

Research on Automatic Generation Algorithm for the Supporting Structure in FDM Process

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Abstract. According to the forming characteristics of FDM process in the Additive manufacturing, an algorithm for automatic generation of thin plate structure support based on the slice projection method is proposed. For the closed surface model (such as STL model, NURBS model), the algorithm uses slice projection method to automatically generate a series of crossed and parallel and spaced thin plates to provide external support. The algorithm reduces the computation problem from three-dimensional support area to the calculation of two dimensional support areas. The algorithm is stable and reliable, and the supporting structure has smaller volume and better stability. The supporting structure and part structure are independent to each other. Different path planning methods can be used for FDM path planning, and different materials can be used for the supporting structure and part structure. It is easy to dismantle the supporting structure in the postprocessing and greatly improves the flexibility of FDM process.

Introduction

The design of the supporting structure is one of the key technologies in FDM (Fused Deposition Modeling) process in the Additive manufacturing. When the parts have a suspended structure, it is necessary to have a supporting structure to support the suspended structure, otherwise collapse deformation will occur, which will leading to the failure of forming. The rationality of supporting structure has a great influence on the accuracy and efficiency of FDM parts, especially for large-scale building structures.

At present, the most common supporting structures including complete supporting structure and incomplete supporting structure. For example, the unsintered material in the SLS process forms a complete supporting structure. In the FDM process, taking into account the removability of supporting structure, incomplete supporting structure is usually used. Incomplete supporting structures usually are tree-shaped, wall-shaped, gallows-shaped, etc. The wall-shaped and gallows-shaped supporting structures have good stability, but more consumables. Tree-shaped structure are few consumables, but poor stability^[1-2].

The construction algorithms for supporting structure can be divided into two categories, one is based on the 3D model of closed surface structure, such as STL model and NURBS model, according to its geometric characteristics (such as the direction of the outer normal vector), the supporting areas are calculated and the complete or incomplete supporting structures are constructed^[2-6]. The other is based on the two-dimensional slice contour model, boolean operation is used to calculate the supporting area of each layer and to construct a complete supporting structure^[7-9].

In this paper, an automatic generation algorithm using thin plate supporting structure based on the slice projection method is proposed for the closed surface model (such as STL model, NURBS model). In the supporting direction of the solid model, the slice projection method is used to automatically generate a series of thin plates with longitudinal and horizontal parallel intervals, which are used to provide external support. The algorithm reduces the dimension of the calculation from three-dimensional support area to that of two-dimensional support area. The algorithm is stable and reliable. The supporting structure obtained is incomplete, small and stable. The supporting structure and part structure are independent to each other. Different path planning

methods can be used for FDM path planning, and different materials can be used for the supporting structure and part structure. It is easy to dismantle the supporting structure in the postprocessing and greatly improves the flexibility of FDM process.

Algorithmic Description

The automatic generation algorithm using thin plate supporting structure based on slice projection method can be divided into the following steps:

(1) Determine the direction of forming, that is to determine the growing direction of the solid model. It is set to parallel to the Z axis in this algorithm. The effect of this step on the formation of supporting structure, forming quality and efficiency is described in reference [1]. As shown in Figure 1, the direction of the molding is chosen as the Z axis of the model.

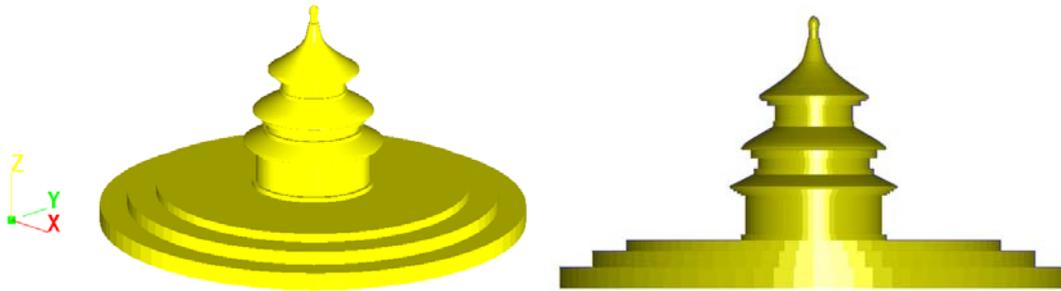


Figure 1. Determine the direction of forming

(2) In the Y direction, the model is sliced into a series of contour on the slice plane by a series of plane which paralleled to the ZOZ plane, and gets, as shown in Figure 2 below. This process is actually an equal interval stratification on the model, and the realization of specific algorithm is described in reference [10].

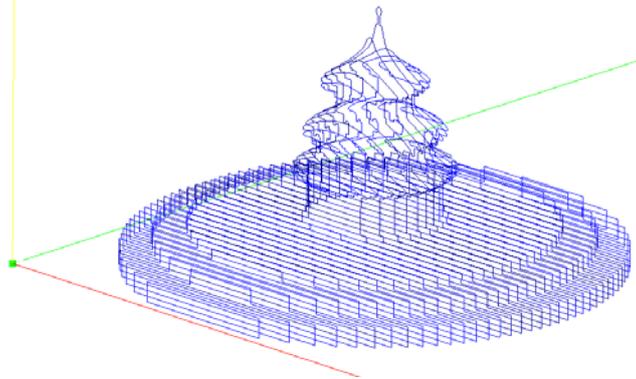


Figure 2. The slice contour paralleled to the ZOZ plane

(3) On every slice plane paralleled to ZOZ (as shown in Figure 3A below), according to the contour, the projection method is used to construct the supporting contour. As shown in Figure 3B, the shadow area is the supporting contour area.

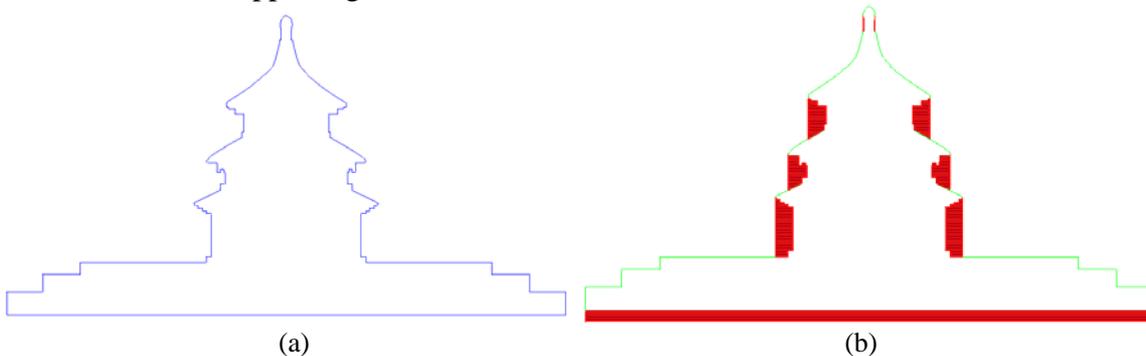


Figure 3. Slice contours and supporting areas paralleled to ZOZ

(4) Similarly, in the X-axis direction, the model is sliced into a series of solid contour on the slice plane by a series of plane paralleled to the YOZ plane, as shown in Figure 4 below.

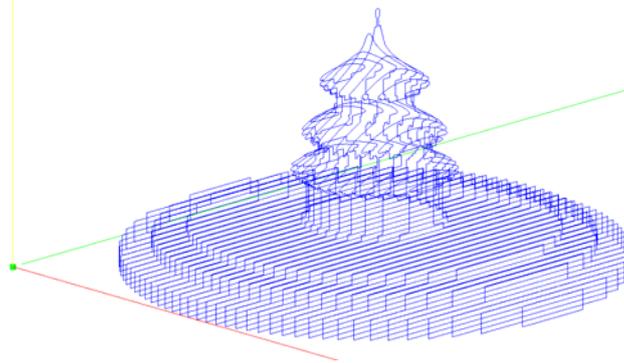


Figure 4. The slice contour paralleled to the YOZ plane

(5) The supporting profiles in two directions are combined to form a cross grid thin plate supporting structure.

Projection Method to Construct Supporting Contour

As shown in Figure 5, on the section contour, the feature of the supporting contour is that the normal vector of the line segment is downward. The ABC, DEF, GHJ, KLM and NPQ segments as shown in the figure are the contours which needed supporting.

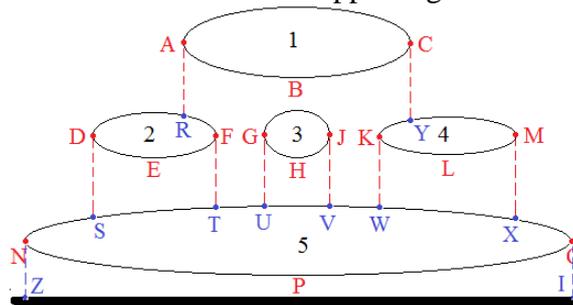


Figure 5. The feature points on the slice contour

Definition 1: The division point between the upper-normal-line and the adown-normal-line on the contour is called S-point. S-points are divided into two types: A type S-point is not covered by other outlines, such as point A, D, M, N, Q in Figure 5. B type S-point is covered by other outlines, such as points F, G, J and K in Figure 5.

Definition 2: The projection point of S-point on the other contour is called IO-point. As shown in Figure 5, points R, S, T, U, V, W, X, Y are IO-points. IO-points are also divided into two types: A type S-points correspond to A type IO-points, and B type S-points correspond to B type IO-points.

Definition 3: The projection point of S-point on the ground horizontal line is called G-point. As shown in Figure 5, Z and I point are G-point.

The external contours of model are divided into two types: some are the suspended contours; the others are the non-suspended contours. The outer contour which is not contacted with the ground is called the suspended contour. The outer contour which is contacted with the ground is called a non-suspended contour. As shown in Figure 5, the five contours are all suspended. In order to unify the description of the algorithm, the non-suspended contour can be transformed into suspended contour by geometric transformation. Therefore, the algorithm can be uniformly described as a support construction algorithm for suspended contour.

For the suspended contour LA, the algorithm for constructing the supporting contour is described as follows:

(1) Starting from the leftmost S-point of outer contour LA, go down vertically, and three cases may be meet:

(a) Case 1: If there are no other contours met in the downward process, it will fall directly to the

ground (G-point on the left), then it should move right along the ground.

(b) Case 2: If an IO-point T on other contour LB is met in the downward process, it will be as an entrance point to this contour LB, and then proceed from the IO-point along the reverse direction (clockwise) of contour LB. It will meet two types exit on this contour LB:

Case 2-1: It meets another IO-point U on LB, then leave this contour LB from the IO-point U and go up to an S-point G on the contour LC which is corresponding to the IO-point U. Then go along with the contour LC in the reverse direction (clockwise).

Case2-2: It meets the left S-point D on the contour LB (A type S-point), then leave the contour LB from this S-point D, and go down vertically.

Repeat above described steps iteratively until it falls on the ground PLD (left G-point), then turn right along the ground.

(c) Case 3: If an IO-point on contour LA is met in the downward process, it will be as an entrance point to this contour LA, and then forward along the reverse direction of the contour LA (clockwise) until it returns to S-point to forming a closed supporting contour.

(2) Starting from the rightmost S-point of outer contour LA, go down vertically, and three cases may be meet:

(a) Case1: If it don't meet any other contours in the downward process, and drop directly to the ground (G-point on the right), then move left along the ground.

(b) Case2: If an IO-point T on other contour LB is met in the downward process, it will be as an entrance point to this contour LB, and then proceed from the IO-point along the direction (counter clockwise) of contour LB. It will meet two types exit on this contour LB:

Case 2-1: It meets another IO-point U on LB, then leave this contour LB from IO-point U and go up to an S-point G on the contour LC which is corresponding to the IO-point U. Then go along with the contour LC in its direction (counter clockwise).

Case2-2: It meets the right S-point D on the contour LB (A type S-point), then leave the contour LB from this S-point D, and go down vertically.

Repeat above described steps iteratively until it falls on the ground PRD (right G-point), then turn left along the ground.

(c) Case3: If an IO-point on contour LA is met in the downward process, it will be as an entrance point to this contour LA, and then forward along the contour LA (counter clockwise) until it returns to S-point to forming a closed supporting contour.

(3) On the ground, start from a G-point on the left, forward to the right, until it meet a G-point on the right to forming a closed support contour.

(4) During the construction process, some old outer contour are wrapped in a newly constructed support outer contour, and it will be treat as an inner contour, such as contour 3 as shown in figure 5.

Cases Studies

Taking the slice contour shown in figure 5 as an example, the thin plate support constructed using the slice projection method is shown in figure 6 below. Two supporting regions are formed: supporting region 1 is composed of outer contour ARFEDSXMLKCBA and inner contour 3, and supporting region 2 is composed of outer contour NZIQPN.

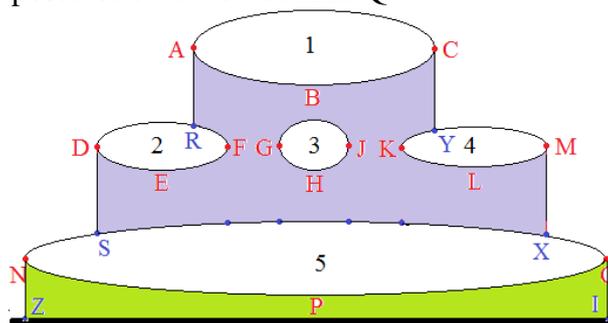


Figure 6. Slice contour and supporting contour

Taking the model shown in figure 1 as an example, the thin plate supporting structure constructed by the slice projection method is shown in figure 3b and the dark part in figure 7.

This algorithm reduces the calculation problem from three-dimensional supporting area to that of two-dimensional supporting area. It is stable and reliable. The obtained supporting structure is incomplete support. It has smaller volume and better stability. It is suitable for 3D printing of large building components. The supporting structure and part structure are independent to each other. Different path planning methods can be used for FDM path planning, and different materials can be used for the supporting structure and part structure. It is easy to dismantle the supporting structure in the postprocessing and greatly improves the flexibility of FDM process.

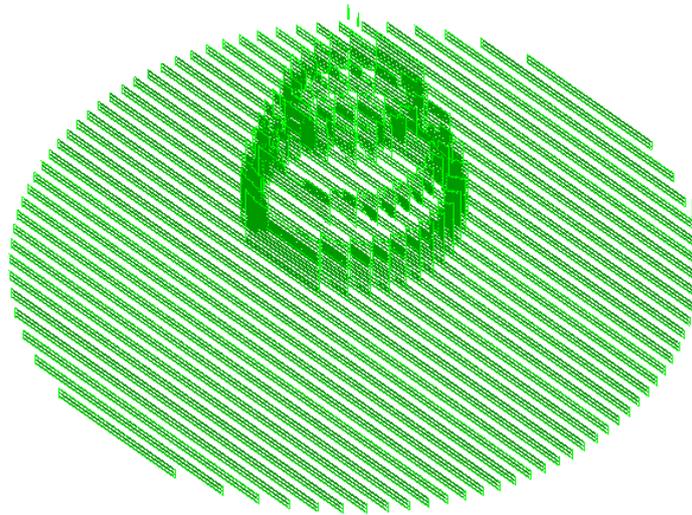


Figure 7. Thin plate supporting structure

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