IMPLEMENTATION OF INVERSE PERSPECTIVE MAPPING ALGORITHM IN IMAGE PROCESSING FOR THE CALCULATION OF THE SPEED OF TRAFIC VEHICLES

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Summary: *Calculating the speed of traffic vehicles plays an extremely important role in the collection of traffic flow data in any traffic operations and management system. In Vietnam, with the characteristic of traffic flow being mixed, it is difficult to use these conventional technologies and methods to calculate the speed of vehicles. This paper presents application of the image processing technology and the inverse perspective mapping algorithm to calculate speed of vehicles serving traffic flow data collection in traffic operations and management systems in big cities in Vietnam.*

I. Introduction

The calculation of speed of traffic vehicles is no longer a new problem with the use of simple technologies such as inductive loop, ultrasound, infrared, microwave, and so on. Yet, all these methods have common disadvantages. For example, they have an impact on the geometric structure of the road, limit of the measuring range and types of vehicles. The image processing is a new technology to measure the speed of vehicles on the road that has superior features. There features include: capability of measuring speed over a wide range with many different lanes, distinguishing the types of cars and also not affecting the geometric structure of the road.

Using image processing technology to collect traffic flow data is the solution that was studied early in Vietnam. In the first time, the lecturers at Faculty of Electrical and Electronic Engineering, University of Transport and Communications began researches to build a system to collect traffic data by application of image processing technology [1]. After that this system was brought into pilot implementation to collect the traffic data at in Hanoi City [2]. In this system, the authors have used image processing to measure the speed of vehicles on the basis of geometric calculation and mounting position of camera on the road. However, there are several geometric parameters and mounting positions of the cameras which are complex and difficult to calculate the speed of vehicles in traffic [3]. Therefore, the author proposes a new method determining the speed of the vehicles through the projection of images onto a perpendicular plane (inverse perspective mapping algorithm) to process images easier and more convenient.

II. Calculating the speed of vehicles in traffic

A. Steps of calculation

Traffic flows in the big cities in Vietnam often have mixed and high density. As can be seen in images acquired from camera in practice, there were many components in each image frame. However, calculating to determine the speed of all objects in these frames is not necessary. Therefore, according to requirements, we only need to process certain lanes and image areas to calculate the velocity of vehicles.

The calculation has three following basic steps:

Step 1: Applying inverse perspective mapping algorithm

Step 2: Detecting vehicles, calculating the areas of vehicles, and then, determining their center co-ordinates.

Step 3: Tracking vehicles, measuring the speed of each vehicle based on its center co-ordinate and time which it moves through frames.

B. Applying Inverse perspective mapping

The images taken with cameras are 2D projections of the 3D world, and the recovery of 3D information such as depth, length or area requires a model of the projection transformation. The correct model for human vision and cameras is the central projective model (or perspective). Images formed under this model disable the calculation of distance measurements because perspective is a non-linear transformation. All these points belong to parallel yellow lines in the road plane, but these rows are not parallel in the image plane due to the non-linear aspects of perspective. Removing these perspective effects and recover parallel lines requires the application of inverse perspective mapping.

Principle of inverse perspective mapping

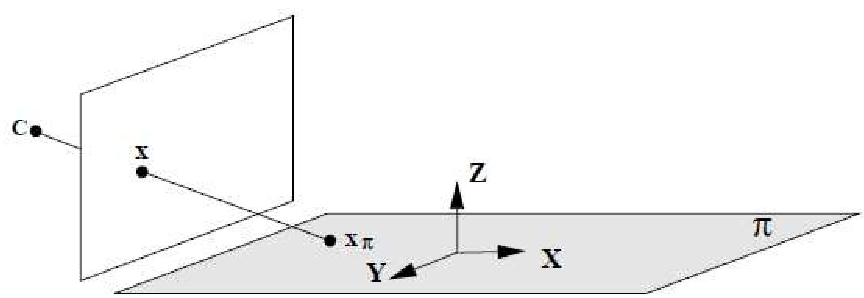

Figure 1. *Projection of the pixels in the viewport.*

Plane transformations mapped pixel: Choosing the world coordinate system so that the plane of the points has zero *z* coordinate (Figure 1 [8]). Then the 3x4 matrix *P* is reduced to:

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} = \begin{bmatrix} p_{11}\ p_{12}\ p_{13}\ p_{14} \\ p_{21}\ p_{22}\ p_{23}\ p_{24} \\ p_{31}\ p_{32}\ p_{33}\ p_{34} \end{bmatrix} . \begin{pmatrix} X \\ Y \\ 0 \\ 1 \end{pmatrix} = \begin{bmatrix} p_{11}\ p_{12}\ p_{14} \\ p_{21}\ p_{22}\ p_{24} \\ p_{31}\ p_{32}\ p_{34} \end{bmatrix} . \begin{pmatrix} X \\ Y \\ 1 \end{pmatrix} \quad (1)$$

Where the 3x3 matrix represents a general plane to plane projective transformation.

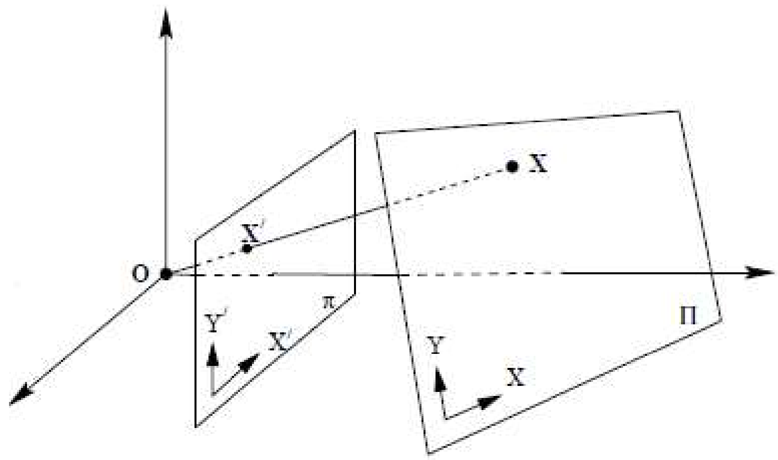

Figure 2. *Vectors map of the observed image.*

In other words, *x'=H.x* (Equation (2)), where *H* is a 3x3 non-singular homogeneous matrix, x' are the coordinates of the target point on the plane, x are the coordinates of the point source image (Figure 2).

$$\begin{pmatrix} x_1' \\ x_2' \\ x_3' \end{pmatrix} = \begin{bmatrix} h_{11}\ h_{12}\ h_{13} \\ h_{21}\ h_{22}\ h_{23} \\ h_{31}\ h_{32}\ h_{33} \end{bmatrix} . \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix} \quad (2)$$

Application of inverse perspective mapping

The theoretical basis of the inverse perspective mapping algorithm is complicated, however, this algorithm is available in the open source library OpenCV [7]. So, the user can easily use this tool to solve the related problems. After performing transformations we obtain the observed image shown in Figure 3.

(a) Before mapping (b) After mapping

Figure 3. *Results extract the observations.*

C. Method of calculating the surface area is occupied vehicle.

Road space is occupied vehicle in this report are calculated using the Background Subtraction method. According to this method, the image of monitoring area F is processed to find the FG, the areas occupied vehicle.

FG is calculated by:

$$FG = F - BG \quad (3)$$

where BG is the background in which the road is without vehicles (Figure 4 [6]).

Area road vehicle occupancy is calculated by:

$$A = K_P . FG \quad (4)$$

where K_P is the conversion factor between the image area and the actual area on the road. K_P is determined by the parameters: camera height, camera angle and the road surface to be monitored.

The percentage area occupied road vehicles are calculated based on the area ratio FG/BG.

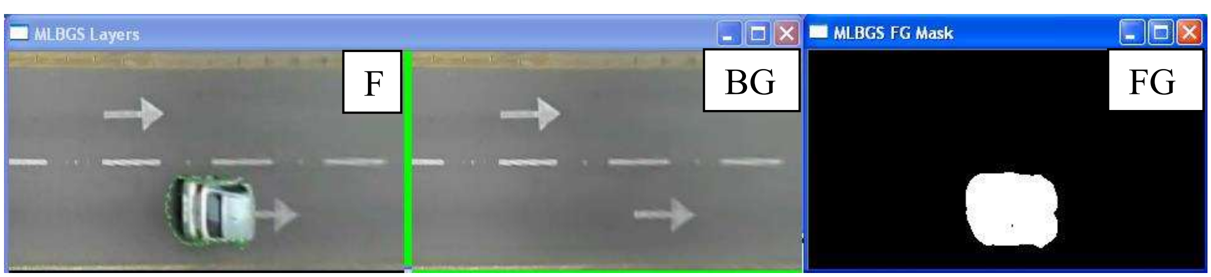

Figure 4. *The process of the boundary area of the vehicle appropriated.*

D. The method of calculating the speed of each vehicle

In this method, the speed of the vehicle is calculated based on the Tracking algorithm for tracking the motion of vehicles from the previous location to the next location. When the vehicle runs into the appropriate location in the observer frame, the two focal points of two consecutive positions is used to calculate the distance between the pixels. Measuring distance can be calculated based on Pythagoras theorem by:

$$Distance_{pixel} = \sqrt{(x_{current} - x_{previous})^2 + (y_{current} - y_{previous})^2} \quad (5)$$

where: $Distance_{pixel}$ is the distance between the center of the vehicle in two frames [pixel]; $x_{current}, y_{current}$ are the coordinates in the x, y in the current frame [pixel]; $x_{previous}, y_{previous}$ are the coordinates in the x, y in the previous frame [pixel].

Length is defined as the distance in meters in the image measured by pixels. Thus the pixel size is calculated to convert into meters. The conversion is calculated as the ratio between the actual distance and pixels in the frame rated up observations. With the actual distance, speed calculated by m/s has to be transformed into km/h:

$$Speed_{km/h} = \frac{Distance_{pixel}.k.3.6}{\Delta_t} \quad (6)$$

where: $Speed_{km/h}$ is speed of vehicle [km/h]; k is the conversion coefficient from pixels to meters; Δ_t is time to move the vehicle from the previous position to the current position [s].

The moving time Δ_t can be usually calculated through the coefficient of camera f_{ps} ($\Delta_t = 1/f_{ps}$). But, when the video is filmed directly, this coefficient is calculated by determining the difference between the time $t_{current}$ at the current location and the time $t_{previous}$ at the previous position of the vehicle, as can be seen in the equation (7). And if video is recorded and repeated, we can approximately calculate this coefficient depending on processing speed of the computer when it is running image processing software and the quality of video.

$$\Delta_t = t_{current} - t_{previous} \quad (7)$$

The vehicle speed measurement result based on the above method is shown in Figure 5. The measured velocity of the vehicle is 64 km/h, coincides with its practical speed on the road.

Figure 5. *Result of Algorithm tracking speed of the vehicle in each frame.*

III. Conclusion

As described above, by image processing technology and inverse perspective mapping, we can quickly compute the area of the road where vehicles occupy and speed of each vehicle on the road. The algorithm has been tested on the video of the different traffic flow, experimental results in daylight conditions are very positive.

The research result in this paper need to continue to be completed to increase the accuracy of processing algorithms in adverse weather conditions and at night time and to apply in practice as soon as possible to solve the problem of collecting traffic flow data in large cities in Vietnam.

IV. References

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