Design of Trajectory Tracking Algorithm of Isolated Observation Point Automatic Distribution Vehicle based on Visual Servo

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Abstract. The medical isolation observation point for epidemic prevention and control is an important part of the epidemic prevention and control link. With the attention paid by all countries to the epidemic prevention and control, the design and construction of the medical isolation observation point for epidemic prevention and control have put forward higher requirements. This design uses a visual servo-based automatic delivery car for trajectory tracking and research on the tracking algorithm to realize the automatic delivery car for the regular delivery of medicines, food and other daily necessities for isolated personnel. The application of automatic trolleys in the epidemic prevention and control medical isolation observation point can effectively alleviate the pressure on staff, avoid infection, and improve the efficiency of epidemic prevention. Aiming at the complexity of its motion trajectory, a tracking algorithm of vision and information fusion is used to implement the trajectory tracking of the smart car. The trend of the target trajectory is determined by the least square method. The image information collected by the image binarization algorithm is added to a certain anti-jamming program. The PID algorithm is used to optimize the control of the steering gear and the drive motor, improve the operating efficiency and system stability, and meet the actual application.

1. Introduction

The medical isolation observation point for epidemic prevention and control is an important part of the epidemic prevention and control link. With the attention paid by all countries to the epidemic prevention and control, the design and construction of the medical isolation observation point for epidemic prevention and control should further standardize and strengthen the epidemic prevention and control work and improve the prevention ability. The automatic delivery trolley is used to regularly distribute medicines and food for the isolation personnel. It has high efficiency in transportation and distribution, can effectively relieve the pressure of the staff, avoid personnel infection, and improve the protection ability of the isolation observation point.

The epidemic prevention and control medical isolation observation point service robot needs to achieve accurate autonomous control. Because the epidemic prevention and control medical isolation observation point temporarily expands or contracts the site, this uncertainty causes the scene environment to be complicated. Therefore, there is a certain risk in using a sensor to identify the path.
2. Test Content and Environment Simulation

The test environment uses the target trajectory as a black trajectory, the target guide line width is 25mm, and the simulated corridor floor color is beige tiles. Considering that the automatic delivery trolley needs a load, a wheeled trolley is used as a carrier, and the steering gear is used to control the front wheels to achieve steering [1]. The automatic distribution car collects the road information with the camera, and obtains the image data by sampling the video signal with the single chip microcomputer. Combined with the information fusion of photoelectric sensor and speed sensor, the image data is analyzed, the target guiding line is extracted, the path is recognized, and the steering gear and driving motor control is controlled to realize the precise tracking path of the car [2].

After extracting the feature points of the target trajectory, the center position of the target trajectory is extracted. This design uses an image binarization algorithm to extract the path center position [3]. The process is shown in Figure 1.

![Figure 1. Target trajectory center position extraction flowchart](image)

The position data of the centerline of the target track is transmitted to the upper computer through the serial port for display, and the position accuracy of the centerline observed through the upper computer serial port assistant is high. When the target trajectory is a straight line, the black line is in the center of the target trajectory. An image is acquired with 15 rows and 50 columns, so its center is about 25 columns in each row.

For the prediction of the target trajectory trend, in order to determine the type of the target trajectory (straight, curve), it is necessary to further calculate the center position of the 15 target trajectories, and use the least square method to fit the target trajectory into a straight line (as shown in Figure 2), so as to obtain the properties and trends of target trajectory for speed control [4].
Figure 2. schematic diagram of target trajectory fitting by least square method

Let the fitted straight-line equation be \( x = ay + b \), then the fitted residual can be expressed as:

\[
\sum e^2 = \sum (ay_i + b - x_i)^2
\]  

(1)

Given \( y_i \) and \( x_i \), to minimize the residual, we can take the partial derivative of \( a \) and \( b \) and set it equal to 0. By substituting in the central coordinates of the 15 target trajectories obtained previously, \( a \) and \( b \) can be obtained by calculation, and the following can be obtained:

\[
\begin{align*}
\frac{\partial f(a,b)}{\partial a} = 0 & \Rightarrow \sum (ay_i + b - x_i) \times y_i = 0 \\
\frac{\partial f(a,b)}{\partial b} = 0 & \Rightarrow \sum (ay_i + b - x_i) = 0
\end{align*}
\]

(2)

Where \( a \) is the slope of the front target trajectory, which is the angle between the body and the target trajectory; \( b \) is the deviation of the target trajectory at infinity; \( \sum e^2 \) is the sum of squares of the fitted residuals. In the case of straight and curve, this value will change greatly, which can be used to judge the bending condition of the road ahead, so as to realize the judgment condition of turning in.

When the target trajectory is straight, then the road parameter \( a: 0 \pm \pm 5, b: 0 \pm \pm 30, \sum e^2 <500; \)

When the target trajectory is ready to enter the curve (the curve turning trajectory takes a quarter arc with a radius of 1 meter as an example), then the road parameter \( a: \pm 5 \pm \pm 10, b: 0 \pm \pm 30, \sum e^2 : 1000~3000; \)

When the target trajectory is already in the curve (the curve turning trajectory takes a quarter of an arc with a radius of 1 meter as an example), then the road parameter \( |a| >11, b: \pm 20 \pm \pm 100, \sum e^2 >3000. \)

3. Design and debugging of isolated observation point automatic distribution vehicle based on visual servo

The images collected by the camera are near large and small, and the distant images and the picture next to the lens will be distorted [5]. Therefore, combined with reflective infrared sensors to complete the detection of road information, with its higher sampling rate to compensate for the shortcomings of
long camera acquisition cycles [6]. Prevent the car from deviating from the target track in the process of moving.

This experiment combined with functions and costs, and the camera chooses OV7620 [7], using analog output signal, through high precision A/D conversion module to perform image acquisition, the processing capacity of integrated controller and the actual need to collect the amount of data. The system collects data of 15 rows and 50 columns. The specific steps are: initializing the timer ADC, field interrupt signal, line interrupt signal, collecting data at intervals of 10 rows, sampling and storing the analog signal of the camera A/D [8], and storing the collected data of A/D into an array. The reflective infrared sensor is sensitive to the ambient light, and the intensity of the ambient light interferes with the sampled A/D value. In the test site, the A/D value of natural light and infrared light is first collected, and then the A/D value is collected, and the median filtering algorithm is used for processing [9].

Since the target track includes two colors of black track and beige floor, which have a large contrast, the image segmentation method is used to select a segmentation threshold [10], and the gray image binarization is adopted in this test. However, due to the uncertainty of light conditions and anti-interference ability of different sites, the segmentation threshold should be dynamically calculated based on the gray histogram of the acquired image to improve the compatibility of different lighting conditions [11]. Limited by the site and experimental equipment, this test only adopted a fixed threshold. When the sample value is less than the threshold value, the sample value is equal to 1. The sample value is greater than the threshold value, which is equal to 255. The target black line is extracted, the image information collected by image binarization algorithm is observed through the upper computer software, 1 is represented as a black spot, 255 as a white spot, the test results are good.

Due to the cost, the selected camera's operating frequency is 60Hz. The priority of the camera's field interruption and real-time interruption needs to be considered. In order to ensure the accuracy of the acquisition speed, the interrupt period of the pulse accumulator needs to be shorter than the field interrupt period of the camera. In this test, the real-time interrupt cycle is set as 10ms, and the frequency division of real-time interrupt is based on the crystal frequency rather than the bus frequency. As the image acquisition is greatly affected by the site light and the target trajectory, the anti-interference ability of the cart is improved, and turn a single white point into a black point and a single black point into a white point to remove noise from the image [12]. The acquisition range of cameras is certain. If the path of the epidemic prevention and control medical isolation observation point is set with a sharp turn, the camera will not detect the target trajectory when the car encounters a large road turning angle. To ensure that the car is correctly and effectively controlled when the camera cannot capture the target trajectory, at this time, let the car travel at a lower speed, and the steering angle of the servo increases, so that the camera can quickly find the target track.

In order to better achieve trajectory tracking, it is necessary to optimize the control of the movement of the trolley, mainly to optimize the control of the steering gear and drive motor to improve the tracking speed and stability. The method of PID adjustment is used to control the steering Angle of the steering gear. After testing, the method is better than the method of looking up the table in response speed, steering continuity and prediction of steering Angle. The servo control adopts position PID control [13], the integral link should consider the delay of the servo. Adopt a constant P parameter to control the car. The car is prone to swaying when running on the straight road, so the follow-up processing is set for the proportional parameter setting [14]. When there is a deviation between the center line of the target trajectory and the center line of the target trajectory, the proportion output is 0 when the deviation is -2~2. When the absolute value of deviation is between 2 and 8, a small value is output to fine-tune the displacement generated by the trolley. When the absolute value of deviation is greater than 8, the proportional coefficient increases, making the steering gear move quickly to correct the large deviation. To make the control of the servos smoother, the average of the three output values collected by the steering gear is taken. The system can be adjusted slowly on the straight and move quickly when passing the curve.
The speed is measured by a through-beam infrared sensor, the single-chip pulse accumulator is initialized, and the rising edge of the pulse is captured. Through the real-time interrupt processing of the single-chip microcomputer, the pulse number is sent every 10ms to calculate the current speed value, and then PID control is adopted to quickly adjust the speed to reach the predetermined value [15].

The brake function is normal to ensure the safe operation of the car. In order to ensure the safety of all kinds of personnel in the medical isolation observation point for epidemic prevention and control during the operation of the car, the car must brake in the shortest time when the detection environment is close to the personnel. The car makes the method of rapid deceleration: when the detection personnel are close to each other and the speed difference is large, the motor reverses; when the detection personnel are close to each other but there is a certain distance from the car and the speed difference is small, the car moves slowly [16].

Through the open-loop debugging, the brake function is debugged first, and the method of reversing the motor is used to determine the accurate braking. Then test the maximum safe driving speed of the car at different turning angles, record the PWM duty cycle corresponding to the speed, set the safety threshold for the later safety test, and finally perform closed-loop debugging.

4. Conclusion
The image information collected by the camera is transmitted to the upper computer through the single-chip computer serial port after A/D conversion, and the acquired image is displayed by the software of the upper computer. The anti-interference processing and algorithm of software are used to track the trajectory. Track conditions can be better identified (straight and curve have obvious contrast), and the collected image is shown in figure 3.

This design has completed the camera image acquisition, target black line extraction, target trajectory center position extraction, steering gear control, drive motor control and other functions. Thus, the design and implementation of the tracking algorithm of the isolated observation point automatic distribution vehicle based on visual servo are completed.

The steering gear debugging adopts the position type PID algorithm. When only the proportional P adjustment is added to the steering gear, the car is easy to rush out of the target trajectory when crossing a curve, and it is easy to cause oscillation when crossing a straight line. When PID adjustment is added to the steering gear, the car maintains a constant speed to achieve steering, and the speed is relatively continuous when cornering. The driving motor is debugged using incremental PID algorithm. If $K_p$ is adjusted separately, the speed of the car does not change at the beginning of operation, so it is necessary to adjust the three parameters $K_p$, $K_i$, and $K_d$ at the same time. When the car enters the curve from the straight road, the speed adjustment time is faster than that of the open loop, the speed deceleration time is shorter, and the conversion is more stable; When passing the curve, the speed change of the trolley is smaller than that of the open loop debugging. From the curve into the straight, the speed acceleration time is short, the speed curve is smoother.

In order to realize the safety and stability of the operation of the automatic delivery trolley, the maximum operating speed threshold of the driving area is sent to the PID controller, and the reverse braking work mode is started when necessary. The speed control mainly judges the road condition (straight road, curve road) by judging the slope and residual size, and sets different travel speed
according to the characteristics of the road, and realizes the speed adjustment through the incremental PID algorithm.

In the circuit, the combination of camera and photoelectric sensor is used to realize the safety and stability of the automatic distribution car. The camera makes up for the defect of the close observation distance of the photoelectric sensor, and the photoelectric sensor makes up for the accuracy and real time of the camera control. In the later period, we will further study the trajectory tracking algorithm of multi-camera automatic distribution vehicle in complex environment (such as large turning angles, etc.).

**Fund projects**

2020 school-level scientific research projects

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