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Face Detection-based System to Sense Pedestrians At High Risk of Collision

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***Abstract*—In this study, we propose a novel system that assesses pedestrians at high risk of collision and accordingly warns the driver of the vehicle. Numerous warning systems to prevent contact accidents between pedestrians and vehicles have recently been proposed. One desideratum of warning systems that prevalent systems lack is that they should only warn the driver about pedestrians that are at high risk of collision with the vehicle. To develop such a system, we focus on detecting pedestrian's faces. Pedestrians not looking at the vehicle are then determined to be at high risk of collision based on the face detection feature. We verified the effectiveness of our recognition system using video sequences captured by an in-vehicle camera.**

Keywords-image processing; in-vehicle camera; face detection

I. INTRODUCTION

In recent times, several warning systems have been proposed that detect pedestrians and warn drivers of their presence in order to prevent contact accidents between pedestrians and vehicles. These systems can detect a pedestrian, who might be difficult to spot with the naked eye at night, for instance, using far-infrared camera[1], and can detect an obstacle and a pedestrian using a stereo camera and a millimeter wave radar[2].

Systems such as the above aim to recognize pedestrians and warn drivers. However, such systems do not assess the danger of collision between a detected pedestrian and the vehicle. Therefore, these systems can detect pedestrians to whom the driver need not pay any attention because they are not at any ostensible risk of collision with the vehicle in question. Examples of such low-risk pedestrians include pedestrians that notice and wait for passing vehicles, pedestrians that walk on sidewalks isolated from the roadway, etc. However, since existing pedestrian warning systems will bring even these low-risk pedestrians to the attention of the driver of the vehicle, this can result in the driver being subjected to such an excessive amount of information that it might cause him/her to overlook high-risk pedestrians that do need to be minded.

With this in mind, we propose and develop in this paper a pedestrian sensing system that assesses the danger of collision between a recognized pedestrian and a vehicle using face detection. We provide the concept of the proposed system and its details using a monocular camera and an image processing to be coming my concept. We then report the results of an experiment to show the effectiveness of our system using images of people from video captured by an in-vehicle camera.

II. SENSING SYSTEM FOR PEDESTRIANS AT HIGH RISK OF COLLISION

A. Concept

The concept underlying our system is to not only recognize pedestrians, but to also determine the risk of collision between vehicle and pedestrian using a monocular camera. To realize the above, we focus on detecting the pedestrian's face. Specifically, we show two situations in Figure 1 involving the vehicle and the pedestrian.

1. As shown in Fig. 1(a), the pedestrian does not look in the direction of the vehicle. At this time, it is possible that the pedestrian will not spot the vehicle and make a dangerous move that the driver might not expect.
2. As shown in Fig. 2(b), the pedestrian looks at the vehicle. At this time, it is highly likely that the pedestrian recognizes the vehicle and highly unlikely that the pedestrian will make a dangerous move that the driver does not expect.

From these suppositions, we think it is possible to judge a pedestrian at high risk from result of face detection using the image by the in-vehicle camera.

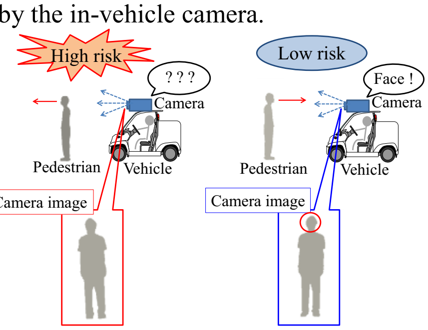

Fig. 1: Concept of proposed system.

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B. Image Processing Algorithm

We provide here the details of the image processing algorithm used in our in-vehicle system as well as its operation in the face of the illuminations changes and background changes of the outdoor environment. The procedure of this algorithm is shown in Figure 2.

The system first detects a pedestrian using the Histograms of Oriented Gradients (HOG) feature in an image from a monocular camera mounted at front of a vehicle. The HOG feature is calculated using histograms of a luminance in the local area with a gradient direction [3]. Therefore, it is possible to represent the general shape and outline of an object. This feature is hence suitable for detecting humans. Furthermore, when this feature is calculated in an image area divided into defined zones, it can reliably detect human figures in images in lighting changes to normalize at that area.

Following this, the extracted image, which is a head image periphery of the result of human detection, is expanded four times. The region of the extracted image is determined according to the result of pedestrian detection, and is shown in Figure 3. Fig. 3(a) shows the results of pedestrian detection. As can be seen, we obtain an upper-left point and a bottom-right point on a pixel coordinate. We designate these as $pt1(x, y)$ and $pt2(x + w, y + h)$, respectively. In the figure, w is the width of the human detection frame and h is its height. In Fig. 3 (b), the area in the red frame is the extracted image. This area is determined using the coordinates of the human detection frame. The demarcating points of the extracted area here are $pt3(x + w/4, y)$ and $pt4(x + (w \times 3/4), y + h/3)$.

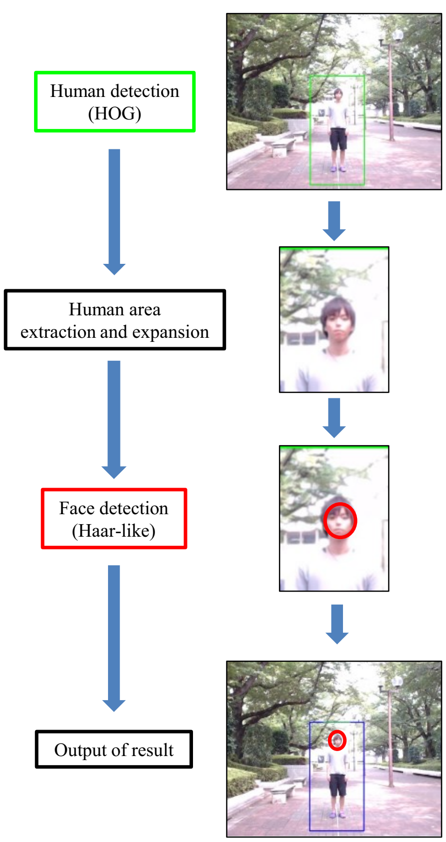
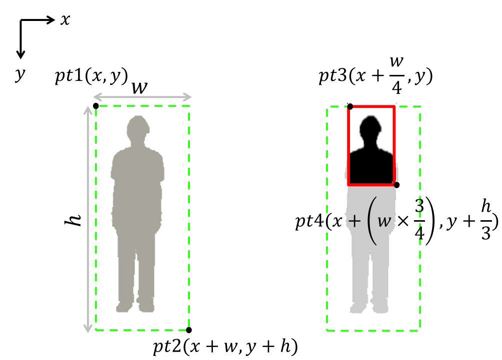


Fig. 2: Image processing algorithm.

The system then detects faces using Haar-like features in the expanded image. Haar-like features are calculated by using the luminance difference at the next to each other area like short bill [4]. Therefore, it is possible to represent the relationship between the appearance of objects and gradations of light. Thus, this feature is suitable for face detection. Moreover, not using luminance that trend to shift a lighting condition to using luminance difference is possible to detect strongly of face in lighting change.

If the system detects the face of the pedestrian in addition to his/her mere outline, the image of the detected human is surrounded by a blue frame. If only the form of a pedestrian is detected, the detected image is in a red frame.

This system has two merits. First, limiting the face detection area mitigates the misdetection of faces. Second, using expansion processing to detect faces with Haar-like features allows us to use functions to detect features in the face image that cannot be detected without the expansion.



(a)Human detection area (b)Extracted area

Fig. 3: Designated extraction area.

III. EXPERIMENT

In this section, we report the results of experiments to verify the effectiveness of our system. We test our system's ability to detect pedestrians at high risk of collision using human images from video captured from an in-vehicle camera.

A. Experimental Conditions

We captured the image of a subject standing outdoors using an in-vehicle camera. The in-vehicle camera was set up in front of the vehicle, approximately 1.2 m from the ground. The distance between the subject and the vehicle was approximately 10 m. These conditions are shown in Figure 4.

The horizontal angle-of-view of the in-vehicle camera was 77 degrees, and the size of the captured image was 1920 pixels × 1080 pixels.

We tested our system using two kinds of images: images of the subject facing away from vehicle, which we call back-face images, and images of the subject facing the vehicle, called front-face images.

The subject does not move in these situations as we capture the images. We captured the images from an in-vehicle camera moving at 4 km/h.

B. *Experiment Result*

The results of our system's recognition of back-face images and front-face images are shown in Table 1.

Of course, the back-face image cannot be used to detect the face of the subject in our system as the subject does not look at the vehicle. Thus, this situation supposes that the detected pedestrian is at high risk of collision. The recognition rate of our system for back-face images was 98.2% when the vehicle and the subject were 10 m apart.

For the other set of images, our system can detect faces in front-face images as the subject looks at the vehicle in these. In this situation, the system concludes that the pedestrian at low risk of colliding with the vehicle. For these cases, our system recorded a 76.1% recognition rate with vehicle and the subject at 10 m from each other.

According to the above results, our system is effective at detecting pedestrians at high risk of collision when the distance between the vehicle and the pedestrian is less than 10 m.

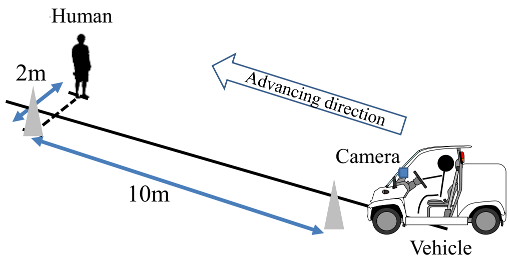


Fig. 4: Experimental conditions.

TABLE I RECOGNITION RATE OF EACH SET OF IMAGES

Back face image[%]	Front face image[%]
98.2	76.1

IV. CONCLUSION

In this paper, we developed a system to detect pedestrians at high risk of collision with vehicles based on face detection in order to improve collision warning systems. We conducted an experiment to test our system using two kinds of images of people from video captured by an in-vehicle camera. We found that our system recognized back-face images in 98.2% of the cases and front-face images in 76.1%, when the distance between vehicle and the subject was 10 m.

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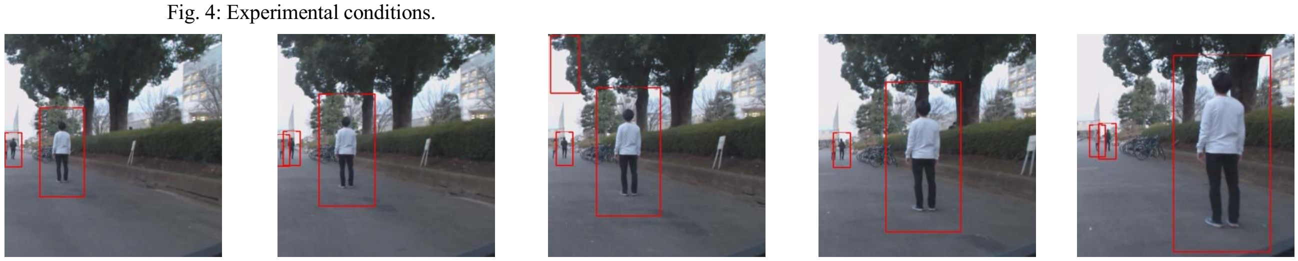
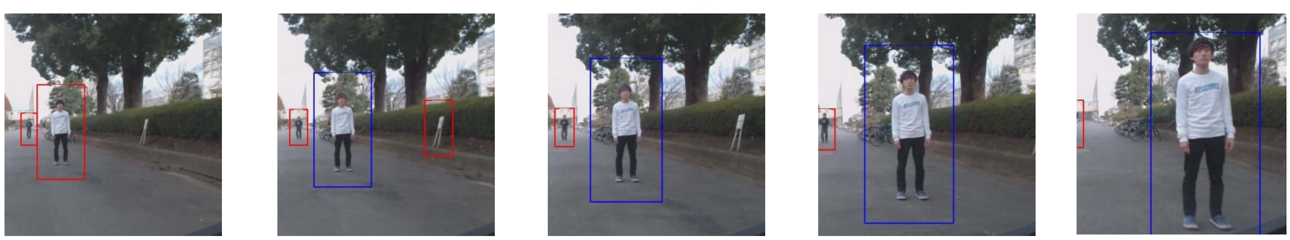


0[s] 1[s] 2[s] 3[s] 4[s]

(a)Back face image



0[s] 1[s] 2[s] 3[s] 4[s]

(b)Front face image

Fig. 5: Result of experiment