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Homework 1 - Readings Ch1 & Ch2

1. Define OpenGL, OpenGL ES and WebGL. Describe their relationship.

2. What is the difference in the software architecture of a webpage and a webpage using WebGL. Describe all components involved in the two cases.

3. In HTML, what is the <canvas> tag?

4. In Javascript, what line of code one writes to retrieve a 2D rendering context?

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1) OpenGL: a cross-language, cross-platform API for rendering 2D and 3D graphics. It's used in desktop applications, including games and simulations.
OpenGL ES: a lightweight version of OpenGL designed for mobile devices and embedded systems. It removes some features of standard OpenGL to improve performance on less powerful hardware.
WebGL: a JavaScript API based on OpenGL ES that enables rendering 3D graphics within any compatible web browser without plugins. It brings GPU-accelerated graphics to the web.
Relationship: WebGL is based on OpenGL ES, which in turn is a subset of OpenGL.
OpenGL → OpenGL ES → WebGL
(Desktop) → (Mobile) → (Browser)

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2) A standard webpage uses HTML, CSS, and JavaScript to render content through the browser's CPU. In contrast, a WebGL-enabled page uses the <canvas> element and the WebGL API to render interactive 2D/3D graphics using the GPU. This setup involves shaders and a graphics pipeline, allowing real-time, high-performance rendering in the browser.

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3) It creates a drawable area in HTML where graphics can be rendered using JavaScript, including 2D and 3D content via WebGL.

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4) var ctx = canvas.getContext("2d");

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Homework 1 - Linear Algebra

1. **Normalize the vector $\mathbf{v} = [1, 2, 3]$. Round your answer to 2 decimal points.**

   $|\vec{v}| = \sqrt{1^2+2^2+3^2} = \sqrt{1+4+9} = \sqrt{14} = 3.74 \Big\} \hat{v} = \left[\frac{1}{3.74}, \frac{2}{3.74}, \frac{3}{3.74}\right] \approx [0.27, 0.53, 0.80]$

2. **Simplify and Find the Length of the Vector**

   (a) **3 * [1, 1] + 2 * [-1, 1]**

   $3 \cdot [1,1] = [3,3]$
   $2 \cdot [-1,1] = [-2,2]$ $\dashrightarrow [3,3] + [-2,2] = [1,5]$

   (b) **Find the length of the vector calculated in (a)** $|\vec{v}| = \sqrt{1^2+5^2} = \sqrt{1+25} = \sqrt{26} \approx 5.10$

3. **Calculate the Cross Product**

   (a) $[\mathbf{0}, \mathbf{1}, \mathbf{1}] \times [\mathbf{1}, \mathbf{1}, \mathbf{0}]$

   (b) $[\mathbf{2}, \mathbf{3}, \mathbf{4}] \times [\mathbf{1}, \mathbf{0}, \mathbf{0}]$

   (c) $[\mathbf{0}, \mathbf{3}, \mathbf{4}] \times [\mathbf{2}, \mathbf{2}, \mathbf{2}]$

   a) $x = 1 \cdot 0 - 1 \cdot 1 = -1$
   $y = 1 \cdot 1 - 0 \cdot 0 = 1$
   $z = 0 \cdot 1 - 1 \cdot 1 = -1$
   $[-1, 1, -1]$

   b) $x = 3 \cdot 0 - 4 \cdot 0 = 0$
   $y = 4 \cdot 1 - 2 \cdot 0 = 4$
   $z = 2 \cdot 0 - 3 \cdot 1 = 3$
   $[0, 4, -3]$

   c) $x = 3 \cdot 2 - 4 \cdot 2 = -2$
   $y = 4 \cdot 2 - 0 \cdot 8 = 8$
   $z = 0 \cdot 2 - 3 \cdot 2 = -6$
   $[-2, 8, -6]$

4. **Calculate the Dot Product**

   (a) $[\mathbf{1}, \mathbf{0}, \mathbf{1}] \cdot [\mathbf{0}, \mathbf{1}, \mathbf{1}]$

   (b) $[\mathbf{0}, \mathbf{3}, \mathbf{4}] \cdot [\mathbf{1}, \mathbf{0}, \mathbf{0}]$

   (c) $[\mathbf{2}, \mathbf{3}, \mathbf{4}] \cdot [\mathbf{6}, \mathbf{4}, \mathbf{3}]$

   a) $= (1)(0) + (0)(1) + (1)(1) = 0 + 0 + 1 = 1$
   b) $= (0)(1) + (3)(0) + (4)(0) = 0$
   c) $= (2)(6) + (3)(4) + (4)(3) = 12 + 12 + 12 = 36$

5. **Consider a triangle formed by connecting the three points $\mathbf{p_1} = (\mathbf{0}, \mathbf{0}, \mathbf{0})$, $\mathbf{p_2} = (\mathbf{1}, \mathbf{0}, \mathbf{0})$ and $\mathbf{p_3} = (\mathbf{1}, \mathbf{1}, \mathbf{1})$.**

   (a) **Find the area of the surface of this triangle.**

   $= (0 \cdot 1 - 0 \cdot 1, 0 \cdot 1 - 1 \cdot 1, 1 \cdot 1 - 0 \cdot 1) = (0, -1, 1) \rightarrow \sqrt{0^2 + (-1)^2 + 1^2} = \sqrt{2} \rightarrow \text{Area} = \frac{1}{2}\sqrt{2} \approx 0.71$

   (b) **Find the vector which is perpendicular to the surface of this triangle, AND has a positive z-direction.** $\vec{n} = \vec{a} \times \vec{b} = (0, -1, 1) \rightarrow [0, -1, 1]$

6. **Calculate the Matrix**

   (a) $\begin{bmatrix} 1 & 2 & 5 \\ -1 & -1 & 1 \\ 4 & 4 & -2 \end{bmatrix} \cdot \begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$

   $1 \cdot 1 + 2 \cdot 2 + 5 \cdot 3 = 1 + 4 + 15 = 20$
   $-1 \cdot 1 + -1 \cdot 2 + 1 \cdot 3 = -1 + -2 + 3 = 0$
   $4 \cdot 1 + 4 \cdot 2 + (-2) \cdot 3 = 4 + 8 - 6 = 6$

   $\begin{bmatrix} 20 \\ 0 \\ 6 \end{bmatrix}$

   (b) $\begin{bmatrix} 2 & 0 & 3 \\ 0 & -1 & 2 \\ 3 & 2 & -2 \end{bmatrix} \cdot \begin{bmatrix} -1 & -4 & 1 \\ 1 & -1 & 4 \\ 0 & 0 & 5 \end{bmatrix}$

   $2 \cdot (-1) + 0 \cdot 1 + 3 \cdot 0 = -2$
   $0 \cdot (-1) + (-1) \cdot 1 + 2 \cdot 0 = -1$
   $3 \cdot (-1) + 2 \cdot 1 + (-2) \cdot 0 = -1$

   $2 \cdot (-4) + 0 \cdot (-1) + 3 \cdot 0 = -8$
   $0 \cdot (-4) + (-1) + 2 \cdot 0 = 1$
   $3 \cdot (-4) + 2 \cdot (-1) + (-2) \cdot 0 = -14$

   $2 \cdot 1 + 0 \cdot 4 + 3 \cdot 5 = 2 + 0 + 15 = 17$
   $0 \cdot 1 + (-1) \cdot 4 + 2 \cdot 5 = -4 + 10 = 6$
   $3 \cdot 1 + 2 \cdot 4 + (-2) \cdot 5 = 3 + 8 - 10 = 1$

   $\begin{bmatrix} -2 & -8 & 17 \\ -1 & 1 & 6 \\ -1 & -14 & 1 \end{bmatrix}$

7. **Consider two lines $\mathbf{y} = \frac{4}{3}\mathbf{x} - \mathbf{1}$ and $y = 0$:**

   (a) **Find the intersection point between the two lines (Draw the lines on a graph if stuck).** $\frac{4}{3}x - 1 = 0 \Rightarrow \frac{4}{3}x = 1 \Rightarrow x = \frac{3}{4}$, $y = 0$ $\left(\frac{3}{4}, 0\right)$

   (b) **Are these lines perpendicular?**

   $\frac{4}{3} \cdot 0 = 0 \neq -1 \Rightarrow$ No, they are not perpendicular!