
# Triangulation of Solid Models having Flat Shapes

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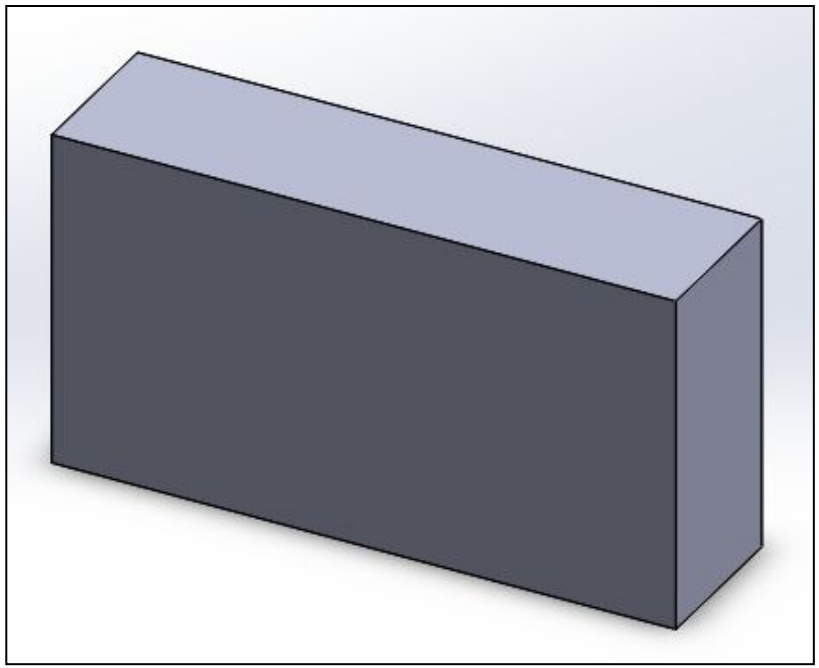
# Problem Definition

**To Triangulate a flat shaped solid model of SOLIDWORKS® using Delaunay Triangulation and then generate a .STL file.**



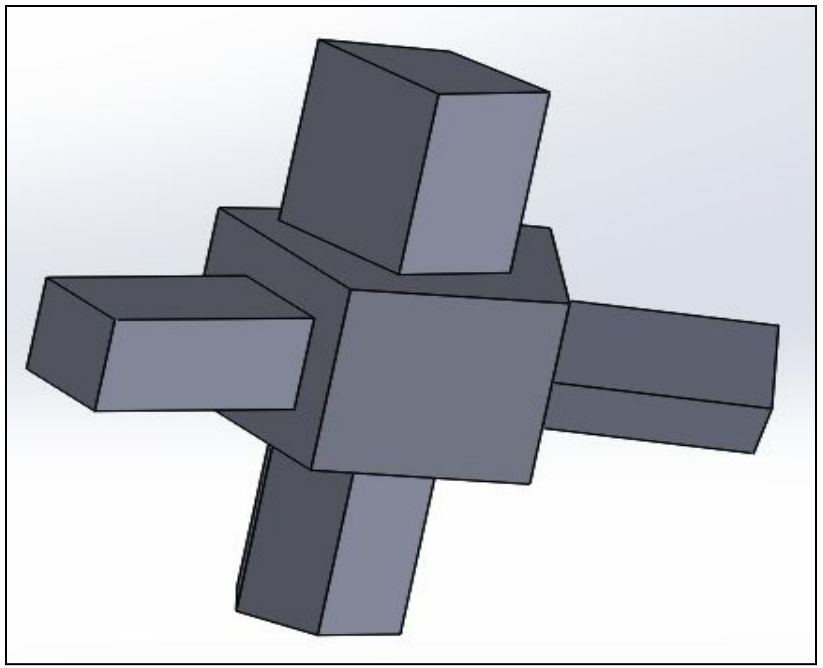


Fig : Solid Model

# Problem Definition

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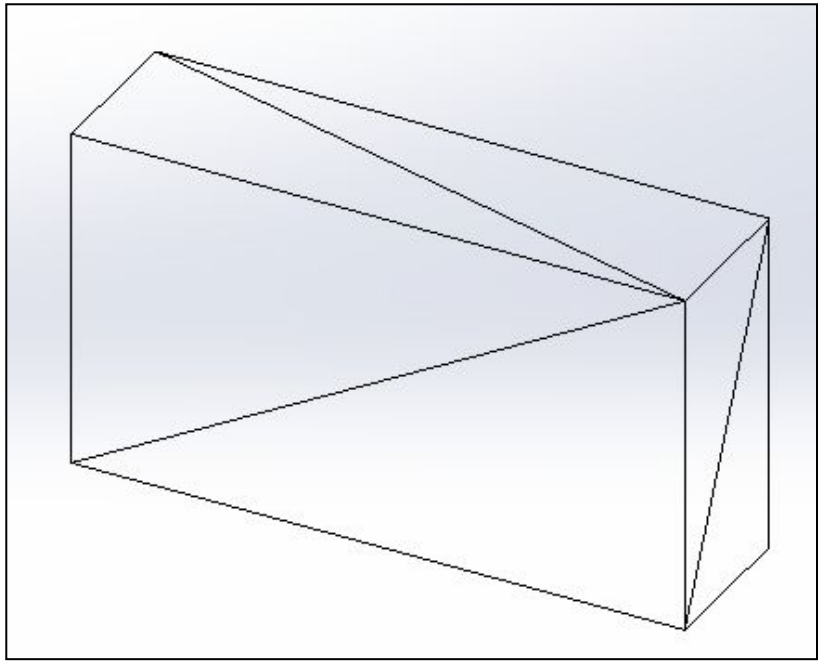


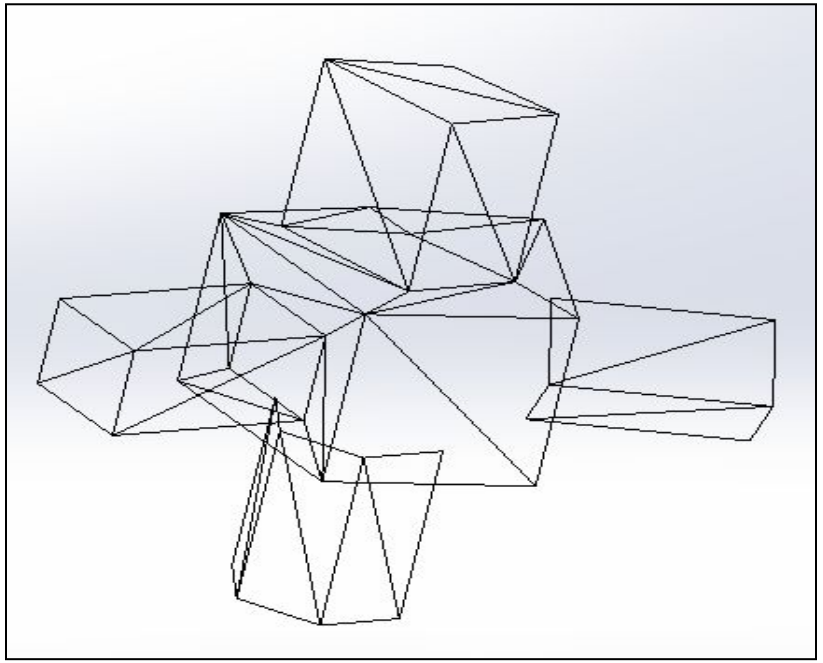


Fig : Triangulated Model

# Application

## Rapid Prototyping Industry:

- In all RP processes, the solid model of a component to be produced is created in CAD environment. A tessellated (.STL) version of the CAD model can then be exported and is sliced before transferring the data to the RP machine.
- Tessellated CAD model has become a standard of RP technology

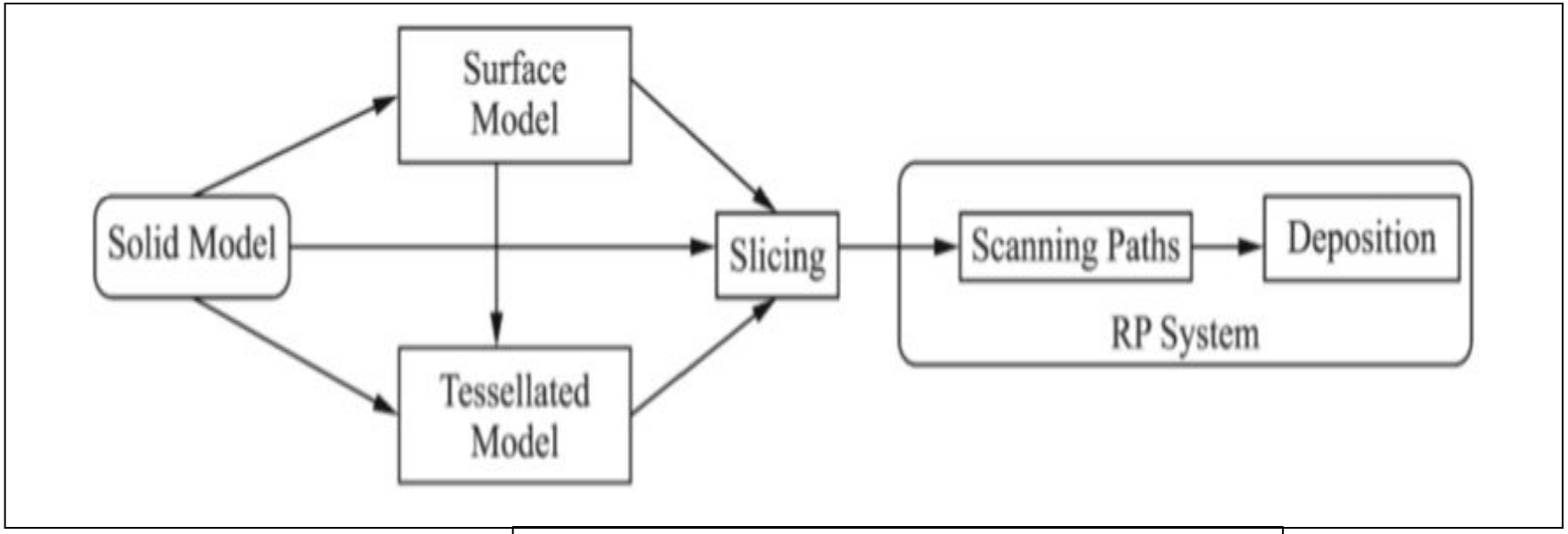
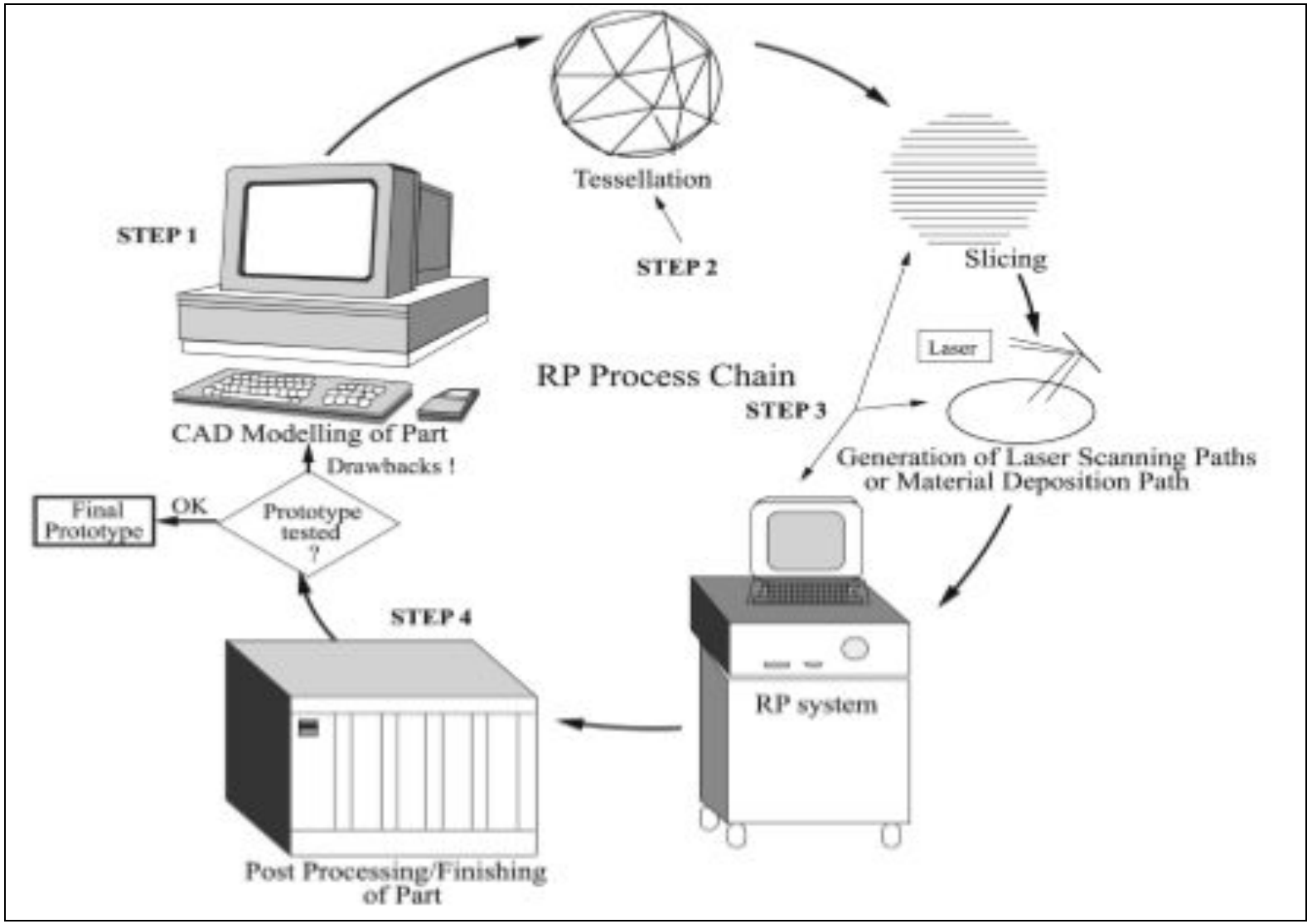



Fig: Rapid Prototyping Process

# Application

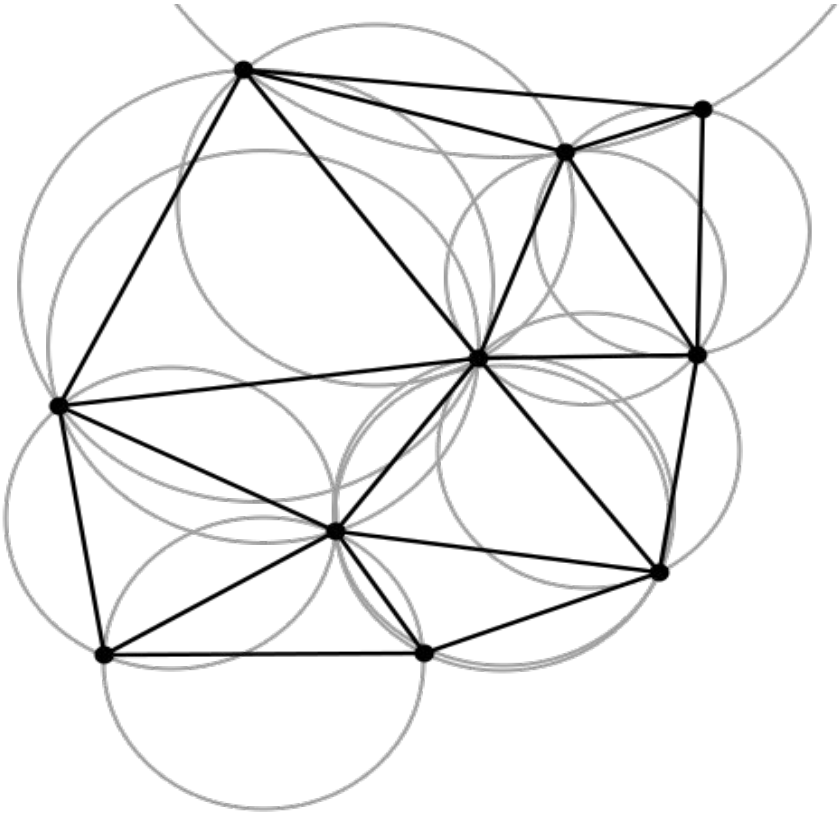
## Rapid Prototyping Process



# Background Research

**Keywords: Delaunay Triangulation, .STL File**

**1. Delaunay Triangulation:** A Delaunay triangulation for a set P of points in a plane is a triangulation DT(P) such that no point in P is inside the circumcircle of any triangle in DT(P).



# Background Research

## 2. STL File:

- STL is a file format native to the stereo lithography CAD software created by 3D Systems.
- STL stands for "Standard Triangle Language" and "Standard Tessellation Language.
- An STL file describes a raw unstructured triangulated surface by the unit normal and vertices (ordered by the right-hand rule) of the triangles using a three-dimensional Cartesian coordinate system
- **Syntax:**

```
facet normal ni nj nk
    outer loop
        vertex v1x v1y v1z
        vertex v2x v2y v2z
        vertex v3x v3y v3z
    endloop
endfacet
```

# Solution Algorithm

Import the Given part file (.sldprt) in SOLIDWORKS

↓

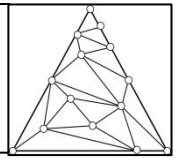
Obtain the vertices of all faces as .txt file

↓

Read the Text file using MATLAB.

↓

Apply Delaunay Triangulation on each face



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Obtain the Output as .STL file.

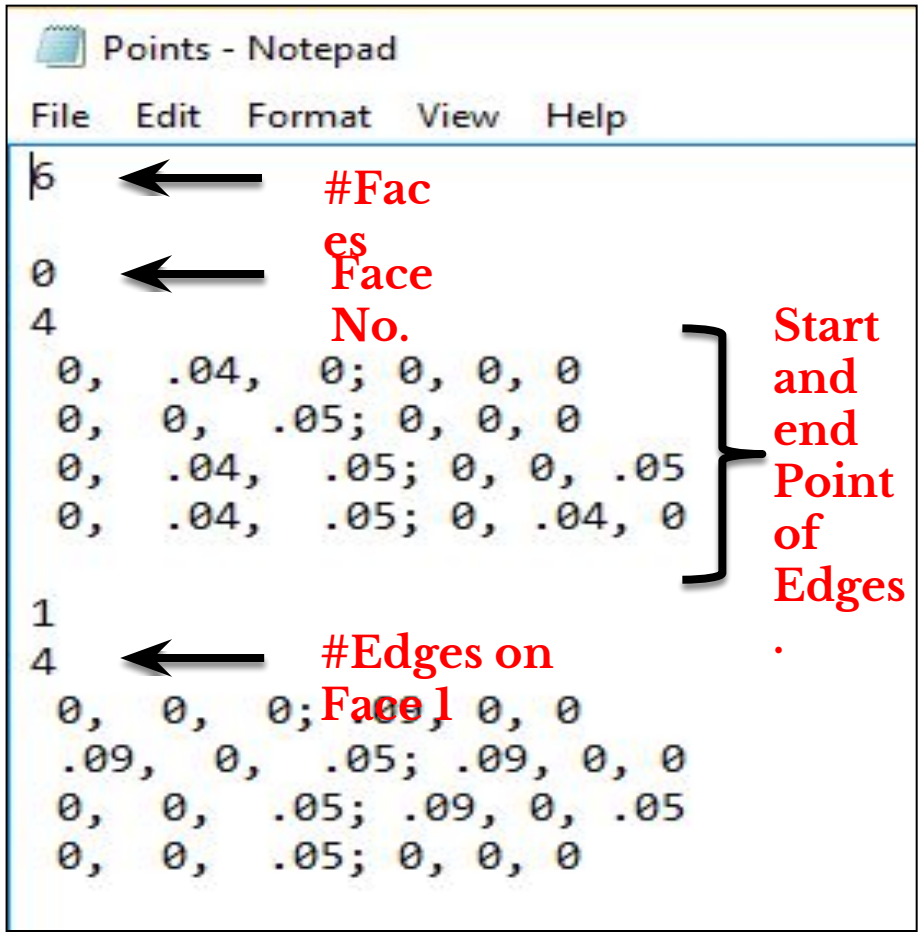
# Solution Approach

1. **Obtain the vertices of all faces as .txt file:**
   The Following Syntax of **SW API Programming** are used for generating the .txt file:

| Operation | Syntax |
|---|---|
| Number of Faces: | swBody.GetFaceCount |
| Select a Face | swBody.GetFaces |
| Number of Edges | swFace.GetEdgeCount |
| Select a Edge | swFace.GetEdges |
| Get Start Point | startVertexObj.GetPoint |
| Get End Point | endVertexObj.GetPoint |
| Create Text file | file.CreateTextFile("Points.txt“) |
| Write Text File | filecreate.WriteLine |
| Execute MATLAB | Interaction.Shell ("matlab.exe") |

# Solution Approach

2. Read the Text file using MATLAB:
   The Code has been written for reading the following text file.




***MATLAB code:***

```
%% Input Points
Data = fileread('Points.txt');
Data = strrep(Data, ',', '');
Data = strrep(Data, ';', ' ');
FID = fopen('Points1.txt', 'w');
fwrite(FID, Data, 'char');
fclose(FID);
N = textread('points1.txt');
```

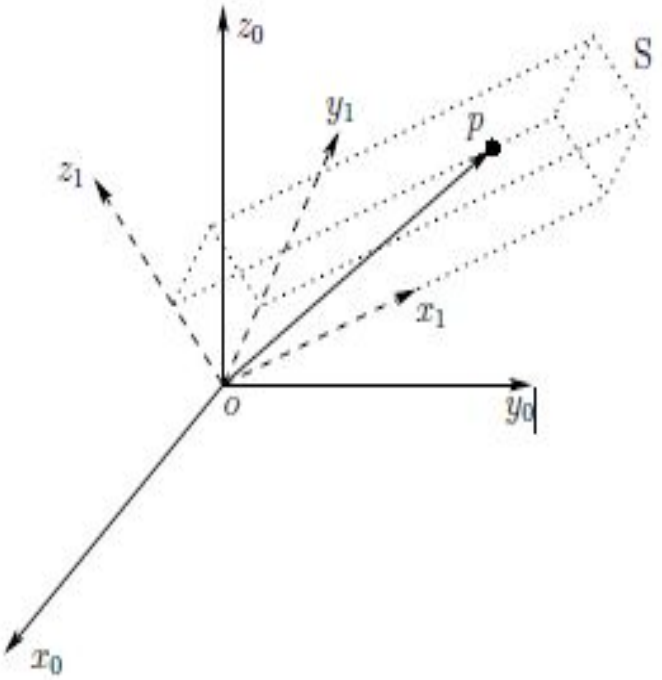
# Solution Approach

## 2. Apply Delaunay Triangulation on each face.

The Delaunay Triangulation is done with following steps:

**Step 1: Rotation of any Arbitrary Plane :**

- An arbitrary plane is rotated such that it is parallel to x-y plane
- $x_o, y_o, z_o$ are the original coordinates (i,j,k).
- w is the unit normal vector to the plane.
- u,v are the orthonormal vectors with respect to w.
- $(P^1)^T = (P^o)^T * R$
- $$R = \begin{bmatrix} u_1 & v_1 & w_1 \\ u_2 & v_2 & w_2 \\ u_3 & v_3 & w_3 \end{bmatrix}$$
- **Syntax:** R = [null(w), transpose(w) ];




**Source:** Mark W. Spong , "Robot Modeling and Control", First Edition, John Wiley & Sons, Inc., New York.

## Solution Approach

**STEP 2:** Make a super Triangle

**STEP 3:** Insert points of plane one by one .

**STEP 4:** Check whether the point violates the Delaunay Triangulation Principle. If yes, Collect all the edges of violated triangles.

**STEP 5:** Join those edges with a added point to form new triangles.

**STEP 6:** Delete the super Triangle

**STEP 7:** Get the number of faces (triangle) and vertices of all triangles.

**STEP 8:** Retransform the Triangle back to its plane and obtain new triangle vertices. Calculate its normal.

# Solution Approach

## 3. Obtain the Output as .STL file format:

File Edit Format View Help

```
solid Part1
   facet normal -1.000000e+00 0.000000e+00 0.000000e+00
      outer loop
         vertex 0.000000e+00 0.000000e+00 0.000000e+00
         vertex 0.000000e+00 0.000000e+00 3.000000e-02
         vertex 0.000000e+00 6.352088e-02 3.000000e-02
      endloop
   endfacet
   facet normal -1.000000e+00 0.000000e+00 0.000000e+00
      outer loop
         vertex 0.000000e+00 0.000000e+00 0.000000e+00
         vertex 0.000000e+00 6.352088e-02 3.000000e-02
         vertex 0.000000e+00 6.352088e-02 0.000000e+00
      endloop
   endfacet
   facet normal 0.000000e+00 1.000000e+00 0.000000e+00
      outer loop
         vertex 0.000000e+00 0.000000e+00 0.000000e+00
         vertex 0.000000e+00 0.000000e+00 3.000000e-02
         vertex 1.150124e-01 0.000000e+00 3.000000e-02
      endloop
   endfacet
```

*MATLAB code:*

```
%% STL File
fid = fopen('stl.txt','at');
for st=1:NF
    for v=1:3
    xv(v)=X(T_out(st,v));
    yv(v)=Y(T_out(st,v));
    zv(v)=Z(T_out(st,v));
    end
    TM=[xv',yv',zv'];
    Tnew=TM*(inv(RM));
    Tnew=round(Tnew,5);
    v1=Tnew(2,:)-Tnew(1,:);
    v2=Tnew(3,:)-Tnew(1,:);
    ntc=cross(v1,v2);
    nt(st,:)=ntc/norm(ntc);
```

# References


1. **SOLIDWORKS API HELP:**
   http://help.solidworks.com/2012/English/api/sldworksapiprogguide/Welcome.htm

2. **Create .txt file using SW Macro:**

   https://msdn.microsoft.com/en-us/library/aa265018(v=vs.60).aspx

3. **Rotate 3D object to align with x-y plane.**
   Book: Mark W. Spong , "Robot Modeling and Control", First Edition, John
   Wiley & Sons, Inc., New York.

   http://in.mathworks.com/matlabcentral/newsreader/view_thread/306882

4. **Free online STL viewer.**
   http://www.viewstl.com/