AutoBiVision - A Novel Vision-Based Bicycle Warning System

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***Abstract*—This article presents the concept of a novel vision-based bicycle warning system (AutoBiVision). AutoBiVision system warns the driver of the approaching bicycles without offering redundant or disturbing information, which means when the driver is focusing on one specific area, the system will focus on the other areas that the driver is not paying attention to. To this end both the driver and cyclists require to be monitored, which means two camera systems are needed: The inner camera system captures the interior of the vehicle while the outer camera system captures the bicycle lane as well as the cyclists. With the purpose of intelligently detecting and tracking the bicyclist in wider ranges, two rotatable cameras, which are components of the outer camera system, are mounted on the top of the left and right back mirrors of the vehicle, respectively. The angle control of the rotatable cameras depends on the results of bicycle tracking and bicycle lane detection. In this contribution, the main structure of the system and the initial results of a series of novel methods of bicycle lane detection, are presented. A patent is pending.**

***Index Terms*—bicycle warning system; bicycle lane detection; rotatable cameras**

I. Introduction

As a result of the increasing number of the automotive vehicles and other road participants, driving is becoming more and more complicated for the drivers despite the advanced technology in automotive industry [1]. In urban areas the vehicles could be very dangerous for the bicyclists, especially in the right turn situation (Fig. 1 and Fig. 2).

Figure 1. Common right turn situations.

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Figure 2. Dangerous right turn situations.

A. *Problem Addressed*

Normally when making a right turn, the driver should pay attention to the bicycles coming from both sides on the bicycle lane which is parallel to the original driving direction of the vehicle (Fig. 3). In particular during the rush hour, the driver needs to turn his/her head from left to right again and again to make sure that the situation is safe enough to make a turn.

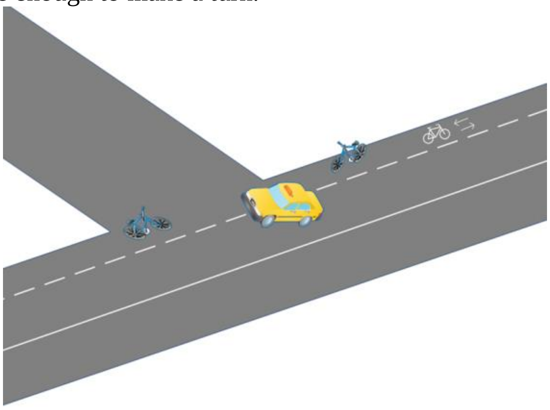

Figure 3. Right turn situation with approaching bicycles from two directions.

There are two warning cases in the bicycle warning system: partial-cover case (when the driver turns head) and full-cover case (when the driver is looking forward or affected by dazzling effect or drowsiness):

1) Partial-cover case

Normally the driver is able to figure out the situations in the area where he is looking at. Then in order to avoid confusing or frightening the driver with some redundant information, the onboard driving assistance system must be designed to monitor the other areas that the driver is

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not paying attention to. For this reason, the system needs to know where the driver is looking at in real-time, e.g., when the vehicle is making a right turn and the driver is paying attention to the bicycles coming from the left side, then the system will only monitor the bicycles coming from the right side, and if an approaching bicycle is detected, a danger signal representing the bicycle coming from the right will be sent to the driver.

2) Full-cover case

When the driver is looking forward, the bicycles approaching from both sides need to be monitored. In addition, when the driver is sleepy or dazzled by strong external light sources, the driving safety is severely affected and it is difficult for the driver to figure out the situation on the street in time. Therefore even the driver turns head to one side, the system must pay attention to the bicycles coming from both sides.

In order to meet the requirements mentioned above, a novel vision based bicycle warning system – AutoBiVision, is built. "Auto" stands for automobile vehicles, and "Bi" stands for not only bicycle detection but also that the system has "bi-function", which means the proposed system can monitor both the driver and cyclists. Hence two camera systems, inner and outer camera systems, are applied for these tasks (Fig. 4). Inner camera system consists of two cameras which monitor the interior of the vehicle (mainly the driver). The two rotatable cameras of the outer camera system are mounted on the top of the left and right back mirror, respectively.

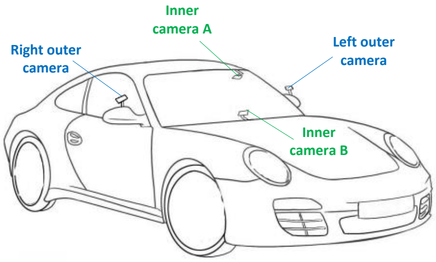


Figure 4. Camera setup of the AutoBiVision system.

Moreover, in some existing vision-based driving assistance systems, the cameras are also fixed on the back mirror or other parts of the car to monitor the other vehicles and bicycles coming from behind. However, when the vehicle is turning, the bicycle lane will not be covered due to the limitation of the camera's covering range [1]. Even when the camera is tuned to capture the bicyclist during the turning situation, the system may still miss the bicycle lane because the setups of the motor road and bicycle lane are not always the same. In all these cases the system cannot detect the bicycle or fails in tracking bicycle. To solve this problem, the two outer cameras in AutoBiVision system are rotatable cameras, whose angles can be automatically adjusted depending on the results of bicycle tracking and bicycle lane detection.

B. Related Work

The vision-based bicycle detection has been a hot research topic in last decade. The feature of the bicycles can be employed in the detection procedure, e.g., ellipse approximation [2], edge features of the bicycle [3], and deformable part model [4]. Alternatively some approaches employ the features of the cyclists, such as MSC-HOG feature [5] and RealAdaBoost [6]. However, all these methods require that the main axis of the camera and the bicycle has a specific range of angle. To maintain this specific angle range, our proposed system mounts the rotatable cameras on the top of the back mirror, whose angle to the bicycle lane can be intelligently adjusted.

The automatic rotation of the camera is partly controlled by the information of bicycle lane, therefore the technology of lane detection is involved. Integrated synergies [7] and Around View Monitoring [8] can be applied to detect the straight lane, while many other approaches provide algorithms for curve lane tracking, such as Gradient-Enhancing Conversion [9], Random Sample Consensus [10] and Improved River Flow [11]. However, the methods mentioned above can only detect the motor lane with painted separating line. Currently there are no robust methods for bicycle lane detection. In addition, there are many kinds of bicycle lanes, e.g., in some countries many bicycles lanes and motorways are not separated by painted marks.

II. Working Principle of AutoBiVision System

This section briefly introduces the working principle of AutoBiVision system. As Fig. 5 illustrates, the inner camera system (black part) captures the interior of the vehicle while the outer camera system (blue part) captures the bicycle lane as well as the cyclists. The inner camera system determines on which side/sides the bicycle should be detected, and then this information is transmitted to the outer camera system. The outer camera system will perform the corresponding bicycle detection according to this information. The detailed function of the inner and outer camera systems are introduced in the following two sub-sections.

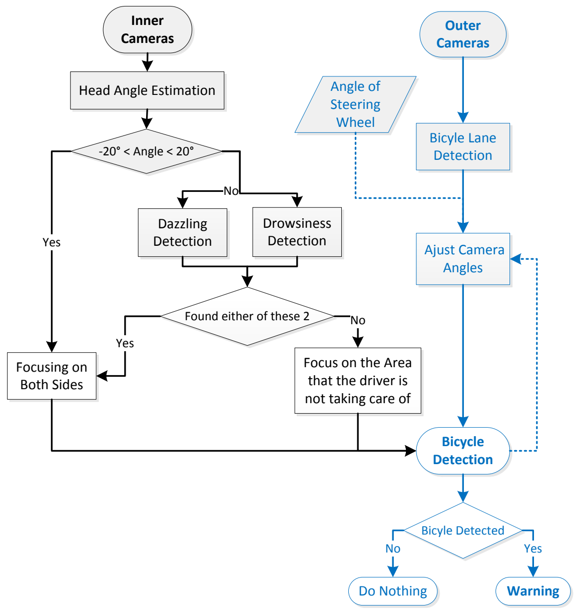


Figure 5. Camera setup of the AutoBiVision system.

A. Inner Camera System

In the first place the system should determine whether the driver is looking to the front. The two cameras form a 3D camera system and the movement of the driver's head is monitored in 3D space. The rotation angle of the driver's head can be estimated based on several important facial features, such as eyes, ears as well as nose, which can be obtained by face detection and tracking. If the absolute value of the rotation angle of driver's head is smaller than 20°, then this case is defined as looking forward. Under this assumption the bicycles coming from both sides need to be monitored by the outer camera system.

When the driver is not looking forward, the inner camera system does not immediately inform the outer camera system on which side the bicycle detection should focus. Instead the inner system will perform two critical sub-detections in parallel, which are dazzling and drowsiness detection. Dazzling effect are caused by strong external lights, e.g., low positioned sun or headlights from the other vehicles. Dazzling effect can be determined by the ratio of the brightness of the driver's face and the ceiling of the vehicle [1], meanwhile drowsiness is recognized by using the eye information. Dazzling effect and drowsiness are very dangerous for driving [12], and in these two cases the driver tends to rotate his/her head. But this kind of rotation does not mean that the driver's attention is focusing on one specific side, and therefore the outer camera system should still concentrate on the approaching bicycles from both sides.

When there is neither dazzling effect nor drowsiness, it represents that the driver's head is performing a normal rotation, then the system will focus on the other side in order to offer useful real-time information to the driver. In addition, this can significantly save the processing time of onboard computer.

B. Outer Camera System

As mentioned before, the outer camera system consists of 2 rotatable cameras, each of which is mounted on the top of the left and right back mirror, respectively. The rotation angles can be automatically adjusted based on the angle of steering wheel and the information of detected lanes and tracked bicycles, by this mean the outer cameras are always able to capture the required scene, especially when turning. Then the outer camera system can perform the bicycle detection. If there are bicycles approaching, the driver will be warned. The details about bicycle lane detection is described in the following section.

III. Proposed Mehtods for Bicycle Lane Detection

The result of bicycle lane detection and tracking provides important information for controlling the rotation angle of the two outer cameras. Different from the monotonous motor lane, there are many different types of bicycle lane, such as bicycle lane with painted bicycle symbol, bicycle lane with painted separating line or bicycle lane marked simply by a special color. In addition, the bicycle lane can also be a combination of the three types mentioned above. The following sub-sections briefly introduce the methods and results of detecting the three types of bicycle lane.

Figure 6. Example of bicycle lane with only color information in Germany.

A. Bicycle Lane with Only Color Information

In many European countries the bicycle lanes are marked only by some specific colors. Fig. 6 illustrates a typical bicycle lane in Germany. It does not position next to the motor lane but has intersections with the motor lane at the crossings (Fig. 7), which is even more difficult for the driver to notice the existence of the approaching bicycles when turning. To detect such bicycle lanes, AutoBiVision System applies an appearance-based object detection [13] to segment the bicycle lane, the performance is improved by adding blobs detection to the algorithms.

Figure 7. Example of the intersection of the bicycle lane and motor way in Germany.

Figure 8. Example of bicycle lane with painted separating lines and with same color as the motor way.

B. Bicycle Lane with Only Painted Separating Lines

In most of the Asian countries the bicycle lanes are located next to the motor lane and separated by a solid line or dash. The line or dash should be recognized at first to separate two regions: the motor lane region and bicycle lane region, the width of these two lanes can be used to classify them because the bike lane is much narrower than the motor way. Afterwards the Gradient-Enhancing Conversion [9] is employed and improved for Fig. 8 to track the bicycle lane.

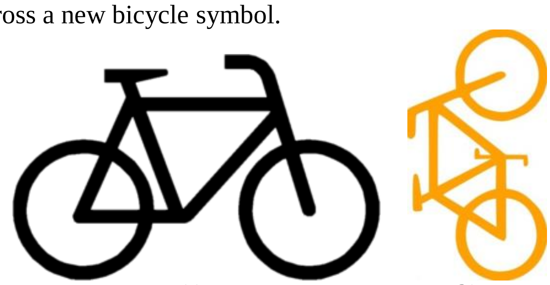
C. Bicycle Lane with Painted Bicycle Symbol

We can often notice that a bicycle symbol is painted on the road to indicate a bicycle lane. Sometimes the symbol is painted on the road with a different color from the motor way (Fig. 9), and sometimes the symbol is painted directly on the asphalt pavement (Fig. 10). The proposed method of detecting this kind of bicycle lane is to recognize the symbol at first, and then track the road based on the information of the separating line or the color of the road.

Figure 9. Example of bicycle symbol painted on the road with different color from the motor way.

Figure 10. Example of bicycle symbol painted on the road with same color as the motor way.

The bicycle symbols are not always the same (Fig. 11-a and Fig. 11-b), but they all have some similar features, such as the number of circles, triangles and lines. In addition, as the outer cameras are rotatable, the bicycle symbol needs to be recognized from different viewing angles. To this end we train our own classifiers to robustly detect these bicycle symbols based on the features mentioned above. The training function in Intel OpenCV Library is employed [14]. After recognizing the bicycle symbols, the method described in sub-sections *A* and *B* can be used for the cases of Fig. 9 and Fig. 10, respectively. The system will be adjusted when coming across a new bicycle symbol.



(a) (b)

Figure 11. Example of different bicycle symbols captured from different viewing angles: (a) Bicycle symbol with black color captured from the vertical viewing direction. (b) Bicycle symbol with yellow color captured from the biased viewing direction.

D. Performance Evaluation

Three groups of images of bicycle lanes (each group contains 1000 images) are captured to verify the effectiveness of the proposed methods for the detection of different types of bicycle lane. The corresponding results of the detection rate are listed in Table I. From the table it is obvious that the proposed methods for the detection of bicycle lane can achieve satisfying results, especially for the bicycle lanes with painted information (second and third cases in the table).

TABLE I. RESULTS OF BICYCLE LANE DETECTION

Type of Bicycle Lane	**Detection Rate**
Bicycle lane with only color information	80.4%
Bicycle lane with only painted separating lines	88.7%
Bicycle lane with painted bicycle symbol	96.3%

IV. FUTURE WORK

Although AutoBiVision system has achieved satisfying results, several goals should be achieved in the future.

For the bicycle warning system, the warning signal must be generated instantly. Therefore the speed of image processing is critical to the whole system. The algorithm mentioned in [15] can be improved to realize a high-speed processing for the inner camera system. Moreover, the inner and outer camera systems should be perfectly synchronized.

(a) (b)

Figure 12. Example of bicycle prohibition symbol.

According to the results in Table I, the detection rate for bicycle lane with only color information needs to be further improved. In addition, the system will learn how to distinguish different types of bicycle lanes and automatically choose the appropriate detection methods.

Sometimes the bicycle symbol painted on the road does not denote the bicycle lane but the prohibition symbol for bicycles (Fig. 12). These symbols should be correctly detected to prevent generating inaccurate or redundant information to the driver.

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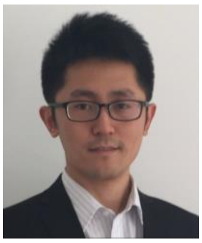

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