SEYYED MOHAMMAD SADAT HOSEINI, Ph.D.
E-mail: Sadathoseini1@yahoo.com
Transportation Research Institute
Tehran, Iran
MAHMMOOD FATHI, Ph.D.
E-mail: mahfathi@yahoo.com
Iran University of Science and Technology
Department of Computer Engineering
Tehran, Iran
MANOUCHEHR VAZIRI, Ph.D.
E-mail: manouchehrvaziri@yahoo.com
Sharif University of Technology
Department of Civil Engineering
Tehran, Iran

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CONTROLLING LONGITUDINAL SAFE DISTANCE BETWEEN VEHICLES

ABSTRACT

Controlling the safe distances between vehicles on freeways can be used to prevent many accidents. In this research, image-processing techniques have been used to develop an online system that calculates the longitudinal distances between vehicles. This system facilitates controlling safe distances between vehicles without the need for high technology devices. Our approach is real-time and simple, but efficient operations have been used to reduce the image occlusion problem. The main concept of this system is using simple, quick, and effective algorithms for calculating the position of each vehicle in each image. In this way, traffic parameters like speed and distances between vehicles can be calculated for each vehicle in real time. In addition, aggregate parameters like average speed, density, and traffic flow can be calculated using gathered data of single vehicles. As an application of the developed system, controlling the safe distance between vehicles has been introduced. In this system, in case of a driver who does not observe the safe distance, the scene of violation is stored and can be used by the police agencies.

KEY WORDS

image processing, traffic, longitudinal safe distance, real time, occlusion

1. INTRODUCTION

Development of digital image processing technology has enabled its implementation in transportation engineering. There are various systems for measuring traffic characteristics of vehicles that operate in different parts of the world [1, 2, 3]. Most of these systems are used for measuring the quantitative or qualitative traffic parameters [4, 5]. Most of the methods that are used for calculating the position of vehicles are based on complicated algorithms [6, 7] that have large amounts of calculations and their implementation as a real-time system can produce many problems. The main problem lies in the fact that these algorithms try to process all parts of the image.

There are several systems for controlling safe distance between vehicles. They must be installed on the vehicles to prevent accidents. Simulation results of these systems demonstrate that, if they be installed on all of the vehicles, they can decrease accident rate and increase road capacity [8, 9]. Considering difficulties of installing the safe distance controller on all of the vehicles, an image processing system is proposed to enforce drivers to consider safe distance.

In this research, we have proposed a simple and effective approach that can be implemented in real time. In the created system, the vehicles are distinguished on the freeway and their position in each frame is calculated. In this way, longitudinal distances between vehicles, speed and trajectory of each vehicle can be determined.

The trajectory of vehicles can be used for modelling the drivers' behaviour [10, 11]. The drivers' behaviour models can be used for micro simulating of traffic [12, 13, 14]. In addition, macroscopic traffic parameters including, the number of passing vehicles, average speed, and other traffic characteristics can be calculated. Using the image-processing techniques instead of manual methods increases the accuracy of measurements and what would be tedious work for humans can be done by a machine. Using simple algorithms enables us to satisfy our needs without using high-technology devices.

2. STRUCTURE OF THE DEVELOPED SYSTEM

Hardware of the developed system consists of a video player or a camera, a frame grabber, and a computer. The output of the camera or video player is connected to the input of the frame grabber board that converts analogue video signal to a digital image. A computer program is prepared for processing the digital image.

In many images taken from the streets, in addition to the considered vehicles, there are other vehicles and passers moving in other places near the considered street. Thus, it becomes important to distinguish the considered vehicles from other moving objects in the taken images. In this research, the considered street has been divided into windows and subsequently used for image processing. The size of these windows is determined as if they could produce a complete view of the considered street with sufficient resolution and accuracy.

The windows are arranged in horizontal rows. Each row contains a number of windows. Considering the non-linear projection of 3D images to 2D images, the vertical distances between rows of windows are determined by a non-linear equation. This equation is proven in Section 3. Figure 1 shows the distribution of windows on a sample image of a freeway. The distribution of the windows is determined as if all of the distances between rows of the windows showed a specified distance (e. g. 2.5 metres) in the street. Thus, each window can be matched to a specified space in the street.

Each window is processed in order to detect whether there is a vehicle in it or not. The developed computer program uses an effective algorithm to detect the vehicles in each window [4, 5]. In this algorithm, averaging the pixels of that window in the sequence of images produces the background of each window, and then moving vehicles can be detected by differencing each image from its background. In the differenced picture, pixels, which feature high value, may be considered the result of object motion, that in this case, the object is a vehicle.

Since the system is dependent on the background, the changes in illumination, shades of trees and so on, can reduce the accuracy of the system. Therefore, the background of the windows must be updated every time interval. In this research for every 5 minutes the background has been updated.

When the number of pixels related to a vehicle exceeds a threshold, that window is considered to have detected a vehicle. Such a process is done for all of the windows in the images. So, all of the vehicles can be detected in the considered part of the street and the position of vehicles can be calculated in every image.

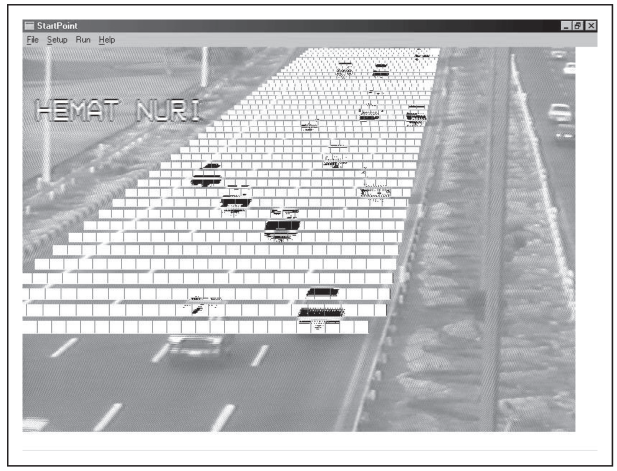

Figure 1 - Windows on an image frame

For example, it can be seen in Figure 1 that there are 40 rows of windows, each one containing 24 windows on the width of the street. If a vehicle can be seen through any of these windows, the corresponding value of that window will become 1, otherwise it will become 0. In this way, for each frame of the moving vehicles in the street, there is a 40 by 24 matrix that 0 indicates the absence and 1 indicates the presence of vehicles in the respective window. Thus, data of an 800 by 600 pixel image can be compressed to a 40 by 24 binary image.

As explained in Section 3, partitioning the image into windows is done in such a way that each window indicates horizontally about 66 centimetres and vertically about 2.5 metres of the street surface. Therefore, in the created matrix, each number indicates a 2.5 by 0.66 metres rectangle of the street surface.

Figure 2 shows the created matrix of Figure 1. As can be seen in Figure 2, each vehicle can be distinguished as a group of 1s which are named spots in this paper. There are 13 spots in Figure 2 corresponding to 13 cars shown in Figure1.

It can be seen in the created matrix of the image that the lengths of vehicles are shown longer than their real lengths. This problem occurs because of the camera view that cannot see behind the vehicle and considers it as part of it. The more the distance between the vehicle and the camera increases, and the height of the vehicle increases, the mentioned problem is intensified.

For detecting the vehicles positions individually, it is better to consider the front edge of vehicles for determining their positions. In this way, in the created matrix of the street image, the first row of each group of 1s is considered as the front edge of vehicles, and the template of a vehicle is matched to it. Vehicles that are larger than a passenger car, like buses and trucks, have bigger width and according to their width, the template of a bus or truck must be matched to their front edge.

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Figure 2 - The resulting matrix

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000001100000    000001100000
000001111000    000001111000
000000011000    000000011000
000000011000    000000011000
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Figure 3 - Separation of two vehicles using template matching

Using the above method it is possible to solve the occlusion problem to some extent. If images of two vehicles are occluded, they can be separated after detection of their front edges and each one can be matched by its proper template. Figure 3 shows an example of the mentioned problem that is solved by template matching.

Figure 3 shows a 3 by 2 element template that is used for a car. Although spots related to two cars are joined and form one group, by using templates of cars on the front edge of spots, the two cars are distinguished [11].

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0 0 0 0 0 0 0 0 0 0 0 0 2 2 0 0 0 0 0 1 1 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0 0 0 0 1 1 1 1 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0
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Figure 4 - The resulting matrix after assigning a number to each car

A number or character is assigned to each spot to be distinguished from other spots. Figure 4 shows a matrix created after assigning a number to each spot.

The above process is done in real time and frames are processed one after another. After converting the images into matrices, the processing will be done on the matrices instead of images. The position of each spot is calculated to be used as the position of the corresponding vehicle. The position of each vehicle in each time is stored in an array with the form of (ID, X, Y, K, t)

where:

- ID – Identity number of vehicles,
- X, Y – longitudinal and lateral position,
- K – vehicle type according to its size (0 for passenger car, 1 for bus and truck)
- t – time on which the vehicle was positioned.

This array is stored for each time step and for each vehicle in a table and it is saved in a text file. By means of vehicle positions in the sequence of images, the trace of each vehicle can be found.

For example, consider arrays (i, X_j, Y_j, 0, t_j) and (i, X_{j+1}, Y_{j+1}, 0, t_{j+1}), that means there is vehicle i in (X_j, Y_j) in the j-th time step and in (X_{j+1}, Y_{j+1}) in the (j+1)-th time step, where X is the longitudinal and Y is the lateral position. Longitudinal distance travelled by vehicle i in j-th time step can be calculated by Equation 1.

$$Dx_{i,j} = X_{j+1} - X_j \tag{1}$$

In addition, the speed of each vehicle can be calculated using the position and time of that vehicle. For example, the speed of vehicle i in j-th time step can be calculated by Equation 2.

$$v_{i,j} = \frac{X_{j+1} - X_j}{t_{j+1} - t_j} \tag{2}$$

Macroscopic parameters like average speed can be calculated by averaging the speed of each vehicle, respectively.

3. THEORETICAL FUNDAMENTALS OF DETERMINING THE POSITION OF WINDOWS

By means of a projective model, a point on the street can be related to its respective point on the screen. Thus, positions of all points on the street are known. Camera picture co-ordinates (Xv, Yv) can be converted to street co-ordinates (Xs, Ys) using Equations 3 and 4.

$$X_{si} = \frac{C_1 X_{vi} + C_2 Y_{vi} + C_3}{C_4 X_{vi} + C_5 Y_{vi} + 1} \tag{3}$$

$$Y_{si} = \frac{C_6 X_{vi} + C_7 Y_{vi} + C_8}{C_4 X_{vi} + C_5 Y_{vi} + 1} \tag{4}$$

where C_1... C_8 coefficients are used for calibrating the camera. As a prerequisite for the usage of this model, only four points on the street must be known, and they must be recognizable on the screen. Exactly two points out of four points must lie on one line. Figure 5 shows four points in the real world and their corresponding points in the image.

There are four points (Xv_i, Yv_i) in the real world, and four points (Xs_i, Ys_i) in the image corresponding to them. Inserting coordinates of these points in Equations 3 and 4, there are 8 equations and 8 coefficients to be calculated [2]. After calculating the C_1.. C_8, the camera has been calibrated.

The distances between rows of windows must be determined as if the distance between each two rows of windows be equal to a specific distance in the real world. It means that for a specific distance in the real world, a corresponding distance in the image must be calculated.

Regarding Equation 3 and considering a horizontal line in the street, $Y_{v(i+1)}=0$ and $Y_{vi}=0$ yields:

$$X_{si} - X_{s(i+1)} = \frac{C_1 X_{vi} + C_3}{C_4 X_{vi} + 1} - \frac{C_1 X_{v(i+1)} + C_3}{C_4 X_{v(i+1)} + 1} \tag{5}$$

Considering:

$$d = X_{vi} - X_{v(i+1)} \tag{6}$$

we have:

$$X_{si} - X_{s(i+1)} = \frac{(C_1 - C_4 C_3)d}{C_4^2 X_{vi}^2 + (2C_4 - dC_4^2)X_{vi} - C_4 d + 1} \tag{7}$$

After calibrating the camera, Ci coefficients are calculated, and after specification of distance d, distances between rows of windows in the image can be calculated using Equation 7.

There are cases, when there is a curve in the road. In these cases, the curve equation must be estimated. Here, it is simply supposed that the street margins are straight lines, so the beginning of all the rows is placed on a straight line. In the same way, the ends of all of the rows are placed on another straight line. Knowing two points of a straight line, the equation of that line can be determined. Thus, for determining the equa-

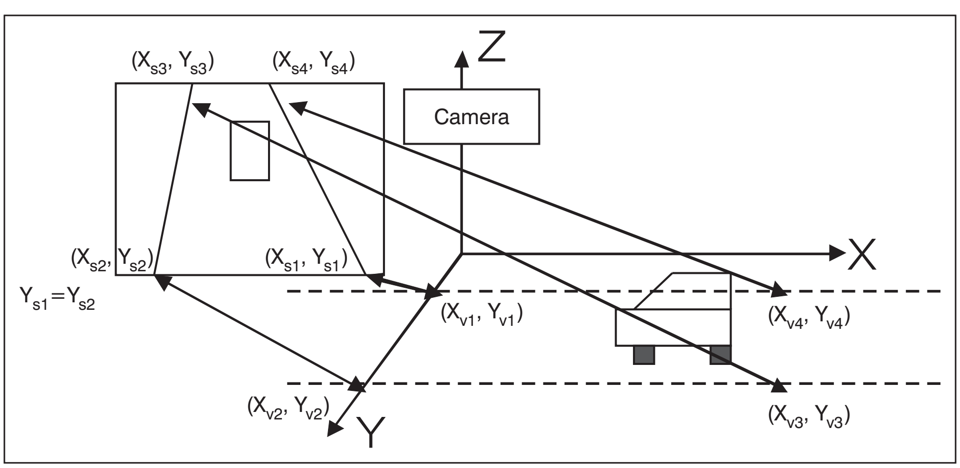

Figure 5 - Four points in the real world and their corresponding points in the image

tion of street margins, two points of each margin like (X_1, Y_1) and (X_2, Y_2) are considered and the equation of that margin is determined by Equation 8.

$$Y = \frac{Y_1 - Y_2}{X_1 - X_2}(X - X_2) + Y_2 \tag{8}$$

The same equation is applied for the other street margin. These two equations determine the beginnings and ends of the rows of windows.

4. MINIMUM SAFE DISTANCE

The definition of the safe distance which is stated in the driving regulation handbook is different from the safe distance which can be calculated using the movement laws. In this section, the minimum safe distance between vehicles is introduced according to both definitions.

According to the driving regulations in Iran, safe distance between two vehicles is determined by every 15km/hour speed the same as the vehicle length. This length of safe distance refers to all types of roads including urban and rural roads [15], which can be shown by the equation below:

$$d_{safe} = \frac{V_{ID} \cdot L_{ID}}{15} \tag{9}$$

where:

d_{safe} – safe distance according to the driving regulations in Iran (meter),

V_{ID} – speed of the vehicle (km/h),

L_{ID} – length of the vehicle (meter).

It is known that the mentioned formula for calculating the safe distance is not based on motion dynamics of vehicles, but as it is still in use in Iran, the same formula is used in this research.

For calculating the safe distance using the movement laws, suppose Vehicle 2 is following Vehicle 1 and their speeds are V_2 and V_1, respectively, the distance between vehicles is d metres and L is the length of the front vehicle. It is necessary to calculate the safe distance for reducing the probability of accident between the vehicles.

If the front vehicle sees an obstacle and brakes in t_0; Vehicle 2 will brake after a reaction time τ in $t_0+\tau$. In order to prevent the accident between the vehicles, it is important that the two vehicles keep safe distance according to their primary speed and brake deceleration.

Considering the movement equation of vehicles to avoid accident between them, Equation 10 must be applied, where, a_1 and a_2 are the brake decelerations of Vehicles 1 and 2, respectively.

$$L + V_2\tau + \frac{V_2^2}{2a_2} = \frac{V_1^2}{2a_1} + d \tag{10}$$

Equation 11 shows the minimum safe distance to the front Vehicle 2 for preventing an accident. The minimum safe distance of each cell is calculated with due attention to the speed of the front vehicle.

$$d_{safe} = d = L + V_2\tau + \frac{V_2^2}{2a_2} - \frac{V_1^2}{2a_1} \tag{11}$$

5. STATISTICAL RESULTS OF CALCULATING DISTANCES BETWEEN VEHICLES

The developed system can calculate the longitudinal position of vehicles with an accuracy of about 2.5 metres for 95% of vehicles, when the front edge of vehicles can be seen. However, when occlusion of vehicles increases, the accuracy decreases. The occlusion is related to the position and shape of the vehicles. The more the density of vehicles on the street increases, the more occlusion is produced. It is an occlusion when the front edge of a vehicle cannot be seen because there is another vehicle in front of it. Regarding the fact that the lack of safe distance observance is one of the main reasons of accidents in Iran, the calculation of longitudinal distances between vehicles on the Hemmat expressway in Tehran is introduced as an application of the developed system.

For measuring the longitudinal distances between vehicles, the longitudinal distances between centres of vehicles that their lateral distances are less than a lane width (about 4 metres) have been measured.

A sample film of the Hemmat expressway in a 5-minute interval is used for calculating the longitudinal distances between vehicles. The image size is 800*600 pixels as can be seen in Figure 1. After measuring the longitudinal distances in the sample film of the expressway, the frequency of distances between vehicles has been calculated and shown in Figure 6. During film-taking, the average speed was approximately constant, about 45km/h.

As can be seen in Figure 6, the more the distance between the vehicles increases, the more the frequency of vehicles increases. This fact is because of reducing the risk of accidents between vehicles. The increase of frequency with the increase in longitudinal

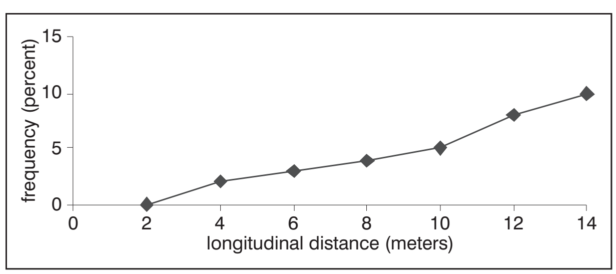

Figure 6 - Frequency of longitudinal distances

distance is true up to the safe distance, and after that, the graph loses its monotonousness.

In the gathered data of the Hemmat Expressway, the average speed of vehicles was about 40-50km/h, so safe distance between vehicles must be about 2.5 to 3.5 counts of a vehicle length, about 10 to 15 metres. When the longitudinal distance increased more than the safe distance, drivers did not try to increase their distance any more. So, the frequency of longitudinal distances between vehicles with more than the safe distance is not related to their traffic behaviour but rather it is mainly related to their distribution through the driving lanes. It is also visible in Figure 6 that many of the drivers do not observe the safe distance.

6. CONTROLLING SAFE DISTANCES BETWEEN VEHICLES

If the introduced system is installed for controlling the safe distance on an individual freeway, it can distinguish the violator vehicles and take the photos of the violating scene. In this way, the traffic enforcement agencies can control traffic more easily and more accurately.

The developed system is used for controlling the safe distances between vehicles on a section on the Nuri expressway in Tehran, which was about 100 metres long. A sample film of about 5 minutes is used for detecting the vehicles that do not consider longitudinal safe distances. The image size is 800*600 pixels. Every time a longitudinal distance between vehicles shorter than the longitudinal safe distance is detected, the scene of the violation is stored as a bitmap image file and the violator car is distinguished. The scene of violation can be sent to the police agencies.

If the camera is located in front of the vehicles as shown in Figure 7 in most cases in which a vehicle does not consider the safe distance, its license plate cannot be seen because of the occlusion by the front vehicle. An example of this situation is shown in Figure 7.

As can be seen in Figure 7, although the distance between the front and the following vehicle is shorter than the safe distance, the license plate of the following vehicle, which is the violator driver, cannot be seen because of the camera view. It is suggested that the camera be located behind the vehicles. In this way the license plate of the violator can be seen.

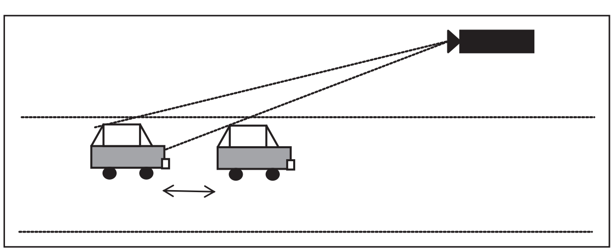

Figure 7 - Occlusion of the license plate

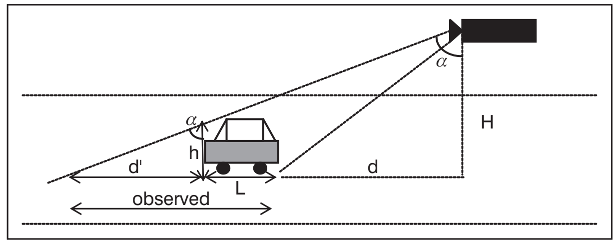

Figure 8 - Real and observed length

In Figure 8 the observed length of a vehicle is calculated using the height of the camera and the distance between the camera and the vehicle. Consider α to be the angle shown in Figure 8. tan α can be calculated using Equation 12.

$$\tan\alpha = \frac{d+L+d'}{H} \tag{12}$$

where:

- d – distance between camera and observed vehicle,
- L – real length of a passenger car,
- H – height of the camera, and
- d' – difference between real and observed length of vehicle as shown in Figure 8 and calculated using the equation below:

$$d' = \tan\alpha \cdot h = \frac{d+L+d'}{H} \cdot h \tag{13}$$

where:

- h – height of a car.

Therefore:

$$d' = \frac{(d+L)h}{H-h} \tag{14}$$

Considering that the position of each row of windows is known, the distance between the vehicle and the camera, d, in Equation 14 can be calculated according to the first row of windows in which the vehicle has been detected.

Although different passenger cars have different heights and lengths, the observed length of vehicles can be calculated with the accuracy of more than 2.5 metres, except for vans which holding tall loads. For the studied case the accuracy of the longitudinal position was about 2.5 metres, so that the height of the vehicles does not reduce the accuracy of the system. Generally, the height of a vehicle can be ignored with respect to the height of the camera. If the height of a vehicle differs from the normal vehicle height, d'' can be calculated using Equation 15.

$$d'' = \frac{(d+L)\cdot h \cdot (1 \pm e_h)}{H - h\cdot(1\pm e_h)} \approx \frac{(d+L)\cdot h\cdot(1\pm e_h)}{H-h} = d' \cdot (1 \pm e_h) \tag{15}$$

where:

- d'' – difference between real and observed length of vehicle considering error in vehicle height,
- e_h – error in the vehicle height.

As can be seen in Equation 15 if there is e_h percent error in vehicle height there will be e_h percent error in d' as well. In practice, for controlling the safe distance it is better to consider $d'. (1+e_h)$ instead of d' . In this way some of the violator drivers will be missed but there is no regular driver who is detected as a violator.

Considering vehicle height to vary from 1.35 metres to 1.95 metres [16],

$$e_h = \frac{1.95-1.35}{(1.95+1.35)/2} = 0.36.$$

If $d_{safe} < 1.36.\ d'$, the following vehicle is considered as the violator. If $d' < d_{safe} < 1.36.\ d'$, the following vehicle is the violator, but it is not distinguished by this system. However, this is not important in many cases, because a small number of violations is usually ignored by the police agencies.

Suppose there is a vehicle in front of the considered vehicle in Figure 8, and the distance between them is less than d", where d" is defined in Equation 15. Using the simple mentioned method which is used in this research the image of these vehicles will be oc-

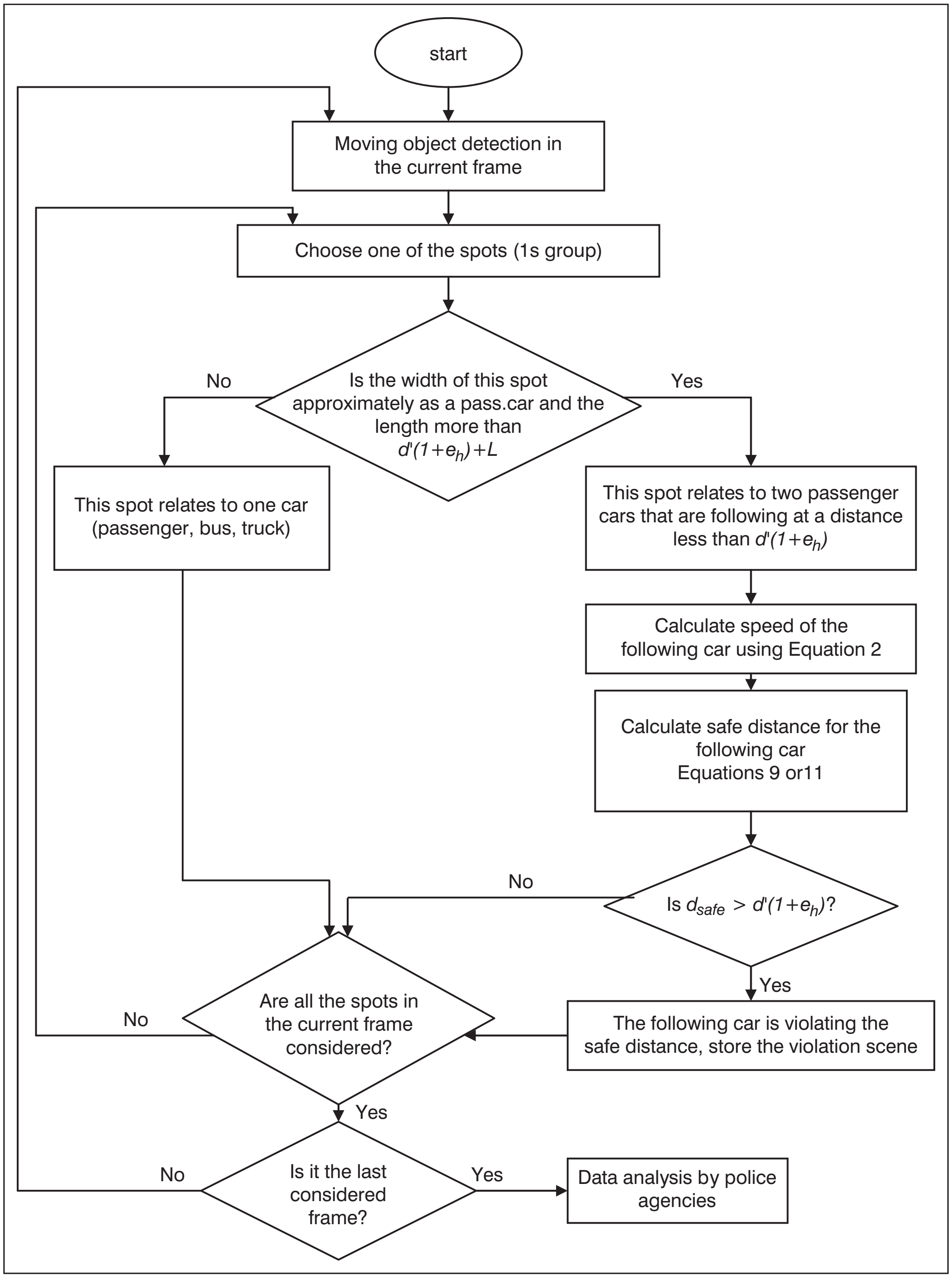

Figure 9 - Algorithm for detecting safe distance violation

cluded and it will be impossible to distinguish them individually. Although the exact position of each vehicle cannot be distinguished, still the driver observance of safe distance can be tested. The algorithm for detecting the violation of safe distance is shown in Figure 9.

As shown in Figure 9 the moving object in the current frame is detected and groups of 1s or spots as was described in Section 2 are detected. The size of the spots are tested, if the width of a spot is approximately as a passenger car and the length of it more than $d'(1+e_h)+L$ that spot corresponds to two passenger cars that are following at a distance less than d'. Considering the speed of the following car which is equal to the speed of the related spot, the observance of safe distance is tested and if the safe distance was not observed by the following car the scene of violation is stored. In this way, without the detection of the position of each vehicle individually the violator drivers can be detected.

7. CONCLUSION

In the developed system, the position of vehicles can be determined without the need for special devices or losing the capability of real-time processing. In addition, without knowing the pan, tilt, focus, and height of the camera, only knowing the co-ordinate of 4 points of the image in the real world, the distances and positions in the street can be calculated.

As an application of the developed system, controlling the safe distances between vehicles has been introduced and tested in the laboratory. The developed system can detect vehicles which do not observe the safe distance, even when their images are occluded by the image of other vehicles, but it will miss many violator vehicles in special cases which are explained in this paper. If the developed system is used by the police agencies, it can increase their ability to enforce drivers to observe safe distances.

Regarding the fact that many accidents are caused by the lack of observance of safe distances, it is necessary to perform more researches for measuring the distances between moving vehicles and in general about traffic behaviour. The developed research introduced a fast and efficient method for calculating the distance between vehicles. Using data of vehicle positions, other quantitative and qualitative parameters can be measured as well.

This system in heavy traffic when the images of vehicles conflict and the front edge of vehicles cannot be seen, loses its efficiency. It is suggested that in the future activities by using the parameters such as colour, shape, and dimension, the vehicles are detected more accurately and the occlusion problem is reduced.

LITERATURE

[1] Internet_TRAFICON Web Site, (2004), www.traficon.com.

[2] Internet_ViVAWebSite, (2004), www.kernfahrbahn.ch/viva.html

[3] Internet_Control Traffic Web Site, (2004), http://www.cttraffic.com.

[4] **Fathi, M.** and **Siyal M.**: *Image processing Techniques for real-time qualitative road traffic data analysis*", International journal of real-time imaging, Academic press, USA, Vol. 5: 103-106, 1999

[5] **Fathi, M.** and **Siyal M.**: *A window based image processing techniques for qualitative and quantitative analysis of road traffic parameters,* IEEE transaction on vehicular technology, Vol. 47, No 4: 1342-1350, 1998

[6] **Sadough. Yazdi, H.**, **Fathi, M.**, **Lotfizade, M.**: *Vehicle tracking at Traffic Scene with Modified RLS*, International Conference on Image Analysis and Recognition, LNCS. 3212, pp 623-632, Porto, 2004

[7] **Lee, M-s.**, **Kim, Y-H.**: *An efficient Multi Target Tracking Algorithm for Car Application*, IEEE Trans. Industrial electronics, Vol. 50, No. 2, 2003

[8] **Mar, J.**, **Lin, H.**: *A car-following collision prevention control device based on the cascaded fuzzy inference system*, Fuzzy Sets and Systems, Vol. 150, Issue 3, pp. 457-473, 2005

[9] **Goto, Y.**, **Furusawa, H.**, **Araki, M.**, **Fukunda, T.**: *A safe traffic speed control in AHS*, International Conference on Intelligent Transportation Systems, Proceedings IEEE/IEEJ/JSAI, pp 459-464, 1999

[10] **Kazi Iftekhar, A.**: *Modeling drivers` acceleration and lane changing behavior*, Ph. D. dissertation, Transportation Department, Massachusetts Institute of Technology, 1999

[11] **Sadat Hoseini, S.**, **Fathi M.**, and **Vaziri M.**: *Determination of position of vehicles using image processing for studying the behavior of drivers in expressway*, 2nd Iranian Conference on Machine Vision & Image Processing. (in Persian), 2003

[12] **Gunay, B.**: *Modeling lane discipline on multilane uninterrupted traffic flow*, Traffic Engineering+Control: 440-447, 1999

[13] **Heng, W.**, **Meyer E.**, **Lee J.**, and **Chuen F.**: *Characterizing and modeling observed lane-changing behavior*, Transportation Research Record, 1710: 104-113, 2001

[14] **Sadat Hoseini, S.**, **Shafahi Y.**, and **Vaziri M.**: *Combination of Car Following and Lane Changing Models as a Drivers' Optimization Process*, 8th International Conference on Applications of Advanced Technologies in Transportation, ASCE, China: 601-605, 2004

[15] *Driving Regulation Handbook*, (in Persian), 2006

[16] *Neufert Architects' Data*, Black well publishing, p. 432, 2000