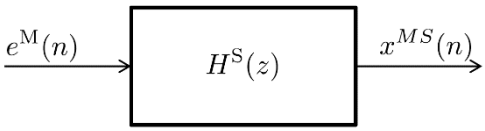
DAAP Homework #1

Talking Instrument



For this homework assignment, you will be exploring the topic of Linear Predictive Coding (LPC) and implementing a *Talking Instrument* using LPC-based cross-synthesis. You will be provided with a test speech signal (`speech.wav`), a monophonic piano track (`piano.wav`), and an exemplary processed clip for reference (`expected_result.wav`). Please note that the reference file is only for illustrative purposes and should not be used in carrying out the homework.

Your task is to perform short-time LPC analysis on both speech and music signals and feed the residual error signal of each music segment to the all-pole filter computed from every speech segment (see Figure.) This way, the "excitation" pertaining to the music signal (which contains pitch information) will be "shaped" by the time-varying resonant peaks characterizing the speech production mechanism (e.g., the formants.) Keep in mind that music and speech prediction filters may have different orders, resulting in a different number of taps. Furthermore, the short time analysis of speech and music may have different temporal resolutions. Please be prepared to explain your choices. Done, explain choices and implementation in report No different order/resolution

You must solve LPC using a Wiener filtering approach. First, you will compute the closed-form solution of the Wiener-Hopf equations (see slide sets 03 and 05.) Second, you will implement the *steepest descent* iterative method (see slide set 04.) In doing so, you must check and report on the stability of the algorithm. Please provide a comparison between the two methods from both a theoretical and practical standpoint. Implemented, still not checked the stability, still no comparison

Going forward, you must apply the whitening and shaping filters thus obtained in the frequency domain (see slide set 01) rather than using direct convolution or time-domain filtering. Since the entire process is carried out in a frame-by-frame fashion, the output signal should be computed via the overlap-and-add (OLA) algorithm; ensure that the COLA condition is met and combat time-domain aliasing with proper means. Done, explain choices and implementation in report

Finally, save the cross-synthesis result to a WAV file. Done

While there is no specific programming language required for this assignment, we strongly recommend using either MATLAB or Python (NumPy.) Please note that this homework assignment is designed for didactic purposes, so you should refrain from using built-in functions or library methods that carry out high-level operations. Examples of functions to be avoided include, e.g., MATLAB's `lpc(x,p)` and many `scipy.signal` methods. As a rule of thumb, if a method provides functionalities that go way beyond basic statistical operations, linear algebra, or time-frequency transforms it is likely to be avoided. Nevertheless, you are encouraged to use high-level built-in functions and external libraries as debugging tools to check whether various parts of your implementation are working correctly.

Lastly, you are expected to explain and justify all your design choices and refer to the course materials if necessary.

Assignment rules:

- Groups of **at most 2 people** are allowed.
- Each group should upload the code on WeBeep as a **single zip file.** One student will submit a zip file for the entire group; **do not upload the same HW twice.**
- The zip file should be named with the surnames of all group members, e.g., Mario Rossi and Maria Bianchi will upload a file named `DAAP_HW1_Rossi_Bianchi.zip`
- Please **include the synthesized audio file** in the zip folder, e.g., `Rossi_Bianchi_result.wav`.
- Shortly after the submission, you will discuss your implementation during a **short oral presentation** (about 10 minutes.)
- A bonus of **3/30** is awarded to those groups who upload the HW on WeBeep **by 11:59 pm on March 31st, 2023.**
- Only the groups that have already submitted their code are entitled to discuss the HW with the instructor.
- Oral presentations will be held either in presence or via Webex. The modality will be agreed upon on a case-by-case basis.
- Refer to the course rules and the most updated grading scheme for subsequent deadlines to avoid late-submission penalties.