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Research on Path Planning of Industrial Robots based on Improved Swarm Algorithm

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Abstract. In this paper, a trajectory optimization method of intelligent is designed. Firstly, genetic algorithm based on genetic evolution is used to get the initial value of the population. Path length, number of turns and energy consumption of the moving manipulator were used as evaluation parameters. A new adjustable crossover and mutation operator is proposed. Finally, genetic algorithm, Artificial bee colony algorithm is used to evaluate the proposed method for trajectory optimization of mobile robots. The results can effectively prevent the local minimum, reduce the time spent in the process of robot movement, and greatly improve the efficiency of the motion trajectory.

Keywords: Improved Bee Colony Algorithm; Industrial Robots; Path Planning; Adaptive Genetic Algorithm; Combinatorial Optimization.

1. Introduction

Online shopping platforms represented by Taobao, Jingdong and Pinduoduo have risen rapidly. With their operational capabilities and service quality. At present, the research of intelligent warehouse optimization has become a hot spot, and the picking route planning of warehouse robot is a key step of warehouse optimization. At present, scholars at home and abroad mainly use intelligent algorithms such as genetic algorithm (GA) to optimize route planning of multiple target points. Some researchers have combined PSO with genetic algorithms to find the best locations for the best particles to achieve better results [1]. Some studies have shown that the objective function of conflict probability evaluation is introduced into non-conflict path optimization to speed up the convergence and convergence of the algorithm. Some scholars have adopted A hybrid dynamic window algorithm based on A-* to realize real-time avoidance of random obstacles. Some scholars have established a path optimization model based on the shortest path and turning Angle to make the robot's motion trajectory smoother. This paper introduces a trajectory optimization method of mobile robot based on genetic algorithm, and combines it with directed search method. Some researchers use hybridization operators to eliminate multiple paths, thereby improving the optimization ability of the population. Some researchers have designed a population-based transfer mechanism to replace traditional population-based screening, thus improving the performance of the model [2]. Some researchers have proposed an improved chaotic genetic algorithm. The initial group selection method based on probability is proposed. Aiming at the problems existing in the walking process of the mobile robot arm, this paper adopts a variable step size optimization method based on ant colony clustering. The convergence of a new gene optimization method and a new immune cloning operator has been improved greatly. Some researchers have proposed an adaptive genetic algorithm based on inversion operators. There are many problems with these algorithms. It is ignored that excellent individuals are difficult to change the evolution, and in the selection process, only the individuals with the best adaptive value are usually selected, which leads to the algorithm easily falling into the local extreme value. Aiming at the operational problems in warehouse operation, this paper studies the artificial beehive gene algorithm [3]. Firstly, the population initialization method based on genetic algorithm is adopted. The path optimization model is established with three indexes, including path length, number of turning nodes and energy consumption of path operation, as evaluation indexes. A new global optimization method is proposed for path length, turning node and energy consumption.

2. Hybrid Improved Artificial bee Colony Algorithm

2.1. Improvement of Food Source Updating Formula

In the standard bee colony algorithm, honeybees and observation bees search and update the honey source near the honey source. However, this update is only based on the random selection of other nectar sources in the vicinity of the current nectar source, which will cause the information between individuals to be not fully utilized, resulting in weak local search ability and poor population elimination effect of the algorithm. Therefore, it is considered to introduce the current optimal honey source position x_{bestj} into the food source update formula [4]. According to the linear combination distribution theory, the distribution $Levy$ meets the stable distribution with heavy tail, which has the characteristics of both normal distribution and Cauchy distribution, and can generate appropriate step size. When the evolution is trapped in the local optimal, random numbers following the $Levy$ distribution can guide individuals to jump out quickly, so that the algorithm has a better global search ability. The food source renewal formula after the introduction of $Levy$ distribution can be expressed as:

$$u_{ij} = x_{ij} + Levy(\alpha)(x_{bestj} - x_{kj}) \tag{1}$$

x_{bestj} indicates the optimal location of the current nectar source. $Levy(\alpha)$ represents the $Levy$ distribution corresponding to x_{ij} with an obedience index of α, That is: :

$$Levy(\alpha) = \frac{1}{\upsilon}\int_0^{\infty} \cos(tr)e^{-\kappa t^{\alpha}}dt, (0 < \alpha \le 2) \tag{2}$$

Where, κ=1 is usually set. Because the step size generated by $Levy$ distribution is relatively complex, the symmetric Levy stable distribution can be realized by Mantegna algorithm. Formula (3) is used to calculate the step size:

$$Levy(\alpha) = f / |g|^{1/\alpha} \tag{3}$$

The range of α values is the same as above, and $\alpha = 1.5; f, g$ usually means that it follows a normal distribution.

$$f \sim N(0, \sigma_f^2), g \sim N(0, \sigma_g^2) \tag{4}$$

The σ_μ and σ_g expressions are as follows:

$$\sigma_\mu = \left\{ \frac{\Theta(1+\alpha)\sin(\upsilon\alpha/2)}{\Theta\left[(1+\alpha)/2\right]\alpha 2^{(\alpha-1)}/2} \right\}^{1/\alpha}, \sigma_g = 1 \tag{5}$$

Θ represents the standard Gamma function. The food source renewal formula is:

$$g_{ij} = x_{ij} + \frac{f}{|g|^{1/\alpha}}(x_{bestj} - x_{kj}) \tag{6}$$

2.2. Improvement of Random Search Strategy

The scout bee randomly is x_i according to the formula of the random search strategy. Because the solution randomness generated by the formula is too strong, the algorithm extreme value in the optimization process [5]. In order to overcome this defect, a Cauchy distribution is introduced, and the random transformation $rand(0,1)$ is replaced by a Cauchy mutation operator $\varepsilon(0,1)$. The

Cauchy mutation operator enables the formula to make full use of the information currently searched and increases the anti-disturbance ability of the algorithm. The improved random search formula is as follows:

$$x_i^j = x_{\min}^j + \varepsilon(0,1)(x_{\max}^j - x_{\min}^j) \tag{7}$$

3. Experimental Evaluation

3.1. Experimental Results

The motion trajectories in various cases are simulated by using GUI, and the actual motion trajectories are verified by experiments. In order to better simulate the spatial distribution of actual obstacles, a large number of blocky structures are introduced in this paper, which can effectively prevent robots from crossing obstacles caused by fewer obstacles [6]. Under the same path length, smoothness and survival rate, the path optimization strategy of reaching the end point first was adopted, and compared with the traditional path optimization strategy. Figure 1 shows a trajectory design method for a mobile robot arm.

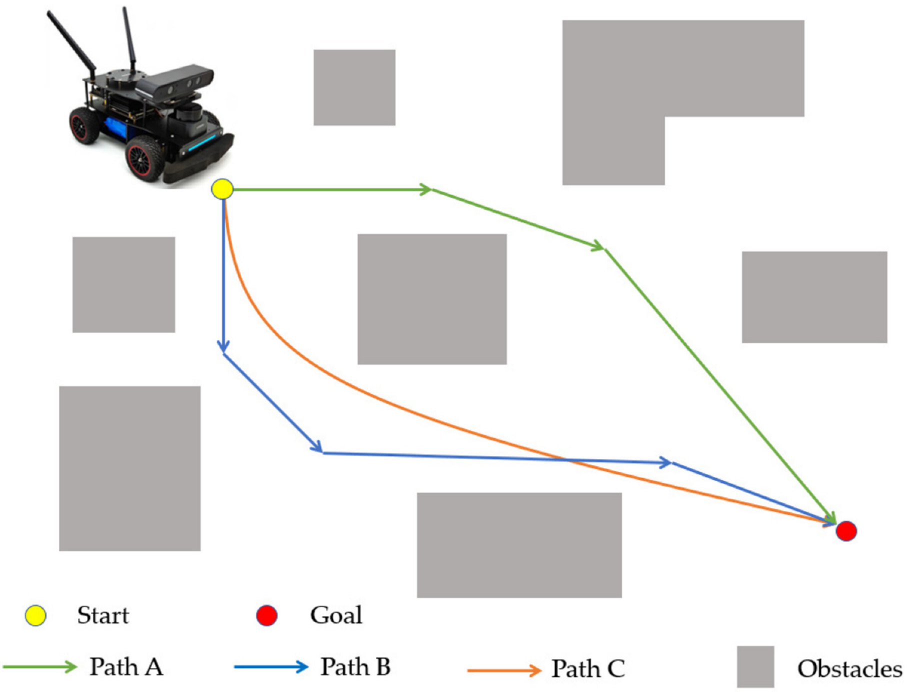

Fig 1. Path planning of mobile robot

3.2. Algorithm Performance Indicators

3.2.1. Evaluation Parameters

The number of bees is NPs, the optimization parameter is iterMax, and the algebra value is 3. Among them, the number of honey sources NP is the number of points selected in the solution space of the problem, and this parameter has a certain influence on the effect of the algorithm, but there is no significant change. The optimization parameter iterMax is the maximum number of iterations [7]. As this coefficient increases, so does the number of iterations. However, after testing, the performance of the algorithm gradually flattens out when it is greater than 200.

The cost function for path update is defined as:

$$g_{\cos t} = \| P_{t\arg et} - D_{curpos} \|_2^2 + (\lambda P_{coll} + g_{old\cos t} + L_{ct}) \bullet \frac{1}{2}\sqrt{U_x^2 + U_y^2} \tag{8}$$

$P_{t\arg et}, D_{curpos}$ is the target position point and the current position point respectively. $\|\bullet\|_2^2$ stands for 2 norm squared. λ is to control the number of particles around the obstacle. $P_{coll}, g_{old\cos t}, L_{ct}$ is the location of the obstacle, the cost function value before the update, and the distance between the obstacle and the target object. U_x, U_y is used to prevent paths from crossing obstacles, that is, $\frac{1}{2}\sqrt{U_x^2+U_y^2}$ is the diagonal distance to avoid obstacles during path planning [8]. In reality, the number of particles around the obstacle is too much or too much, which will cause the difficulty of finding the way. A trajectory plan with the number of fence edge particles of 3000, 6000 and 9000 is shown in Figure 2 (image cited in Mobile robot path planning using artificial bee colony and evolutionary) programming). The number of particles around the fence was set to 6000, and the experiment was compared and analyzed.

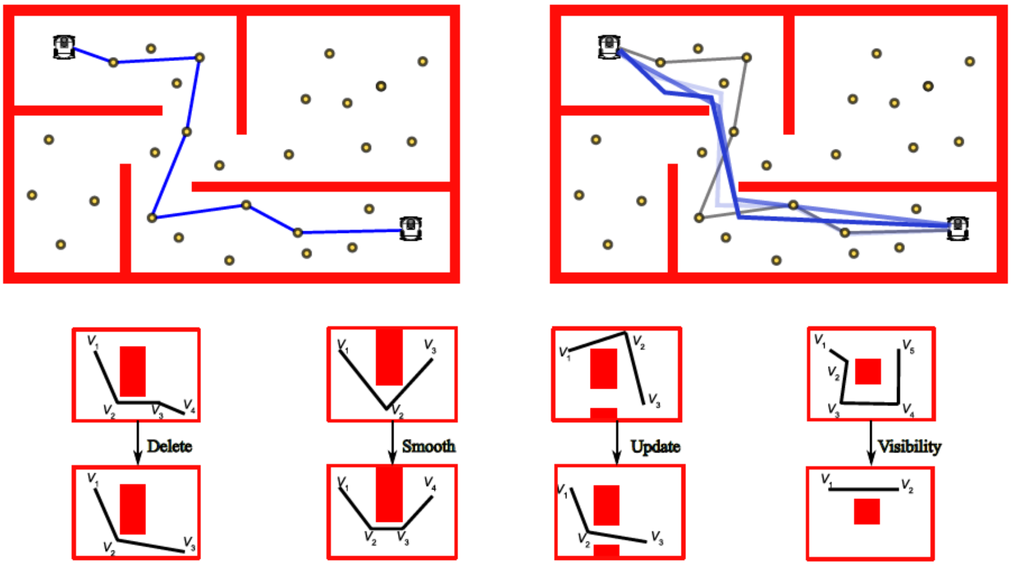

Fig 2. Path planning analysis

3.2.2. Performance Comparison

The paths of the robot planning experiments based on genetic algorithm, $B*$ algorithm and classical artificial bee colony algorithm are compared. In the robot path planning experiment of algorithm $B*$, the evaluation function $g'(n)$ is:

$$g'(n) = s'(n) + f'(n) \tag{9}$$

$s'(n)$ and $f'(n)$ are shortest path heuristic values to the goal, respectively. The distance between the Cartesian coordinates $L_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}, (x_i, y_i)$ and (x_j, y_j) are the position coordinates of the moving object. When $f(n) \le f'(n), f'(n)$ is usually replaced by $f(n)$, and the information of $f(n)$ is usually obtained by the constraints when estimating the value of the node. When there is more information and more constraints, more nodes will be eliminated, better evaluation function, better algorithm. It's going to take more time, more time [9]. The cumulative loss function of the genetic algorithm and the final evolution state is shown in Figure 3. As can be seen from Figure 4, under different crossover probabilities, the number of evolution has a great influence on particle selection, and it is not linear, and the state convergence is fastest when the crossover probability is 0.7. Therefore, the experiment set the population size of genetic algorithm as 40, the maximum genetic algebra as 50, the individual length as 20, the gap is between 0.95 and 0.7. A* method was used to carry out the track planning, and the tabular data are shown in Table 1.

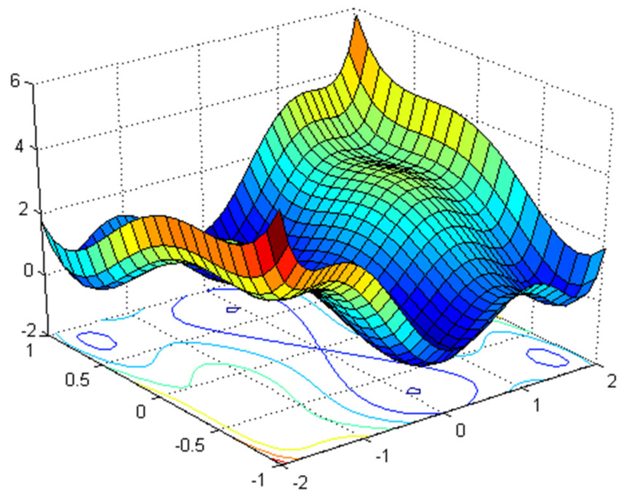

Fig 3. Cumulative loss function space

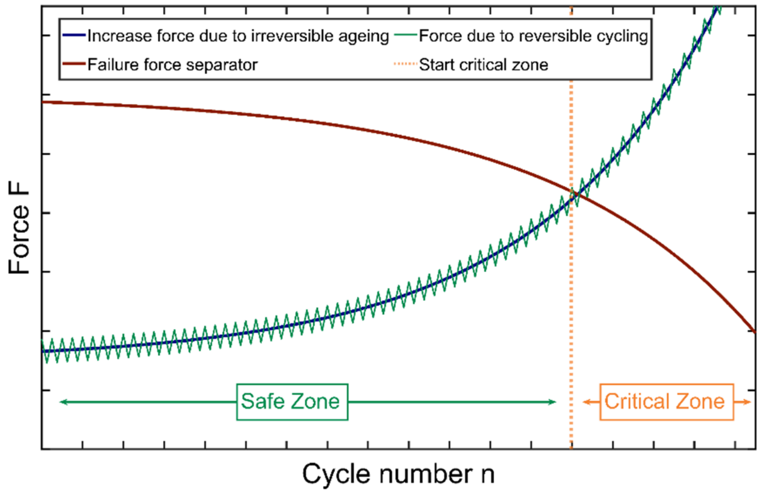

Fig 4. The relationship between microparticle selection and evolution time under different hybridization probabilities

Table 1. Time and length of path planning

run times	GA algorithm		A* algorithm		Classical swarm algorithm		Improved swarm algorithm	
	Length	Time /s	Length	Time /s	Length	Time /s	Length	Time /s
1	27.34	7.86	26.82	5.96	26.86	6.68	26.78	5.95
2	28.39	8.18	26.79	6.02	26.86	6.70	26.78	5.97
3	27.55	8.25	26.82	5.98	26.86	6.72	26.78	5.99
4	27.55	8.28	26.79	6.02	26.88	6.79	26.78	5.96
5	27.66	8.07	26.79	5.95	26.86	6.70	26.78	5.93
6	27.66	8.39	26.79	6.02	26.86	6.75	26.78	5.99
7	27.34	7.83	26.79	6.02	26.88	6.81	26.78	6.00
8	27.55	8.25	26.79	6.02	26.86	6.69	26.78	6.01
9	27.34	7.81	26.79	6.02	26.88	6.81	26.78	6.00
10	27.55	8.23	26.79	6.02	26.86	6.70	26.78	6.02
Mean value	27.56	8.11	26.80	6.00	26.86	6.74	26.78	5.99

According to Table 1, compared with genetic algorithm, A* algorithm and classical bee reduces the calculation of path length by 2.83%,0.08% and 0.31% respectively, while the corresponding time loss decreases by 26.19%,0.17% and 11.13% respectively. A* method is a classical heuristic optimization method, which can get the optimal result in theory, but it needs a lot of computing time. In the absence of A viable route, the A* method will exhaust all possible scenarios. However, this method only needs to plan the particles and does not need to gather all the particles together, greatly saving computational time. It is particularly suitable for large scenes and has more significant advantages. The results indicate that this method can obtain more optimization results, indicating its feasibility.

4. Conclusion

On this basis, a new method for solving objective function optimization problems is proposed. A new intelligent swarm algorithm was adopted for path planning of industrial robots. Finally, an example was used to demonstrate the correctness of this algorithm. Experiments show that in the iterative process, the proposed method will continuously optimize the route, and finally will tend to the global optimal. In this method, the detection method is used to prevent bees from falling into the local minimization state, and the neighbor search method is used to gradually bring them closer to the minimization state. Through the random selection of the follower, the optimal configuration of the guide individual is realized.

References

[1] Wei Bo, Yang Rong, Shu Sihao, et al. Path planning of mobile robot based on ion motion-artificial bee colony algorithm. Journal of Computer Applications, Vol. 41(2021) No. 2, p.379-383.

[2] Li Yan-Sheng, Wan Yong, Kuang Hengyang, et al. Path planning method of warehouse robot based on artificial bee swarm-adaptive genetic algorithm. Chinese Journal of Scientific Instrument, Vol. 43(2022) No. 4, p.99-103.

[3] Ren Xinlei, Xu Jianlei, Chen Haihui, et al. Research on robot path planning in 3D environment. Sensors and Microsystems, Vol. 41(2022) No. 8, p.14-22.

[4] Wang Yuan-Guo, YU Hai-Bing, Li Yun-Chen, et al. Path optimization strategy design of nuclear power inspection robot based on improved artificial swarm algorithm. Electronic Design Engineering, Vol. 31(2023) No. 6, p.70-74.

[5] Yao Jiangyun, Wu Fangyuan. Robot trajectory planning based on hybrid search swarm algorithm. Automation and Instrumentation, Vol. 37(2022) No. 10, p.40-43.

[6] Guo Fang, Chen Chen, Mi Yang, et al. Cable laying path planning based on artificial bee colony algorithm. Control Engineering, Vol. 30(2023) No. 3, p.74-77.

[7] Guo Zhen. Path planning of library service robots with improved ABC algorithm. Information Technology, Vol. 46(2022) No. 12, p.19-23.

[8] Pei Xiaobing, Wang Shihui. Research on multi-objective shop scheduling based on game artificial bee colony algorithm. Journal of Wuhan University: Engineering Edition, Vol. 56(2023) No. 3, p.92-99.

[9] Xia Xiaoyun, Zhuang Helin, Yang Huogen, et al. Adaptive large neighborhood search algorithm for vehicle routing problem with capacity constraints. Computer Integrated Manufacturing Systems, Vol. 28(2022) No. 11, p.3545-3557.