**ENGR 2013: Engineering Analysis and Applications**

**Laboratory No. 3: Who Says Gamers Don’t Know Math?**

**Goal:** This lab demonstrates how the simple concept of matrix multiplication can be used to rotate and translate objects. This is a core operation in computer graphics and the backbone of computer gaming. Special purpose chips, such as Graphical Processing Units (GPUs), have been designed to do these operations very efficiently.

**Preliminary Work:** In this lab we are going to explore the following matrix equation, $Y=Ax$:

$$\left[\begin{matrix}y\_{1}\\y\_{2}\end{matrix}\right]=\left[\begin{matrix}a\_{11}&a\_{12}\\a\_{21}&a\_{22}\end{matrix}\right]\left[\begin{matrix}x\_{1}\\x\_{2}\end{matrix}\right]$$

where $x\_{1}$ and $x\_{2}$ are inputs, and $y\_{1}$ and $y\_{2}$ are outputs. The matrix $A$ is referred to as a transformation matrix. In this lab, we will load this matrix from a file so it can be easily changed.

Review how to load a text file containing a matrix into a numpy array by using this file:

/data/courses/engr\_2011/current/labs/lab\_03/picone\_joseph/data.txt

This file contains samples of a square whose side has a length of 1 centered at (1.5,1.5) in an xy coordinate system.

**Tasks:**

1. *Visualize the Data:* Write a Python program, **p01.py**, that plots this data using an xy plot with ranges of [-5,5] for both the x and y axes. Your command line interface should be:

p01.py data.txt

Remember to use what we learned about plotting previously (e.g., establishing a connection that supports graphical output).

1. *Rotate the Image:* Write a script, **p02.py**, that:
2. reads the data, which can be thought of as a list of vectors, from a file;
3. reads a matrix, $A$, from a file;
4. transforms each input using the matrix $A$ by implementing the above matrix equation;
5. writes the data to a new file.

The command line interface for your script should be:

p02.py data.txt matrix.txt new\_data.txt

Test this program using the file **matrix\_0.txt**, and by plotting the data in your output file, **new\_data.txt**, using **p01.py**. What do you observe? Does this make sense?

1. *Evaluate Different Transformations:* Repeat no. 2 for the files matrix\_[1-4].txt and explain whether the results make sense.
2. *Generalize Your Result:* The general form of the transformation matrix you are experimenting with is:

$$\left[\begin{matrix}y\_{1}\\y\_{2}\end{matrix}\right]=\left[\begin{matrix}cosθ&sinθ\\-sinθ&cosθ\end{matrix}\right]\left[\begin{matrix}x\_{1}\\x\_{2}\end{matrix}\right]$$

Modify your program to take an argument – the angle $θ$ – instead of a transformation matrix file and demonstrate that you can produce arbitrary rotations of the image. Your interface should be:

p03.py data.txt theta new\_data.txt

Generate several test files and show that you get the same results as you obtained in (3) if you use angles of $45^{°}$, 90$°$, 135$°$ and 180$°$.

1. *Have Some Fun:* Generate a new data file, **mydata.txt**, that represents an interesting shape, such as the letter A, or a binary image of your favorite pet animal, and demonstrate that you can rotate it using **p03.py**.

**Summary:**

One of the core operations in computer graphics is an image rotation. This is now done in 3D at very high speeds, which requires lots of computation. Translation, sliding the image in some direction (e.g., moving the image to the right by one unit) is also an important part of this operation. Later we will learn how to combine these two operations so they can be computed efficiently.