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In-process point cloud generation and predictive correction in Selective Thermal Electrophotographic Process

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Abstract

As a novel additive manufacturing technology, Selective Thermal Electrophotographic Process (STEP) draws inspiration from widely used electrophotographic printing techniques, creating possibilities for large-scale additive manufacturing. To obtain real-time dimensional information during manufacturing, this paper proposes a methodology to acquire the in-process point cloud of the printed object by stacking height information from layered scanning. By inferring point-wise deformation vectors and applying corrections to the in-process point cloud, the corrected point cloud is obtained that accurately reflects the shape of the object after cooling, with up to 0.204 mm difference of average length.

Process monitoring, Metrology, Additive manufacturing, Dimensional prediction

1. Introduction

Selective Thermal Electrophotographic Process (STEP) employs the established 2D printing process at a large scale to construct 3D components, bonding layers combining application of heat and pressure [1]. Due to the complex temperature gradients variations and material state changes involved in the STEP printing [2], the possibility to have effective in-process would affect process accuracy and part quality. Figure 1 shows the STEP process and the laser profiler in the printer. For each layer printed, the building plate undergoes one reciprocal motion, which is utilized by the laser profiler to scan the surface and stich the linear profiles into a heightmap [3].

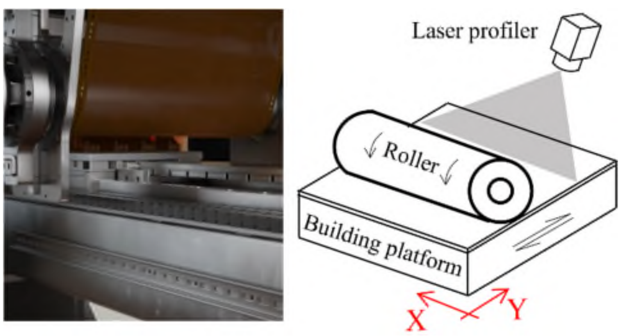

Figure 1. Selective Thermal Electrophotographic Process.

Due to the cooling deformation at room temperature after printing completion, the in-process dimensional information obtained by the laser profiler cannot accurately reflect the final dimensions of the printed components. In this study, the height maps obtained through layer-by-layer scanning are processed and stacked to generate an in-process point cloud synchronized with the printing process. Through a specially designed neural network which is trained to infer the deformation vector on each point, the point cloud corresponding to the cooled state is derieved to describe the expected shape after deformation.

2. Methodology

2.1. In-process point cloud generation by stack of height maps

A matrix consisting of cubes measuring 25 mm × 25 mm × 7.5 mm is printed, and layerwise heightmaps of single cubes are obtained through laser profiler during the printing process.

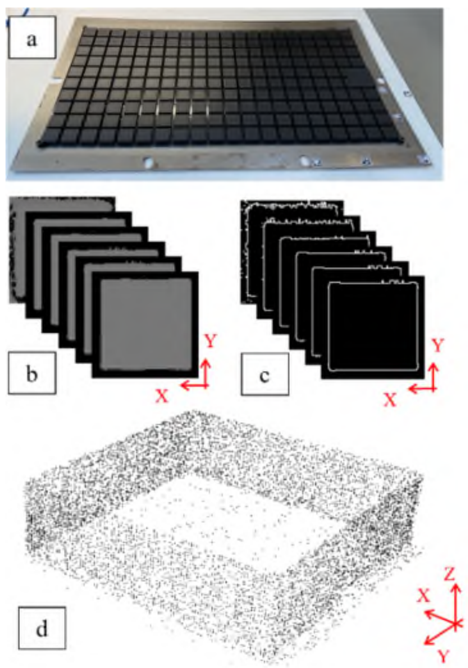

Figure 2. In-process point cloud generation. a. cube matrix; b. example of heightmaps of a cube during printing; c. edges of height maps; d. generated in-process point cloud.

Figure 2 shows the generation of in-process point cloud., The heightmap generated by laser profiler each printed layer undergoes edge detection, where only the outermost pixels are retained and converted from their positions in the image to X and Y coordinates. The Z coordinates of the pixels are determined based on the current layer of the print and the thickness of each layer. The heightmap of the final layer is not subjected to edge processing but is directly transformed into 3D points overlaid at the top. The purpose of this is to obtain a shell-shaped point cloud that describes the outer contour of the printed object.

2.2. Correction by inferences of cooling deformation

Scanning the object after cooling deformation yields the target point cloud. By comparing the in-process point cloud with the target point cloud, a dataset of deformation vectors is obtained. Specifically, both the target and in-process point clouds are downsampled, with the number of points in the target point cloud significantly exceeding that in the in-process point cloud. In this study, the target point cloud is downsampled to 10,000 points while the in-process point cloud is downsampled to 500 points. For each point in the in-process point cloud, the nearest point is searched in the target point cloud, creating point pairs. This process results in a dataset of vectors pointing from points in the in-process point cloud to corresponding points in the target point cloud, with a total of 500 pairs.

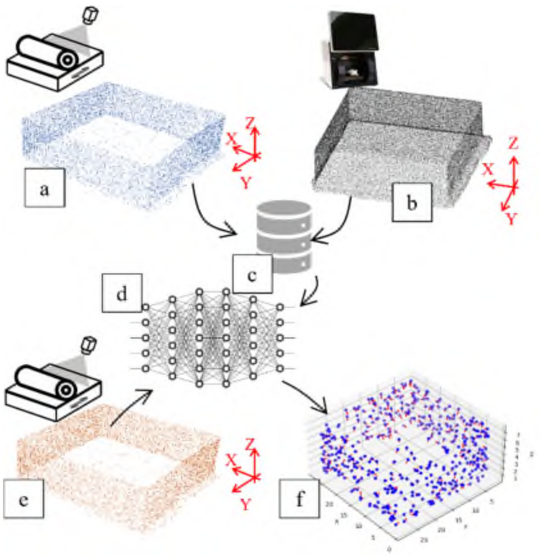

Figure 3. Correction on in-process point cloud. a. in-process point cloud for dataset; b. point cloud of objects after colling deformation; c. deformation vector dataset; d. neural network for deformation vector inference; e. in-process point cloud; f. derieved deformation vector.

As shown in Figure 3, the deformation vector dataset is then employed to train a neural network which infers deformation vectors for each point in the input point cloud. The collection of points at the ends of all deformation vectors forms a set, constituting the corrected point cloud, which describes the shape of the printed object after cooling deformation.

3. Results and analysis

To verify whether the correction on point cloud, dimensions are mearsured on both generated point cloud and the real object.

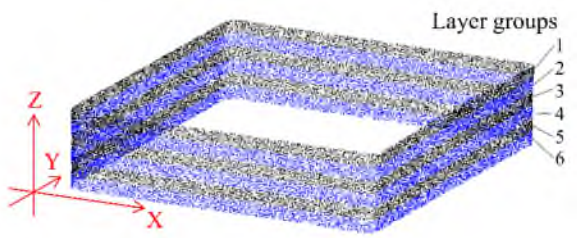

Figure 4. Slices and layer groups to measure.

As shown in Figure 4, point clouds are sliced into 6 layer groups from top to bottom so that dimensions can be obtained at different positions. Figure 5, indacates the comparison of the generated point cloud and the real ones. It can be observed that the dimensions of the point cloud, after correction, align more closely with the actual dimensions.

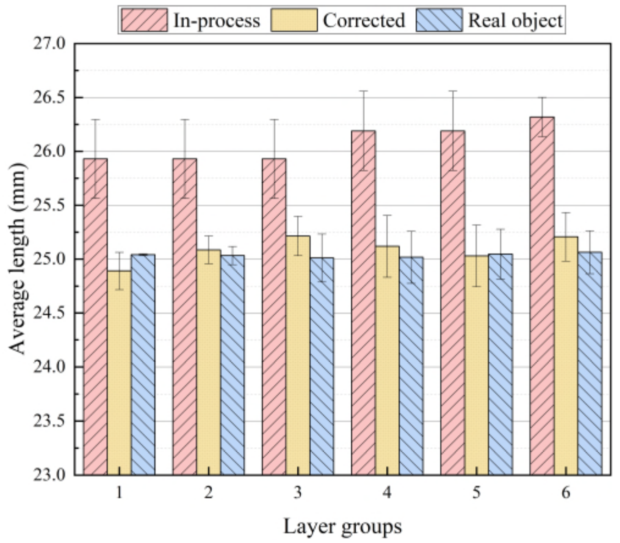

Figure 5. Comparison of dimensions in in-process generated point cloud, corrected point cloud and real object measurement .

Table 1 shows the difference on average lengths between the real objects and corrected point clouds. Despite inconsistency in different layers groups, the maximum difference in the corrected point cloud is up to 0.204mm.

Table 1 Difference on lengths between corrected point cloud and real object, where $\Delta = \bar{L}_{real} - \bar{L}_{corrected}$.

Layer groups	1	2	3	4	5	6
Δ (mm)	0.150	0.052	0.204	0.102	0.016	0.143

4. Conclusion and future works

In this paper we propose a novel in-process poing cloud generation approach in STEP. Laser line profiler is employed to perceive the height maps layer by layer during the process, which are then post-processed and accumulated into point cloud. A neural network is trained to infer the deformation caused by cooling. After the correction the point cloud can faithfully describe the object with maximum 0.204 mm difference on average length. This approach provides real-time measurements as well as final cooling deformation predictions for the STEP process.

References

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