University of Glasgow | School of Computing Science

CSC1103 Laboratory/Tutorial 10: File Operations and Matrices

1. Matrix operation is a powerful tool in solving different type of engineering and computer science problem statement. Given two input matrix $\mathbf{A}$ and $\mathbf{B}$ as followed, we can obtain another third matrix $\mathbf{C}$ with the following matrix addition operation

$$\mathbf{C} = \mathbf{A} + \mathbf{B}$$

The elements of matrix $\mathbf{C}$ are obtained as follows:

$c_{ij=}\, a_{ij} + b_{ij}$ for all i, j . For example,

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \end{bmatrix}, \mathbf{B} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} a_{11} + b_{11} & a_{12} + b_{12} & a_{13} + b_{13} & a_{14} + b_{14} \\ a_{21} + b_{21} & a_{22} + b_{22} & a_{23} + b_{23} & a_{24} + b_{24} \\ a_{31} + b_{31} & a_{32} + b_{32} & a_{33} + b_{33} & a_{34} + b_{34} \end{bmatrix}$$

For subtraction operation

$$\mathbf{C} = \mathbf{A} - \mathbf{B}$$

The elements of matrix $\mathbf{C}$ are obtained as follows:

$c_{ij=}\, a_{ij} - b_{ij}$ for all i, j where

$$\mathbf{C} = \begin{bmatrix} a_{11} - b_{11} & a_{12} - b_{12} & a_{13} - b_{13} & a_{14} - b_{14} \\ a_{21} - b_{21} & a_{22} - b_{22} & a_{23} - b_{23} & a_{24} - b_{24} \\ a_{31} - b_{31} & a_{32} - b_{32} & a_{33} - b_{33} & a_{34} - b_{34} \end{bmatrix}$$

For multiplication operation

$$\mathbf{C} = \mathbf{A}.\mathbf{B}$$

assuming

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \end{bmatrix}, \quad \mathbf{B} = \begin{bmatrix} b_{11} & b_{12} & b_{13} & b_{14} \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}$$

The elements of matrix $\mathbf{C}$ are obtained as follows:

$c_{ij=}\, \sum_{k=1}^{P} a_{ik}\, b_{kj} = a_{i1}b_{1j} + a_{i2}b_{2j} + \cdots a_{iP}b_{Pj}$ where

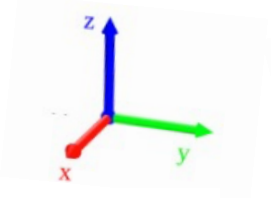
$$\mathbf{C} = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} + a_{13}b_{31} + a_{14}b_{41} & a_{11}b_{12} + a_{12}b_{22} + a_{13}b_{32} + a_{14}b_{42} & a_{11}b_{13} + a_{12}b_{23} + a_{13}b_{33} + a_{14}b_{43} & a_{11}b_{14} + a_{12}b_{24} + a_{13}b_{34} + a_{14}b_{44} \\ a_{21}b_{11} + a_{22}b_{21} + a_{23}b_{31} + a_{24}b_{41} & a_{21}b_{12} + a_{22}b_{22} + a_{23}b_{32} + a_{24}b_{42} & a_{21}b_{13} + a_{22}b_{23} + a_{23}b_{33} + a_{24}b_{43} & a_{21}b_{14} + a_{22}b_{24} + a_{23}b_{34} + a_{24}b_{44} \\ a_{31}b_{11} + a_{32}b_{21} + a_{33}b_{31} + a_{34}b_{41} & a_{31}b_{12} + a_{32}b_{22} + a_{33}b_{32} + a_{34}b_{42} & a_{31}b_{13} + a_{32}b_{23} + a_{33}b_{33} + a_{34}b_{43} & a_{31}b_{14} + a_{32}b_{24} + a_{33}b_{34} + a_{34}b_{44} \end{bmatrix}$$

Design the algorithm and pseudocode using function and pointers variable to perform following tasks.

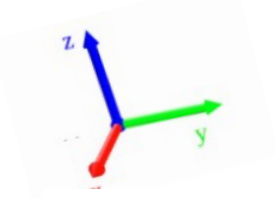
- create a main program that call three other programs that perform the following
  - a program that contain a function that read matrix
  - a program that contain a function that print matrix
  - a program that do following a function that performs matrix operation
    - add two matrix;
    - subtract two matrix; and
    - multiply two matrix
- use a header file to link all the four programs including main program together

Hence, write C programs for the above pseudocode.

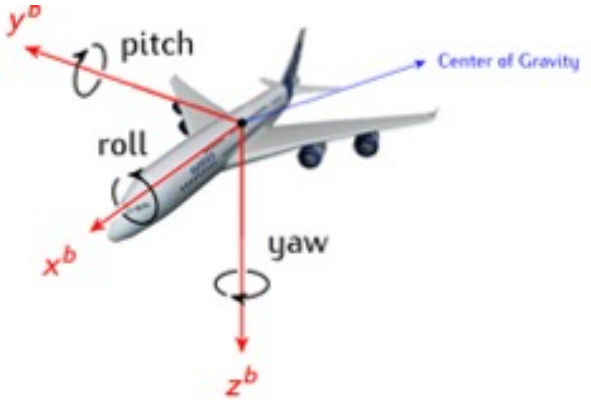
2. A operation that is frequently performed in the real world is the transformation of a vector $\mathbf{F}$ in the 3D space $x - y - z$ coordinate system to a new vector $\mathbf{F}'$ in a different coordinate system such as $x' - y' - z'$ or vice versa as shown below. The application of such operation is found in all rigid body frame where the coordinate system is local to their body frame and need to map to the world coordinate system such as in a IoT system such as car/plane inertial navigation measurement (IMU) system.



Global navigation coordinates $\mathbf{F}$



body frame coordinates $\mathbf{F}'$



The vector matrix equations that describe such operation is

$$\mathbf{F} = \mathbf{C}_{\mathbf{b}}^{\mathbf{N}}\mathbf{F}'$$

$$\begin{bmatrix} f_x \\ f_y \\ f_z \end{bmatrix} = \begin{bmatrix} cos\psi & -sin\psi & 0 \\ sin\psi & cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} cos\theta & 0 & sin\theta \\ 0 & 1 & 0 \\ -sin\theta & 0 & cos\theta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\phi & -sin\phi \\ 0 & sin\phi & cos\phi \end{bmatrix} \begin{bmatrix} f_x' \\ f_y' \\ f_z' \end{bmatrix}$$

where ψ, θ, ϕ represent the yaw, pitch and roll angles of the rotation about the body frame.

Design an algorithm and pseudocode to compute the above global coordinates using multidimensional array and pointer variable. Assume the program need to read in the rotation angle namely ψ, θ, ϕ and the body frame vector $\mathbf{F}'$. Hence implement in a C program.