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Introducing Automatic Control Method of Safety Standards in Horizontal Curves by Processing Images Taken by Mobile Mapping System

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ABSTRACT

The Mobile Mapping System is a trend that provides a comprehensive database of information including video images. The goal of this paper is to introduce an image processing method that could be integrated with GPS data to automatically control the road safety standards for speed limit signs before horizontal curves and identify the problems. The proposed method introduced a new trend in the area of image processing and pattern recognition. The results substantiated a high percentage of success in identification and accuracy in sign distinction. Application of support vector machine led to 92% accuracy in the identification of the signs and 97% accuracy in speed limit distinction.

Keywords: Horizontal curve, image processing, mobile mapping system (MMS), road safety audit, speed limit sign, Support Vector Machine (SVM)

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INTRODUCTION

Safety is a fundamental element whose unceasing presence guarantees the fruitfulness of road life. Safety inspection standards and identification of the causes related to the road in the chain of the factors of accidents is one of the main goals of safety inspection and a preventive method based on field observations; which is a major

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method of identification, based on physical specifications of the road and identification of the safety defects.

MMS (Mobile Mapping System) as one of the identification methods consists of specific components including an imaging system, rangefinder, positioning, and surveying. Its main output includes geographical data, digital maps, and different types of imaging and video formats. This paper focuses on visual data for image processing. In a previous study, MMS had been widely used as a three-dimensional scanning technology using Lidar (Florkova et al., 2018). In this research rain, fog or shiny surfaces reduced the reflectivity of LIDAR (Light Detection And Ranging) beams. But the method proposed in this study did not require Lidar data. Gathering Lidar data requires substantial more cost and effort to be integrated into the automated method to do road safety audits. While in this research we did not necessarily need 3D visualization.

The main purpose of this paper is to present a new method to automatically identify the safety defects and problems based on visual data processing and maintain accuracy in controlling the safety standards to save time and cost. The signs and safety equipment on the roads are exposed to damages resulting from environmental unfavourable factors, a collision of transit traffic, and social anomalies. The performance of continuous and regular inspection operations by MMS to control the appropriate functioning of their physical conditions is essential.

The data collected by the MMS presents the latest safety condition of the road so that the required decisions can be made at appropriate junctures of time. In addition to the analysis of the data in this paper, the control of the safety standard is also taken into consideration. For this purpose, the safety standards of the speed limit signs before the horizontal curves on intercity roads are taken into consideration. Due to the priority for the observation of safety standards on intercity roads, speed limit signs on these routes are taken into consideration. It is worth mentioning that these signs are both in Farsi and English language.

Previous studies on subjects such as locating the road features like guard rails, horizontal and vertical signs with 0.3-meter precision (Ishikawa et al., 2007), fast and cheap collection of geographical and dimensional data of the road network (Tao, 2009), and collection of precise details without causing any danger for the users and interference in traffic current while inspecting road pavement (France & Glennie, 2011) had introduced the MMS as a well-established technology.

In this paper, the analysis and processing of the data were done by MATLAB software. The efficiency of this software has been substantiated in the analysis of the data related to the absolute or relative dimensions and specifications of objects appearing in the images (with 40 centimetres measuring accuracy for a dimension of 0.6 to 3 meters within a distance of 35 meters) (Madeira et al., 2010).

The horizontal curves are of the most significant road safety issues (Bhatnagar, 1994) and their importance in the rate of rural road accidents is more than the lane width and the sight distance (Gupta & Jain, 1975). The presence of each sharp curve in each kilometre leads to a 34% increase in the statistics of single-vehicle accidents (McDonald, 2004). The presence of such perceptional signs and symbols such as speed limit signposts in a safe and clear distance before the curve plays a significant role in the reduction of the number of accidents and their severity (Charlton, 2007).

The risk factors involved in horizontal curves are the inattention or failure of concentration and attention to the curve (McDonald & Ellis, 1975) as well as lack of understanding and awareness to adjust speed to the road curvature (Johnston, 1982). The rate of attention and the required concentration for driving at 64 kilometres per hour for a 17-degree curve is 42%, while it is 23% for straight sections of the road (McDonald & Ellis, 1975). Speed limit signs as warning parameters are of the most important factors for the increase of attention and concentration of drivers (Knowles & Tay, 2002); the presence of these signs before the curve is also the sign for the curve sharpness inducing a suitable understanding of the grade of curvature to drivers (Retting & Farmer, 1998). The requirement for passing over the curve is in time warning and awareness of the change of the direct path to predict the required standards such as speed reduction at a safe distance before the curve (Reymond et al., 2001). The speed limit signposts suggested being placed at suitable distances before the curves are the most important factors for the determination of the speed of driving over the curve by law-abiding drivers guarantee the safe passage over the curve (Charlton, 2004).

The above issues justify the necessity for an intelligent system of automatic identification of safety standards related to the presence or absence of speed limit signpost at a safe distance before the horizontal curve and distinction of the speed limit on the signpost as well as speed control proportional to the radius of the horizontal curve. Implementation of such a system requires the definition of two separate phases.

The first phase identifies the curve, determines the radius, and calculates the speed proportional to the obtained radius. The required data for this phase are the coordinates obtained by GPS (Global Positioning System) installed on the vehicle (Koloushani et al., 2014). Based on the image processing method proposed in this research, the simple video image data and the image processing outputs could be combined with GPS analysis to develop a more comprehensive approach to do road safety audits regarding horizontal curves. We examined the efficiency of the GPS processing phase in our previous research (Koloushani et al., 2014).

The second phase is the processing of images to identify the speed limit signposts. This phase is divided into two stages: in the first stage, the initial identification is done and the presence or absence of the speed limit signpost at a safe distance from the curve is specified and in the second stage, the speed limit on the signpost is determined. Ultimately, the speed limit, proportional to the curve radius (obtained in the first phase) is compared with the speed limit on the signpost (obtained in the second phase) and the result of the control of the safety standards related to the rate of the speed limit and the place of the signpost is presented to the user.

So far, to distinguish the horizontal curves on the road, the method of optic flow study of video frames has been used (Eichner & Breckon, 2008), but the radius of the curve is not determined and only the deviation from the straight path is taken into consideration. Also, another research conducted by Gao et al. (2017), used Lidar to extract pavement marking in an automated way.

The main focus of this paper is on the processing of video images obtained from the MMS. Fast and cheap collection of video images to capture precise details without causing any danger for the users and interference in the traffic flow while inspecting the roadway pavement is among the most distinguishing advantage of this image processing method. In continuation explanations on the second phase will be provided. Based on previous studies, numerous methods have been used to identify and distinguish traffic signposts. For example, by examining the colour of the traffic signposts in HSV space, the specifications of the Haar wavelet transform and six neural networks have classified the signposts into six groups (Chen et al., 2011). Also, to identify the traffic signposts, their geometrical shapes (without considering colour) are used and to distinguish the speed limit, separation of the numbers on the signposts as well as neural networks are employed (Moutarde et al., 2007).

A method has also been proposed for the distinction of different types of traffic signposts by the use of SVM (Support Vector Machine) which enjoys colours and geometrical shapes to classify the signposts (Maldonado-Basco & Gomez-Moreno, 2007). Also, YCbCr colour space and Hough transform were used to identify the signposts, and 4 neural networks (LVQ, RBF, MLP, Hopfield) were employed for the distinction of the speed limit on the signpost, while the whole signpost was considered as the network input (Damavandi & Mohammadi, 2004). In other studies, the YCbCr colour space and the MLP neural network were used for the identification and distinction, respectively (Eichner & Breckon, 2008). In the identification phase of the frames consisting of the traffic signposts, YCbCr colour space, as well as the geometrical shape of speed limit (red circle), was used and for the distinction of the amount of speed limit on the signposts, separation of the numbers (Moutarde et al., 2007) and extraction of suitable specifications of the existing numbers on the signposts along with a classifier system of SVM (Heydari et al., 2013) were proposed in the system presented in this paper.

To sum up, in this paper, we intend to propose a low-cost image processing method as a part of a more complicated automated methodology to improve road safety in horizontal curves. To do so, we would be integrating it with the GPS analysis phase. We previously examined the effectiveness of the GPS phase in another research (Koloushani et al., 2014).

MATERIALS AND METHODS

Classification into seven groups is sufficient concerning the goal the system is defined in its direction. These groups include limits of 30 to 90 kilometres an hour (the sharp curves have a radius of fewer than 300 meters and the equivalent speed is less than 90 kilometres an hour). The above classification has been done based on the separation and extraction of suitable specifications of the numbers on the signposts along with a classifying system of the SVM. Extraction of the suitable specification of the numbers and their use as the input for the SVM in place of the number itself reduces the number of the samples required for training, leading to better results (Burges, 1998).

Collection of the Required Data

In this first stage, there is a need for a sample of video data to define, train, and test the intelligent system of image processing. To have access to the data, one stage of image taking was performed. For this purpose, a 1536 × 2048 pixel digital colour film recorder with the capture rate of 15 frames a second was installed on a vehicle (moving at 40 Km/hr.). The film recorder had the variable capability of changing the shutter speed. By selecting small values for the time (1/15000 seconds), the problem of motion blurring of the video frames due to the movement was removed.

Concerning the goal of distinguishing the signposts in this paper which is to control the safety standards by video images obtained from the MMS, there is no need for immediate processing of the data by the system, since it is possible to record the path at specific hours of the day when there is enough light and we do not face a wide spectrum of light when filming which leads to better results.

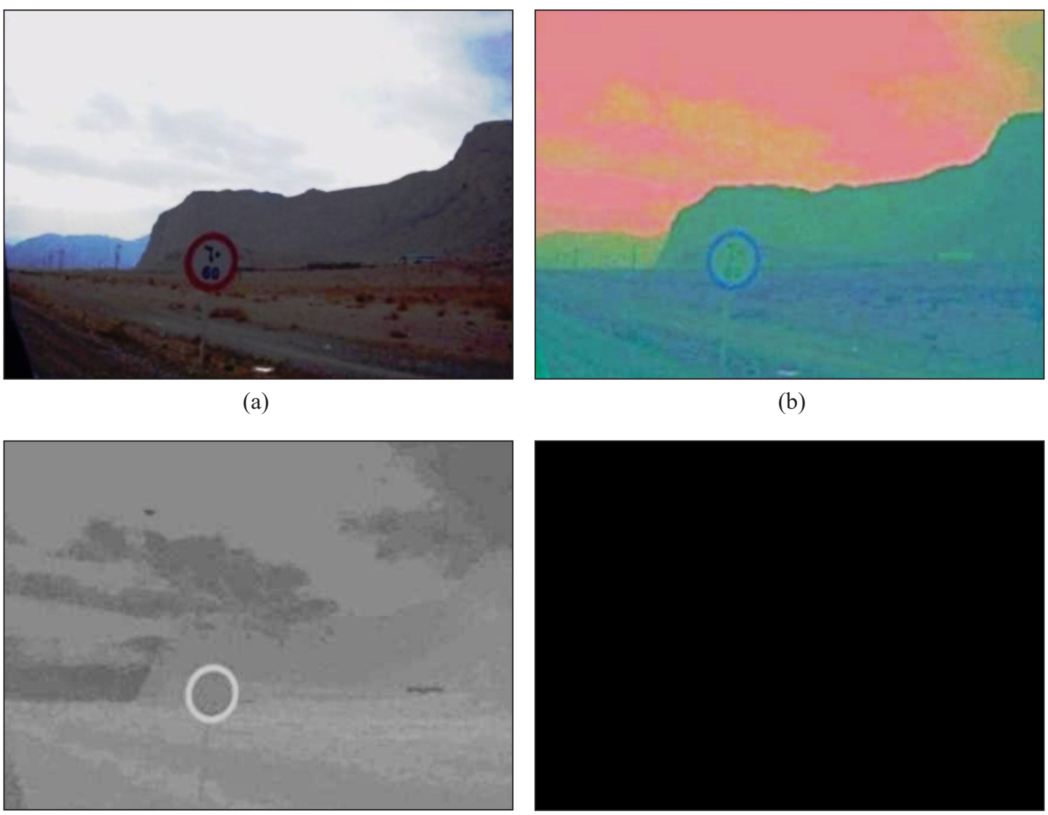
Identification of the Frames of Traffic Signposts

To identify the speed limit signposts by the image data taken by the MMS cams, the frames should be processed first and those containing the signposts should be separated. At this stage, all the signposts with red margin (including triangle, circle, square, rectangle, and hexagon) were identified. To study the first condition of the presence or absence of a signpost in one frame, the red margin is used. To identify the red colour, a sample frame of the signpost was transferred to different colour spaces like RGB, HSL, and YCbCr and the triple components in each image are studied. Ultimately, based on visual observations, the third component of the YCbCr colour space was selected as the best state to distinguish the red colour (Cr). The desired frame was transferred from the RGB colour space to the YCbCr space and the values of the pixels of the third component (YCbCr) were studied. After performing the local averaging operation on the Cr component and comparison of the obtained image with the value of a suitable threshold, a binary image was produced to separate the red margin of the signpost. The values higher than the threshold value were the signpost margin and the values lower than that were assumed to be the background or the inner part of the signpost. The above stages are depicted in Figure 1.

The Distinction between Speed Limit Signposts and Other Identified Signposts with Red Margins

To distinguish the speed limit signposts and other identified signposts with red margins, the binary image obtained from the previous stage was used.

First, a standard was introduced for the control of the object to be circular as in Equation 1. By determining the value of the above standard for each object and its comparison with a standard threshold value, the non-circular objects obtained from the image were deleted. The value of the standard threshold was considered to be 0.8



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

Figure 1. (a) Speed limit sign in an RGB colour space; (b) Transferred to YCbCr; (c) The third component of YCbCr; (d) A binary image of speed limit sign.

and values higher than the threshold value were considered to be circular (the value of this standard is equal to one for a circle).

$$metric = \frac{4 \times \pi \times A}{P^2} \qquad \text{Equation 1}$$

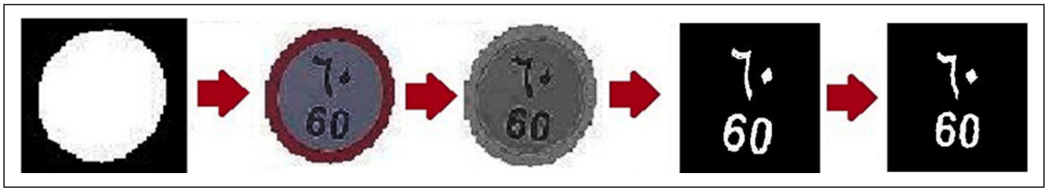
In Equation 1, A is the area and p is the circumference of the geometrical shape. Then, for the deletion of the non-speed-limit signposts from among other signposts with circular shapes, the number of the independent objects inside the circle was counted. If four black independent objects were identified inside the obtained circle, the desired frame was classified among the frames with speed limit signposts. At the stage of the training the SVM, those signposts without speed limit but with four objects identified on them (like height limit signpost), were separately classified.

To define and extract the features of the identified numbers and also their distinction (at the next stage), after the identification stage and before the stage of the separation of the numbers and extraction of the features, a suitable rotation was performed on the images of the signposts so that the numbers were arranged vertically relative to the horizon level because when video images were taken, the speed limit signposts are at different angles relative to horizon. In this case, it is possible to compare the features defined for the numbers on all the signposts at different angles at the time of imaging in a similar condition. This stage is depicted in Figure 2.

The Distinction of Speed on the Speed Limit Signpost

To distinguish the speed on the speed limit signpost, first, the two Farsi and Latin numbers on the signpost were extracted and each was placed in a 10*20 pixel window for normalization. Then, to distinguish each of the extracted numbers, six unique features of each of the numbers and an SVM classifying system were employed.

As it was mentioned above, the main goal of this research was to control the safety standards of the speed limit signposts before sharp horizontal curves (with a radius of fewer than 300 meters) and the speed appropriate with these curves at 30 to 90 kilometres an hour. As a result, seven-speed limit signposts (30 to 90 kilometres an hour) were selected with 30 sample images of the above signposts (210 in totals) and the SVM was trained by these 210 samples. The twelve-fold features (six features of each decimal) for distinction are:



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

Figure 2. (a) Speed limit signs in an RGB colour space; (b) Transferred to YCbCr; (c) The third component of YCbCr; (d) A binary image of speed limit sign; (e) Rotated sign.

(1) The number and location of the peaks in the vector resulting from the sum of the rows of pixels

To extract these features for a number, first, the values of the lit pixels of the ith row of the 10*20 image were added together which replaced the ith array of a 1*20 vector. This sum was calculated in the same manner for all the rows of the 10*20 image. Then, to delete the high frequencies, the resulted vector was passed through a low pass filter. Now, the number of the obtained vector peaks was counted and stored as a feature of the desired number. In continuation, the number of the row where the peaks were produced (location of the peaks) were added together and divided by the number of the peaks and considered as another feature of the desired number. The above two features were calculated for the two Farsi and Latin numbers (four features in total).

(2) The number and location of the peaks in the vectors resulted from the column addition of the pixels

To extract this feature, it was acted as the precious case too, except that the lit pixels of the columns were counted. First, for each number, the values of the lit pixels of the jth column of 10*20 images were added together which replace the jth array of a 1*10 vector. The resulted vector was passed through a low pass filter and then the number and location of the peaks were determined as before. These two features were also defined for each of the two Farsi and Latin numbers (four features in total).

(3) Geometrical specifications of numbers

As the fifth feature, the area (the number of lit pixels in the 10*20 image) and as the sixth feature, the area of the obtained number were calculated (the number of pixels around the light part in the 10*20 image). These two features were also defined for each of the two Farsi and Latin numbers (four features in total).

Comparison of the Rates of the Speed Limit on the Signposts with the Speed Rates Proportional to the Curve Radius

At this stage, the speed limit on the speed limit signpost before the horizontal curve as the output of the image processing section of the system was compared with the speed proportional to the curve radius. Based on the analysis of the coordinates of the points collected by a GPS receiver in the MMS, it is possible to automatically calculate the radius of the curve. According to the obtained radius and (2), it is possible to determine the speed proportional to the curve and ultimately, identify the safe distance before the curve for the installation of speed limit signpost about the existing safety standards in the road geometric design code.

Ultimately, based on the value of the obtained speed and the safe distance before the curve, it is possible to identify the safety condition of the curve concerning the speed limit signpost. If the distinguished speed limit signpost is installed at the suitable distance before the curve according to the proper speed on it, the above safety standards are verified, otherwise, an appropriate message concerning the inappropriate speed limitation or wrong location of the signpost is provided for the user.

$$\frac{V^2}{127(e+f)} \quad \text{Equation 2}$$

In Equation 2, R is the radius of the curve in terms of meter, V is the speed in terms of kilometre per hour, e is the superelevation, and f is the coefficient of transverse friction.

RESULT AND DISCUSSION

The employment of MMS as one of the path safety inspection methods provides accurate and complete image data of the side features of the path and presents the physical position of the signs and signposts. In this paper, by concentrating on the section of the processing of the image by this system, a new method was presented for automatic control of safety standards related to the speed limit signposts before the horizontal curves. Based on the obtained results, the rate of accuracy at the identification phase (presence or absence of the signpost) was estimated to be 92% and at the pattern recognition phase (determination of the value of limitation on the signpost) it was 97%. The results obtained from the processing of the video images of MMS for identification and the distinctions of speed limit signpost are presented in Table 1. The reason for the difference in the rate of accuracy between the two phases is the more significant effect of factors such as the angle of taking images, weather conditions, and the physical situation of the signpost on the frame understudy at the identification phase relative to the distinction phase.

Other safety standards such as the condition of the margin of the path can also be automatically evaluated within the framework of the intelligent systems, but the ultimate goal is not limited only to the detection of the safety defects whether existing or potential, but the required efforts should also be made to find safety

Table 1
Result of the identification and determination of the speed limit signs via the proposed method

Duration of the film (min)	The total number of speed signs (between 30-90 km/hr.)	No. of valid identification of presence or absence of the signpost		No. of valid determination of the value of limitation on the signpost		
		No.	%	No.	% To the number of identified signs	% To the total number of speed sign
24	7	7	100	7	100	100
18	12	11	91.7	11	100	91.7
33	16	14	87.5	13	92.9	81.3
12	9	8	88.9	8	100	88.9
27	14	13	92.9	12	92.3	85.7

improvement opportunities for the black spots.

Based on the acceptable accuracy obtained using the proposed method, Mobile Mapping Systems (MMS) can be successfully employed for road safety inspection purposes to capture video images. The main output captured by MMS includes geographical data and different types of imaging and video formats. By recording and registering image and geographical data of the roadway, this system can present the latest safety situation on the roadway, which can facilitate the safety auditing process to make informed decisions timely. Note that there is no need for immediate processing of the data for the quality control of the safety standards by the video images obtained from the MMS. It is possible to record the roadway at specific hours of the day when there is enough light, and we did not face a wide spectrum of light when filming, which leads to better results.

The MMS-based image processing method presented in this paper is capable of being used in other private and public vehicles as operating in-vehicle active systems so that by installing a system in the vehicles based on the proposed method and processing the road images and identifying the value of the speed limit on the sign within the framework of in-vehicle active system it is possible to reduce the speed automatically. The proposed method in this research could be used in other types of roads and also other road users to prevent roll-over accident accidents using the identification of speed limit signs. It also could be used for other road users to prevent non-motorized accidents using the identification of speed limit sign (Shirani et al., 2018) and improving connected vehicles technologies for the safety of aging population (Kidando et al., 2018).

CONCLUSION

Due to the centrifugal force imposed on the vehicle, confusing the driver to predict the situation of the path ahead, the horizontal curves of the path which are more dangerous relative to other linear sections of the path impose more responsibility upon the driver. Accordingly, the study of the safety situation of the horizontal curves has always been one of the major areas of the activity of specialists and road engineers to improve the safety situation of the network of the roads.

In this paper, by concentrating on the section of the processing of image by this system, a new method was presented for automatic control of safety standards related to the speed limit signposts before the horizontal curves. On the basis of the results obtained from the application of the automatic method in controlling the safety standards related to speed limit signs before the horizontal curves in the image processing phase and on the basis of processing the road video images (recorded by the cameras installed on MMS vehicles) the rate of precision in the identification section (presence or absence of sign) was estimated to be 92% and in the distinction section (determination of the limit value on the sign) it was 97%. The output results of the proposed method within the framework of the maps and comprehensible values in the area of the identification of the black spots can be useful for the road engineers and the designers. The introduced intelligent system is able to automatically control the safety standards related to the proposed speed value on them saving time and cost compared with other field methods of road safety auditing. The sign and safety equipment on the roads are exposed to damages resulting from environmental unfavorable factors, collision of transit traffic, and social anomies. Performance of continuous and regular inspection operations by MMS to control the appropriate functioning of their physical conditions is essential. Of course, the ultimate goal is not only limited to detect the safety defects, but the required efforts should also be taken to find chances for the improvement of the safety of the road and the elimination of the black spots.

LIMITATION AND FUTURE RESEARCH

It is worth mentioning that based on some studies conducted on the speed limit signs, the effect of the signs and warnings of the danger of the curve on the perceptional system of drivers has been evaluated to be negligible (Jorgensen & Wentzel-Larsen, 1999). It also revealed that the warning signs before the curves had very little effect on the reduction of entering speed of drivers to the curves (Shinar et al., 1980). Therefore, in addition to the speed limit signs, perceptual and concentration-enhancing factors are also required (Recarte & Nunes, 1996). Of these perceptual factors, one can point to pavement signs including rumble strips in the middle on the sides of the road (Rasanen, 2005).

We intend to utilize the result of the previous study related to GPS analyzing (Koloushani et al., 2014) and integrate the outputs with image processing results to propose a new concept that could automatically evaluate the safety condition before horizontal curves. The before-mentioned GPS analyzing phase could provide guidelines in determining the speed limit values based on the curve radius, identify a safe and appropriate location for the speed limit sign before the curve based on the speed limit on the straight roadway segment, and compares the speed value and sign location given the existing conditions. We plan to expand this research in this direction soon. Additionally, it would be a valuable extension if the application of this image processing method is considered in the connected vehicle field.

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REFERENCES

Bhatnagar, Y. S. (1994). Observations on the use of chevron alignment markers. *Proceedings of 17th Australian Road Research Board Ltd (ARRB) Conference, 17*(5), 65-81.

Burges, C. J. (1998). A tutorial on support vector machines for pattern recognition. *Data Mining and Knowledge Discovery, 2*(2), 121-167.

Charlton, S. G. (2004). Perceptual and attentional effects on drivers' speed selection at curves. *Accident Analysis and Prevention, 36*(5), 877-884.

Charlton, S. G. (2007). The role of attention in horizontal curves: A comparison of advance warning, delineation, and road marking treatments. *Accident Analysis and Prevention, 39*(5), 873-885.

Chen, L., Li, Q., Li, M., & Mao, Q. (2011). Traffic sign detection and recognition for intelligent vehicle. In *IEEE Intelligent Vehicles Symposium IV* (pp. 908-913). https://doi.org/10.1109/IVS.2011.5940543

Damavandi, Y. B., & Mohammadi, K. (2004). Speed limit traffic sign detection & recognition. In *IEEE Conference on Cybernetics and Intelligent Systems 2004* (pp. 797-802). https://doi.org/10.1109/ICCIS.2004.1460690

Eichner, M. L., & Breckon, T. P. (2008). Integrated speed limit detection and recognition from real-time video. In *2008 IEEE Intelligent Vehicles Symposium* (pp. 626-631). https://doi.org/10.1109/IVS.2008.4621285

Florkova, Z., Duris, L., Veselovsky, M., Sedivy, S., & Kovalova, D. (2018). Three-dimensional mobile mapping system and its use in road engineering. *MATEC Web Conference, 196,* 1-7. https://doi.org/10.1051/matecconf/201819604082

France, J., & Glennie, C. (2011). A step-by-step description of a mobile mapping project reveals the tricks of the trade. *Earth Imaging Journal,* (7), 28-30.

Gao, Y., Zhong, R., Tang, T., Wang, L., & Liu, X. (2017). Automatic extraction of pavement markings on streets from point cloud data of mobile LiDAR. *Measurement Science and Technology, 28*(8), 1-13.

Gupta, R. C., & Jain, R. P. (1975). Effect of certain roadway characteristics on accident rates for two-lane, two-way roads in connecticut (abridgment). *54th Annual Meeting of the Transportation Research Board* (pp. 50-54). Washington, USA: Transportation Research Board (TRB).

Heydari, M., Amirfattahi, R., Nazari, B., & Bastani, A. (2013). Iron ore green pellet diameter measurement by using of image processing techniques. In *2013 21st Iranian Conference on Electrical Engineering (ICEE)* (pp. 1-6). https://doi.org/10.1109/IranianCEE.2013.6599563

Ishikawa, K., Amano, Y., Hashizume, T., & Takiguchi, J. (2007). A study of precise road feature localization using mobile mapping system. In *2007 IEEE/ASME International Conference on Advanced Intelligent Mechatronics* (pp. 1-6). https://doi.org/10.1109/AIM.2007.4412541

Johnston, I.R. (1982). Modifying driver behaviour on rural road curves: a review of recent research. *Proceeding of the 11th Australian Road Research Board (ARRB) Conference*, *11*(4),115-124.

Jorgensen, F., & Wentzel-Larsen, T. (1999). Optimal use of warning signs in traffic. *Accident Analysis and Prevention, 31*(6), 729-738.

Kidando, E., Moses, R., Ghorbanzadeh, M., & Ozguven, E. E. (2018). Traffic operation and safety analysis on an arterial highway: Implications for connected vehicle applications. In *2018 21st International Conference on Intelligent Transportation Systems (ITSC)* (pp. 2753-2758). https://doi.org/10.1109/ITSC.2018.8569636

Knowles, D., & Tay, R. S. (2002). Driver inattention: More risky than the fatal four? In *2002 The Road Safety, Policing, and Education Conference*, (pp. 107-111). Available from http://eprints.qut.edu.au/

Koloushani, M., Fatemi, A., & Tabibi, M. (2014). Application of global positioning system data collected by mobile mapping system for automatic control of safety standards in horizontal curves. *The 93rd Annual Meeting of the Transportation Research Board* (pp. 1-13). Washington, USA: Transportation Research Board (TRB).

Madeira, S., Goncalves, J., & Bastos, L. (2010). Photogrammetric mapping and measuring application using MATLAB. *Computers and Geosciences, 36*(6), 699-706.

Maldonado-Basco, S., & Gomez-Moreno, H. (2007). Road-sign detection and recognition based on support vector machines. *IEEE Transaction on Intelligent Transportation Systems, 8*(2), 264-278.

McDonald, L. B., & Ellis, N. C. (1975). Driver workload for various turn radii and speeds. *Transportation Research Record: Journal of the Transportation Research Board, 530*(1), 8-30.

McDonald, N. (2004). Look and learn: capitalizing on individual responsibility in speed management. In *The Australian Institute of Traffic Planning and Management (AITPM) National Conference* (pp. 73-83). Toombul, Queensland, Australia: AITPM.

Moutarde, F., Bargeton, A., Herbin, A., & Chanussot, L. (2007). Modular traffic signs recognition applied to on-vehicle real-time visual detection of American and European speed limit signs. In *2007 IEEE Intelligent Vehicles Symposium* (pp. 1122-1126). Beijing, China: ITS America.

Rasanen, M. (2005). Effects of a rumble strip barrier line on lane keeping in a curve. *Accident Analysis and Prevention, 37*(3), 575-581.

Recarte, M. A., & Nunes, L. M. (1996). Perception of speed in an automobile: estimation and perception. *Journal of Experimental Psychology, 2*(4), 291-304.

Retting, R. A., & Farmer, C. M. (1998). Use of pavement markings to reduce excessive traffic speeds on hazardous curves. *ITE Journal, 68*(9), 30-36.

Reymond, G., Kemeny, A., Droulez, J., & Berthoz, A. (2001). Role of lateral acceleration in curve driving: Driver model and experiments on a real vehicle and a driving simulator. *Human Factors, 43*(3), 483-495.

Shinar, D., Rockwell, T. H., & Malecki, J. A. (1980). The effects of changes in driver perception on rural curve negotiation. *Ergonomics, 23*(3), 263-275.

Shirani, N., Doustmohammadi, M., Haleem, K., & Anderson, M. (2018). Safety investigation of non-motorized crashes in the city of Huntsville, Alabama, using count regression models. *The 97th Annual Meeting of the Transportation Research Board* (pp. 1-17). Washington, USA: Transportation Research Board (TRB).

Tao, C. V. (2009). Mobile mapping technology for road network data acquisition. *Journal of Geomatics Engineering, 2*(2), 1-13.