EO 294: Systems for Machine Learning
## Indian Institute of Science, Bangalore
Assignment #1
Deadline: 29th January, 11:59 PM

(The numbers in the braces denote the points)
Please write the solution in latex. Put all your codes and the PDF into a zip file and submit. The zip file name should be <first_name>_<last_name>.zip. There should be no recursive zip file. The submitted code should be properly commented and the name of the variables should be intuitive. The code should be implemented by yourself. Marks will be deducted due to codes without comments, with non-intuitive variable names, with high similarity with web as well as your peers.

Problem 1: Consider a convolution operation with below parameters. The figure shows the description of the parameter.

$N = 8, C = 4, H = 32, W = 32, R = 5, S = 5, M = 32$
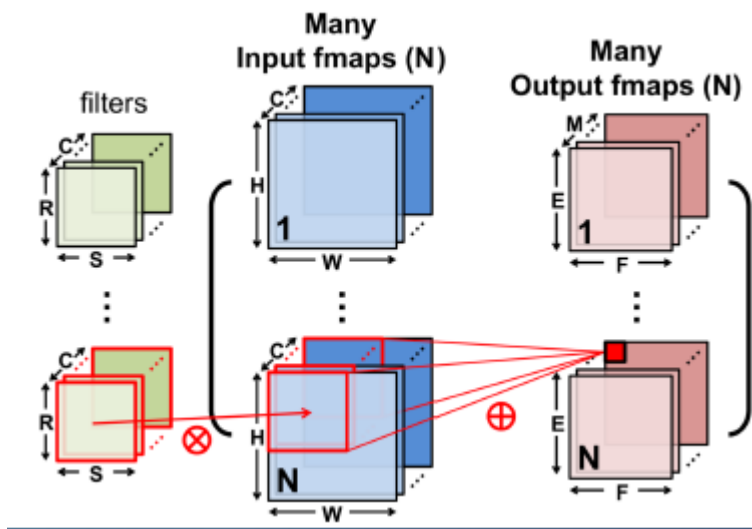
Draw a random number between 0 and 1, randomly choose positive/negative sign and assign to each weight value and input fmap value. Assume average pooling, zero padding and stride length of two.

a) Implement the 7-loop naïve implementation of convolution. **(5)**
b) Implement the convolution by flattening. **(5)**
c) Show that both cases produce equal output. **(5)**
d) Obtain and report number of instructions and execution time for both a) and b) using perf command. **(5)**
e) Analyze and comment on the above results. **(5)**

No library (even numpy and pandas) is allowed to use to perform the above exercises.

Problem 2: Given an input feature X whose dimension is [h=3, w=3, i=2]

$$X = \begin{bmatrix} -8 & 4 & 8 \\ -2 & -9 & -7 \\ 7 & -5 & 7 \end{bmatrix}, \begin{bmatrix} -7 & 6 & 7 \\ -9 & -3 & -8 \\ 1 & -3 & 0 \end{bmatrix}$$

Given a convolution weight whose dimension is [h=2,w=2, i=2, o=3]:

Woutchannel1 $= \begin{bmatrix} -8 & 1 \\ -2 & 3 \end{bmatrix}, \begin{bmatrix} -6 & -6 \\ 2 & 5 \end{bmatrix}$

Woutchannel2 $= \begin{bmatrix} -6 & 9 \\ -7 & 5 \end{bmatrix}, \begin{bmatrix} -4 & 7 \\ -1 & 0 \end{bmatrix}$

Woutchannel3 $= \begin{bmatrix} -2 & -3 \\ -2 & 1 \end{bmatrix}, \begin{bmatrix} -3 & -9 \\ 1 & 0 \end{bmatrix}$

Other 2D convolution parameters are {no zero padding, stride=1, average pooling}.

a) What is the dimension of Y = Conv2D(W, X), and what is the total number of elements in the output feature? **(13)**

b) Convert Y = Conv2D(W, X) into matrix multiplication Y ' = W ' × X' using the Toeplitz matrix generation technique introduced in the class. **(12)**

Work out the above example in text itself (i.e., not through coding).