Assignment 2

CSE471: Computer Graphics

Fall 2022

Computer Science and Engineering

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Objectives

- The purpose of this assignment is to learn:
  - 3D geometric transformations
  - 3D coordinate systems (local ↔ world ↔ screen)
  - Camera view
  - Orthographic/perspective projection

- Please read the entire slides carefully before you start your work – Do NOT start coding without reading the whole slides!

Introduction

OpenGL View

- (old) OpenGL pipeline is fixed
  - Model view
    - Local to world to camera coordinates
    - glMatrixMode(GL_MODELVIEW)
  - Projection
    - Orthographic/perspective projection
    - glMatrixMode(GL_PROJECTION)
- Although modern OpenGL deprecates the fixed pipeline, we will use this approach to understand the computer graphics system better.

OpenGL View

- Matrices
  - GL_MODELVIEW and GL_PROJECTION maintain their own matrices
  - It is common to switch view before you draw something
  - For example, in your display function:

```
Def display():
        glMatrixMode(GL_PROJECTION)        # projection matrix is loaded
        glLoadIdentity()
        # do some projection
        glMatrixMode(GL_MODELVIEW)         # view matrix is loaded
        glLoadIdentity()
        # do some geometric transformations
```

OpenGL View

- From GL_MODELVIEW and GL_PROJECTION, you can read their current state (matrix) using
  - glGetDoublev(GL_MODELVIEW_MATRIX)
  - glGetDoublev(GL_PROJECTION_MATRIX)
- Remember OpenGL is a state language, so the state matrices can be obtained as needed

OpenGL Geometric Transformations

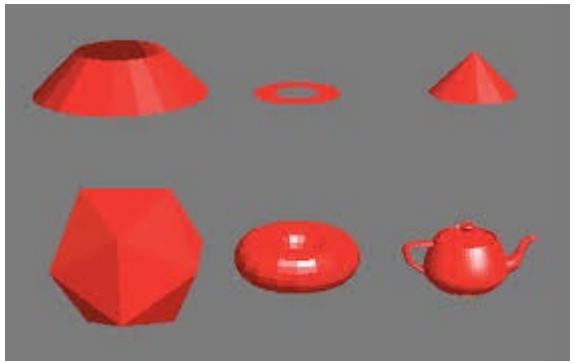
- There are two popular ways to define geometric transformations
  - Define matrices as we've done in assignment 1
  - Use OpenGL functions:
    - glTranslatef()
    - glScalef()
    - glRotatef()
    - These functions create and multiply a new matrix to the current matrix (projection or view matrix)
  - The two approaches above are equivalent

OpenGL Projection Functions

- glOrtho
  - Parallel (orthographic) projection
- glFrustum
  - Perspective projection
- gluPerspective
  - Perspective projection using FoV
  - The glu library needs to be imported

GLUT Solid Shapes

- GLUT provides predefined 3D objects
  - glutSolidTeapot
  - glutSolidSphere
  - glutSolidTorus …



Example Solid Shapes in GLUT

Assignment 2

Task 1

- Implement a camera view function

- You will need to:
  - Convert coordinate systems from world to camera
  - Implement a function
    - Arguments: "center of projection (px,py,pz)", "at (ax,ay,az)", "up (ux, uy, uz)"
    - Output: a camera view matrix (world to camera)

Task 2

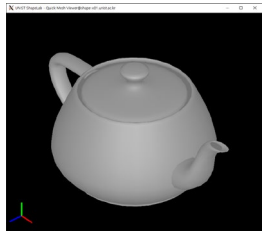
- Implement virtual trackball

- You will need to:
  - Update camera pose
  - Use min(window_width, window_height)/2 for the radius of your trackball
  - If $x^2 + y^2 > r^2$, scale down x and y to be $x^2 + y^2 = r^2$ (we covered this strategy in the lecture)
  - Implement a function
    - Arguments: "window coordinates (x, y) – starting point", "window coordinates (x, y) – destination point",
    - Output: a camera view matrix (rotation matrix)

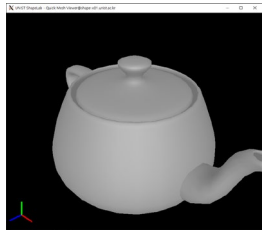
Task 3

- Implement orthographic/perspective projection

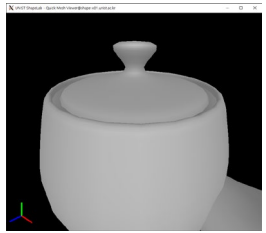
- You will need to:
  - Interactively update projection (FoV)
  - Update the distance to the projection plane accordingly
    - Please review how FoV was defined in the lecture notes
    - Note: if you simply change FoV without distance update, you will see wrong scale in your distortion



Orthographic



Fov=45



FoV=90

Task 4

You can bind different keys/mouse behaviors, but if so, you must describe how to operate your tool

- Implement user interface
  - Rotation of the scene: drag left button
    - Rotation should appear real time; you should show the change of the scene interactively
  - Scaling/zoom of the scene: mouse wheel (if you don't have a wheel, use keys "+" and "-")
    - Wheel up (or +): scale up by 0.1 (if scale is 0.1-1), 1 (if scale is 1-5) (zoom in)
    - Wheel down (or -): scale down by 0.1 (if scale is 0.1-1), 1 (if scale is 1-5) (zoom out)
    - Min scale: 0.1, Max scale: 5
  - Translation/panning of the scene: drag right button
    - Your scene moves along right button movement
  - Fov change: "down" and "up" keys
    - down: reduce by 5 degree, up: increase by 5 degree
    - Min FoV: 0 (i.e., orthographic projection), Max FoV: 90; do not exceed these numbers!

Task 4

You can bind different keys/mouse behaviors, but if so, you must describe how to operate your tool

- Implement user interface
  - Press "d"
    - To reset the default camera view (translation = (0, 0, 0), rotation = identity, scale = 1)
  - Press "0"
    - To reset projection (degree = 0, orthographic)
  - Press "esc"
    - To exit

Task 4

You can bind different keys/mouse behaviors, but if so, you must describe how to operate your tool

- Implement a “resize” function to interactively change window size
  - You can bind a resize event handler to glutReshapeFunc
  - You may want to adjust the projection matrix depending on your window size because the clipping volume will be affected
  - You could also customize viewport to handle the aspect ratio as needed
  - Your trackball’s radius should be synchronized with resize
  - Your 3D object should maintain its original ratio and fit (proper scale) to the screen
  - See also:
    - https://www.opengl.org/resources/libraries/glut/spec3/node48.html
    - https://registry.khronos.org/OpenGL-Refpages/gl2.1/xhtml/gluPerspective.xml
    - https://registry.khronos.org/OpenGL-Refpages/gl2.1/xhtml/glOrtho.xml
    - https://registry.khronos.org/OpenGL-Refpages/gl4/html/glViewport.xhtml

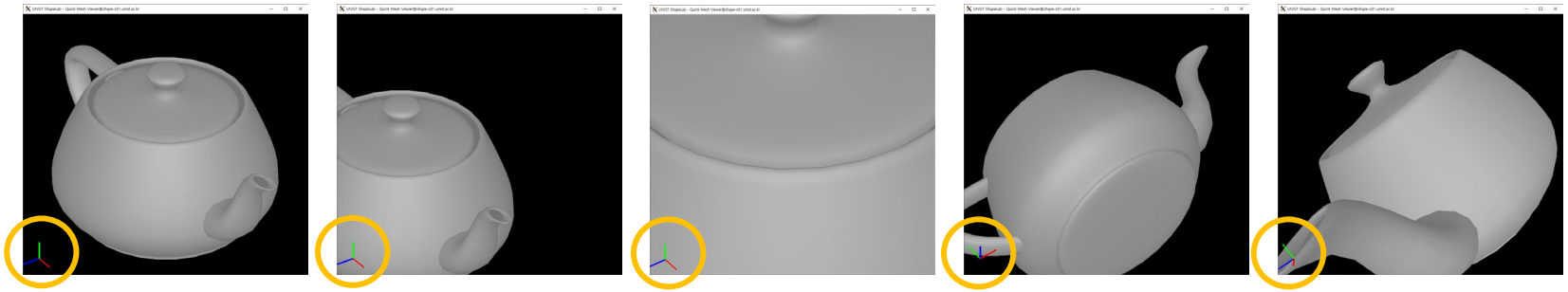
Task 5

- Configure a default environment
  - Use 3D object: GLUT teapot with size of 0.5
    - https://www.opengl.org/resources/libraries/glut/spec3/node89.html
    - Feel free to use test other objects, but make a "teapot" version for your submission
  - Set your camera to look at (0, 0, 0) from (0, 0, 1) and up=(0, 1, 0)
  - Use a sufficient clipping volume of projection that can fully contain the teapot
  - Set orthographic projection

Bonus (extra credit)

- There will be an extra credit if you can display the current axes of your scene at the bottom regardless of scaling/translation and projection types
- Submit a brief description of how you implement

Axes are drawn in orthographic projection independent of geometric transformations except for rotation



Translation Scaling Rotation FoV

Be Aware

- Please DO (you will otherwise lose your credits):
  - Provide sufficient comments on what you implement; also, put Task # in your code
  - Provide user instructions to run your program
  - Do not make multiple files for your implementation – a single source file will be enough
- Feel free to use functions implemented in your first assignment that you might think useful

Submission

- What to submit
  - Your implementation and user manual
- Where to submit
  - Blackboard
- When to submit by
  - November 6th by midnight, 14 days including now (no extension – start as soon as possible)

Questions?

- Use Blackboard (Discussions → Course Board)
- Email/call the instructor
- Useful resources:
  - https://www.opengl.org/
  - http://www.songho.ca/opengl/index.html
  - http://pyopengl.sourceforge.net/context/tutorials/index.html