University of Illinois at Urbana-Champaign
Department of Computer Science

Midterm 1

CS 498: Virtual Reality
Spring 2017

Duration: 1h 50m

Name:
Netid:

- Print your name and netid, *neatly* in the space provided above.
- Throughout the exam, please print legibly.
- This is a *closed book* exam. No notes, books, dictionaries, calculators, laptops, smartphones, or virtual reality interfaces are permitted.
- Write your answers in the space provided for the corresponding problem.
- If any question is unclear, ask us for clarification.
- Throughout the exam we use **right-handed coordinate system** only.

Question	Points	Score
Problem 1	20	
Problem 2	40	
Problem 3	40	
Total	100	

Multiple Choice (20 points; 2 each): Circle one choice only for each part.

1. As commonly used in class, what does FOV stand for?

   (a) Fiber Optic Vitreous (b) Fist Of Vengeance (c) Fovea Only Vision (d) Field Of View

2. Which quaternion in (a, b, c, d) form represents counterclockwise rigid-body rotation by an angle $\theta \in [0, \pi]$ about the Y axis?

   (a) $(-\frac{1}{\sqrt{2}}, 0, -\frac{1}{\sqrt{2}}, 0)$ (b) $(1, 0, 1, 0)$ (c) $(\frac{1}{\sqrt{2}}, 0, \frac{1}{\sqrt{2}}, 0)$ (d) $(\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 0, \frac{1}{\sqrt{2}})$

3. Which quaternion represents the inverse rotation of the rotation represented by (a, b, c, d)?

   (a) (d, c, b, a) (b) $(a, -b, -c, -d)$ (c) $(-a, -b, -c, -d)$ (d) $(1/a, 1/b, 1/c, 1/d)$ (e) $(d, c, b, -a)$

4. Which quaternion represents a rotation equivalent to the rotation represented by (a, b, c, d)?

   (a) (d, c, b, a) (b) $(a, -b, -c, -d)$ (c) $(-a, -b, -c, -d)$ (d) $(1/a, 1/b, 1/c, 1/d)$ (e) $(d, c, b, -a)$

5. Which part of the human eye provides the greatest optical power (largest diopter)?

   (a) cornea (b) lens (c) vitreous humor (d) aqueous humor (e) dark humor

6. Suppose a simple lens has focal length 10cm. If an object is placed at distance 50cm, then how far away will its real image be from the lens?

   (a) 5cm (b) 10cm (c) 12.5cm (d) 20cm (e) 50cm

7. As commonly used in class, what does DOF stand for?

   (a) Depth Of Focus (b) Degrees Of Freedom (c) Diopter Of Fovea (d) Divergence Of Focus

8. If two thin, simple lenses are placed next to each other and their focal lengths are 2 and 5 centimeters, respectively, then what is the power of the resulting optical system in terms of diopters?

   (a) 7 D (b) 70 D (c) 75 D (d) 1000 D (e) 35 D

9. Consider collimated light propagating through a spherical lens. The focal distance does not depend on:

   (a) Humidity
   (b) Refraction index of the lens
   (c) The surface curvature of the lens
   (d) The distance from the light source to the lens

10. Which one is the inverse of the homogeneous transform $T_1T_2^{-1}T_3^{-1}T_4^{-1}$?

    (a) $T_1^{-1}T_2T_3T_4$ (b) $T_4T_3T_2T_1^{-1}$ (c) $T_4^{-1}T_3^{-1}T_2^{-1}T_1$ (d) $T_4T_3T_2T_1$

True or False (40 points; 2 each): Circle one choice only for each part.

11. **T / F:** The Nintendo Virtual Boy was the first virtual reality headset.
12. **T / F:** Vergence and accommodation change together (in other words, are coupled) when viewing images in a virtual reality device.
13. **T / F:** The canonical transformation matrix preserves the relative ordering of the virtual objects z-values (depths).
14. **T / F:** Chromatic aberration refers to a display problem in which gamma correction has not been accurately applied.
15. **T / F:** Incoming light hits a layer of neurons and blood vessels before the photoreceptors.
16. **T / F:** This quaternion represents the identity rotation: $(-1, 0, 0, 0)$.
17. **T / F:** A homogeneous transformation matrix applied to transform a rigid body corresponds to a translation followed by a rotation in a global coordinate frame.
18. **T / F:** The images of objects on the retina are upside down in comparison to the physical world.
19. **T / F:** A pincushion distortion is corrected by applying the so-called beanbag distortion.
20. **T / F:** The inverse of a 3D rotation matrix is simply its transpose.
21. **T / F:** To convert the cyclopean view to that required for the left eye, a positive translation along the eye X axis is applied to the virtual objects.
22. **T / F:** Euler's Rotation Theorem states that yaw, pitch, and roll are appropriate representations of 3D rotations.
23. **T / F:** The blind spot in our retina is not perceptible under normal circumstances because it is extremely small.
24. **T / F:** At the fovea, the retina has the highest density of rods.
25. **T / F:** The combined optical power of a 5D and a -5D lens, if placed closely together, results in 0D (optically like a thin sheet of glass).
26. **T / F:** A speaker that emits sound can be considered as a kind of display.
27. **T / F:** Accommodation is the process by which the human eye lens changes its focal length.
28. **T / F:** The fovea contains more rods than cones.
29. **T / F:** In the chain of transformations for rendering points on the screen, the last matrix applied, T_{dist}, is responsible for illumination models of the light sources in the virtual scene.
30. **T / F:** In the idealized physical world, the rays emanating from a point light source are never parallel, unless lenses or mirrors are involved.

Short Answers (40 points):

1. (5 points) In one sentence, explain what the following homogeneous transformation matrix accomplishes when applied for a point (x, y, z), in terms of yaw, pitch, roll, and translation.

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 0 & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$

2. (5 points) Determine the inverse of the previous 4x4 matrix. Your answer need not be simplified, and may be represented as a single matrix or the product of two or more matrices.

3. (5 points) Name five lens aberrations.

4. (5 points) In terms of diopters, explain what happens to the normal human eye lens from the time of being a young adult (around 20 years old) to being an older adult (around 50 years old).

5. (5 points) Put the following transforms in the order that occur in the chain for rendering points on the screen:
   T_{eye} (viewing), T_{vp} (viewport), T_{rb} (rigid body), T_{can} (canonical view), T_{left} (left eye shift; we are ignoring the right-eye case).
   Write your answer as a product of matrices (in other words, determine the correct subscripts for $T_1T_2T_3T_4T_5$).

6. (10 points) Suppose the following matrix product is used to as the viewing or eye transform:

$$T_{eye} = \begin{pmatrix} a & b & c & 0 \\ d & e & f & 0 \\ g & h & i & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 & j \\ 0 & 1 & 0 & k \\ 0 & 0 & 1 & \ell \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

You may assume that it is correctly formed. Determine the following in terms of $a, b, \ldots, \ell$:
Use right hand coordinate for this question.
a) the eye position (in world X, Y, Z coordinates)

b) the eye up vector (in world X, Y, Z coordinates)

c) the eye looking direction vector (in world X, Y, Z coordinates)

7. (5 points) Consider an object (letter R) that is originally placed flat in the XZ plane with its vertical portion aligned with the X axis of the world. Write a quaternion that represents the rotation of the object from its original orientation to the one in which the object is placed in the XY plane with its vertical portion aligned with the vector (1,1,0), as depicted in the figure below. Your solution need not be simplified if it involves a composition of quaternions.