CSCB07 – Software Design

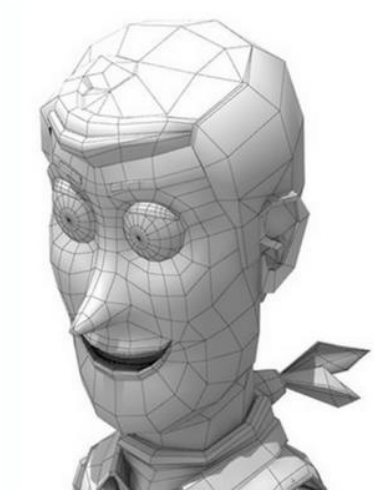
Assignment

Logistics

- This assignment is worth 8% of the course grade and it is due on Nov 2, 2021
- It should be done individually

Instructions

In computer graphics, an object is usually represented by dividing its surface into a set of polygons (also called *faces*). Such set is called a mesh.



Graphical elements such as vertices, polygons, and meshes can be transformed (e.g. translated, rotated, etc.) using transformation matrices. For example, to rotate a vertex $v = (v_x, v_y, v_z)$ about the x-axis with angle θ, we can multiply the following matrix by the column vector representing v:

$$R_x(\theta) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & -sin\theta \\ 0 & sin\theta & cos\theta \end{bmatrix}$$

That is, v would be transformed into $v' = \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & -sin\theta \\ 0 & sin\theta & cos\theta \end{bmatrix} \begin{bmatrix} v_x \\ v_y \\ v_z \end{bmatrix} = \begin{bmatrix} v_x \\ v_y cos\theta - v_z sin\theta \\ v_y sin\theta + v_z cos\theta \end{bmatrix}$

Similarly, the following matrices can be used to rotate v about the y-axis and the z-axis respectively:

$$R_y(\theta) = \begin{bmatrix} cos\theta & 0 & sin\theta \\ 0 & 1 & 0 \\ -sin\theta & 0 & cos\theta \end{bmatrix} \qquad R_z(\theta) = \begin{bmatrix} cos\theta & -sin\theta & 0 \\ sin\theta & cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Several file formats can be used to represent meshes: OBJ, PLY, STL, FBX, etc. In this assignment, we will only target the OBJ and PLY formats.

OBJ format

The OBJ files to be considered consist of two consecutive sets of lines: the first set (lines starting with a "v") represents the unique vertices contained in the mesh and the second set (lines starting with an "f") represents the faces of the mesh. For example, the mesh below contains two polygons: the first includes the vertices defined at lines 1, 2, and 3 and the second includes the vertices defined at lines 2, 3, and 4.

```
v 5.1 1.2 0.3
v 4.9 1.5 0.3
v 3.8 1.4 0.5
v 4.1 1.6 0.6
f 1 2 3
f 2 3 4
```

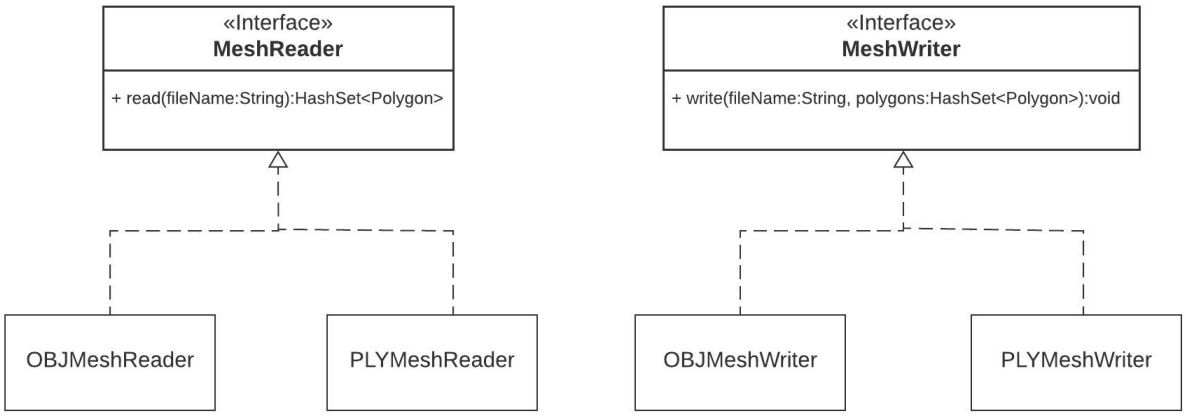
PLY format

The PLY format is similar to OBJ except for the following:

- It has a header that specifies different aspects including the number of vertices and the number of faces. You can assume that the highlighted parts are fixed.
- The lines representing the vertices do not start with a "v".
- The lines representing the faces do not start with an "f". Instead, they start with the number of vertices included in the corresponding face.
- Vertex indexing starts at 0 instead of 1. That is, the first line containing a vertex is labelled 0.

```
ply
format ascii 1.0
element vertex 4
property float32 x
property float32 y
property float32 z
element face 2
property list uint8 int32 vertex_indices
end_header
5.1 1.2 0.3
4.9 1.5 0.3
3.8 1.4 0.5
4.1 1.6 0.6
3 0 1 2
3 1 2 3
```

1. Create a new java project and add to it a package named **assignment**
2. Define a class named **GraphicalObject** representing graphical objects that could be transformed using a matrix. It has the following **void** methods:
    a. **transform**: an abstract method that takes a two-dimensional matrix of **double** representing the transformation matrix.
    b. **rotateXAxis**: a concrete method that rotates the graphical object about the x-axis. It takes one argument of type **double** representing θ.
    c. **rotateYAxis**: a concrete method that rotates the graphical object about the y-axis. It takes one argument of type **double** representing θ.
    d. **rotateZAxis**: a concrete method that rotates the graphical object about the z-axis. It takes one argument of type **double** representing θ.
3. Define class **Vertex** as follows:
    a. It has three fields of type **double** representing the coordinates of the vertex.
    b. It has a constructor that takes three arguments of type **double** and initializes the coordinates accordingly.
    c. It inherits from **GraphicalObject**.
    d. It overrides **hashCode** and **equals**.
    e. It overrides **toString** by returning a string containing the three coordinates separated by spaces.
4. Define class **Polygon** as follows:
    a. It has one field of type **LinkedHashSet<Vertex>** named **vertices**
    b. It has a constructor that takes one argument of type **LinkedHashSet<Vertex>** and initializes **vertices** accordingly.
    c. It inherits from **GraphicalObject**. Transforming a polygon is done by transforming all of its vertices.
    d. It overrides **hashCode** and **equals**.
5. Define interfaces **MeshReader** and **MeshWriter**, as well as classes **OBJMeshReader**, **PLYMeshReader**, **OBJMeshWriter**, and **PLYMeshWriter** according to the following UML class diagram. Each of the classes is supposed to provide an implementation that reads/writes polygons as per the corresponding format.



6. Define class **Mesh** as follows:
    a. It has a field of type **HashSet<Polygon>** named **polygons**
    b. It has a field of type **MeshReader** named **reader**
    c. It has a field of type **MeshWriter** named **writer**
    d. It has a **void** method named **setReader** that takes an argument of type **MeshReader** and sets **reader** accordingly.
    e. It has a **void** method named **setWriter** that takes an argument of type **MeshWriter** and sets **writer** accordingly.
    f. It has a **void** method named **readFromFile** that takes a file name as an argument and uses **reader** to read the polygons from the file.
    g. It has a **void** method named **writeToFile** that takes a file name as an argument and uses **writer** to write the mesh to the file.
    h. It inherits from **GraphicalObject**. Transforming a mesh is done by transforming all of its polygons.
    i. It overrides **hashCode** and **equals**.
7. Write enough JUnit tests to test your code properly and maximize coverage. Test methods that aim at increasing coverage by adding code that is not relevant to the assertion are not allowed.
8. Kindly take note of the following:
    a. Adding extra fields or methods to the aforementioned interfaces and classes is not allowed.
    b. You can test your code using the files “car.obj” and “car.ply” provided with this assignment.
    c. You can visualize OBJ and PLY files online (e.g. https://3dviewer.net/) if you do not have an appropriate viewer installed.
    d. You might want to use the following methods when reading OBJ and PLY files
        i. Method **split** of class **String**

ii. Method **parseDouble** of class **Double**

e. The following code reads a mesh from an OBJ file, rotates it about the y-axis by π/3, and saves the rotated mesh to OBJ and PLY files:

```
public static void main(String [] args) {
    Mesh mesh = new Mesh();
    mesh.setReader(new OBJMeshReader());
    mesh.readFromFile("/Users/rawad/car.obj");
    mesh.rotateYAxis(Math.PI/3);
    mesh.setWriter(new OBJMeshWriter());
    mesh.writeToFile("/Users/rawad/car_rotated.obj");
    mesh.setWriter(new PLYMeshWriter());
    mesh.writeToFile("/Users/rawad/car_rotated.ply");
}
```

Submission

Upload the java files as a single archive file to “Assignment” on Quercus by Nov 2nd at the latest.