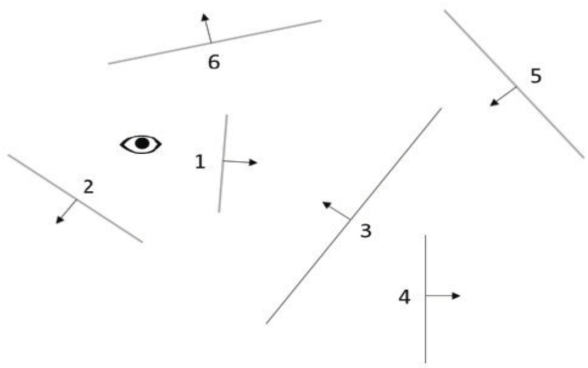
ICG 2018 Midterm

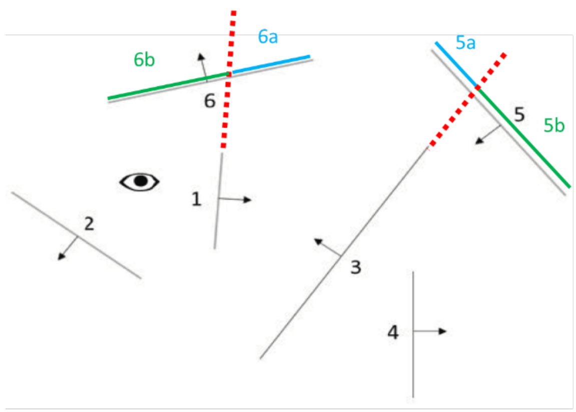
參考解答(不保證為標準答案)

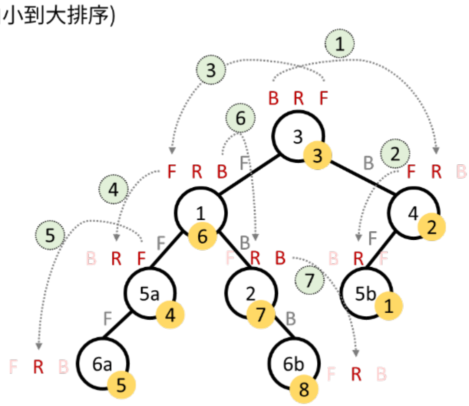
1. BSP Tree (10%)
   - Construct the Binary Space Partitioning (BSP) tree of the following figure. Please use the node “3” as the root, and choose smaller numbers as the sub-tree root node. (5%)
   - From the BSP tree of previous question, derive the display sequence in terms of the given viewing position in this figure. (5%)



解答：

以上為a、下為b；若水平線才以左為a、以右為b(且數字由小到大排序)





順序：5b, 4, 3, 5a, 6a, 1, 2, 6b

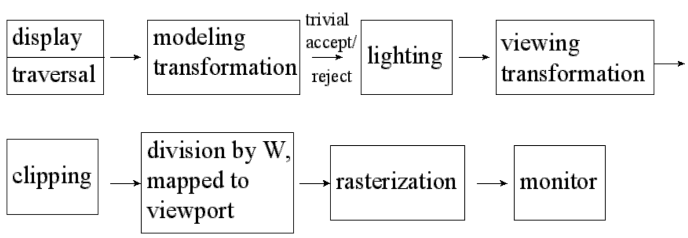
2. Shading (6%)
    - In homework 1, you implement three kinds of shading. Consider each figure below, determine which kind of shading it uses and explain your reason respectively. (6%)

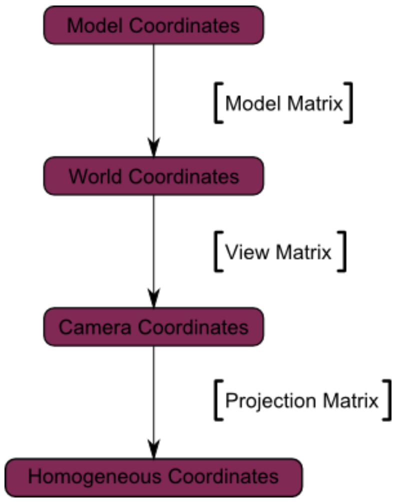
(A) (B) (C)

解答：(A) Flat shading, (B) Gouraud shading, (C) Phong shading

3. GPU rendering pipeline (10%)
    - Describe the GPU rendering pipeline. (4%)
    - What is the meaning of model matrix, view matrix and projection matrix? Please describe them respectively. (6%)

解答：





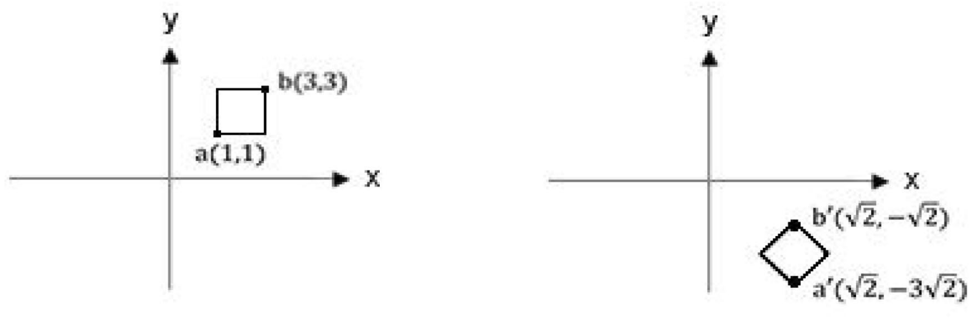
Model Matrix：從 Model Space 轉換到 World Space 的(運算)矩陣
View Matrix：從 World Space 轉換到 Camera Space 的(運算)矩陣
Projection Matrix：從 Camera Space 轉換到 Homogeneous Space 的(運算)矩陣

(src)

4. Transformation matrix (12%)

   For the following questions, consider as 2d plane. You need to write down all 3x3 matrices respectively and the matrix multiplication order.

   - For the figures below, find transform matrices to convert the square in (A) into the square in (B) (6%)



(A) (B)

1. 先將原圖移至原心(中心點與原心重疊)
2. 進行旋轉
3. 再將旋轉後之圖片，移至結果位置(B 點)

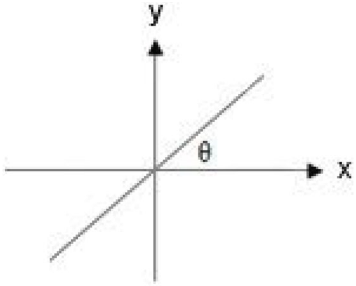
$$\begin{bmatrix}-1\\-1\\1\end{bmatrix}=\begin{bmatrix}1&0&-2\\0&1&-2\\0&0&1\end{bmatrix}\begin{bmatrix}1\\1\\1\end{bmatrix},\quad \begin{bmatrix}1\\1\\1\end{bmatrix}=\begin{bmatrix}1&0&-2\\0&1&-2\\0&0&1\end{bmatrix}\begin{bmatrix}3\\3\\1\end{bmatrix}$$

$$\begin{bmatrix}0\\-\sqrt{2}\\1\end{bmatrix}=\begin{bmatrix}\frac{1}{\sqrt{2}}&-\frac{1}{\sqrt{2}}&0\\\frac{1}{\sqrt{2}}&\frac{1}{\sqrt{2}}&0\\0&0&1\end{bmatrix}\begin{bmatrix}-1\\-1\\1\end{bmatrix},\quad \begin{bmatrix}0\\\sqrt{2}\\1\end{bmatrix}=\begin{bmatrix}\frac{1}{\sqrt{2}}&-\frac{1}{\sqrt{2}}&0\\\frac{1}{\sqrt{2}}&\frac{1}{\sqrt{2}}&0\\0&0&1\end{bmatrix}\begin{bmatrix}1\\1\\1\end{bmatrix}$$

$$\begin{bmatrix}\sqrt{2}\\-3\sqrt{2}\\1\end{bmatrix}=\begin{bmatrix}1&0&\sqrt{2}\\0&1&-2\sqrt{2}\\0&0&1\end{bmatrix}\begin{bmatrix}0\\-\sqrt{2}\\1\end{bmatrix},\quad \begin{bmatrix}\sqrt{2}\\-\sqrt{2}\\1\end{bmatrix}=\begin{bmatrix}1&0&\sqrt{2}\\0&1&-2\sqrt{2}\\0&0&1\end{bmatrix}\begin{bmatrix}0\\\sqrt{2}\\1\end{bmatrix}$$

$$\Rightarrow \begin{bmatrix}1&0&-2\\0&1&-2\\0&0&1\end{bmatrix}*\begin{bmatrix}\frac{1}{\sqrt{2}}&-\frac{1}{\sqrt{2}}&0\\\frac{1}{\sqrt{2}}&\frac{1}{\sqrt{2}}&0\\0&0&1\end{bmatrix}*\begin{bmatrix}1&0&\sqrt{2}\\0&1&-2\sqrt{2}\\0&0&1\end{bmatrix}=\begin{bmatrix}\frac{1}{\sqrt{2}}&-\frac{1}{\sqrt{2}}&-\sqrt{2}\\\frac{1}{\sqrt{2}}&\frac{1}{\sqrt{2}}&-4\sqrt{2}\\0&0&1\end{bmatrix}$$

- The simplest way to simulate a mirror is to copy objects which is symmetric to the mirror. Now given a mirror line with angle θ , please find transform matrices to do this. (6%) (Hint : use scale matrix with minus value)



解答 1：直接轉 2θ 度

$$\begin{bmatrix} a' \\ b' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos(2\theta) & -\sin(2\theta) & 0 \\ \sin(2\theta) & \cos(2\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} a \\ b \\ 1 \end{bmatrix}$$

解答 2：先轉 90-θ 度，鏡射 y 軸(x 加負號)，再轉 θ-90 度回來

$$\begin{bmatrix} a' \\ b' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos(\theta-90) & -\sin(\theta-90) & 0 \\ \sin(\theta-90) & \cos(\theta-90) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\begin{bmatrix} \cos(90-\theta) & -\sin(90-\theta) & 0 \\ \sin(90-\theta) & \cos(90-\theta) & 0 \\ 0 & 0 & 1 \end{bmatrix} * \begin{bmatrix} a \\ b \\ 1 \end{bmatrix}$$

5. Ray intersection (8%)
   - In ray tracing, we need to judge if the ray intersects with a shape or not. Given a ray in 3d (x_t , y_t , z_t) = (v_x , v_y , v_z) × t + (o_x , o_y , o_z) $t \geq 0$, and a square formed by 4 points (-r, -r, 0), (-r, r, 0), (r, r, 0), (r, -r, 0), where and (v_x , v_y , v_z) = (−1 ,−1 ,−1), r = 2.5. Check if the ray intersects with the square, and (o_x , o_y , o_z) = (4, 5, 6), calculate the intersection point if any one of them exists.

解答：四點之平面可視為 z=0，則求：(x, y, 0) = (-1, -1, -1)t + (4, 5, 6)即可

⇨ (x, y) = (-2, -1)

故假設 r >= 2 or r <= -2，則方形與射線之交點為(-2, -1, 0)，反之無交點

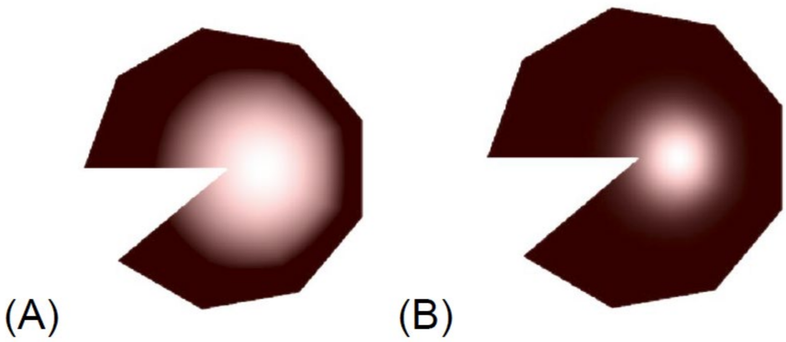
6. (5%) What is your term project for this semester? What are the technical difficulties involved in the project? (You can refer to the project listing).

解答：自行回答，只要有針對題目回答，基本上是送分題；可參考：
http://www.cmlab.csie.ntu.edu.tw/~cchank/term_project_list.pdf

7. Phong illumination model (4%)

$$I = k_a I_a + \sum_{lights} (k_d I_{m,s} \cos\theta + k_s I_{m,d} \cos^{\alpha}\theta)$$

- In Phong illumination model, the specular value α is also a parameter of material. Compare images below, which specular value is larger? (4%)



解答：B，因為金屬表面的反射光點會較為集中

8. Rendering equation (6%)

$$L_o(\mathbf{x}, \omega_o, \lambda, t) = L_e(\mathbf{x}, \omega_o, \lambda, t) + \int_{\Omega} f_r(\mathbf{x}, \omega_i, \omega_o, \lambda, t)\, L_i(\mathbf{x}, \omega_i, \lambda, t)\, (\omega_i \cdot \mathbf{n})\, d\omega_i$$

- Can Phong illumination model solve the rendering equation? Why or why not? (6%)

解答：無法，因為光線打到物體便停止，若要做 Rendering，光線需繼續多次反射，且不能假設物品表面為光滑

9. Volume Rendering / Marching Cubes (12%)

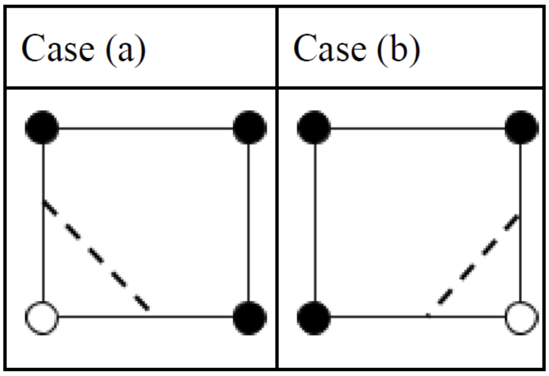
- Please give two examples for Volume Rendering applications. (4%)

解答：

Volume Rendering 定義：藉由 2D 資料，建模後視覺化成 3D 資料，且可能會用顏色加以辨識。故舉例可為：1. 醫療用(MRI, CT)、 2. 天氣模擬：(颱風、龍捲風)

- Volume Rendering use marching cubes to determine the contour of the volume. Now we consider the 2d condition, i.e. square marching. The square marching consists of two steps. First, apply the threshold of contour, and label the point with black if the value of the point is lower than threshold, otherwise label with white.

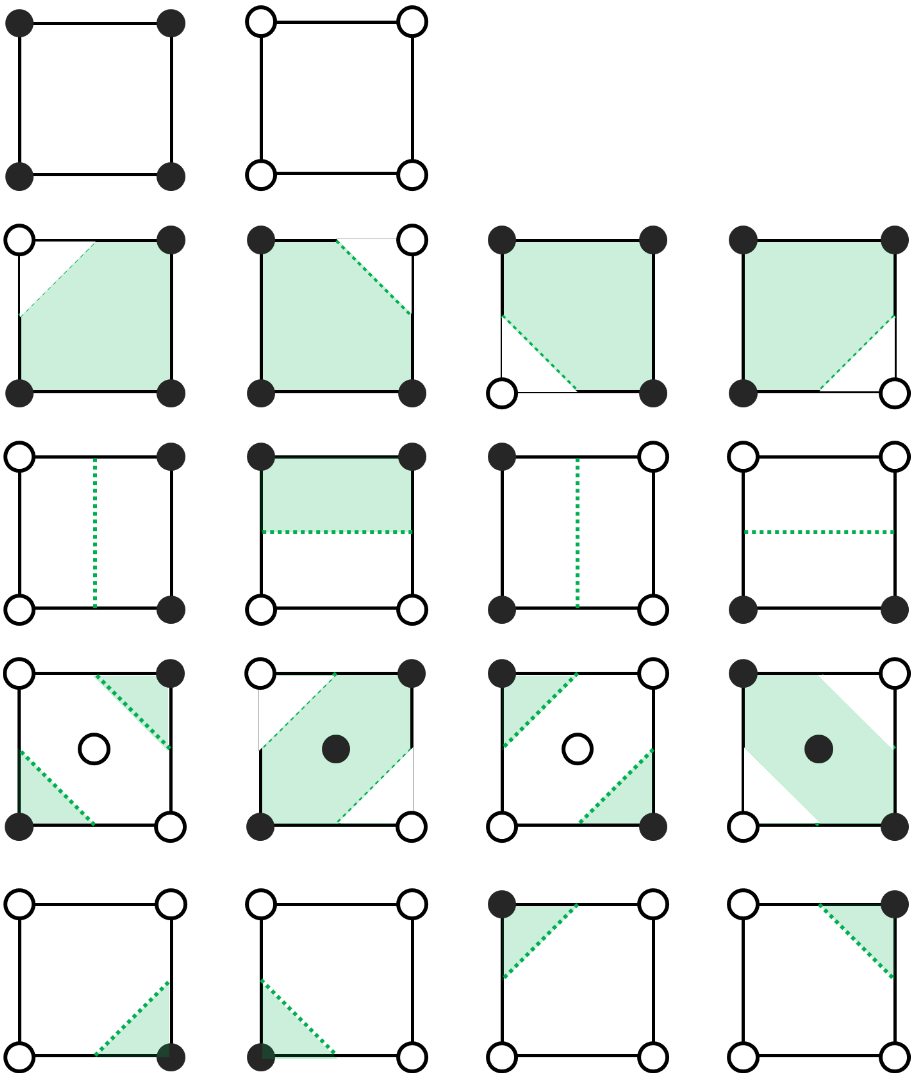
  Second, determine the contour by the case of 4 points' color. For example, in the case (a) and case (b), the contour is the dash line shown in the picture.



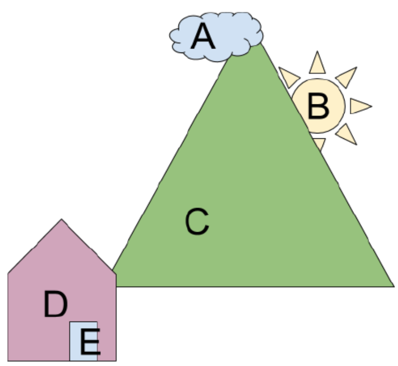
  - How many cases should square marching consider? Draw all of them. Each case should include 4 points and contour. Note that case(a) and case(b) are different. If there are any ambiguity of possible contour exists, just draw one of them. (8%)

解答：

以四點為例，正常只需考量 $2^4 = 16$ 種，但因為有些特定狀況，無法判定中心，故要再細分(第 5 橫排)



10. Painter's algorithm (4%)



E is a door of the house D.

- In image above, what is the drawing order if we use painter's algorithm? If multiple possible answers exist, answer one of them. (4%)

解答：Painter's Algorithm 是由後往前畫(有重疊則無法實作)，故基本上以下三組解答均正確：
B, C, A, D, E 或 B, C, D, E, A 或 B, C, D, A, E

11. (8%) It is said that Microsoft game machines X-Box (1, and 360) are costing more than their sale prices, and then use the game software revenue to compensate for the loss in hardware.
    (a) If this is true, what advantages for Microsoft in developing the hardware platform can be predicted from this business model? (4%)
    (b) In the above case, is it easy for companies from Korea or Taiwan to develop their own game machines or clones of these machines? Why and why not? (4%)

解答：Painter's Algorithm 是由後往前畫(有重疊則無法實作)，故基本上以下三組解答均正確：
(a) 其策略是以便宜的硬體，來推廣、搶佔市場，一個資本戰的概念
(b) 很難，因為需要極其大量的資金，以台、韓企業來說，執行上有困難

12. (15%) Modified Distribution Ray tracing
    (a) What's the weakness of ray-tracing as compared to the Rendering equation? (short answer) (5%)

解答：Ray tracing 假設物體表面光滑、且光線不會多次反射；故其缺點為：無法處理粗糙表面物體，及無法非常準確模擬現實世界之狀況(否則運算量過大、速度過慢)。

    (b) In the photo below, there are very bright spots under the glass sphere, called caustics. One way to improve the previous ray-tracing is to combine the rays (light packets) shooting from the lights, and store the (location, direction) information at the light-surface intersection points, called photon maps. (10%)

For caustics, we only store the photon map when rays hit the highly specular surface or pass through a transparent object and finally reach a diffuse surface.

After the photon maps are created, we can use ray-tracing to shoot rays from the eye until it hits the surfaces with the photon maps. Why is this method successful in solving the Rendering Equation? Please give your own algorithm describing the previous solution.

解答(本題為開放式題目)：
Caustics 是結合 Ray tracing 與高中物理，在可能會發生錯誤的狀況下，特別處理。