Indian Institute of Space Science and Technology
AV336 - Digital Signal Processing Lab
Department of Avionics

Labsheet 4

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1. Review the following from the textbook (Lee & Varaiya)
   (a) discrete Fourier transform (DFT) of a discrete time signal $x[n]$
   (b) the inverse DFT

2. Using the internet
   (a) https://en.wikipedia.org/wiki/Fast_Fourier_transform,
   (b) http://www.dspguide.com/ch12/2.htm,

   or using the textbook by Oppenheim and Schafer, study what fast Fourier transform (FFT) is. Then using Matlab's documentation (or internet resources) study what the following inbuilt Matlab functions do. Pay attention to the inputs and outputs of these functions

   (a) dftmtx
   (b) fft
   (c) ifft
   (d) fftshift

3. Implementation of DFT and IDFT.
   (a) Write a Matlab function named "mydft1" that computes the N-point DFT of a discrete time signal $x[n]$ where $n \in \{0, 1, \ldots, N-1\}$.
      i. The input $x[n]$ is assumed to extend from 0 to $N-1$ and can be a Matlab vector, and
      ii. the function should implement DFT using loops, and
      iii. the function should return the N-point DFT as another Matlab vector.
   (b) Write a Matlab function named "myidft1" that computes the N-point IDFT of a DFT $X[k]$ where $k \in \{0, 1, \ldots, N-1\}$.
      i. The input $X[k]$ is assumed to extend from 0 to $N-1$ and can be a Matlab vector, and
      ii. the function should implement IDFT using loops, and
      iii. the function should return the N-point signal $x[n]$ as another Matlab vector.
   (c) i. Using mydft1() compute the 16-point DFT of $x[n] = cos(2\pi(0.25)n)$ for $n \in \{0, \ldots, 15\}$.
      ii. Test whether myidft1(mydft1($x[n]$)) $= x[n]$.
   (d) Write a Matlab function named "mydft2" that computes the N-point DFT of a discrete time signal $x[n]$ where $n \in \{0, 1, \ldots, N-1\}$.

   i. The input $x[n]$ is assumed to extend from 0 to $N-1$ and can be a Matlab vector, and
   ii. the function should implement DFT using dftmx,
   iii. the function should return the N-point DFT as another Matlab vector.

(e) Write a Matlab function named "myidft2" that computes the N-point IDFT of a DFT $X[k]$ where $k \in \{0, 1, \ldots, N-1\}$.
   i. The input $X[k]$ is assumed to extend from 0 to $N-1$ and can be a Matlab vector, and
   ii. the function should implement IDFT using dftmx, and
   iii. the function should return the N-point signal $x[n]$ as another Matlab vector.

(f) i. Using mydft2() compute the 16-point DFT of $x[n] = cos(2\pi(0.25)n)$ for $n \in \{0, \ldots, 15\}$.
   ii. Test whether myidft2(mydft2($x[n]$)) = $x[n]$.

4. Let $x[n] = cos(2\pi(0.25)n)$ for $n \in \{0, \ldots, 15\}$.
   (a) Compute the 16-point DFT of $x[n]$ using fft
   (b) Assuming that $x[n]$ was obtained by sampling at a rate of 1 Hz, plot the DFT (magnitude and phase separately) with the frequency axis in the range $[0, 2\pi]$
   (c) Assuming that $x[n]$ was obtained by sampling at a rate of 1 Hz, plot the DFT (magnitude and phase separately) with the frequency axis in the range $[-\pi, \pi]$. Use the fftshift function for this task.
   (d) Check if ifft(fft($x[n]$)) is $x[n]$.

5. Suppose we have two signals defined as follows:

$$
\begin{aligned}
x[n] &= \begin{cases} (0,1,2,3,4) \text{ for } n \in \{0,1,2,3,4\}\,, & \text{and,} \\ 0 \text{ otherwise} \end{cases} \\
h[n] &= \begin{cases} (1,1,1,1,1) \text{ for } n \in \{0,1,2,3,4\}\,, & \text{and,} \\ 0 \text{ otherwise} \end{cases}
\end{aligned}
$$

   (a) Calculate the circular convolution of $x[n]$ and $h[n]$ manually.
   (b) Using Matlab array operations or vector operations compute the circular convolution of $x[n]$ and $h[n]$
   (c) Using Matlab documentation study what the inbuilt function circshift does. Compute the circular convolution of $x[n]$ and $h[n]$ using circshift. Compare with the result obtained above.
   (d) Using Matlab documentation study what the inbuilt function cconv does. Compute the circular convolution of $x[n]$ and $h[n]$ using cconv. Compare with the results obtained above.
   (e) Using fft and ifft compute the circular convolution of $x[n]$ and $h[n]$ and verify with the results obtained above

6. Suppose we have two signals defined as follows:

$$x[n] = \begin{cases} (0,1,2,3,4) \text{ for } n \in \{0,1,2,3,4\}, \text{ and,} \\ 0 \text{ otherwise} \end{cases}$$

$$h[n] = \begin{cases} (4,5,3) \text{ for } n \in \{0,1,2\}, \text{ and,} \\ 0 \text{ otherwise} \end{cases}$$

   (a) Calculate the linear convolution of $x[n]$ and $h[n]$ manually.

   (b) Using fft and ifft compute the linear convolution of $x[n]$ and $h[n]$ and verify with the result obtained above

7. Suppose we have a periodic signal $x[n]$ with period 5 defined as follows:

$$x[n] = (0,1,2,3,4) \text{ for } n \in \{0,1,2,3,4\}.$$

   Also let $h[n]$ be defined as

$$h[n] = \begin{cases} (3,2,1) \text{ for } n \in \{0,1,2\}, \text{ and,} \\ 0 \text{ otherwise} \end{cases}$$

   Let $y[n]$ be $x[n]$ considered for 5 periods, i.e., $y[n] = x[n]$ for $n \in \{0, \ldots, 24\}$. Also let $y[n] = 0$ for all other n.

   (a) Compute the linear convolution of $y[n]$ with $h[n]$ in time domain.

   (b) Compute the linear convolution of $y[n]$ with $h[n]$ using fft and ifft. Compare your result with that obtained above.

   (c) Review the overlap and add method taught in class from your class notes. Compute the linear convolution of $y[n]$ with $h[n]$ using overlap and add method. Choose at least 3 segments for the $y[n]$ signal. Check whether the linear convolution that you obtain matches with the results above.