Research of Path Planning for Polishing Robot

Based on Improved Genetic Algorithm

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Abstract—The path planning for traditional polishing robot is teach-play-back method. That is, after adjusting offset errors, the polishing robot repeats the same fixed program in a pre-determined path. Obviously, fixed program makes transferring the robot to new operations difficult. In this paper, the path planning schemes based on improved genetic algorithm (IGA) are proposed. The encoding ways, crossover operator and mutation operator of genetic algorithm (GA) are researched. Simulation shows that this method of path planning for polishing robot is effective.

Keywords—polishing robot; path planning; genetic algorithm; heuristic search

I. INTRODUCTION

In the manufacturing field of polishing industry, polishing is a time-consuming and tedious job, and requires a considerable amount of high-precision skill. Some workers tend to gradually avoid the polishing work because of the poor environment caused by dust and noise. In order to reduce the polishing time and cope with the shortage of skilled workers, the polishing robots are developed [1-3]. However most of the current robots are tech-play-back robots. That is, after adjusting offset errors, these polishing robots repeat the same fixed program in a pre-determined path. Obviously, fixed program makes transferring the robot to new operations difficult. In recent years, robots control systems which integrate both visual sensors and robots together have received a lot of attentions, especially in the field of intelligent robots [4-7].

The path planning for polishing robot is a high complex nonlinear optimal problem. There are many traditional optimal approach to path planning (e.g. gradient decent [8], greedy [9], A* graph search algorithm [10], potential fields [11]). However, gradient decent is easy to run into local least points, graph search algorithm and greedy are limit to multi-dimensions optimal problem, potential fields are likely to lose some useful information of solution. In addition, traditional optimal approaches are short of enough robust in dealing with the complex nonlinear optimal problem of path planning for polishing robot [12].

GA is a random search algorithm based on Darwin’s evolutionism, which has more advantages to deal with complex nonlinear optimal problem than traditional search algorithms [13]. But there are some problems to path planning by traditional GA in complex environment. For example, reasonless designing of individual encoding result in lower evolution efficiency; evolution efficiency are not evident due to reasonless designing of crossover operator and mutation operator [14].

In order to overcome the problem of traditional GA, the scheme of combining heuristic search with traditional GA is proposed. This paper is organized as follows. Section II presents problem description. The path planning for polishing robot based on IGA are given in Section III. In Section IV, simulation results are provided to demonstrate the effectiveness of the proposed path
planning scheme. Conclusions are drawn in Section V.

## II. PROBLEM DESCRIPTION

Supposing the workpiece need to polish by robot with local nick, and the number of nick is \( n \), which is illustrated in Figure 1. After image processing, a binary image is depicted in Figure 2. Then after image grid processing, the grid with nick is shown in Figure 3, and the polishing center coordinates can be given in Table 1. Corresponding the no. of nick, there are the no. of local target starting point and end point. That is,

\[
\{ p_i \to p_{i1}, p_{i2} \to p_{i2}, \ldots, p_n \to p_{n1}, \ldots, p_m \to p_{mf} \} \quad i = 1, 2, \ldots, \ n
\]

where \( p_{si} \) is the no. \( i \) of nick starting point coordinate, \( p_{ei} \) is the no. \( i \) of nick end point coordinate, the length of local path between \( p_{si} \) and \( p_{ei} \) is fixed value \( d(p_{si}, p_{ei}) \).

### Table 1 The length and coordinates of Local path

<table>
<thead>
<tr>
<th>No. of nick</th>
<th>Starting point coordinates</th>
<th>Middle point coordinates</th>
<th>End point coordinates</th>
<th>The length of ( d(p_{si}, p_{ei}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(10, 50)</td>
<td>(30, 50)</td>
<td>(50, 30)</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>(30, 150)</td>
<td>(30, 130)</td>
<td>(30, 110)</td>
<td>40</td>
</tr>
<tr>
<td>3</td>
<td>(70, 90)</td>
<td>(70, 70)</td>
<td>(90, 70)</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>(110, 30)</td>
<td>(130, 50)</td>
<td>20 ( \sqrt{2} )</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>(110, 130)</td>
<td>(130, 130)</td>
<td>(130, 110)</td>
<td>40</td>
</tr>
</tbody>
</table>

The problem of global polishing path planning can be described as follows:

Searching the arrangement \( M(Z) = \{ m_1, m_2, \ldots, m_i, \ldots, m_{n} \} \) \((m_i \in Z)\) of this integral set \( Z = \{1, 2, \ldots, n\} \), make the length of global path least, where the no. \( n \) corresponding the no. \( n \) of nick.

## III. RESEARCH OF PATH PLANNING METHODS

### A. Genetic Algorithm

GA is a search procedures based on the mechanics of natural evolution. It use simple representations to encode complex structures and improve these structures by means of simple transformations. So it has the characteristic of simple, robust, parallelism, self-adaptive and self-learning [15-16], which can deal with complex nonlinear problem instead of traditional search approach.

The procedures of search the best optimal solution by GA is as follows.

1) Initializing populations \( P(t) \);
2) Computing the individual fitness of populations \( P(t) \);
3) Making new populations \( P(t+1) \) by selection, crossover and mutation operator;
4) Computing the individual fitness of populations \( P(t+1) \) and let \( t = t + 1 \);
5) If it can satisfy scheduled index, the optimal solution are attained. Otherwise, return 3).

Because the path planning for polishing robot is the characteristic of random and complex, the path planning efficiency isn’t desirable by traditional GA method. For example, reasonless designing of individual encoding
result in lower evolution efficiency; evolution efficiency are not evident due to reasonless designing of crossover operator and mutation operator. So sometimes the best path planning couldn’t be found.

### B. Improved Genetic Algorithm

In this research, real number encoding, heuristic crossover and mutation approaches are used, and are applied to path planning for polishing.

1) Improved individual encoding

The ways of individual encoding is real number encoding, the path individual are a series of points from starting points to aim points. i.e.,

\[ P = \{ P_s \rightarrow P_{s1}, P_{s2} \rightarrow P_{s2}, \ldots, P_a \rightarrow P_{af}, \ldots, P_m \rightarrow P_{mf} \} \]

The advantage of direct real number encoding is overcome the shortage of binary encoding, because polishing coordinate \((x, y)\) is a gene, and the length of individual is relative to polishing coordinate, so polishing coordinate \((x, y)\) can be mutated at the same time, which can extend search scope.

2) Defining Fitness Function

The fitness function is defined by the following formula,

\[
    f(x) = \frac{1}{\left( \sum_{i,j=1,i \neq j}^{n} d(p_i, p_j) + \sum_{i=1}^{n} d(p_i, p_{i+1}) \right)}
\]

where \( d(p_i, p_j) \) is the distance between the no. \( i \) nick and the no. \( j \) nick. \( d(p_i, p_{i+1}) \) is the length of local path. When polishing path has the shortest length, fitness function \( f(x) \) has the biggest value.

3) Improved crossover operator

Simple crossover operator is used where the crossover site is at a random intersection of randomly chosen couples. This random crossover operator cause that the possible solutions are at random sites. The search rate is too low to obtain a optimal path within a given time.

Heuristic crossover is a method which makes use of heuristic information from relative fields. Let

\[
    f(n) = \sqrt{(x_s - x_n)^2 + (y_s - y_n)^2}
\]

where \( f(n) \) is the distance between the end point of this nick polished and the starting point of the next nick polished, \( x_s, y_s \) is the starting point coordinate of the next nick polished, \( x_n, y_n \) is the end point coordinate of this nick polished. The way of heuristic crossover is illustrated in Figure 4.

![Fig. 4. The way of heuristic crossover](image)

4) Improved mutation operator

Simple mutation operator is random mutation, which can mutate only one “\( x \)” coordinate or one “\( y \)” coordinate. The mutation rate is too low to search efficiently unknown regions.

Heuristic mutation is a method which makes use of heuristic distance information. That is, computing the biggest \( f(n) \) value of this path, then obtaining the corresponding two points coordinates, canceling the local path between this two points by mutation operator. This way of heuristic mutation is illustrated in Figure 5.

![Fig. 5. Heuristic mutation](image)
IV. SIMULATION RESULTS

The path planning for polishing is simulated with the proposed IGA, and the effect of path planning by the two methods of GA and IGA are contrasted.

The result of path planning by GA is shown in Figure 6 and Figure 7, and the result of path planning by IGA is depicted in Figure 8 and Figure 9.

Where the parameters are chosen as follows: the population sizes are 30, the probability of crossover is 0.8, the probability of mutation is 0.1, and the same initial path is given to two methods.

In Figure 8, the biggest fitness value is 0.00227. However, the biggest fitness value in Figure 9 is 0.00229. It shows the effect of path planning by IGA is the optimal path, which is given in Figure 7, however the path in Figure 6 is the hypo-optimal path. In addition, the convergence generation by the method of GA is 35, comparing with the convergence generation by the method of IGA is 14. It proves IGA can improve the convergence speeds and attain the global optimal solutions.

V. CONCLUSION

The proposed path planning based on improved genetic algorithm for polishing robot has been implemented in this paper. Based on the problem description about polishing robot, the encoding ways, crossover operator and mutation operator of genetic algorithm are improved. The improved genetic algorithm has more advantages to deal with complex nonlinear optimal problem than traditional genetic algorithm in complex environment. The effectiveness of this method is proved by simulation experiments.

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References


