

Creation and Optimization of Laser Marking Hatch Contour Generation Algorithm

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Abstract: Laser marking has been increasingly applied to industrial processing. In this paper, by studying Zigzag Parallel and Contour Parallel Hatch, we established mathematical models, designed and optimized algorithms. We first draw the fitted edge line, then find the intersection of the horizontal line and edge line. We propose an algorithm to solve this problem, named Bottom to Top Crossing Line Algorithm, we draw edge line and hatch line, and choose hatching paths based on the number of intersections. By using two given parameter groups, we establish the Space Cost Function to calculate the total length, and the Time Cost Function to calculate the average running time. And we use a similar strategy, the difference lies in the processing of the picture common nested part. The increase in the number of intersection points of Edge line and Hatch Line make the algorithm more complicated. Therefore, we divide it into several areas to hatch, and also calculate the two sets of data. Then propose two improved algorithm models. 1) An improved linear edge path optimization model based on curvature value, which is used to improve accuracy and efficiency of zigzag parallel hatching. 2) An improved algorithm model based on particle swarm optimization, which is used to shorten the time of searching seed points when laser marking multi-layer contour pattern, especially when the diameter of the marking spot is very small. The random particle swarm in the specified boundary moves continuously and calculates the distance from the contour boundary. We calculate time cost, space cost and improve rate of the two after improving our model. Also, we found when $IHdistance \in [0.07, 0.1]$ (for contour, it's $[0.06, 0.1]$), improve rate is little, elapsed time and total lengths have a less change, but when $IHdistance \leq 0.06$ (contour's 0.05), the two parameters change a lot.

1. Introduction

Based on the following analysis on the image in the attachment, we need to accomplish the following three questions [1]. Realize the sawtooth parallel and contour parallel hatches of the single-layer contour pattern in Annex 1; Here, serrated parallel hatches are considered only in the horizontal direction (0 degrees). Please realize incubation under two groups of input parameters according to the graph coordinate point data in Attachment 1 (unit: mm):

- (1) Internal shrinkage boundary distance 1mm, hatch spacing 1mm
- (2) Internal shrinkage boundary distance 0.1mm, hatch spacing 0.1mm

Under the two groups of parameters, the total length of hatching curve body of broken line parallel line and contour parallel line was calculated, and the number of horizontal lines of broken line parallel line and circle number of contour parallel line were calculated [2]. Calculate the average running time (unit: MS) based on the number of runs of the incubation program, and calculate the running time ratio of the program under parameter groups (2) and (1).

Then realize the sawtooth parallel and contour parallel hatching of the nested multi-layer contour pattern in Attachment 2; Here, serrated parallel hatches are considered only for horizontal (0 degrees) hatching. Please realize incubation under two groups of input parameters according to the coordinate point data:

- (1) Internal shrinkage boundary distance 1mm, hatch spacing 1mm
- (2) Internal shrinkage boundary distance 0.1mm, hatch spacing 0.1mm.

Under the two groups of parameters, calculate the total length of hatching curve of line parallel and contour parallel, calculate the number of horizontal lines of line parallel and the number of circles of line parallel[3]. Calculate the average running time (unit: MS) based on the number of runs of the incubation program, and calculate the running time ratio of the program under parameter groups (2) and (1). The spot diameter produced by laser marking machine is very small. Laser marking line spacing is generally 0.01mm-0.1mm. Laser marking produces a large amount of contour data, and any contour line of any shape has a high requirement on the operation efficiency of the program. Check the running time of your incubation algorithm and analyze its performance to provide a strategy or direction for optimizing the performance and efficiency of the incubation algorithm so that it can meet the efficiency requirements of practical industrial applications.

2. Model analysis and construction

2.1 Model analysis and hypothesis

As required in the problem, the internal contraction boundary is at least 0.1mm, while the data given in Graph1 and Graph2 are discrete points, and the distance between points in the special area is too large. Therefore, it is necessary to preprocess the original data, interpolate and fit the logarithm data points, and turn the discontinuous line segment into continuous line segment. After forming a continuous closed pattern, carry out the following marking process. And assume only one hatch is used for hatching, without considering the situation that multiple hatches hatch at the same time; Hatching Zigzag Parallel from bottom to top[4].

2.2 Bottom to Top Crossing Line Algorithm

In the drawing of Zigzag Parallel Hatch in the example, it is worth noting that there are two kinds of lines, one is the edge line with a distance of 1mm from the pattern boundary, and the other is the horizontal line connecting all points on the edge line, which is named hatch line by this paper. We design an algorithm to hatch by drawing edge line and hatch line successively.

We propose an algorithm to solve the problem, which is named Bottom to top Crossing Line Algorithm based on the number of intersection points[5]. The specific algorithm is described in detail as follows:

- 1) Import the point coordinates in graph1.csv and draw the image.
- 2) Determine the point coordinates of the edge line.

In this step we use mathematical method to determine the curve formed by any close three points in the original data, find the slope of the tangent line at the midpoint (namely the derivative value of the point), then find the slope of the vertical tangent line, do binary equations, so as to find out the horizontal and vertical coordinates of the point indented 1mm or 0.1mm. All the points in the original data can be indented in this way to find the coordinate points, that is, the coordinates of each point of edge line. This step is described in detail below:

- (1) Use that coordinates of $(x_1, y_1), (x_2, y_2), (x_3, y_3)$, the parabolic equation pas through the three points is obtained, assuming that $ax^2 + bx + c = y$ where a and b can be obtained by substituting the coordinates of the three points.
- (2) If you make a tangent at the midpoint (x_2, y_2) , the tangent slope of this point is equal to the derivative value of this point, and $k = 2ax_2 + b$.

- (3) The vertical line passing through (x_2, y_2) is taken as the vertical tangent, the slope of the vertical line is $k' = \frac{1}{k}$, and the length of the vertical line is 1 mm or 0.1 mm.

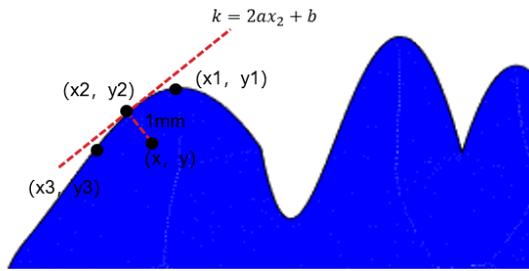


Figure 1-Determine the point coordinates of the edge line

According to the vertical slope = k' and the vertical segment length is known, the following binary equations can be listed to find the coordinates of the inward mapping point (x, y) .

$$k' = \frac{y_2 - y}{x_2 - x} = \frac{1}{2ax_2 + b}$$

$$d = \sqrt{(x_2 - x)^2 + (y_2 - y)^2} = 1mm / 0.1mm$$

All points on edge line can be obtained by the above method, and finally all points are connected to fit the real edge line.

The actual algorithm flow chart is shown in figure 2

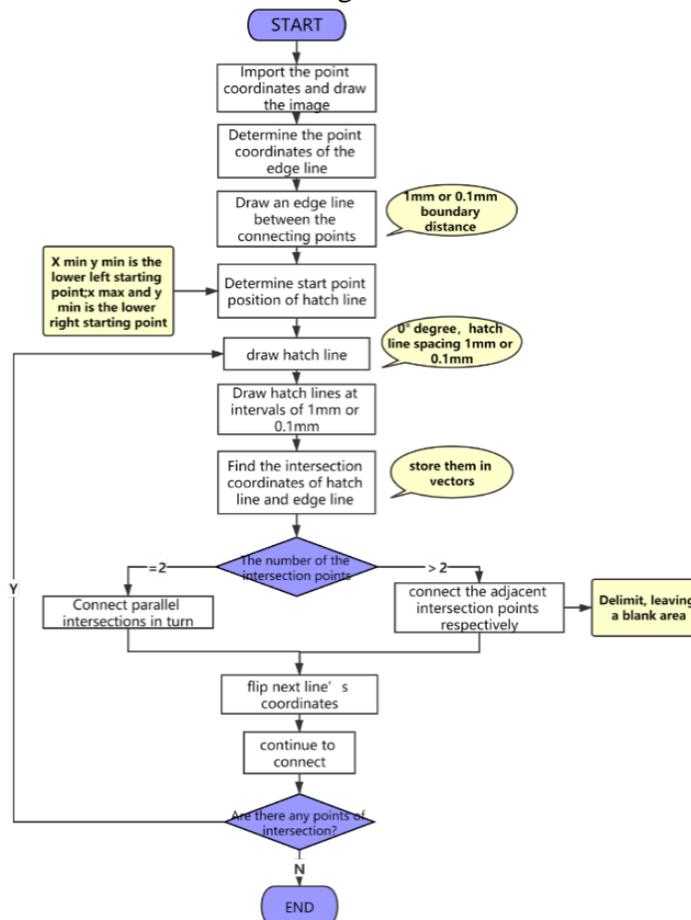


Figure 2 The algorithm flow chart of Zigzag Parallel Hatching

It is worth noting some of these special points: such as contour junctions, where the multi-channel becomes a single channel junction, and where marking starts, hatching starts and ends are specified. For ease of memory, we call these four types of points initial Point (IP), demarcation Point (DP), Junction Point (JP), and Stop Point (SP). The following is indicated in the figure.

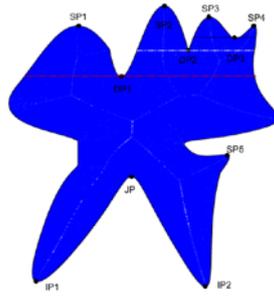


Figure 3 The mark of IP, DP, JP, SP

3. Model Results

Based on the above algorithm and model establishing, we do similar work to the two groups of parameters (1mm and 0.1mm), and eventually get the zigzag parallel hatching and contour parallel hatching results. We drew the following images using MATLAB. Zigzag parallel hatching at boundary distance 1mm, hatch line spacing 1mm.

Zigzag parallel hatching at boundary distance 0.1mm, hatch line spacing 0.1mm

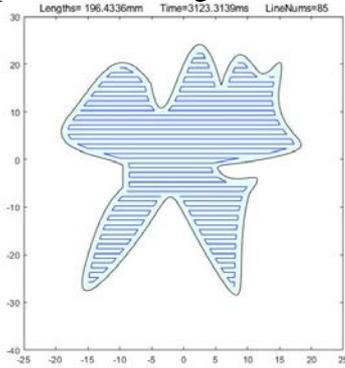


Figure 4 Zigzag parallel hatching 1mm, 1mm

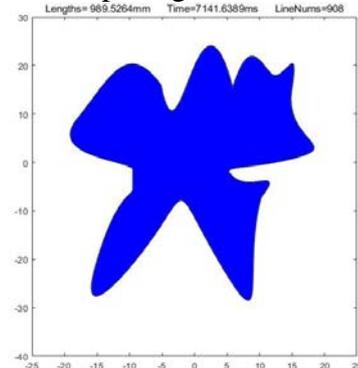


Figure 5 Zigzag parallel hatching 0.1mm, 0.1mm

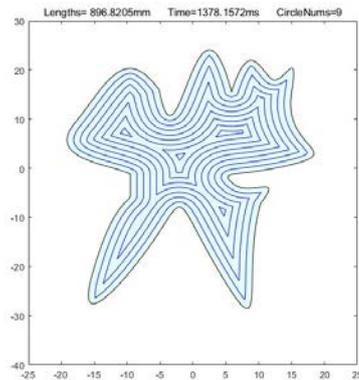


Figure 6 Contour parallel hatching 1mm, 1mm

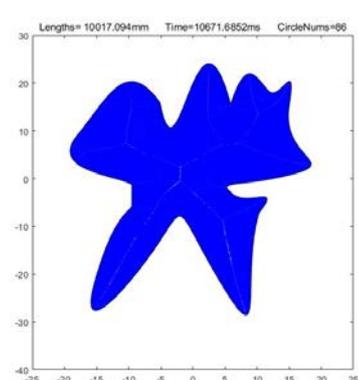


Figure 7 Contour parallel hatching 0.1mm, 0.1mm

(1) Calculate the total length of hatching lines of the hatched curves subject of zigzag parallel and contour parallel hatch (unit: mm):

Table 1: Total length of hatching lines of the hatched curves

Total length of hatching lines(unit:mm)	Parameter	zigzag parallel hatch	contour parallel hatch
	1mm 1mm		196.4336
0.1mm 0.1mm		989.5264	10017.094

(2) Count the number of horizontal lines of zigzag parallel hatch, and the number of circles of contour parallel hatch:

Table 2: The number of horizontal lines of two types hatch

Horizontal lines/circle number	Parameter	zigzag parallel hatch	contour parallel hatch
	1mm 1mm	85	9
	0.1mm 0.1mm	908	86

(3) Count the average elapsed time based on the multiple runs of hatching program (unit: ms):

Table 3: The average elapsed time based on multiple runs of hatching program

Average elapsed time(unit:ms)	Parameter	zigzag parallel hatch	contour parallel hatch
	1mm 1mm	2823.3139	1078.1572
	0.1mm 0.1mm	6741.6389	10171.6852

(4) Calculate the ratio of elapsed time for program running under conditions of parameter groups (2) and (1):

Table 4: The ratio of elapsed time for program running under conditions

Parameter	zigzag parallel hatch	contour parallel hatch
The ratio of elapsed time(group2/group1)	2.3878	9.4343

In summary, the results of Problem 1 in the following table as shown in Table 2-5.

Table 5: Summary of the results for Problem 1

Types	Parameter	Total length(mm)	Average elapsed time(ms)	Lines/Circle number	Ratio of elapsed time
zigzag parallel hatch	1mm 1mm	196.4336	2823.3139	85	2.3878
	0.1mm 0.1mm	989.5264	6741.6389	908	
contour parallel hatch	1mm 1mm	896.8205	1078.1572	9	9.4343
	0.1mm 0.1mm	10017.094	10171.6852	86	

4. Conclusions

By calculating the number of points and the row and row coordinate values of the equally-spaced parallel lines passing through the region, there is no stack overflow. Our model overcomes the defects of polygon region filling algorithm, such as certain limitation to the region, seed filling algorithm's requirement to determine a point in the region, and repeated judgment of pixel points in the region. but we only consider the range provided in the question, which is [0.01,0.1]. We should expand the scope and then discuss the applicability of the model.

References

- [1] Jiang Qiuyan, Xie Jinxing, Ye Jun. Mathematical Model (Fourth edition) [M]. Beijing: Higher education press. 2011:230-250.
- [2] Si Shoukui. Mathematical modeling algorithm and program. [M]. Yan Tai: Naval aeronautical engineering college. 2007:595-605.
- [3] Kuang Yan, Wu Yunfeng, Wu Bo, Wu Jianping. Extraction and optimization of marking path in laser marking system[J]. Laser technique, 2012, 36(01):131-133.
- [4] Liang Wenbin, Xie Yuelei, Peng Chengcheng. A low - complexity laser marking inflection point detection algorithm[J]. Laser technique, 2015, 39(02):202-205.
- [5] Yang Taiping, Hu Qianwu, Zeng Xiaoyan. Research on generating algorithm of section profile in direct laser forming of metal parts[J]. Electrical processing and tooling, 2003(06):32-35+70.