Research of 3D Printing Model Block Algorithm

Yiyang Lin

College of Automotive and Mechanical Engineering, Changsha University of Science & Technology, Changsha, China
zhaixian@ldy.edu.rs

Abstract. 3D printing can be used widely in many fields. With the development of the society, the needs of using 3D printing are growing faster and faster. People can use 3D printing technology to make a new bone to the patients, create something new and fix some damaged items. In recent years, people use 3D printing machine to print large objects. However, printing large object directly will bring a lot of problems, such as the creation of supports, the collision of the nozzle with the object, low efficiency and unstable structure. Decomposition 3D printing is important in additive manufacturing. This paper revolves around three perspectives 1) reducing support 2) improving efficiency 3) printing large parts. Some suggestions will be given to improve the lack of 3D print decomposition. This research will have an important value in the 3D printing decomposition and make the readers know which algorithm can meet their needs.

Keywords: 3D printing, Decomposition, Package.

1 Introduction

In 3D printing fields, support structures are one of the biggest problems. Printing support structures brings many disadvantages. The first is that it will waste materials and increase printing cost. The second is that the support structures adhere to the surface of model and removing the support structures will destroy the surface of the model. The third is that it prolongs the printing time and reduce the work efficiency [1]. In conclusion, support structures are bad for 3D printing by increasing time and material or damaging the surface. Improving efficiency is also important in 3D printing development. Nowadays, many countries are pursuing lightweight production. The goal of lightweighting is to minimize the weight of the structure under a given boundary condition, while meeting certain life and reliability requirements. Improving efficiency means that people need to reduce printing time, decrease material consumption, and increase fidelity [2]. It fulfills the needs of lightweight production and follows the trend of the development. As the limitation of printing space and the needs of printing large objects, it requires a way to solve these problems. It is too expensive to make a big 3D printing machine. When transport a large object to another place, it is easy to be broken on the road. But if decomposition large objects, it can avoid this situation and save space. More important, it also

Y. Yue (ed.), *Proceedings of the 2024 International Conference on Mechanics, Electronics Engineering and Automation (ICMEEA 2024)*, Advances in Engineering Research 240,
https://doi.org/10.2991/978-94-6463-518-8_12

facilitates cost-effective maintenance. Generally, decomposition 3D printing can reduce support, improve efficiency and print large objects.

The first part is to reduce support. The researchers use a way to increase segmentation. As the number of segmentation increases, it will be easy to become no collision and approximate no support printing solution.

The second part is to improve efficiency. The researchers divide a model into several parts by different ways. Using some new approaches to package them and printing them at the same time to improve efficiency.

The last part is to print large objects. It uses voxels methods to divide a model into many small cubes, then assemble them in different ways.

2 Literature Review

2.1 Reduce support

Reducing support is one of the most important problems to solve. Decomposing 3D printing model can effectively reduce support. Geng Guohua, et al. proposed a model segmentation and packaging algorithm, which divides a given model into pyramid shapes and uses voxels methods. They get the best packaging method by using the improved taboo algorithm. Then, taking the initial chunking packaging sequence as the starting point, the search begins. The researchers choose the size of the supporting structure of the whole pile to get the optimal printed sequence [3]. Gao Yisong first proposed a model segmentation algorithm with the minimum segmentation number and the minimum support constraint. The targets are no collision, minimal support, and the smallest possible number of segments. The researcher describes the problem of model segmentation and printing order planning as one of global optimization for an orderly segmentation sequence. This involves designing a target function based on the improved genetic algorithm. The iterative process begins with a segmentation number of 1, aiming to find the least number of segmentations. The goal is to achieve no collision and an approximate no-support printing solution, which would be considered the optimal segmentation result. Second, he proposed a semantic-guided model segmentation algorithm. The algorithm is to obtain semantic information and transform it into segmentation surface, combined with no collision and less support target segmentation, proposed the method of quickly planning the segmentation order and detecting the effectiveness of segmentation and the segmentation adjustment framework by semantic information constraints, taking the feasible solution to approximate with semantic information as the segmentation result. Finally, the interaction model processing system is built, and the interaction model processing system is built based on the Visual Studio and Qt development platforms. The system has the functions of display, processing and interactive segmentation. Guided by the results of user segmentation, it automatically plans the printing order and adjusts the segmentation, outputting the model blocks, printing order and key parameters of multidirectional motion [4]. Filoscia, et al. proposed a method to automatically divide 3D objects into parts. The algorithm mainly depends on the width value（The larger the width value, the fewer segmentations will be generated, and the smaller the width value, the more segmentations will be generated）, the constraints on the printed part and the size of the printed part(The larger the print, the more fragmentation it produces). This method mainly focuses on minimizing the influence of the surface affected by the support, breaking down the object into multiple parts, automatically selecting the printing direction of these parts, placing the influence of the support and cutting in the occlusion area of the object, and maintaining the visual quality of the final object to reassemble [5].

It can be seen that the purposes of the three are not the same. The algorithm proposed by Gao Yisong can get a better segmentation number, which can achieve approximate no support, but it does not consider how to segment and assemble, and the segmentation algorithm proposed only stays at the theoretical level and does not practice [4]. The algorithm proposed by Geng Guohua, et al. consider segmentation and packaging together at the same time, and the number of segmentation is relatively small, but the printed parts are bonded together (Figure 1), which will have an impact on the surface [3]. The method proposed by Filoscia, et al. is to reduce the surface affected by the support and ensure the visual quality of objects. However, this method only considers the segmentation and does not consider the assembly of parts. In the complex printing model, this method will produce parts that are difficult to install [5].

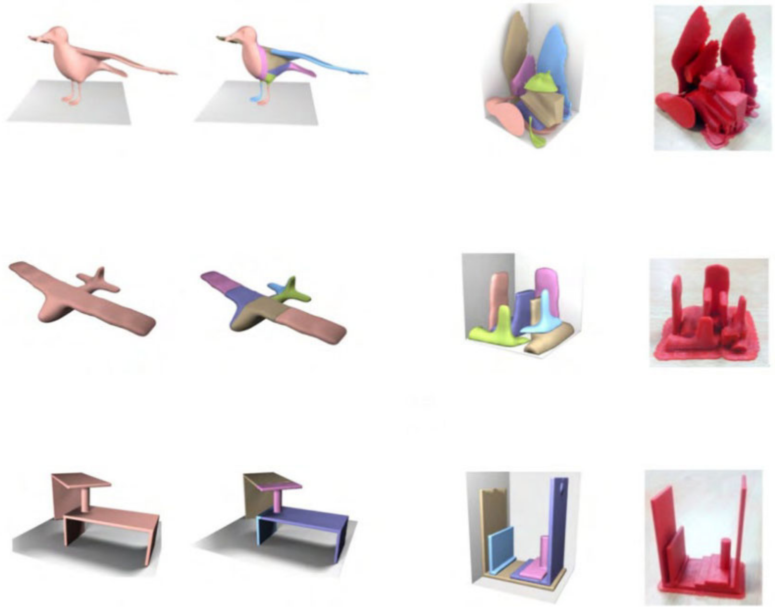

Fig. 1. the printed outcomes by using Geng Guohua, et al. [3].

2.2 Increase efficiency

Improving printing efficiency by decomposition and packaging is a common method in 3D printing model segmentation. Anupam Keshari, et al. proposed a computational framework that decomposes the initial object design into multiple components to reduce the total time of 3D printing. The framework determines the breakdown of individual products into several parts, which helps to decrease the total printing height and volume required for the printing platform. In order to seek components, it requires a suitable cutting platform. Decomposing a whole component through a selective cutting platform is important. The computational framework is shown in Figure 2 flowchart. This process has two main functional steps: 1) determining the possible layers that can be used as the cutting plane, and (2) determining the selected optimal cutting plane by minimizing the TPT [6]. Angshuman Deka, et al. proposed a part separation technique to improve productivity by minimizing processing time. It offers the total number of parts that should be separated and corresponding building direction. This technique uses a genetic algorithm to optimize the cutting surface to minimize the processing time and generate the optimal cutting plane for part separation. For the best processing time, this technique provides 1) the optimal number of components to be separated from a given target and 2) their corresponding orientations. This approach also reduces construction and assembly time, improving the whole printing efficiency [7].

Ilke Demir et al. proposed a near convex segmentation method by dividing the input objects into a set of components, each components follow a set of shape criteria and put them on the printing layer. Then, it provides a powerful algorithm to package the components to achieve efficient printing job during the configuration phase. The near-convex segmentation can reduce the supporting material and create a smooth outer surface. Its packaging algorithm can effectively improve the work efficiency and simultaneously print the components of the group in a plane, it greatly saves time [2]. Xuelin Chen, et al. proposed Dapper, which is a global optimization algorithm for decomposition and packaging problems. It roughly decomposes the model into several parts, and connects the parts to the heap through top-down iteration, while introducing cutting. This method improves printing efficiency and combines the decomposition and packaging. Dapper can reduce the search space to improve the efficiency, however when people face the number of complex parts and blocks, the search space becomes more, the efficiency will also decline [8]. Yosep Oh, et al. proposed a two-stage method: (1) part decomposition, the parts into several pieces; (2) 2D batch placement, the decomposed parts on multiple batches. The research compares the 2D batch placement with the 3D bath placement and find that the 2D bath placement is better than the 3D bath placement. In phase 1, large objects are redesigned into small blocks through a binary space partition (BSP) with hyperplanes, where parts are decomposed recursively until no part exceeds the finite size of the workspace. In phase 2, the decomposed components were grouped into batches to complete the serial building process using a single additive manufacturing machine. In one batch, the decomposed parts are placed based on a two-dimensional packaging method. The parts are not placed on other parts to avoid the support structures of each parts having potential damage [9].

The Dapper model proposed by Xuelin Chen, et al. has some similarities with a two-stage method proposed by Yosep Oh et al. but the Dapper model proposed by Xuelin Chen, et al. can make the stacking of parts more reasonable and make printing fast and convenient [8,9]. Although the computing framework proposed by Anupam

Keshari, et al. can improve the efficiency, most of the segmentation models of this algorithm are segmented along the horizontal plane with a single direction. Most of the models are regular shapes, which has great limitations [6]. The method of near-convex segmentation proposed by Ilke Demir, et al. may not yield good results for thin and curved models [2].

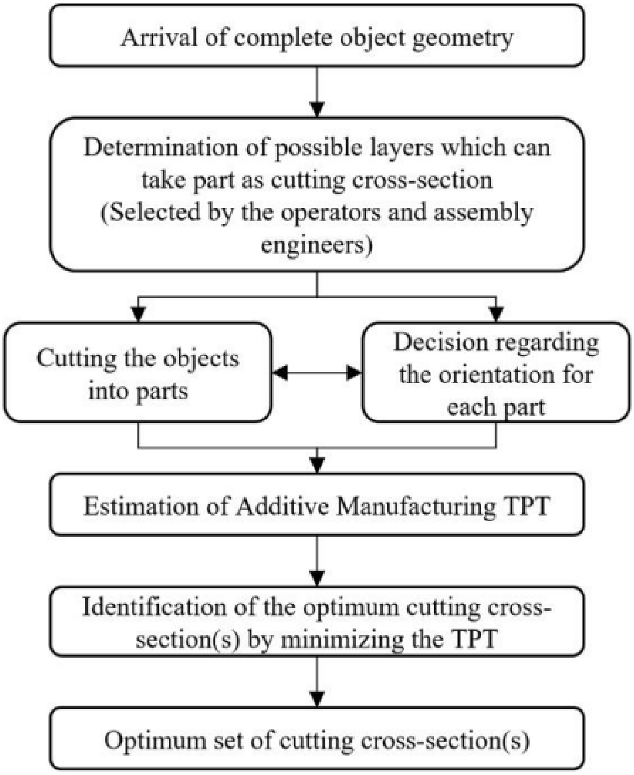

Fig. 2. the computational framework of Anupam Keshari, et al. [6].

2.3 Print large objects

Segmenting 3D printing models into blocks is crucial for printing large objects and can also save time. Linjie Luo, et al. put forward the framework of Chopper. The researchers built a BSP tree from top to down gradually and decompose large 3D model into small parts, and then print out small parts and assembly for original object. Chopper optimized printing adaptation, assembly, efficiency, the feasibility of the connector, structural integrity, beautiful standards. It can output prototype to final decomposing parts. Figure 3 is the chopper decomposition chair model [10]. Jingbin Hao, et al. proposed an efficient partition method based on curvature. Large complex models are decomposed into smaller and simpler submodels with similar shape joints, reducing the complexity. Partitioning the large-scale model by constructing a feature ring and splitting it into triangular patches within the feature ring can improve the segmentation process. It can also improve the manufacturing efficiency of submodels and the feature ring can be used to distinguish meaningful components directly. The feature ring has higher efficiency for the segmentation of the large-scale model [11]. Yahan Zhou, et al. proposed a method that uses a continuous folding sequence. It converts a 3D object into a cube or box, folding from one shape to another without collision. This method divides the object into voxels, connecting adjacency diagrams, with the node as the voxel, the edge as the potential hinge position, and then tree fitting. Finally, the printed object can be turned into a cube through calculation [12].

Peng Song is also using the method of voxel, divide a given three-dimensional model into three-dimensional interlocking parts, the first step is the model voxenized, and then build a significant connection diagram, calculate the significance value of each point, by finding the significant value to get the adjacent points, generate the initial 3D interlocking parts, then the boundary voxel attached to the initial 3D parts, refine the seams to enhance the model's aesthetic appeal. To ensure that the generated 3D parts have good structure and connect 3D interlocking, the method transforms the local geometry of 3D models to avoid voxel fragmentation, creates the initial interlocking parts using the internal voxels, and analyzes the local shapes within the voxels to guide the construction of the final part [13]. Comparing Yahan Zhou, et al. with Peng Song, et al., the method of Peng Song, et al. can ensure that each voxel can be well connected. The gap is greatly reduced and become compact and firm. The appearance of decomposing model is similar to the initial model [12,13] (the difference between Figure 3 and Figure 4). While Yahan Zhou, et al. has fewer steps and can transform the model into cubes through the algorithm [12]. Chen Mingyong proposed a three-dimensional grid model segmentation algorithm based on skeleton line. This method can maximize retention the local features of the model and reduce the use of support materials during the printing process. In the segmentation process, the skeleton lines of the 3 D grid model are extracted through the Laplace grid shrinkage, and then the fitting plane is generated by the local concave set of the 3D grid model through the neighbor least square plane fitting algorithm. Finally, a skeleton line feature point extraction method is designed to form the skeleton feature points with the normal vector of the fitting plane [14].

Although the method of decomposition into voxels can greatly reduce the printing volume, this method has obvious disadvantages: the model gap is relatively large after printing, the appearance is not similar to the model characteristics before decomposition, it takes time to assemble the components. Although the segmentation method of skeleton line can make each structure complete, the calculation time of the algorithm is long, and it will produce problems such as support in printing. Chopper's framework can divide the model into small blocks and consider the assembly problem. However, in the case of sufficient printing space, the mechanical properties of some parts without blocks may be better than the performance of blocks, and will also produce support problems. Chopper uses BSP to partition with many restrictions and it cannot meet some ideal partitions.

Fig. 3. the printed outcome of Yahan Zhou, et al. [12].

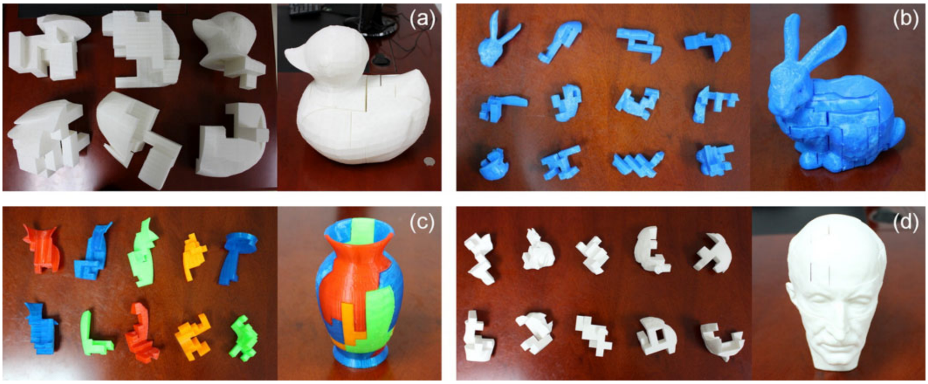

Fig. 4. the printed outcome of Peng Song, et al. [13].

3 Conclusion

This paper studies the current situation of decomposition 3D printing model algorithm and concludes that the main goals of current decomposition algorithms for 3D printing models are to reduce the need for support, improve printing efficiency, and facilitate the printing of large parts. Most of the existing methods to print large parts are to break them down into voxels or into blocks, then put them together by stitching them together or using glue. In terms of improving printing efficiency, the way to increase the number of printed models simultaneously is to decompose and package.

Dividing the parts into several groups and unifying printing parts according to the characteristics of each group can improve the efficiency of printing. Common methods to reduce support include increasing the number of cuts and optimizing the size and volume of the support structures to determine the best printing sequence. These methods can make the models become unsupported structure to improve the surface accuracy and smoothness.

However, most of the algorithms did not study the assembly after dividing with the model which are assembled by glue. Although this method is convenient, it will affect the appearance and strength. It can be designed to make each part into a mortise and tenon structure similar to China, which can make a high connection strength and stable structure. The details of the connection can be hidden to make the overall appearance more beautiful. In terms of reducing support, the current research is to decompose some simple models to achieve the approximate to no support, but it is difficult to achieve the approximate to no support in some more complex models.

References

1. Miao, L.: Research on 3D printing support algorithm based on voxel model. Henan Polytechnic University (2020).
2. Demir, İ., Aliaga, D.G., Benes, B.: Near-convex decomposition and layering for efficient 3D printing. Additive Manufacturing 21, 383–394 (2018).
3. Geng, G., Shi, C., Wei, X., et al.: 3D Model segmentation and packaging in printing. Optics and Precision Engineering 24(6), 1439–1447 (2016).
4. Gao, Y.: Model segmentation for multi-directional FDM 3D printing. Beijing University of Technology (2021).
5. Filoscia, I., Alderighi, T., Giorgi, D., Malomo, L., Callieri, M., Cignoni, P.: Optimizing Object Decomposition to Reduce Visual Artifacts in 3D Printing. Computer Graphics Forum 39, 423–434 (2020).
6. Keshari, A., Simeone, A., Tiwari, M.K.: Assembly Design of Additive Manufacturing Products: A Computational Framework for Part Separation. Procedia CIRP 96, 121 – 126 (2021).
7. Deka, A., Behdad, S.: Part Separation Technique for Assembly-Based Design in Additive Manufacturing using Genetic Algorithm. In: 47th SME North American Manufacturing Research Conference, NAMRC 47, Pennsylvania, USA (2019).
8. Chen, X., Zhang, H., Lin, J., Hu, R., Lu, L., Huang, Q., Benes, B., Cohen-Or, D., Chen, B.: Dapper: decompose-and-pack for 3D printing. ACM Trans. Graph. 34(6), Article 213 (2015).
9. Oh, Y., Zhou, C., Behdad, S.: Part decomposition and 2D batch placement in single-machine additive manufacturing systems. Journal of Manufacturing Systems 48, Part A, 131–139 (2018).
10. Luo, L., Baran, I., Rusinkiewicz, S., Matusik, W.: Chopper: partitioning models into 3D-printable parts. ACM Trans. Graph. (Proc. of SIGGRAPH Asia 2012) 31(6), 129:1–129:10 (2012).
11. Hao, J., Fang, L., Williams, R.E.: An efficient curvature-based partitioning of large-scale STL models. Rapid Prototyping Journal 17(2), 116–127 (2011).
12. Zhou, Y., Sueda, S., Matusik, W., Shamir, A.: Boxelization: folding 3D objects into boxes. ACM Trans. Graph. (Proc. of SIGGRAPH 2014) 33(4), 71 (2014).

13. Song, P., Fu, Z., Liu, L., Fu, C.-W.: Printing 3D objects with interlocking parts. Computer Aided Geometric Design 35-36, 137–148 (2015).
14. Chen, M.: Research on 3D printing model segmentation and path planning algorithm. Jiangsu University of Science and Technology (2023).