Direct Tool Path Planning for Roughing from Point Cloud using Z-Segmentation

(ME735 - Computer Graphics and Product Modelling)

under

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Abstract :-
The project aims to generate efficient tool path for roughing operation. Its starts with generation of point cloud from the free form surface. Then the surface is segmented into planes and points are projected on it. The cutting areas are identified based on bi-colour and binary map. Finally, the surface is voxelized for tool path generation and optimization.

Objectives :-

1. Generation of the point cloud from free form surface
2. Cloud segmentation and projection on XY plane
3. Cloud segmentation and projection on XY plane
4. Pixelization of the projected area
5. Toolpath planning and optimization.

Methodology :-
Starting from the point cloud direct tool path generation is
done by following the steps below :

- ***Alignment of the point cloud*** :-

Orientation of selected object in space, establishing the axes system and determining the upper and lower limits on the Z axis.

- ***Cloud segmentation on Z axis***:-

Here slicing done on perpendicular planes to the Z axis, the slicing pitch is determined taking into account the parameters of the cutting operation (tool geometry, material, feed rates, etc.) and the geometry of the component that will be cut.

- ***Point recovery*** :-

All points that are found above the sectioning plane in which the tool path is calculated are projected on that plane from top to bottom. This operation aims to use all points to generate the tool path correctly and to avoid collisions with already chipped areas.

- ***Cloud segmentation on XY plane***:

For each layer obtained from point recovery done earlier a grid is made. It will be generated starting from the x=0 and y=0 point.

- ***Identify the milling area***:-

The grid defined after point recovery is individually analyzed and each unit is assigned a colour of Red if it contains points and Yellow if it doesn’t contain points.

- ***Direct tool path generation***:-

The tool path generation and optimization is done based on various methods(Zig-zag, spiral, HSD)

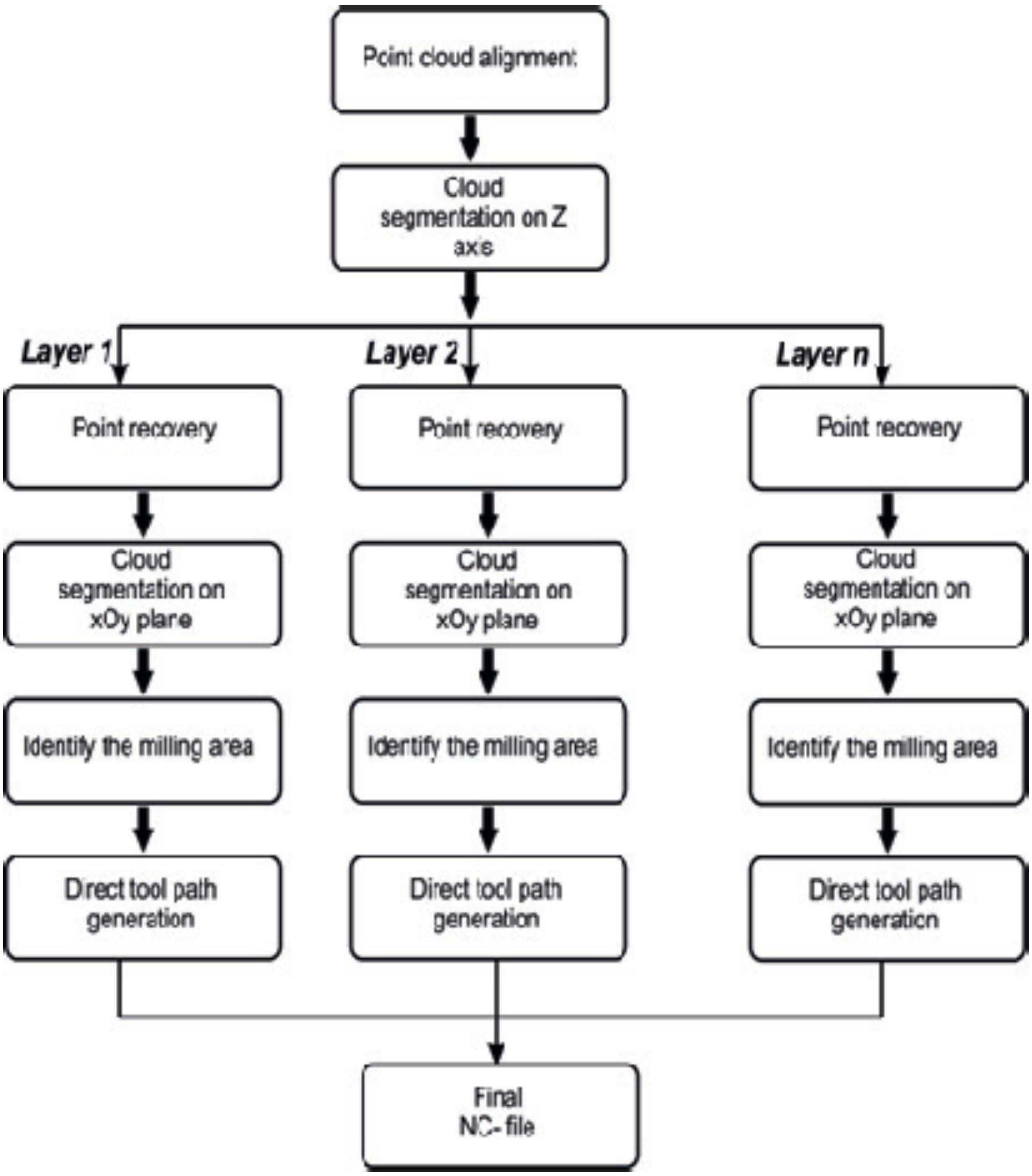
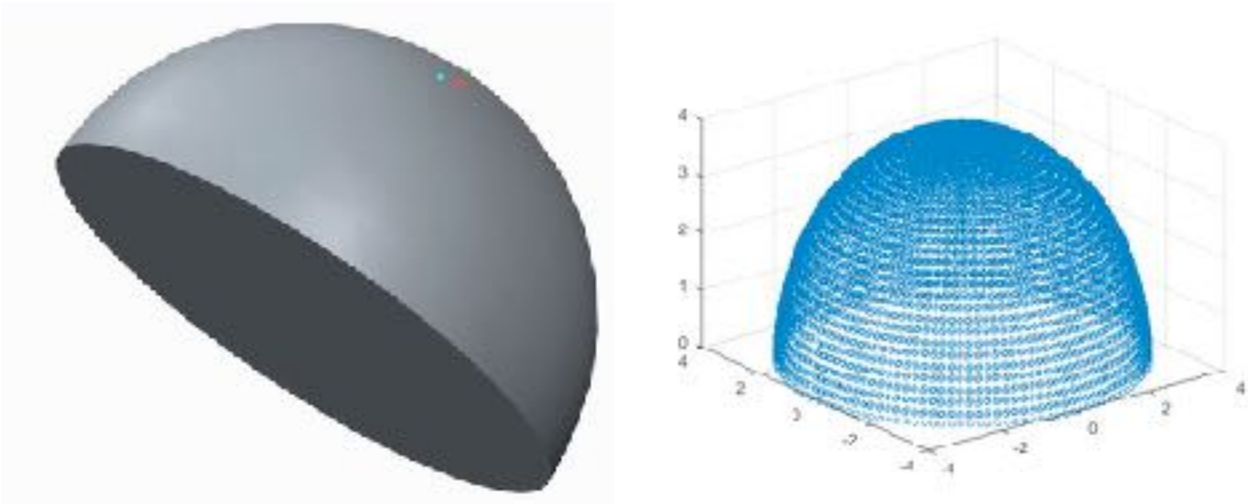


Figure 1: Methodology

Illustration and implementation of the processing algorithms :-
The point cloud of a particular object is generated from STL file of that object .



(a) (b)

Figure 2 : CAD Model (a) ; Point cloud (b)

Every point in the point cloud is defined as ‘V’, as a function of X,Y,Z axes.

V= f (x,y,z)

After generating point cloud, segmentation of Z-axis is done obtaining planes parallel to XY plane as shown in the figure below.

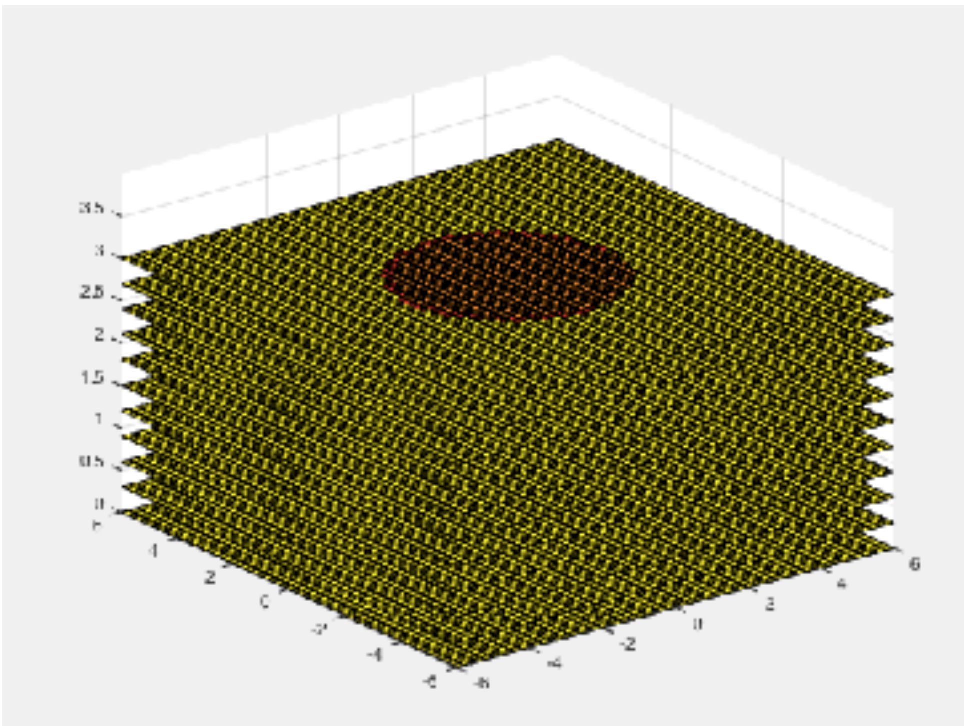


Figure 3 : Z-axis Segmentation

Now slicing pitch(depth of the slice) is set, based on the quality of the geometry of the machined surface and quality of the point cloud (density, ordered, etc.). Distance between two consecutive planes (Z) is defined as

$$Z = (0.3 * d)/4$$

where ‘d’ is the diameter of the cutting tool. Total number of layers(n) formed after Z-axis segmentation can be found out by

$$n = (Z_{max} - Z_{min})/Z$$

In the next step i.e point recovery, the projection of all points that are above current sectioning plane are found. This operation is done by changing the Z coordinate of the points that are above the current plane to the value of Z coordinate of that plane. Projection is done on the planes beginning from Z_{max} upto Z_{min}.

For cloud segmentation on XY plane, each layer obtained through point recovery is formed into grids (mesh) of equal sizes starting from ‘Gridstart’ to ‘Gridend’ which are determined by minimum and maximum values of X and Y axes.

Now areas of the grid where points are found is identified. Each grid which contains the points is coloured Red and the grids which doesn’t contain points are coloured yellow. Thus, a bi-coloured map is formed where the area to be milled is identified i.e, grids which are coloured yellow represent the milling area.

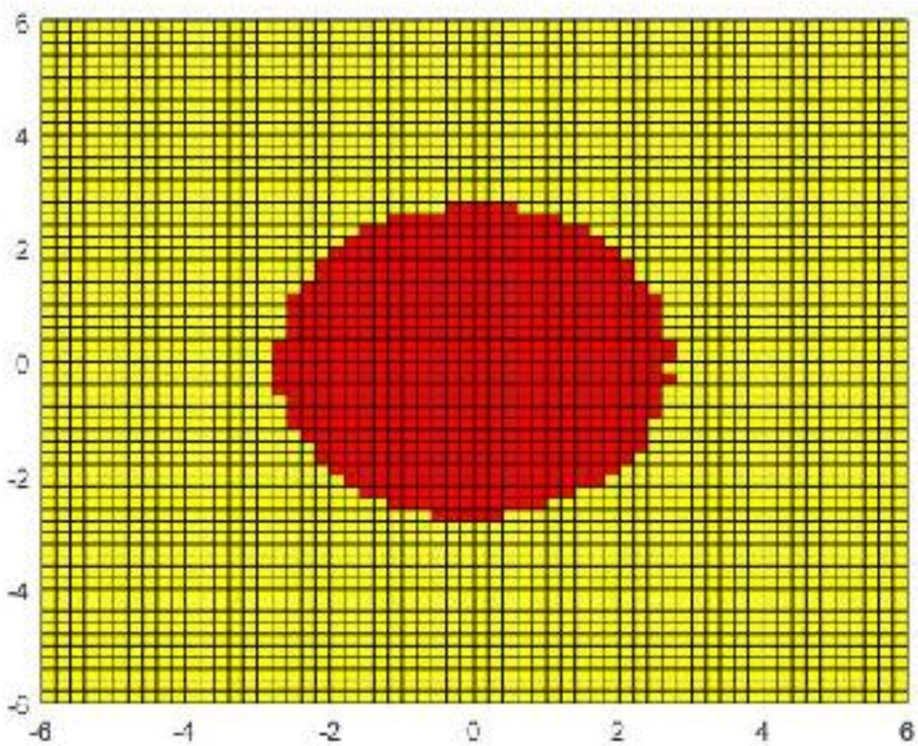


Figure 4 : Bi-colour map

After finding out the milling area, generation of tool path was done based on the following methods:-

i) **Zig-Zag tool path with minimum air time for roughing**

Step-1 :- Convexhull is constructed, which represents the shape of the object, for each plane along the Z-axis. The area which is not covered by the convexhull is the milling area.
Step-2 :- The area to be milled is machined in a zig zag pattern which starts at X=0, Y=0 (Gridstart) and the value of 'X' is incremented by one unit (grid spacing), keeping the 'Y' value as constant. This increment is done till either it reaches the 'Gridend' or till the moment it encounters a red coloured grid (which represents the object).
Step-3 :- All the red coloured grids that are identified in the process are saved, so that milling can be done on the other side of the object.
Step-4 :- After reaching either of them, 'Y' is incremented by one unit and 'X' is decremented by one unit till it reaches Gridstart. The process is repeated till the milling completes.

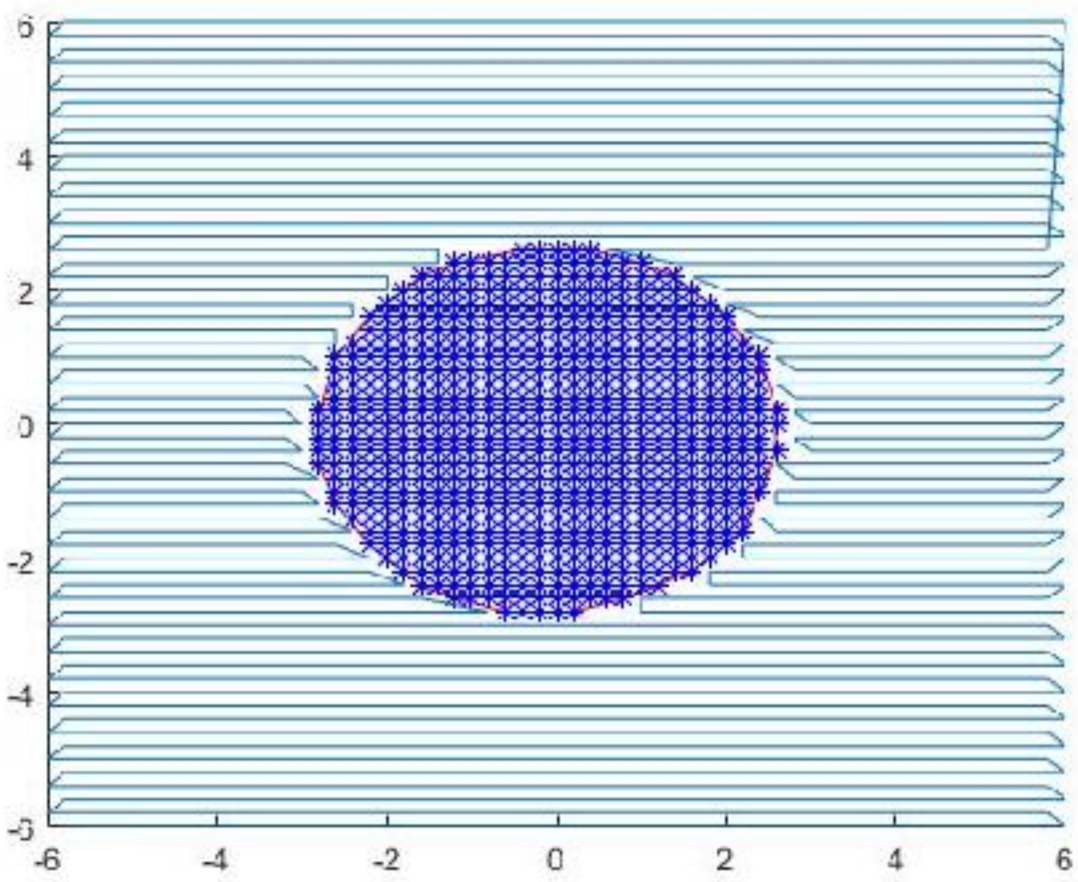


Figure 5 : Zig-Zag path

ii) **Spiral method**

Step-1 :- Convexhull is constructed, which represents the shape of the object, for each plane along the Z-axis.
Step-2 :- Starting from origin (X=Xmin, Y=Ymin), the value of 'X' is incremented till it reaches its maximum value (Xmax) with value of 'Y' remaining constant. Now, the value of 'Y' increments till its maximum value with 'X' remaining constant (Xmax).
Step-3 :- After reaching the maximum point (Xmax,Ymax), the value of 'X' decrements till it reaches 'Xmin' with value of Y (Ymax) constant. Now, value of 'Y' is decrements till it reaches 'Ymin' with X (Xmin) remaining constant.
Step-4 :- After completion of first spiral contour, the starting point for the next contour is determined by incrementing both 'X' and 'Y' with one unit. New starting point would be (Xmin+1unit, Ymin+1unit) and the above steps are followed till the tool reaches midpoint of the object.
Step-5 :- In the process of moving in contours if the tool encounters any points which are present in convexhull then all the surroundings points are checked in clockwise direction to find out the point which lies outside the convexhull and the control is shifts to that point.

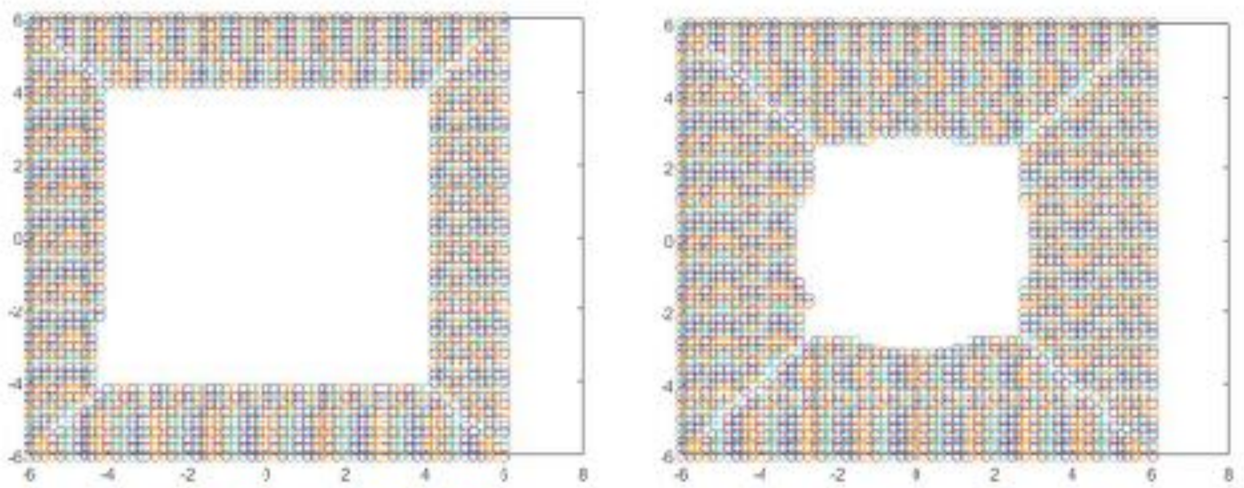


Figure 6 : Spiral path

<u>Results</u> :-
When run for a single layer, the following results have been observed:-

i) Zig-Zag tool path with minimum air time for roughing
Simulation time :- 0.2 secs
Cutter location data :- 3629 points
Machining data/ path length :- 617

ii) ***Spiral method***

Simulation time :- 5.814780 seconds

Cutter location data :- 2365 points

Machining data/ path length :- 673.7628 mm

Future scope :-

- Machining strategy can be done using above methods for the objects having intersecting features.
- Voxelization can be used for simulation and tool path planning
- Planning can be done for finishing paths.

References :-

[1] K. Castelino, R. D'Souza, P.K. Wright, Toolpath optimization for minimizing airtime during machining, J. Manuf. Syst. 22 (2003) 173–180. doi:10.1016/S0278-6125(03)90018-5.

[2] D. Popescu, F. Popister, S. Popescu, C. Neamtu, M. Gurzau, Direct toolpath generation based on graph theory for milling roughing, Procedia CIRP. 25 (2014) 75–80. doi:10.1016/j.procir.2014.10.013.