Bilkent University

EEE321-02 Lab 2 Report

Atalay Üstündağ

22203554

Purpose of the Experiment:

The main objective of this experiment is to utilize the impulse response of an LTI system to determine its output. Since both MATLAB and the recording device sample the continuous sound signal and store it as a discrete signal, the convolution process will be represented in discrete form. Even though the system is not fully time-invariant, because of the Odeon environment, we neglect the environmental effects and assume that the system is time-invariant. The discrete impulse response for continuous-time invariant systems can be determined using the following formula in the Equation 1.

$$y[n] = h[n] * x[n] = \sum_{k=-\infty}^{\infty} h[k] \cdot x[n-k]$$

Equation 1

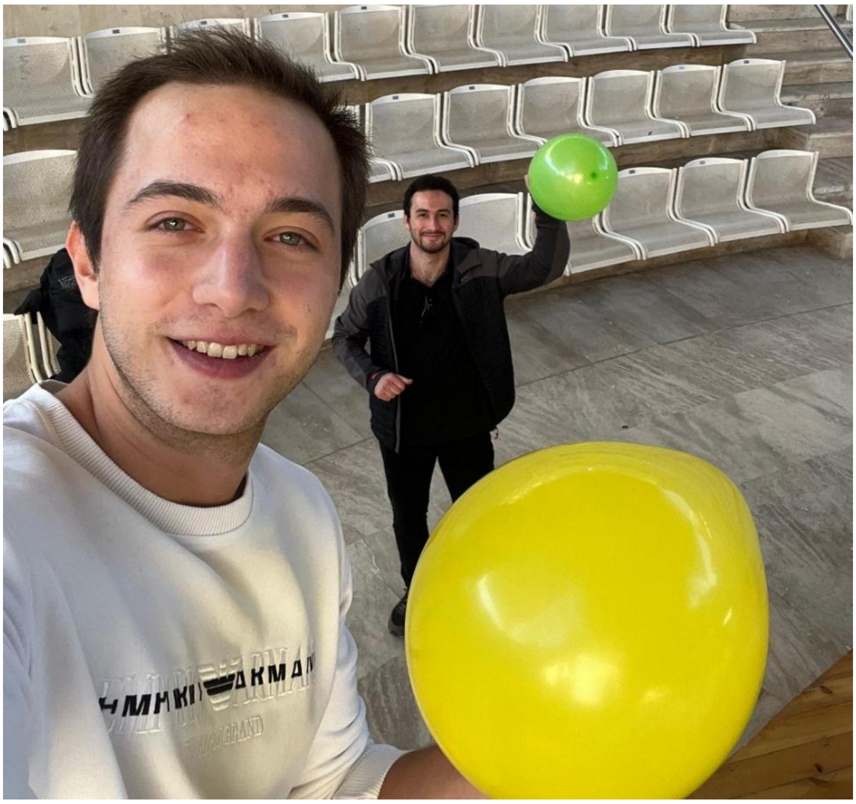
By blowing up the balloon, we simulate an impulse response. By recording it from a high place in Odeon with our phones, we record the impulse response. The music record (mozart_vl1_6) which is an anechoic signal is the input in our LTI system, when it is convolved with the impulse response signal, we get the output signal [1]. Below the summary is given:

1. x[n] = Input Signal = Anechoic Music Record of Mozart (mozart_vl1_6).

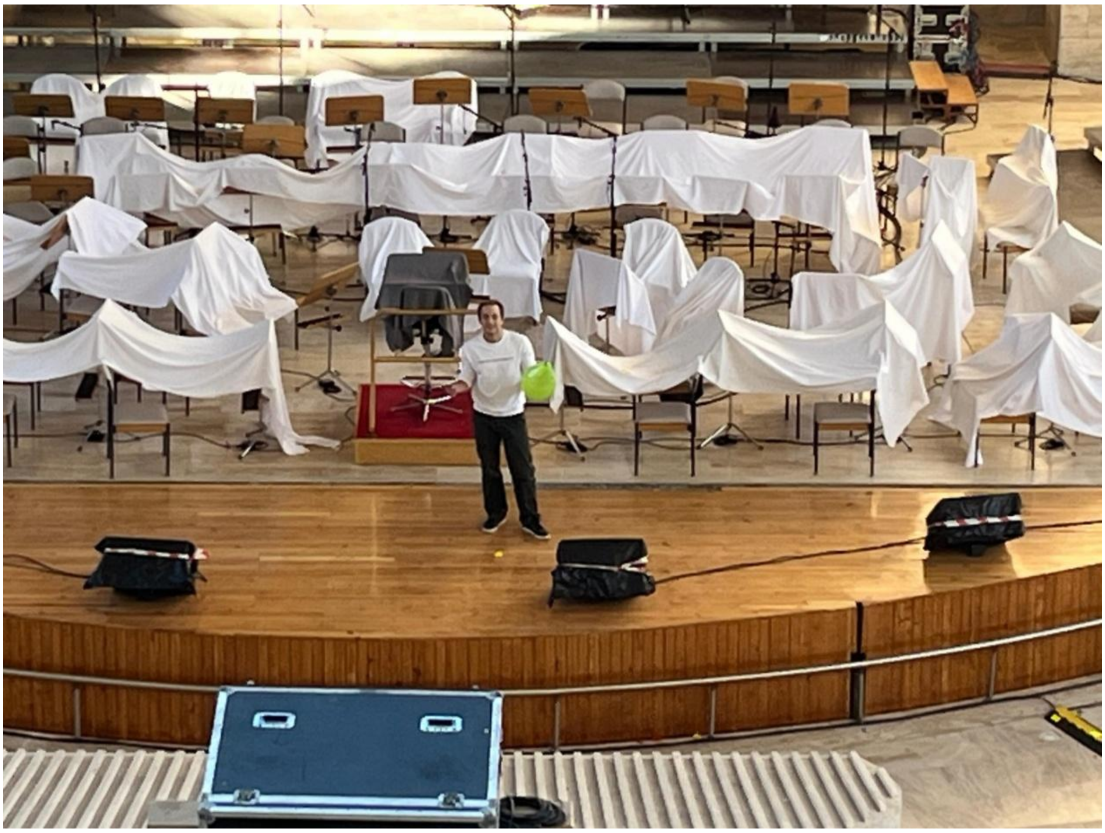
2. h[n] = Impulse Response = The Voice of the Balloon Blowing Up.

3. y[n] = Output Signal = The Result of the Convolution of x[n] and y[n] in other words the music we can hear on the Odeon.

In Figure 1, me and my friend Batuhan Yeşilbağ can be seen. Firstly, he went to a higher a place and took my photo before I blow up the balloon. You can see the photo in the Figure 2. Afterwards, I blown up the balloon and Batuhan recorded the sound of the impulse response.



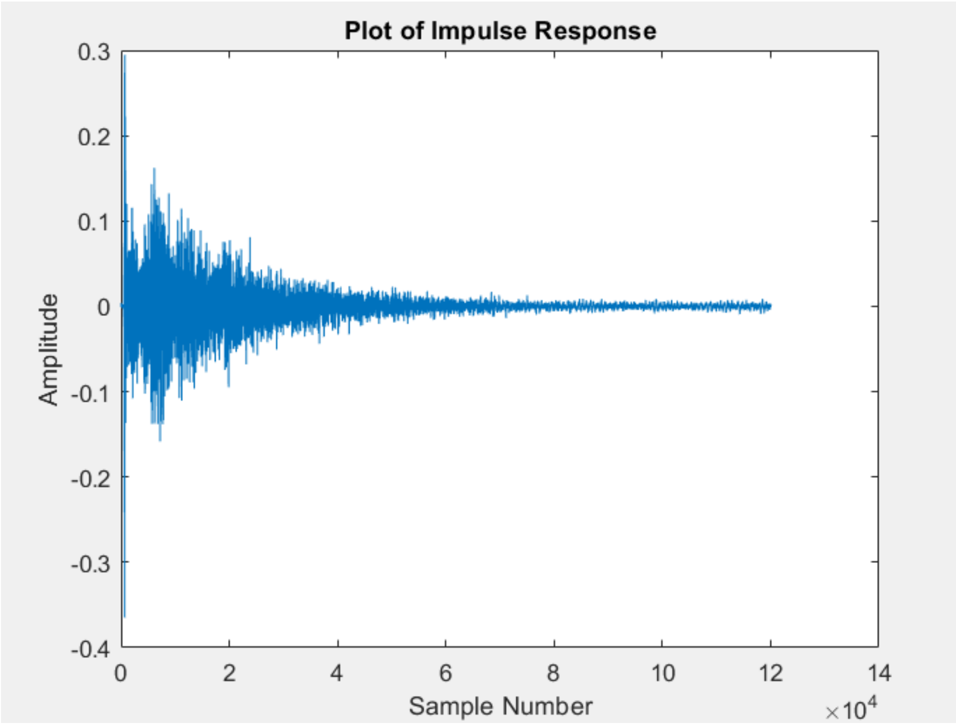
[Figure1: The Photo of Me and My Friend Batuhan]



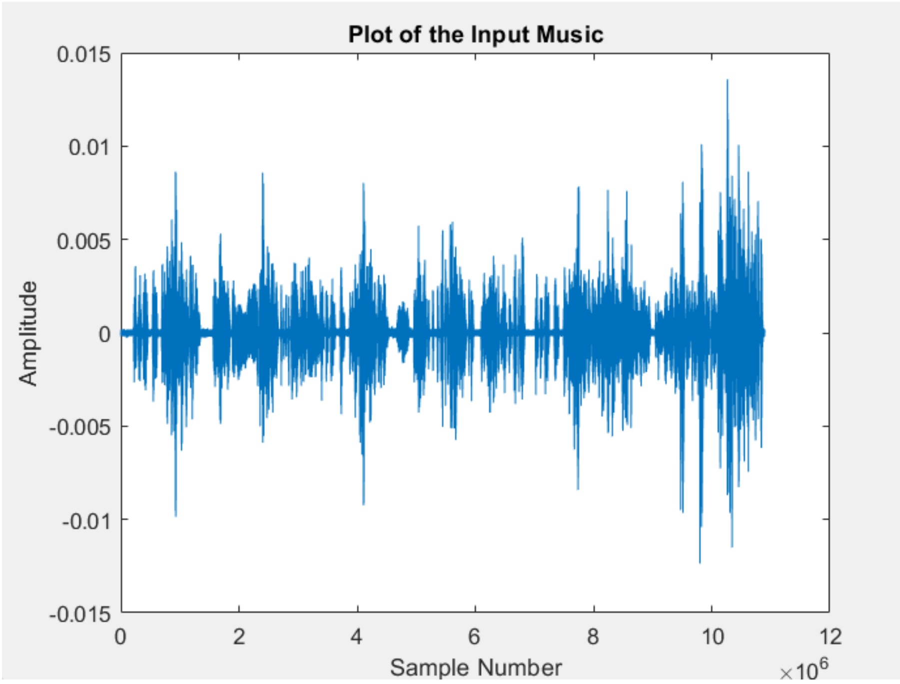
[Figure 2: Photo of me Before I Blow It]

Analysis:

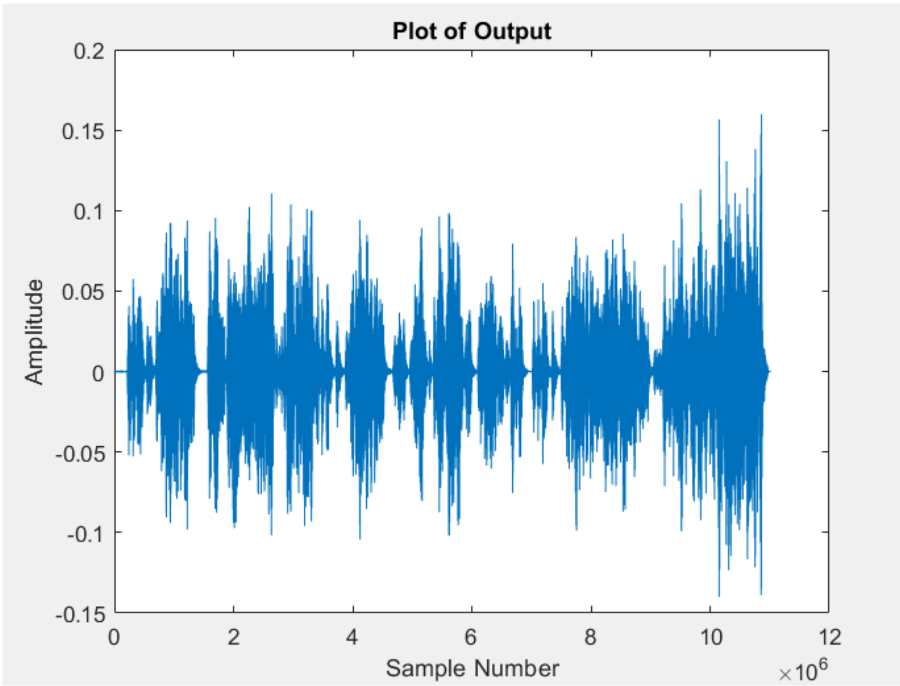
MATLAB was used to perform the whole analysis after the sound was captured at the Odeon. An anechoic recording of mozart_vl1_6 serves as the input sound [1]. MATLAB was used to process the anechoic sound, which was the input signal, and the sound of the balloon burst, which indicated the impulse response of the system. The balloon's sound recording was sampled at the point of blowing in order to guarantee the causality of the system. Since $h[n] = 0$ for $n<0$. Then the convolution is done with the impulse response and the input music signal, then we get the output signal. Figure3, Figure 4 and Figure 5 shows the corresponding signals' plots. The result of the experiment was satisfactory since the output signal was very close to the input music signal.



[Figure 3: Plot of the Impulse Response]



[Figure 4: Plot of the Input Music]



[Figure 5: Plot of the Output Signal]

COMMENTS:

1) Comment About Quality of Impulse:

In this experiment, bursting a balloon to produce an impulse response provides a useful and efficient method of imitating an ideal impulse signal. An impulse's transient energy release is well captured by the rapid, high-pressure air release produced by a balloon burst. By ensuring that the impulse signal is strong and brief, this technique reduces any unwanted secondary sounds or residual noise that can skew the response's quality. However, phone microphones might introduce slight distortions or background noise, which could impact the clarity and precision of the impulse response. The Odeon environment introduces reflections, reverberation, and ambient noise that might affect the time-invariance of the impulse response. These effects can cause minor deviations, but as stated, assuming the system is time-invariant simplifies the process.

2) Comment About Nature About The Impulse Response

The balloon burst in this experiment produced an impulsive response, which provides a useful illustration of how sound energy acts in the Odeon's surroundings. We can see how the hall's material and architectural features impact sound reflections and reverberations by using the burst to create a sharp, wide-frequency impulse that spreads throughout the room. This response provides information on the venue's acoustics by capturing how spatial design and surfaces like the walls, ceiling, and seats shape and alter the original sound. Every element of the Odeon's construction and composition makes a distinct contribution to the impulse reaction. For example, surfaces' curvature and placement affect reverberation times and reflection pathways, while materials like wooden flooring and cloth chairs have the ability to either reflect or absorb sound frequencies. Environmental elements like temperature, humidity, and air density also affect how sound waves travel, somewhat changing the rate at which reflections in a space fade.

3) Comment About Validity of The LTI System Assumption of The Acoustic Environment

The Odeon must react consistently to the same inputs in all circumstances, independent of time or environmental changes, in order to be regarded as a true LTI (Linear Time-Invariant) system. However, a number of variables, like crowd size, humidity, air temperature, and background noise, affect the Odeon's acoustic qualities. The Odeon does not fully satisfy the time-invariance criteria because of these characteristics, which marginally change sound propagation and reflection. However, for the sake of this experiment, such differences are taken to be negligible and can be ignored, so we can concentrate on the architectural elements that have a greater influence on the impulse response. Since air is a nearly perfect medium for sound waves of standard amplitude, the system's response can be roughly described as linear in terms of linearity. The superposition concept is valid within these bounds, allowing the convolution process to efficiently describe responses. Linearity would break down at high amplitudes, such as those present in shock waves, because variations in pressure might alter the speed of sound and distort wave interactions. The air's reaction, however, stays sufficiently linear at typical sound levels to permit the use of convolution.

4) Comment About Distortions and Their Reasons

Certain distortions in this experiment may have an impact on the impulse response's accuracy and, in turn, the final outcomes. Sound waves from an impulse (like a balloon rupture) will bounce off several surfaces in a vast area like the Odeon, producing overlapping echoes. It can be challenging to distinguish the direct sound path from reflected paths due to these overlapping reflections, especially if they are not equally distributed, as they might produce distortions by merging early reflections with later ones. Also, phone mics are not as sensitive as professional audio equipment. They might not precisely record all of the impulse's frequencies, especially at the high and low ends of the spectrum. This could lead to an irregular or constrained frequency response, which could skew the actual impulse.

5) Comment About Noise During Recording and Its Effects

The quality and precision of the impulse response in this experiment can be greatly impacted by recording noise. It becomes more difficult to separate the actual impulse response from noise, which might be from equipment, the environment, or even faint handling noises. By introducing unnecessary sounds, noise obscures the impulse signal's clarity, making it difficult to discern between background noise and the impulse response. As a result, the portrayal of the space's reaction to the impulse is frequently less accurate.

REFERENCES:

[1]T. Lokki, “Anechoic recordings of symphonic music - Department of Media Technology,” research.cs.aalto.fi. https://research.cs.aalto.fi/acoustics/virtual-acoustics/research/acoustic-measurement-and-analysis/85-anechoic-recordings.html

APPENDIX:

```
[baloon_imp, Hz] = audioread('C:\Users\atato\Odeon.m4a');
%sound(baloon_imp, Hz);
baloon_imp = baloon_imp(8000:end);

figure;
plot(baloon_imp);
title('Plot of Impulse Response ');
xlabel('Sample Number');
ylabel('Amplitude');

[Music, Hz] = audioread('C:\Users\atato\mozart_vl1_6.mp3');
sound(Music, Hz);
%sound(LTIsystem, Fs);

figure;
plot(Music);
title('Plot of the Input Music');
xlabel('Sample Number');
ylabel('Amplitude');


final_result = conv(baloon_imp, Music);
save('final_result.mat', 'final_result');
load final_result.mat final_result
figure;
plot(final_result);
title('Plot of Output');
xlabel('Sample Number');
ylabel('Amplitude');
```