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Adaptation Computing Parameters of Pan-Tilt-Zoom Cameras for Traffic Monitoring

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Abstract: The Closed- CIRCUIT television (CCTV) cameras have been widely used in recent years for traffic monitoring and surveillance applications. We can use CCTV cameras to extract automatically real-time traffic parameters according to the image processing and tracking technologies. Especially, the pan-tilt-zoom (PTZ) cameras can provide flexible view selection as well as a wider observation range, and this makes the traffic parameters can be accurately calculated. Therefore, that the parameters of PTZ cameras are calibrated plays an important role in vision-based traffic applications. However, in the specific traffic environment, which is that the license plate number of the illegal parking is located, the parameters of PTZ cameras have to be updated according to the position and distance of illegal parking. In proposed traffic monitoring systems, we use the ordinary webcam and PTZ camera. We get vanishing-point of traffic lane lines in the pixel-based coordinate system by fixed webcam. The parameters of PTZ camera can be initialized by distance of the traffic monitoring and specific objectives and vanishing-point. And then we can use the coordinate position of the illegally parked car to update the parameters of PTZ camera and then get the real word coordinate position of the illegally parked car and use it to compute the distance. The result shows the error of the tested distance and real distance is only 0.2064 meter. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: PTZ Camera, Traffic monitoring, Camera Calibration, Camera parameter.

1. Introduction

The basic function of vision based traffic monitoring system (*VTMS*) is to obtain adaptively the traffic information that includes the position of the vehicle, vehicle speeds and the traffic violation. And then the traffic information can be achieved using image processing and analysis. Especially, the position and speed of the vehicle can be calculated and simulated, through image tracking techniques [1, 2]. The accuracy of the simulated the position and speed of the vehicle depends on the system of camera and the tracking algorithm. Recently, the *CCTV* cameras have been used for traffic monitoring. Due to the *CCTV* cameras have the feature which is that the view and range can be flexibly obtained by setting and updating the pan tilt zoom. So accurate calibration of *PTZ* cameras is very important.

Fortunately, many calibration methods have been researched. In [3] and [4], the parameters of *PTZ* cameras can be calculated by sets of parallel lines of a hexagon. In [5-7], the parameters of *PTZ* cameras can be computed using know features in a scene. In view of the features of traffic scene, the parameters of *PTZ* cameras can be estimated by parallel lane lines.

In [8] and [9], the multiple parallel lane lines and a special perpendicular line are used to compute the parameters of *PTZ* camera. In the methods of [5-9] the lane lines are detected by manual operation.

In order to solve above the problems, the method of [10] have estimated the *PTZ* cameras using a novel focal length equation. The derivation requires only a single set of parallel lane markings, the lane width, and the camera height. In [10], the parallel lane markings are automatically detected by image processing. Using lane-marking edges and the derived focal length equation, one can estimate the focal length and the tilt and pan angles of *PTZ* cameras.

The method of [10] is the newest and efficient. Once the parameters of *PTZ* cameras have calculated, they cannot be changed. They certainly cannot be updated according to specific objects. So it can be applied to simulate the position and speeds of the vehicle. However, in the specific traffic environment, which is that the license plate number of the illegal parking is located, the parameters of *PTZ* cameras have to be updated according to the position and distance of illegal parking.

In this paper, the *VTM*S have two cameras, which are ordinary webcam and *PTZ* camera. We can use this system to catch the car that is parked illegally and get the number of this car. In detail, we can get an image by fixed webcam. And then the coordinate position of illegally parked car and vanishing-point of traffic lane lines can be obtained in the pixel-based coordinate system. Due to the experiment environment is appointed and the features, which are the buildings or traffic lights, are not changed, we can initialize the parameters of *PTZ* camera by distance of the *VTMS* and specific objectives and vanishing-point. And then we can use the coordinate position of the illegally parked car to update the parameter of *PTZ* camera and then get the real word coordinate position of the illegally parked car and use it to compute the distance of the illegally parked car and the *VTMS*. Moreover, we can use the distance to control the *PTZ* camera to get the number of the car.

The rest of the report is organized as follows: Section 2 shows the existing initializing method of parameter of *PTZ* and Fixed cameras. Section 3 explains the proposed updating of parameter of *PTZ* camera. Section 4 represents the results of experimental.

2. Existing Initializing Method of Parameter of PTZ and Fixed Cameras

In [10], the camera calibration is to calculate all the required parameters for estimating the world coordinates from the pixel coordinates (u, v) of a given point in an image frame which is captured by *PTZ* camera. So the relationship of the world coordinates and pixel coordinates is very important. As the camera view changes, the change in camera height, inherent bias and internal deviation is negligible. These parameters can be considered as fixed in vision-based traffic applications and are calibrated only once during the *PTZ* camera installation. The change in the focal length, the pan and tilt angles is very obvious. So these parameters have to be determined.

In [10], the coordinate systems used in the PTZ cameras calibration are presented. Fig. 1 shows three coordinate systems to derive the mathematical relationship between real world coordinate system and pixel coordinate system, namely: 1) the world coordinate system (X,Y,Z) ; 2) the camera coordinate system (X_c,Y_c,Z_c) ; and 3) the camera-shift coordinate system (U,V,W) . Fig. 1(a) depicts the top view of a ground plane in the world coordinate system. Lines L_1 , L_2 , and L_3 represent parallel lane markings, and point O is the origin of the world coordinate system on the road plane. The pan angle θ is defined by the angle between the Y axis and lane markings, f is the focal length, and ω is the width between parallel lanes. The symbol d denotes a shift distance, which is a perpendicular distance between the projection of the principle point of the camera and L_3 . Fig. 1(b) depicts the side view of the road scene, which is used to describe the geometrical relation between the ground plane and the camera; the direction of vector $\overrightarrow{CO}$ is perpendicular to the image plane. In Fig. 1(b), ϕ is the tilt angle of the camera, h is the installed camera height, and F is the length of vector $\overrightarrow{CO}$. Moreover, in [10], the counterclockwise rotation is positive in expressing the sign of the angles.

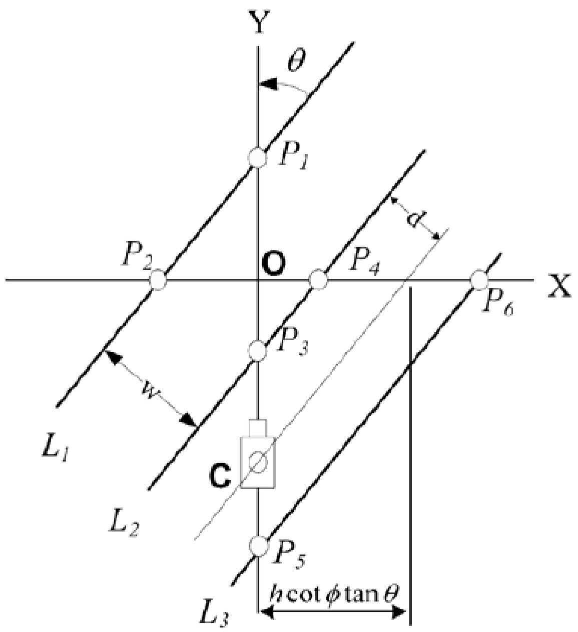

Fig. 1 (a). Coordinate systems used in the PTZ camera calibration: top view of the road map on the world coordinate system.

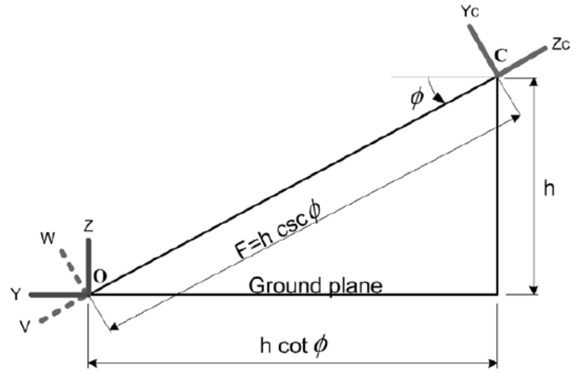

Fig. 1 (b). Coordinate systems used in the PTZ camera calibration: side view of the camera setup and its coordinate systems used in calibration.

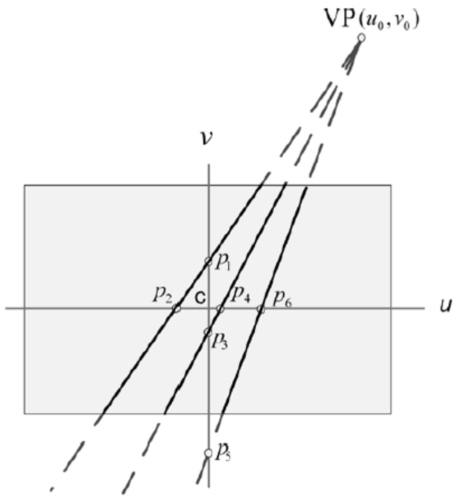

Fig. 1 (c). Coordinate systems used in the PTZ camera calibration: road schematics used in the pixel-based coordinate system.

In [10], the derivation process is shown. The camera-shift coordinate system can be obtained by rotating the world coordinate system an angle ϕ around the X axis. The relationship between the camera-shift coordinate frame and the world coordinate frame is given by

$$\begin{bmatrix} U \\ V \\ W \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}. \quad (1)$$

By shifting the camera-shift coordinate frame from point O to point C along the vector $\overrightarrow{CO}$ and inversing the V axis of the camera-shift coordinate frame, one can obtain the camera coordinate system. The camera coordinates of any point on the road plane (where Z equals to zero) can be expressed as a function of the world coordinate via a coordinate transformation between the camera-shift coordinate frame and the world coordinate frame,

$$\begin{bmatrix} X_c \\ Y_c \\ Z_c \end{bmatrix} = \begin{bmatrix} U \\ W \\ -V-F \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & \sin\phi \\ 0 & -\cos\phi \end{bmatrix} \begin{bmatrix} X \\ Y \end{bmatrix} - \begin{bmatrix} 0 \\ 0 \\ F \end{bmatrix}. \quad (2)$$

As given by the pinhole camera model, any point in camera coordinates has a perspective projection on the image plane. The relationship between pixel and camera coordinates can be written as

$$u = -f\frac{X_c}{Z_c} = -f\frac{X}{-Y\cos\phi - F}. \quad (3)$$

$$v = -f\frac{Y_c}{Z_c} = -f\frac{Y\sin\phi}{-Y\cos\phi - F}. \quad (4)$$

The pixel coordinate system is shown in Fig. 1(c), in which the rectangular region represents the sensing area of the image sensor. Solid lines represent the lane markings that can be observed by the camera. Dashed lines denote the lane markings that are out of the field of view of the camera and cannot be observed. The parallel lines in Fig. 1(a) are projected onto a set of lines in Fig. 1(c) that intersect at a point known as vanishing point *VP*. The vanishing point lies at a position where the Y coordinate of (X, Y, Z) approaches infinity. The coordinate (u_0, v_0) of *VP* is given by

$$\begin{aligned} u_0 &= \lim_{Y\to\infty} u \\ &= \lim_{Y\to\infty}\left(-f\frac{X}{-Y\cos\phi - F}\right) \\ &= \lim_{Y\to\infty}\left(-f\frac{Y\tan\theta}{-Y\cos\phi - F}\right) \\ &= f\tan\theta\sec\phi \end{aligned}. \quad (5)$$

$$\begin{aligned} v_0 &= \lim_{y\to\infty} v \\ &= \lim_{Y\to\infty}\left(-f\frac{Y\sin\phi}{-Y\cos\phi - F}\right) \\ &= f\tan\phi \end{aligned}. \quad (6)$$

As shown in Fig. 1(a), L_1, L_2, and L_3 intersect the X axis and Y axis at six points; these points are denoted by $p_1 - p_6$. From the perspective model, the corresponding coordinates of these points in the image plane can be obtained. Through geometrical analysis, it will be straightforward to derive the focal length equation as

$$am^2 + bm + c = 0. \quad (7)$$

where m is f^2. Table I summarizes the variables used in (7). The solution f^2 of (7) must be positive. Accordingly, the focal length f is

$$f = \sqrt{m}. \quad (8)$$

$$\phi = \tan^{-1}\frac{v_0}{f}. \quad (9)$$

$$\theta = \tan^{-1}\frac{v_0}{f\sec\phi}. \quad (10)$$

Table 1. List of variables for focal length equation.

Variables	Meaning and Description
m	f^2
a	$B-\beta_2^2$
b	$B(u_0^2+v_0^2)-\beta_1^2-v_0^2\beta_2^2$
c	$-v_0^2\beta_2^2$
B	$\beta_1^2\left(\frac{qw}{hu_4}\right)$
β_1	$\frac{av_1v_3-v_1v_3}{av_1-av_3}$
β_2	$\frac{av_3-v_1}{av_1-av_3}$
q	$q=\frac{1}{1-\alpha}$
α	$\frac{u_2}{u_4}$
u_2	u coordinate of point p_2
u_4	u coordinate of point p_4
v_1	v coordinate of point p_1
v_3	v coordinate of point p_3

3. Proposed Adaptive Updating Method of Parameters of PTZ Cameras

Fig. 2 shows the experiment environment, which is fixed, that can be attained by Webcam of *VTMS*. And then we can see the some features that are traffic lamps, lanes and street lamps. The features cannot be changed for several years. According to this character, we propose updating method of parameter of *PTZ* Cameras. In Fig. 2, *Ox* and *Oy* are original of pixel-based coordinate system.

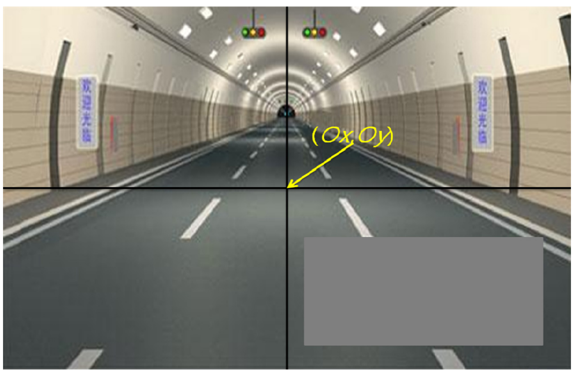

Fig. 2. Experiment environment.

3.1. The Linear Regression Equation of Lane and Vanishing-Point

In order to compute the vanishing-point, we have to choose the lanes from the Fig. 3. The selected lanes are line1 and line2 and the VP (u0, v0) is vanishing-point.

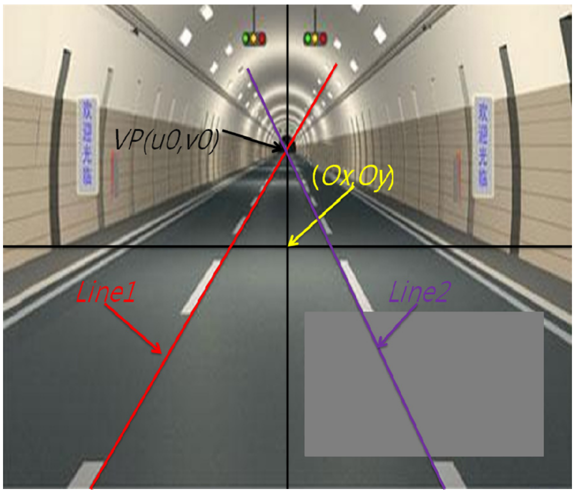

Fig. 3. Lanes and vanishing-point.

Each lane will then be represented by a linear polynomial equation

$$y = \lambda x + \rho \quad (11)$$

where λ and ρ are the real numbers. We can use a least square approximation to obtain λ and ρ by the twenty points of each lane. The vanishing-point can be computed by two linear polynomial equations of lanes. We can see the process from the Fig. 4.

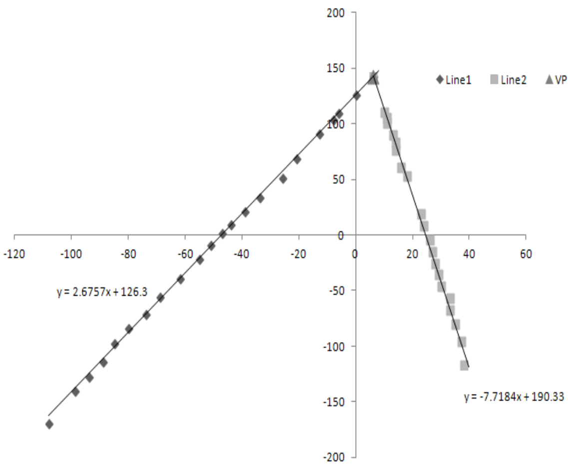

Fig. 4. The parameters of linear polynomial equations of lane and vanishing point.

3.2. Proposed the Initializing Method of Parameters of PTZ Cameras

According to the character of testing environment, we can know the actual distance of the *VTMS* and original point of pixel-based coordinate system, the height of *PTZ* camera and vanishing point. So the parameters of *PTZ* cameras can be computed.

$$\phi = arc\csc(\frac{F}{h}), \tag{12}$$

where F and h are the actual distance of the *VTMS* and original point of pixel-based coordinate system and the height of *PTZ* camera. We can calculate the radian of tilt by Fig. 1(b).

$$f = \frac{v0}{\tan(\phi)}, \tag{13}$$

where *v0* is the vanishing point. The focal length can be computed by (13). And then we can calculate the radian of pan by (10). Therefore, the parameters of *PTZ* can be initialized by (10), (12) and (13).

3.3. Proposed the Update Method of Parameters of PTZ Cameras

When we find the illegally parked car by Webcams, we can compute the coordinate of car in the real word coordinate systems by initialized parameters of *PTZ* cameras by

$$Y = \frac{h}{f}\frac{v}{\sin^2\phi}\frac{v_0}{v_0 - v}. \tag{14}$$

$$X = \frac{h}{f}\frac{u}{\sin\phi}\frac{v_0}{v_0 - v}. \tag{15}$$

where X and Y are the coordinate of car in the real word coordinate systems. And then u and v are coordinate of car in the pixel-based coordinate system [10].

By Fig. 1(b), we know the ground distance of *VTMS* and original of pixel-based coordinate system is $GP = h\cot\phi$. We can calculate the ground distance of VTMS and car by

$$b = GP + Y. \tag{16}$$

$$a = |X|. \tag{17}$$

$$\theta' = \frac{b}{a}. \tag{18}$$

$$c = \frac{a}{\cos(\theta')}. \tag{19}$$

where c is the ground distance of *VTMS* and car in the real word coordinate systems. And then the means of a and b are shows in Fig. 5. The θ' is the updated the pan parameter.

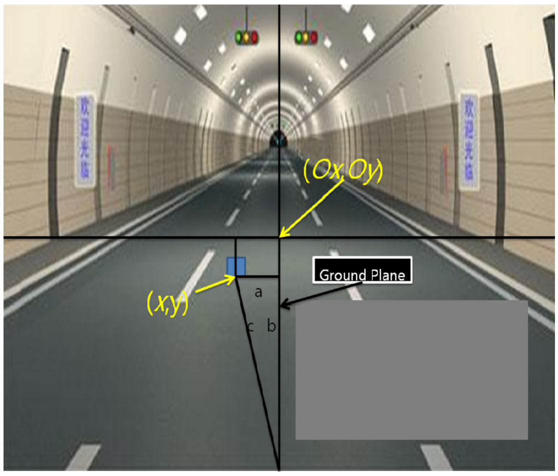

Fig. 5. The process for update the pan parameter.

According to the function of Fig. 1(b), we can calculate the update the tilt parameter and distance of *VTMS* and car by

$$\phi' = \arctan(\frac{h}{c}). \tag{20}$$

$$\text{Distance}_{car} = \frac{c}{\cos(\phi')}. \tag{21}$$

4. Experiments

In this experiment the height of the PTZ camera is 6m, the testing point is shows in the Fig. 5. We can initialize the parameters of PTZ by (10), (12) and (13). And then the actual distance of VTMS and testing point by from (16) to (20). The result is showed in Table 2.

Table 2. Result.

Number	Real Distance (m)	Test Distance (m)	Error (m)
1	16.1310	16.0103	0.1207
2	16.2862	16.1645	0.1217
3	30.4625	30.0856	0.3769

The Fig. 6 shows the position of test point. From the Table 2, we can see the tested distance is closed to real distance. And the average error is only 0.2064 meter.

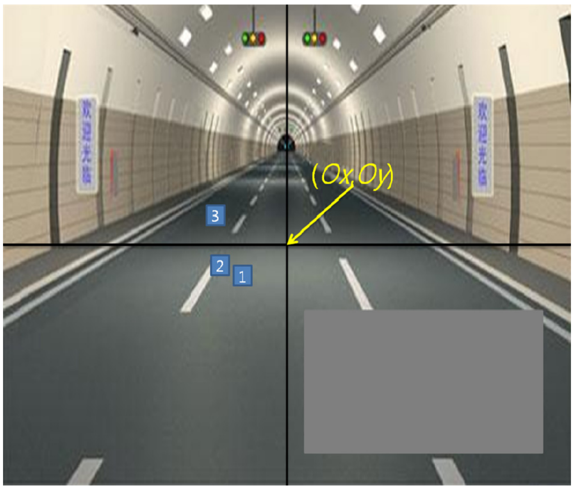

Fig. 6. The position of test point.

5. Conclusion

A novel adaptation computing parameters of Pan-Tilt-Zoom cameras for traffic monitoring, which is that the license plate number of the illegal parking is located, has been proposed. Firstly, we initialize the parameters of *PTZ* camera by distance of the *VTMS* and specific objectives and vanishing-point. Secondly, we use the coordinate position of the illegally parked car to adaptively update the parameter of *PTZ* camera and then get the real word coordinate position of the illegally parked car and use it to compute the distance of the illegally parked car and the *VTMS*. Moreover, we can use the distance to control the *PTZ* camera. The result shows the error of the tested distance and real distance is only 0.2064 meter. So the proposed method is relatively accurate.

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