An Improved Pedestrian Detection Method for DSS (Driver Supporting System) using an Attitude Measurement Unit

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Synopsis

This paper proposes an improved method for pedestrian detection using an Attitude Measurement Unit (AMU) in conjunction with multi-slit data. During the next decade, on-board pedestrian detection systems will play a key role in the challenge of increasing traffic safety. The main goal of these systems, to detect pedestrians in urban scenarios, involves overcoming difficulties like processing outdoor scenes from a mobile platform and searching for aspect-changing objects in cluttered environments. Using our new method, it becomes possible to decrease the margin of error of parameters by revising the image width. It is demonstrated that using an AMU as a means of on-road pedestrian detection for automobiles eliminates the need for finding specific configurations on the scene plane. Previously finding these configurations has been too time-consuming for practical use. Our results indicate that the integration of the proposed techniques will give rise to a more economical, accurate, and versatile system.

KEYWORDS: person detection, attitude measurement unit, multi-slit method, vanishing line

1. Introduction

Pedestrian detection is for the safety of both drivers and pedestrians themselves. There are various kinds of hardware and software used for pedestrian detection. As for its applications, a pedestrian detection system can be very useful for monitoring traffic flow, in on-board driver assistance systems, for intelligent pedestrian crossing systems, etc. Using computer vision, pedestrians can be detected and segmented from complex backgrounds. This allows the system to ascertain both the size and position of pedestrians in the camera's field of view. Methods of pedestrian detection can be mainly categorized into two types: motion analysis and shape analysis. In motion analysis [1-4], a continuous segmentation of pedestrian movement is analyzed. Although these motion-based methods are effective for reducing the rate of false detection of pedestrians, there are still some limitations. They cannot detect motionless pedestrians or any unusual motion of a pedestrian, such as jumping or crawling. Also, a pedestrian's legs must clearly appear in the image for patterns of pedestrian motion to be recognized, but this does not always occur. Furthermore, a sequence of images is required for segmentation and recognition, which cannot be done within a single image. In shape analysis, specific pedestrian characteristics are analyzed for segmentation and recognition [5,6]. Obviously, the advantage of almost all of these shape-based methods is that multiple images are not required.

Further improving upon this advantage, we have developed two module systems based on both 2D and 3D sensor cues. The first module uses pitch and roll angles for calculating the vanishing line on the image to select a coherent set of Regions Of Interest (ROIs) to be further analyzed. The second module develops a modified multi-slit method to classify the incoming ROIs into pedestrian and non-pedestrian in order to refine the final results. [7,8] Our method utilizes horizontal slicing of the image, called the "multi-slit" method and associates the

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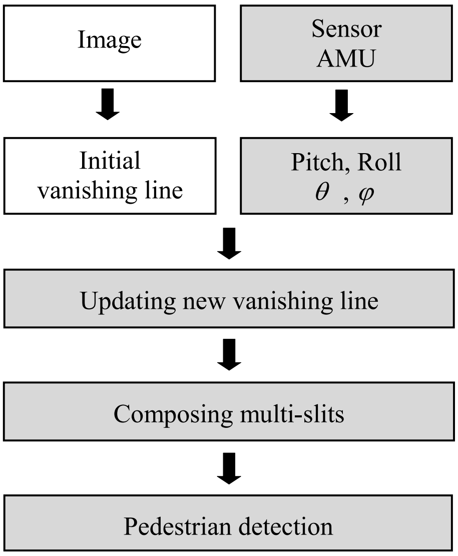


Fig.1 Overview of proposed system.

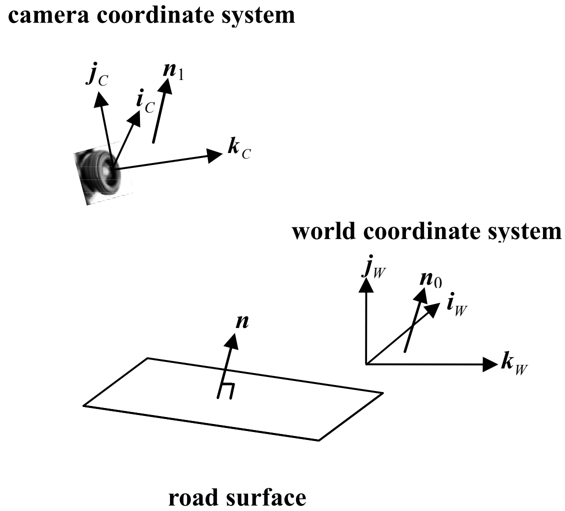


Fig.2 Normal vectors of the road surface in two coordinate systems.

multi-slit data with histograms of oriented gradients. In the multi-slit method, the use of vanishing lines is a key feature. The multi-slit approach is a new line of research which utilizes projective geometry and homogeneous coordinates. Depending on the setting, the geometric relationship between the object space and the image space is described via either similarity, affine or projective transformations. It is known that these transformations can be recovered by analyzing the vanishing points and vanishing lines. The most common approach to finding the vanishing line for a scene plane is first to determine two vanishing points from two sets of linear features parallel to the plane, and then construct the vanishing line through the two vanishing points. However, these linear features may not be readily available for every scene and their generation may be prone to errors if the linear features are short in distance. Other methods include estimation from equally spaced coplanar parallel lines and using orthogonal relationships among vanishing points and lines [9)]. However, these methods still require parallel lines on the scene plane or specific configurations which are hard to retrieve for practical use.

In contrast to these approaches, in this paper we mainly focus on robust real-time vanishing line estimation for driver assistance applications by using an AMU which measures the altitude or inclinations in both object space and image space (Fig.1). Attitude, pitch and inclination measurement are required in a wide variety of markets such as aerospace, industry and instrumentation. The tilt sensor technique has many advantages; for example, it is low cost, small size, lightweight, and is easy to be intelligent and integrated [10)].

The rest of this paper is organized as follows. In Section 2, we establish a technique for constructing the vanishing lines using AMU units. The experimental results are shown in Section 3 and Section 4 contains concluding remarks.

2. Pedestrian detection using multi-slit method

In this paper, we assume a pin-hole camera model. In addition, the normal vector $\boldsymbol{n}$ on the road surface is expressed as $\boldsymbol{n}_0$ in the world coordinate system $(\boldsymbol{i}_W, \boldsymbol{j}_W, \boldsymbol{k}_W)$ and $\boldsymbol{n}_1$ in the camera coordinate system $(\boldsymbol{i}_C, \boldsymbol{j}_C, \boldsymbol{k}_C)$ as shown in Fig.2. The vanishing line in an image is obtained from the normal vector $\boldsymbol{n}_1$. The vanishing line is obtained by the following procedure.

[Step1] Suppose $\boldsymbol{j}_C$ shows $\boldsymbol{j}_W$ rotated through θ_0 about the x-axis (Pitch) and φ_0 about the z-axis (Roll).

$$\left.\begin{aligned}&\boldsymbol{j}_C = (a_0, b_0, c_0) = a_0\boldsymbol{i}_W + b_0\boldsymbol{j}_W + c_0\boldsymbol{k}_W, \left|\boldsymbol{j}_C\right| = 1,\\ &\text{where } \boldsymbol{i}_W = (1,0,0),\ \boldsymbol{j}_W = (0,1,0),\ \boldsymbol{k}_W = (0,0,1).\end{aligned}\right\} \tag{1}$$

And a_0, b_0, c_0 are obtained from the next expressions as shown in Fig.3:

$$a_0 = b_0 \tan\varphi_0,\ b_0 = 1/\sqrt{\tan^2\varphi_0 + 1 + \tan^2\theta_0},\ c_0 = -b_0 \tan\theta_0. \tag{2}$$

In addition, the rotating matrices are

$$\boldsymbol{R}_1(\theta) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{pmatrix},\ \boldsymbol{R}_2(\varphi) = \begin{pmatrix} \cos\varphi & -\sin\varphi & 0 \\ \sin\varphi & \cos\varphi & 0 \\ 0 & 0 & 1 \end{pmatrix} \tag{3}$$

We obtain θ and φ by resolving the following expressions:

$$\boldsymbol{j}_C = \boldsymbol{j}_W \cdot \boldsymbol{R}(\theta_0, \varphi_0) = \boldsymbol{j}_W \cdot \boldsymbol{R}_1(\theta) \cdot \boldsymbol{R}_2(\varphi) = (a_0, b_0, c_0), \tag{4}$$

$$\theta = -\sin^{-1}(c_0),\ \varphi = \sin^{-1}\left(a_0 / \cos\theta\right). \tag{5}$$

Therefore, the camera coordinate system is obtained by the following expressions:

$$(\boldsymbol{i}_C, \boldsymbol{j}_C, \boldsymbol{k}_C) = (\boldsymbol{i}_W, \boldsymbol{j}_W, \boldsymbol{k}_W) \cdot \boldsymbol{R}(\theta_0, \varphi_0) = (\boldsymbol{i}_W, \boldsymbol{j}_W, \boldsymbol{k}_W) \cdot \boldsymbol{R}_1(\theta) \cdot \boldsymbol{R}_2(\varphi) \tag{6}$$

$$\left.\begin{aligned}&\boldsymbol{i}_C = (-\cos\varphi, \sin\varphi, 0)\\ &\boldsymbol{j}_C = (\cos\theta \cdot \sin\varphi, \cos\theta \cdot \cos\varphi, -\sin\theta)\\ &\boldsymbol{k}_C = (\sin\theta \cdot \sin\varphi, \sin\theta \cdot \cos\varphi, \cos\theta)\end{aligned}\right\} \tag{7}$$

[Step2] We can calculate the road surface normal vector $\boldsymbol{n}_1 = (a_1, b_1, c_1)$ in the camera coordinate system from vanishing line parameters m, d ($y = mx + d$) to be provided from an input image. We obtain vanishing line parameters by two ways: finding manually and (2) calculating a_1, b_1, c_1 using the next expressions:

$$\sqrt{a_1^2 + b_1^2 + c_1^2} = 1,\ \tan\theta_1 = d / L_V = -c_1 / b_1,\ m = \tan\varphi_1 = a_1 / b_1, \tag{8}$$

$$b_1 = 1/\sqrt{m^2 + 1 + \left(d / L_V\right)^2},\ a_1 = m \cdot b_1,\ c_1 = -b_1 \cdot d / L_V. \tag{9}$$

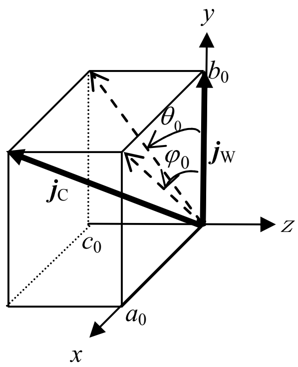


Fig.3 Normal vector.

Here, L_V is expressed for a pixel unit for relative role and imagination as a vertical angle and a vertical resolution of image at distance from the lens center to screen. We illustrate by Section 3 in more detail. Therefore, when the normal vector of $\boldsymbol{n}_0$ is expressed as (a_0', b_0', c_0') in the world coordinate system, the $\boldsymbol{n}_0$ is converted from the camera coordinate system into in the world coordinate system the following expression:

$$\boldsymbol{n}_0 = (a_0', b_0', c_0') = a_1\boldsymbol{i}_C + b_1\boldsymbol{j}_C + c_1\boldsymbol{k}_C. \tag{10}$$

The road surface normal vector $\boldsymbol{n}_0$ in the world coordinate system is fixed.
[Step3] When the camera attitude is changed, we calculate the new camera coordinate system $(\boldsymbol{i}_C', \boldsymbol{j}_C', \boldsymbol{k}_C')$ from the new camera attitude angles by Eq.(7). Therefore, we calculate $\boldsymbol{n}_1$ by the following expressions from Eq.(10):

$$a_1' = \boldsymbol{n}_0 \cdot \boldsymbol{i}_C', b_1' = \boldsymbol{n}_0 \cdot \boldsymbol{j}_C', c_1' = \boldsymbol{n}_0 \cdot \boldsymbol{k}_C'. \tag{11}$$

[Step4] And, we obtain new vanishing line parameters m', d' ($y = m'x + d'$) by the following expressions from Eq.(9):

$$d' = L_V \cdot c_1' / b_1', m' = a_1' / b_1'. \tag{12}$$

Therefore, when the camera attitude is changed, we can update the new vanishing line from new attitude using the road surface normal vector in the world coordinate system.

This section explains processing that extracts head nominators by multi-slit method. The multi-slit method calculates the position (slit) with the possibility with the pedestrian on the image, and it tries to improve the detection accuracy by judging whether there is pedestrian's feature in each slit. The multi-slit method utilizes y-position of vanishing line as the scale factor. The effectiveness of this technique is proven by the reference [7,8] .

3. Experimental Results

The effectiveness of the proposed method is confirmed through our experimental results. We took pictures in a variety of camera attitude angles (pitch and roll angles), and we estimated the vanishing line to each image by using pitch and roll angles obtained from an AMU at the same time.

L_V is expressed for a pixel unit for relative role and imagination as a vertical angle and a vertical resolution of image at distance from the lens center to screen as shown in Fig.4. Specifically, because the verticality angle of view of the camera used by the experiment is 37.8° and the verticality resolution of image 2448 pixels, the value of L_V is obtained by the following expression:

$$L_V = 1224 / \tan(18.39°) = 3575.015. \tag{13}$$

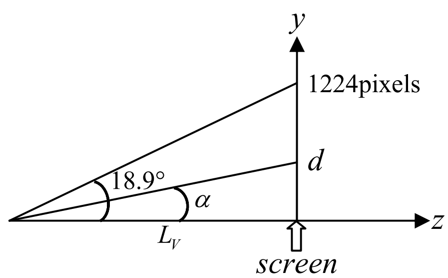


Fig.4 Image of L_V.

Calculation using L_V may cause error between d' and d. It is also necessary to revise the magnification of image width to correct for error between m' and m as shown in Fig.5. Therefore, we introduce a correction coefficient on experimental basis by the following expression:

$$L_V' = L_V \times 0.863 = 3085.238. \tag{14}$$

$$x' = 1/0.9968 \cdot x. \tag{15}$$

Then, the mean of the error margin of d and d' has been improved from 44 to 9 and that of m and m' from -0.0031 to -0.0029 as shown in Table 1. Fig.6(a),(b) shows the error margin of the vanishing line parameters. Examples of multi-slit drawn using vanishing lines estimated by L_V' are shown in Fig.7.

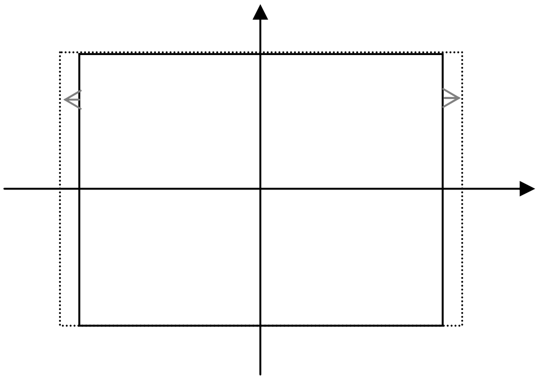
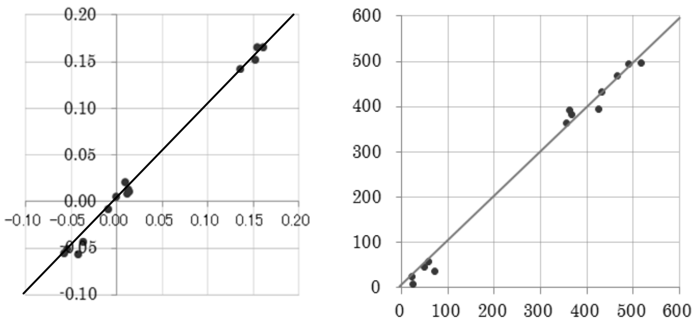


Fig.5 To revise the magnification of image width.



(a) m and m' (b) d and d'

Fig.6 The error margin of the vanishing line parameters using L_V' and x'.

Table1. The error margin using L_V, x and L_V', x'

		SD	MEAN
L_V, x	$m'-m$	0.0044	-0.0031
	$d'-d$	33	44

		SD	MEAN
L_V', x'	$m'-m$	0.0043	-0.0029
	$d'-d$	28	9

Fig.7 Examples of multi-slits using L_V' and x'.

4. Conclusion

We have developed an improved method for pedestrian detection using an AMU in conjunction with multi-slit data. In this paper, we proposed a fast and simple technique for obtaining the vanishing lines using an AMU. This system was shown to keep the necessary precision. Therefore, it is possible to combine the multi-slit lines with the data from an AMU mounted in a vehicle in real-time even when the car moves or wobbles around while driving. The effectiveness of our proposed method was confirmed by our experimental results. However, it has here been assumed that the road surface is perfectly level and smooth. As this is of course not always the case, it will be for future research to develop a real-time system for practical use that can handle more generally encountered conditions.

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