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Research on automatic robot charging based on infrared and ultrasonic information fusion

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Abstract: In order to realize long-term, continuous, stable and reliable operation of wheeled robot without intervention, the principle of autonomous charging technology is analyzed, and the common and key technologies of wheeled robot autonomous charging are introduced. Aiming at the disadvantages of traditional autonomous charging system. A robot automatic charging docking method based on the combination of infrared radiation sensor, photoelectric tube tracking sensor and ultrasonic distance sensor is adopted. through the data fusion of Kalman filter algorithm for the distance value obtained by ultrasonic sensor, a high precision distance estimation value is obtained, which makes up for the lack of measurement accuracy in traditional infrared method. Experimental tests show that the docking accuracy between robot and charging seat is high. The docking is completed well.

1. Introduction

The energy supply of mobile robots mainly comes from high-quality built-in batteries. The traditional charging method is generally manual intervention or manual battery replacement, which makes the robot break away from the continuous working ring, and the process is tedious and inefficient, which is not consistent with the current development trend of robot automation and intelligence^[1]. With the development of robot automatic charging technology, it can better solve this main problem. By monitoring the battery status of the robot and conveying charging instructions to the robot, it can realize the automatic control of the charging process of the robot^[2]. In the 1940s, Walter and others made the first robot that can charge automatically, equipped with a light sensor and a charger, and used the light emitted by the charging post to dock the robot^[3]. Ye and others apply the infrared shooting technology to the autonomous charging of the robot, and realize the autonomous charging of the robot through infrared tracking^[4]. Su KuoLan and others cooperate with laser ranging, obtain the location coordinates through wireless communication technology, and charge automatically^[5]. In this paper, infrared shooting technology, ultrasonic distance measurement and photoelectric tube tracking technology are adopted on the self-developed differential wheeled robot, and a good docking effect is obtained.

2. Introduction of automatic charging system

The charging model of the robot in this paper consists of two infrared emitters isolated by the shading plate and a tracking mark marked on the central axis. When the robot enters the charging state, it will accept the modulated infrared signal emitted by the infrared transmitter on the charging seat. According to the situation that the infrared receiver on the robot receives the signal, the robot is directed toward the charging seat and further moves to the tracking route mark near the middle of the



charging seat. The automatic charging model is shown in figure 1. The robot tracks and measures the distance through the tracking sensor and ultrasonic ranging sensor, and obtains the accurate ranging estimation by Kalman filter to complete the docking between the robot and the charging base.

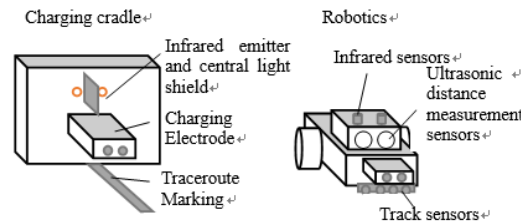


Figure 1 Robot automatic charging model

3. Overview of wheeled robots and charging cradles with IR signal distribution

The wheeled robot mentioned in this paper is equipped with two ultrasonic sensors in front, two infrared receiving sensors at the top and four light tracking sensors at the bottom. The robot model and signal distribution are shown in figure 2.a. The two infrared receiving heads A and B respectively correspond to the receiving area 1 and the receiving area 2 respectively. The receiving area 3 is the common receiving area of the connector A and the connector B. The angle between them is α and the ultrasonic ranging range is fixed.

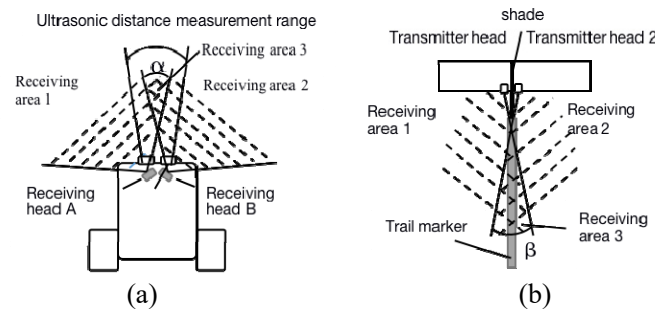


Figure 2 Robot model and signal distribution

The two infrared emitting heads on the charging base are isolated by an opaque shading plate, so that the covering angle is β , thus forming covered areas 1, 2, 3, and the tracking mark is located in the middle of the charging base. The infrared signal distribution of the charging seat is shown in figure 2.b.

4. Infrared Modulation, Ultrasonic signal and Kalman filter estimation

4.1 Infrared modulation signal

The infrared signal frequency of the receiver and the transmitter is set to 38KHz, the duty cycle is 1 beat 3, and the data and square wave are modulated into a carrier for transmission. After receiving the infrared signal, the receiver demodulates and filters the signal to get the carrier information. In order to ensure that a certain signal will not be lost, it is necessary to set the sum of the signal period of the two transmitting heads which is more than 2 times of the receiving interval of the receiving head and the time of its own signal. When the robot is in a common signal coverage area, infrared signals from both transmitting heads can be received at the same time.

4.2 Ultrasonic distance measurement

The ultrasonic wave propagates in the air and returns to the receiver after encountering obstacles. Through the continuous monitoring of the transmitting phase and the returning phase, the counter can get the time difference between transmitting and receiving Δt , and the sound velocity is constant C . The approximate monitoring distance L can be calculated.

The basic ranging formula is as follows.

$$L = (\Delta / 2) * C \quad (1)$$

Kalman filtering to obtain valuation

In practical applications, robots can reduce the measurement accuracy due to various external factors, such as wheel slippage, etc. In this paper, the Kalman filter is used to improve the ultrasonic distance measurement accuracy by multi-sensor fusion.

The input value of Kalman filter is the distance of charging seat obtained from ultrasonic range sensor and the tracing speed obtained from robot differential motor encoder. The distance and speed relationship can be obtained

$$R = R_0 + \int_0^t v dt \quad (2)$$

Given the initial conditions

$$X_0 = \begin{bmatrix} R_0 \\ v_0 \end{bmatrix} \quad (3)$$

$$P_0 = \begin{bmatrix} \sigma^2 & 0 \\ 0 & \sigma^2 \end{bmatrix} \quad (4)$$

X_0 is the initial system status information. R_0 , V_0 are the initial distance and initial velocity values of the system, respectively, P_0 is the covariance matrix, σ^2 is the initial value of the covariance matrix.

1) System state prediction and covariance prediction

$$X_{k+1} = \Phi X_k + W_k \quad (5)$$

$$P_{k+1} = \Phi P_k \Phi^T + Q \quad (6)$$

Φ is the system state transition matrix, W_k is the noise matrix of the system with covariance Q .

2) Calculate Kalman gain

$$K = P_{k+1} (P_{k+1} + R^{-1}) \quad (7)$$

where P_{k+1} A is the estimated value.

3) Calculate measurement valuation

$$Z_k = X_k + V_k \quad (8)$$

X_k is the distance measurement between the robot and the charging stand measured by the ultrasonic sensor, V_k is the measurement noise matrix with covariance R .

4) System state and covariance matrix update

$$X_{k+1} = X_{k+1} + K(Z_k - X_{k+1}) \quad (9)$$

$$P_{k+1} = (1 - K)P_{k+1} \quad (10)$$

Finally, the optimal valuation distance is obtained by iterating steps 1 to 4 to update the target distance valuation P_{k+1} between the robot state value X_{k+1} and the charging seat.

5. Algorithm research and docking implementation

The charging mode docking step is mainly divided into two steps.

The first step is mainly for people to adjust the angle of the roaming mode to ensure that the robot can receive infrared modulated signals, and judge that the robot is in a certain receiving area according to the situation of the infrared receiver. When the two infrared receivers of the robot only receive one of the signals of the transmitter 1 or 2, it is judged that the robot is in the infrared coverage area 1 or 2, and it is necessary to guide the robot into area 3 and adjust the robot. So that both receiver A and B can receive transmitter signals 1 and 2 at the same time, and it is determined that the robot enters area 3 and is near the middle of the charging seat.

The second step: the machine is basically in area 3, and find the tracking mark. The robot can

accurately follow the track by returning the state value of four tracking sensors. The control logic is shown in Table 1. Gradually approach the charging seat, cooperate with ultrasonic ranging and Kalma filtering estimation, determine the distance between the robot and the charging seat, and realize the accurate docking with the charging seat.

Table 1 Control Logic

Traction sensor status (black mark 1 is monitored)				Motor response
1	0	0	0	Large angle left turn
0	1	0	0	Small angle left turn
0	0	1	0	Small angle right turn
0	0	0	1	Large angle right turn

On the basis of infrared docking, this scheme makes the robot move closer to the central axis in the public area, and realizes the docking through tracking marks, which avoids redundant paths and invalid guidance, and improves the efficiency of pathfinding.

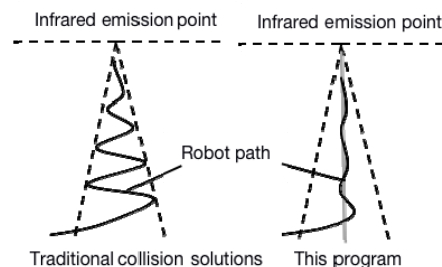


Figure 3 Comparison between traditional solution and this release case

6. Experimental results

In the position of the robot 150 cm from the charging base, the experiment was conducted 50 times at an angle between -40° and 40° , and the docking time used to find the charging base was plotted against the clamped foot as shown in Figure 4.a. Experiments with a specified docking time of no more than 1 minute were recorded as successful docking. Among them, 45 dockings were completed within 50 seconds, 4 dockings were completed within 60 seconds, and 1 docking was completed beyond 60 seconds. The success rate was 98%. The docking test results are shown in Table 2.

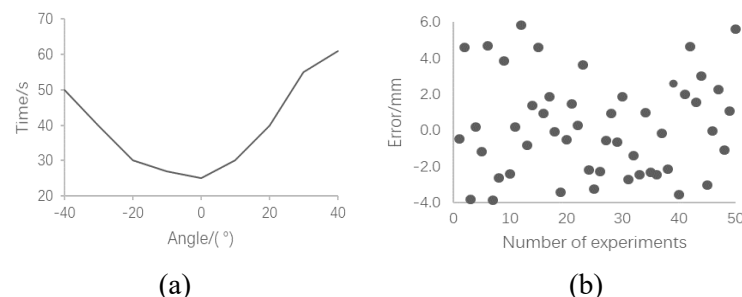


Figure 4 Results of docking test and docking error analysis

Table 2 Docking test results

Time spent	Number of times	Percentage of
<40s	35	70%
40~50s	10	20%
50~60s	4	8%
>60s	1	2%

In a certain range of different distances from the charging base, the robot is automatically charged docking experiments, a total of 50 times docking, the robot starting position from the charging base range between 50 ~ 150cm, where the robot in the charging base left and right are marked as positive and negative, the docking error is specified not more than 5mm that is qualified, the experimental docking error analysis results are shown in Figure 4.b. There are 48 experimental results of the error deviation within the controllable range, two deviations exceed the expected value, docking pass rate of 96%, docking accuracy is high.

7. Conclusion

In this paper, infrared alignment, ultrasonic ranging and photoelectric tube tracking technology are combined to guide the robot with wide coverage and high precision photoelectric tube tracking. Finally, the accurate distance is obtained according to the ultrasonic ranging and Kalman filter estimation, and the accurate docking is completed. Many experiments are carried out from the two aspects of success rate and experimental error, and the results show that the scheme has high docking accuracy.

Acknowledgments

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References

- [1] Goldberg K, Mascha M, Gentner S, et al. Desktop teleoperation via the World Wide Web[C]// Robotics and Automation, 1995. Proceedings. 1995 IEEE International Conference on. IEEE, 1995.
- [2] M.V.Sreenivas Rao, Dr.M.Shivakumar. Overview of Battery Monitoring and Recharging of Autonomous Mobile Robot[J]. International Journal on Recent and Innovation Trends in Computing and Communication, 2018, 6(5):174-179.
- [3] WALTER, GREY W. The Living Brain[M]. New York: W.W. Norton & Company, 1963.
- [4] Ye, Chen. An optimal reactive navigation approach for mobile robots in unknown environments[D]. University of Nottingham, 2006.
- [5] Su K L, Liao Y L, Lin S P, et al. An Interactive Auto-recharging System for Mobile Robots[J]. International Journal of Automation and Smart Technology, 2014, 4(1):43-53.