Robot automatic path-finding algorithm based on computer vision and neural network model

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ABSTRACT

Motion control of mobile robot is the premise of completing all tasks, and trajectory tracking control, as an extremely important part of motion control, is the basis for robot to complete all tasks. For different fields, the problem background and application scenarios faced by robots are different, but in any application scenario, it is necessary to ensure that the mobile robot can track a given trajectory or target quickly and stably in the process of motion control, so as to realize real-time trajectory tracking control. The path-finding method introduced in this paper is to optimize the traditional back propagation neural network (BPNN) from the perspective of structure and weight setting under the environment model established by grid method, and then, according to the characteristics of high-speed parallel operation of neural network, an automatic path-finding algorithm based on logical judgment and memory is proposed, which can achieve ideal results by combining it with the improved BPNN. The simulation results show that the algorithm can effectively overcome the influence of uncertain factors such as model error and external disturbance, and its trajectory tracking effect is better than the traditional trajectory tracking control algorithm.

Key words: Mobile robot; Automatic pathfinding; Computer vision; Neural network

1. INTRODUCTION

Robots are widely used because of their high production efficiency, high degree of freedom and adaptability to harsh production conditions. Mobile robot is not an independent individual, it is an integrated product of many disciplines, and its development can also promote the progress of other related fields[1]. Robot is not a humanoid machine in the ordinary sense, but an automatic control machine or program. Generally speaking, people call a machine controlled by a program, which can work instead of people and has some or some functions of people or creatures as a robot [2]. Mobile robot is a complex system, which has many functions such as environmental detection, command analysis, action control and execution. Robot technology not only represents the degree of industrial modernization in today's world, but also fully reflects the latest development level of human disciplines[3]. As a new tool of operation, production and service in today's society, it plays an important role in saving labor, optimizing production mode and improving the efficiency of economic development, and greatly reduces the danger in some special types of work [4]. According to different fields, the problem background and application scenarios faced by robots are different, but in the process of motion control of mobile robots in any application scenario, it is necessary to ensure that mobile robots can track a given trajectory or target quickly and stably in the process of motion so as to realize real-time trajectory tracking control [5].

With the progress of society, people hope that robots can move autonomously and serve human beings to a greater extent, so as to complete more complicated work and achieve more mission goals. Under such requirements, mobile robots have become a hot spot in robot control research. As a main research direction of mobile robots, the basic theoretical knowledge of trajectory tracking control has gradually matured, but efforts still need to be made in tracking accuracy, anti-disturbance ability and stability of nonholonomic constrained dynamic systems with unknown models [6]. The global planner plans based on the perceived map information. Because of the dynamic changes in the actual workspace of the mobile robot, the global path is usually divided into several local processes, and the local planner further plans based on the dynamic point cloud information [7].

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The role of intelligent bionics in automatic pathfinding is more and more obvious. As a representative, neural network is widely used in autonomous navigation and path-finding of robots [8]. Artificial neural network, which simulates human brain information processing mechanism to realize intelligent behavior, is the mainstream method of intelligent control. Therefore, the research on real-time adaptive control framework based on artificial neural network has very important theoretical research value. Traditional autonomous navigation of mobile robot needs to obtain the information of perceptual map in advance, that is, to plan navigation and control in a known environment. Aiming at the unknown discrete obstacle environment, this paper constructs a neural network automatic pathfinding algorithm to realize the vision-based main exploration scheme of the mobile robot, and automatically switches to the navigation function after sensing the environment to realize automatic pathfinding and tracking.

2. METHODOLOGY

2.1 Environmental modeling and information input

At present, the structure and existing forms of mobile robots are various, and the configuration mode is also very flexible. In order to be better used in life, it is necessary to solve the motion control problem of robots [9]. Therefore, establishing a suitable mobile robot model is not only the premise of designing neural network automatic path-finding algorithm, but also the basis of realizing the trajectory tracking control function of mobile robot. In the process of path finding, the robot needs to judge whether a fork in the road passes repeatedly, so as to choose a different direction from the last one, so the neural network is required to have certain memory characteristics. From the input layer to the output layer, the neurons in each layer are connected with each other; Each layer of neurons uses a relatively simple way to process information; The connection weights between layers reflect the learning ability and memory ability of neural network to external knowledge [10].

In the process of automatic path-finding, as the core component of neural network, the hidden layer's information processing scheme can be divided into two types: non-fork road and fork road, and the latter also includes two types of unfamiliar fork road and familiar fork road. After obtaining the environmental information, the neural network first judges whether it is a fork in the road, and if it is not, it simply outputs the heading direction according to the actual road conditions. If it is judged as a fork in the road, the information memory neuron of the fork in the road is further called, and the obtained information is compared with the current environmental information to judge whether it is a strange fork in the road. If it is, it randomly selects the direction not opposite to the route, and updates the fork information memory neurons. However, if you are familiar with the fork in the road, in order to remember all the coming directions and the selected heading directions when the robot repeatedly passes through the same fork in the road, in addition to the coming direction memory neurons, you must also add the coming direction memory neurons and the heading direction memory neurons responsible for memorizing relevant information [11].

From the perspective of using network structural parameters, the training process of BPNN is composed of the sum of the mean square error of each output node, and the neural network obtained in this way can be regarded as a compromise performance of different tasks [12]. It is considered that the sequential circuit can remember information briefly because it stores data through various self-feedback loops, thus generating the sequential function. However, if some neurons are given the ability to change the weight of the information transmission channel in the improved BPNN, the neurons connected by calling this channel again will read the information stored in the weight, so that the whole system has a good memory function. Improving the transmission principle of BPNN input signal to output signal is to realize information transmission by constantly adjusting the weights of hidden layer and output layer. This training process is beneficial to less influence between different task nodes, better training effect and full utilization of network resources.

2.2 Robot automatic pathfinding algorithm based on improved BPNN

In the network structure, the neurons in the previous layer and the neurons in the next layer are connected with each other, and the signals are transmitted between the layers with weights. If you want to change the network's ability to process signals, you can also achieve it by adjusting the weights. It is this unique connection that has formed a wide variety of neural networks. BPNN can contain any number of layers, and each layer can be set with any number of neuron nodes [13]. There is no uniform rule for the design of the number of hidden layers and neurons. Usually, the structure of neural network can be designed by trial and error or empirical method. As long as the effect of BPNN model can reach the expectation after training data, the design of network structure can be considered feasible. There are many kinds of information sensors in the robot itself, as well as data processing and decision-making modules, motion control modules, etc. The different modules are connected through the network system [14]. Among them, the sensor sensing module detects the illumination, noise and motion path of the external environment, and then transmits the obtained data information to the decision-making module to carry out a comprehensive analysis of a series of information such as target tracking, motion path and speed, and provide guidance for the subsequent autonomous navigation and automatic path-finding of the mobile robot. The training process of robot automatic path-finding BPNN model is shown in Figure 1.

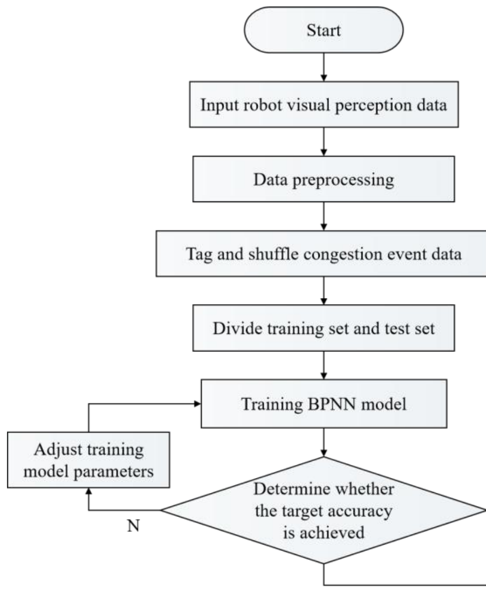

Figure 1. Training process of BPNN model for robot automatic pathfinding

In the process of being controlled, the studied system will inevitably be disturbed by the external environment, which is generally called constraint, and can usually be divided into complete constraint and incomplete constraint, and the system subject to incomplete constraint is called incomplete system. Integrity constraint is a geometric constraint, which limits the spatial position of the controlled system, including position, attitude and so on. The nonholonomic constraint is a kind of motion constraint, that is, it limits the motion speed of the controlled system, including angular velocity and linear velocity, and this motion constraint cannot be transformed into geometric constraint through integration. A system with only integrity constraints is called a complete system, and as long as the system contains any non-integrity constraints, it is called an incomplete system.

Trajectory tracking is to design a control rate so that the mobile robot can track the expected speed and posture with time as a variable. Without considering sideslip, the desired trajectory can be tracked by controlling the linear velocity and angular velocity of the center of mass of wheeled mobile robot.Through continuous learning and training, BPNN can find its regularity from a large number of robot visual perception data with unknown patterns:

$$m = \sqrt{x + y} + R(10) \tag{1}$$

Where m is the quantity of neurons in the hidden layer, x is the quantity of neurons in the output layer, and y is the quantity of neurons in the input layer. The roughness calculation stage of the set X is:

$$R^{-}(X) = \{U_2, U_3, U_4, U_5, U_7\} \tag{2}$$

$$R_{-}(X) = \{U_2, U_4, U_5\} \neq \varnothing \tag{3}$$

Therefore:

$$\rho(X)=1-\frac{|POS_C(X)|}{|R^-(X)|}=0.6 \tag{4}$$

If $X=\{U_2,U_3\}$, it is not definable because:

$$R^-(X)==\{U_2,U_3,U_5,U_7\} \tag{5}$$

$$R_-(X)=\left\{x\in U\,\middle|\,R(x)\cap X\neq\varnothing\right\}\neq\varnothing \tag{6}$$

In the fuzzy control system, the controller structure can be determined according to the number of input variables and the number of output variables of the path-finding algorithm. Specifically, according to the number of input variables, it can be divided into one-dimensional fuzzy controllers, two-dimensional fuzzy controllers and multi-dimensional fuzzy controllers, and according to the number of output variables, it can be divided into single-variable fuzzy controllers and multi-variable fuzzy controllers. Nonlinear dynamic adaptive inertia weight strategy is adopted to improve the performance of robot automatic path-finding algorithm. Its update status is as follows:

$$w(t)=w_{end}+(w_{start}-w_{end})\times\exp\left(-k\times\left(\frac{t}{t_{\max}}\right)^2\right) \tag{7}$$

Among them, k is the control factor; Control the smoothness of w and t curves. Calculate the total path index:

$$S_k=\frac{1}{F}\left(\frac{n+1}{h_y\cdot j}\right) \tag{8}$$

Where S_k represents the distance between the k waypoints; 1/F stands for the return distance of the robot after the task is completed; $h_y\cdot j$ is the adjustment coefficient of the total path; n is the total path index value.

3. RESULT ANALYSIS AND DISCUSSION

Trajectory tracking control is an indispensable part in solving the problem of robot motion control, and it is also the key to determine whether the robot can complete the specified task. Because of the strong nonlinearity of mobile robot system and its inherent nonholonomic constraints, it is difficult to realize trajectory tracking control. Model predictive control is a model-based optimization control algorithm, which focuses on the predictive function rather than the form of the model, so nonlinear systems, transfer functions and step response models can all be used as models of the algorithm to calculate the future output of the system. In order to collect reliable data different from this model in the model training stage, a trajectory tracking algorithm based on traditional control method is constructed by using sliding mode control method. The algorithm only needs to design a discontinuous control function according to the kinematics model of the controlled object and make it reach a stable state, so as to obtain the motion control quantity to control the robot to track. In order to verify the effectiveness of the algorithm, simulation should be carried out based on Matlab software. The processing of removing outliers from the visual perception data of the mobile robot is shown in Figure 2.

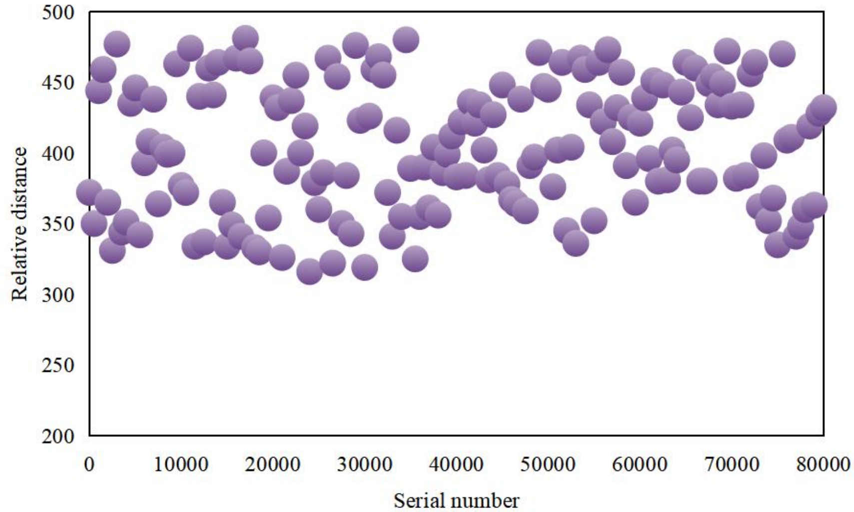

Figure 2. Processing of removing outliers from robot perception data

Using these data, the improved BPNN is trained and better network weights are obtained. Then substituting the obtained network weights into BPNN can become the basic model of automatic path-finding for mobile robots. The mobile robot system is a nonlinear system with two inputs and three outputs. In order to realize the trajectory tracking control of the mobile robot, it needs to be accurately modeled.

The training methods of the output layer and the hidden layer of improved BPNN are different. The hidden layer adopts nonlinear optimization strategy to adjust the connection weights and thresholds online based on the radial basis function of neurons, while the output layer adopts linear optimization strategy to adjust the connection weights and thresholds online based on the linear function of neurons. In the practical application of the algorithm, we constantly explore how to improve the algorithm to achieve better search results. Under the reinforcement mechanism, when the event that the iterative process fails to optimize the optimal sequence is triggered continuously and reaches a preset threshold, the currently obtained optimal sequence will be used as the initial sequence for the next iteration. The training result of the algorithm is shown in Figure 3.

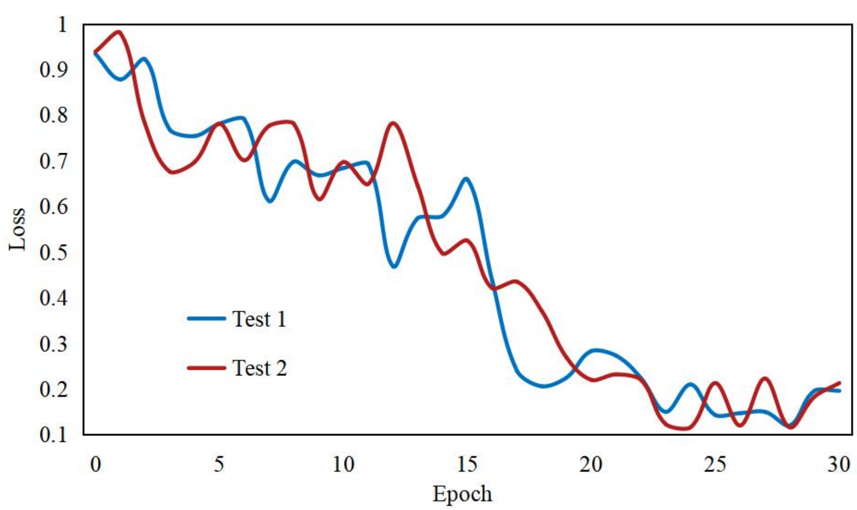

Figure 3. Training results of the algorithm

The improved BPNN used in the algorithm plays a very good role in optimization, and at the same time, it designs the existing models and plans the selection of crossover and mutation operators. Adopting the automatic path-finding algorithm based on logical judgment and memory can make the whole robot automatic path-finding system predictive and adaptive to robot trajectory control.

In order to complete the optimization control task, the prediction function of BPNN model mainly relies on historical input and output information and future input information to predict the future state or output of the model. The performance experiments of automatic routing algorithm are carried out under different transaction sets, and the routing errors of different algorithms are compared as shown in Figure 4. The comparison of path-finding accuracy of different algorithms is shown in Figure 5.

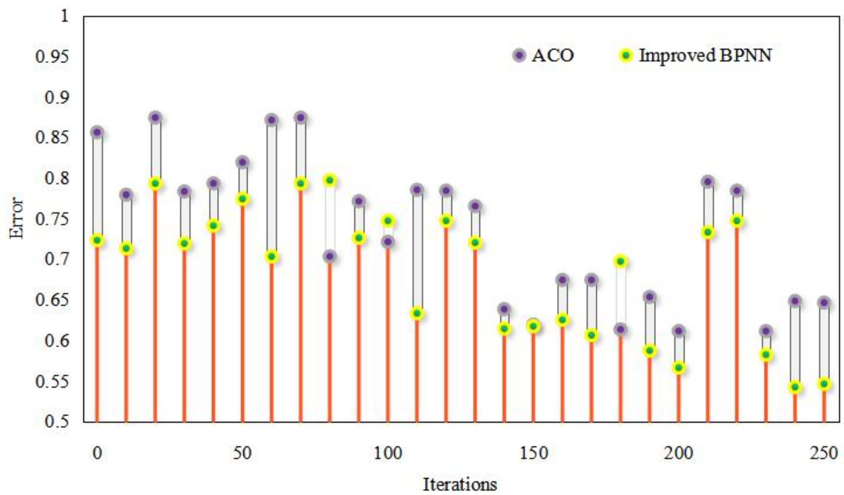

Figure 4. Path-finding errors of different algorithms

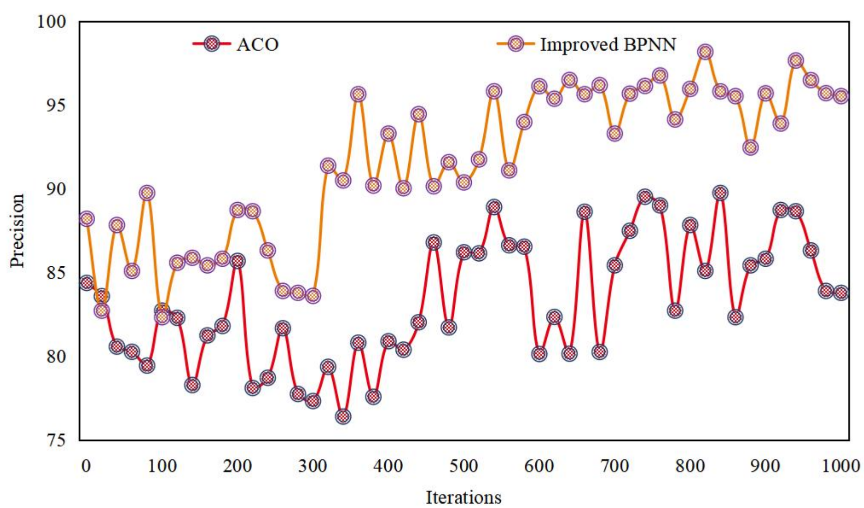

Figure 5. Path-finding accuracy of different algorithms

Experiments show that the automatic path-finding algorithm based on improved BPNN has small errors and excellent accuracy, which can reach more than 96% after repeated iterative evolution. Based on the error and precision of different algorithms, it can be seen that the performance of the robot automatic path-finding algorithm in this paper is relatively good. When the problem becomes complex, the possibility of finding the optimal solution by automatic path-finding algorithm will decrease, which requires adjusting the parameters in BPNN. Under the same disturbance, compared with the general automatic path-finding algorithm, the method proposed in this paper has faster tracking speed, and has certain reference value for other nonholonomic systems on the basis of satisfying convergence and stability.

4. CONCLUSIONS

According to different fields, the problem backgrounds and application scenarios faced by robots are different, but in any application scenario, it is necessary to ensure that the mobile robot can track a given trajectory or target quickly and stably in the process of motion control, so as to realize real-time trajectory tracking control. The role of intelligent bionics in automatic pathfinding is more and more obvious. As a representative, neural network is widely used in autonomous navigation and path-finding of robots. Artificial neural network, which simulates human brain information processing mechanism to realize intelligent behavior, is the mainstream method of intelligent control. In this paper, the traditional BPNN is optimized from the perspective of structure and weight setting, and then an automatic path-finding algorithm based on logical judgment and memory is proposed according to the characteristics of high-speed parallel operation of neural network. Combining it with the improved BPNN, the automatic path-finding can achieve ideal results. The improved trained BPNN and model predictive control are used to solve the quadratic optimization problem of the path-finding algorithm, that is, to solve the optimal control quantity of each step of the mobile robot, with the goal of tracking the expected trajectory. Finally, compared with the traditional trajectory tracking control algorithm, it is verified that the algorithm not only has accurate modeling, but also has good tracking control effect. Theoretically, this path-finding method can find exits in various maps, especially in the case that all environmental information cannot be obtained at one time, it will show strong path-finding ability.

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