Intelligent Speed Bump System With Dynamic License Plate Recognition

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***Abstract*—We present an intelligent bump system incorporated with the speed detection and dynamic license plate recognition techniques. The idea is to determine the enforcement of the speed bump based on the speed and identification of the vehicle. As a part of intelligent transportation systems for providing the traffic flow control, the proposed technique makes the driving safer and more comfortable. In the dynamic license plate recognition stage, the adaptive tracking is carried out for license plate allocation, followed by character segmentation and identification. "Tesseract OCR" is then used to construct sample images and perform the character recognition task. The experiments are carried out on a prototype system with embedded computation to demonstrate the feasibility of this work.**

I. Introduction

An intelligent system has many features, such as combined with a variety of fields, customized design, automatic processing and intuitive functions, without the full human control and easy to use and replace. In recent years, intelligent systems with the Internet of Things (IoT) development have been increasingly popular and widely used in diverse applications. One important aspect is the connectivity and mobility for the task execution. In this work, we propose an intelligent traffic control technique based on the IoT concept. The objective is to develop a vision enabled mechatronics system as part of transportation infrastructure.

For pedestrian or driving safety purposes, a traffic facility called "speed bump" is commonly installed on some road sections such as in the neighborhood of hospitals, schools, parking lots, or particular intersections. It is used to remind the drivers to pay more attention to the surrounding area and slow down to prevent traffic accidents. However, the speed bumps have many drawbacks under certain circumstances. For instance, those installed near a hospital may increase the pain of patients, and possibly delay the first-aid time. In more general situations, the speed bumps still make the driver and passengers uncomfortable even the vehicle is in a low driving speed. Thus, it is desirable to have a mechanism to selectively enforce the speed bump deceleration according to the information of the incoming vehicles.

To identify a vehicle, a commonly adopted method is based on the recognition of its license plate. The related research is one of the most important topics and has been extensively studied in the intelligent transportation systems (ITS) [1]. In recent years, license plate recognition techniques have been physically utilized in many facilities, such as the small-scaled private parking systems and the large-scaled electronic toll-collection systems (ETCs). Except for using the license plate information, there also exist other validation approaches based on active sensing technologies. RFID is one popular technique and generally robust under various weather and illumination conditions [2], [3]. However, in addition to the installation of sensing devices, RFID tags need to be carried with the vehicles for identification.

In this paper, we present an adapted speed bump system which can temporarily disable the road bump to avoid the collision and uncomfortable driving. Based on the license plate recognition result and the query from a database, the speed bump will adjust automatically for registered vehicles. Moreover, it can also deal with the vehicles with acceptable driving speed. The trigger time difference between two pressure sensors with a known distance on the ground is used to compute the vehicle speed for the activation of road bump enforcement. Experiments are carried out with license plate recognition of the real scene images. A miniature prototype system based on the proposed technique is constructed using

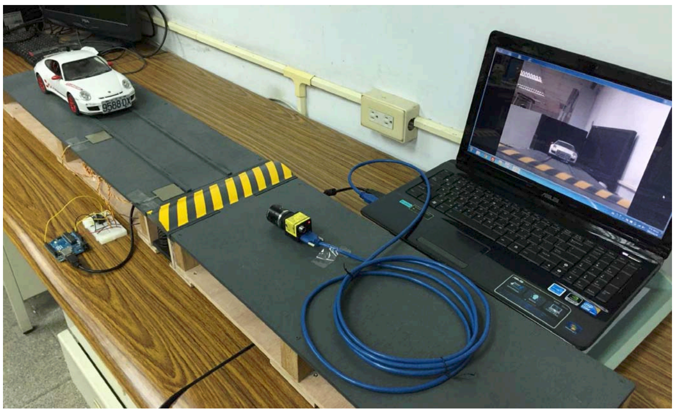


Fig. 1. A prototype system based on the proposed technique. It includes an embedded board, a hardware circuit, a sensing device, an image capture device, and a test platform constructed using 3D printing.

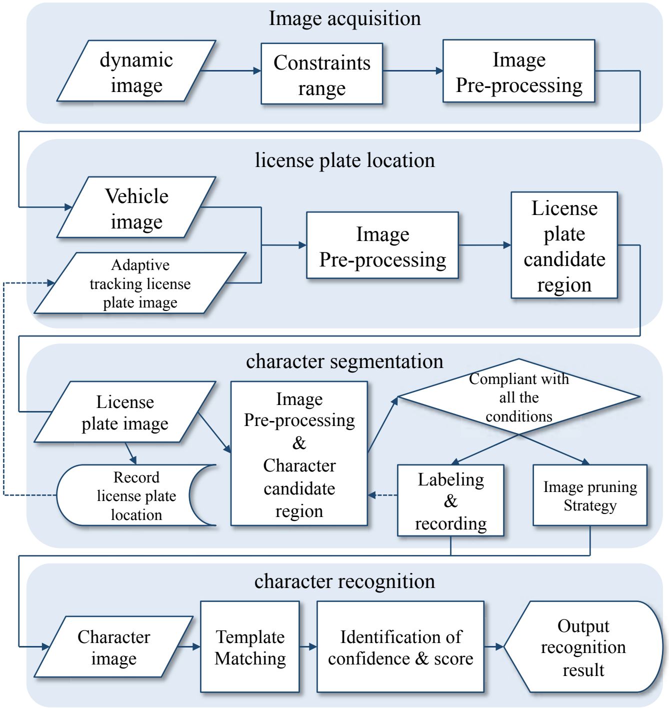


Fig. 2. The system flowchart of the proposed license plate recognition approach for the intelligent speed bump application. It begins with the image acquisition stage, followed by license plate location detection, character segmentation and recognition.

3D printing and an embedded control platform as shown in Fig. 1. The experimental results have demonstrated the feasibility of our work.

II. Related Work

The proposed techniques consist of two parts, one is the design of adjustable speed bump mechanism and the other is the license plate recognition. A speed bump is a commonly adopted traffic control facility, but its fixed height is a serious issue for comfort driving [4]. To solve this problem, the idea of intelligent speed bump has been proposed in the past few years [5]. The existing intelligent speed bumps can be categorized into the electronic, hydraulic, and mechanic types [6], [7]. For the electronic speed bumps, accelerometers are utilized to measure the vibrations created by the tires when rolling over the bump. The hydraulic and mechanic speed bumps adopt hydraulic and mechanical structures to control and lift the arch part of the bumps, respectively. Blair *et al.* created a portable speed bump with a variable length by connecting multiple removable bump cells [8]. Kokowski and Makarewicz dealed with the traffic noise associated with the speed bumps [9].

Although the literature survey on intelligent speed bump is not extensive in academic research, there exist a number of patents available for many years due to the potential applications [10], [11]. Nevertheless, the traditional speed bumps are still widely used in most places for traffic control mainly because of their advantages on the cost, durability, and maintenance issues. To promote the intelligent speed bump, it requires to have multiple functions instead of the single deceleration purpose. Some examples include the combination of vehicle identification or classification with the speed bump applications. The image-based techniques are currently the most popular methods with a great possibility of extension.

License plate recognition is an image analysis application closely related to the intelligent transportation systems [1]. Although it is possible to identify the license plate using a mobile camera, most application scenarios only require a static camera for license plate recognition. When using a static camera, the input source can be either a still image or a video sequence. The former case is easier to process but requires a better image quality. On the other hand, the latter takes the image sequence to analyze and increase the robustness of the recognition result.

In general, a license plate recognition process consists of three stages. The first stage is to locate the license plate in an input image. It can be implemented using the local methods based on SCW (sliding concentric window) [12], image transform [13], Adaboost classifier [14], VQ (vector quantization) trained [15] and Gaussian mixture model [16], etc. The second stage is to extract the characters. Simple techniques such as finding the connected components from the horizontal and vertical projections of a binary image are commonly adopted. As for the last stage, character recognition algorithms are performed using SVM (support vector machine) classifier [17], template matching methods [18] and neural networks [19], etc.

III. License Plate Recognition

The proposed license plate recognition algorithm consists of five stages: (i) dynamic image acquisition and pre-processing, (ii) license plate location identification, (iii) character segmentation, (iv) adaptive license plate localization and adaptive character labeling, and (v) character recognition. The system flowchart of our license plate recognition approach is shown in Fig. 2.

A. Dynamic image acquisition and pre-processing

In the proposed intelligent bump system, a video camera is placed in the middle of a lane. It is installed on the ground to allow the incoming traffic. The target imaging distance is about 5 to 40 meters. Due to the property of perspective image formulation, maintaining the observed vehicle position in the center of the FOV (field of view) is not possible. Thus, a subimage region of 600×400 pixels is extracted from the original image (with the resolution of 1600×900 pixels) for further processing, as the region of interest (ROI) illustrated in Fig. 3.

A simple image processing task with background subtraction is used for vehicle detection. To quickly detect the moving objects, background modeling is carried out first, followed by the pixel-wise subtraction between the input and background images. If the subtraction result is greater than a threshold value Th, the pixel is assigned to the foreground image.

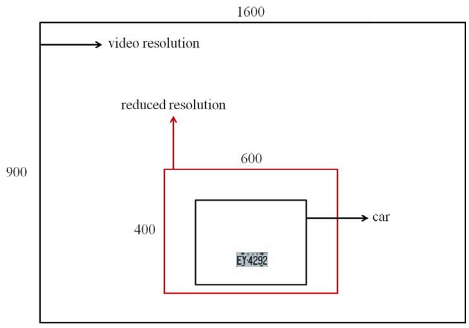


Fig. 3. An ROI (region of interest) of 600×400 rectangle extracted from the input image (1600×900) for license plate location identification and further processing.

Assume $I_t(x, y)$ and $B_t(x, y)$ are the input and background images at time t, respectively. Then the difference image $D_t(x, y)$ is defined as

$$D_t(x, y) = |I_t(x, y) - B_t(x, y)| \tag{1}$$

The background image is constantly updated over time by taking the average of continuous inputs

$$B_0(x, y) = \frac{1}{N} \sum_{t=1}^{N} I_t(x, y) \tag{2}$$

where $B_0(x, y)$ is an initial background image, and N denotes the number of image frames. To make the background image more robust under scene changes, it is adjusted with a weighted sum of the previous background and current input images

$$B_{t+1}(x, y) = W \cdot B_t(x, y) + (1 - W) \cdot I_t(x, y) \tag{3}$$

where the weighting $W = N/(N + 1)$ is the proportion of the previous background for update. Finally, the foreground image $F_t(x, y)$ is given by

$$F_t(x, y) = \begin{cases} 1 & D_t(x, y) > Th \\ 0 & \text{others} \end{cases} \tag{4}$$

B. License plate location identification

Given an image containing a vehicle, the first step of license plate recognition is to identify the location of the license plate. The Sobel filter is an ideal edge detector to extract the character features, and can be used to locate the character region. Since the characters in license plates are arranged horizontally, a horizontal differential mask

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{5}$$

is used to detect the vertical edges of the characters and convolve with the license plate image.

After the vertical edges of the characters are obtained, a morphological operation is carried out to connect the character components, followed by license plate region extraction using a pre-defined aspect ratio. The results in Fig. 4 illustrate the license plate extraction process. A bounding box with a fixed aspect ratio is applied to the binary image as shown in Fig. 4(b) to identify the region of interest.

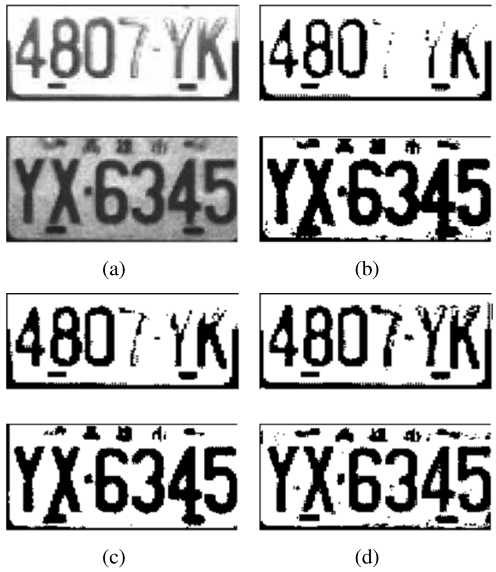


Fig. 5. The image binarization results using various techniques. (a) Original image; (b) The result using a fixed threshold value; (c) The result using Otsu method; (d) The result using the adaptive binarization approach.

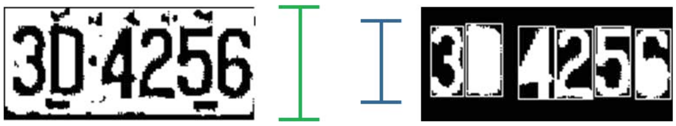


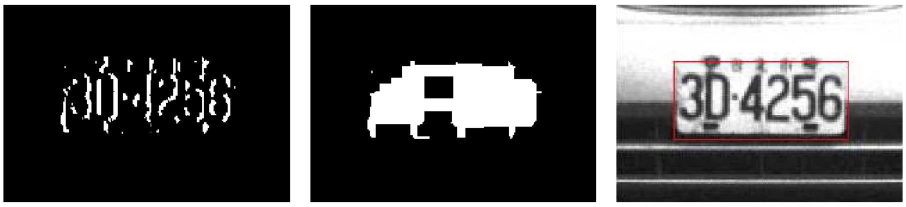
Fig. 6. The character recognition result with the restriction on the height of the character regions.

C. Character segmentation

The derivation of a binary image is the most important part of character segmentation. A good binarization method can completely separate the character and non-character regions to keep the integrity of each character. In this work, an adaptive binarization technique [20] is adopted. Fig. 5 shows the binary images obtained using a fixed threshold, Otsu's method [21], and the adaptive method.

Next, the candidate characters are selected by finding the contour regions. The objective is to find the pre-defined number of correct characters. In our case, there are six characters in a license plate. Suppose six connected components are found in the image, they do not necessarily represent the correct characters. For example, the height of a character cannot be too long, and the connected component should not be influenced by noise. Thus, the aspect ratio is used to verify the character regions. Table I tabulates the rules used to extract the character regions, and a character detection result is shown in Fig. 6

If an incorrect number of characters is found, it is necessary to further separate or merge the connected components, or even detect the missing ones. Figs. 7(a) and 7(b) illustrate an



(a) (b) (c)

Fig. 4. The license plate location identification result. (a) After the horizontal differential mask convolved with the license plate image; (b) The morphology processing result; (c) Extraction of the license plate region.

TABLE I
THE RULES USED TO EXTRACT THE CHARACTER REGIONS.

Type	Rules
License plate aspect ratio	2 < width/height < 3
Character aspect ratio (1/2)	0 - 9, A - Z: 1.5 < width/height < 2.3
Character aspect ratio (2/2)	1, I: 3 < width/height < 6.6
Character height	plate_height/2 < character_height < plate_height - T

(a) (b) (c)

Fig. 7. The character region detection of noisy license plates. (a) The dirty character cases; (b) The candidate character regions; (c) The character regions extracted using our method.

example of noisy license plate and false character extraction. To deal with this problem, we first observe that the characters are normally located in the middle of a license plate. By sorting the candidate regions based on their height, the median value can be used as the standard character to filter out the non-text region. Consequently, the potential character region can be binarized with a suitable threshold as shown in Fig. 7(c).

D. Adaptive license plate localization and character labeling

To detect the license plate in a dynamic scene, it is possible to search the candidate regions based on the previous image frames. This adaptive tracking strategy is able to fast identify the license plate. Furthermore, the vehicle detection step can be removed once the license plate is tracked accurately. The adaptive license plate localization of the present system is based on the result of the character segmentation. If the candidate region in the previous image frame contains character components, then only a search area of 50 pixels up, down, left and right is carried out for license plate tracking in the current image frame.

The use of adaptive character labeling can automatically record the location and sequence of the characters. In the identification step, we can clearly know which character is

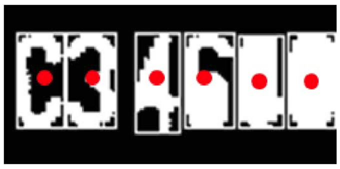


Fig. 8. Adaptive character labeling using the centers marked with assistance of connected components.

under processing. Even if there are less than six character regions in the image, the location of the missing characters can be predicted by the sequential constraint. For the initial character locations, six connected components are detected and the centers are marked as shown in Fig. 8. With the better identification and ordering result of the candidate region detection, it is able to increase the recognition rate of individual characters.

In general, the center positions will change if the scene changes in the succeeding image. The following steps are carried out for our character location prediction process.

- Step1: Find the six characters regions, update the initial center points, and label the character sequence.
- Step2: If six character regions are found in the succeeding image, update all character center points.
- Step3: If the center point falls within the character region in the succeeding image, update the character center point and return to Step2.

E. Character recognition

The open source optical character recognition tool "Tesseract OCR" is adopted in this work [22]. Tesseract OCR supports character recognition of multiple languages. It is essentially a template matching algorithm, and the character samples can be self-trained. In addition to the fast recognition, the technique is able to build the text samples easily. We train the text samples as shown in Fig. 9 from adaptive binarization images.

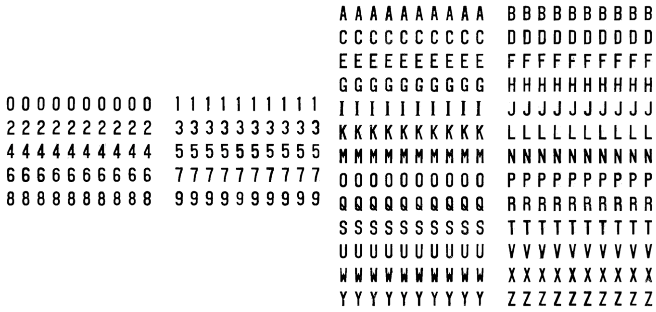


Fig. 9. The training text samples used for character recognition. They are extracted from license plates with adaptive binarization.

TABLE II
THE CHARACTER RECOGNITION SCORING MECHANISM BASED ON THE TESSERACT OCR DETECTION RELIABILITY.

Reliability Range	Score	Result
90 – 100	5	High
80 – 90	3	Median
70 – 80	1	Low
0 – 70	0	Zero

Tesseract OCR provides the character recognition reliability detection results range for 0 to 100 in integers. According to the detection reliability, our character recognition scoring mechanism is given in Table II. In the experiments, we find the highest score from 36 characters (A – Z, 0 – 9) and output the final character recognition result.

In character recognition, the error results usually happen on similar character shapes. Some common cases include 0 and D, 2 and Z, and 1 and I. These similar characters still remain some differences after they are precisely identified. To deal with this problem, a post-processing stage is performed with the horizontal and vertical projections. We utilize the prior knowledge of local analysis as shown in Fig. 10 to distinguish the similar characters.

IV. Implementation and Experimental Results

In the experiments, we use a PointGrey USB 3.0 camera Flea 3 (FL3-U3-32S2C/M-CS) to capture the dynamic images. Fig. 11 shows the images taken in a slow lane at National Chung Cheng University. The vehicle speed is about 10 – 30 km per hour. There are totally 31 image sequences collected in our database, with each one corresponds to a different vehicle. We test our license plate recognition algorithm on two embedded boards (Raspberry Pi and Banana Pi) and a personal computer. The specifications of the hardware are shown in Table III. For the PC-based processing, the success rate of license plate recognition is shown in Table IV.

A prototype intelligent speed bump system is implemented with embedded platforms. It includes the image-based license plate recognition system, the speed sensing and hardware control system, and structural design of the speed bump system. The image sequences acquired by a video camera are processed by a PC for license plate recognition. Fig. 12(a) shows the prototype bump made by 3D printing. Four springs are placed underneath such that the bump can be lowered down if the electromagnetic suckers (attached on both sides of the bump as shown in Fig. 12(b)) are not enables. The speed sensing and control hardware are shown in Fig. 12(b). Two presure sensors and electromagnetic suckers are connected to an Arduino embedded board to measure the vehicle speed and control the bump. Alternatively, the vehicle speed can also be obtained using image based techniques [23], [24]

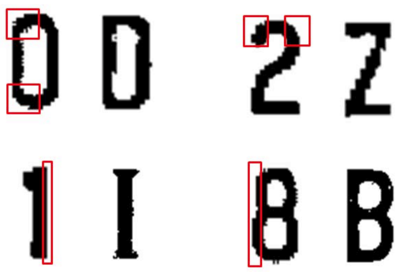


Fig. 10. The similar characters appeared in license plates distinguished with the prior knowledge of our local analysis approach.

Fig. 11. The image sequence taken in a slow lane on campus for the license plate recognition experiment. The camera is placed on the ground, facing the incoming traffic.

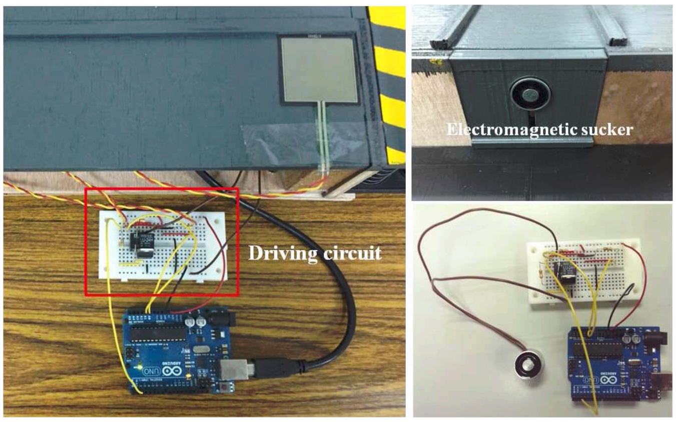
TABLE III
THE HARDWARE SPECIFICATION OF THE EMBEDDED PLATFORMS USED IN THE EXPERIMENTS.

	CPU	Memory	OS
Raspberry Pi	Single-Core 700 MHz	512 MB	Linux
Banana Pi	Dual-Core 1 GHz	1 GB	Linux
PC	Quad-Core 3.3 GHz	4 GB	Windows 7

TABLE IV
THE SPECIFICATION AND PARAMETERS OF PC-BASED PROCESSING FOR LICENSE PLATE RECOGNITION.

Specification	Parameter
Number of image frames	31
Image resolution	1600×900
Processing region size	600×450
License plate location accuracy	100%
Character segmentation accuracy	96.67%
Identification correct rate	96.67%
Computing platform	Personal computer
Processing time per frame	25 – 35 ms

(a) The prototype bump made by 3D printing.



(b) Upper-left: the presure sensor for speed detection. Upper-right: the electromagnetic sucker to fix or free the bump. Bottom: driving circuit and embedded computing unit.

Fig. 12. The implementation of our prototype intelligent speed bump system. It consists of the bump design, embedded computing devices, and mechatronics system.

V. Conclusion

This paper we present an intelligent speed bump system incorporated with the dynamic license plate recognition technique. We design a novel intelligent system and customize production to demonstrate the feasibility of this work. The adaptive tracking and character labeling are carried out for license plate allocation and identification of individual characters. Additional image post processing techniques are used to distinguish the similar characters to increase character recognition rate. Finally, the road bump control is enabled by the license plate recognition result. The experiments using PC based system and embedded platform have demonstrated the feasibility of the proposed intelligent speed bump control concept.

Acknowledgment

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References

[1] C. N. Anagnostopoulos, I. E. Anagnostopoulos, I. D. Psoroulas, V. Loumos, and E. Kayafas, "License plate recognition from still images and video sequences: A survey," *Trans. Intell. Transport. Sys.*, vol. 9, no. 3, pp. 377–391, Sep. 2008.

[2] A. Chattaraj, S. Bansal, and A. Chandra, "An intelligent traffic control system using rfid," *Potentials, IEEE*, vol. 28, no. 3, pp. 40–43, May 2009.

[3] P. Blythe, "Rfid for road tolling, road-use pricing and vehicle access control," in *RFID Technology (Ref. No. 1999/123), IEE Colloquium on*, 1999, pp. 8/1–816.

[4] B. Anti, D. Pei, M. Vujani, and K. Lipovac, "The influence of speed bumps heights to the decrease of the vehicle speed belgrade experience," *Safety Science*, vol. 57, pp. 303 – 312, 2013.

[5] D. Garcia-Pozuelo, A. Gauchia, E. Olmeda, and V. Diaz, "Bump modeling and vehicle vertical dynamics prediction," *Advances in Mechanical Engineering*, vol. 6, 2014.

[6] J. L. Welford, "Electronically controlled speed bump device," Dec. 7 1993, uS Patent 5,267,808.

[7] A. Follman, "Road speed limiting device," Jan. 4 2000, uS Patent 6,010,277.

[8] W. H. Blair, D. R. Blair, and R. E. Steele, "Portable speed bump," Sep. 23 2003, uS Patent 6,623,206.

[9] P. Kokowski and R. Makarewicz, "Predicted effects of a speed bump on light vehicle noise," *Applied Acoustics*, vol. 67, no. 6, pp. 570 – 579, 2006.

[10] C. T. Mastronuzzi Jr, "Retractable speed bump," Aug. 3 1982, uS Patent 4,342,525.

[11] S. Mandavi, "Vehicle speed bump device," Dec. 4 1990, uS Patent 4,974,991.

[12] K. Deb, I. Khan, A. Saha, and K.-H. Jo, "An efficient method of vehicle license plate recognition based on sliding concentric windows and artificial neural network," *Procedia Technology*, vol. 4, pp. 812 – 819, 2012, 2nd International Conference on Computer, Communication, Control and Information Technology(C3IT-2012) on February 25 - 26, 2012.

[13] W. Wen, X. Huang, L. Yang, Z. Yang, and P. Zhang, "Vehicle license plate location method based-on wavelet transform," in *Computational Sciences and Optimization, 2009. CSO 2009. International Joint Conference on*, vol. 2, April 2009, pp. 381–384.

[14] S. Du, M. Ibrahim, M. Shehata, and W. Badawy, "Automatic license plate recognition (alpr): A state-of-the-art review," *Circuits and Systems for Video Technology, IEEE Transactions on*, vol. 23, no. 2, pp. 311–325, Feb 2013.

[15] R. Zunino and S. Rovetta, "Vector quantization for license-plate location and image coding," *Industrial Electronics, IEEE Transactions on*, vol. 47, no. 1, pp. 159–167, Feb 2000.

[16] J. Gao and J. Yang, "An adaptive algorithm for text detection from natural scenes," in *Computer Vision and Pattern Recognition, 2001. CVPR 2001. Proceedings of the 2001 IEEE Computer Society Conference on*, vol. 2, 2001, pp. II–84–II–89 vol.2.

[17] K. Kim, K. Kim, J. Kim, and H. Kim, "Learning-based approach for license plate recognition," in *Neural Networks for Signal Processing X, 2000. Proceedings of the 2000 IEEE Signal Processing Society Workshop*, vol. 2, 2000, pp. 614–623 vol.2.

[18] S.-L. Chang, L.-S. Chen, Y.-C. Chung, and S.-W. Chen, "Automatic license plate recognition," *Intelligent Transportation Systems, IEEE Transactions on*, vol. 5, no. 1, pp. 42–53, March 2004.

[19] J. Nijhuis, M. ter Brugge, K. Helmholt, J. Pluim, L. Spaanenburg, R. Venema, and M. Westenberg, "Car license plate recognition with neural networks and fuzzy logic," in *Neural Networks, 1995. Proceedings., IEEE International Conference on*, vol. 5, Nov 1995, pp. 2232–2236 vol.5.

[20] J. Sauvola and M. Pietikinen, "Adaptive document image binarization," *Pattern Recognition*, vol. 33, no. 2, pp. 225 – 236, 2000.

[21] N. Otsu, "A threshold selection method from gray-level histograms," *Systems, Man and Cybernetics, IEEE Transactions on*, vol. 9, no. 1, pp. 62 –66, jan. 1979.

[22] R. Smith, "An overview of the tesseract ocr engine," in *Proceedings of the Ninth International Conference on Document Analysis and Recognition - Volume 02*, ser. ICDAR '07. Washington, DC, USA: IEEE Computer Society, 2007, pp. 629–633. [Online]. Available: http://dl.acm.org/citation.cfm?id=1304596.1304846

[23] H.-Y. Lin, K.-J. Li, and C.-H. Chang, "Vehicle speed detection from a single motion blurred image," *Image Vision Comput.*, vol. 26, no. 10, pp. 1327–1337, Oct. 2008.

[24] A. Harvey and H. Cohen, "Vehicle speed measurement using an imaging method," in *International Conference on Industrial Electronics, Control and Instrumentation*, 1991, pp. 1730–1733.