Attitude determination of sanitation sweeper in working process

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Abstract. During the working process of the sanitation sweeper, it needs to be parallel to the curb and keep a certain distance to complete the cleaning work, so the driver must observe whether the distance between the side of the vehicle and the curb meets the working requirements at all times while considering the longitudinal driving. This will undoubtedly increase the workload of drivers, but also bring a lot of driving difficulties, easy to drive fatigue, resulting in traffic accidents. In this case, it is necessary to use the auxiliary driving technology to assist the sanitation sweeper driver to complete the cleaning work. Based on the actual working condition of sanitation sweeper, a scheme suitable for judging the attitude of sanitation sweeper is proposed. A line laser assisted vision rangefinder is designed to judge the attitude of sanitation sweeper. This scheme is simple and easy to operate, and the image processing speed is fast, which is suitable for popularization.

1. Introduction
An intelligent vehicle is an important part of an intelligent transportation system. It uses various sensing technologies to obtain the vehicle body and external information, and transmits the results to the driver or control system through algorithm processing, so as to reduce the drivers' work burden and reduce the possibility of traffic accidents [1]. In recent years, all countries in the world have been using a variety of advanced technologies to study this issue, but due to technical bottlenecks, legal issues, policies and other practical problems, there is still a certain gap to achieve a full sense of automatic driving [2]. Therefore, vehicle assistive technology has become a research hotspot for domestic and foreign scholars [3]. Compared with the complicated traffic conditions of civil vehicles, the sanitation sweeper is more suitable for assisted driving technology because of its fixed route and repetitive and single working mode.

2. Background
As one of the environmental sanitation equipment, sanitation sweeper has the function of saving time and labor. The sanitation sweeper can remove dust and purify the air medium on the road, ensure the cleanliness and tidiness of the road, prevent the dust from flying, maintain the good working condition of the road surface, reduce and prevent the occurrence of traffic accidents and further extend the
When the sanitation sweeper works, it is necessary to contact the end of the sweeper plate with the curbstone, clean the curbstone and clean the road surface to remove dust. The actual working situation of the sanitation sweeper is shown in figure 1.

Figure 1. Working pictures on site

The above situation is similar to the mid-lane deviation technique of assisted driving, both of which need to ensure that the vehicle can drive in a straight line in normal driving and the attitude of the body does not deviate. Lane deviation technology is based on the identification of lane lines on the road [6]. However, as the sanitation sweeper works on the outermost side of the road and the road conditions are changeable, not all roads are marked with standard lines. Therefore, it is necessary to improve on this basis to find new references and ranging methods to determine the body attitude. According to the field investigation, the only relatively fixed reference for the sanitation sweeper in the process of driving is the kerb stone, and the shape, size and color of the kerb stone in each section are not completely consistent, and the size of the kerb exposed to the ground is generally between 10mm-20mm.

3. Range Finder
There are four ranging methods commonly used in modern cars: ultrasonic wave, radar, camera and laser ranging [7]. However, as the curb stone is only less than 200mm higher than the road surface, and the tires of the sweeper are more than half a meter higher than the road surface, the general ultrasonic wave, millimeter wave radar and laser ranging are not suitable for the actual situation, so it is decided to adopt the method of video ranging. Due to the changeable environment of the scene and the changing kerb, the general video ranging system needs to filter too much information, which will lead to a great increase in the time and difficulty of image processing. Therefore, it is decided to design a rangefinder by using line laser assisted marking line, which can effectively reduce the difficulty of image processing and speed up the processing speed.

3.1. Ranging Experiment
The COMS camera model OV2710 was used in the experiment, with a focal length of 3.6mm and a maximum resolution of 1920*1080. In order to improve the image processing speed, 640*480 resolution with 50 frames per second was selected. The laser adopts red one-word laser laser to locate the light marker, with the output wavelength of 650nm, and the line width of the laser line is adjustable from 0.4mm-30mm.
The situation of the simulated line laser hitting the curb stone is shown in figure 2. Figure 2 shows that there are three intersecting line segments in the image, among which L1 is the line segment used in the experiment. L1, L2 and L3 are laser segments projected on the upper side of the kerb, the outer side of the kerb and the plane of the pavement respectively. Since the top side of the pavement is parallel to the road, and the outside side of the pavement is perpendicular to the road, L2, L1 and L3 are not parallel, that is, the slope of the line segment is different from the other two. Because the laser line segment produced by the laser is very different from the light in the background, the original image obtained by the camera can be easily recognized and extracted with simple image processing, which greatly improves the processing efficiency. By setting the threshold, the position coordinates of each red pixel can be obtained by using the binary method, and then the information of the line segment can be obtained. Since the position and Angle of the laser emitter and camera can be controlled and fixed, the line segment can be placed vertically each time for the convenience of calculation, so that the horizontal axis of the center line on the line segment is equal.

3.2. Experimental Verification

The plane where the camera and laser transmitter are located is taken as plane 1, the plane of the measured object is taken as plane 2, the distance between the two planes is L. Starting from 300 mm, a group of data is measured every 50 mm and binarized to remove all lines whose slope absolute value is less than 50, that is, only the feature of line L2 is left. After image processing, the images obtained from different distances are integrated into one image, and the results are shown in figure 3.
As can be seen from figure 3, the distance $L$ between the two planes corresponds to the abscissa of line $l_2$, showing an obvious functional relationship. The horizontal distance $L$ is taken as $X$, and the abscissa of the center line of each line segment is taken as $Y$. The information in figure 3 is fitted into the curve, and the result is shown in figure 4.

\[ y = -0.008 * x^3 + 0.172 * x^2 - 15.786 * x + 679 \] 

The formula (1) is stored in the computer, and another picture is processed within the measurement range. The corresponding distance $L$ can be obtained by inputting the center line coordinate of line segment 2. This method is feasible.

3.3. Plan to Improve

According to the above, the position and Angle of the laser emitter and camera can be controlled and fixed, so that the horizontal coordinate of the center line on the line segment can be equal. Moreover, after fixing, the image information of the line segment corresponding to each distance is basically unchanged, so the image features of only a certain area can be recognized to accelerate the image processing speed. As can be seen from figure 3, take the upper left corner as the origin, the right side as the positive $x$ direction, and the downward side as the positive $Y$ direction. Set the region of $200 < y < 250$ as region 1. By narrowing the detection range, the detection speed can be further accelerated by only detecting the range of region 1. However, the edge recognition of laser line segment must meet the requirements while the scope is narrowed.

Generally, line segment recognition has binary method and edge detection algorithm, and the above experiment USES binary method. The binarization method needs to select a threshold value first. When the gray value of a pixel point is greater than this value, the pixel point is interpreted as a white point and denoted as 1. On the other hand, the judgment is a black spot, denoted as 0. However, this threshold value is a fixed value, and white points and black points can't be judged normally at the edge of the image due to the influence of light. Therefore, this method is highly influenced by the environment. Since all three segments are produced by lasers, the color and light intensity can be customized within a certain range, which can be clearly distinguished from the natural light in the environment, but the intensity of the background light will affect the results.

The camera adopted in this experiment has a resolution of 640*480. A row with 640 pixel points
can be regarded as 640 columns. The threshold value is determined from the first pixel point. In actual conditions, the line segments hit by the laser on the road surface are not exactly the same brightness. The edge brightness is less than the middle brightness, so the edge part will have fuzzy deviation, so the threshold processing cannot be simple. Here, an edge processing method can be introduced to determine the desired line segment by judging the threshold difference between adjacent pixel points. The specific method is as follows.

![Figure 5. Edge method](image)

We set each line of the first point to the origin, so I = 0, the last point I = 639. The threshold difference is not simply between two adjacent points due to the possibility of fuzzy deviation at the edge. Each laser line occupies 6 to 8 pixels, so the difference between the gray values of point I and point I-3 in each row is judged in turn to be greater than the positive threshold. If yes, store the value of I in ZBJ (note that this is the value of I, not the gray value of the point of I), as shown in figure 5 (a); If the difference between the gray values is less than the negative threshold, store the value of (I-3) in YBJ, as shown in figure 5. \( (ZBJ + YBJ) / 2 \), the coordinates of the center of the laser line can be obtained [8]. More accurate location information can be obtained by calculating the average of all center-line coordinates in region 1. Using this method can not only increase the speed of graphics processing, but also improve the stability and accuracy.

4. Attitude Determination Scheme

4.1. Analysis of Actual Conditions

The distance relationship between the car body and the curb stone can be simply regarded as the relationship between two straight lines, which can be roughly divided into three cases, as shown in figure 6.
As can be seen from figure 6, in order to better deal with the distance relationship between the car body and the curb stone, the distance between two points on the body of the road sweeper and the curb stone should be understood at least, that is, two distance meters should be placed. During normal operation, the sanitation sweeper is parallel to the curb stone and $L=400\text{mm}$ or so, as shown in figure 6 (a); In abnormal operation, parallel but $L>400\text{mm}$, or the car body and curb stone will have a certain Angle, as shown in figure 6 (b), 6 (c). In order to ensure that the camera can avoid accidental contact during work and rest, the camera is fixed at 2m away from the road surface. After simple trigonometric function calculation, the camera is about 2.04m away from the road edge when the garbage sweeper works normally.

Make a quantitative analysis of the traffic conditions of the garbage sweeper in abnormal operation, as shown in figure 7. As shown in figure 1, the length of the sweeper is about 4m, that is, $AD=4\text{m}$. Put the two rangefinders at 1m from the front and end of the sweeper respectively, $AB=1\text{m}$, that is, the distance between the two rangefinders is 2m, $BC=2\text{m}$. Once the Angle and position of the rangefinder are determined, it cannot be moved, so the distance measured by the rangefinder is the distance perpendicular to the plane on the right side of the vehicle. When the vehicle body is not aligned with the curb stone, the distance measured by the rangefinder is the distance between the camera point and the curb stone, i.e. $BG, CI$. By obtaining the size of $BG$ and $CI$, and then the length of $BF$ and $EG$, the position relationship between the car body and the curb stone can be easily obtained.

In a limiting case, the Angle between the body of the road sweeper and the curb stone is 30 degrees, i.e. $D0I=30^{\circ}$, and the point on the right nearest to the curb stone is just equal to the normal working distance, i.e. $AE=0.4\text{m}$. It can be seen from figure 7 that Angle $FBG=30^{\circ}$, Angle $HCI=30^{\circ}$, $OC=3.8\text{m}$, Easy to get that $BG=1.04\text{m}, CI=2.19\text{m}$. Since the camera is fixed 2m from the road surface, the actual limit distance is 2.97m. Therefore, the range finder required is 2.04m-2.97m.
4.2. Experimental Verification

The focal length of the camera used in the above experiment is 3.6mm, and the measuring range of the rangefinder is 0.3m-1.1m. The measuring range of the rangefinder required in the scheme is 2.04m-2.97m. Since an object with a distance of about 3 times is needed, a lens with a focal length of 12mm is selected. By setting the distance and Angle between the lens and the laser emitter, the same experimental process is carried out again, and the measurement range is set to about 2m-3m.

The curve equation is obtained as follows:

\[ y = -7.3e - 05 \cdot x^3 + 0.071 \cdot x^2 - 26.39 \cdot x + 3611 \]

The measurement range was set as 1.95m-3.1m through experiments, and the actual measurement was carried out. Some data were obtained as shown in table.1.

| Actual value (m) | Measured value(m) | Error (m) |
|------------------|-------------------|-----------|
| 1.95             | 1.953             | 0.003     |
| 2.10             | 2.098             | -0.002    |
| 2.30             | 2.296             | -0.004    |
| 2.50             | 2.501             | 0.001     |
| 2.70             | 2.698             | -0.002    |
| 2.90             | 2.903             | 0.003     |
| 3.10             | 3.104             | 0.004     |

5. Conclusion

The information obtained by the rangefinder can be simply processed to tell the driver the attitude information of the car body in the form of sound or image, so that the driver does not need to pay attention to the road condition in both directions at the same time when working. The experiment proves that the precision of the rangefinder meets the requirement and the scheme is feasible.

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