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

An Effcient Method for Extraction of Vehicle License Plate for Various Applications in Smart Cities

Khursheed Aurangzeb

Department of Computer Engineering, College of Computer and Information Sciences, King Saud University, Riyadh, Saudi Arabia

E-mail: kaurangzenb@ksu.edu.sa

ABSTRACT

The detection and identification of Vehicle License Plate (VLP) is essential in many smart cities applications including smart car parking, stolen vehicle' recovery, traffic monitoring, automatic toll payment etc. Based on the fact that images/video contain huge information, the object extraction, identification and tracking using image/video processing techniques is one of the attractive methodologies that can be applied in the aforementioned applications. The detection and tilt correction of VLP is an important task which significantly affects the accuracy of the character segmentation/recognition and in turn the VLP identification. In this work, I have explored and developed an effective scheme for the extraction of VLPs in images captured from various angles and at varying distances. I have applied convolution based method which uses vertical and horizontal filtering for localizing the horizontal and vertical borders of the VLP. Based on these borders, the VLP is extracted from the captured images. In the experiments, the real captured images of the vehicles at various distances and angles from the vehicle are used. The simulation results show that the proposed method is efficient for extracting the VLP from the images.

Keywords: *Image processing, object extraction, vehicle license plate, vehicle identification, smart cities, smart transportation system.*

1. INTRODUCTION

In [1], the authors identified the constituents parts of smart cities which include smart transportation, smart buildings, information and communication technology (ICT), smart grids, good governance, efficient healthcare system etc. The smart cities are well organized because of the successful operations of these individual constituent parts. The authors further said that smart city is a city where daily activities and other services are made efficient, well organized and manageable.

It can be generalized that, in a smart city, the communication and other latest technologies are converted into enhanced services for inhabitants. The communication and other advance technologies are applied in smart city for enhancing the quality of life of the inhabitants.

The main promising and enabling technologies for transforming ordinary cities into smart cities are Big Data (BD) analytics, ICT and Internet of Things (IoT). In the last few years, there has been remarkable progress in the mentioned technologies because of the progression in communication infrastructure, embedded systems, hardware/software design methods and BD generated from many sensors. The BD generated by various sensors in the smarts cities, can be processed and transformed into useful information by utilizing the advance machine learning and deep learning methods.

Although the technology is advance enough for transforming existing cities into smart cities but still there are a lot of challenges and opportunities for advancements in these technologies. The smart transportation system is one of the key constituent parts of the smart cities and it has a profound impact on the social, economic and environmental aspects of the smart cities. The smart parking and traffic monitoring systems are the core research areas [2]-[10].

The smart parking systems in smart cities not only help in the reduction of the cost related to monitoring and collecting fines/fee but it also assists in traffic congestion reduction. By deploying the smart parking system in the smart cities, the drivers can quickly localize the empty parking places [2]-[6].

The development and deployment of efficient traffic monitoring system is highly important for managing congestion in the smart cities. In the last several years, many researchers and practitioner have given considerable attention to the problems of traffic management in big cities. Many organizations proposed and implemented various projects for solving many issues such as huge waiting time at inter-sections, safety, reliability and congestion reduction [7]-[10].

In [7], the authors proposed an intelligent transport system and their focus has been on the improvement of the traffic flow on the roads of Hong Kong. They collected and analyzed road traffic data for reducing the traffic congestion. In [8], the authors investigated the collected data from sensors for congestion avoidance on the roads. In [10], the authors developed a model for exploring the impact of the vehicles on safety, jamming, congestion and environment. Their focus has been on enhancing traffic safety.

In [12] and [13], the authors investigated, developed and deployed a traffic monitoring system for work zone. The authors in [14] investigated a traffic congestion method based on discovery and quantification. They applied fuzzy assessment for improving the real time performance. Their simulations results indicate that their investigated technique can be used for precisely replicating the road condition.

The aim of all these explorations by different researchers in various projects has been on reducing the pollution, increasing safety as well as reducing the stuck

Volume 7, Issue 1
February 2018

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

time in traffic. It will result in smooth traffic flow at roads and junctions as well as healthier citizen in the smart cities.

The vehicle recognition is the fundamental part in the different core research areas of smart transportation systems such as smart parking system [2]-[6], smart traffic monitoring systems [7]-[10] and automatic toll payments system [15]. The accuracy of these systems is dependent on performance of VLP detection/recognition system. The recognition of the vehicles based on image processing algorithms is challenging due to many reasons such as vehicle movement at capturing time, harsh outdoor environment, different background and many VLP formats [2]-[12].

The VLP in the captured images may be tilted due to the vehicle's movement at image capturing time, which significantly affect the accuracy of the vehicle identification. The VLP may also be represented by fewer or larger number of pixels corresponding to smaller and larger area in the captured images due to image capturing from nearby or faraway point. Accurate VLP detection in the captured images is important and vital for the complete vehicle identification system.

The smart car parking, stolen vehicle' recovery, traffic monitoring and automatic toll payment systems requires accurate and reliable VLP detection and identification system, which is main scope of this work. The focus is on the description of an approach for the extraction of the VLP based on image sensing and processing.

So, for evaluating the performance of the proposed approach, vehicle's images captured from varying distances and at various rotations are required. Using these images, I evaluated the efficiency and accuracy of the proposed VLP detection scheme. The image processing flow from capturing up to VLP detection includes many complex tasks including pre-processing, filtering, segmentation and morphology.

The key contribution of the proposed work is to present a new strategy for sensing with multimedia sensors based on the extraction of the VLP and its transmission to the end user. The focus is on the specification of a strategy intended to extract the VLP based on image sensing and processing.

There is a possibility for there to be significant variations in the background illumination, the location and the alignment of the VLP in the captured images. Thus, for analyzing the efficiency of the VLP extraction scheme, images of the vehicles captured from different distances and various angles are required. Based on these captured images, the aim is to determine the effectiveness of the VLP extraction algorithms. Specifically, the interest is in extracting VLP from captured images where it is at different locations as well as at different angles in the images.

In the rest of the paper, firstly, the related work is provided in Section II. The experimental setup of the strategy for VLP extraction is presented in Section III. The Section IV presents the results and discussion while Section V provides the conclusion of the paper.

2. RELATED WORK

The extraction and recognition of license plate is a core research area, which has gained significant attention from the researchers over the years. The detailed survey/review articles of license plate detection/recognition systems were presented in [16], [17].

A Vehicle License Plate Detection and Recognition System was presented in [18]. A Region based accurate object detection and segmentation was presented in [19]. Vertical edge based car license plate detection/matching methods were explored in [20], [21]. Application-oriented license plate recognition was explored in [22].

Morphology based approach for license plate detection was investigated in [23]. A region and edge based vehicle license plate detection method was explored in [24]. The inter-correlation based VLP detection method was explored in [25]. The authors in [26]-[28], explored color image based methods for VLP detection. The authors in [21], presented VLP detection method based on a fast vertical edge detection algorithm (VEDA) for enhancing the speed and unwanted-line elimination algorithm (ULEA) for enhancing the image. They concluded that VEDA performs better in terms of accuracy, complexity, and processing time.

The authors in [22], divided vehicle license plate recognition (LPR) into three major categories. They proposed a solution based on parameter settings for the three categories of applications. Their solution is based on three modules for plate detection, character segmentation, and recognition. They explored and used the application-oriented license plate (AOLP) database for assessing the performance of their proposed solution. They experimentally proved that their solution performs better than many of the previous solutions.

The authors in [23], explored a morphology based license plates detection method. They applied a morphology based method for extracting important contrast features. Then, they applied a recovery algorithm to reconstruct a license plate from its fragmented parts. Their Experimental results proved to be better in terms of robustness and effectiveness for license plate detection.

In [24], the authors explored a region-based filtering method for license plate detection. They used the Sobel operator for extracting the vertical edges and morphological filtering for extracting the candidate regions. Their experimental results show that they achieved appropriate performance in different scenarios.

For extracting car plate among the candidate region in the image, the authors in [28], considered color descriptors and geometrical criterion. The geometrical criterion includes geometrical restrictions to remove many of false positives from nominee region. They used colour information to spot the license plate among nominee regions. They proved the robustness of their method by performing tests on the images of the car in very complex scene.

The neural network (NN) based techniques for VLP detection are intended to train classifiers for offering appropriate response to the VLP images. In order to increase the convergence precision of the NN, the authors in [29]

Volume 7, Issue 1
February 2018

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

used the gradient technique to excellently train the NN and to determine the global optimum with decent performance. The authors in [30]-[32], also investigated VLP detection method based on NN technique.

All the above mentioned VLP extraction methods are computationally intensive and require high processing power as well as increased execution time. Hence, there is a need for a VLP extraction method which involves few arithmetic operations and thus will require less processing power and execution time.

In this current work, an efficient scheme for VLP extraction based on applying 2D convolution on the pre-processed images is proposed and evaluated. Initially, the gradient of the captured image is determined both in the vertical and the horizontal directions. Then the 2D convolution is applied on the gradient image to determine the vertical and horizontal boundaries of the VLP. Finally, using the determined boundaries, the VLP is extracted from the original image.

3. Methodology

The VLP is a unique identification of the vehicle and it corresponds to exactly one vehicle. So, accurate extraction and processing of the VLP is essential for the traffic monitoring. The image processing flow for the extraction of the VLP is presented in Fig. 1, where the resultant images at different intermediate stages of the algorithm are shown.

Image capture: In the first step, the image of the car is captured which is shown in Fig. 1 (A).

Grey scale conversion: Since, the goal is to determine the boundaries of the car license plate, which are exactly the same in color and grey scale images. But the processing complexity of the algorithm will be reduced by applying it on the grey scale image. So, the captured RGB image is converted into grey scale image by using equation (1), where the G, R and B are the Green, the Red and the Blue components of the color image respectively. The resultant grey scale image is shown in Fig. 1 (B).

$$\text{Image}_{\text{grey scale}} = 0.299 * \text{R} + 0.587 * \text{G} + 0.114 * \text{G} \tag{1}$$

Gradient Image: In this step, the gradient image from the grey scale image is determined. Let us consider that N (a two dimensional matrix) represents the grey scale image and G represents the gradient matrix. The gradient matrix can be determined using equation (2).

$$\text{G} = \sqrt{\left(N(i+1,j) - N(i,j)\right)^2 + \left(N(i,j+1) - N(i,j)\right)^2} \tag{2}$$

Fig. 1 (C), shows that, due to the slow movement of the gradient, the areas with constant grey scale values in the grey image are converted into dark areas.

2D Convolution: The 2D convolution (equation (3), (4)) is applied on the gradient image. The matrices Y, G and F in equation (3) and (4) are the output image, gradient image and the impulse response of the filter respectively.

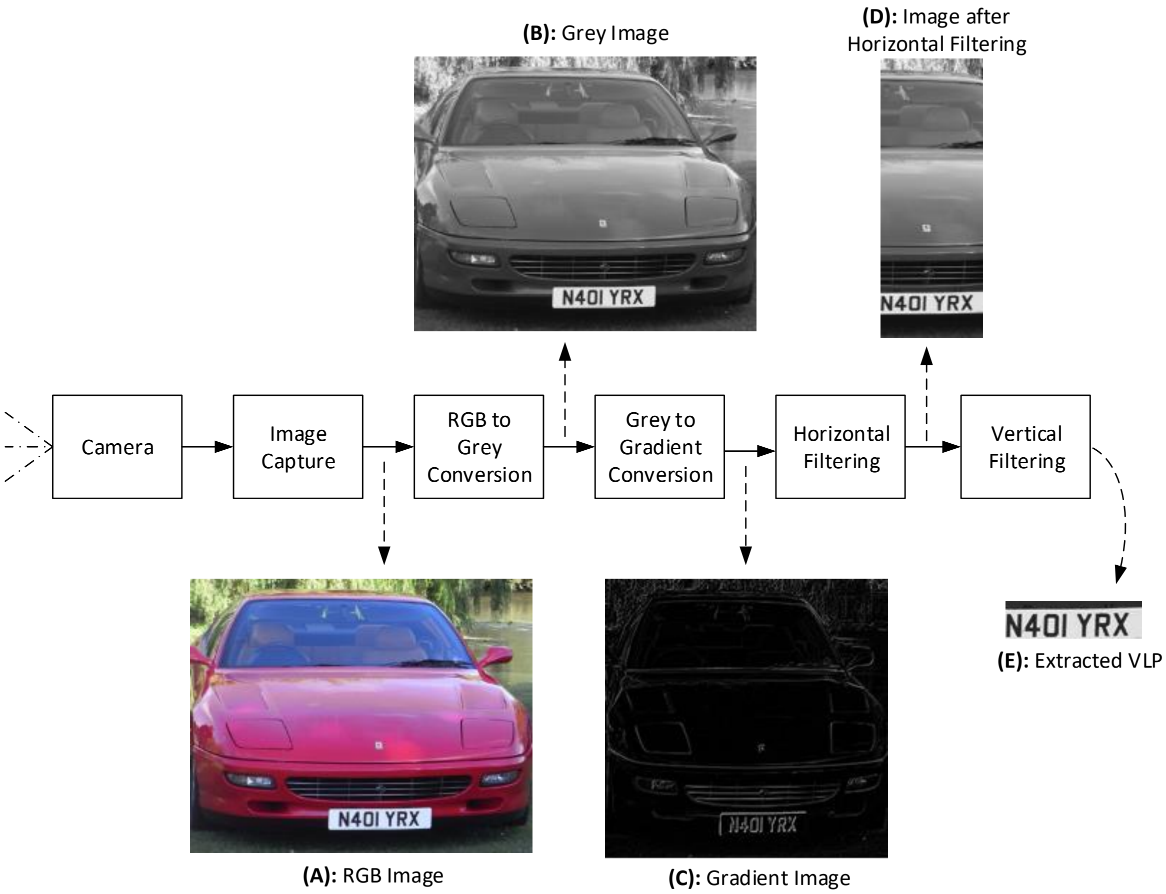


Fig. 1. The flow of the tasks along with results at different stages of the algorithm.

Volume 7, Issue 1
February 2018

ITEE Journal
Information Technology & Electrical Engineering

ISSN: - 2306-708X

The 2D matrix F which is impulse response of the filter is formed for filtering the gradient image. The purpose is to separate out the VLP from the rest of the car image.

$$Y[m,n] = G[m,n] * F[m,n] \tag{3}$$

$$Y[m,n] = \sum_{i=1}^{M}\sum_{j=1}^{N} G[i,j]F[m-i,n-j] \tag{4}$$

By carefully observing the gradient image of Fig. 1 (C), one can see that the boundaries of the digits/letters have more white pixels compared to the rest of the image. Though there are noise (white pixels) at some other boundaries in the image but their width is small compared to the width of the boundaries of the digits/letters (VLP) and hence can be easily filtered out by the convolution. The VLP in the gradient image can be localized by convolving the gradient image with 2D unit impulse function. The 2D unit impulse function acts as a filter, for extracting the VLP.

By utilizing the shifting property of the 2D unit impulse function, one can easily separate out the bright area of the gradient image (the bright area corresponds to the VLP). Equation (5) represents 2D unit impulse function.

$$\delta_2[m,n] = \begin{cases} 1 & \textit{for} \quad m=0, n=0 \\ 0 & \textit{otherwise} \end{cases} \tag{5}$$

One of the important property of unit impulse function is shifting which is shown in equation (6) below

$$\sum_{m=-\infty}^{\infty}\sum_{n=-\infty}^{\infty} \delta_2[m-m_0, n-n_0]P[m,n] = P[m_0,n_0] \tag{6}$$

Equation 6 implies that the unit impulse function can be used to pick out another function P (the VLP in this case) at x-axis when m=m0 and at y-axis when n=n0.

Horizontal Filtering: Firstly, the gradient image is filtered horizontally. The reason for this is that the VLP normally holds bigger size in horizontal direction. So, it will be beneficial to remove the unwanted noise in horizontal direction. For removing noise in horizontal direction, gradient image is convolved with the filter's impulse response.

The filter's impulse response is a 2D matrix (also known as kernel image), whose rows are exactly the same as that of the gradient image. The width (the columns of the 2D matrix) of the filter's impulse response is approximated based on the width of the object to be detected (the VLP in this case). I tried various values for the width (i.e. columns) and selected 20 columns based on my experiments with different images. Based on equation (5), all values in the kernel image are 1's.

It is previously observed that the boundaries of the digits/letters of VLP in the gradient image are white pixels. So, the brightest area in the resultant image after convolution, corresponds to the VLP. The horizontal boundaries of the VLP are determined in the convolved image using a threshold value of 0.5. All the pixels of the resultant image are scanned row wise and are compared with the selected threshold value. The VLP area in the resultant image is the brightest and hence pixels' values in this area are greater than 0.5.

So, in the proposed algorithm, the column index of the first pixel in a row where the pixel's value is greater than the threshold is saved/stored. Similarly, in scanning the same row, the column index of the first pixel where the pixel's value becomes less than the threshold is saved/stored. In this way the two horizontal boundaries of bright area are obtained. But the detected boundary could belong to some noise in the resultant image (convolved image). So, the strategy is to count the number of pixels between the detected boundaries and select the farthest boundaries. Since, VLP is wider than any other small noise, so in this way the true boundaries of the VLP is selected. Based on the determined horizontal boundaries of the VLP, the horizontal part of the VLP is extracted from the Grey image and is shown in Fig. 1 (D).

Vertical Filtering: Normally, the width of the VLP is about the double of its height. Based on this observation, the number of columns in the kernel image is selected to be 10 (i.e. half of horizontal filtering), while the number of rows in the kernel image are kept the same as that of gradient image.

Using the horizontal boundaries of the VLP, the horizontal part of the VLP is extracted from the gradient image and is convolved with the new kernel image. Again, the brightest area in the resultant image (newly convolved image) corresponds to the VLP. Similar to the procedure used for detecting the horizontal boundaries, the vertical boundaries of the VLP is determined using a threshold value of 0.5. By using the vertical and horizontal boundaries, the VLP from the grey image is extracted and shown it in Fig. 1 (E).

4. RESULTS AND DISCUSSION

The various image processing tasks of the algorithm in Fig. 1, are implemented using Matlab. The developed Matlab script is used to process different images of the vehicles captured in different conditions such as varying distances from the vehicle and various capturing angle of the camera. The grey images of the vehicle and the detected license plates are shown in Fig. 2, for varying distances between the vehicle and the camera. The purpose is to evaluate the robustness of the developed algorithm against images captured at various distances. Fig. 2 (A) shows that the VLP in the image captured from a closer distance is large compared to that of Fig. 2 (B).

Fig. 2, clearly shows that the image of the vehicle is captured from varying distances between the camera and the vehicle. Even though the images were captured from different distances, but still the developed algorithm accurately detected the vehicle license plates. The reason for this is that in in the developed algorithm, the image is scanned row wise from left to right and starting and ending pixels of the brightest object/area are determined.

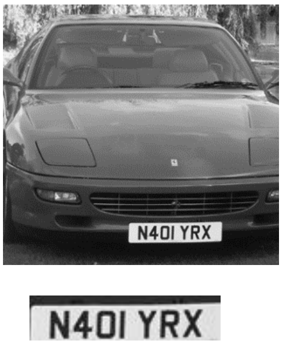
The two boundaries which are farthest from each other are selected for ensuring that the VLP is accurately detected. The connected bright pixels belonging to unwanted noise are not farthest from each other. This is the main reason, which resulted in accurate extraction of the VLP in the images with varying distances of the vehicles from the camera (Fig. 2). So, the location of the VLP in the images is not important.

ITEE Journal
Information Technology & Electrical Engineering
ISSN: - 2306-708X

(A): The grey image captured at distance 1 and detected VLP

(B): The grey image captured at distance 2 and detected VLP

(C): The grey image captured at distance 3 and detected VLP



(D): The grey image captured at distance 4 and detected VLP

Fig. 2. Varying distances between the vehicles and the camera.

The grey images of the vehicle and the detected license plates for varying capturing angles of the camera are shown in Fig. 3. Even though the images in Fig. 3 are captured from different angles but still the proposed algorithm accurately detected the VLP. So, the proposed algorithm is resilient to both the capturing angle and varying distance of the vehicle from the camera.

(A): The grey image captured at angle α and the detected VLP

(B): The grey image captured at angle β and the detected VLP

Fig. 3. Detected VLPs for varying capturing angles.

5. CONCLUSIONS

In this work an algorithm is developed and evaluated for VLP extraction in images of vehicles captured in varying conditions such as different background, different capturing angles and varying distances between the camera and the vehicle. The extraction and the tilt correction of the VLP is an important task which considerably affects the accuracy of the character segmentation/recognition. In this work, an effective scheme is developed and explored for the extraction of VLPs in images captured from various angles and at varying distances. The convolution based method is applied which uses vertical and horizontal filtering for localizing the horizontal and vertical borders of the VLP. Based on these borders, the VLP is extracted from the captured images. The developed algorithm accurately detected the VLP in the different images captured under different circumstances such as different background, capturing angle and capturing distance. By detecting the VLP accurately with few arithmetic operations, the execution time of the algorithm will be low which will lead to longer network lifetime.

REFERENCES

[1] S. P. Mohanty, U. Choppali, E. Kougianos, "Everything you wanted to know about smart cities: The Internet of Things is the backbone", IEEE Consum. Electron. Mag., vol. 5, no. 3, pp. 60-70, Jul. 2016.

[2] S. Lee, Yoon D. and A. Ghosh, "Intelligent parking lot application using wireless sensor networks,". Proc. of the International Symposium on Collaborative Technologies and Systems, May 19-23, 2008, Irvine, CA., pp: 48-57.

[3] B. Zhang, D. Jiang, F. Wang, and T. Wan, "A design of parking space detector based on video image," in Intl Conf on Electronic Measur'nt Instruments, 2009, pp. 2:253–256.

[4] S. Lee, Yoon D. and A. Ghosh, "Intelligent parking lot application using wireless sensor networks,". Proceedings of the Int'l Symposium on Collaborative Technologies and Systems, May 19-23, 2008, Irvine, CA., pp: 48-57.

[5] T. Nguyen and C. Nguyen, "An approach for building an intelligent parking support system," in Symp on Inf. and Communication Technology, 2014, pp. 192–201.

[6] D. Bong, K. Ting, and K. Lai, "Integrated approach in the design of car park occupancy information system (COINS)," IAENG Int'l J. of Computer Science, vol. 35, no. 1, pp. 7–14, 2008.

[7] C. N. E. Anagnostopoulos, I.E. Anagnostopoulos, V. Loumos, E. Kayafas, "A license plate-recognition algorithm for intelligent transportation system applications," IEEE Trans. Intell. Transp. Syst., 7 (2006), pp. 377-391.

[8] Hong Kong Government. Intelligent Transport System: http://www.roadtraffic-technology.com/projects/hong-kong/ (accessed on Feb 05, 2018).

[9] C. N. E. Anagnostopoulos, I.E. Anagnostopoulos, V. Loumos, E. Kayafas, "A license plate-recognition algorithm for intelligent transportation system applications," IEEE Trans. Intell. Transp. Syst., 7 (2006), pp. 377-391.

[10] N. Al-Holous, M. Syed Masud and U. Mohammad, "A Multi-Dimensional Model for Vehicle Impact on Traffic Safety, Congestion, and Environment," Available online: http://mioh-utc.udmercy.edu/research/ts-45/index.htm (accessed on Feb 05, 2018).

[11] J. Jiao, Q. Ye, Q. Huang, "A configurable method for multi-style license plate recognition", Pattern Recognition, vol. 42, no. 3, pp. 358-369, 2009.

[12] M. Bathula, M. Ramezanali, I. Pradhan, N. Patel, J. Gotschall and N. Sridhar, "Poster abstract: Measuring traffic in short-term construction work zones," International Conference on Information Processing in Sensor Networks, vol., no., pp.361-362, 13-16 April 2009.

[13] M. Bathula, M. Ramezanali, I. Pradhan, N. Patel, J. Gotschall, and N. Sridhar, "A Sensor Network System for Measuring Traffic in Short-Term Construction Work Zones". In Proceedings of the 5th IEEE Int'l Conference on Distributed Computing in Sensor Systems (DCOSS '09).

[14] L. Rui, Y. Zhang1, H. Huang and X. Qiu, "A New Traffic Congestion Detection and Quantification Method Based on Comprehensive Fuzzy Assessment in VANET," KSII Transactions on Internet and Information Systems, vol. 12, no. 1, pp. 41-60, 2018. DOI: 10.3837/tiis.2018.01.003.

[15] A. A. Chapate and D. D. Nawgaje, "Electronic Toll Collection System Based on ARM," International Journal of Science, Engineering and Technology Research (IJSETR), Volume 4, Issue 1, January 2015.

[16] S. Du, M. Ibrahim, M. Shehata, W. Badawy, "Automatic license plate recognition (ALPR): a state-of-the-art review,". IEEE Trans. Circuits Syst. Video Technol 23(2):311–325.

[17] C. Anagnostopoulos, I. Anagnostopoulos, I. Psoroulas, V. Loumos, E. Kayafas, "License plate recognition from still images and video sequences: a survey," IEEE Transactions on Intelligent Transportation Systems, Vol. 9, Issue 3, pp. 377 - 391, Sept 2008.

[18] K. W. Maglad, "A Vehicle License Plate Detection and Recognition System," Journal of Computer Science 8 (3): 310-315, 2012.

[19] R. Girshick, J. Donahue, T. Darrell, J. Malik, "Region-based convolutional networks for accurate object detection and segmentation,". 2016, IEEE Trans Pattern Anal Mach Intell 38:142–158

[20] A. R. Isra, A. Gokulanathan, "Vertical-Edge-Based Car-License-Plate Detection Method," IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) ISSN: 2320-3331, Volume 12, Issue 1 Ver. II (2017), PP 01-06.

[21] A. Al-Ghaili, S. Mashohor, A. Ramli, A. Ismail, "Vertical-edge-based car-license-plate detection method," IEEE Transactions on Vehicular Technology, Vol. 62, Issue 1, pp. 26 - 38, Jan. 2013.

[22] G. S. Hsu, J. C. Chen, Y. Z. Chung, "Application-oriented license plate recognition, ". 2013, IEEE Trans. Veh. Techn. 62:552–561

[23] J. Hsieh, S. Yu, Y. Chen, "Morphology-based license plate detection from complex scenes," 16th IEEE International Conference on Pattern Recognition, pp. 176 – 179, 2002.

[24] M. A. Lalimi, S. Ghofrani, D. McLernon, "A vehicle license plate detection method using region and edge based methods,". Comput. Electr. Eng. 2012, 39(3):834–845.

[25] L. Hu and Q. Ni, "IoT-Driven Automated Object Detection Algorithm for Urban Surveillance Systems in Smart Cities,". DOI 10.1109/JIOT.2017.2705560, IEEE Internet of Things Journal.

[26] X. Shi, W. Zhao, and Y. Shen, "Automatic license plate recognition system based on color image processing," in Lecture Notes on Computer Science, vol. 3483, O. Gervasi et al., Eds. New York: Springer-Verlag, 2005, pp. 1159–1168.

[27] K. I. Kim, K. Jung, and J. H. Kim, "Colour texture-based object detection: An application to license plate localization," in Lecture Notes on Computer Science, vol. 2388, S.-W. Lee and A. Verri, Eds. New York: Springer-Verlag, pp. 293–309.

[28] E.R. Lee, P.K. Kim, H.J. Kim "Automatic recognition of a car license plate using colour image processing," Proc. of IEEE Int'l Conf. on Image Processing, Austin, Texas. 1994, 2:301-305P.

[29] G. Sun, C. Zhang, W. Zou, G. Yu, "A new recognition method of vehicle license plate based on genetic neural network," The 5th IEEE Conference on Industrial Electronics and Applications, pp. 1662 – 1666, 2010.

[30] M. Fukumi Y. Takeuchi H. Fukumoto Y. Mitsura M. Khalid "Neural network based threshold determination for

Malaysia license plate character recognition," Proc. 9th Int. Conf. Mechatron. Technol. pp. 1-5 2005.

[31] B. Li, Z.Y. Zeng, J.Z. Zhou and H.L. Dong, "An Algorithm for license plate recognition using radial basis function neural network," Proc. of the Intl. Symp. on Computer Science and Computational Technology, Dec. 20-22, IEEE Xplore Press, Shanghai, pp: 569-572. DOI: 10.1109/ISCSCT.2008.272.

[32] M. A. Rafique, W. Pedrycz, M. Jeon, "Vehicle license plate detection using region-based convolutional neural networks," Soft Computing (2017). 1432-7643, https://doi.org/10.1007/s00500-017-2696-2.

AUTHOR PROFILE

Khursheed Aurangzeb received the B.S. degree in computer engineering from COMSATS Institute of Information Technology Abbottabad, Pakistan in 2006. He obtained his MS degree in Electrical Engineering (System on Chip) from Linkoping University, Sweden in 2009. He received his Ph.D. degree in Electronics Design from Mid Sweden University Sweden in June 2013. From July 2013 to Jan 2016, he was Assistant Professor/HoD in Electrical Engineering department at Abasyn university, Peshawar, Pakistan. Currently, he is Assistant Professor in the College of Computer and Information Science, King Saud University, Riyadh, Saudi Arabia. His area of research includes embedded and pervasive computing, big data, cloud computing, machine learning, deep learning and renewable energy.