Traffic Sign Recognition Using Hybrid Camera System

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Abstract Traffic sign recognition systems can be used to assist drivers and improve road safety. The system is expected to recognize traffic signs at even greater distances in order to give drivers as much warning as possible based on the road conditions. A hybrid camera system is proposed in this paper with the goal of increasing the recognition distance compared to the conventional systems. In this system, an active telephoto camera is used as an assistant to a wide angle camera. Traffic sign detection and classification are processed separately for the different images from the wide angle camera and telephoto camera, respectively. The image from the telephoto camera provides enough information for a classification when the resolution of the detected traffic sign is low from the wide angle camera. The experimental results demonstrated that the recognition distance of the proposed system is improved compared to the conventional systems.

Key words: Traffic sign recognition, Hybrid camera system, Galvanometer mirror, Detection, Low resolution

1. Introduction

Traffic signs are the main guide of road transportation. They deliver road information to transportation participants and warnings about potentially risky situations. The information can be extracted based on the shape, color and the inner symbol of traffic signs. A complete response to traffic signs depends on drivers’ vision perception and behavior output. The response process can be divided into four stages based on the psychology perception theory. The four stages are: detection, recognition, decision and action. In general, the further away a traffic sign may be recognized, the better it is. A longer recognition distance allows more time for the driver to react to the message of traffic signs without missing any other necessary information.

Based on the analysis of drivers’ response to traffic signs, the recognition system should identify traffic signs as far as possible. Many proposals have been published to realize traffic sign recognition1-3. The more common traffic sign recognition systems comprise a single video camera mounted at the front of a vehicle, and adopt two-step processing, in which classification is conducted after detection3). The classification needs more information comparing to detection, so in monocular camera system, the classification resolution decides the recognition distance. In this paper to extend the recognition distance, we propose a hybrid camera system and develop a proper method of traffic sign recognition based on the structure of the system.

The hybrid camera system is composed of two cameras which differ in field of view and accuracy. One active telephoto camera is equipped as an assistant of a wide angle camera. The telephoto camera can acquire enough information for classification when object is detected from the wide angle camera at low resolution. Therefore, the detection resolution in the wide angle camera decides the recognition distance in the proposed system. By means of the additional telephoto camera, the proposed system realizes the objective of extending the recognition distance of traffic sign.

The telephoto camera provides more information about object, meanwhile, the changing of telephoto camera direction consumes more time compared to a monocular camera system. One difficulty in this research is that the direction of telephoto camera needs to be controlled correctly and effectively. In addition, the minimum resolution at which a traffic sign can be detected in the wide angle camera needs to be as low as possible for maximum detection distance. In this research, we solve above two problems and make the
proposed system to recognize traffic signs effectively.

The paper is organized as follows. In section 2, the hardware structure of hybrid camera system is presented. The motivation of design and the advantage of system are also explained. The details of traffic sign recognition are described in section 3. The mechanism of controlling the direction of telephoto camera and the method of traffic sign detection at low resolution are explained in this section. In section 4 and 5, the experimental results and conclusions are discussed.

2. Hybrid Camera System

The hybrid camera system is presented in Fig. 1. This system is a combination of two cameras with different focal length. The wide angle camera ensures the view field of the system, but broad view field results in information compression of captured object. Another camera in the system is the telephoto camera. It consists of a telelens and a Charge Coupled Device (CCD), as shown in the rectangle of Fig. 1. The focal length of telelens can be adjusted manually, which makes the telephoto camera more flexible in zoom factor relative to wide angle camera. The telelens narrows the view angle of telephoto camera and increases the information of the object of interest. The telephoto camera is like a human eye equipped with a telescope.

In fact, the hybrid camera system is a multi-focus vision system. The multi-focus vision system is mainly applied in humanoid robots and autonomous vehicles. The multi-focus vision system was also applied to make traffic sign recognition more reliable. In these conventional systems, the direction of telephoto camera is changed by rotating camera. The inertia of the camera reduces the performance of rotating motion. To overcome the weakness of conventional multi-focus camera system, we apply two galvanometer mirrors as reflectors in our hybrid camera system, as shown in Fig. 1. The two mirrors are placed in front of the telephoto camera. The optical path entering the telephoto camera can be changed by rotating the two mirrors. Because the mirror is lighter than a camera, the motion performance of our telephoto camera is much better. We define the response time of the telephoto camera as the time from inputting the position of the interested object in the wide angle camera to capturing a correct image of the object. Based on experiments, the maximum response time is 0.1 second. The hybrid camera system is faster than other multi-focus vision systems in scan processing.

The main advantage of the system is a partial examination with high accuracy while keeping a large part of environment in view. The advantage is just right for extending the object recognition distance. We can use some features to locate an object in the wide angle camera, but these features should be reliable at low resolution. The classification can be conducted based on more information captured from the telephoto camera. In theory, the system can recognize object at the moment of detection. Because the system moves on road in our application, the motion caused by the time delay of detection and mirror controlling need compensating. Additionally, the usage frequency of the mirrors needs to be reduced. These problems will be solved in next section.

3. Method of Traffic Sign Recognition

In this section, the method of traffic sign recognition using the hybrid camera system is introduced. The framework of the recognition system is shown in Fig. 2.

In this paper, we focus on the recognition of circular traffic signs at low resolution. Some circular traffic signs are shown in Fig. 3. But the recognition of other shape traffic signs also can be exploited using this sys-

![Fig. 1](image1.png) The hardware structure of hybrid camera system.

![Fig. 2](image2.png) The framework of traffic sign recognition using hybrid camera system.
Fig. 3 The images of some circular traffic signs.

system. In addition, when the resolution of traffic sign is high enough for classification in the wide angle camera, the conventional method in monocular camera system can be used to recognize traffic sign from the wide angle camera.

Generally, traffic sign recognition includes two stages: detection stage, which finds the image regions containing traffic signs and classification stage where the detected signs are classified. In the proposed system detection and classification are processed in two types of images from the wide angle camera and telephoto camera separately. In the detection step, the shape, color and information of previous frames are used together for improving the detection accuracy at low resolution. The relationship between detected candidates in different frames in time is considered for mirror controlling. For classification, an ellipse detection is proposed to reject false positive candidates before matching. This speeds up the classification. The details of these algorithms are described in the following sub-sections.

3.1 Detection and Mirror Controlling

Because traffic signs can be categorized according to their shape and color, most conventional detection methods used these features are to locate the positions of traffic signs. In many works, the most step of the detection consists of a segmentation processing by thresholding with a given color space to extract the sign color from image\(^{11,17}\). Direct thresholding over the Red Green Blue (RGB) space is seldom used because it is very sensitive to lighting changes. The most frequently considered space is the Hue Saturation Intensity (HSI) system because color information, which is encoded with hue and saturation components, presents low variations for objects of interest with a similar color\(^{17}\). Other methods for detection have been developed based on shape features. The most popular algorithm applied in shape-based detection is Hough Transformation (HT) and its derivatives. Especially, the fast HT based on radial symmetry property has been widely applied because of the real-time performance\(^{10,19}\). Some methods use shape and color features together. Normally the color feature is used to locate traffic signs, and the shape feature is utilized to verify the detected candidates\(^{11,12}\). Because the recognition resolution of a traffic sign is determined by the classification stage in monocular camera system, few conventional proposals aim at detection at low resolution.

In outdoor environment, the lighting condition is variable, which is considered in the feature selection for detection. The shape feature is the character of contour, which exhibits by the contrast between object and background. Strictly speaking, the shape feature is a simple pattern based on intensity contrast. The contrast of intensity makes the shape feature invariant to the light changing. Therefore, the shape feature is more robust comparing to the pure color information. When the resolution of traffic sign is low, the connected region of homogeneous color is small and is easily divided by noise. This makes, for our proposed system, the color feature less reliable than the shape feature. Therefore, the shape feature is adopted to detect traffic signs in the first step.

(1) Shape detector

The fast shape detector based on radial symmetry\(^{10}\) operates on the gradient of a gray scale image and exploits the nature of shapes that vote a center point for circular signs. Every pixel in image generates voting along the pixel gradient direction. The voting distance is a pre-defined radius. If there is a circular object with the pre-defined radius, the voting value at the center is greater than other area in the voting image. Because traffic signs appear in image with different radii, we need to define a series of radii and get several voting images at different radii. The center of a circular object is located by thresholding the sum of all voting results at different radii. Then the all voting values of the detected center at different radii are checked, the corresponding radius of the maximum voting is the radius of the circular object.

In the shape detector, the threshold of center detection is an important parameter. If the value of the threshold is small, the number of false negative candidate is reduced, but the number of false positive candidate will be increased. In the reverse condition, the number of true positive candidate is decreased. The meaning of these candidates will be discussed in next section. In this paper, we define a small value as the threshold for ensuring most of traffic signs can be detected. Furthermore we reduce the number of candidate using color information.

(2) Color detector

The color detector consists of a segmentation stage by thresholding with a given color space to extract the
color from image. In fact, the image detector such as Charge-Coupled Device (CCD) is designed to produce electrical signals that are linear related to the amount of luminous energy impinging on it. We adjust the shutter time to simulate the different lighting conditions and capture images of a color-checker (Fig. 4 (a)) at different shutter times. The color values of different color block are recorded in RGB space, as shown in Fig. 4(b).

The color value of one color block changes linearly with shutter time until one component of RGB saturates. We can use this characteristic to build a color space based on RGB color space. We propose an improved RGB color space, of which the parameters are defined as equation (1)-(3). The RGB cube is projected to a part of sphere, by \( \text{Angle}(R) \)^2 + \( \text{Angle}(G) \)^2 + \( \text{Angle}(B) \)^2 = 1. The color values of one color block at different shutter times are projected to the same position in the improved RGB color space. Therefore, the improved RGB color space is invariant to illumination change. We will search the color range of traffic signs in this color space.

\[
\begin{align*}
\text{Angle}(B) &= B/\sqrt{B^2 + G^2 + R^2} \\
\text{Angle}(G) &= G/\sqrt{B^2 + G^2 + R^2} \\
\text{Angle}(R) &= R/\sqrt{B^2 + G^2 + R^2}
\end{align*}
\]

To search the range of blue and red color in the defined color space, we manually selected 12000 pixels in the images of traffic signs in our database. The values of these pixels in the improved RGB color space are shown in Fig. 5 (a), the corresponding range in RGB color space is shown in Fig. 5 (b).

The weight of the red or blue pixels in a defined area of the detected candidate is used to verify that the candidate is a traffic sign. The defined area is the ring between two concentric circles. The outer radius is the detected radius in the shape detector (corresponding to the edge of the traffic sign). The internal radius is set to 0.75 times the outer radius. This parameter is decided based on the structure of traffic signs.

After the shape and the color detector, some false positive candidates are removed. The voting value at the center, the detected radius, and the color weight of the detected candidate are obtained in the detection step. These values are used to sort the order of the detected candidates. This simple process makes the candidate similar to traffic sign to be recognized early.

(3) Mirror controlling

Even though the shape and color features are utilized together for detection, some false positive candidates still exist. Therefore, the information of previous frames is used to reduce the number of false positive candidates and the frequency of mirror rotation. The flowchart of mirror controlling is shown in Fig. 6.

Each detected candidate is labeled using a score and a captured flag. The score is a function of the voting value at the center, the detected radius, and the color weight of the detected candidate. The captured flag influences the behavior of mirrors and telephoto camera for each candidate. As shown in Fig. 6, if the detected candidate in the current frame was never found in previous frames, then the information of this candidate is
stored for future operation. Otherwise, the score of the candidate is updated and used to sort the candidate order. In the next step, the captured flag of each candidate is checked. If the candidate has not been captured before, the mirrors and telephoto camera are operated to capture a high resolution image of this candidate. Because of the time delay between detection and mirror rotation, motion estimation should be done before the mirrors are controlled.

In this process, the matched candidates are searched in consecutive frames using block matching. This search process is important to improve the accuracy and efficiency of the system. Firstly, the final detection result includes candidates that are detected in at least two consecutive frames, which reduces the number of false positive candidates. Secondly, the previous information of candidates is considered in updating of score, which is more reasonable. Thirdly, the position information of two matched candidates in different frames can be used to compensate the motion of the system using linear prediction. Finally, the captured flag of each matched candidate memorizes the behavior of mirrors and telephoto camera of the candidate, which is used to reduce the frequency of mirror operations and improve the efficiency of the system.

3.2 Preprocessing and Classification

The high resolution image of a candidate is obtained after above steps, as shown in Fig. 7 (a). This image includes the information of both the candidate traffic sign and background. In addition, the captured candidate may be a false positive candidate. This unnecessary information can be removed using preprocessing.

The purpose of preprocessing is to separate the region of the traffic sign from the high resolution image. This step removes the information of the background and saves the information of traffic sign. The shape detector is utilized again in the high resolution image, which is resized to make it homogeneous with the image from the wide angle camera. The shape detector can reject some false positive candidates fast, and separate candidates when there are more than one traffic sign in one image, as shown in Fig. 7 (a). Fig. 7 (b) shows the detection result. The radius of the detected circle is magnified 1.3 times to include the whole image of the traffic sign. The separated regions are shown in Fig. 7 (c). The correct candidate can be chosen based on the relationship between the high resolution image and the image from wide angle camera.

The image of the separated candidates includes the rough region of a candidate. To get the exact region of the traffic sign, ellipse detection is used, because the shape distortion due to camera direction is more severe in the high resolution image from the telephoto camera. The ellipse detection is explained in Fig. 8. The ellipse center is located first. A basic property of ellipse-diameter bisection is utilized for voting, as shown in Fig. 8 (a). The principle of diameter bisection states that two points on an ellipse whose tangent lines are parallel are the end of an ellipse diameter. Consequently, the midpoint of these two points is the center of the ellipse. Therefore, if the endpoints of the ellipse diameter can be located, then the center of the ellipse can be computed. For a point on an ellipse, the direction of the tangent line and the direction of pixel gradient are vertical. The gradient direction can be chosen for points searching. By searching points on an ellipse, a voting image is built. Accumulation of voting makes the value of the ellipse center greater than other region, and the points on the ellipse are labeled at the same time. As shown in Fig. 8 (b), the red point is the detected center and the white points are the voting points.

We slightly modify the algorithm of ellipse detection, to speed up the ellipse detection and to obtain the outer ellipse only (corresponding to the edge of the traffic sign). The voting points are divided into 36 groups according to their direction relative to the detected center, as shown in Fig. 8 (c). In each group, one point is selected according to its distance to the center. The distance from the selected point to the center is further than the average distance of points to the center in same group and near to the average distance. This selection method saves the voting points on the outer ellipse. The selected points are shown as Fig. 8 (d). We can calculate the parameters of the ellipse equation using some voting points and generate an ellipse. By comparing the generated ellipse and the edge image, the best ellipse is found as the edge of traffic sign, as shown in Fig. 8 (e), the red ellipse is the best one.
Based on ellipse detection, the exact region of the traffic sign is obtained from the high resolution image. The information in the region can be used for classification, as shown in Fig. 8 (f).

The methods in other proposals can be applied in the classification step. When we choose method, both the processing time and accuracy should be considered. The distance transform has been used to generate a feature image and shows good performance[3]. In this paper, this method is adopted for the generation of a feature image. First, the ellipse region is transformed to a circle shape based on the parameters of the detected ellipse. The edge image of the transformed image is shown in Fig. 9 (a). Next, the edge information in the defined circle is used to generate a feature image by distance transform, as shown in Fig. 9 (b) and (c). The feature image is used for matching with the templates in the database. The most similar template is output as classification result.

4. Experiment

The experiment device is shown in Fig. 10 (a). The test data used in the experiments, was captured by the proposed system mounted on a car while driving around a city. The images from wide angle camera and telephoto camera are shown in Fig. 10 (b). The average velocity of vehicle was about 40 km/h. The result of experiment is evaluated in following subsections.

4.1 Detection

We judge the performance of detection and preprocessing by means of Recall and Precision defined in equation (4) and (5), which are commonly used in the field of Information Retrieval[3]. True positive means that the traffic sign is detected correctly, false positive is incorrect detection and false negative is the undetected traffic sign. Recall is also known as detection rate.

\[
\text{Recall} = \frac{\text{true positive}}{\text{true positive} + \text{false negative}} \quad (4)
\]

\[
\text{Precision} = \frac{\text{true positive}}{\text{true positive} + \text{false positive}} \quad (5)
\]

In the test data, 71 circular traffic signs appear 1695 times in 1050 frames, the radius range of the detected traffic signs is from 4 to 12 pixels. The result of detection is shown in Table 1. The verification using color feature and information of previous frame step reduce the number of false positive candidate and enhance the value of Precision. This result can reduce the operation time of the mirrors and the telephoto camera and make the system work more effectively. The value of Recall is decreased to 89.61%. One reason is the verification using previous information ignores the detected candidate at first time. In experiment, 66 signs can be detected when radius is 5 pixels and all signs can be detected when radius is 7 pixels. The detection rate is 92.9% when the radius is 5 pixels.
4.2 Mirror Controlling

The mirror controlling is conducted after detection. The positions of the two mirrors are rotated according to the position of the detected candidate in the image of the wide angle camera. Because of the movement of the system, the position of detected candidate changes with time in the image of the wide angle camera. We adopt linear prediction to compensate the movement of detected candidate.

Before we evaluate the accuracy of the linear prediction, we analyze the permissible error of the proposed system. The permissible error is measured in the wide angle camera. In the proposed system, the resolution of the image from the telephoto camera is width × height. The zoom factor of the telephoto camera is z times relative to the wide angle camera. Suppose that the radius of a detected traffic sign is r pixels in the image of the wide angle camera. The traffic sign should have a radius of z × r pixels, and be located at the central position in the image of the telephoto camera, if the mirrors controlling is accurate. Therefore, the system has a permissible error $E_x$ along the horizontal direction, and permissible error $E_y$ along the vertical direction, as shown in equation (6) and (7).

$$E_x = \frac{\text{width}/2 - z \times r}{z} \quad (r < \frac{\text{width}/2}{z}) \quad (6)$$

$$E_y = \frac{\text{height}/2 - z \times r}{z} \quad (r < \frac{\text{height}/2}{z}) \quad (7)$$

In other words, the telephoto camera still can capture a whole high resolution image of a traffic sign, if the error of compensation is less than the permissible error of the system. In the proposed system, the resolution of the telephoto camera is 240 × 320, and the zoom factor z is 8. The performance of the linear prediction is presented in Table 2. In the experiment, 71 traffic signs are detected, and linear prediction is conducted for these traffic signs. The Average error and Maximum error between the linear prediction and actual position are shown in Table 2. Maximum errors along two directions are all less than the permissible errors at different radii. The Table 2 illustrates that the linear prediction is effective in compensating the movement of the system.

4.3 Preprocessing and Classification

In the evaluation of preprocessing and classification, we supposed that the high resolution image has been captured. There are 500 images, 250 images include traffic sign. The result of preprocessing is shown in Table 3. After ellipse detection, 29 traffic signs are rejected as a negative candidate, because occlusion exists in the high resolution image and results in the failure of the ellipse detection. There are 20 false positive candidates, because other ellipse objects like traffic light exist in the database. Finally, 209 traffic signs can be classified correctly, the classification rate is 83.6%. Even we got a high resolution image from telephoto camera, the performance of the classification did not improve. One reason is that preprocessing defines a strict rule for candidate and leads to some false negative candidates.

4.4 Processing Time

Preprocessing time is another evaluation factor. All experiments were done on Intel Core i7-930 Processor with 3GB RAM. We use an example to explain the average processing time of each step, as shown in Fig. 11.

We assume that there are 3 candidates in the image of the wide angle camera. The first candidate is a new candidate and it is traffic sign, the second one has been

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Table 1: The performance of detection.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Detection using shape feature</th>
<th>Verification using color feature</th>
<th>Verification using color and previous results</th>
</tr>
</thead>
<tbody>
<tr>
<td>True positive candidate</td>
<td>1629</td>
<td>1508</td>
<td>1519</td>
</tr>
<tr>
<td>False negative candidate</td>
<td>66</td>
<td>97</td>
<td>176</td>
</tr>
</tbody>
</table>

Table 2: The performance of linear prediction.

<table>
<thead>
<tr>
<th>Number</th>
<th>Radius</th>
<th>Permissible error $x$</th>
<th>Average error $y$</th>
<th>Maximum error $z$</th>
</tr>
</thead>
<tbody>
<tr>
<td>66</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>3.3, 4.1</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>9</td>
<td>14</td>
<td>3.7, 3.3</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>8</td>
<td>13</td>
<td>4, 5</td>
</tr>
<tr>
<td>5</td>
<td>2</td>
<td>7</td>
<td>13</td>
<td>4, 5</td>
</tr>
</tbody>
</table>

Table 3: The performance of preprocessing.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Preprocessing</th>
</tr>
</thead>
<tbody>
<tr>
<td>True positive candidate</td>
<td>221</td>
</tr>
<tr>
<td>False negative candidate</td>
<td>29</td>
</tr>
<tr>
<td>False positive candidate</td>
<td>20</td>
</tr>
<tr>
<td>Recall</td>
<td>88.4%</td>
</tr>
<tr>
<td>Precision</td>
<td>91.7%</td>
</tr>
</tbody>
</table>
recognized in previous frames, and the last one is a new candidate which is not an ellipse object. The average time of the detection step is 0.21 seconds if the resolution is VGA (640×480). For the first candidate, we need to do motion estimation and control the mirrors, which use 0.1 second. After capturing the high resolution image, the preprocessing and classification will be done, using 0.2 second. Then the second candidate is processed. Because it has been captured in a previous frame, the classification result can be obtained from the previous frame. For the last candidate, motion estimation and mirror controlling are similar to the first candidate, but the classification is not necessary, since it is not an ellipse object. In this example, until the end of classification of this frame, we need 0.65 second. For the second candidate, the mirror controlling, preprocessing and classification are not conducted, which can make system more effective. In a test experiment, 89 candidates were detected from wide angle camera, the mirrors were controlled 18 times. This result also denotes that the proposed method can reduce the frequency of mirror controlling.

In the future, we can use parallel processing method to save more time. A supposed system is shown in Fig. 12. The assumption of Fig. 12 is same to the condition in Fig. 11. In Fig. 12, two processor units (e.g. FPGA) have different functions. The first processor is responsible for detection and mirror controlling. The high resolution image is captured by first processor after mirror controlling. The classification is conducted by the second processor. As shown in Fig. 12, when mirrors are rotated to a new position by the first processor, the classification of previous candidate can be conducted by the second processor. The classification and detection of next frame also can be done at the same time. Theoretically, the supposed parallel processing can speed up our system.

4.5 Recognition Distance

The objective of this paper is to extend the recognition distance. The distance is inverse proportion to recognition resolution. There is a comparison with other proposals about recognition resolution, as shown in Table 4. Our proposed system achieves a recognition rate of 78.9% at 10×10 resolution, and 88.7% at 14×14 resolution. The result approaches to other conventional methods. The reason is that in our system the telephoto camera is equipped as an assistant of the wide angle camera. The telephoto camera can capture a higher resolution image for the detected traffic sign. Therefore, even if the resolution of traffic sign in wide angle camera is not enough for recognition, the telephoto camera can provide a higher resolution image for recognition, and make accurate traffic sign recognition possible.

In fact, the recognition rate is effected by three steps: detection, mirror controlling and classification. In the experiment, when radius of traffic sign is 7 pixels in the wide angle camera, all 71 traffic signs can be detected, and the high resolution images of these traffic signs were captured by the telephoto camera. The recognition rate is 88.7% in such case. From our analysis, the recognition error is caused by our classification algorithm. The classification algorithm is independent, and the system can provide high resolution images of traffic signs.

Table 4 The comparison of recognition resolution.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Baro et al. ((14))</th>
<th>Ruta et al. ((15))</th>
<th>Fleyeh ((16))</th>
<th>Our proposed method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognition resolution</td>
<td>35×35</td>
<td>60×60</td>
<td>36×36</td>
<td>10×10</td>
</tr>
<tr>
<td>Recognition rate</td>
<td>98%</td>
<td>93.5%</td>
<td>88.4%</td>
<td>78.9%</td>
</tr>
</tbody>
</table>
we apply other method for classification, such as Baro et al., at least we can obtain the equal performance (98%) at 14 × 14 resolution theoretically. Therefore, it is potential for improvement of the recognition rate.

Suppose that the resolution of wide angle camera is VGA (640 × 480) and the focal length is 1300 pixels, the detected traffic sign is the first candidate, the velocity of vehicle is 60 km/h. The proposed system can recognize a traffic sign with 30 centimeters radius at 70 meters and warn driver before 4 seconds.

5. Conclusion

A hybrid camera system is proposed and applied in the traffic sign recognition to extend the recognition distance. The shape, color feature and information of previous frames are used to detect a traffic sign at low resolution in the wide angle camera. The proposed mechanism of mirror controlling speeds up the recognition system and compensates the system motion. We have shown that the developed algorithms proposed in this paper, can overcome the challenges of the hybrid camera system, and realize traffic sign detection at low resolution.

Although the main novelty of this paper is in the proposed detection method, the experiments analysis indicate that the performance of our system is currently limited by the classification method. Recently, local feature and learning-based methodology have shown good performance in traffic sign recognition. Therefore, we plan to improve the classification as our future research. In addition, the parallel processing, the application of FPGA and the recognition of triangle and rectangle traffic signs need considering.

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(References)


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