

Development of Slicing Software Based on python for 3D Printing

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Abstract

3D printing technology is widely used in the medical, automotive, aerospace and construction fields. Its data processing mostly adopts the way of plane layering and is processed by 3-axis printer. However, this treatment requires the addition of support when many parts are molded and inevitably has a step effect. Surface layering and five-axis 3D printing can solve this problem very well, the paper is based on the Python, through the STL file surface separation, surface plane intersection to obtain a five-axis 3D printing path, and developed the corresponding software. After simulation and experimentation, the proposed method is proved to be reliable and effective.

Keywords

Additive manufacturing; 3D printing; 5-axis printer; Slicing software.

1. INTRODUCTION

Additive manufacturing, also known as 3D printing, plays a pivotal role in modern manufacturing and product development. 3D printing technology is the use of three-dimensional modeling software for digital design, through layer-by-layer printing, material accumulation and curing formation of metal powder or plastic and other bondable curable materials into solid parts of the technology. Common 3D printing processes include FDM (Fused Deposition Modeling) ,SLA (Stereo lithography Appearance),LOM (Laminated Object Manufacturing),SLS (Selective Laser Sintering),EBM (Electron Beam Melting) , etc. [1] 3D printing technology as an additive manufacturing method, compared with casting, cutting and other traditional manufacturing methods, without molds, fixtures, can manufacture three-dimensional shapes of any degree of complexity, and a variety of materials can be made, which has played a role in the research and development of new products. [2]3D printing technology has many advantages over traditional manufacturing technology, such as high material utilization, products with complex structures can be processed, significantly reduce the product development cycle. However, there will be a step effect and support addition problems during the printing process of the model, which not only increases the overall printing time cost and material cost, but also increases the roughness of the model surface.

2. RESEARCH REVIEW

Researchers have tried to solve the problem of ladder effect and support addition through various means. For example, Alsharhan et al. proposed an extrusion forming method based on the non-planar additive manufacturing process, which obtains the surface forming path data layer by layer from the input surface equation model, so as to realize the surface-based additive manufacturing forming manufacturing. Generate data using MATLAB software that contains the position coordinates of XYZ, the direction of the X and Y axes around the tool frame, and the linear and angular velocities of the nozzle tip. [3] Singamneni et al. propose a surface layering method that stacks formed wires along curved paths rather than planar paths, using the

mathematical expression of free surfaces to obtain surface layer slices by offsetting each point along the surface normal by shifting a certain slice thickness. [4] First, the text information of the G code is generated using the CAM module, and then the text information is retrieved and sorted by the MATLAB program. Huang uses the vector fork multiplication method based on the point cloud data on the surface of the part, combining adaptive layering and surface layering, while considering the patch angle and residual height for adaptive layering, so that the surface layering results of the 3D model can be directly obtained. [5] After the STL format files are layered by adaptive layering and surface layering to different thicknesses, the toolpath is generated using matlab software, and finally the toolpath is imported into the FDM printer for testing. Ajinkya S. uses Powermill Ultimate CNC CAM software to develop software plug-ins that can be used to layer surfaces and generate surface toolpaths. The movement of the spindle is changed to the movement of the extruder, and the final printing file is generated to meet the printing requirements of the 3D printer. [6] Hong et al. use the Prusa i3 MK3s printer to expand to five-axis, RepRap firm as a five-axis printing system, and generate print paths through grosshoper. Set the printing parameters in grosshoper, use the mouse to select a reference curve, the reference curve is offset, the toolpath is generated after the offset, and finally the toolpath can be simulated in Rhino software. [7] Dyndrite Corporation has developed the GPU-based native geometry modeling engine Dyndrite Kernel, and the additive manufacturing software Dyndrite Additive Toolkit based on this kernel engine, which can directly process CAD modeling files with direct support for native modeling data (such as splines, etc.) and drive the entire model data processing process for additive manufacturing by maintaining the original modeling data. This simplifies the traditional direct STL-based file data processing process, while improving the accuracy and output quality of STL-based model data processing.

Scholars have done a lot of research on surface layering and five-axis printing, but there is no one-size-fits-all set of surface slicing tools for five-axis 3D printers, so this paper uses python to design a data processing software that can be used for surface layering and FDM five-axis 3D printing.

3. PROGRAM

3.1. Software Design

In order to realize the functions of surface layering and five-axis 3D printing, the main functions of the system include: STL file import, model display, setting slice parameters, layering preview, print path planning and printing parameter settings. The data processing flow is shown in Figure 1.

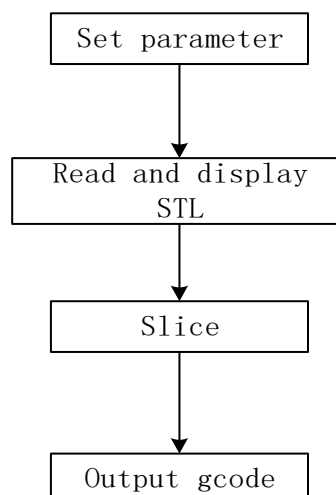


Figure 1. Design process

3.2. Reading and Display of STL Models

STL (Stereo Lithography) is a file format developed by 3D Systems in 1987 to describe geometric information about 3D models. STL files approximate a 3D solid model using mesh elements composed of triangular patches, each of which is defined by the 3D coordinates and normal vectors of the three vertices of the triangle. Reading an STL file is to save the vertex information and the normal vector information of the triangle patch in the STL format file in a matrix format. To improve the model slicing speed, a topological relationship is established for the STL file. By judging whether the triangle patch has two identical vertices, it is determined whether the triangle patch is an adjacent triangle patch, and the adjacent triangle face information is established to provide fast information retrieval for subsequent tiles.

```

solid <Name>
  facet normal n1 n2 n3
    outerloop
      vertex V1x V1y V1z
      vertex V2x V2y V2z
      vertex V3x V3y V3z
    endloop
  endfacet
.....
endsolid <Name>
    
```

Figure 2. The STL file content format

Use the open source library VTK to visualize the STL file, input the data, filter the data, and then map the data, encapsulate it into an object, and then add this object to the render scene, using the render window to render the display.

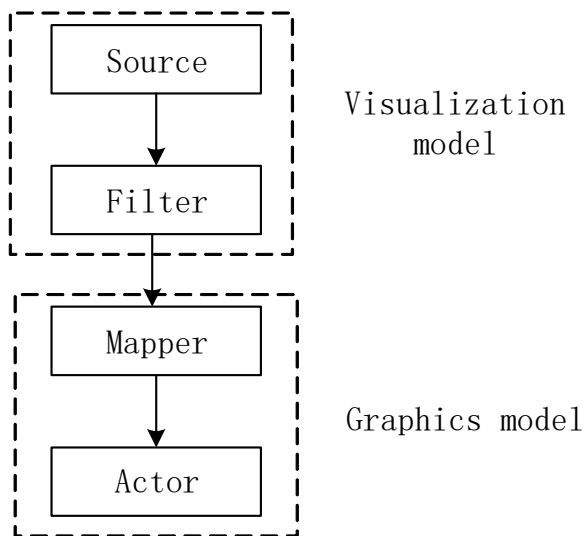


Figure 3. Data flow

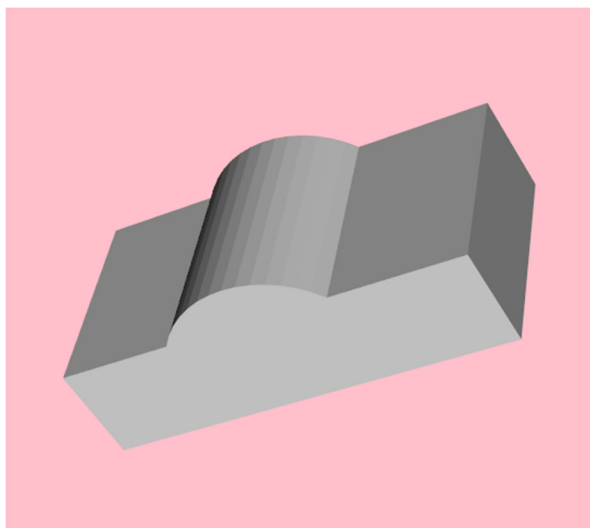


Figure 4. display model by VTK

3.3. Slice and Layer

Layering the surface of a model first obtains the footprints of the surface and then paths the interior of the profile of the upper surface. The acquisition of the contour line of the upper surface can be offset by the upper surface of the model in the specified direction and the triangular patch intersection with the remaining models, and the shape formed by the first splicing of the line segment obtained after the triangular patch intersection is the contour line of the surface on the surface of the model being sought. First, the model surface is extracted from the characteristics of the angle relationship between the normal vector of the triangular patch of the surface and the z-axis. The angle θ of the triangle patch normal vector and the z-axis where the model surface is located is between the angle of all the triangle piece normal vectors and the Z-axis, and the model surface is extracted by judging the angle and the topological relationship between the established triangle patch, like figure5 . Second, the surface is offset, because the extracted surface is composed of triangular patches, so as long as the triangular patches are offset by a specified distance in the direction of the normal vector, the offset of the entire surface can be completed. Each triangular patch normal vector in the model surface is not the same, and when adjacent triangular patches are offset at the same distance in the opposite direction of their respective normal vectors, intersecting or clearing between the biased triangular patches occurs. Therefore, the average coordinates of the vertices in different triangle patches after the offset are calculated, instead of the original common vertices, so that the adjacent triangle patches after the offset regain the same vertices, so as to avoid the intersection or gap problems of the triangular patches. Model layering is divided into surface layering and plane layering, so it is necessary to segment the model, the surface model layering first uses the last offset curve to face the model travel segmentation, after the split model is destroyed, use python third-party library trimesh to repair the damaged model, and finally extract the contour line of the surface layering, that is, extract the intersection of the triangular patch in the surface and the triangular patch in the surface layered submodel. [8]

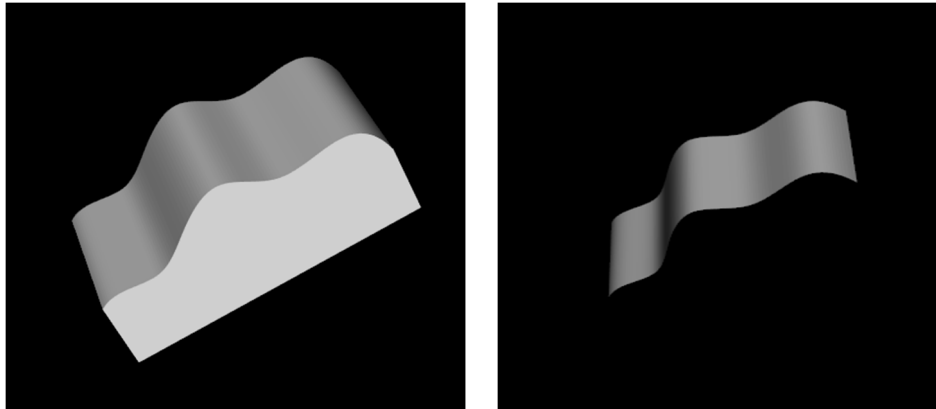


Figure 5. Surface separation

In the process of surface layering, the following problems occur: overlapping lines, intersecting lines as isolated segments, layered contours that cannot be closed, and intersecting lines as one point. In order to exclude these segments, all intersecting segments are first saved as a matrix, each row represents an intersection, the row index value defines the location where the intersection segment is saved in the matrix, the first three columns of the line are the coordinates of the starting point of the segment, and the last three columns of the line are the coordinates of the end of the segment. Then use the unique and where functions in the numpy class to reject invalid segments, and finally stitch the segments with the same starting point and the same end point to obtain the required surface outline. When layering a planar stratified submodel, select an equidistant plane to intersect the STL model for solving. Since the STL model is composed of triangular patches, the outline of the plane layering can be obtained by simply requiring the intersection of the triangular patches and connecting them into a closed shape. In order to reduce the layering time and improve the efficiency of layering during plane layering, the maximum and minimum values are calculated for the vertex coordinates on the Z-axis of each triangular patch, which helps to calculate the plane position where the triangular patches intersect. Calculations within this interval can quickly locate the intersection plane.

Surface filling often uses a plane parallel to YOZ to intersect the extracted surface, and constantly change the distance between the planes to obtain ordered parallel segments to each other, and these segments are combined in an orderly manner to form the path of the surface fill. To increase the diversity of surface fills, this article uses variable angle filling. From the original parallel to the YOZ surface to a certain angle of the filling of the YOZ surface. First of all, the extracted curved face is projected on the XOY surface, and the experimental model is projected as a rectangle, with the diagonal of the rectangle as the normal vector, and the vertex of the diagonal of the rectangle is the most point, forming a plane Π , only need to rotate a certain angle around the Z axis of Π , forming a plane with a variable angle, and intersecting the path of surface filling in the plane.

3.4. Five-axis Angle Calculation

In the above slicing process, the corners of the BC axis are not added, and the corners of the BC axis are added to export the Gcode to be recognized and performed by the five-axis 3D printer. For the surface print layer part, the surface print track point has been obtained by surface layering and filling, and the surface print track point is used as the position vector at the end of the extrusion head. In the process of surface printing, the normal vector of the printed trajectory points in the surface is constantly changing.

According to Yuan Jin's [9] research, the ideal printing strategy is to ensure that the center axis of the printer extrusion head is always perpendicular to the surface, so that the extruded filament can be accurately deposited, and the vertical force applied by the extrusion head tip is

connected to the previous print layer, reducing the gap between the print layers. Set the origin of the extrusion head coordinate system in the initial state of the printer to coincide with the origin of the printing platform coordinate system, and in the extrusion head coordinate system, the extrusion head attitude vector is $(0,0,1)^T$

Each translational axis of the printer coordinate system is (x,y,z) relative to the initial position vector in the printing platform coordinate system. The pose vector of the extrusion head position file printed in this motion platform coordinate system is $(i,j,k)^T$. The printing platform rotates around the C and B axes, and the homogeneous coordinate transformation matrix of the rotation are $R_C(\theta_C), R_B(\theta_B)$.

$$R_C(\theta_C) = \begin{pmatrix} \cos(\theta_C) & -\sin(\theta_C) & 0 & 0 \\ \sin(\theta_C) & \cos(\theta_C) & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (1)$$

$$R_B(\theta_B) = \begin{pmatrix} \cos(\theta_B) & 0 & \sin(\theta_B) & 0 \\ 0 & 1 & 0 & 0 \\ -\sin(\theta_B) & 0 & \cos(\theta_B) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad (2)$$

$$\begin{pmatrix} i \\ j \\ k \\ 1 \end{pmatrix} = R_C(\theta_C) \cdot R_B(\theta_B) \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \quad (3)$$

Spatial coordinate transformation based on printer motion chain obtains the attitude vector of the extrusion head relative to the coordinate system of the printing platform.

A double solution occurs during the calculation, and the shortest rotational angle path method is adopted as the rotation angle of the BC axis for the selection of angles.

4. TEST

After using Python to implement the slicing algorithm, the software interface design is completed with pyQT and PySide libraries, and the running results are shown in Figure 4.

The first step is to open the file, select the target file on the computer, and the model is displayed on the computer window. The second step sets the printing parameters, which are the layer thickness, the fill angle, and the number of surface layers. In the third step, click the plane layering button, the model is plane layered, and you can select the output plane layering Gcode. The fourth step is to select the Blend Layering button to output the model surface layering and plane layering Gcode, and the status window monitors error messages.

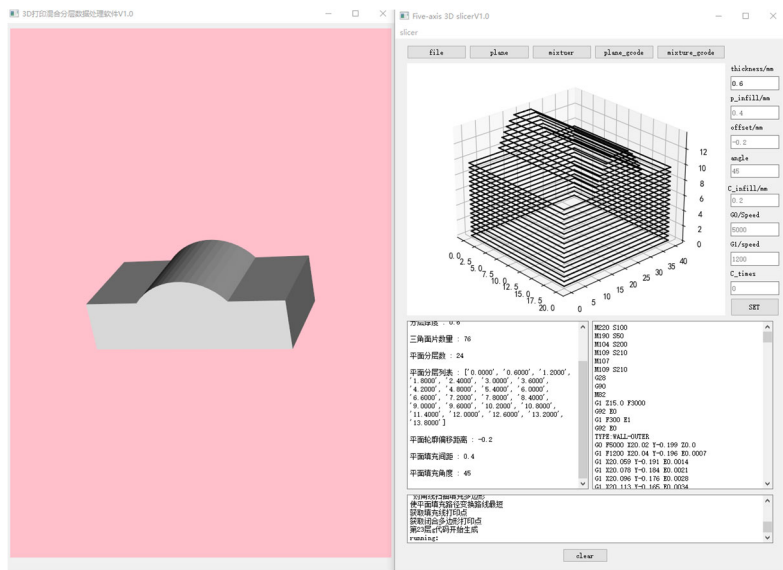


Figure 6. Software interface

In order to verify the accuracy of the five-axis machining of G codes, the Magic 2.0 five-axis laser 3D printer in the VERICUT additive machining simulation module is used for simulation verification, and the printing system adopts a CNC system with RTCP function, and the experimental surface processing is shown in the figure7.

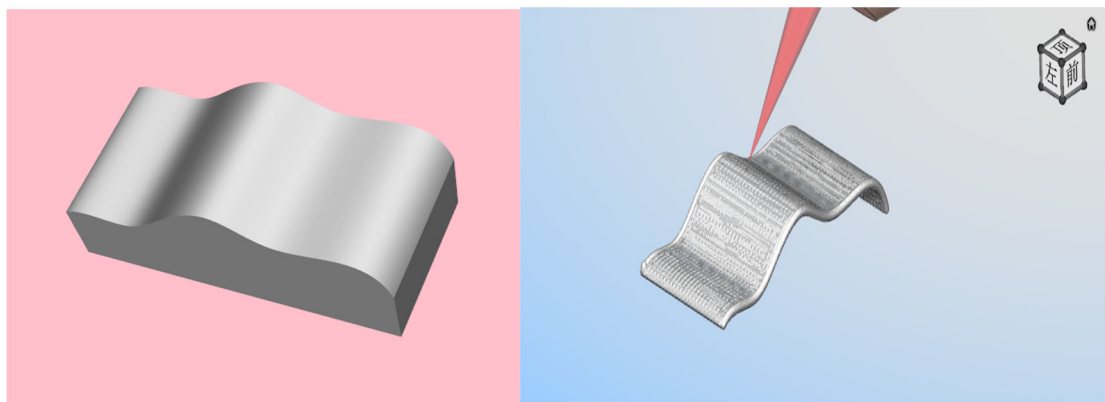


Figure 7. 5-axis 3D printing simulation

After the software outputs the plane layered Gcode and the hybrid layered Gcode, the model file printed by using the 3D printer printing has an obvious step, but the surface of the model printed by the surface layering method is relatively smooth and there is no ladder effect. Experiments have shown that the software is capable of layering the planes and surfaces of the model.

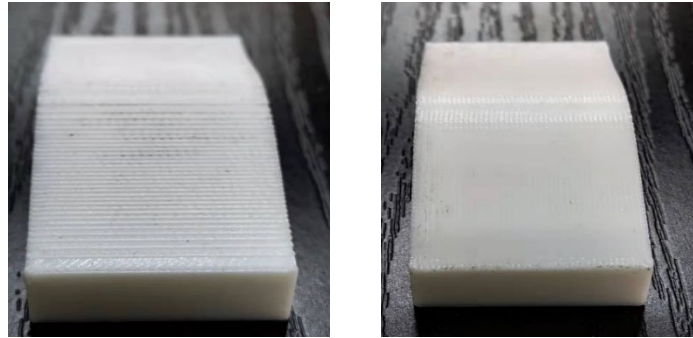


Figure 8. 3D printing experiment

5. CONCLUSION

Through the analysis of the STL model file, the surface offset intersection method is used to layer the model surface, and the rotation matrix is used to calculate the angle of the rotation axis. Surface layering software was developed using python, and the surface layering function was added to the traditional slice software, which effectively proved the usability of the software in experiments and simulations.

REFERENCES

- [1] Zhu Yufang, Peng Chen, Yang Jiquan, et al. An integrated design and fabrication approach for heterogeneous objects. *Advanced Materials Research*, (2012), 383: 5810-5817
- [2] Marro A, Bandukwala T, Mak W. Three-dimensional printing and medical imaging: a review of the methods and applications. *Current Problems in Diagnostic Radiology*, Vol.45(2016) No. 1, p. 2-9
- [3] ALSHARHAN A T, CENTEA T, GUPTA S K. Enhancing mechanical properties of thin-walled structures using non-planar extrusion based additive manufacturing. *International Conference on Materials and Processing*, (Los Angeles, California, USA, June, 2017).
- [4] SINGAMNENI S, ROYCHOUDHURY A, DIEGEL O, et al. Modeling and evaluation of curved layer fused deposition. *Journal of Materials Processing Technology*, Vol. 212 (2012) No. 1, p. 27–35
- [5] HUANG B, SINGAMNENI S B. Curved Layer Adaptive Slicing (CLAS) for fused deposition modelling. *Rapid Prototyping Journal*, Vol. 21 (2015) No. 4, p. 354–367
- [6] Patil, Ajinkya S: Fabrication of Nonplanar Surfaces Via 5-Axis 3D Printing (MS., Rochester Institute of Technology, USA 2022), p.23–50.
- [7] Freddie Hong,: Open5x: Accessible 5-axis 3D printing and conformal slicing. *CHI Conference on Human Factors in Computing Systems*. (New Orleans LA USA, 29 April-5 May, 2022). Vol. 399, p.1–6.
- [8] ZHANG Xi,LIU Yushan,WANG Hui . Research and implementation on curved slicing approach for 3D printing. *Journal of Tianjin University of Technology and Education*, Vol. 31 (2021) No. 4, p. 14-18
- [9] Jin Y, Du J, He Y, et al. Modeling and process planning for curved layer fused deposition. *The International Journal of Advanced Manufacturing Technology*, Vol. 91 (2017) No. 1, p. 273-285.