Multi-DOF 3D Printing with Visual Surveillance

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ABSTRACT
In this poster, we propose a multi-DOF (degree of freedom) 3D printing system with visual surveillance assistance. Different from common 3D printers with only three translational axes, our printer is equipped with two additional rotational axes, and a visual surveillance module which helps to enhance the printing precision during the rotation. The input model is first segmented such that each part can be printed in a direction with less supporting material. We demonstrate that the proposed system could save most of the supporting materials compared to existing works.

CCS CONCEPTS
• Computing methodologies → Shape analysis;

KEYWORDS
Multi-DOF; 3D printing; FDM; Visual surveillance

ACM Reference Format:

1 INTRODUCTION
The 3D printing technique has been developed rapidly in recent years. It has been widely utilized in various fields such as industry, medicine, life science, etc. Most of the existing 3D printers (e.g., Fused deposition modeling - FDM printer) can only print in the vertical direction. However, only the models with a tree-like structure can be printed directly [Hu et al. 2014], while others types of model need additional supporting structure during the printing process, which need to be removed in a post-processing step. Such printing scheme involves the waste of printing materials, and the cleanup step also has the influence on the appearance of the printed object, which has to be performed very carefully.

To enhance the flexibility of printers, several multi-DOF 3D printing systems have been designed [Peng et al. 2016; Wu et al. 2017]. All these multi-DOF printers are “blindly” controlled. The printing accuracy depends only on the precision of the mechanical system. However, if there is error occurred during the printing process, it is difficult to locate and solve such a problem. In this poster, we propose a novel multi-DOF 3D printing system, which uses a five-axis mechanical system to control the printer and a visual surveillance device to monitor the printing process. Given a 3D model to be printed, it is first segmented into several components such that each component can be printed in its own printable direction with as little as additional support. Then, the printing path is planned automatically, by which the components are printed following the planned order. Once certain component is printed, the object is rotated automatically so that the the supporting plane for next component is horizontally aligned. Furthermore, a visual surveillance module is used to ensure the accuracy of the rotation, which helps to correct and calibrate the rotation process and ensures the quality of the printing.

2 OUR SYSTEM
In this section, we briefly introduce the proposed printing system, which include the hardware setup and the corresponding software implementation.

2.1 Hardware Setup
The hardware of our system consists of a mechanical device with three translational axes and two rotational axes under the printing platform and a high-quality digital camera. The translational axis on the base is the X-axis. The translation axis on the portal frame is the
2.2 Software Implementation

The software is designed to control the printing procedure via the hardware system shown in Fig. 2(left). It consists of three main modules, i.e., model segmentation, printing control and visual surveillance. We briefly explain each step in the following.

2.2.1 Model segmentation. In this step, the Shape Diameter Function (SDF) [Shapira et al. 2008] is first applied to segment the model into individual components, which can be printed in a single direction without any support [Wu et al. 2017]. Then, we fit a plane for the segmentation boundary, and use this plane to cut the model into two parts. This plane is further used as the supporting plane of the incident component during the printing. Note that other sophisticated segmentation techniques can also be applied, such as the primed decomposition [Hu et al. 2014]. We choose SDF due to its simplicity and efficiency.

2.2.2 Printing control. This module is designed to control the whole printing process. It includes the printing program planning, the component printing and the platform rotation parts. The printing program is planned by using the breadth-first traversing scheme. During the printing process, once a component is printed, the platform is rotated so that the bisecting plane between the printed part and the next part to be printed is horizontal.

2.2.3 Visual surveillance. Each time after rotating the printing platform, the image of the printed parts is captured and the intersection region is extracted from the snapped image. Then, we match the intersection region from the captured image and the rendered image using the moment invariant algorithm [Hu 1962]. By analyzing the mapping between these two images, the rotation is corrected again if necessary. The visual surveillance guarantees that the next printing plane is horizontally aligned.

The printing process of our system is shown in Fig. 2(right). It shows that the platform is rotated to different directions when different components are printed.

3 RESULTS AND DISCUSSION

Our system uses the prusa i3 new MK8 extruder for printing, and the printing material is PLA. We first compare our system against the traditional 3D printer using the same input model. The results are shown in Fig. 1 and Fig. 3. Our printer does not need any supporting structure, while the traditional printer requires 4.0g and 1.6g support materials, respectively. One advantage of our system compared with the segmentation-based printing algorithm is that we can print the model in only one pass, without any glue operation. Fig. 4 shows a comparison with the most recent work of Wu et al. [Wu et al. 2017], which uses a mechanical system with 6-DOF. The models printed by our system have similar precision with that of [Wu et al. 2017], but our system is much easier to control.

In the future, we would like to investigate more sophisticated technique for better segmentation, as well as to improve the stability and the scalability of our system.

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