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Digital Signal Theory 2

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<p style="text-align:center">Report on Final Project</p>

This project aims to simulate the impulse response of a box-shaped room using the image-source method and obtain the binaural reproduction of a sound source in the room. Custom-made hardware built with an Arduino board and an inertial measurement unit (IMU) is utilized to track head orientation and control the direction of arrival of a sound source by applying head-related transfer functions (HRTF).

The image-source method is a geometric solution to simulate room impulse response (RIR). Let the sound source and the receiver be in a room. The sound waves propagate in the air and reflects over surfaces of the room, projecting images with opposite directions. The accumulated images shape the impulses response of the room. The contribution of each image can be estimated by computing the direction, distance, and the filtering effect due to the absorption of sound energy by the walls. The detailed walkthrough of the algorithm can be found in ".\references\RoomImpulseResponseImageSourceExample". The project adapts the algorithm to accommodate binaural audio rendering with head tracking using external hardware.

The hardware is made of an Arduino Uno Rev3 board and an Invensense MPU-9250 sensor which contains the following units: gyroscope, accelerometer, and magnetometer. In this application, a digital filter is used to fuse raw data from the gyroscope and accelerometer units,

converting them into yaw-pitch-roll values. The desired position of the sound source over the receiver is obtained by the yaw and pitch data, also known as azimuth and elevation. Next, the desired position will be matched with the HRTF dataset to find the impulse response at the position. Finally, the audio signal is filtered with the HRTF impulse response to achieve binaural reproduction.

In the event that the user does not have the appropriate hardware connection, a simulation of head movement can be selected to substitute the Arduino board. Detailed walk-through is explained in "JerryXu_FinalProject.mlx". Referencing articles and MATLAB documents are included in the folder "references".