BIL 105E – Introduction to Scientific and Engineering Computing (C)

Spring 2016-2017

Homework 4
Treasure Hunt

Assignment Date: 07.04.2017
Due Date: 17.04.2017 - 23:59
Duration 10 days

In this homework, you will implement tracking device for a treasure hunter. Our treasure hunter is eager to find the treasure but he is not able to carry it. He needs to know the coordinates of the treasure for extraction. You will implement a system using linear algebra to determine coordinates of the treasure.

Treasure hunter has following set of instructions that he can conclude.

- Move
- Change basis
- Rotate
- Dig

We assume treasure hunter has no idea where the treasure is, but a treasure expert (you) tells him what to do at each step. You are going to provide commands to the hunter in runtime.

Preliminary Information

Vector: A vector is a set of numbers that defines a point in the space. In this homework, you are going to deal with 2D space, which means your vectors will have 2 numbers shown as $\begin{bmatrix}3\\5\end{bmatrix}$. Each number in a vector indicates a displacement with respect to a basis. Thus a point represented by a vector relies the basis in use. Point that a vector shows can be changed with the basis we use. Each member in the vector shows a movement along the basis respectively.

Basis: Basis is a set of vectors that defines a coordinate system. Since 2D spaces will be considered in this homework, any basis that will be defined would include two vectors that forms a 2x2 matrix. A standard basis which represents Cartesian coordinate system can be shown as:

$$standard\ basis = \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$$

In standard basis, first basis vector is $\begin{bmatrix}1\\0\end{bmatrix}$, which means first basis has 1 unit on x axis and 0 units on y axis. Second basis vector is $\begin{bmatrix}0\\1\end{bmatrix}$, which means second basis has 0 units on x axis and 1 unit on y axis.

Different basis can be defined in linear systems such as:

$$custom\,basis = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$$

In such a custom basis, first basis vector is $\begin{bmatrix} 1 \\ 3 \end{bmatrix}$, which means first basis has 1 unit on x axis and 3 units on y axis. Second basis vector is $\begin{bmatrix} 2 \\ 4 \end{bmatrix}$, which means second basis has 2 units on x axis and 4 unit on y axis.

Movement: With a vector $\begin{bmatrix} 3 \\ 5 \end{bmatrix}$, hunter will move 3 times of the first basis vector and 5 times the second basis vector. You get the movement in x and y axis by multiplying basis matrix and the movement vector.

$$new coordinates = basis matrix * movement vector + previous coordinates$$

$$\begin{bmatrix} 13 \\ 29 \end{bmatrix} = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} * \begin{bmatrix} 3 \\ 5 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix}$$

Rotation: Rotation changes the basis by rotating the basis in the Cartesian coordinate system. You get the rotated basis by multiplying the previous basis by rotation matrix

$$rotated basis = previous basis * rotation matrix$$

$$\begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} * \begin{bmatrix} \cos 90 & -\sin 90 \\ \sin 90 & \cos 90 \end{bmatrix}$$

Hint: Check out the rotation matrix

Instructions

You should implement following instructions as functions.

Treasure hunter starts at coordinates (0,0) with standard basis.

Move: Move instruction is denoted by the letter 'm'. This instruction gets 2 integers after the character 'm', that creates a vector. The vector shows treasure hunter to where to move respect to current basis vectors.

$$m \;\; 1 \;\; 3 \rightarrow move \begin{bmatrix} 1 \\ 3 \end{bmatrix}$$

Change basis: Change basis instruction is denoted by the letter 'c'. This instruction gets 4 integers after the character 'c', that creates a matrix. Each column of the matrix becomes a new basis vector.

$$c \;\; 1 \;\; -1 \;\; 1 \;\; 1 \rightarrow change\,basis \begin{bmatrix} 1 & -1 \\ 1 & 1 \end{bmatrix}$$

Rotate: Rotate instruction is denoted by the letter 'r' or 'l'(L). These instructions gets 1 integer[0,180] after any of the characters 'r' or 'l', that is the rotation angle in degrees. 'r' instruction rotates current basis vectors to the right with the given angle. 'l' instruction rotates current basis

vectors to the left with the given angle. You can use sin and cos functions provided in mathematics library for C programming language. Note that these functions work in radians.

$$r \quad 30 \rightarrow rotateright\ 30\ degree$$
$$l \quad 30 \rightarrow rotateleft\ 30\ degree$$

Dig: Dig instruction is denote by the letter 'd'. This instruction means the treasure hunter is at the coordinate of the treasure. Treasure hunter digs the treasure and sends the coordinations to base by printing on screen. Program should print the console the coordinates of the treasure and terminates.

Important: Please note that this is an assignment to practice matrix and vector operations in C. Therefore, points should be represented by vectors(arrays) and basis should be represented by matrices.

GRADING

Compiling: Your code should be able to compiled using gcc on ssh.itu.edu.tr without any errors or warning. Your code will be compiled with the following line while grading.

gcc homework4.c -lm -o homework4

Your code will be run as following line while grading.

./homework4

Run Time: In the run time, user will enter command and parameters. As an example, following line can be entered to test your code.

m 1 3 c 1 -1 1 1 m 2 2 r 30 m -1 4 l 60 m 1 5 d

We assume the entered commands and parameters are always in correct format. For example there always will be two integers after 'm', four integers after 'c', one integer after 'r' or 'l'. Entered angle will be in degree format and it will always be between 0-180 deg. [0,180]

Please check **illustration.pdf** to have a further understanding about the homework.

Output: When the 'd' command is entered, program terminates after printing coordinates with 2 precision after the floating point.

Coordinates: -8.29 15.29

Important:

- Do not print something else
- Your code should print “Coordinates: “ and print the coordinates nothing else

Termination: Your code should terminate after it prints the coordinates. Successful functions returns with 0. Do not forget to return 0 if your code worked as it should.

Example Compilation and Run:

```
airlab@mia:~/Cihan/BIL-105E/Homework4$ gcc homework4.c -lm -o homework4
airlab@mia:~/Cihan/BIL-105E/Homework4$ ./homework4
m 1 3 c 1 -1 1 1 m 2 2 r 30 m -1 4 l 60 m 1 5 d
Coordinates: -8.29 15.29
airlab@mia:~/Cihan/BIL-105E/Homework4$
```

Evaluation Criterion:

- Compiling and linking with gcc
- Clear and efficient code
- Move operation
- Change basis operation
- Rotate operation
- Clean run and correct output in requested format

All the assignments are considered individual assignments and you are expected to do it by yourself. Any form of plagiarism, even partial, will not be tolerated. It is subject to serious disciplinary actions. Note that professionals help in any form or shape is considered as an act of plagiarism.