Department of Software Engineering

College of Engineering

University of Salahaddin-Erbil

Subject: Computer Graphics

Course Book – *Fourth Year*

Rina Dinkha Zarro, BSc, MSc in Software Engineering

Academic Year: 2019/2020

Course Book

1. Course name	**Computer Graphics**
2. Lecturer in charge	**Mrs. Rina Dinkha Zarro**
3. Department/ College	**Software Engineering\Engineering**
4. Contact	**e-mail: rina.zarro@su.edu.krd**
5. Time (in hours) per week	**Theory: 2** **Practical: 2**
6. Office hours	**Monday 9:00-1:00 and Wednesday 9:00-1:00**
7. Course code	**SE402**
8. Teacher's academic profile	
9. Keywords	**Computer Graphics, OpenGL**

10. Course overview:

This course is one of the main subjects in 4th year software engineering. It is a mandatory requirement for the BSc in Software Engineering. Computer Graphics is one of the most exciting 'application' fields of Computer Science. This course is intended to introduce the basics of Computer Graphics, laying the foundation for more advanced graduate classes or industry work. The basic graphics pipeline is covered in this course, along with an introduction to OpenGL. This course will be conducted with an application perspective. Therefore, students will be expected to implement several techniques learnt in the lectures.

11. Course objective:

This course is designed to provide a comprehensive introduction to computer graphics leading to the ability to understand contemporary terminology, progress, issues, and trends.

A thorough introduction to computer graphics techniques, focusing on 3D modeling, image synthesis, and rendering. Topics cover: geometric transformations, geometric algorithms, software systems (OpenGL, shaders), 3D object models (surface, volume and implicit), visible surface algorithms, image synthesis, shading and mapping, ray tracing, radiosity, global illumination, sampling, Monte Carlo path tracing, photon mapping, and anti-aliasing.

The interdisciplinary nature of computer graphics is emphasized in the wide variety of examples and applications.

12. Student's obligation

- Commitment to the Class and schedule.
- Cheating is prohibited and the student will be awarded zero.
- No makeup exam without legitimate causes. Paper from the department will be required.
- In case there is an assignment, deadline date must be honoured. No delay will be accepted.

13. Forms of teaching

Lectures:

The lectures are designed to be an interactive naturalist. The lectures are listed as power point slides which includes the necessary learning materials. The students should find an extended version of the lecture in their textbook.

Practices:

The practical sessions will focus on using slides for introducing the basic and advance instruction used by OpenGL and C++. These slides along an illustration program will be used to give a proper understanding for each instruction and its use in graphics effect. In addition to these slides, some materials such as additional reading books and websites will be provided to enhance the student knowledge.

14. Assessment scheme

First Semester Theoretical Exam: 12 %
Assignments: 10%
Daily activities (quiz): 3%
Second Semester Theoretical Exam: 12 %
Assignments: 10%
Daily activities (quiz): 3%

Total Course work mark 50%
Final Exam 50%

15. Student learning outcome:

- Know and be able to describe the general software architecture of programs that use 3D computer graphics.
- Know and be able to discuss hardware system architecture for computer graphics. This includes, but is not limited to: graphics pipeline and frame buffers.
- Know and be able to use a current 3D graphics API (e.g., OpenGL).
- Know and be able to use the underlying algorithms, mathematical concepts, supporting computer graphics. These include but are not limited to:
- Composite 3D homogeneous matrices for translation, rotation, and scaling transformations.
- Plane, surface normal, cross and dot products.
- Hidden surface detection / removal.
- Scene graphs, display lists.
- Know and be able to select among models for lighting/shading: Colour, ambient light; distant and light with sources; Phong reflection model; and shading (flat, smooth, Gourand, Phong).
- Know and be able to use and select among current models for surfaces (e.g., geometric; polygonal; hierarchical; mesh; curves, splines, and NURBS; particle.
- Know and be able to design and implement model and viewing transformations, the graphics pipeline and an interactive render loop with a 3D graphics API.
- Be able to design and implement models of surfaces, lights, sounds, and textures (with texture transformations) using a 3D graphics API.

- Be able to discuss the application of computer graphics concepts in the development of computer games, information visualization, and business applications.
- Be able to discuss future trends in computer graphics and quickly learn future computer graphics concepts and APIs.

16. Course Reading List and References:

- “Computer Graphics with OpenGL”, 3rd edition, Donald Hearn, M. Pauline Baker, Prentice Hall, 2004. (main textbook)
- “Computer Graphics Using OpenGL”, F.Hill, Prentice Hall, 2000 and 2005.
- “The OpenGL Programmer's Guide” (the Redbook), 7th edition, 2009, Addison-Wesley

17. The Topics:

Week 1	**Introduction to Computer Graphics**
Week 2-4	**Mathematics for Computer Graphics**
Week 5	**Output Primitives**
Week 6-7	**Scan Line Conversion**
Week 8-9	**2D Geometric Transformations**
Week 10	**2D Viewing**
Week 11-12	**Curves and Surfaces**
Week 13	**3D Object Representations**
Week 14-16	**3D Geometric and Modelling Transformations**
Week 17-18	**3D Viewing**
Week 19-20	**Illumination Models**
Week 21-22	**Surface-Rendering Methods**
Week 23	**Texture Mapping**
Week 24	**Visible-Surface Detection Methods**
Week 25	**Computer Animation**
Week 26-28	**Fractals and special Mathematics**
Week 29-30	**Review Week**

18. Practical Topics (If there is any)

19. Examinations:

3D transformation Q1: IF the object A is scaled (Sx=0.5, Sy=3) and rotated about the line y=5, x=0 by 45 degree, find the transformation matrix?

Solution

Since the object is parallel to z axis (x=0), then we translate the object to the z-axis first,

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Then we scale the object according to Sx, Sy and Sz:

$$S = \begin{bmatrix} 0.5 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Then, rotate by 45 degree,

$$R = \begin{bmatrix} \cos 45 & -\sin 45 & 0 & 0 \\ \sin 45 & \cos 45 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Finally, we translate back to the original location

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The final Transformation Matrix is :

$$M = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 45 & -\sin 45 & 0 & 0 \\ \sin 45 & \cos 45 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.5 & 0 & 0 & 0 \\ 0 & 3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Q2: Two objects A and B are rotated in two phases about x and z coordinates. Object A is rotated 90 degree about x-axis and then 90 degree about z-axis. Object B is rotated about z-axis by 90 degree and then rotated about x-axis by -90 degree. Are the two rotation gives the same results? Show that with transformation matrices.

Solution

For Object A

$$R_x = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & \cos 90 & -\sin 90 & 0 \\ 0 & \sin 90 & \cos 90 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_z = \begin{bmatrix} \cos 90 & -\sin 90 & 0 & 0 \\ \sin 90 & \cos 90 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_{xz} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

For Object B,

$$R_z = \begin{bmatrix} \cos 90 & -\sin 90 & 0 & 0 \\ \sin 90 & \cos 90 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_x = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & \cos -90 & -\sin -90 & 0 \\ 0 & \sin -90 & \cos -90 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$R_{zx} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 & -1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Since Rxz not equal Rzx, therefore the two transformation is not equal.

Express a quadratic Bezier curve $\mathbf{p}(t) = \sum_{i=0}^{2} \mathbf{p}_i B_{0,2}(t)$ in monomial form, i.e., in the form $\mathbf{p}(t) = \mathbf{a}_0 + \mathbf{a}_1 t + \mathbf{a}_2 t^2$.

Solution:

$$\begin{aligned}\mathbf{p}(t) &= \mathbf{p}_0 B_{0,2}(t) + \mathbf{p}_1 B_{1,2}(t) + \mathbf{p}_2 B_{2,2}(t)\\ &= \mathbf{p}_0(1-t)^2 + \mathbf{p}_1 2t(1-t) + \mathbf{p}_2 t^2\\ &= \mathbf{p}_0(1-2t+t^2) + \mathbf{p}_1(2t-2t^2) + \mathbf{p}_2 t^2\\ &= \mathbf{p}_0 + 2(\mathbf{p}_1 - \mathbf{p}_0)t + (\mathbf{p}_0 - 2\mathbf{p}_1 + \mathbf{p}_2)t^2\end{aligned}$$

Q4: For the above exercise, what will be the C2 continuity conditions for the two curves if you know the 3 points from the first curve but not the second curve?

Solution

We have p0, p1, p2 for first curve and p3, p4, p5 for first curve. The conditions are as follows a.

1. Qn-1(1)=Qn(0). Therefore, p2=p3
2. Qn-1 ′ (1)=Qn ′ (0).

   Then,

$$Q_{n-1}{}'(t) = 0 + 2(p_1 - p_0) + 2(p_0 - 2p_1 + p_2)t$$
$$Q_{n-1}{}'(1) = 2(p_1 - p_0) + 2(p_0 - 2p_1 + p_2) = 2(p_2 - p_1)$$
$$Q_n{}'(0) = 2(p_4 - p_3)$$

   Hence,

$$2(p_2 - p_1) = 2(p_4 - p_3)$$
$$(p_2 - p_1) = (p_4 - p_3)$$
$$p_4 = p_3 + (p_2 - p_1) = 2p_2 - p_1$$

3. c. Qn-1 ′′(1)=Qn ′′(0).

$$Q_{n-1}{}'(t) = 0 + 2(p_1 - p_0) + 2(p_0 - 2p_1 + p_2)t$$
$$Q_{n-1}{}''(t) = 2(p_0 - 2p_1 + p_2)$$
$$Q_{n-1}{}''(1) = 2(p_0 - 2p_1 + p_2)$$

$$Q_n{}''(0) = 2(p_3 - 2p_4 + p_5)$$
$$thus, 2(p_0 - 2p_1 + p_2) = 2(p_3 - 2p_4 + p_5)$$
$$(p_0 - 2p_1 + p_2) = (p_3 - 2p_4 + p_5)$$
$$(p_0 - 2p_1 + p_2) = (p_2 - 2(2p_2 - p_1) + p_5)$$
$$p_5 = p_0 - 4p_1 + 4p_2$$

20. Extra notes:

21. Peer review پێداچوونەوەی هاوەڵ