

Programming Lab #5a

Spinning Cube

Topics: Two-dimensional subscripting, nested loops, calling C functions from assembly

Prerequisite Reading: Chapters 1-6
Revised: March 22, 2020

Background¹: In 3D computer graphics, object surfaces are modeled as a collection of triangles. (E.g., each face of a cube may be modeled using two triangles.) Each vertex of a triangle is represented as a vector $V = [V_x, V_y, V_z]$, where V_x , V_y and V_z are the usual Cartesian coordinates in 3-space. Linear algebra and matrix multiplication are used to modify the position of vertices and thus the position and orientation of objects. For example, multiplying matrix M^x (given below) times vector V creates a new vector V' that corresponds to rotating the position of the vertex represented by vector V around the x -axis by θ radians:

$$V' = \begin{bmatrix} V'_x \\ V'_y \\ V'_z \end{bmatrix} = M^x \times V = \begin{bmatrix} 1.0 & 0.0 & 0.0 \\ 0.0 & \cos \theta & -\sin \theta \\ 0.0 & \sin \theta & \cos \theta \end{bmatrix} \times \begin{bmatrix} V_x \\ V_y \\ V_z \end{bmatrix}$$

The product of two 3x3 matrices is another 3x3 matrix. Given two matrices M^x and M^y that rotate vertices around the x and y -axis respectively, the product $M^{xy} = M^x M^y$ is a single matrix that combines both rotations, where the value in row r , column c of M^{xy} is given by:

$$M_{r,c}^{xy} = \sum_{k=0}^{k=2} M_{r,k}^x \times M_{k,c}^y$$

Assignment: Create function `MatrixMultiply` in assembly language, with the function prototype:

```
void MatrixMultiply(int32_t A[3][3], int32_t B[3][3], int32_t C[3][3]) ;
```

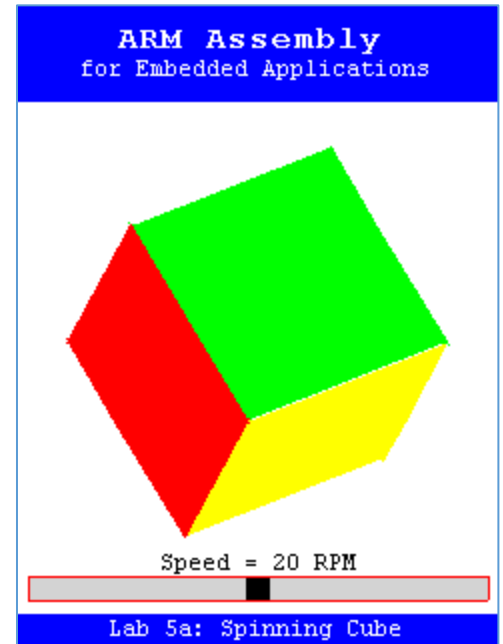
that implements matrix multiplication based on the following pseudo-code:

```
for row ← 0 to 2 do:
  for col ← 0 to 2 do:
    set Arow,col ← 0
    for k ← 0 to 2 do:
      Arow,col ← MultAndAdd(Arow,col, Brow,k, Ck,col)
```

For example: $A_{0,1}$ is the sum of products of corresponding elements from row 0 of matrix B and column 1 of matrix C:

$$\begin{bmatrix} A_{0,0} & A_{0,1} & A_{0,2} \\ A_{1,0} & A_{1,1} & A_{1,2} \\ A_{2,0} & A_{2,1} & A_{2,2} \end{bmatrix} = \begin{bmatrix} B_{0,0} & B_{0,1} & B_{0,2} \\ B_{1,0} & B_{1,1} & B_{1,2} \\ B_{2,0} & B_{2,1} & B_{2,2} \end{bmatrix} \times \begin{bmatrix} C_{0,0} & C_{0,1} & C_{0,2} \\ C_{1,0} & C_{1,1} & C_{1,2} \\ C_{2,0} & C_{2,1} & C_{2,2} \end{bmatrix}$$

Test your implementation of the `MatrixMultiply` function using the C main program downloaded from [here](#). Note that function `MatrixMultiply` should call function `MultAndAdd` that is implemented in the C source code file². If your code is correct, the display should display a rapidly spinning cube like the image above. Use the blue pushbutton to pause or the slider to change the speed. Any errors detected in your function will be displayed as **white text on a red background**.



¹ Adapted from: https://en.wikipedia.org/wiki/Transformation_matrix

² **IMPORTANT:** Don't replace function `MultAndAdd` with integer multiply and add instructions; we've hidden the fact that it actually uses floating-point to do arithmetic. Just code your solution assuming that the arrays hold 32-bit integers.