A Novel Real Time Monitor System of 3D Printing Layers for Better Slicing Parameter Setting

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ABSTRACT
We proposed a novel real time monitor system of 3D printer with dual cameras, which capture and reconstruct the printed result layer by layer. With the reconstructed image, we can apply computer vision technique to evaluate the difference with the ideal path generate by G-code. The difference gives us clues to classify which might be the possible factor of the result. Hence we can produce advice to user for better slicing parameter settings. We believe that this system can give helps to beginner or users of 3D printer that struggle in parameter settings in the future.

ACM Classification Keywords
I.3.8 [Computer Graphics]:Applications

Author Keywords
3D printer; dual camera; monitor system; slicing parameters; machine vision;

INTRODUCTION
Over the few years, three dimensional printing has become a very useful technology. However, it is not easy for users to get started with. There are multiple parameters which can affect the quality or durability of the printed objects. Users have to observe the printing process manually to modify the parameters. By observing the melted filament's features and its attaching style to the printing surface, we can get some hints to improve the result.
To get the images during printing process, Sitthi-Amorn et at.[1] placed a camera on the top view and scan the surface of the platform after the whole layer is finished. However, this approach can not get the immediate images and will prolong the printing process. In our work, we present a system with two near-field cameras that can record real time images and reconstruct the full-layer image simultaneously during printing process. Further analysis and computer-aided suggestion of parameters are possible with these information.

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OUR APPROACH
Our goal is to compare every reconstructed layers of 3D printing object with the ideal extruder path according to the G-code generated by slicing software. G-code path can be the ground truth of printing process while hardware problem such as missing steps is eliminated. Our proposed approach doesn't consider the situation of hardware defects because it is impractical to resolve the build defects by modifying parameters. We only focus on the parameters in 3D printing. The compared result can offer clues for the problem of printing, thus we can classify the issue through this observation. Our study integrated a special designed multiple cameras system with image processing algorithm to address this problem, the flowchart is shown in Figure 1.

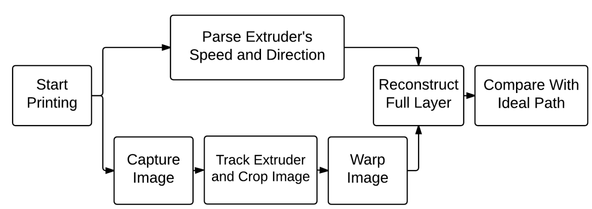

Figure 1. System Flowchart

As shown in Figure 2a, two near-field cameras with 60 Hz frame rate are positioned perpendicularly to each other and closely around the extruder. This design can avoid occlusion problem and reconstruct the path better in all directions by processing the images from the 2 cameras.

Before the printing started, camera calibration is performed to obtain the transform matrix of both cameras and the scale between captured images and real distance. During the printing process, the position of extruder is tracked to locate the image of melted filaments in Figure 2b. Then, we cropped the image around the extruder for the reconstruction. Those images can be warped to the top view of the printing layers

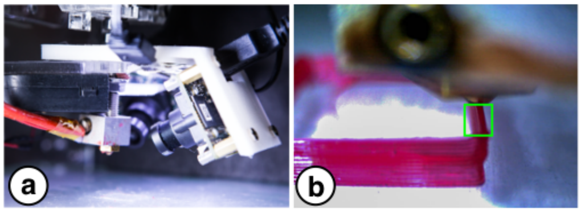

Figure 2. (a) Our near-field multi-camera module positioned around the extruder can (b) automatically track the extruder and crop the image-under it during the printing process.

by the transform matrix, we can get two warped image from top view after this process. The warped images from 2 cameras can be combined proportionally according to the angle of the path directions. We can use a weight function for the proportion of the combination. Using the G-code information and the speed setting of the printer, we can put those image fragments on the correct position. We aligned the images by applying edge detection, and shift them according to their offset. After the above process, we can reconstruct a top view of the entire single layer.

The difference between the reconstructed layer images and the ideal path can be calculated by standard computer vision techniques such as edge detection, skeletonization and subtraction. The above information can represent the quality of the printing result and give us the clue to modify the parameters for the next print.

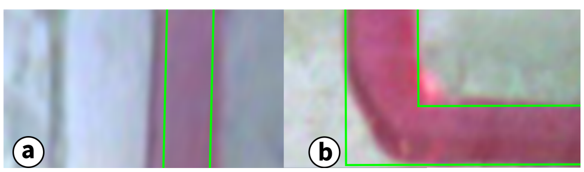

Figure 3. Difference between our recontructed image and ideal path. (a) shows the case of the straight line, and (b) shows the case of corner

For example, in the case of straight line Figure 3a, we can subtract image of the ideal path from reconstructed image to get the difference between them. With the difference of the image, we will be able to categorize the result. If the printed filament is thicker than the ideal path, it is possible for the case that the we should lower the temperature of the extruder, and speed up the printing process. On the other side, if the printed filament is thinner, we should probably slow down the printing speed or raise the temperature of the extruder. We can also make an observation of the corner Figure 3b. The ideal case of the corner should contain two vertical edges, but sometimes the result will be more like a curve. We can use curve fitting to measure the printing error of the corner. If the result is away from the ideal case, the printing speed might be too fast or the stickiness of the filament to the lower layer is too low.

We also skeletonize the reconstructed image to get the route of the extruder. The layer showed in Figure 4a is failed due to the printing speed according to the skeletonized path and the corner fitting result on the upper-right corner. The thickness of the straight line is also failed in other part. The quality is significantly improved after we changed the printing speed Figure 4b.

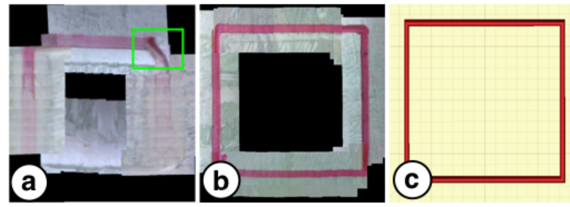

Figure 4. The layer images can be reconstructed from 2 cameras such as the red part in (a) and (b), which will be compared with (c) the ideal path from G-code.

CONCLUSION AND FUTURE WORK

Our proposed approach introduced a novel solution that can help users to monitor the printed structures layer by layer without prolonging the printing time. We can evaluate the quality of the printed object by computer vision techniques to compare reconstructed images with the ideal paths generated from the G-code.

Combining our system with the Machine Learning models, we can categorize the problems of 3D printing and generate better parameter settings to iteratively improve the printing process. For the beginners, the wasted time before the first success can be significantly decreased by utilizing our system.

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