AN ADAPTIVE DE-CUBING PROCESSING FOR LAMINATED OBJECT MANUFACTURING (LOM) BASED ON CONTOUR PROPORTION IN EACH SQUARE CUBE

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ABSTRACT
A Laminated Object Manufacturing (LOM) technique, which is one of a rapid prototyping technique, creates a physical model directly from 3D CAD model without mold and dies by using laminated material. To complete a model, a tool is used to cut laminated material each layer according to layer contours in which the waste material has to remove as de-cubing process. The de-cubing process is to assign shape of waste material into generally small square shape that can be easily remove in order to reduce time and avoid prototype damages. This paper presents a process to assign the size of waste material in the de-cubing process. The adaptive de-cubing process has been established by using proportion of a length of contour section per a length side of a considering square shape. If the proportion is more than a threshold, then the considering side will be divided. On the other hade, if the proportion is less than the threshold, then the considering side will be skipped. The result showed the variety size of waste material.

Keywords: Rapid prototype, Laminate Object Manufacturing

1. INTRODUCTION

Rapid prototyping process is a manufacturing process that manufactures products directly from CAD model without mold and die. It was introduced to shorten prototype construction time. This process converts a 3D CAD model to be a stack of 2D contours which are used to generate machine commands to build an object layer by layer. In this process, material is added to produce a part layer by layer. Several techniques have been developed for rapid prototyping process and they can be classified into 3 categories based on the initial state of materials [1] liquid-based, solid-based and powder-based. Stereolithography apparatus (SLA), a popular technique in a liquid-based system, is the first commercial rapid prototyping system. In this technique, UV laser is used to solidify photo-curable liquid polymer to form layers. Selective Laser Sintering (SLS) is a famous technique in a powder-based rapid prototyping system. This technique is similar to SLA but instead of curing liquid polymer with UV laser, CO2 laser is used in SLS to sinter powder to form a layer. Similarly, 3D printing is also a popular technique in a powder-based rapid prototyping system. Besides using UV laser, glue had been applied. Last group of rapid prototyping system is solid-based. In this group, there are several types of solid material used including wire, roll of laminated sheet and pellets. Popular techniques of this group are Laminate Object Manufacturing (LOM) and Fused Deposition Modelling (FDM) [2].

To complete a model created by LOM, a tool is used to cut laminated material each layer according to layer contours in which the waste material has to remove as de-cubing process. The de-cubing process is to assign shape of waste material into generally small square shape that can be easily remove in order to reduce time and avoid prototype damages.

This paper presents a process to assign the size of waste material in the de-cubing process. The adaptive de-cubing process has been established by using proportion of a length of contour section per a length side of a considering square shape.

2. LITERATURE REVIEW

Based on the process of cutting laminate material in LOM, a defective model is generally occurred during contour cutting step. A method of “cut then bond” had been introduced [6]. The outer area of model contour is cut into equal squares, called uniform de-cute, simultaneously cutting outer contour. For this method,

the edging of prototype isquite rough and difficult to separate between model and scrap. Moreover, Hur and Lee [7] proposed the problems occurred during de-cubing process: the cumulative error, which is introduced into the serious problem and the rest of scrap material that sticks with the model especially, a complexity model and a hollow model. For the hollow model, Cho and Lee [8] were proposed an approach to create by using LOM. There are two steps: cut outer contour of model for a concurrent layer then remove the scrap material before bound with a pervious layer. This approach presented more accumulative error.In order to reduce the accumulative error, Chiu, et al. [9] proposed the bridge generation to connect the inner model area and the outer model area. Even though this approach reduce error in X and Y axis but error in Z axis is increase in which the model is bended and twisted.

3. AN ADAPTIVEDE-CUBING ALGORITHM

An adaptive de-cubing is to assign shape of waste material into generally small non-uniform square shape that can be easily remove in order to reduce time and avoid prototype damages. The algorithm is proposed, as shown in figure 1. An input is an image of 2D layer contour. Since the contour image presents the redundancies areas that are not related with contour information, a contour bounding box is crated to identify a working area. This working area presents both outer and inner areas of particular layer contour. By using a scan line algorithm, the outer and inner areas are identified and the image pixels of inner area are assigned by black color otherwise white color is applied. This working area is divided into four main equal cubes based on the half points along Y axis and Y axis. Then, an adaptive de-cube calculating is applied on each cube, starting from four main equal.

Each main cube is investigated to calculate adaptive de-cube. The adaptive de-cubing process applies proportion of a length of contour section per a length side of a considering square shape. If the proportion is more than a threshold, then the considering side will be divided. On the other hade, if the proportion is less than the threshold, then the considering side will be skipped. A condition for dividing cube using threshold is established in equation (1).

$$\frac{\sum_{i=1}^{n} x_i}{N} \times 100 \geq l_{th} \qquad (1)$$

when x is number of pixels that represent inner areas, N is number of pixels in particular cube and l_{th} is the threshold.

This condition is applied until there is no sub-cube contains pixel more than threshold. When the particular cube is assigned to divide, the cutting points on X axis and Y axis are recorded. Finally, the output of this process are cutting points that can be use to generate tool path planning for adaptive de-cubing.

4. CASE STUDY

To implement the adaptive de-cube algorithm, a cylinder model was studied, as shown in figure 2, by obtaining layer contours image. Then, the contour bounding box concept and the scan line algorithm were applied, the working area and both inner area (black pixels) and outer (white pixels) area were established, respectively, as shown in figure 3.

After working area was define, the working area was divided into four main uniform cubes, as shown in figure 4(a). Then, the adaptive de-cube was applied for all main cubes, as shown in figure 4(b).

The result showed the variety size of waste material, as shown in figure 4(c). All cutting points were recorded for tool path planning that were assigned on the waste material, as show in figure 5.

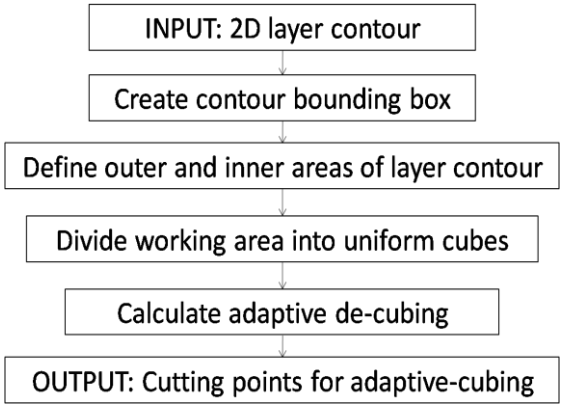

Figure 1: Adaptive de-cubing algorithm

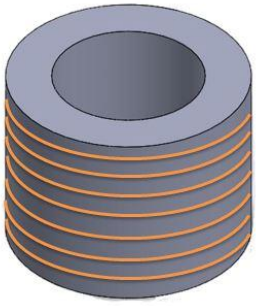

Figure 2: Layer contours of sliced cylinder model

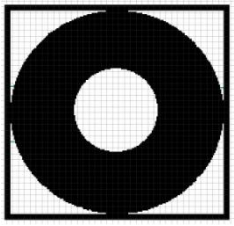

Figure 3: The working area of particular layer contours

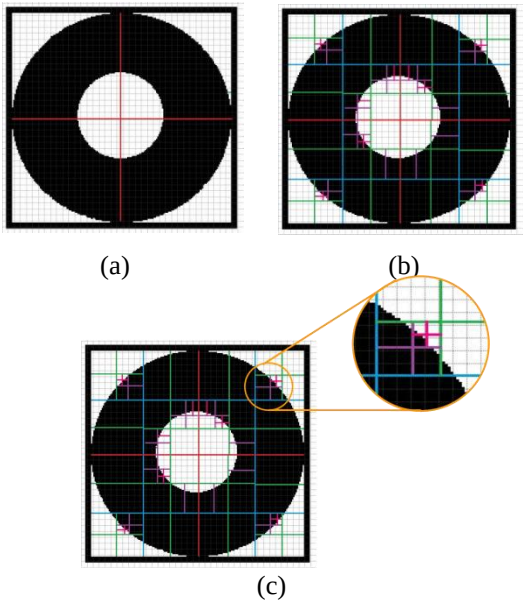

Figure 4: The adaptive de-cubes of layer contour

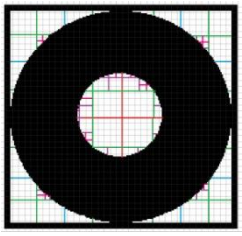

Figure 5: Tool path for adaptive de-cubing

5. CONCLUSION

The adaptive de-cubing process has been established by using proportion of a length of contour section per a length side of a considering square shape. The variety sizes of waste material were established in order to easy remove waste from model edge. By using this algorithm, the automatically identify threshold comparing with the model error will be studied as a future work.

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