Istanbul Technical University

Computer Engineering BLG 354E

Signals & Systems for Computer Engineering, Homework 2

Prepared by: Dr. Yusuf H. Şahin – Arş. Gör. Aycan Şahin

E-mail: sahinay21@itu.edu.tr

Deadline: 14.05.2025

Question 1 (30 pts)

You are given a mixed_q1.wav audio file that contains two overlapping sounds: a musical instrument tone (e.g., flute or saxophone, 600–900 Hz, Sampling rate: 44100) and a band-limited human voice (100–250 Hz and Sampling rate: 44100). These two components occupy different frequency ranges.

Your goal is to:

- Apply a frequency-based method (e.g., Fourier Transform + bandpass filtering) to separate the components.
- Save the separated instrument and voice as two individuals .wav files using libraries like *scipy.io.wavfile* or *pydub*.
- Plot and compare their frequency spectra.

Question 2 (30 pts)

Using the two audio files you obtained in Question 1 - one for the separated musical instrument tone and one for the separated band-limited human voice tone - your task is to:

- Combine these two .wav files into a single audio file by overlaying them (You may need normalization).
- Plot and compare the frequency spectrum of the **reconstructed audio** with that of the **original mixed audio** from Question 1.

- Discuss whether the reconstruction successfully matches the original signal in terms of frequency content and overall waveform.

Question 3 (40 pts)

The **Discrete Fourier Transform (DFT)** converts a sequence of time-domain samples into its frequency-domain representation. For a sequence x[n] of length N, the DFT is defined as:

$$X[k] = \sum_{n=0}^{N-1} x[n] e^{-j\left(\frac{2\pi}{N}\right)kn}, \qquad k = 0, 1, \dots, N-1$$

Here,

- N is the number of DFT points (e.g., 4 or 8),
- x[n] is the time-domain sample at index n,
- X[k] is the frequency-domain output at index k,
- j is the imaginary unit.

You are given a dataset of audio signals consisting of three waveform types: sine, square, and triangle and a **representative prototype file** for each type is provided (e.g., sine.wav, square.wav, triangle.wav, Sampling rate: 44100). Without using any machine learning techniques, perform a classification task using Discrete Fourier Transform (DFT).

Task:

- Use 4-point and 8-point DFT to extract features from each signal. Based on these features, determine which signal corresponds to which waveform type. Explain your approach and reasoning.

Justify your answer based on your observations from the DFT results.