Slicing Procedure for Layered Manufacturing

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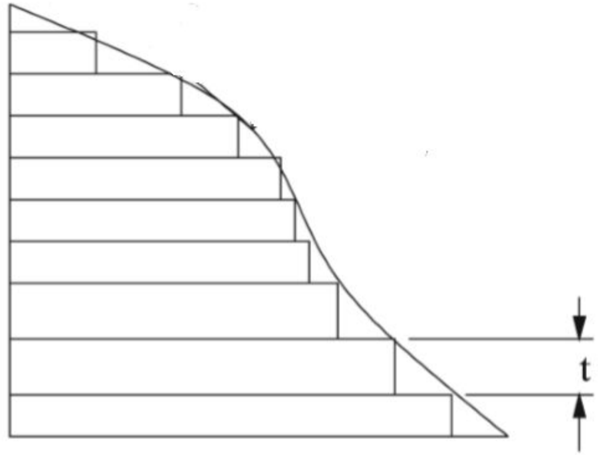
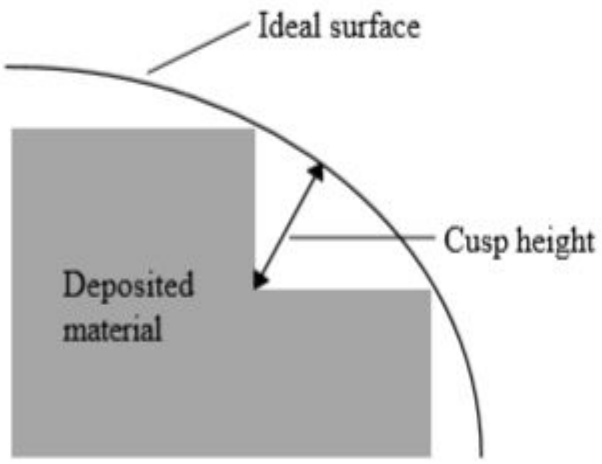
Problem Definition

- The slicing procedure directly affects the extent of the ***staircase effect***. The simplest slicing procedure is a method where the object is sliced at equal intervals. This is referred to as ***uniform slicing***.

- Uniform slicing can typically result in a large staircase effect since this procedure neglects most of the geometric information available from the model. It also results in a loss of control over the (surface) accuracy of the model, since each layer has a different ***cusp height.***

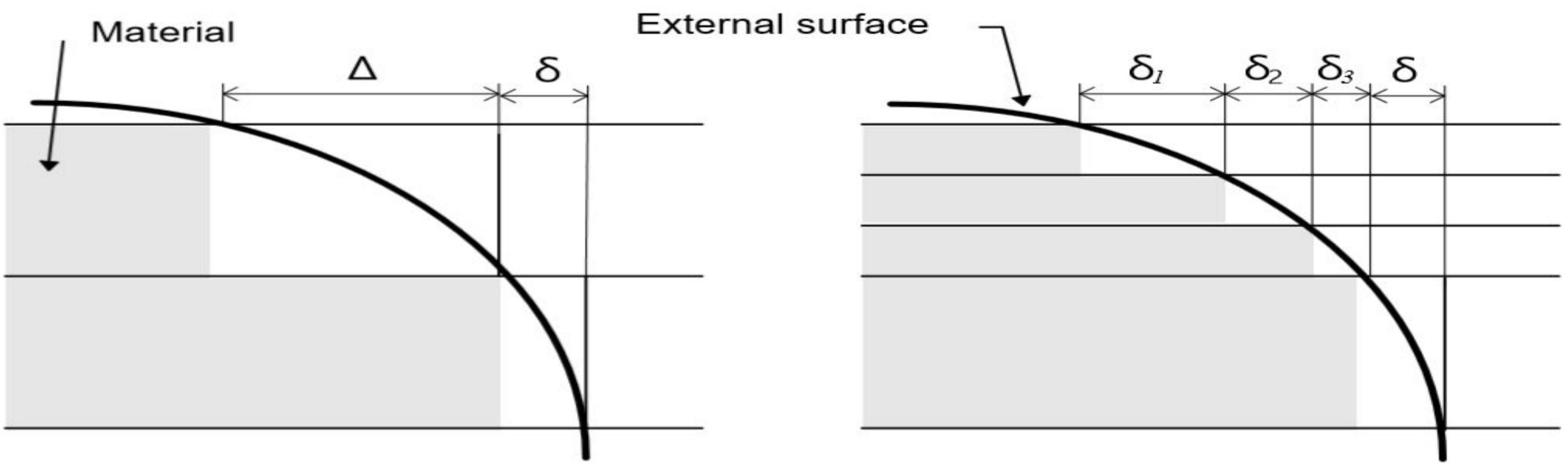




Objectives

- For controlling the accuracy of the model and for reducing the staircase effect, ***Adaptive slicing*** needs to be performed.

- In this procedure, the user can specify a maximum allowable cusp height for the object. Then, the layer thicknesses are computed based on the surface geometry and the prescribed cusp height.



(a) Large slicing produces large error: $\Delta >> \delta$

(b) Adaptive slicing reduces the errors: $\delta_1 \approx \delta_2 \approx \delta_3 \approx \delta << \Delta$

"To overcome the problem faced by the rapid prototyping industry and let them attain enhanced part accuracy by using adaptive slicing method."

Background Research

Layered Manufacturing:

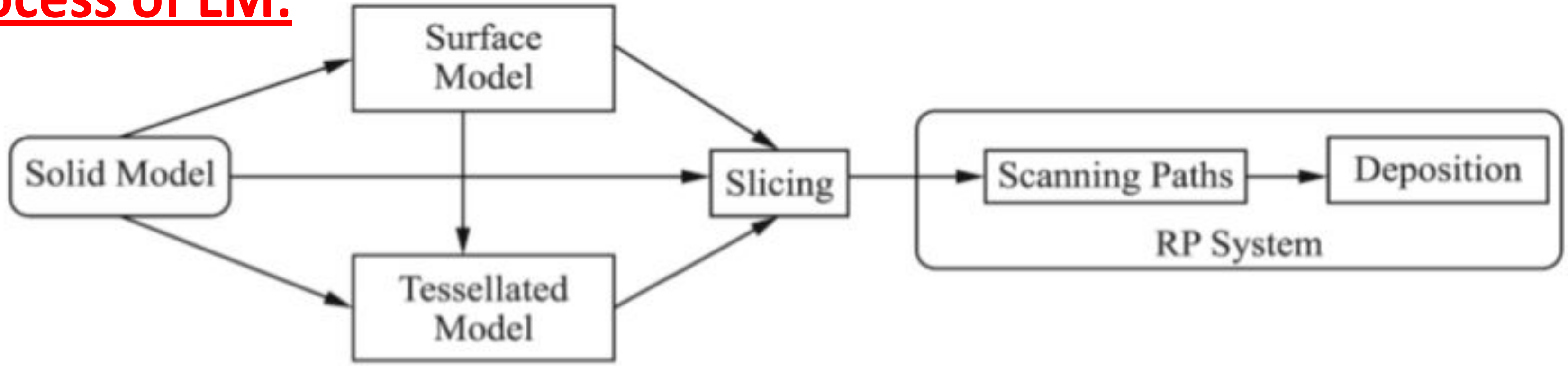
- Layered manufacturing (LM) refers to the fabrication of physical parts layer-by-layer.

- It involves successively adding raw material, in layers, to create a solid of some predefined shape. Some names that have been used to describe LM processes include Desktop Prototyping and Solid Freeform Fabrication.

- Much of the use of LM is currently restricted to prototyping, i.e. creating a physical part for the purposes of analyzing its form, fit or function.

- The use of LM (instead of conventional metal forming/cutting technologies) typically results in a significant reduction in the prototyping time. Hence, in industry, LM technologies are often referred to as Rapid prototyping (RP) technologies.

Process of LM:

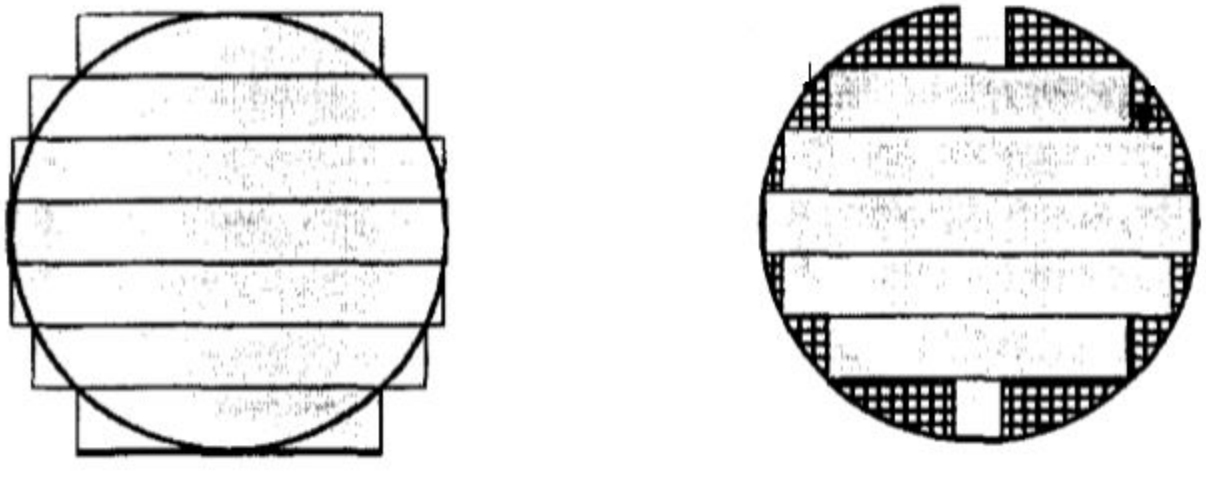


Background Research

Containment Problem:

Depending on the intended application of the LM part, we require containment situations (a) or (b) shown in fig below.

- Situation **(a)** implies extra material has been deposited in the LM process to enable a polishing operation (for surface quality). We call this approximation as being one with '***Positive Tolerance***'.
- If the LM part is to act as a master pattern for making cores. then we would require situation **(b),** since a smaller core would imply extra material in the mould enabling a surface finishing process. Situation (b) is referred to as an approximation with ***'Negative Tolerance'.***



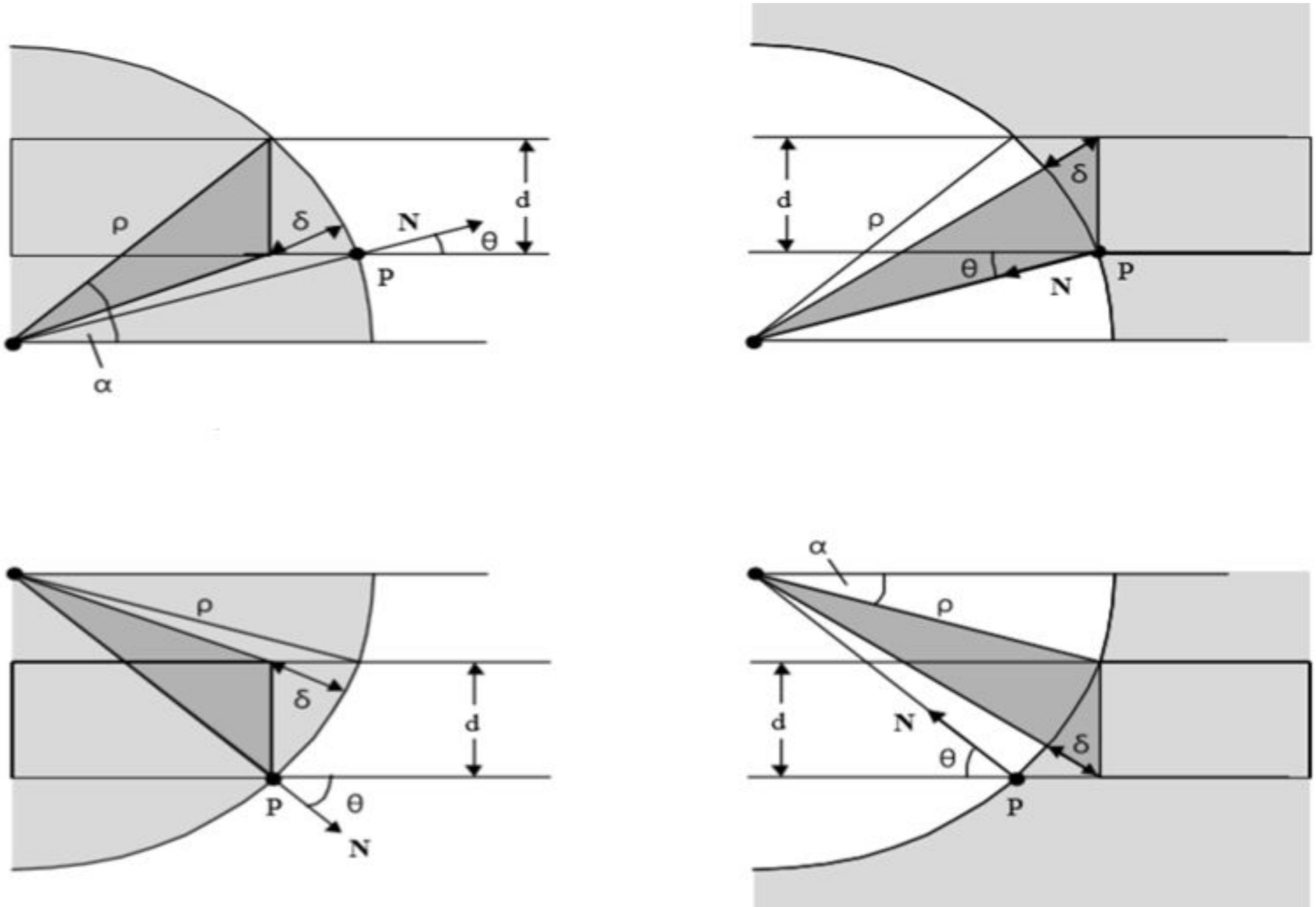
(a) (b)

[Source: Kulkarni et. al., 1996]

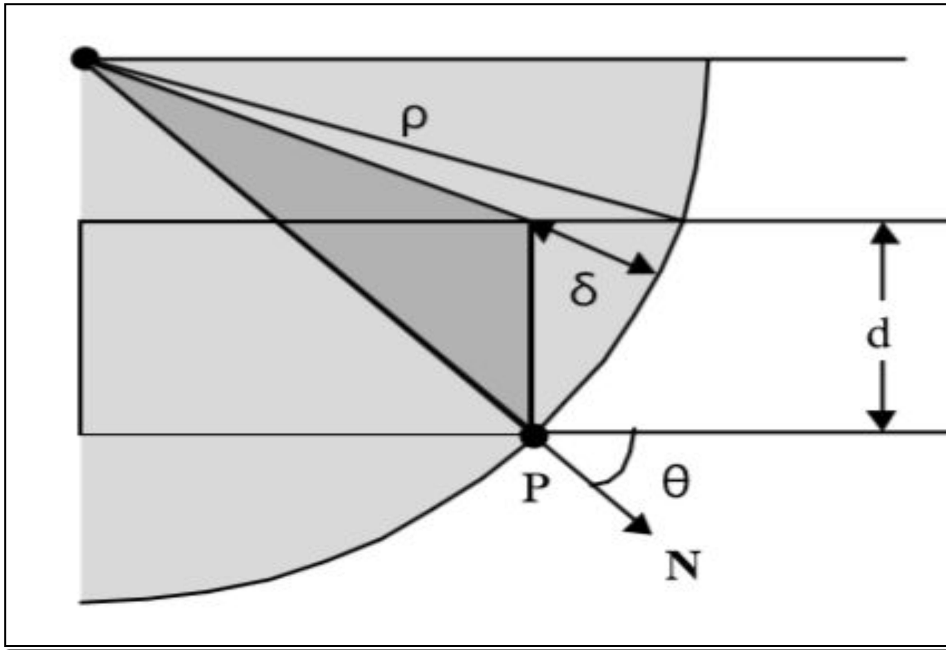
Background Research

Compute adaptive build layer thickness value:

Depending upon the containment and surface requirement, there are ***four possible configurations*** that need to be handled when using this method.



Background Research



P: a point on the part surface
N: the surface normal at P
θ: the angle that N makes to the horizontal
ρ: the radius of curvature at P
δ: the allowed cusp height
d: the layer thickness to be computed

By applying the ***law of cosines*** to the shaded triangle as shown in fig, we get the following equation

$$(\rho - \delta)^2 = \rho^2 + d^2 - 2\rho d \cos(90 - \theta)$$

Where $(90 - \theta)$ is the included angle between sides ρ and d

Background Research

Using the definition $cos(90-\theta)=\sin(\theta)$ equation (1) becomes

$$(\rho-\delta)^2 = \rho^2 + d^2 - 2\rho d\, sin(\theta)$$

Simplifying gives: $\rho^2 - 2\rho\delta + \delta^2 = \rho^2 + d^2 - 2\rho d\, sin(\theta)$

$$d^2 - (2\rho\, sin\theta)d + (2\rho\delta - \delta^2) = 0$$

The ***build layer thickness (d)*** can now be determined using the quadratic equation:

$$d = \frac{(2\rho\, sin\theta) - \sqrt{(2\rho\, sin\theta)^2 - 4(2\rho\delta - \delta^2)}}{2}$$

Simplifying gives:

$$\boxed{d = \rho\, sin\theta - \sqrt{(\rho\, sin\theta)^2 - 2\rho\delta + \delta^2}}$$

Proposed Solution

- ✓ The ***Adaptive Slicing Procedure*** has been used to solve the given problem.
- ✓ The ***basic principle of adaptive slicing*** is to evaluate local surface geometries to determine the build layer thickness that can be used while maintaining a user-defined surface tolerance, usually measured by the cusp height.
- ✓ The ***MATLAB Program*** has been designed to perform adaptive layer slicing on a given surface.

Algorithm of Program

1. **Input:** The User will specify the layer thicknesses and surface geometry. Layer thicknesses are usually distinct values bound by [Lmin, Lmax] and are limited by the fabrication capabilities of the specific LM process.

2. **Process I:** The derived mathematical expressions predict the cusp height at discrete locations along a given slice.

3. **Process II:** The Program then uses maximum Cusp height expressions to determine the optimal thickness for each layer based on the part surface curvature.

4. **Output:** The Program will display the thickness for each layer along with graphical representation of layered surface geometry

Future Work

- We would develop the ***Program to evaluate adaptive build layer thickness for a parametrized equation given by user***. This equation should be depending on single parameter and symmetric about y-axis .

- Instead of building layer from bottom to top, we would now build layers from top to bottom so that enhanced part accuracy can be achieved.

References

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2. Kulkarni, P., and Dutta, D., "An Accurate Slicing Procedure for Layered Manufacturing," Computer-Aided Design, vol. 28, no. 9, September 1996, pp. 683-697.

3. Sabourin, E., Houser, S. A., and Bøhn, J. H., "Adaptive Slicing Using Stepwise Uniform Refinement," Rapid Prototyping Journal, vol. 2, no. 4, 1996, pp. 2026.

4. Justin T. Tyberg, Local Adaptive Slicing for Layered Manufacturing, Copyright 1998