Computer Graphics **Instructor: Steve Seitz**

CSE 457, Spring 2002

Homework #1

Display Devices, Image Processing, Hierarchical Modeling, Affine Transformations

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Assigned: Friday, April 12th
Due: Friday, April 26th, **at the beginning of class**

Directions: Please provide short written answers to the questions in the space provided. If you require extra space, you may staple additional pages to the back of your assignment. Feel free to discuss the problems with classmates, but please ***answer the questions on your own*.**

Name:____

Problem 1. Short Answer (8 points, 2 each)

Provide a short answer (typically one or two sentences) to each of the following questions. In each case, you must clearly justify your answer.

a. Which blurring filter will do a better job removing salt and pepper noise: median or mean? Why?

b. Is the median filter a convolution filter? Explain why it is or isn't.

c. Color lookup tables are useful even with used with a true color framebuffer. Give an example of what the lookup table might be used for.

d. In the graphics pipeline, why might it be preferable to use a matrix multiplication to represent translation rather than vector addition?

Problem 2. Display Devices (12 points)

In order to allow more time for transmitting and displaying each pixel, the American broadcast television standard (NTSC) uses an "interlaced" type of refresh, in which each video frame is broken into two "fields," each containing one-half of the picture. The two fields are "interlaced" in the sense that each field contains every other scan line: all odd-numbered scan lines are displayed in the first field, and all even-numbered scan lines are displayed in the second.

The purpose of an interlaced scan is to place some new information in all areas of the screen at a high enough rate to avoid flicker, while allowing the hardware more time for accessing and displaying each pixel.

a. (1 point) If the video controller displays each field in $1/60^{th}$ of a second, what is the overall frame rate for displaying the entire screen?

b. (2 points each) An interlaced refresh works well as long as adjacent scan lines display similar information. In which parts, if any, of the following images would you expect to see flicker on an interlaced display (and briefly mention why):

- A single pixel wide horizontal white line on a black background?

- A single pixel wide vertical white line on a black background?

- A checkerboard of black and white, where each black or white square is 8 x 8 pixels?

- A checkerboard of black and white, where each black or white square is a single pixel?

c. (3 points) On interlaced displays, there is a very noticeable artifact when objects on the screen are moving fast. What is this artifact, and how will it appear if the video is of a white box moving horizontally on a black background?

Problem 3. Image Filters (9 points)

Each of the matrices below represents a cross-correlation kernel. Below each filter, write all of the characteristics from the following list that apply:

- Mean blurring
- Gaussian blurring
- Edge-preserving blurring
- Blurring in x only
- Blurring in y only
- Gradient in x
- Gradient in y
- Edge detection
- Rotation
- Translating
- Identity (no effect)
- Invert

(a)

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

(b)

Median filter over 4x4 region.

(c)

$$\frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

(d)

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

(e)

$$\frac{1}{25}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix}$$

(f)

$$\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & -1 & 0 \end{bmatrix}$$

(g)

$$\frac{1}{5}\begin{bmatrix} 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

(h)

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

(i)

$$\begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & -1 \end{bmatrix}$$

To experiment with these filters yourself, go to the graphics lab and use Adobe Photoshop. You can experiment with various convolution kernels using Filter->Other->Custom, or with median blurring using Filter->Blur->Smart Blur.

Problem 4. Filters (8 points)

1. (4 points)

- **H** is a 3x3 kernel
- **F** is an input image
- **G** is the result of applying the filter **H** to the image **F** using cross-correlation

$$\mathbf{H}\ \begin{array}{|c|c|c|}\hline a & b & c \\ \hline d & e & f \\ \hline g & h & i \\ \hline \end{array} \quad \otimes \quad \mathbf{F}\ \begin{array}{|c|c|c|c|c|}\hline 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 1 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 \\ \hline \end{array} \quad = \quad \mathbf{G}\ \begin{array}{|c|c|c|c|c|}\hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \end{array}$$

a) Fill in the entries of **G**, above. Leave the border pixels of **G** blank and just compute the center 3x3 block.

b) Suppose we replaced cross-correlation with convolution. Below, give the result of convolving **H** with **F**.

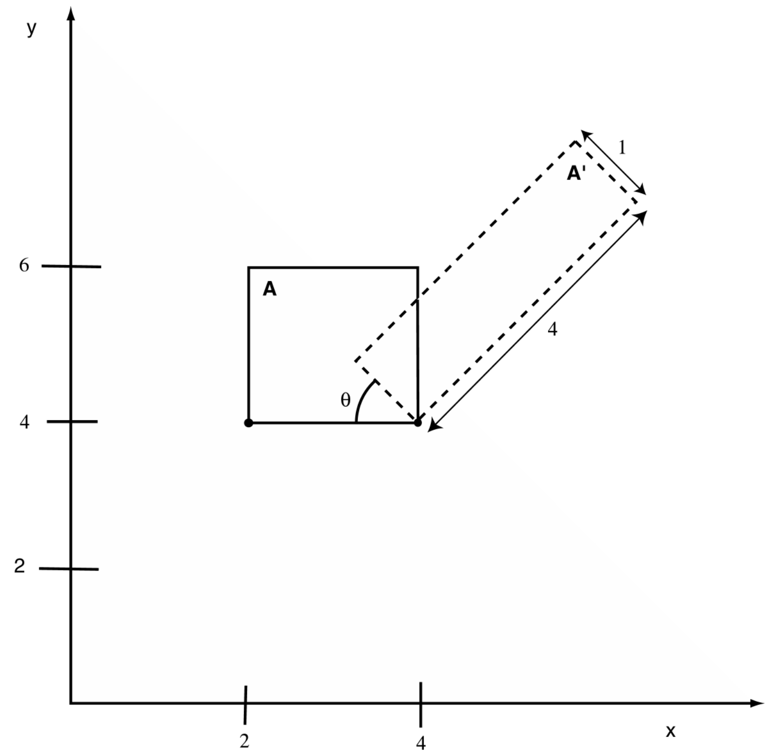
$$\mathbf{H}\ \begin{array}{|c|c|c|}\hline a & b & c \\ \hline d & e & f \\ \hline g & h & i \\ \hline \end{array} \quad \bigstar \quad \mathbf{F}\ \begin{array}{|c|c|c|c|c|}\hline 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 1 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & 0 \\ \hline \end{array} \quad = \quad \mathbf{G}\ \begin{array}{|c|c|c|c|c|}\hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \ & \ & \ & \ & \ \\ \hline \end{array}$$

2. (4 points)

Immediately to the right is an original, unfiltered image. Below the original are a mean filtered (middle) and a Gaussian filtered version (bottom). The mean filtered image is noticeably more blocky—see the online version of this HW to see it more clearly. Explain the cause of the blockiness in light of Part 1 of this question.

Problem 5. 2D Affine Transformations (6 points)

Write out a sequence of 3×3 translation, scaling, and rotation matrices that transforms the square **A** into the rotated rectangle **A'**, as shown in the diagram below. Assume that the product **M** of your sequence of matrices will be applied to each point **p** of **A** by post-multiplication, i.e., **Mp** = **p'**. θ is the only variable, all other entries of your matrices should be filled in with numbers.

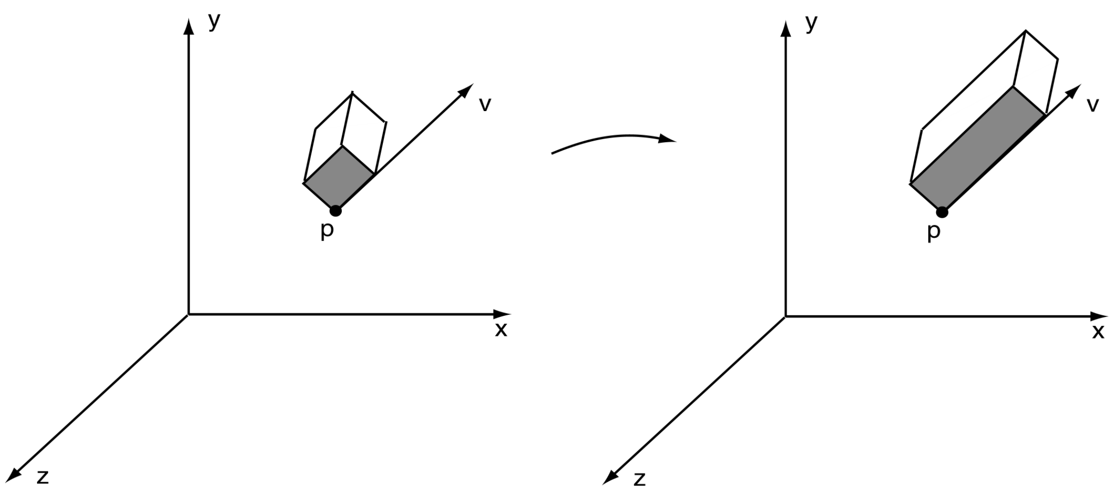


Problem 6. 3D Affine transformations (6 points)

The basic scaling matrix discussed in lecture scales only with respect to the x, y, and/or z axes. Using the basic translation, scaling, and rotation matrices, specify how to build a transformation matrix that scales along any ray in 3D space. This new transformation is described by the ray origin **p** = (x_0, y_0, z_0) and unit direction vector **v** = (x_1, y_1, z_1), and the amount of scaling s_{pv}.

You can use any of the following standard matrices (from lecture) as building blocks: Euler angle rotations $R_x(\theta)$, $R_y(\theta)$, $R_z(\theta)$, scales $S(s_x,s_y,s_z)$, and translations $T(t_x,t_y,t_z)$. You don't need to compute exact formulas for the rotation angles, but you must describe how to compute each of the rotation angles using words and drawings. You don't need to write out the entries of the 4x4 matrices, it is sufficient to use the symbols given above.

For clarity, a diagram has been provided, showing a box being scaled an unknown amount with respect to a given ray. Your answer should work for any ray, not just the case shown in the picture.

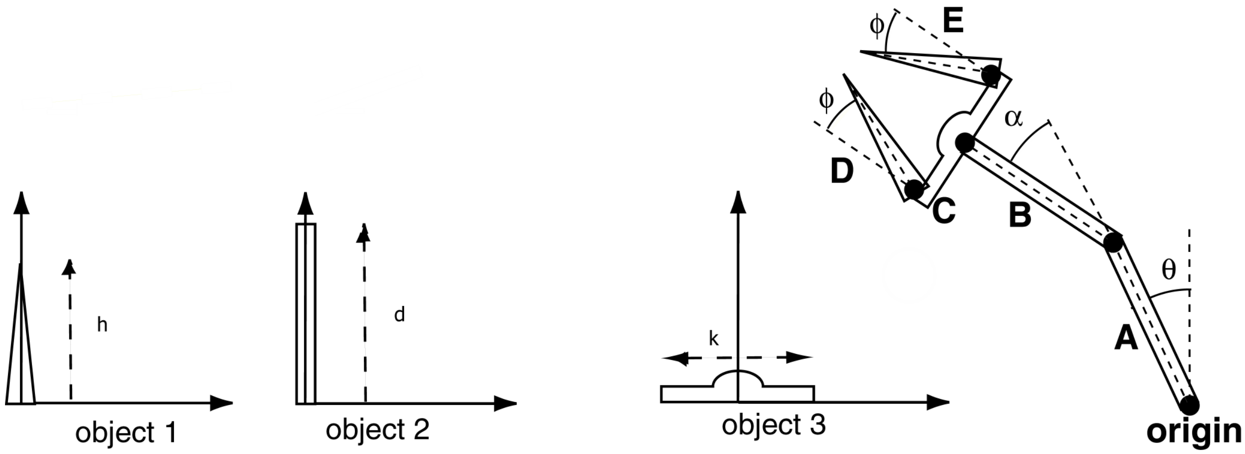


Problem 7. Hierarchies (12 points)

Suppose that you want to model the pincher figure below. The pincher is made of five parts, **A**, **B**, **C**, **D**, and **E**. each part is drawn using one of the three primitives below.

The following transformations are available to you:

- R(t) - rotate by t degrees (counter clockwise)
- T(a, b) – translate a units along the x–axis, b units along the y–axis.



a) Construct a tree to specify the pincher given in the diagram. Along each edge of the tree, write expressions for the transformations that are applied along that edge, in terms of the symbols given above (do not write the 3x3 matrices).

b) Write out the full transformation expression for the part labeled **E**.