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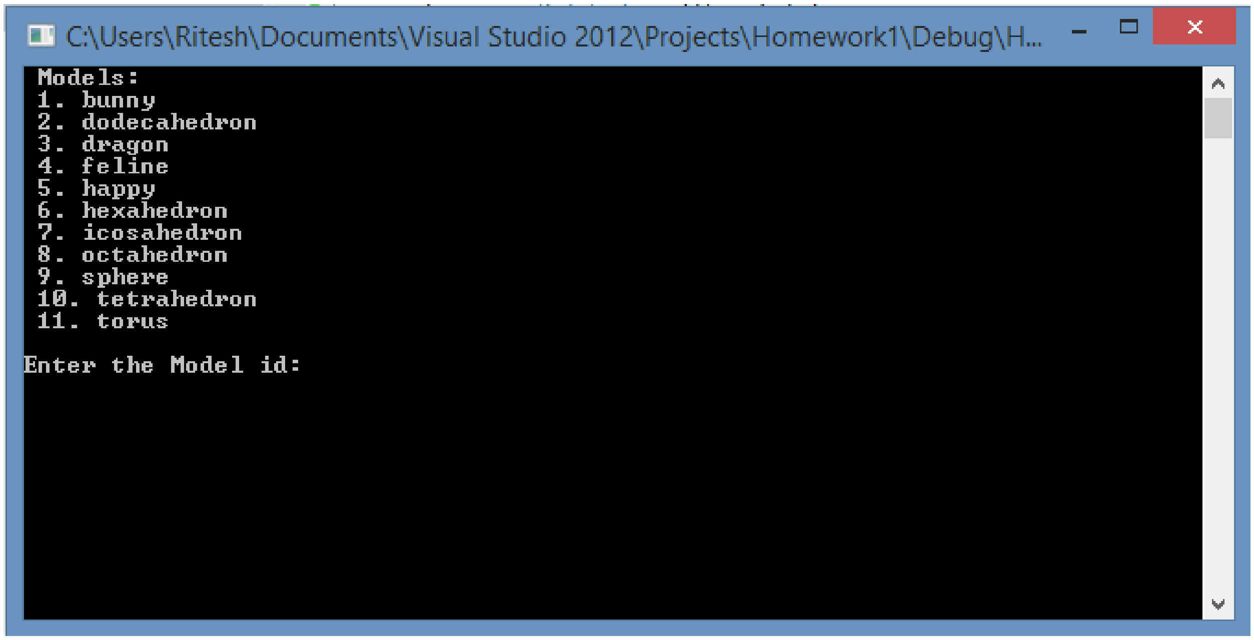
[Date]

# Homework #2

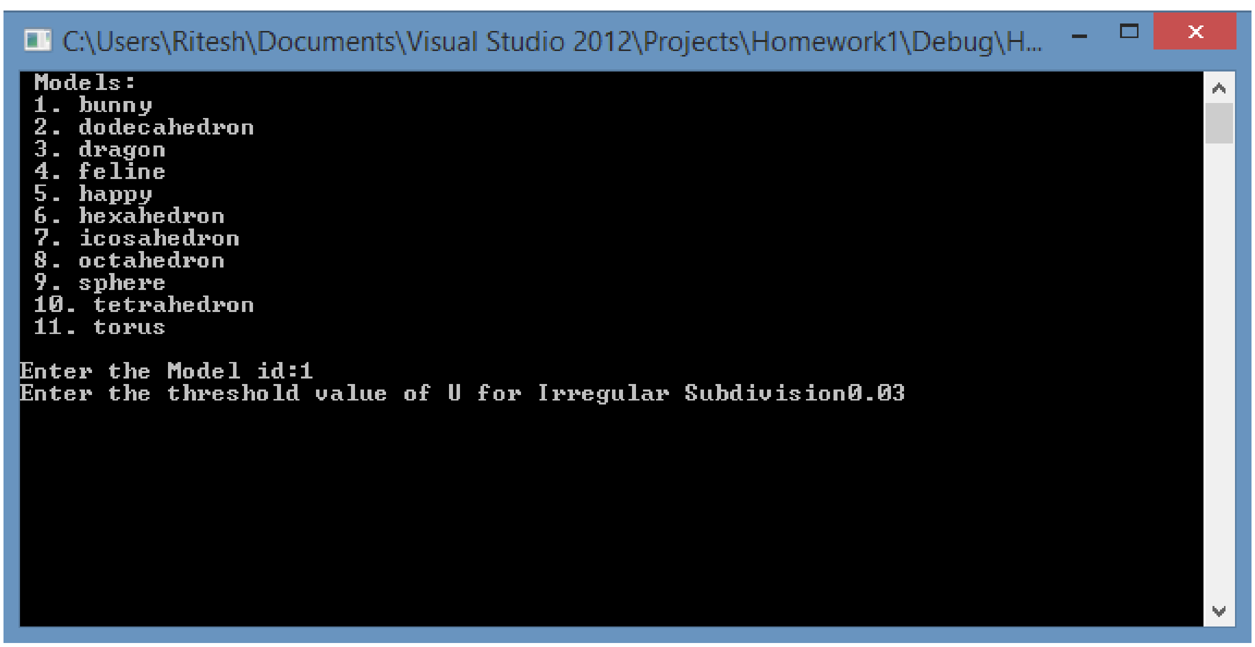
## CS 554

OREGON STATE UNIVERSITY

It is always important to provide a better and easily accessible GUI for the user to use the software. I have tried to build the GUI as simpler as it can be. Right after the launch of the project, the below screen appears:

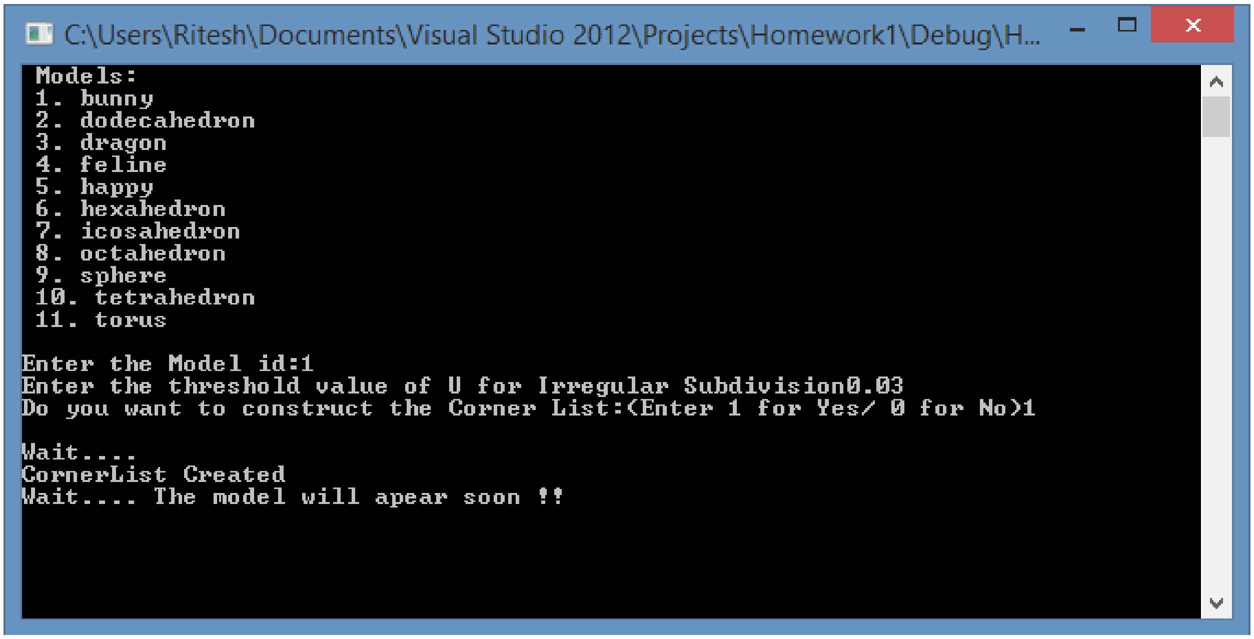



Here user is asked to enter the model id. After the user enters the model id. It ask what should be the threshold value of the edge length when the edge should be divided in case of irregular subdivision.

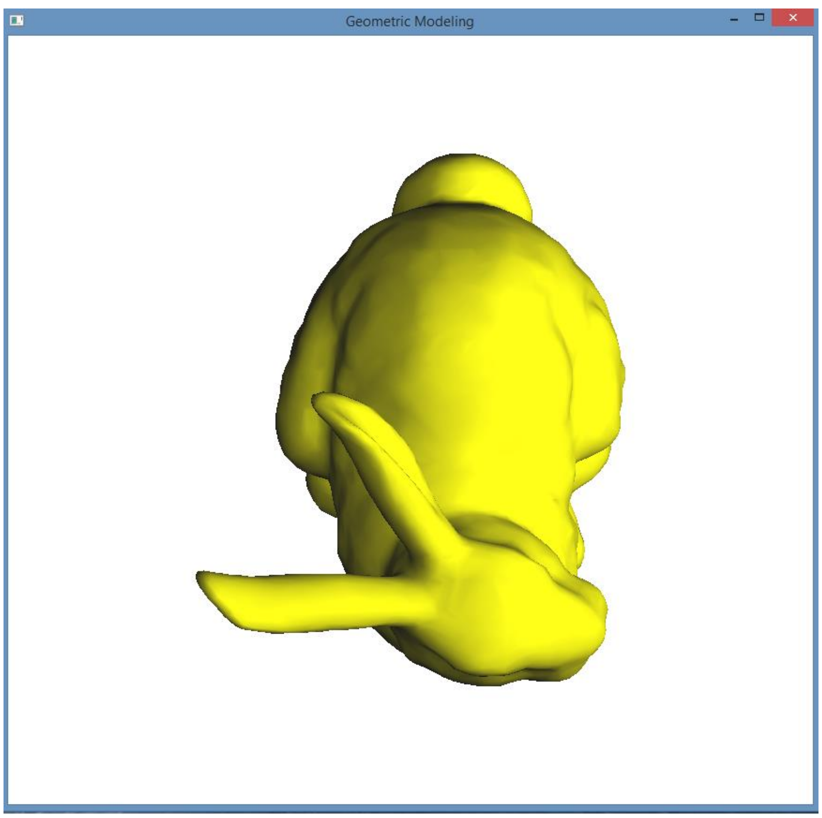



Here I have selected the bunny model and the threshold value is taken as 0.03. While working with different values I found that whenever I entered values more than 0.1 the irregular subdivision is not significant.

In the next step, User is asked to whether he/she wants to construct the corner list. The user needs to press 1 for **Yes** and and 0 for **No**. The user needs to wait until the creation of construct list is completed.




Then model appears on the screen as shown below:



And the command prompt shows the information of the model and shows the further choices to select from the list. The screenshot is given below:

```
C:\Users\Ritesh\Documents\Visual Studio 2012\Projects\Homework1\Debug\H...
 Models:
 1. bunny
 2. dodecahedron
 3. dragon
 4. feline
 5. happy
 6. hexahedron
 7. icosahedron
 8. octahedron
 9. sphere
 10. tetrahedron
 11. torus

Enter the Model id:1
Enter the threshold value of U for Irregular Subdivision0.03
Do you want to construct the Corner List:(Enter 1 for Yes/ 0 for No)
1

Wait....
CornerList Created
Wait.... The model will apear soon !!

The Euler characteristics of the mesh in the model without subdivision is:  5002
 - 15000 + 10000 = 2
The Euler characteristics of the mesh in the model after loop subdivision(Regula
r) is:  20002 - 60000 + 40000 = 2
The Eulercharacteristics of the mesh in the model after Irregular subdivision is
:  18389 - 55161 + 36774 = 2
Euler Characteristics=5002-15000+10000=2
Number of handles:0Press the number as shown against the choices :
 1. Original Mesh
 2. Loop Subdivision(Regular Subdivision)
 3. Irregular Subdivision based on threshold value=0.030000
 4. 3D checker board color scheme
 5. 3D checker board color scheme with Loop Subdivision
 6. 3D checker board color scheme with Irregular subdivision
 7. Highlight valence deficit on the original mesh
 8. Highlight valence deficit after Loop Subdivision(Reguular Subdivision)
 9. Highlight valence deficit after Irregular Subdivision
```

## 0. Corner List

The construct a corner list. I devise my algorithm as follows (assuming I have the information about the triangles which is provided by the code while reading a .ply file):

Step 1: First take the list of triangles.
Step 2: Loop through each of the triangle until the triangle list is exhausted
Step 3: From each triangle consider each vertices as a corner and process the information available from the triangle list. (Since the triangle list gives us the information gives us the information about its edges and vertices, we can find the edges, vertices, triangle, previous and next corners)
Step 4: To find the opposite edge, loop through the corner list and find the corners where the corner edges are same and assign the opposite corners to both of them.

The data structure used for corner list is as follows:

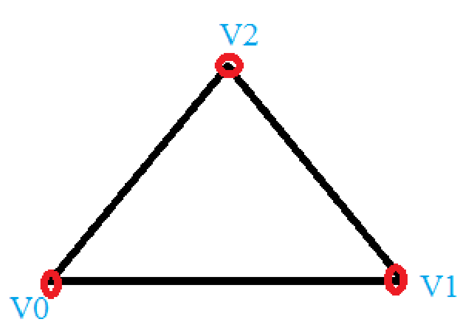
```
class Corner{
public:
	Vertex *vert;
	Edge *edge;
	Triangle *tri;

	Corner *previous;
	Corner *next;
	Corner *opposite;
};
```

Once the corner list is created, it can be stored in the table in anyway the user wants to store.

## 1. Loop Subdivision(Regular Subdivision)

In case of regular subdivision, we follow the following steps:
Step 1: Take one triangle at a time from the triangle list.



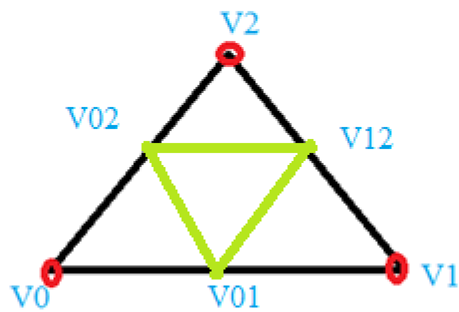
The Euler characteristics for the above triangle is given as,

$\alpha$ = Number of Vertices (V) – Number of Edges (E) + Number of Faces (F)

In the above triangle, V = 3, E=3 and F=1, then

$$\alpha = 3\text{-}3\text{+}1\text{=}1$$

Step 2: Now take midpoint at each edges and connect them.




Let us see the Euler characteristics after the subdivision,
In the above triangle, V= 6, E=9 and F=4, then

$$\alpha = 6\text{-}9\text{+}4\text{=}1$$

It is found that the after following the step 1 and step 2 for loop subdivision, the Euler characteristics is same.

The results for each of the model are shown after the solution 2.

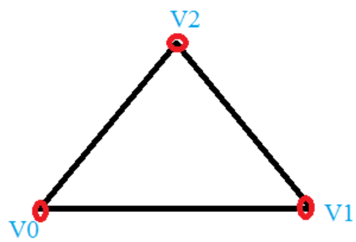
## 2. Irregular Subdivision

In case of the irregular subdivision following algorithm is implemented as said in the assignment:

```
Ask for a user-provided threshold u
   While there are edges whose lengths are larger than u
          Identify all such edges and tag them.
          Place a new vertex in the middle of every tagged edge.
          For each face t = (A, B, C)
              If t has one tagged edge, say BC
                  Connect A with the new vertex on BC
              Else if t has two tagged edges, say AB and BC
                  Connect the new vertices on the tagged edges
                  Connect one of the new vertices to the opposite original vertex
```

Else if t has three tagged edges
Subdivide t using regular subdivision

From the above algorithm, it is seen that the problem can be divided into four cases based on the number of tagged edges.
Let us consider the below triangle.




The Euler characteristics for the above triangle is given as,

$\alpha$ = Number of Vertices (V) – Number of Edges (E) + Number of Faces (F)

In the above triangle, V = 3, E=3 and F=1, then

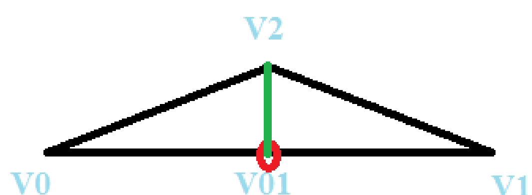
$$\alpha = 3-3+1=1$$

**Case 1: Zero Edge Tagged**

In this case, the triangle is not subdivided and thus the Euler characteristics remains the same.

**Case 2: One Edge Tagged**

Let the edge length between V0 and V1 is greater than threshold value.




We find the midpoint (V02) of the connected edge {V0, V2} and join V02 to V1.

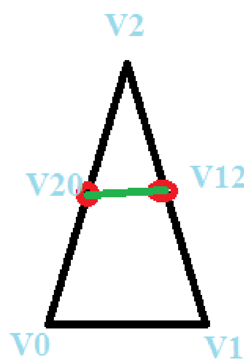
Let us see the Euler characteristics after the subdivision,
In the above triangle, V= 4, E=5 and F=2, then

$$\alpha = 4-5+2=1$$

We see that the Euler characteristics is maintained even after the subdivision.

**Case 3: Two Edge Tagged**

Let the edge length between V0 and V2 and V1 and V2 be greater than threshold value.




We find the midpoint (V02) of the connected edge {V0, V2} and join V02 to V1.

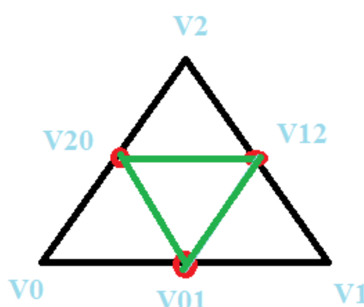
Let us see the Euler characteristics after the subdivision.
In the above triangle, V= 4, E=5 and F=2, then

$$\alpha = 4\text{-}5\text{+}2\text{=}1$$

We see that the Euler characteristics is maintained even after the subdivision.

**Case 4: Three Edge Tagged**

Let the edge length of edge {V0, V1}, edge {V1, V2} and edge {V0, V2} be greater than threshold value.



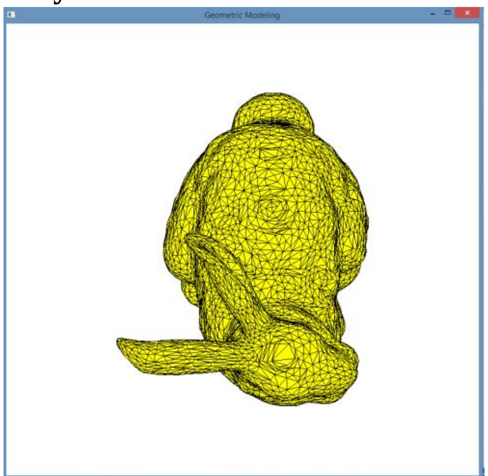

We find the midpoint (V02) of all the edges and connect them.

Let us see the Euler characteristics after the subdivision.
In the above triangle, V= 6, E=9 and F=4, then

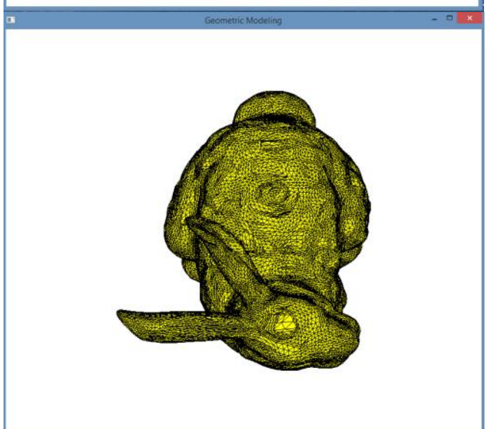
$$\alpha = 6\text{-}9\text{+}4\text{=}1$$

We see that the Euler characteristics is maintained even after the subdivision.
The results for all of the model was found to maintain the Euler characteristics. Out of all two models are shown below:

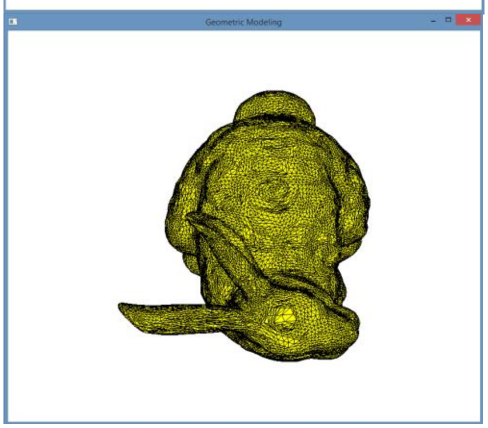
**Bunny**




Euler Characteristics before subdivision:
5002-15000+10000 = 2

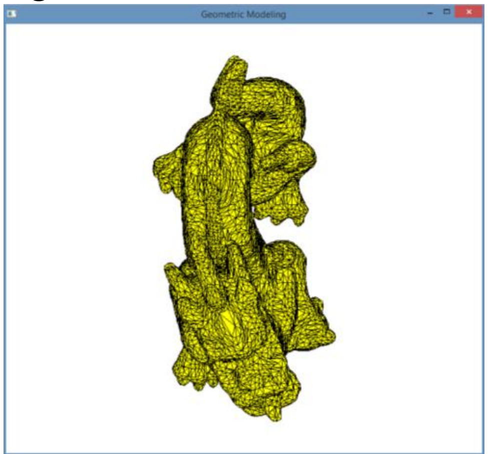



Euler Characteristics after loop subdivision:
20002 – 60000 + 40000 = 2

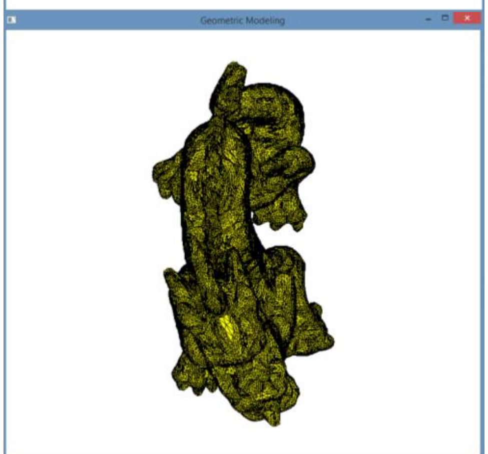



Euler Characteristics after Irregular subdivision based on the threshold value =0.03
18389 – 55161 + 36774 = 2

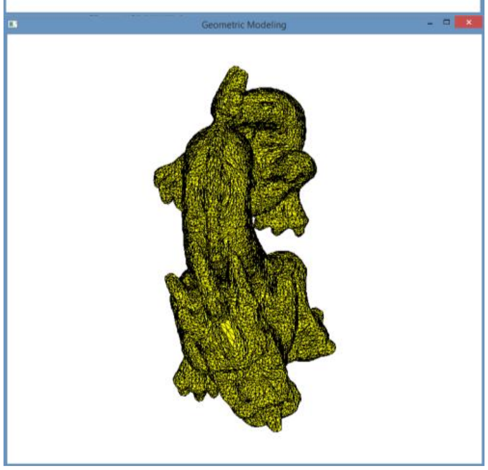
**Dragon**




Euler Characteristics before subdivision:
10000-30000+20000 = 0

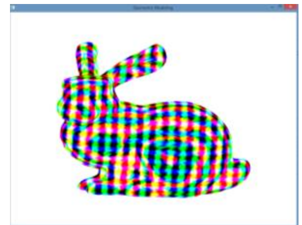
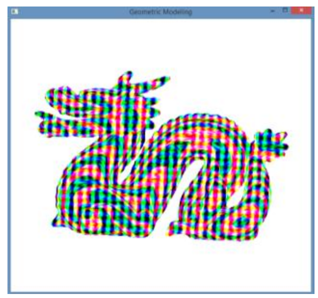
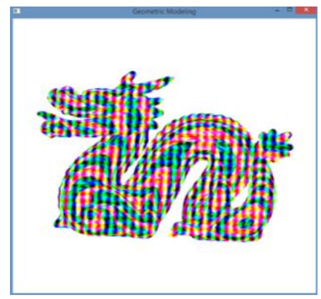
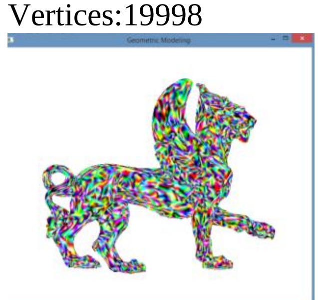
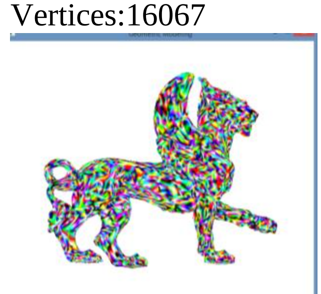


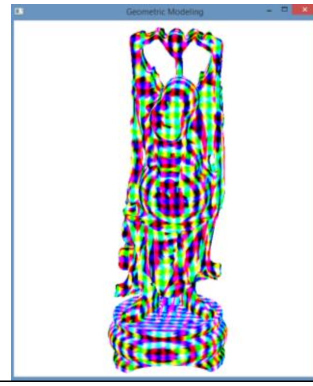
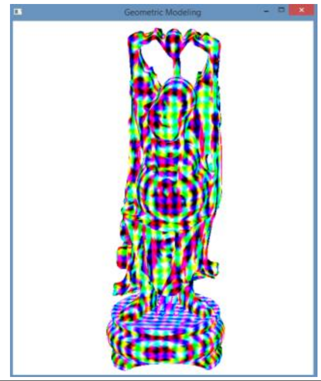

Euler Characteristics after loop subdivision:
40000 – 120000 + 80000 = 0




Euler Characteristics after Irregular subdivision based on the threshold value =0.03
25860 – 77580 + 51720 = 0

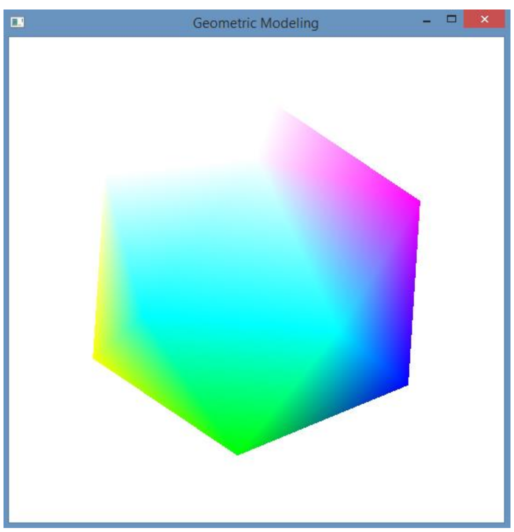
### 3. 3D Checkerboard Pattern

| Model | Without subdivision | With Regular Subdivision | With Irregular Subdivision |
|---|---|---|---|
| Bunny | Number of Vertices:5002  | Number of Vertices:20002  | Number of Vertices:18389  |
| Dragon | Number of Vertices:10000  | Number of Vertices: 40000  | Number of Vertices:25860  |
| Feline | Number of Vertices:4998  | Number of Vertices:19998  | Number of Vertices:16067  |

| | | | |
|---|---|---|---|
| Happy | Number of Vertices:9990  | Number of Vertices:39990  | Number of Vertices:23346  |

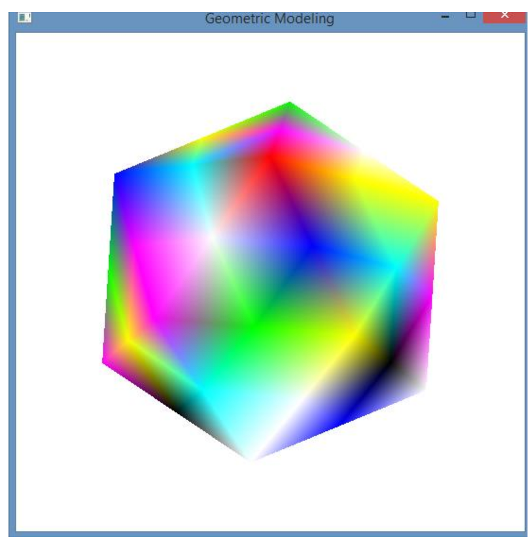
In homework 1, since we had very few vertices, the grids were not visible significantly. But now as we divide the triangle into smaller and smaller triangle, we have a better results. The results are shown below:

Result obtained from homework 1



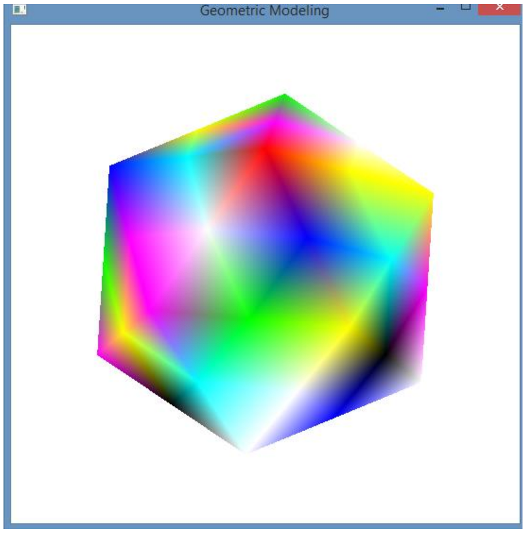

Number of vertices:12

Result after Regular subdivision




Number of Vertices: 42

Result after Irregular subdivision

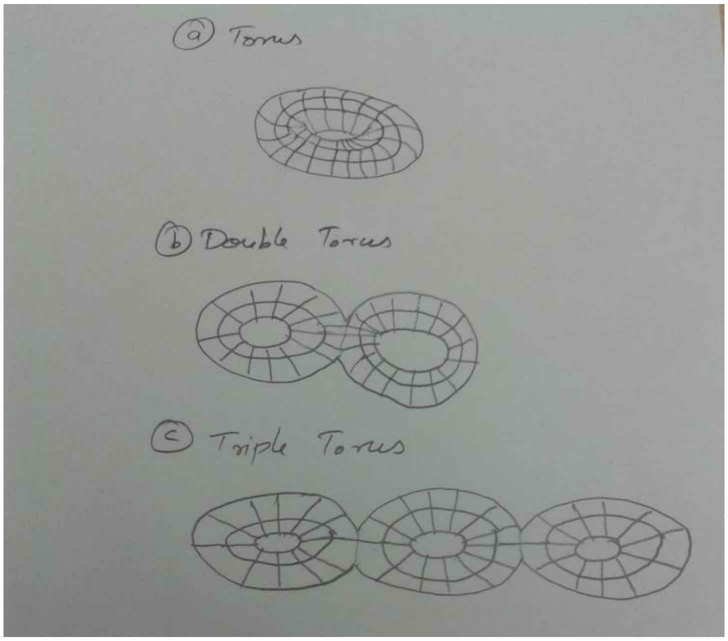



Number of Vertices: 42

After running the program it is also observed that the results after regular and irregular subdivision is same. The reason behind this same result is that the triangles in the Icosahedron are equilateral triangle.

Yes, the solution is possible if the icosahedron is subjected to more subdivision.

4.



In our last homework, we found the relationship between Euler characteristic and the number of handle. The relationship was:
Number of handles = 1 – 0.5*Euler characteristics

Let us write this as follows:
Euler characteristics = 2 – 2*number of handles

Now if we add a handle, the quantity (2-2*number of handles) will decrease which will result in the decrement of Euler characteristics by twice the number of handles added.

# 5. Color coding based on Valence Deficit

## a.

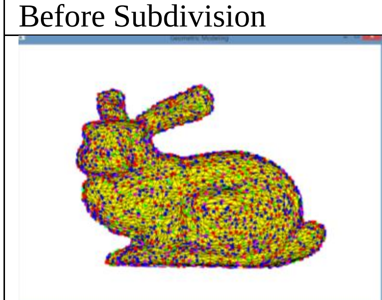
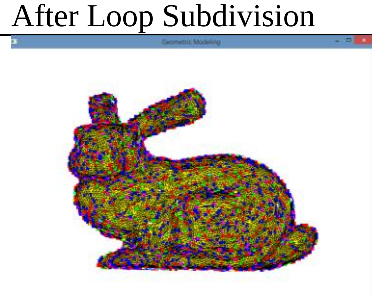
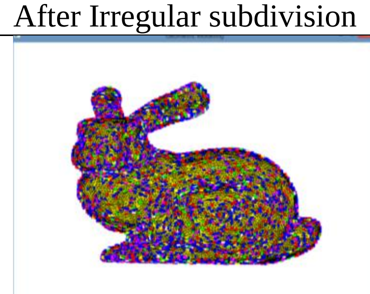
I have used the following step to find the valence deficit and then assigned unique color to each of them according to how much valence deficit it has.

Step 1: Fetch one triangle at a time from a triangle list and then find the number of edges attached to that vertex. Loop through the entire triangle list.

Step 2: Now subtract the number of edges attached to vertex from 6 to obtain the deficit for that vertex.

Step 3: Assign unique color according to the valence deficit. If
Deficit: 1 = Blue
Deficit 2 = Green
Deficit 3 = Cyan
Deficit -1 = Red
Deficit -2 = Magenta
Deficit -3 = Yellow
Deficit >3 = White

One of the example is given below:

| Before Subdivision | After Loop Subdivision | After Irregular subdivision |
|---|---|---|
|  |  |  |

**b.**

**Valence Deficit:**

The results for all the models are given below:

| Models | Before subdivision | After Subdivision |
|---|---|---|

| | | |
|---|---|---|
| Bunny | 12 | 12 |
| Dragon | 0 | 0 |
| Feline | -12 | -12 |
| Happy | -60 | -60 |
| Icosahedron | 12 | 12 |
| Octahedron | 12 | 12 |
| Sphere | 12 | 12 |
| Tetrahedron | 12 | 12 |
| Torus | 0 | 0 |

**c.**

**Angle Deficit:**
The results for all the models are given below:

| Models | Before subdivision | After Subdivision |
|---|---|---|
| Bunny | 720 | 720 |
| Dragon | 0 | 0 |
| Feline | -720 | -720 |
| Happy | -3600 | -3600 |
| Icosahedron | 720 | 720 |
| Octahedron | 720 | 720 |
| Sphere | 720 | 720 |
| Tetrahedron | 720 | 720 |
| Torus | 0 | 0 |

**d.**

From the above results, it can be said that the angle deficit has a relationship with the valence deficit. Since maximum valence of a vertex in a triangular mesh can be 6 and we know that the total angle around the vertex is 360. So 1 Valence deficit means the angle difference of 360/6 = 60 degrees. Therefore we can generalize the formula of angle deficit as,

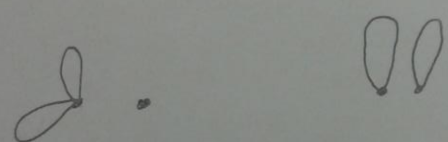
**Total angle deficit = 60 degrees * Total Valence deficit**

**e.**
Since in the mesh, where the angle deficit is less than 360, we can say that from the formula derived at 5d above that there will be valence deficit. So if the angle deficit at the vertex is less than 360 in the irregular mesh that vertex will also have valence deficit. This also says that the vertex where there is positive angle deficit or valence deficit, that vertex will be at the sharp edge of the model and will be convex at that point. Also when the angle or valence deficit is negative, that point in the model will be concave.

**6.**

(a) $H_0 = 1$ , $H_1 = 4$ $H_2 = 0$

(b) $H_0 = 2$ $H_1 = 2$ $H_2 = 0$



(c) $H_0 = 2$ $H_1 = 2$ $H_2 = 2$