# Detecting Structural Deformation in Ear using Earables

MTP-I by Deepank Agrawal

Under Supervision of
Dr. Sandip Chakraborty

# Introduction

## Part 01

# Scope

## The Problem Domain



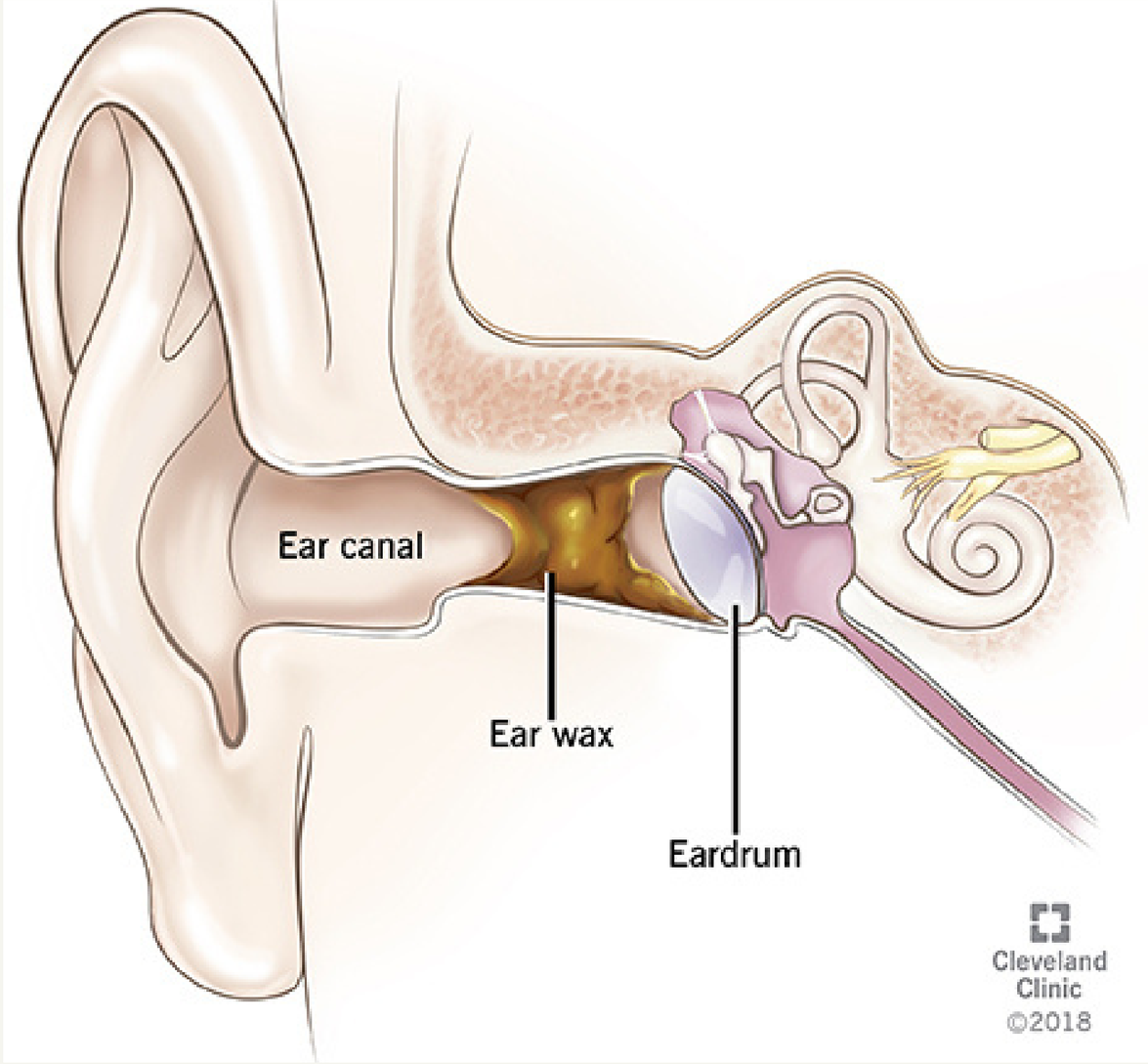
The swift development in the semiconductor industry and better algorithms have made earphones an indispensable device

Ear blockages are becoming increasingly common due to the increased amount of air pollution

Often, these infections cause structural deformation of the ear, which can be detected early

We consider this problem and base our solution approach on basic signal processing

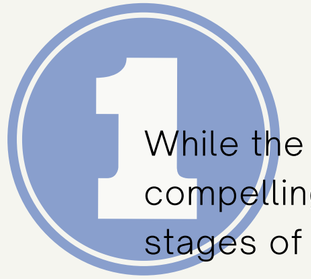
# Illustrative Ear Blockage




Source: https://my.clevelandclinic.org/health/diseases/14428-ear-wax-buildup–blockage

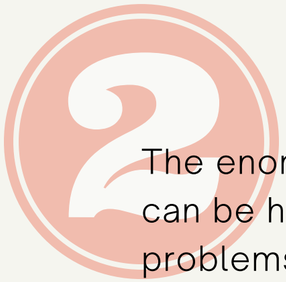
# Motivation

## Why Do This?

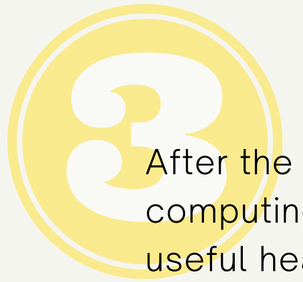


While the idea of earable smart computing is compelling and promising, it is still in the earlier stages of development





The enormous increase in computing power can be harnessed to solve a vast number of problems that can benefit from an earable device



After the enormous success of wearable computing via smart wristwatches that provide useful healthcare information of the body below the neck, earables may cater to healthcare information related to a person's head

# Objectives

## What we want to achieve

Provide early information about possible complications in ear canal

Release a smartphone application, which will analyze the structural changes in the ear canal over time and suggest the users consult an ENT specialist in case of severe deformations

We believe that a simple solution using basic signal processing techniques can be proposed

# Work Done Till Now

## Brief overview

1

Conducted an experiment to study one possible approach direction where we cross-correlate the received signal with the original signal

2

Performed this experiment for two different hollow objects. The actual experiment setup and steps are discussed later

3

Calculated the Structural Similarity Index (SSIM) for intra-class and inter-class comparisons

# Related Work

## Part 02

Decoding speech in low-SNR environment is a prominent issue since it is a complex problem in signal processing

AUTHORS SEE POTENTIAL OPPORTUNITIES IN SIGNAL PROCESSING

**Speech Recognition at Low SINR Regimes**

In recent years, there have been advancements in observing and recording the user's gaze direction by tracking head gestures

TWO IMUS ON EACH SIDE OF THE EARPHONE CAN TRACK NUMEROUS ASPECTS OF HUMAN MOTION

**Motion and Health Tracking**

Since human lungs produce a relatively minor vertical oscillation of the head as they inflate and deflate, recognizing breathing patterns is clearly challenging

BREATHING SOUNDS MIGHT BE PICKED UP BY IN-EAR MICROPHONES

**Breathe Capturing**

When a person eats, the mandible, or lower jaw, hinged at the back of the skull moves up and down. The teeth also make contact with each other, causing vibrations

---

THE IMU ADDS UP ALL OF THE SIGNALS AND DISPLAYS DIFFERENCES DEPENDING ON THE ACTIVITY'S TYPE AND LOCATION

**Eating Habit Tracking**

In the patent submission, the authors use the built-in microphone and speaker of cellphones to check for the presence of middle ear fluid

---

FINDINGS SHOW THAT A SMARTPHONE HAS THE CAPABILITIES TO BE A MINIMAL AND RELIABLE DIAGNOSTIC TOOL

**Otitis Media Diagnosis**

# The Problem Statement

## What we want to study

Structural Deformation of ear canal using a probe sound and analysis of reflected sound

## Specific Scenario

Initial experimentation done using hollow plastic objects

# Health Considerations

## Health Vulnerability

Acoustic experiments with high-frequency sound can damage human ear

## Initial Solution

Use the commonly available hollow objects to understand the effects of various parameters like length, shape, the diameter of an object on initially released probe sound

# Experiment

## Part 03

# Experiment and Results



Setup

Experiment

Results

# Experiment Setup

## Brief overview

1

Acoustic-based experiments are quite sensitive to noise in the surrounding, the acoustic reflectance of the object's material, and the probe sound

2

Due to resource constraints, we could not acquire a soundproofed room to serve as an optimal experimentation environment

3

Developed a simple Android 11 based application to perform the steps of the experiment with reasonable accuracy

# Hollow Objects


Object - ED

Object - Sip

# Hollow Objects

## Details



### Object - ED

A recyclable cylindrical object closed at one end with 35 cms depth

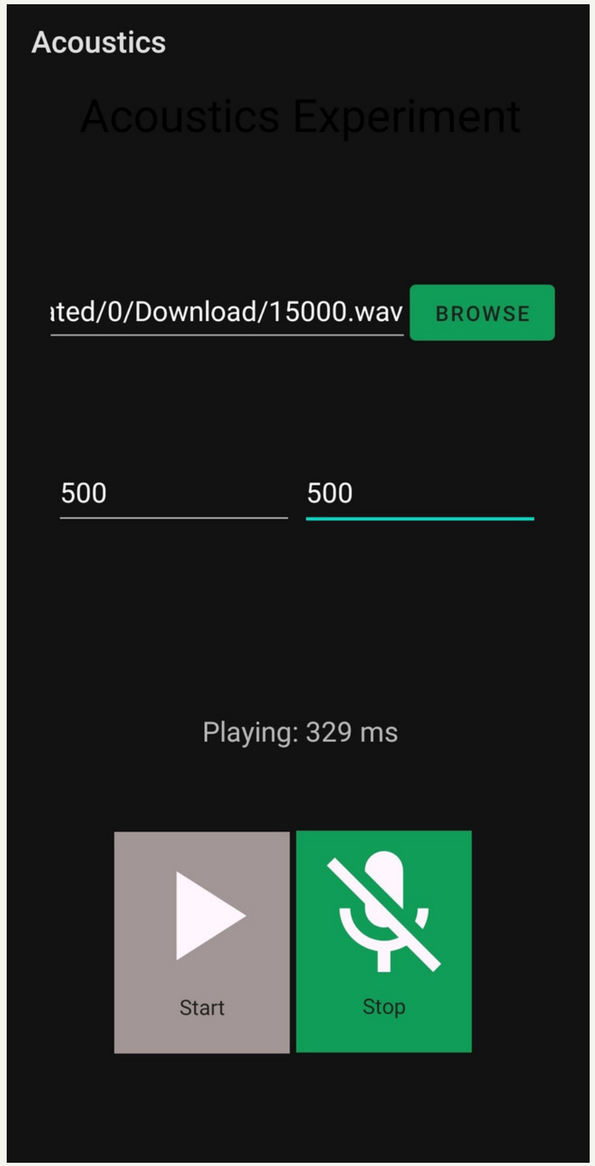
### Why Plastic?

Plastic has nearly same reflectance as a human ear canal. Unlike metal, there is no resonance effect in plastic

### Object - Sip

A commonly available cylindrical container closed at one end with 17 cms depth

# Android 11 App



# Android App

## Brief overview

1

App gives control over the various default raw audio processing algorithms employed by the built-in applications

2

The application is able to play a custom probe sound in .wav format for a configurable playing time and record the reflected sound for a configurable record time

3

Vital feature is that it supports accurate play-record repetition cycles and saves each recorded clip for analysis

# Cross-correlation

## Definition

### Physics Behind It

An acoustic signal on reflection, experiences phase change. When correlated with the original signal, this phase-delayed signal unravels the multi-paths



### Matlab Function

We use the xcorr function available in Matlab

# Experiment

## Details



### Steps

The smartphone is slightly (1-2 cms) inserted into the container, and a probe sound is played using the app. We then analyze the recorded sound using Matlab

### Cross-correlation

We believe that the multi-paths are unique for a container and can help in understanding the internal structure

### SSIM Index

Used for intra-class and inter-class comparisons

# Structural Similarity Index

## Definition

### Definition

It is a perceptual metric that quantifies image quality degradation caused by processing such as data compression or by losses in data transmission. It can be used for measuring the similarity between two images



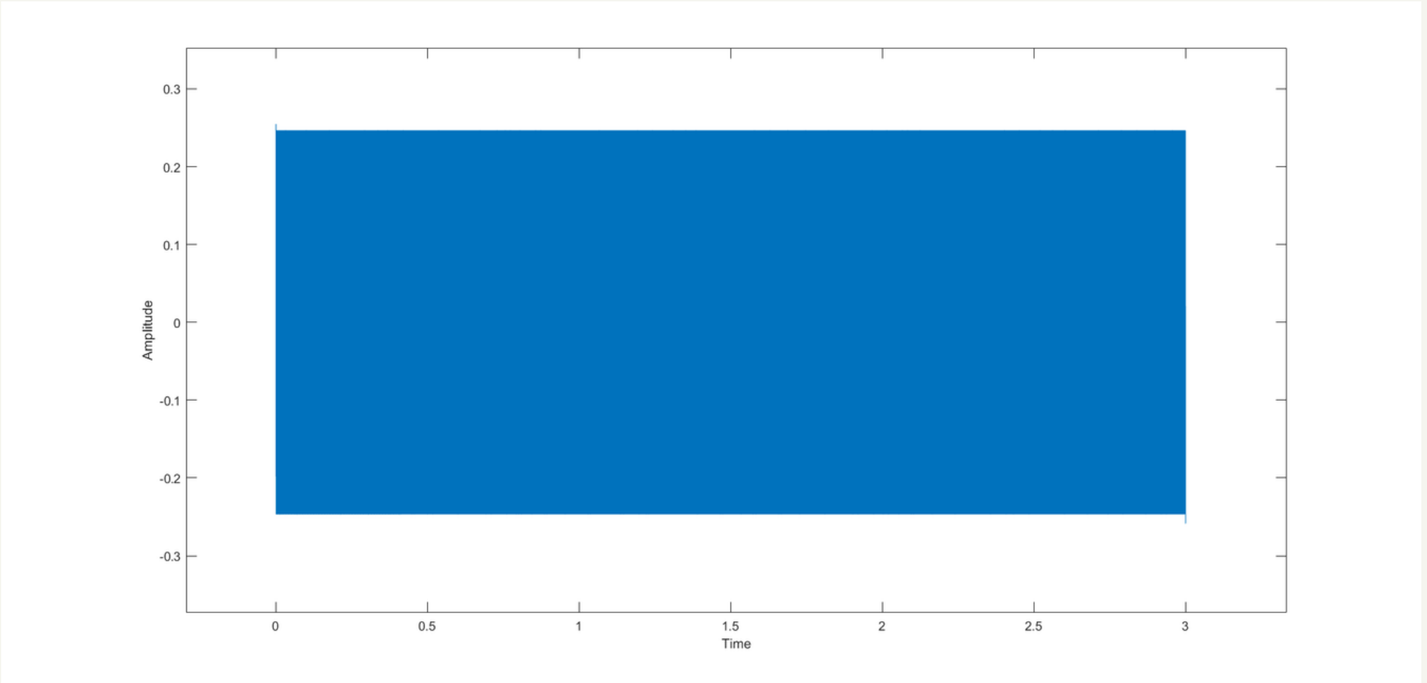
### Matlab Function

We use the ssim function available in Matlab

# Probe Sound

Using Pulse-modulated signal

Inspired from Radar

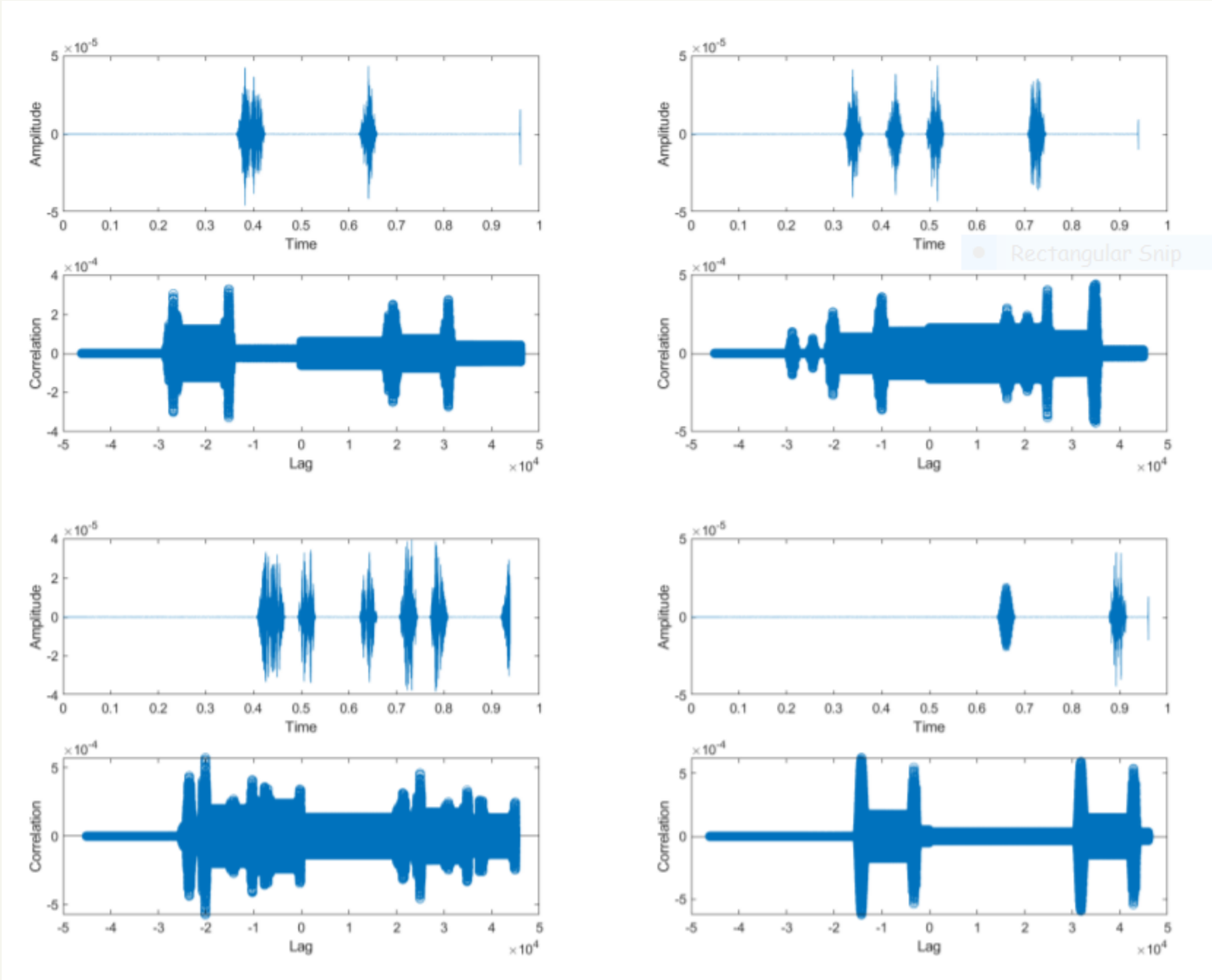


# Results

Delay pattern + SSIM scatter plot

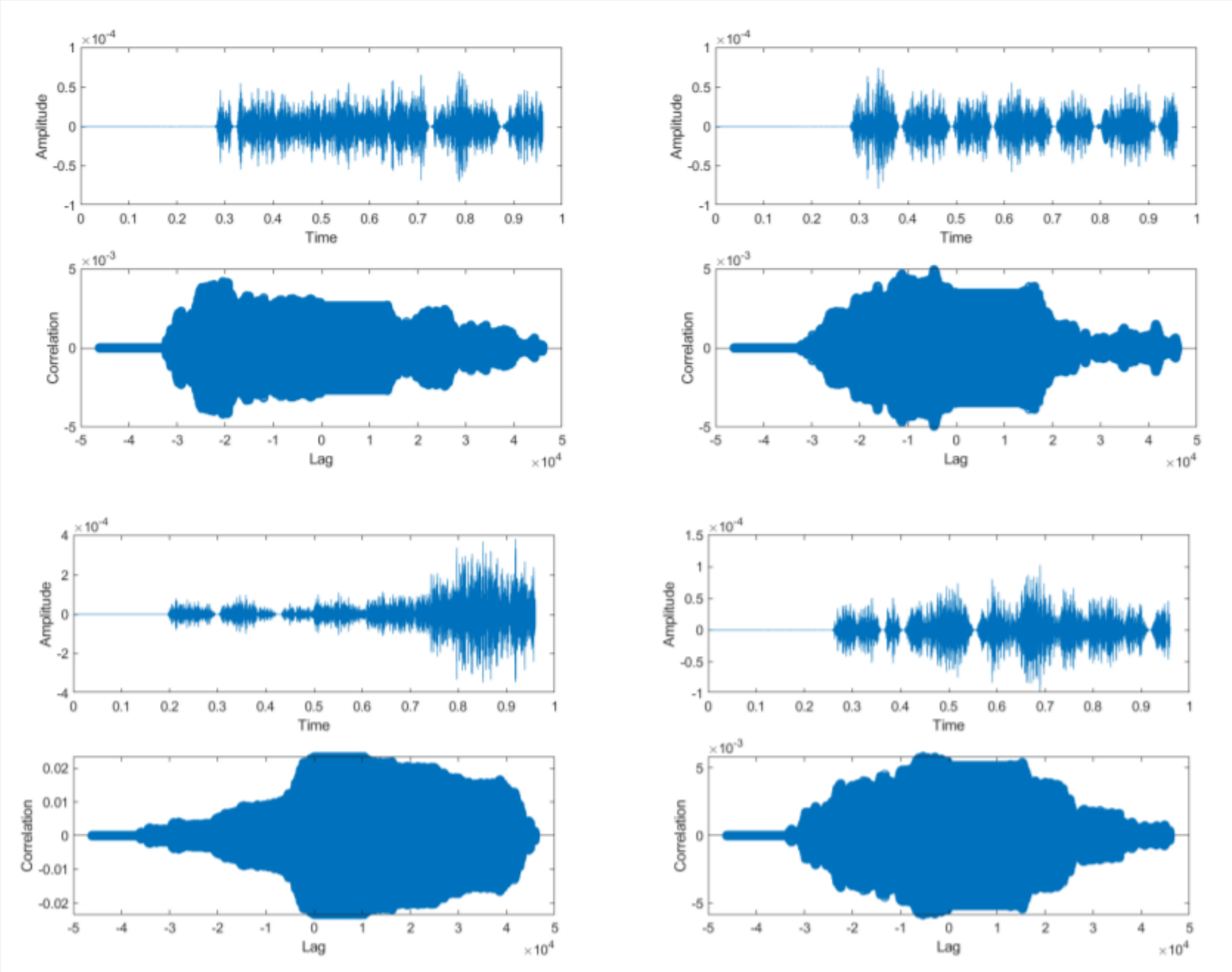
# Delay Pattern

Object - ED

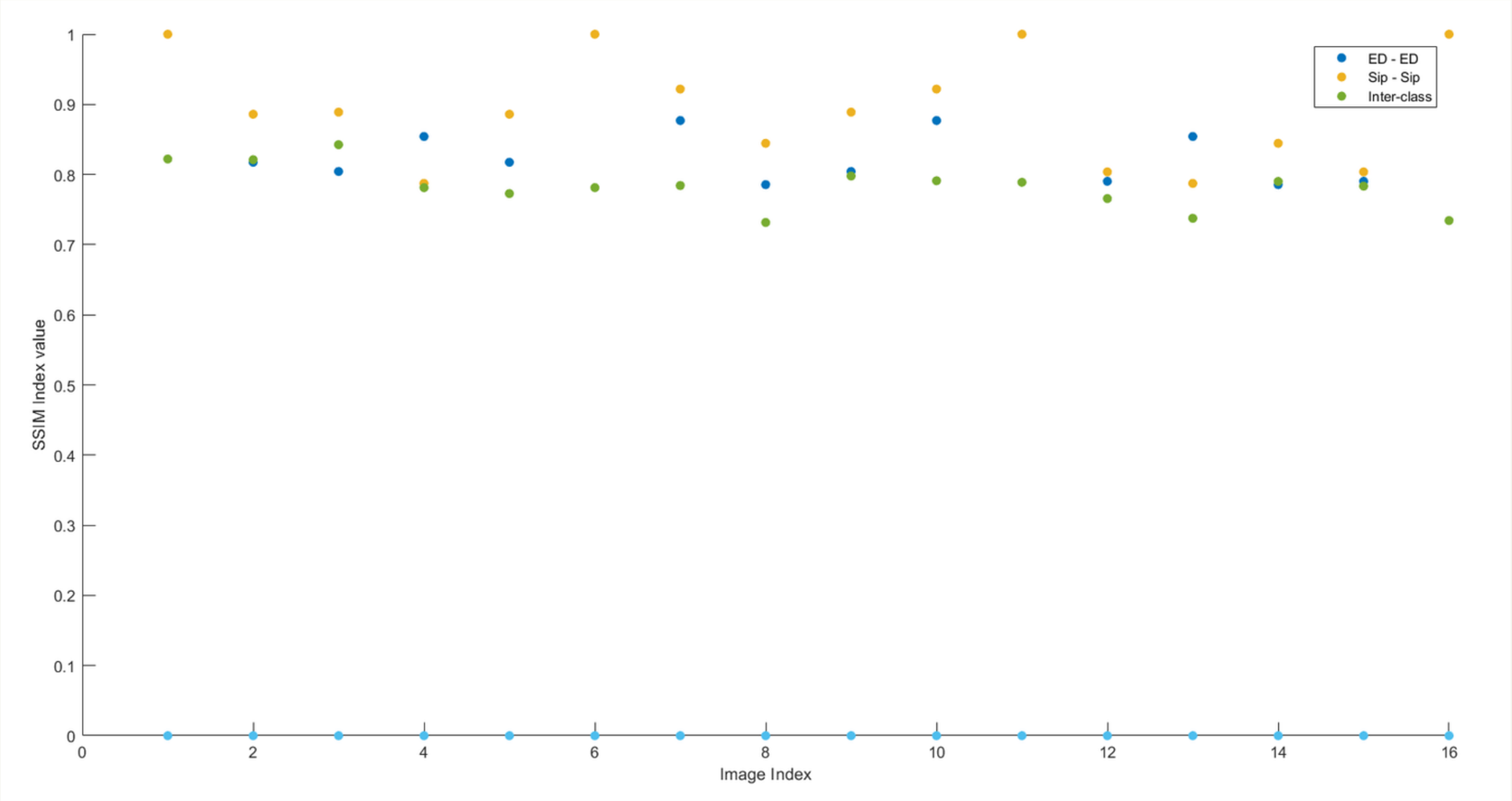


# Delay Pattern

Object - Sip



# SSIM Index


ED - ED
Sip - Sip
Inter-class
SSIM Index value
Image Index
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16

# Observations

## What can we infer?

### Delay Pattern

Clear difference in cross-correlation plots of object ED and Sip

### Inference

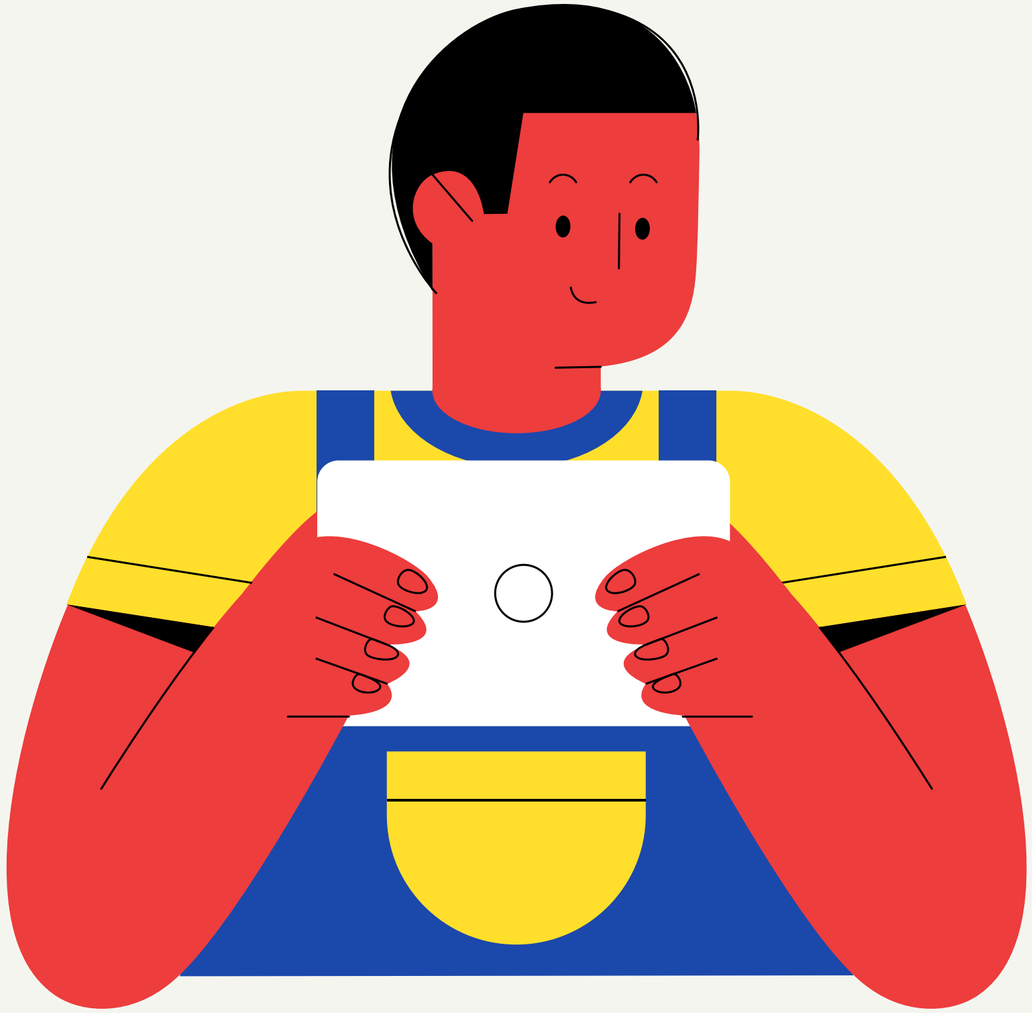
It is too early to make a factual inference about the governing characteristics of an object's internal structure. But the direction seems promising

### SSIM Index Scatter Plot

The inter-class SSIM index is low as compared to the intra-class SSIM index

# Conclusion & Future Work

## Part 04



# Conclusion

## Report In Nutshell

### Highlight 1

Sound is actually the only frequency band in which machines and humans can establish two-way communication

### Highlight 2

After many significant advancements in the semi-conductor and earable computing paradigm, the earable devices are gaining wide popularity

### Highlight 3

Detecting structural deformation of the ear canal may help in the early treatment of the underlying cause and prevent any chronic complications from surfacing

### Highlight 4

We believe and demonstrate that this can be achieved using traditional signal processing approaches, and there is no immediate need for a learning-based method

# Future Work

## What's Next?

1

The experiment presented in this work is rudimentary, and more accurate experiments with an actual 3D model of a human ear are yet to be done

2

We also want to analyze the effect on delay patterns by making changes to the internal structure of the hollow objects

3

Ultimately, develop a mobile application that can track structural deformations over time when paired with the earphone

# Thank you!

## Q & A


**Address**

NEHRU HALL, IIT KGP

**Phone Number**

+91 73844 29654

deepank.361998@gmail.com