TELKOMNIKA, Vol.11, No.11, November 2013, pp. 6916~6921
e-ISSN: 2087-278X

Research on the Optimal Layout Problem for NC Machining Based on Improved Genetic Algorithm

Wang Shuqing[1], Lei Lei*[1], Wang Bing[2]
[1]School of Electrical and Electronic Engineering, Hubei University of Technology, Wuhan, China
[2]Air force of the Nanjing Military Command, Air force of the Nanjing Military, Nanjing, China,
Corresponding author, e-mail: 254831618@qq.com, leilei19880716@163.com, 943906831@qq.com

Abstract

In the process of NC machining, the optimization processing of graphic layout is a well-studied problem which has practical application value for improving the utilization rate of raw materials and saving the cost of production. In this paper, a new design of genetic algorithm (GA) is proposed for solving this problem. This improved genetic algorithm combines GA with the improved crossover operator and mutation operator. Moreover, the best individual preservation method is integrated into the algorithm. The improved genetic algorithm expands the search space and enhances the GA's search capabilities. Furthermore, the maximum matching algorithm is proposed based on the lowest horizontal line algorithm, which effectively avoids blind elevating horizontal lines and improves the utilization rate of the lowest horizontal line. It is integrated with the improved genetic algorithm to solve the two-dimensional rectangular parts optimal layout problem which combines the advantages of two kinds of algorithms. The experimental results show that the algorithm can get a good optimization result.

Keywords: *graphics processing, layout optimization, genetic algorithm, rectangular piece*

1. Introduction

In the large industrial production process, it is very important to improve the production efficiency and improve the utilization rate of raw materials for NC machining cutting graphics. So how to design cutting graphics is a very important research task for NC machining.

Rectangular packing problem generally refers to finding an approach to place a set of rectangular items of fixed sizes in a non-overlapping fashion on a strip, which is given width and height [1]. It is required the utilization of the strip highest.

For the process of packing problem solving, many scholars have studied and used many advanced algorithms. The most famous method is the intelligent algorithm such as artificial neural network, ant colony algorithm, simulated annealing algorithm, genetic algorithm, combined with the heuristic layout algorithm such as BL algorithm, down stairs algorithm, the lowest horizontal line algorithm. Artificial neural network belongs to the black box system. It is difficult to mechanism analysis and need to be trained before use. Ant colony algorithm affected by the beginning point's location and the obstacle distribution. It is easy to appear dead lock and circuitous paths. The global search ability of the simulated annealing algorithm is poor and the algorithm is vulnerable to parameters. Genetic algorithm is a simple, convenient operation, has global search strategy and good robustness. Moreover, it can get good results in the layout problem. But the problem such as local optimization and slow convergence speed are easy to appear in general genetic algorithm [2].

In order to avoid the shortcomings in above methods, this paper combines the maximum matching algorithm with improved genetic algorithm to solve the two-dimensional graphic layout optimization problem. This algorithm combines the advantages of two kinds of algorithms to effectively prevent the occurrence of above-mentioned phenomena. It can find the approximate optimal solution quickly and efficiently for the graph layout problem.

2. Summary of the Optimal Layout Algorithm

In this paper, the rectangular packing problem is transformed into an order layout problem. Firstly, the packing sequence and mode of the rectangular pieces are found out

Received May 25, 2013; Revised July 27, 2013; Accepted August 8, 2013

through the improved genetic algorithm. Then the corresponding layout diagram is generated according to the specific rectangular discharge algorithm. By comparing material utilization of different discharge sequences, the offspring population is evolved and the optimal layout result is obtained eventually.

The lowest horizontal line algorithm is one of the most used rectangular packing algorithms. This algorithm rows the rectangular piece in the lowest level of contour line. If there are several lowest horizontal lines can row the rectangular piece, the most left one is selected. Otherwise, the rectangular is discharged in a higher horizontal line. Aiming at the deficiency of the algorithm, it has to be improved in this paper and put forward the maximum matching algorithm. According to the specific dimensions of the rectangle, the most closely matching one is selected from a number of the lowest horizontal line. If all the horizontal lines cannot row this rectangular piece, place it after rotated 90°. This algorithm effectively avoids blind elevating horizontal lines and improves the utilization rate of the lowest horizontal line. Moreover, it can get a better layout.

3. Genetic Algorithm

Genetic algorithm (Referred to as GA) is a kind of high efficient, parallel and global searching method. In this paper, the GA evolution process is improved and the new individual is closer to the optimal solution than traditional GA individual [3].

3.1. Coding

This paper adopts a positive and negative integer coding method. Encode the rectangular pieces from 1 to n and the random combination of n rectangular pieces coding constitutes an individual X=[x1,x2,…,xn], 1<|xi|<n. Each of these genes encoding refers to the code of the corresponding rectangular pieces, and they have positive and negative points. Plus represents rectangular horizontal, i.e. the long edges of the rectangle is parallel to the X axis alignment. Minus sign represents the rectangle rotate 90°to range [4].

3.2. Fitness Function

Fitness function indicates individual quality. Fitness value represents the degree of the individual close to the optimal individual [5]. As the reusable part of the strip is between the highest horizontal line and the top of the strip, the utilization rate of the used part is used as the fitness function value.

$$f = area/(Highest*w) \quad (1)$$

Among them, area is the total area of the rectangular pieces, Highest is the height value of the highest contour and w is plate width. As the size of rectangular parts and sheet is fixed, (1) can be simplified to the countdown value of the maximum height of contour line.

$$f(P) = 1/Highest. \quad (2)$$

Here, f (P) is individual fitness function value of the P generation.

3.3. Selection Operator

Selection operator is the process that high fitness individuals are chosen to replace the inferior individuals as the new population [6]. This article sets the generation gap marked as GGAP. And GAAP*Size individuals are selected from the population through the roulette wheel method.

Table 1. The Influence of the GGAP (CodeL=15)

GGAP	*BestF*
0.8	0.0227
0.7	0.0233
0.6	0.0208
0.5	0.0208
0.4	0.0222

Generation gap GGAP is an important parameter of GA, represents overlapping degree between children and father generation [7]. In order to select the appropriate GGAP, 15 arbitrary rectangular pieces are arranged and through change the GGAP to observe the changes of the best fitness value BestF.

Experiments show that the generation gap GGAP directly affects the best fitness value. The relationship between them is an approximate parabola relationship and here GGAP=0.7.

3.4. The Preservation Method for the Best Individual

In this algorithm, each generation population retains (1-GGAP) *Size higher fitness individuals directly inherit to the next generation without selection, crossover and mutation. This method accelerates the search speed to the optimal solution and prevents the better individual to be destroyed in the iterative process [8].

3.5. Crossover Operator

Crossover operator has the ability of global search and is the main operator in genetic algorithm. This algorithm uses crossover operation on the fitness lower GGAP * Size individuals in the contemporary population. In order to avoid invalid generation, this paper adopts ordered crossover method and the specific steps are given as follows.

The offspring individuals X1', X2' exchange replicate the genetic value that outside two crossover points. After the exchange, X1' may have two duplicated genes A. One is outside two crossover points, marked as A1; the other is between the two crossover points, marked as A2.Find the gene B in X2' that have the same position with A1 in their respective individual. And then A1 is replaced by B. Genes in X1' are replaced in the same way until the genes aren't duplicated. X2' is processed with the same method [9].

Calculate each individual's fitness value, if the fitness value of offspring is bigger than parents', the progeny chromosome is chosen to the next operation. Otherwise, the paternal chromosome is retained to the next operation.

The crossover probability Pc also has certain impact on the optimization results and it should be selected according to the actual situation. 15 rectangular pieces of any size are also ranked and observe the changes of the best individual fitness BestF by changing Pc, so that arrive at the most suitable PC.

Table 2. The Influence of the PC (CodeL=15)

Pc	***BestF***
0.9	0.0222
0.8	0.0233
0.7	0.0233
0.6	0.0222
0.5	0.0217

Experiments show that it generally presents a parabolic relationship between the PC and BestF. When Pc = 0.8, the best individual fitness value is biggest.

3.6. Mutation Operator

Because the algorithm using the unsigned integer encoding, the general mutation operator cannot consider both real values and symbols. In this paper, the mutation operator is divided into the real values and symbols in two parts. For symbol part, this algorithm uses rotation variation to transform the individual gene symbol. It means the individual is rotated 90° before placed [10]. For real value part, this article uses position variation, randomly select two variation points in individuals and invert genes between the two values to produce new individuals [11].

The selection of rotation variation probability Pm1 and position variation probability Pm2 influence the final result of the optimization.10 rectangular pieces with different sizes are ranked and the value of Pm1 and Pm2 are changed many times to choose the optimal values of the two mutation probability.

Table 3. The Influence of the Pm1 (CodeL=10, Pm2=0.02)

Pm1	***BestF***
0.03	0.0256
0.025	0.0278
0.02	0.0256
0.015	0.0286
0.01	0.0286

Table 4. The Influence of the Pm2 (CodeL=10, Pm1=0.015)

Pm2	***BestF***
0.03	0.0256
0.025	0.0294
0.02	0.0303
0.015	0.0278
0.01	0.0270

From Table 3 and 4, it is obvious that Pm2 has a greater influence on the best individual fitness than Pm1. Therefore, in order to strengthen the role of the position variation on the optimization results, Pm2 should greater than Pm1.

4. Maximal Matching Algorithm

In order to get the actual layout results, the reasonable layout algorithm is needed to decode the individual, such as BL algorithm, down stairs algorithm and the lowest horizontal line algorithm.The maximum matching algorithm is put forward in this paper. A rectangular pieces discharge sequence is assumed to be R1...Ri...Rn. Among them, the Ri is the current layout parts. At the same time, the initially lowest horizontal line is set to the bottom edge of the plate. The main steps are given as follows.

1) If R1>0, R1 is horizontally rowed in the lower-left corner of the plate, otherwise vertically placed. Then the coordinates of the rectangular pieces is recorded in the matrix Q. At this time, two contour lines are formed and their coordinate values are stored in the matrix LowLine.

2) When range the rectangular piece Ri, if Ri>0, it will be horizontally placed, otherwise vertically placed. According to the placement mode, all the lowest contour lines that can place it are found out. If the lowest contour line has only one, Ri is ranged in it. But if there are several, the most suitable one is selected from them to place Ri. Then the matrix Q and the horizontal contour line matrix LowLine are updated. In the rectangular arrangement process, the layout width cannot exceed the strip width. Otherwise, the suitable contour line must be matching searched from low to high in the other contour lines. If Ri cannot be ranged in all the contour lines, it is processed according to the following two circumstances:

a. If Ri> 0, the rectangle is rotated 90° and this algorithm is turned to perform step 2.

b. If Ri<0, this algorithm is turned to perform step 3.

3) If all level contour lines can't range the Ri, the rectangular is put cover to the left on top of several contour lines. And then the matrix Q and the horizontal contour line matrix LowLine are updated.

4) Step 2 and step 3 are repeated until all the rectangle pieces are ranged.

5. Analysis of Graphics Layout

In order to validate the practical optimization ability of the algorithm, this article compared with simulation results from the two aspects of the decoding method and the initial population.

5.1. Comparison of Different Decoding Method

To illustrate the impact of different decoding methods on the actual layout result, the rectangular piece i is ranged respectively use the lowest horizontal line algorithm and the maximum matching algorithm. Results showed in "Figure 1" and "Figure 2". When the lowest horizontal line 1 and 2 all can range the rectangular piece i, the lowest horizontal line algorithm blind to select the left one. However, this algorithm left a lower value horizontal line 3 and produced a "blank area" that is difficult to reuse. The maximum matching algorithm searches the most closely matching one from the lowest horizontal line 1 and 2. As a result, the horizontal line 2 is selected. As shown in “Figure 2”, after range the rectangular piece i, the horizontal line fully utilized and not produce the “blank area”. This algorithm effectively improves the utilization rate of the lowest horizontal line.

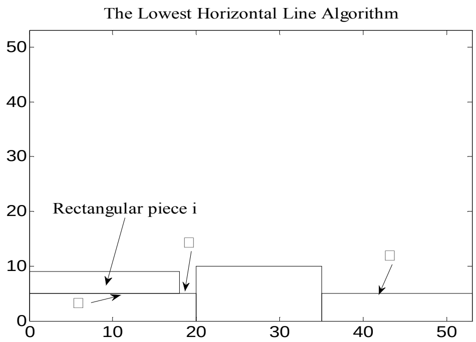

Figure 1. The Lowest Horizontal Line Algorithm

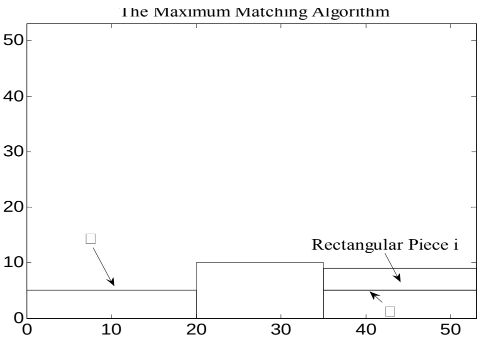

Figure 2. The Maximum Matching Algorithm

5.2. Comparison of Different Initial Population

To test the practical effect of the algorithm, the 10 rectangular pieces of various sizes are placed on the strip. Through the above analysis, this article sets the generation gap GGAP=0.7, crossover probability Pc = 0.8, rotation mutation probability Pm1=0.015, position mutation probability Pm2 = 0.02, maximum number of generations G=55, population size Size=20. Layout results is given in “Figure 3”, which is programmed based on MATLAB. The curve of the highest fitness values as shown in “Figure 4”.

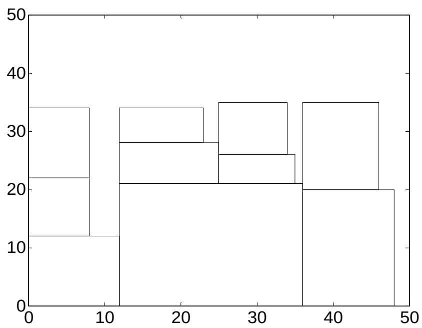

Figure 3. 10 Rectangular Piece Nesting Results 1

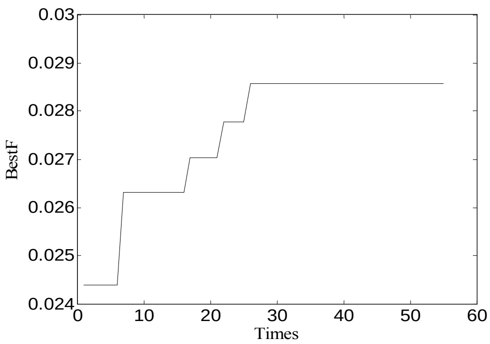

Figure 4. Curve 1

In “Figure 4”, the highest individual fitness remains unchanged from the 28th generation. It has reached the approximate optimal solution BestF = 0.286.

The program is run again under the same conditions and the results are shown in “Figure 5” and “Figure 6”.

In “Figure 6”, the highest individual fitness remains unchanged from the 50th generation and has reached an approximate optimal solution BestF = 0.286.

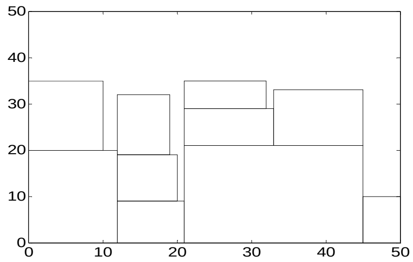

Figure 5. 10 Rectangular Piece Nesting Results 2

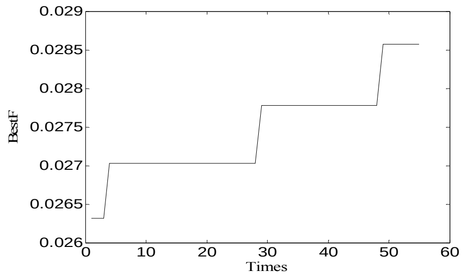

Figure 6. Curve 2

Through the two programs, it can be found that the nesting effect is different but the final maximum fitness value BestF is the same.

Because the approximate optimal individual code changes with the randomly selected initial population, the corresponding layout effect is also different. But the results are always close to the optimal solution and the maximum fitness value is basically fixed.

6. Conclusion

Based on the analysis of the lowest horizontal line algorithm shortcomings, this article makes corresponding improvement. The maximum matching algorithm is put forward and combined with the improved genetic algorithm to solve the rectangular cutting stock problem. After repeated tests, it can be found that the nesting algorithm can effectively reduce production costs, improve the utilization of the plate and achieve the purpose of optimal layout. Moreover, the algorithm is feasible and can be well applied in NC machining.

Acknowledgment

This work is supported by the Natural Science Foundation of Hubei Province No. 2010CDB02503 and project of Hubei Provincial Education Department No.Q20091406.

References

[1] Defu Zhang Yan Kang, Ansheng Deng. A new heuristic recursive algorithm for the strip rectangular packing problem. *Computers and Operations Research*. 2006.
[2] Albano Antonio. *A method to improve two-dimensional layout*. Computer Aided Design. 1977.
[3] XinNing, Chao Chen. Complementing the Two Intelligent Bionic Optimization Algorithms to Solve Construction Site Layout Problem. *IJACT: International Journal of Advancements in Computing Technology.* 2012; 4(1): 1-14.
[4] Wei Liu, Gang Liu. Genetic Algorithm with Directional Mutation Based on Greedy Strategy for Large-scale 0-1 Knapsack Problems. *IJACT: International Journal of Advancements in Computing Technology*. 2012; 4(3): 66-74.
[5] Dmitrii Lozovanu, Stefan Pickl. *An approach for an algorithmic solution of discrete optimal control problems and their game-theoretical extension.* 2011.
[6] Song Lian-chao, ZhuJian-liang, Zhuang Tong. The Smallest Offcut Deletion Algorithm for the Rectangles Cutting Stock Problem. *Journal of Harbin University of Science and Technology*. 2006; 11(5).
[7] Wei Ping ping, Liu Bin. The Rectangular Packing and Optimization on Parallel Genetic Algorithm*. Modular Machine Tool & Automatic Manufacturing Technique*. 2011; 3.
[8] Zhao Xiao dong, Mi Xiao zhen. Application of genetic algorithm model in optimal layout of rectangular part*. Forging & Stamping Technology*. 2007; 32(6).
[9] Stefan Jakobs. On genetic algorithms for the packing of polygons. *European Journal of Operatioanl Research*. 1996; 88: 165-181.
[10] Bo Li, Zhi-Yan Zhao, Ju-Dong Li. *A hybrid algorithm for nesting problems.* Proceedings of the Second International Conference on Machine and Cybernetics. Xi'an. 2003: 1424-1429.
[11] Zhu Guan hua. An Improved Algorithm for Rectangular Parts Blank Layout On The Basis of the Lowest Horizontal Line. *Journal of Maoming College.* 2006: 16(1).