Demo Abstract: Understanding Internal Structure Of Hollow Objects Using Acoustics

Deepank Agrawal
Indian Institute of Technology Kharagpur
Kharagpur, West Bengal, India
deepankagrawal@icloud.com

Soumyajit Chatterjee
Indian Institute of Technology Kharagpur
Kharagpur, West Bengal, India
sjituit@gmail.com

Sandip Chakraborty
Indian Institute of Technology Kharagpur
Kharagpur, West Bengal, India
sandipchakraborty@gmail.com

ABSTRACT

In this paper, we present the idea of using acoustic sensing over smartphones to understand the internal structure of hollow objects. In the core, we use an elegant, yet lightweight, signal processing pipeline that intelligently uses acoustic chirps to understand the internal structure of the hollow objects. Preliminary experiments on regularly used hollow objects show the potential of the idea.

KEYWORDS

signal processing, acoustics, smartphones

1 INTRODUCTION

Acoustic signals, typically through sonograms, are already known to provide imaging of internal organs, tissues and internal structures. However, such are not readily available and are costly. In this paper, we demonstrate how a commercially available smartphone can be used to track structural changes of a hollow object for scenarios other than medical usage. Preliminary experiments on two commonly available household containers show the potential of such an approach and provide insights for further research.

2 SYSTEM OVERVIEW

In this section, we discuss the design of the entire framework which has three main components – (a) hollow plastic objects (b) a smartphone application and (c) a signal processing unit for offline processing. The details of each of these units follow.

2.1 Hollow Plastic Objects

Object material is chosen carefully as it has tremendous effects on the quality of reflected sound. Every surface has a different reflectance coefficient. Some surfaces like metals also produce a resonant sound which may cause hindrance in our experiment. Here, we are using two hollow objects, named ED and Sip, to understand the effect of depth on the reflected sound - (1) ED (Fig. 3a) - A recyclable cylindrical object closed at one end with 35 cms depth. (2) Sip (Fig. 3b) - a commonly available cylindrical container closed at one end with 17 cms depth.

2.2 Smartphone Application

We first develop an Android-based smartphone application that serves as the primary experimental apparatus. In the core, the application imitates a typical pulse-coded radar [2] whereby it plays a chirp, followed by a period where the application records the reflections of the chirp. The details of the construction of the chirp and the application follow.

2.2.1 Constructing the Chirp. The choice of probe sound for studying the internal structure of a hollow object is crucial. TO achieve this, we design a near ultrasound-frequency (15 kHz) pulse-code modulated signal, as our probe sound (see Fig. 1). To produce this pulse-coded chirp, the original sound was sampled at regular intervals of 1 ms followed by quantization to average value in each partition.

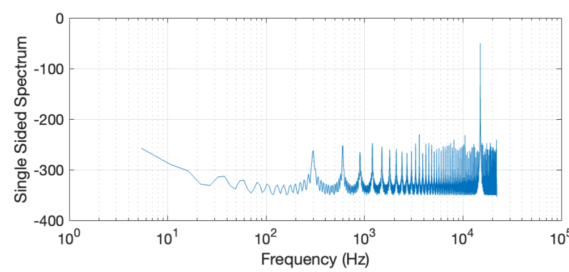

Figure 1: Averaged FFT spectrum for the used chirp.

2.2.2 Design of the Application . For the design of the smartphone application[1], we use the standard `MediaRecorder` framework to implement the application. The application plays the custom designed chirp signal for a configurable duration of playing and record time. During the recording the application captures raw unprocessed reflected sound with a sampling rate of 44.1 kHz and a bit rate of 128 kbps. Additionally, the application supports accurate play-record repetition cycles and saves each recorded clip for analysis.

2.3 Signal Processing Pipeline

To analyze the recorded signal reflected from the internal structure of the container, we first measure the delay of the different reflected signals by performing auto-correlation of the base signal (the designed chirp) and the received signal (see Figure 4). The broad idea behind this approach is to exploit the phase-delay to characterize the multipaths observed in the reflected signal, which in turn can reveal the internal structure of the object under investigation. In this paper, we implement the entire signal processing pipeline using Matlab [1].

3 PRELIMINARY OBSERVATIONS

For evaluating the designed framework we perform some preliminary experiments using two hollow plastic objects, named ED

[1]Application and signal processing source codes are publicly available at: https://github.com/Deepank308/Acoustics-sensing.git

978-1-6654-9624-7/22/$31.00 ©2022 IEEE
DOI 10.1109/IPSN54338.2022.00054

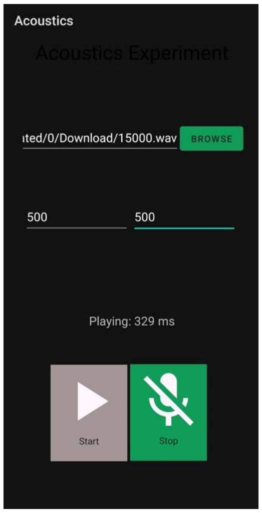

Figure 2: Android application playing-recording the probe sound of 15 kHz frequency and 500 ms of play and record time.

(a) Object ED **(b) Object Sip**

Figure 3: Objects used for the Preliminary Evaluation

(depth 35cms) and Sip (depth 17cms) (See Figure 3). While performing the experiments, the smartphone is inserted into the container (up to ≈ 2cms), and the application is used to play and record for 500 ms in a cyclic manner. For each object, we repeat the experiment 16 times and subsequently use this for further analysis as follows.

For the evaluation, we use Structural Similarity Index (SSIM) for intra-class and inter-class comparisons of the delays obtained after autocorrelation for both the objects. The purpose of this step is to establish a difference between the two objects which in some sense is analogous to comparing two structural changes of a single object. From Figure 5, we see that indeed the inter-class SSIM(s) are clearly higher in comparison to the intraclass SSIM(s), showing the potential for using this as a mechanism for detecting structural variations.

4 CONCLUSION AND FUTURE WORK

This presents an opportunity to track structural changes to a hollow object using COTS smartphones. In the backend, the framework draws inspiration from a pulse-coded radar to achieve significant

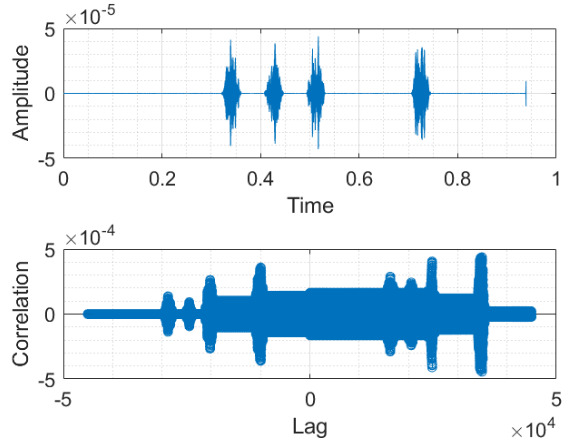

Figure 4: Received Signal and Delay Characteristics

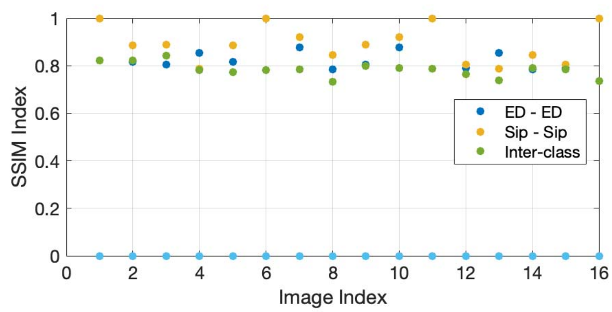

Figure 5: Intra and Inter-class SSIM index values.

accuracy in differentiating two objects with varying internal structures. In the next steps, we will use frequency hoping to enhance the accuracy of sensing across different sized of objects. In the subsequent versions of this work, we plan to apply the discussed approach to detect defects in these objects which can help in the identification and localization of defects in a much more cost-effective manner.

REFERENCES

[1] MathWorks. 2020. *MATLAB - MathWorks - MATLAB & Simulink.* Retrieved December 3, 2021 from https://in.mathworks.com/products/matlab.html
[2] Christian Wolff. 2014. *Intrapulse Modulation and Pulse Compression.* Retrieved December 3, 2021 from https://www.radartutorial.eu/08.transmitters/Intrapulse%20Modulation.en.html