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INTELLIGENT SURVEILLANCE SYSTEMS FOR DETECTION AND MULTI TRACKING OF VEHICLES IN REAL TIME

Saeid FAZLI [1], Morteza RAHMANI [2], Shahram MOHAMMADI [1]

[1] Zanjan University, Electrical Engineering Department, Zanjan, IRAN
[2] Payame Noor University, Department of Electrical Engineering, PO Box 19395-3697, Tehran, Iran
Corresponding author: Morteza RAHMANI, E-mail: Rahmanim@znu.ac.ir

Given the improvement of digital's cameras and the system of video's processing, it have been considering the civil controlling and managing and observation into the traffic. Among this, the computer vision systems have used for creating of some equipments of automatic controlling of traffic. In this article, we have presented the new algorithms by techniques of image processing for an intelligent system of transportation. It can be done some operations of observation into traffic in the real time and by using of a kind of camera, small angle and with the least obtaining information of scene. The applied technique in this study is based on the tracking of optical flow by Horn & Schunck. In order to do this, we selected a part of highway and then obtained the speed for every pixel by using of calculation of derivation of image into the place and time. At last, the system of transit vehicle detected and tracked in the real time and specified the number of those vehicles.

Key words: camera, image processing, optical flow, vehicle, track.

1. INTRODUCTION

The growth of going bade and forth in the highways and civil roads have been explosively recently. Even the manual and traditional systems of traffic controlling aren't responsible to this situation at all. The above factors and a lot of other parameters have led to use of intelligent systems of transportation which is a kind of interdisciplinary technology in the analysis and inspecting of system of traffic [1, 2, 3, 4].

Today, by improving of systems of video's processing, the intelligent method has been increasing for detection and tracking of motion objects. Among this, because of improvement of systems of transportation and getting to parameters of traffic, those intelligent systems of transportation have been considering very much. Observational eco-systems are done by using of any camera that is one of the most applicable device in two recent decade [2]. In a system of traffic, obtaining of parameters such as estimation of movement, speed and sequential distance between vehicles have a key roles. One of the important work in the analysis and video's observation is estimating of movement. For detecting of object's movement, calculating of pathway and speed of object, it should be using of founding field of movement. One of the best method for perceiving of surrounding and those features of intelligent system is two-dimensional images. In the systems based on machine vision, obtaining information and processing of available parameters in the image are among the important factors for observation. Adverting of some high-speed processors allow to process sequencing of images. Since the speed, movement and position of objects is receptive by using of video move, so certainly the available information in sequencing of images are more than those in a single image. One of the most essential methods of extracting information refers to sequencing of images is assigning the speed and sort of movement of current objects in scene of image-tacking. In order to do this, There has been presented some several algorithms by different people. One of the available methods is that offered by Gupte et al. [5]. In this method, the whole part of vehicle have displayed as a single point. But this algorithm has a problem for considering of shadows, occlusions and large vehicles. Another method are contour tracking which has presented by Koller et al. [6]. In this presented model, at first one of the images is setting and selecting from background and then the operation of tracking are doing by detecting the border of objects. However, the main problem of this method refers to occlusion also the algorithm of contour are so sensitive to tracking frames.

Tan et al. proposed a kind of method of detecting and tracking vehicles by 3D model [7, 8]. In this method, the whole part of vehicles are modeling and are detecting in the image and tracking is based on these modeled vehicles. This method can solve the problem of occlusion but modeling of whole part of vehicles as a 3D is hard and fairly impossible [9].

One of the method that proposed by Kamijo et al. is random tracking Markov of algorithm for dividing and tracking of vehicle in a small angle [10]. So that this has been known as a reliable technique for tracking vehicles in crowded situation though it hasn't output and function of 3D.

Our proposal method is using of calculating of optical flow for estimation movement. The optical flow is usually estimated by using of algorithms of place and time differences. We have calculated that optical flow by using of method of "Horn & Schunck". Some advantages of that are high accuracy and speed involved tracking of vehicles.

The arrangement of this study is that will explain the optical flow and algorithms for obtaining it in section 2. In section 3, we are considering some proposal algorithm for detecting and tracking of vehicles and have presents experimental results in section 4. Finally in part 5, the general conclusion about tracking of vehicles are considered.

2. OPTICAL FLOW

The optical flow is called to any speed of movement of pixels in the sequential images and the way of moving objects in the special scene. If we can represent the movement of special object as a vector field so every vector estimates the movement of any pixel or group of pixels. Having some knowledge of 2D and sequential image which has obtained from the 3D image is so impetus [11, 12].

In fact, optical flow is a kind of method for obtaining the movement and speed of available pixels in the frame from which it comes from video. One of the main advantages of this optical flow regard to is other methods is its better results, estimation of movement of motion objects in the images which aren't necessarily rigid body. Algorithm of optical flow is based on this assumption that movement of available objects in the images will change the degree of light of image. Therefore, some kind of information of moving objects in the frame will present. In the systems of machine's vision one of the main factors in this information is related to motion's objects [11, 13].

2.1. Calculation of optical flow

The first step for calculating of optical flow is creating 2D images from 3D space obtaining by camera. Every video's quantized into three time and place and digital ways. Every frame consists of some row of pixels that each of them represents of points on image and every frame is really one moment of especial scene. Also, that movement is creating through temporal distance between the two frames by a object is really spatial difference of that object in the second frame than its position in the first frame which is detectable. The intensity of light of every especial point in the image is really intensity of that pixel opposite of that point. In the most cases, It has been using of this feature for calculating of optical flow. The algorithms in calculation of optical flow are usually based on the combination of assumptions in the time and place and visual fields. That optical flow is bases on visual assumptions has been usually calculating from the understanding of changes of surface's position that has gradient, pattern and context in the image. In this basis, every area in the image has especial own light although the place of that area changed gradually. The methods, based on the derivation and those on the correlation and others have been using of this assumption for calculating of optical flow.

From the temporal perspective, the movement must be gradual. It means that the movement of pixels of special area can't be very big in the distance of two frames.

Regard to place, the adjacent pixels are belong to the same surface and moving together. So that the border of objects can contradict this assumption and create some problems for algorithms of calculation of optical flow [11].

2.2. The method of calculation of optical flow

There has been presenting some several methods for calculating of optical flow. That each of them has advantages and disadvantages and limitations in the function of algorithm. Naturally, every kind of these methods has a better response and function in the especial situation and environment. In general, selection of appropriate method that has the ability of dismantling with high speed and accuracy hold of a lot of significance.

There are different methods for calculating of optical flow including correlation method, the methods based on energy and phase of fast converter of image, and several methods based on gradient. In the method of correlation, the whole area of current image is adaptable with the areas of previous image. The adaptation of special area in two images is occurred when the function of correlation is maximum. So, that optical flow is obtaining through two frames in regard to moving of region in the special time.

The way of method energy and phase of Fourier converting image is based on the output of some filters which are known filters of adaptation speed. The function of these filters is the way that are sensitive to special directions and frequencies. This method in the images with greater complexity has a better output rather than correlation method [11, 14].

One of the most effective method for obtaining a state of object are those methods based on gradient. This method is working based on changes in time and place. The speed of any object is obtaining from the derivation of situation into the time. Thus, the speed of elements any image can get from the time derivations. In the processing of real time, those methods based on the gradient are more effective because of better function and result as well as lower calculation than previous methods. This method presented by Horn & Schunck for the first time. They considered every pixel as a function of time and place ($E(x,y,t)$) and then for calculating of vector field of speed used of images derivation [15,16].

This method has used in due of high speed and appropriate efficient in our proposal algorithm, we explained it completely in the part of explanation of algorithm.

3. PROPOSED ALGORITHM

In this part, we are considering the explanation of different parts that is used in algorithm and their relationships, obviously we did it before presenting of details of real work of system.

Fig. 3 presents the consisting elements of vehicles tracking system of special algorithm.

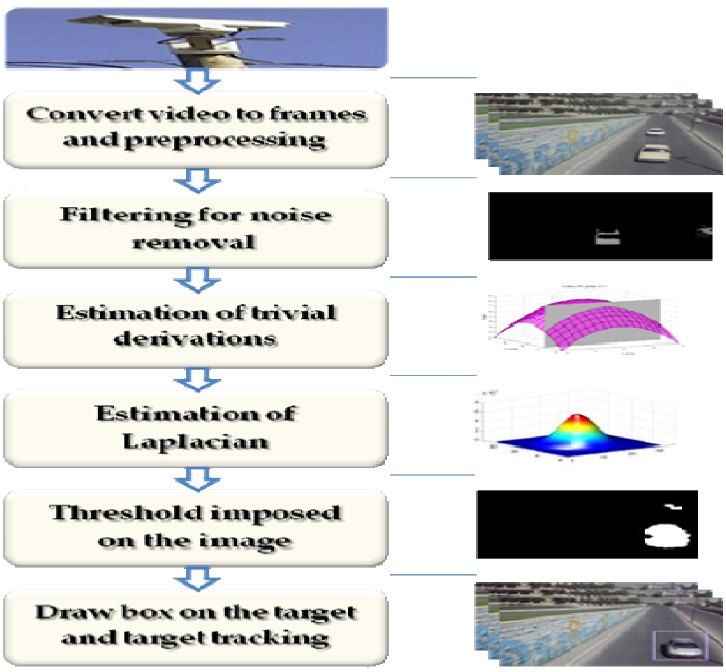

Fig. 3 – System overview.

3.1. Calibration and modeling of camera

Calibration of camera is the important part in the visual system of computer. In order to obtain those internal parameters of camera and the state of its position need to determine of primary geometric figures that taken from the scene of traffic. It can be found its 3D coordination by selecting of any pixel in the image as well as these parameters [1, 2]. However, it is very noticeable that processing of calibration has been accomplished by the simple procedure and without any special equipment.

In our method, there isn't any requirement to calibration of camera. In another word, this method is a kind of calibration that means the parameters of camera is determined from the sequencing of the video and because of this, those geometric figures are provided by the traffic scenes.

3.2. The detection and tracking of vehicles by optical flow

In this project, we accomplished vehicles tracking by using of a kind of camera that put in the higher point into the surface of ground and with low angle into the road. One of the problems in this project is the small angle of cameral that effect of combination of vehicles and absent of separation between them. That using method for tracking from the techniques optical flow is Horn & Schunck those steps are following:

3.2.1. Selection an area for tracking

We have used of just a part of highway for processing as shown in Fig. 4. The operation of tracking is starting by entrance of vehicles into the area.

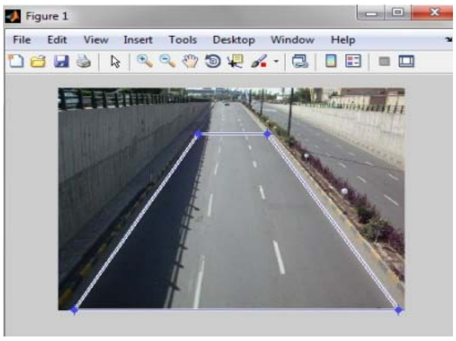

Fig. 2 – Part of highway for processing.

3.2.2. Calculation of optical flow

We need to estimate the state of any vehicles. In order to this, we will use of the techniques optical flow Horn & Schunck for important points and tracking of cars. Horn & Schunck were the people who characterized optical flow by Gradient and derivation of images. Our assumption in this method is that the speed of change in intensity of light is gradual in all parts of image.

In the first step, if intensity of light in image is at moment t and point (x,y) that shown $E(x,y,t)$, so mentioned point will move in the period of time of δt toward x,y by size of δx, δy respectively [11,15,16]. Now by assuming of being constant of intensity of light in mentioned point, we can have this equation

$$E(x,y,t) = E(x,y,t) + \delta x \frac{\mathrm{d}E}{\mathrm{d}x} + \delta y \frac{\mathrm{d}E}{\mathrm{d}y} + \delta t \frac{\partial E}{\partial t} + \varepsilon \,. \tag{1}$$

In the equation (1), ε is related to some higher derivations that can ignore by simplifying of equation and dividing to δt, we get to equation (2)

$$\frac{\partial E}{\partial x}\frac{\mathrm{d}E}{\mathrm{d}x} + \frac{\partial E}{\partial y}\frac{\mathrm{d}E}{\mathrm{d}y} + \frac{\partial E}{\partial t} = 0 \,. \tag{2}$$

If we put:

$$u = \frac{\mathrm{d}E}{\mathrm{d}x} \quad \text{and} \quad v = \frac{\mathrm{d}E}{\mathrm{d}y} . \tag{3}$$

So we get to equation (4) with two unknown u, v:

$$E_x u + E_y v + E_t = 0 . \tag{4}$$

In the above equation, E_x, E_y, E_t, are trivial derivation into the x, y, t. This equation is called constraint equation of optical flow.

By converting of above equation, we get the following equation. In which the vector (E_x, E_y) in this equation is gradient vector of our image

$$\left(E_x, E_y\right).\left(u, v\right) = 0 . \tag{5}$$

In addition, for calculating of optical flow with unclear and rigid object should be used of other techniques. Because of the same speeds of adjacent points related to different objects, the field of speed in light pattern of whole image are changing equally. So, we use of additional constraint that has considered being minimal of squares of size of gradient of speed optical flow as a uniform criterion by using of theory of Hearn and Shank.

Another uniformity relationship of optical flow, sum of several squares Laplacian is elements of *x,y* of optical that defined in the following equation [16].

$$\nabla^2 u = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \quad \text{and} \quad \nabla^2 v = \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} . \tag{6}$$

Since the optical flow is so sensitive to noise we'll smooth the image by using of filter Gaussian to not consider the small movement as a car movement. Now, we are defining some variables that considering as a matrix at $n \times m$. The first, the values of those matrices are zero; that those can place a appropriate number with intensity of changes of pixels in every row and column of adjacent squares during of changes in intensity of light.

3.2.3. Estimation of trivial derivations

We are considering two windows in current and next frame around that pixel for every special pixel. Then we'll consider some estimation for trivial derivation. For calculation of optical flow we need to calculate the trivial derivation, so the equations of (7), (8) and (9) are related to that trivial derivations

$$E_x \approx 1/4\left\{E_{i,j+1,k} - E_{i,j,k} + E_{i+1,j+1k} - E_{i+1,j,k} + E_{i+1,j+1k+1} + E_{i,j,k+1} + E_{i+1,j+1,k+1} E_{i+1,j,k+1}\right\} , \tag{7}$$

$$E_y \approx 1/4\left\{E_{i+1,j,k} - E_{i,j,k} + E_{i+1,j+1,k} - E_{i,j+1,k} + E_{i+1,j,k+1} - E_{i,j,k+1} + E_{i+1,j+1,k+1} - E_{i,j+1,k+1}\right\} , \tag{8}$$

$$E_t \approx 1/4\left\{E_{i,j,k+1} - E_{i,j,k} + E_{i+1,j,k+1} - E_{i+1,j,k} + E_{i,j+1,k+1} - E_{i,j+1,k} + E_{i+1,j+1,k+1} - E_{i+1,j+1,k}\right\} . \tag{9}$$

E_x, E_y, E_t, are related to estimation of trivial derivations in every pixel toward x, y, t, respectively. And k represents of previous frame and k+1 represents of current frame. Also, *i,j* are the place of that pixel through which that optical flow must be calculated.

In fact, in the equation (7), (8) and (9) we considered the average of difference adjacent pixels into two frames as a trivial derivations.

3.2.4. The estimation of Laplacian in optical flow

One of requirements of Horn & Schunck method is calculation of speed toward the *x,y* by using of estimation of Laplacian speed (*v,u*). Thus we calculated speed for every kind of pixel by using of equation (10) and (11) that is useful in the calculation of optical flow.

There is a simple approximation of Laplacian that are following:

$$\nabla^2 u \approx k\left(\overline{u_{1,j,k}} - u_{i,j,k}\right), \tag{10}$$

$$\nabla^2 v \approx k\left(\overline{v_{1,j,k}} - v_{i,j,k}\right). \tag{11}$$

Now, $\bar{u}$ and $\bar{v}$ are specifying as following:

$$\bar{u}_{1,j,k} = 1/6\left\{u_{i-1,j,k} + u_{i,j,+1,k} + u_{i+1,i,k} + u_{i,j-1,k}\right\} + 1/12\left\{u_{i-1,j-1,k} + u_{i-1,j+1,k} + u_{i+1,j+1,k} + u_{i+1,i-1,k} + u_{i+1,i-1,k}\right\} \tag{12}$$

$$\bar{v}_{1,j,k} = 1/6\left\{v_{i-1,j,k} + v_{i,j,+1,k} + v_{i+1,i,k} + v_{i,j-1,k}\right\} + 1/12\left\{v_{i-1,j-1,k} + v_{i-1,j+1,k} + v_{i+1,j+1,k} + v_{i+1,i-1,k} + v_{i+1,i-1,k}\right\}. \tag{13}$$

We can detect the motion vehicles in video by using of thresholding into the image. In the process of thresholding wherever the movement or flow are exist, we ascribe the equal value of 255 into the pixel, and if these isn't any movement or flow we can inscribe the value 0 into the mentioned pixel. The Fig. 3 is shown the detected vehicle.

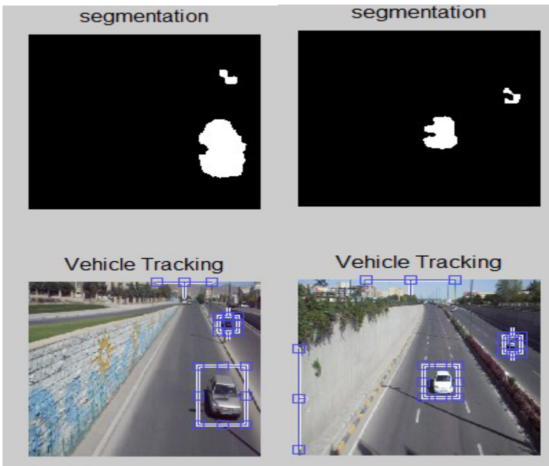

Fig. 3 – Image segmentation and vehicle detection.

3.2.5. Minimizing of error

In order to get a ideal reply with high coefficient of truthfulness in the calculation of optical flow, we should consider a special note; that is the minimizing of sum of errors in the constraint equation of optical flow. These error is defined as following [16]:

$$\varepsilon_b = E_x u + E_y v + E_t. \tag{14}$$

One of the ways of reducing of available error is finding out of appropriate values for u,v. The best method for finding out that values is Euler functions that led to these equations:

$$E_x^2 u + E_x E_y v = \alpha^2 \nabla^2 u - E_x E_t \tag{15}$$

$$E_x E_y u + E_y^2 v = \alpha^2 \nabla^2 u - E_y E_t. \tag{16}$$

u, v are the results of equations of real optical flow and satisfying above equations.

By substituting of approximated values of Laplace that explained at previous steps into the above equations, we get following results

$$\left(\alpha^2 + E_y^2 + E_x^2\right)\left(u - \bar{u}\right) = -E_x\left(E_y \bar{v} + E_x \bar{u} + E_t\right), \tag{17}$$

$$\left(\alpha^2 + E_y^2 + E_x^2\right)\left(v - \bar{v}\right) = -E_x\left(E_y \bar{v} + E_x \bar{u} + E_t\right). \tag{18}$$

In the above equations, instead of every vector of u,v that obtained, the total error will get to the least possible value. Although those value of u,v won't be completely exact, and those are depending on degree of error in calculation related to derivation of light.

Now we can calculate those variables of optical flow by using of two equations (17) and (18). In order to do this, Horn & Schunck used of duplication method of pattern Gauss-Seidel for solving equations. We are calculating some unknown (u,v) in through of duplication steps by this method.

At that previous steps, we defined some variables that u,v are among them. Now, in every step, some values that obtained in previous steps are using for u,v to calculate the new value of u,v. Some calculated values for u,v in the n+1 will be adapted to equations (19) and (20) by using of Gauss-Seidel method. In these equations, n represents of the number of duplication for solving the problem.

$$u^{n+1} = \bar{u}^{n} - E_x \left[E_x \bar{u}^{n} + E_y \bar{v}^{n} + E_t \right] / \left(\alpha^2 + E_y^2 + E_x^2 \right), \tag{19}$$

$$v^{n+1} = \bar{v}^{n} - E_x \left[E_x \bar{u}^{n} + E_y \bar{v}^{n} + E_t \right] / \left(\alpha^2 + E_y^2 + E_x^2 \right). \tag{20}$$

One of the advantages of the method Hearn and Shank is obtaining of optical flow in some areas of image that has constant light. In this way and according to equations (19) and (20), the optical flow of some areas of image that their gradient of light equal to them are zero will be the same as average speeds of those in adjacent. In these areas, there aren't any special local information that can obtain the exact speed of movement in light pattern. In this case, in the mentioned method, some kind of these resulting values in the around of mentioned areas are ascribing to inner parts of areas.

If total values of resulting values of optical flow have the same value for the border of any area, these will be generalize to in the area and also the optical flow of pixels inside them will put the same of those in the border pixels. The finding solution of tracking of vehicles in the large highway represents the high efficiency of this algorithm, so that in the selected area, some transient vehicles can be detect and track exactly.

4. RESULTS

We have tested the observation video's system, that presented in this project in several highways in our country Iran. The system is generally able to track those vehicles based on the least obtained information taken from film taking scene. Those scenes which were considering have different situation of light and environment, so that even the variety of transit vehicles including trucks and typical cars and motorcycles and the color of them as well as the situation of traffic in the selected places were different. At first, in order to do this, we recorded those scenes of traffic by installing a camera in the altitude so higher than surface of road. Also in this proposal method there isn't need to set calibration of camera. The state of the camera was in the small angle that led to operate that work more difficulty but this kind of state of camera lead to have more expansive vision of road and also observation into the traffic is done more efficiently.

Fig. 6 – Camera angles selected.

Figure 4 is shown the scenes of film taking movie in the highway and the angles vision of camera. In addition to above cases, since the number of vehicles in every moment and detected region in the vision of camera are very large, thus it should be used of multi tracking operation. Furthermore, the whole stops of tracking should be done in the real time. So designed algorithms has high speed of processing. Because of this, we used of technique of optical flow by Horn & Schunck to track them. This method is so sensitive to fast changes of pixels and can detect and track any kind of movement. We have assimilated the total steps of work in the software as MATLAB.

Figure 5 is shown several frame of output in algorithm; as shown some transit vehicles in the region that determined previously has been tracked. We could decrease some those interference of shadows of cars with another and occlusion of two cars by using of methods called *Open* and *Close*.

Fig. 5 – Show several frame of output in algorithm and tracked vehicles with draw a box.

In detecting of vehicles, one of the determinate parameters of prosecution is color. So that if the color of car is dark or specially black, the detection of it will be more difficult because of similarity of that to asphalt of road. Figure 6 is shown the frame that consists of some cars with black color that detected and tracked.

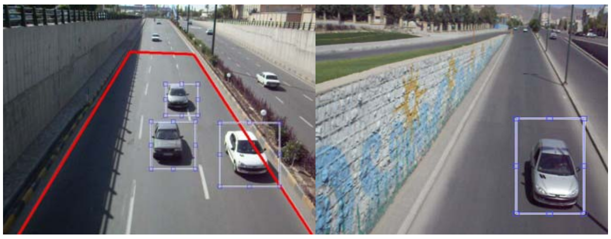

Fig. 6 – Some cars with black color that detected and tracked.

In Table 1 has shown the percent of detection of different vehicles and their tracking in the created videos. The output of algorithm was near to %96.

Table 1

Processing the three sequences, along with the results. The columns show the sequence, number of vehicles (NV), number of vehicles occluded (NVO), number of vehicles tracked (NVD), number of occluded vehicles detected and tracked (NOD) and number of false detections (FP) respectively

Seq.	Video (sec)	NV	NVO	NVD	NOD	FP
1	16	52	11	52 (100%)	8 (73%)	3
2	22	86	12	84 (97%)	8 (67%)	2
3	22	116	19	103 (89%)	14 (74%)	7

Although this algorithm is so sensitive into the smallest movement in the frame and every small movement around the scene has been considering as a object but can be solved this problem by Gaussian Filters. This high sensitivity led to increase of speed and accuracy of tracking in the system.

This presented algorithm has a less error of movement's detection and higher output than other techniques. Generally, the designed system preformed very well some kind of operations including detecting of objects of background, detecting of vehicles and estimating of numbers of transit and moving vehicles.

5. CONCLUSION

We presented a video system of supervising which can detect and track the moving objects. In generally, the purpose of this project is specially detecting and tracking of vehicles in the road of city or highway. This system is able to detect and following vehicles with the minimum resulting information getting from the scenes of film taking. The intelligent systems of vehicles in different countries have approved this assumption that application of these systems cause to increase of coefficient of truthfulness in the traffic of outside roads and highways and also detect of accidental areas. In this study, we have presented the kind of technique that whenever camera put in the lower height than road and its visual angle be expand can obtain the parameters of the traffic scenes.

We used of Horn & Schunck for calculating of optical flow with attachment of image. Since the vector of speed has two elements, the equation of changes of intensity of light in image aren't sufficient for calculating of speed. So, we have used of uniformity of flow as another constraint for calculating it. At last we applied a method of Gauss-Seidel for solving equations and obtaining the optical flow. The overall steps of algorithm have assimilated in the MATLAB and inscripted program well performed in the entrances of video's sequences as a real time. The overall processing accomplished in the real time and also the number of transient cars detected by this algorithm. In this study, the detection and tracking of the cars and their counting have accomplished successfully. In another effort, it can be detected the sort of the transient car in the real time.

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