Dynamic Path Planning of Needle-inserting Robot Based on Fuzzy Reasoning

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Abstract: The dynamic path planning problem of the needle-inserting robot has become a very classic network analysis problem, which requires not only a large amount of calculation, the more stringent parameter setting, but also a strong dependence on the starting value. All these shortcomings lead to difficult to achieve effective overall improvement. In order to improve the overall probability of the best solution, this aggregation program, which avoids search in attempt to finds part of the optimization, can effectively avoid the occurrence of roundabout detection. Search-avoiding has a strong ability in the spiral search, and can give out the actual path network and the set of nodes, so that evaluation can be carried out from the efficiency, invariance and accuracy. The results show that the accuracy of the fuzzy reasoning averaging algorithm for dynamic path planning the needle-inserting robot is 9% higher than that of the avoidance search method, and also the fuzzy reasoning has a good parallelization potential.

1. Introduction

Robot World Cup [1][2] is a form of football, through the competition to test new technologies in order to promote artificial intelligence, robotics and development projects of related areas; meanwhile, it also provides a broad platform to the robot hardware, software technology research. Robot soccer game is put forward in recent years of multi-agent system development platform, and it is a typical multi-agent robotic System. Soccer robot design has become the artificial intelligence and robotics research in the one of the hotspots field [3].

Soccer robot control system [4] [5] as an executive structure control system, the quality of its performance largely determines the outcome of the game; it directly affects the accuracy and flexibility of the robot motion, and the reliability of the whole system [6]. Because of the intelligence of soccer robot be designed at home and abroad is often not high, It can not meet the needs of the robot control system [7]. Therefore, the development of a high-performance control system has become an urgent desire [8].

The control system working environment is dynamic, and the other parties of the robots move are often unpredicTable. This requires the robot can not only control their players accurately, but also can actively control and track the ball [9]. The mobile robot design and manufacture technology, motor drive control, sensors and the requirements of the artificial intelligence are very high. Many researchers have been committed to perfect and improve the performance of the robot [10].

In this paper a new optimal design of soccer robot control system which is based on mechanical analyses and calculations on the pressure and transmutation states of chip kick mechanics, this new control system with high precision for speed control and high dynamic quality.

2. Fuzzy Reasoning Design Ideology and Implementation

2.1 Method Design

Avoidance search [4] is an overall step-by-step approach simulating short-term memory of the human brain. It uses avoidance criteria to avoid meaningless cycling calculations and can accept differential solutions based on contempt criteria to ensure that effective detection along the effective paths different ranges, with very strong partial search capability.

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Fuzzy reasoning is mainly used to overall improvement of large-scale and multi-objective functions. It can realize a kind of self-learning search from the point of view of multiple points and perspectives. The overall optimization ability is very prominent.

When the standard avoidance method [5] is adopted, the adjacent area is constructed by the simple moving operation. Because the obtained solution has high similarity, the ability of the method to avoid the optimal trap is affected. At the same time, in the case of fuzzy reasoning, the variation calculation unit leads to the generation of individual with new features, and the diversity of the path combination is enhanced. Therefore, the above two methods can be combined with the advantages of the characteristics to design the hybrid method [5]. In addition, taking into account the probability of occurrence is cross-cutting, and it is difficult to ensure the sustainable evolution of the population according to the behavior of mutation.

The fuzzy reasoning proposed in this paper first uses the genetic variation calculation unit as a diffuse scheme to construct the adjoining area, which thus can make the individual of the population have a wide distribution in most areas of the solution range. In this way, it can ensure the good optimization ability of whole method, and then the aggregation program determined is the avoidance search method to partly improve the mountain-climbing. In this way, part of the previous best solution has been broken through and can effectively avoid premature convergence. In the diffuse decision fully reflects the group will only, the scope of the diversity of diversity can be greatly increased, and the aggregation program can be used to promote effectively improve the overall implementation, and greatly increase the overall solution of the possibility [6]. In addition, with the increasing number of iterations, the diffuse decision forms an effective constraint on the aggregation decisions. Through this interaction, it is possible to effectively enhance the internal competition mechanism so that the similar best solution can be obtained.

Fitness function: the indicator can be used to conduct an effective analysis on the quality of the loop, in general, the evaluation of individual fitness is based on the path length. As shown in equation (1), the formula for calculating the length of the first X path, $\mathrm{dis}(\bullet)$ represents the distance between two adjacent points, and $C_{n(i)}$ represents the first i point

$$\mathrm{Len}(x)=\sum_{i=1}^{N}\mathrm{dis}\left(C_{n(i)},C_{n(i+1)\bmod N}\right) \quad (1)$$

Adjacent area: When the point positions of initial loop path are changed, a new loop set is generated, which is called the adjacent area. The variance calculation unit with the GA method can promote the increasing diversity of the solution range. In this paper, in order to improve the adjacent area structure effectively and to promote the effective range expansion of the partial search, a variety of methods are adopted for the construction of adjacency area of the original loop, including the reverse order, exchange, shift and other operation to the variation calculation unit.

Move: A move refers to the optimal loop when the initial loop moves to its adjoining zone, and the initial loop of the next iteration is the final move adopted.

Candidate solution set refers to the subset of adjacent regions of the initial loop. The selection of the computing unit can probe into the most likely search scope, so the elite selection method is used to improve the speed of avoiding the search in this paper, that is, to determine the optimal 10 loop in the adjacent area, as a candidate solution set for avoidance search.

Avoidance Table: mainly used to store the avoidance object data structure Often, the object is not selected as a new solution, mainly in order to avoid the emergence of circular search, or call occurrence of some of the best solution.

Contempt criteria: means that if the optimal object obtained by candidate solution aggregation is better than the best solution of history, then although the object is avoided at this time, the best solution of history can still be replaced by it, thus becoming the initial value of the next iteration, that is, the amnesty treatment of the object at this time [7]. In addition, if all the objects in the candidate solution aggregation are avoided, then the optimal candidate solution will be chosen for amnesty.

2.2 Implementation Method

Figure 1 shows the detailed implementation of the fuzzy reasoning method in this paper.

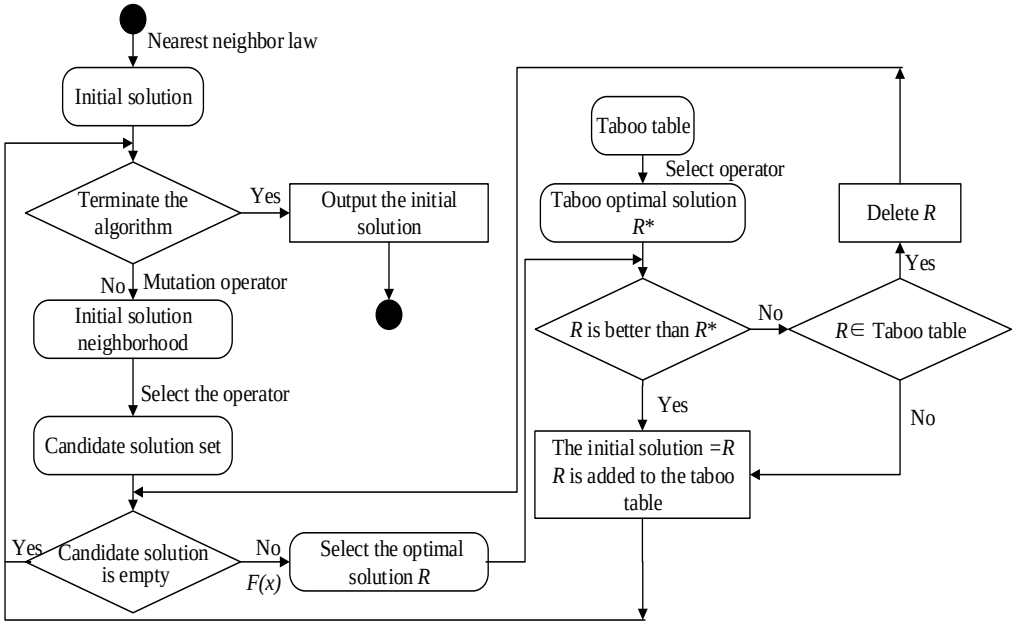

Figure 1. Fuzzy reasoning specific process

Since the optimal avoidance object may be deleted during the search process, the candidate solution set is not completely avoided, and if the candidate set is empty set at this time, it will search within the range of the last initial solution.

3. Test results

In order to verify the correctness of the theoretical research, this chapter will study on the needle-inserting and the path planning. Firstly, use the symmetrical needles for puncture test, and then use force sensors to collect the friction data during the experiment and processing, where the unit length of the needle friction f (x) is obtained for experiment in order to obtain the experimental data of the tip deflection. Path planning experiment. According to the established needle deflection model, the target point is selected is optimized. And then, the experimental results are compared with the theoretical values to verify the path planning model. Figure 2 is the puncture force curve of the needle puncture for bionic tissue, the friction in one unit length of f (x) = 0.006024, and needle deflection model is used to obtain the tip track curve. Based on the above-mentioned tip trajectory prediction curve, two targets were chosen for simulated rout planning. And the target coordinates are G1 (80, 60, 80), G2 (65, 70, 50), and the path planning results are obtained.

The six-dimensional wrist force sensor is used to collect the needle puncture force data and the retracting force data, and the contact stiffness of the needle per unit length is obtained. The theoretical data of the needle deflection are calculated according to the needle deflection model and the theoretical value of the tip trajectory is obtained on basis of it. The real-time tip trajectory in the experiment was acquired by the camera and is processed by Matlab image processing to obtain the tip trajectory of the experimental data. The results show that the needle-specific model based on virtual nonlinear spring support can accurately predict the deflection of the needle, where the maximum absolute error is less than 0.4mm and the average absolute error is less than 0.2mm.

Based on the needle deflection model, the experiment on the route planning of needle-inserting is carried out and the needle trajectory curve is obtained. Two targets are selected, and the optimal path points and the depth of the needle are obtained by the path planning algorithm. Based on the optimal path parameters, measure the actual target position, and then compare with the target locations. The results show that the proposed algorithm based on needle deflection model is simple and effective. The maximum error of target puncture is less than 1.2mm, and the average error is

less than 0.9mm, which meets the requirements of interventional operation.

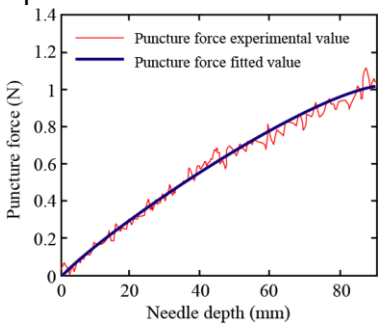

Figure 2. Puncture Force Curve

4. Conclusion

In this paper, we design a fuzzy reasoning method for solving the dynamic path planning problem of need-inserting robot. In this method, part of the detection is implemented to effectively improve the convergence rate of the algorithm. Compared with the simple avoidance search and method, provided that they all have the same solution accuracy, then this method can get better operating efficiency, stronger robustness, and better invariance. In the follow-up research work, it is necessary to strengthen the adaptability of the method of nodes set with different distribution proposed in this paper. At the same time, it is necessary to strengthen the positive transformation and optimization of the algorithm to improve the use efficiency of computational resources, and thus to greatly promote the efficiency improvement of the method.

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References

[1] Algorithm S A G, A F L. The Robot Path Planning Based on Improved Artificial Fish Swarm Algorithm [J]. 2016, 2016(11):1-11.

[2] Yo Kobayashi, Akinori Onishi, Hiroki Watanabe, et al. Developing a method to plan robotic straight needle insertion using a probability-based assessment of puncture occurrence[J]. Advanced Robotics, 2013, 27(6):417-430.

[3] Zoumponos G T, Aspragathos N A. Fuzzy logic path planning for the robotic placement of fabrics on a work Table[J]. Robotics and Computer-Integrated Manufacturing, 2008, 24(2):174-186.

[4] Igarashi T, Stilman M. Homotopic Path Planning on Manifolds for Cabled Mobile Robots[J]. Springer Tracts in Advanced Robotics, 2010, 68:1-18.

[5] Vancamberg L, Sahbani A, Muller S, et al. Needle Path Planning Method for Digital Breast Tomosynthesis Biopsy Based on Probabilistic Techniques[J]. Lecture Notes in Computer Science, 2010, 6136:15-22.

[6] Cowan N J, Goldberg K, Chirikjian G S, et al. Robotic Needle Steering: Design, Modeling, Planning, and Image Guidance[M]// Surgical Robotics. Springer US, 2011:557-582.

[7] Elsheikh E A, El-Bardini M A, Fkirin M A. Practical Design of a Path Following for a Non-holonomic Mobile Robot Based on a Decentralized Fuzzy Logic Controller and Multiple Cameras[J]. Arabian Journal for Science & Engineering, 2016, 41(8):3215-3229.