Optimization Technology of Passenger Service System based on Railway Intelligent Robot

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Abstract. In the post-epidemic era, with the continuous increase of passenger flow in railway stations and people’s increasing attention to public health, traditional service methods such as meal delivery and ticket checking in railway stations cannot keep up with the rhythm of the times, and the transportation sector is facing how to solve the problem of contactless services. This product uses STM32F103 as the core controller to develop a multifunctional intelligent robot system for trains. The system uses A* and artificial potential field algorithms for path planning and obstacle avoidance, combined with integrated software services, cooperates with the cloud to record various data, and finally add intelligence. The power management system ensures that the system can safely, efficiently, accurately and lastingly complete functions such as online ordering, smart ticket checking, temperature measurement and crew call. On the basis of the existing technologies, this paper makes a little technical integration and innovation to complete an intelligent robot system.

Keywords: Multifunctional intelligent robot; path planning; software service; human-computer interaction.

1. Introduction
Facing the outbreak of the global epidemic, the railway station has become a high-risk area for the spread of infectious diseases as a place with a huge flow of people. Effective contactless service for station passengers is an important means to prevent the spread of the epidemic. At present, most of the services on the trains are too scattered and traditional, such as manual ticket checking and dining car service. Manual ticket checking requires a large amount of manpower, time-consuming, and easy ticket evasion. The small amount of food served by dining cars and narrow train aisles can easily cause congestion, and human gatherings can easily cause the spread of the epidemic. Most passengers prefer to use the ordering app to order meals in advance, which makes it difficult to manage, the resources in the station are not used well, and the service content of manual services is single.

In view of the above problems, this project uses the relevant modeling knowledge to design a non-contact, multi-functional intelligent robot system, and proposes a brief idea to optimize the existing system to meet some needs during the epidemic period. Passengers can use operating software to select service content. The software sends data to the cloud platform server, and the server links the management system. After the preparation is completed, the robot system can accurately serve the passengers. Make management more convenient and serve passengers more quickly.
2. System Design Scheme

2.1. In Terms of Overall System Structure
The conceptual design of multifunctional robot system is shown in Figure 1. The system is designed as a regular rectangle, which is conducive to the evaluation of the impact range of the machine by path planning algorithm. The wheel used in the braking system is wheat wheel, which makes the system flexible. The system adopts multi hatch design, which can improve the efficiency of meal delivery. This product takes STM32F103 as the core controller. The overall structure of the system is shown in Figure 2. The system consists of control system, detection system, path planning system, meal delivery interaction system and cloud system. The cloud system receives the relevant instructions from customers and flight attendants, and transmits the information to the control system. The control system controls the path planning system and the detection system to complete the corresponding functions, and completes the information interaction with customers through the human-computer interaction system.

![Figure 1. Conceptual design of multifunctional robot system.](image1)

![Figure 2. Block diagram of overall system structure.](image2)

2.2. Strategy of System Movement

2.2.1. Optimization algorithm of multi machine optimal path. In the case of multiple obstacles and multi motion units parallel, the optimal path needs to consider the factors such as obstacle avoidance and multi vehicle collision prevention. Based on A * algorithm, this scheme adds a multi route parallel
optimization part, which can avoid other motion units while each moving unit is searching for the optimal route while avoiding obstacles.

2.2.2. **Random obstacle processing algorithm.** In practical application, the system not only needs to consider the optimal path problem under the static road network, but also needs to have the ability to deal with random roadblocks. On the basis of the artificial potential field algorithm, the boundary potential field and velocity potential field are introduced to the practical application scenario, and the expression form of the barrier repulsion potential field is optimized. The local minimum trap problem in the traditional artificial potential field method is solved, and the response ability of the system to random obstacles is improved.

Artificial potential field method is a very effective method in the local path planning algorithm. By simulating the force of the object on the system, that is, the target attracts the system and the obstacle repels the target, the resultant force acting on the system is calculated, and then the movement direction of the system is controlled. After topological abstraction of obstacle information and target point information in the train, the resultant force model generated by artificial potential field is defined as

\[ F = \{G, K, B, P\}, \quad \text{where } G \text{ is the resultant force set of the target point in the system path, } K \text{ is the resultant force set of the boundary of the system working area, } B \text{ is the resultant force set of the static obstacles detected when the system is working, and } P \text{ is the resultant force set of the dynamic obstacles detected when the system is working.} \]

It should be noted that G K B is a directed function which depends on the polar coordinates of the target point and the obstacle relative to the system, that is, the relative angle and relative distance of each point relative to the system, while P is a directed function depending on the polar coordinates of the obstacles and the velocity relative to the system.

2.2.3. **Algorithm collaboration mode.** The obstacle information obtained from the artificial potential field algorithm is synchronized with the A* algorithm in real time to assist it to adjust the path in time when new obstacles are introduced. At the same time, after the A* algorithm obtains the optimal path solution, it sets the intersection point of the path and each carriage as the target point, and generates gravity on the system. The system can update the optimal path in real time, and can still follow the planned path when avoiding obstacles. Through modeling experiments, the two algorithms can solve some problems that can not be solved by artificial potential field algorithm.

2.3. **Machine Vision**

2.3.1. **Obstacle recognition algorithm.** In the path recognition algorithm mentioned above, the orientation and plane distance of the obstacles are very important. The stereo matching of obstacles in two cameras can be completed by measuring the gray similarity under different parallax. The gray similarity can be expressed as

\[ C(x_i, y_i) = \begin{cases} \frac{|I_L(x_i) - I_R(y_i)|}{T} & |I_L(x_i) - I_R(y_i)| < T \\ \frac{|I_L(x_i) - I_R(y_i)|}{T} & |I_L(x_i) - I_R(y_i)| \geq T \end{cases} \]

The smaller the value is, the higher the similarity is. In a certain range, the points with the best matching cost (even if \( C(x_i, y_i) \) value is the minimum) are selected as the corresponding matching points. The gray correlation in the normalized cross-correlation matching method can be expressed as

\[ C(x, y, d) = \frac{L(x+i, y+i) - L(x+i, y+i)}{|L(x+i, y+i) - L(x+i, y+i)|} \frac{R(x+d+i, y+i) - R(x+d+i, y+i)}{|R(x+d+i, y+i) - R(x+d+i, y+i)|} \]

The smaller the value is, the higher the similarity is. In a certain range, the points with the best matching cost (even if \( C(x, y, d) \) value is the minimum) are selected as the corresponding matching points. The relative distance and angle of the matching obstacles can be calculated simply by using the similar triangle.

2.3.2. **Face recognition algorithm.** The system uses Haar operator to realize face detection. Cascade classifier based on Haar feature is an effective method for object detection. Face detection works by using Haar cascade feature detector on the image. First of all, read the cascade model file, and then gray-
scale processing of the input image, and use the cascade and model file to predict the image, and finally return the position of the face, and add the face data to the database, and take it as the target of feature detection. Since the face information of all the ticket buyers has been stored in the railway ticket checking database, the system can use this database for feature learning, and use LBP feature detection algorithm to analyze the features of the obtained face, and use SVM vector machine to classify the extracted feature vectors, and complete the recognition. For the constructed face database, 85% of the images can be used as training images, and the remaining 15% of the images can be used as test images. The training images can be extracted by using the recognition method provided by the invention, and the extracted feature vectors can represent the features of the face. The feature vector of the image is used as the input data of SVM binary classification method for supervised learning and used as the training data. When face recognition is needed, we use the program driver and call the camera. After the improved LBP Operator and support vector machine classification method, we can extract the current face features, and compare with the trained data, then we can complete the fast and simple face recognition.

3. Explanation of Path Planning Algorithm

3.1. Simulation of A * Algorithm Model for Multi Machine Execution
A * algorithm is one of the most effective large direct search methods to solve the optimal path in static road network. The implementation of the algorithm is mainly to continuously calculate the sum value of the surrounding walkable units, select the optimal next path by comparing the sum value, and so on to find the optimal path. The sum value is \( F(n) = G(n) + H(n) \). At the same time, two lists are needed to record all the blocks considered to find the optimal path (called the open list) and the blocks that will not be considered (called the close list). In order to calculate the g value, the system needs to obtain the g value from its predecessor, and then add 1. The g value of each block represents the total movement from the initial point to the path formed by the block, and the value H is the movement from the current block to the end point. In this algorithm, the system uses Manhattan formula \( R(n) = |dx + dy| \) to calculate the results. Therefore, the F value of each block, namely \( G + H \), can be obtained. Starting from the initial point, the surrounding walkable blocks are searched. Through the comparison of F values, the minimum f-value block is selected. Then, the next travel route is further selected based on the block, and the final route is the optimal solution. The results of Python simulation test are shown in Figure 3.

![Figure 3. Simulation results of A * algorithm model for multi machine execution.](image)

3.2. Improvement of Artificial Potential Field Algorithm
In practical application, the system not only needs to consider the optimal path problem under the static road network, but also needs to have the ability to deal with random roadblocks. In this paper, based on the artificial potential field algorithm, the boundary potential field and velocity potential field are introduced, and the expression of the barrier repulsion potential field is optimized. The local minimum trap problem in the traditional artificial potential field method is solved, and the response ability of the system to random obstacles is improved. The repulsive potential field formula of obstacle is as follows:
The formula of velocity repulsion potential field is as follows:

\[ U_{rev}(X) = \begin{cases} 
    k_v v_{or} \sin \theta & \rho(q, q_{obs}) \leq \rho_0 \cap \theta \in \left(\frac{-\pi}{2}, \frac{\pi}{2}\right) \\
    0 & \text{else}
\end{cases} \]  

(4)

The magnitude of the resultant force on the system is the sum of the vectors of all the component forces on the system as follows:

\[ F_{total} = F_{att}(q) + F_{r}(q) + \sum_{i=1}^{n} [F_{rew}(q) + F_{req}(q)] \]  

(5)

3.3. Algorithm Collaboration Mode

Figure 5 and Figure 6 show the experimental results after the algorithm cooperation. As shown in Figure 7, the obstacle information obtained from the artificial potential field algorithm is synchronized with the A* algorithm in real time to assist it to adjust the path in time when new obstacles are introduced. At the same time, after the A* algorithm obtains the optimal path solution, it sets the intersection point of the path and each carriage as the target point, and generates gravity on the system. Through modeling experiments, the two algorithms can solve some problems that can not be solved by artificial potential field algorithm.
4. Conclusion
According to the actual situation of the epidemic situation, this paper proposes an intelligent robot system on the train. According to the idea of mathematical modeling, the specific operation of each part is designed and tested by using A* algorithm and obstacle recognition algorithm. This paper focuses on avoiding obstacles and intelligent recognition, and briefly introduces human-computer interaction. The test results by using the modeling are basically consistent with the expected results, which achieves the purpose of the system design.

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