*.STL FILE FORMAT

- by Melwyn F. Carlo

A] Introduction

Full Form : **ST**ereo**L**ithography

Also referred to as :
1. **S**tandard **T**riangle **L**anguage
2. **S**tandard **T**essellation **L**anguage

What it does : It encodes the surface geometry of a 3D object.
It encodes this information using a simple concept called "tessellation".

Tessellation : Tessellation is the process of tiling a surface with one or more geometric shapes such that there are no overlaps or gaps.
If you have ever seen a tiled floor or wall, that is a good real life example of tessellation.

Types of STL File Encoding :
1. ASCII Encoding
2. Binary Encoding

B] ASCII STL File Format

```
solid  name
{
    facet normal  $n_x$  $n_y$  $n_z$
        outer loop
            vertex  $v1_x$  $v1_y$  $v1_z$
            vertex  $v2_x$  $v2_y$  $v2_z$
            vertex  $v3_x$  $v3_y$  $v3_z$
        end loop
    end facet
}+
{
    facet normal  $n_x$  $n_y$  $n_z$
        outer loop
            vertex  $v1_x$  $v1_y$  $v1_z$
            vertex  $v2_x$  $v2_y$  $v2_z$
            vertex  $v3_x$  $v3_y$  $v3_z$
        end loop
    end facet
}+

    ⋮

endsolid  name
```

NOTE:

1. Bold Face indicates a Keyword.
2. Keywords are Case and Space Sensitive.
3. { ... }+ indicates that the contents within the brackets may be repeated one or more times.
4. Italic Face indicates user-spcified values.
5. 'n' is a unit vector
6. 'v' is a vertex point
7. Vertex Point must be a single-precision value. E.g. 1.234000e005

C] Vertex Rule

Statement : Each Triangle must share two vertices with its neighbouring triangles.

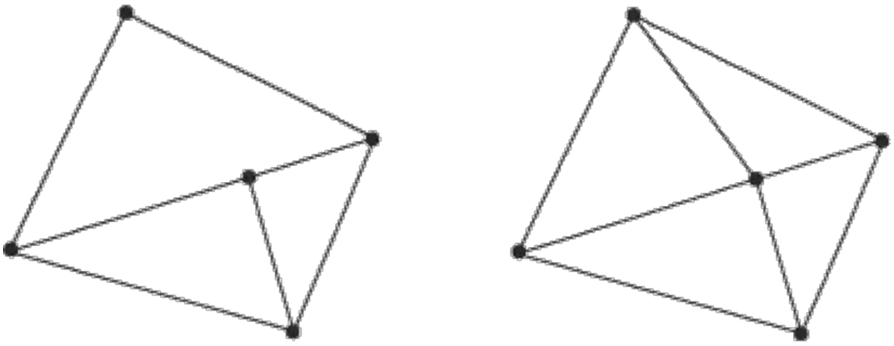


Figure. Invalid vs. Valid Tesselation

D] Orientation Rule

Statement : The orientation of the facet (i.e. which way is “in” the 3D object and which way is “out”) must be specified in two ways.

Way – 1 : The direction of the normal unit vector should point outwards. (when seen from the outside of the 3D geometrical object)
The vector is perpendicular to the surface of the triangle.

Way – 2 : The vertices are listed in counter-clockwise (anti-clockwise) order when looking at the object from the outside (right-hand rule).

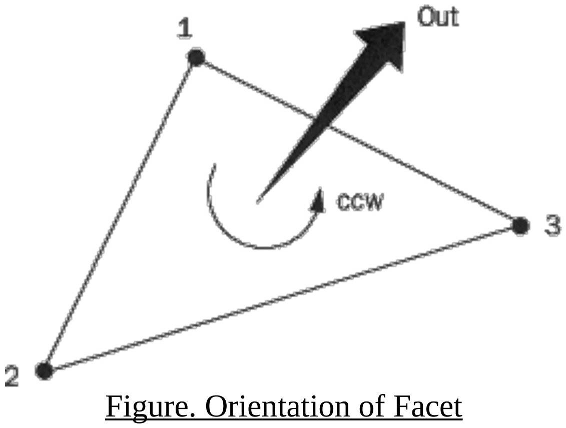


Figure. Orientation of Facet

NOTE : This redundancy exists for a reason. It helps ensure consistency of the data and spot corrupt data. A software can, for example, calculate the orientation from the normal and subsequently from the vertices and verify whether they match. If it doesn’t, then it can declare the STL file to be corrupt.

E] All Positive Octant Rule

Statement : The co-ordinates of the triangle vertices must all be positive.

NOTE : The rationale behind this rule is to save space. If the 3D object was allowed to live anywhere in the coordinate space, we would have to deal with negative co-ordinates. To store negative co-ordinates, one needs to use signed floating point numbers. Signed floating point numbers require one additional bit to store the sign (+/-). By ensuring that all coordinates are positive, this rule makes sure that we are able to use unsigned numbers for the coordinates and save a bit for every coordinate value we store.

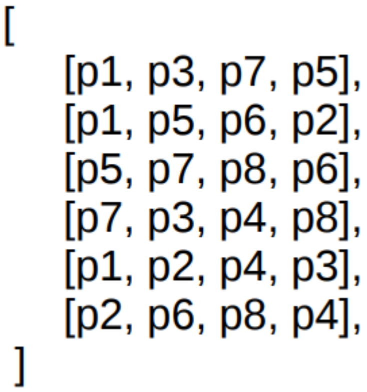
Additional Note : The normal vector ‘n’ can contain negative values.

F] Triangle Sorting Rule

Statement : The triangles should appear in an ascending z-value order. (recommended)

NOTE : This helps Slicers slice the 3D models faster.
However, this rule is not strictly enforced.

G] Example of arranging vertices according to the rule of orientation



```
[
    [p1, p3, p7, p5],
    [p1, p5, p6, p2],
    [p5, p7, p8, p6],
    [p7, p3, p4, p8],
    [p1, p2, p4, p3],
    [p2, p6, p8, p4],
]
```

Figure. Vertices Data

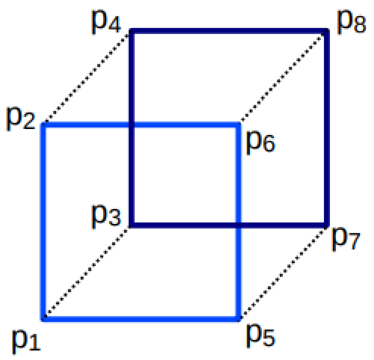
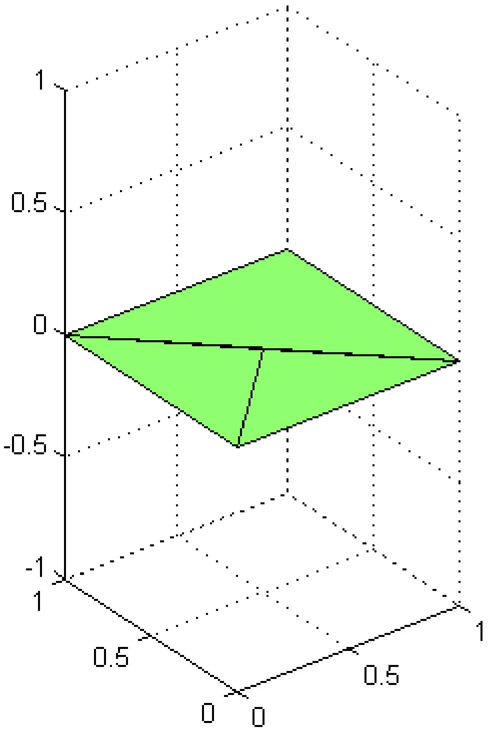


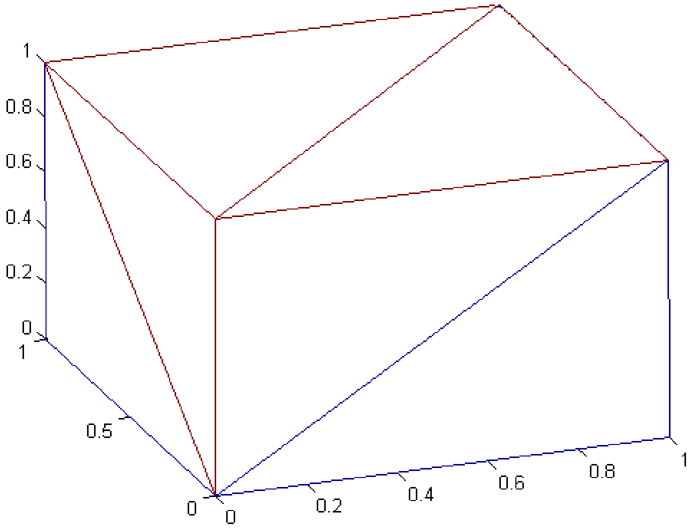
Figure. 3D Cube with Vertex Points

H] Example of a flat shape using 3 triangular faces

```
solid    MYSOLID
     facet normal    0.0    0.0    1.0
          outer loop
               vertex    1.0    0.0    0.0
               vertex    0.5    0.5    0.0
               vertex    0.0    0.0    0.0
          end loop
     end facet
     facet normal    0.0    0.0    1.0
          outer loop
               vertex    0.0    0.0    0.0
               vertex    0.5    0.5    0.0
               vertex    0.0    1.0    0.0
          end loop
     end facet
     facet normal    0.0    0.0    1.0
          outer loop
               vertex    1.0    0.0    0.0
               vertex    1.0    1.0    0.0
               vertex    0.0    1.0    0.0
          end loop
     end facet
endsolid    MYSOLID
```



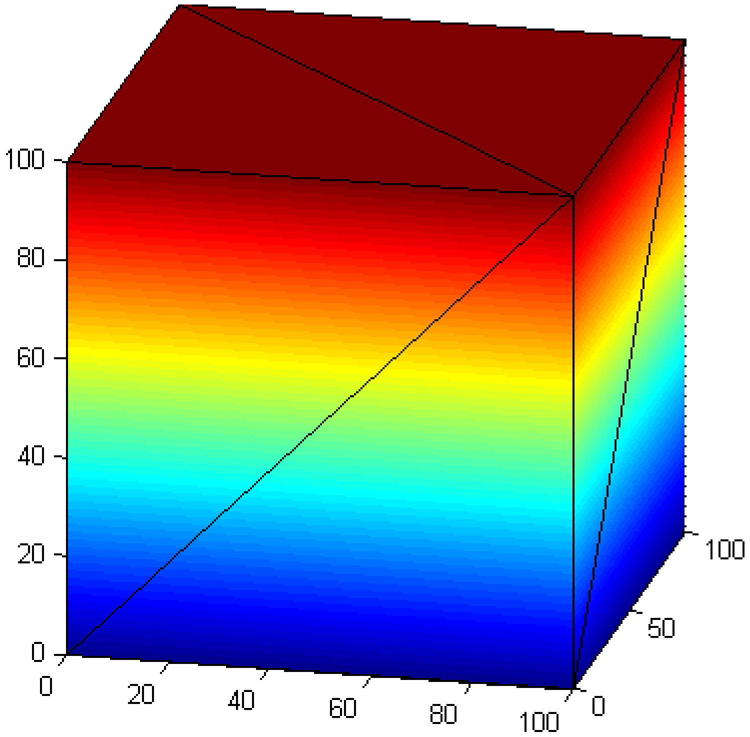
I] Example of a cube using 12 triangular faces



```
solid   MYSOLID
  facet normal   0.0   0.0   −1.0
    outer loop
      vertex   0.0   0.0   0.0
      vertex   1.0   1.0   0.0
      vertex   1.0   0.0   0.0
    end loop
  end facet
  facet normal   0.0   0.0   −1.0
    outer loop
      vertex   0.0   0.0   0.0
      vertex   0.0   1.0   0.0
      vertex   1.0   1.0   0.0
    end loop
  end facet
  facet normal   −1.0   0.0   0.0
    outer loop
      vertex   0.0   0.0   0.0
      vertex   0.0   1.0   1.0
      vertex   0.0   1.0   0.0
    end loop
  end facet
  facet normal   −1.0   0.0   0.0
    outer loop
      vertex   0.0   0.0   0.0
      vertex   0.0   0.0   1.0
      vertex   0.0   1.0   1.0
    end loop
  end facet
  facet normal   0.0   1.0   0.0
    outer loop
      vertex   0.0   1.0   0.0
      vertex   1.0   1.0   1.0
      vertex   1.0   1.0   0.0
    end loop
  end facet
  facet normal   0.0   1.0   0.0
    outer loop
      vertex   0.0   1.0   0.0
      vertex   0.0   1.0   1.0
      vertex   1.0   1.0   1.0
    end loop
  end facet
  facet normal   1.0   0.0   0.0
    outer loop
      vertex   1.0   0.0   0.0
      vertex   1.0   1.0   0.0
      vertex   1.0   1.0   1.0
    end loop
  facet normal   1.0   0.0   0.0
    outer loop
      vertex   1.0   0.0   0.0
      vertex   1.0   1.0   1.0
      vertex   1.0   0.0   1.0
    end loop
  end facet
  facet normal   0.0   −1.0   0.0
    outer loop
      vertex   0.0   0.0   0.0
      vertex   1.0   0.0   0.0
      vertex   1.0   0.0   1.0
    end loop
  end facet
  facet normal   0.0   −1.0   0.0
    outer loop
      vertex   0.0   0.0   0.0
      vertex   1.0   0.0   1.0
      vertex   0.0   0.0   1.0
    end loop
  end facet
  facet normal   0.0   0.0   1.0
    outer loop
      vertex   0.0   0.0   1.0
      vertex   1.0   0.0   1.0
      vertex   1.0   1.0   1.0
    end loop
  end facet
  facet normal   0.0   0.0   1.0
    outer loop
      vertex   0.0   0.0   1.0
      vertex   1.0   1.0   1.0
      vertex   0.0   1.0   1.0
    end loop
  end facet
endsolid   MYSOLID
```

J] Example of a block (cube) of side 100, using 12 triangular faces

```
solid  block100
    facet normal  −1.000000e+000   0.000000e+000   0.000000e+000
        outer loop
            vertex   0.000000e+000   1.000000e+002   1.000000e+002
            vertex   0.000000e+000   1.000000e+002   0.000000e+000
            vertex   0.000000e+000   0.000000e+000   1.000000e+002
        end loop
    end facet
    facet normal  −1.000000e+000   0.000000e+000   0.000000e+000
        outer loop
            vertex   0.000000e+000   0.000000e+000   1.000000e+002
            vertex   0.000000e+000   1.000000e+002   0.000000e+000
            vertex   0.000000e+000   0.000000e+000   0.000000e+000
        end loop
    end facet
    facet normal   0.000000e+000   0.000000e+000   1.000000e+000
        outer loop
            vertex   1.000000e+002   1.000000e+002   1.000000e+002
            vertex   0.000000e+000   1.000000e+002   1.000000e+002
            vertex   1.000000e+002   0.000000e+000   1.000000e+002
        end loop
    end facet
    facet normal   0.000000e+000   0.000000e+000   1.000000e+000
        outer loop
            vertex   1.000000e+000   0.000000e+000   1.000000e+000
            vertex   0.000000e+000   1.000000e+000   1.000000e+000
            vertex   0.000000e+000   0.000000e+000   1.000000e+000
        end loop
    end facet
    facet normal   1.000000e+000   0.000000e+000   0.000000e+000
        outer loop
            vertex   1.000000e+002   1.000000e+002   0.000000e+000
            vertex   1.000000e+002   1.000000e+002   1.000000e+002
            vertex   1.000000e+002   0.000000e+000   0.000000e+000
        end loop
    end facet
    facet normal   1.000000e+000   0.000000e+000   0.000000e+000
        outer loop
            vertex   1.000000e+002   0.000000e+000   0.000000e+000
            vertex   1.000000e+002   1.000000e+002   1.000000e+002
            vertex   1.000000e+002   0.000000e+000   1.000000e+002
        end loop
    end facet
    facet normal  0.000000e+000  0.000000e+000  −1.000000e+000
      outer loop
        vertex    0.000000e+000  1.000000e+002  0.000000e+000
        vertex    1.000000e+002  1.000000e+002  0.000000e+000
        vertex    0.000000e+000  0.000000e+000  0.000000e+000
      end loop
    end facet
    facet normal  0.000000e+000  0.000000e+000  −1.000000e+000
      outer loop
        vertex    0.000000e+000  0.000000e+000  0.000000e+000
        vertex    1.000000e+002  1.000000e+002  0.000000e+000
        vertex    1.000000e+002  0.000000e+000  0.000000e+000
      end loop
    end facet
    facet normal  0.000000e+000  1.000000e+000  0.000000e+000
      outer loop
        vertex    1.000000e+002  1.000000e+002  1.000000e+002
        vertex    1.000000e+002  1.000000e+002  0.000000e+000
        vertex    0.000000e+000  1.000000e+002  1.000000e+002
      end loop
    end facet
    facet normal  0.000000e+000  1.000000e+000  0.000000e+000
      outer loop
        vertex    0.000000e+000  1.000000e+002  1.000000e+002
        vertex    1.000000e+002  1.000000e+002  0.000000e+000
        vertex    0.000000e+000  1.000000e+002  0.000000e+000
      end loop
    end facet
    facet normal  0.000000e+000  −1.000000e+000  0.000000e+000
      outer loop
        vertex    1.000000e+002  0.000000e+000  0.000000e+000
        vertex    1.000000e+002  0.000000e+000  1.000000e+002
        vertex    0.000000e+000  0.000000e+000  0.000000e+000
      end loop
    end facet
    facet normal  0.000000e+000  −1.000000e+000  0.000000e+000
      outer loop
        vertex    0.000000e+000  0.000000e+000  0.000000e+000
        vertex    1.000000e+002  0.000000e+000  1.000000e+002
        vertex    0.000000e+000  0.000000e+000  1.000000e+002
      end loop
    end facet
endsolid  block100
```



*****   THE END   *****