University of Pennsylvania
Department of Electrical and System Engineering
Digital Signal Processing

ESE531, Spring 2019 HW8: DFT Sunday, Mar. 31

Due: Sunday, Apr 7, 11:59PM

- **Recommended Problems for Practice:** From the book: 7.35, 7.39, 8.14
- **Homework Problems:** All problems must be turned in and are not optional for full credit

1. Homework problems from the book: 7.34, 7.45, 8.23

   NOTE: The `flops` command mentioned below seems to be gone from the most recent release of Matlab. You can use any timing method including `clock, etime, tic, toc` to measure the execution time. Just pick one method to measure execution time. To approximate the number of flops, you can use the code available on the Mathworks website here: `https://www.mathworks.com/matlabcentral/fileexchange/50608-counting-the-floating-point-operations--flops-`

2. Matlab problem 1: Calculation of the DFT. In this problem you will measure the execution time and the number of floating point operations (flops) of a direct calculation of the DFT using three different organizations of the algorithm. The definition of the DFT is given by:

$$X[k] = \sum_{n=0}^{N-1} x[n] W_N^{nk} \tag{1}$$

   for

$$W_N = e^{-j2\pi/N} = cos(2\pi/N) - jsin(2\pi/N) \tag{2}$$

   and $k = 0, 1, ...N-1$.

   (a) Two-Loop Program. Write a program (M-file) or a function in MATLAB to evaluate the DFT given above using two nested `for` loops with the inner loop summing over n and the outer loop indexing over k. Time the program for several lengths using the `clock` and `etime` commands. Evaluate the number of flops required for several lengths. Compare the times and flops of your DFT program with the built-in MATLAB command `fft` for the same lengths. Comment on the results. Take into account that the `flops` command will count all arithmetic operations: exponential computation and index arithmetic as well as data arithmetic.

(b) One-Loop Program. Write a DFT program using one loops which steps through each value of k and executes an inner product. Time the program and evaluate the number of flops as was done in (a). Explain the results obtained.

(c) No-Loop Program. Write a DFT program using a single matrix multiplication. Write your own DFT matrix rather than using the built-in `dftmtx`. Use the `exp` command with the exponent formed by an outer product of a vector of `n = 0:(N-1)` and a vector of `k = 0:(N-1)`. Time and evaluate the flops as you did for the previous programs.

(d) Comment on the differences and on the comparisons of the three implementations. How many flops are used in generating the complex exponentials?