M.Sc. Thesis
Master of Engineering Acoustics

DTU Elektro
Institut for Elektroteknologi

Project Definition Report

Enhanced Leak Localization in Headphones through Beamforming and 3D Modelling

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CHAPTER 1
Project Description

1.1 Background

Headphone sound leakage, specifically its directionality, is an area of growing interest in acoustic research. Sound leakage can impact the noise reduction capabilities of headphones, introduce noise during calls due to microphone pickup, and compromise the overall acoustic performance. In public settings, sound leakage can also lead to privacy concerns. The variability in leakage, influenced by factors such as headphone fitment and individual differences, presents challenges in its study. Current methodologies to study this phenomenon have limitations: direct measurements, while accurate, are time-consuming, and indirect methods might lack precision. There is a clear need for a method that combines the efficiency of techniques like beamforming with the accuracy of 3D modeling.

1.2 Prior work

Research into headphone sound leakage, particularly its localization, has been methodically approached from multiple angles.

Initial studies focused on the characterization of headphone leakage. These investigations quantified the impact of sound leakage on acoustic fidelity, emphasizing the challenges introduced in terms of noise reduction [Wel15]. A deeper understanding of leakage localization was pursued, identifying based on intensity prob and 3d scanner [HTK10]. An important consideration in these studies was the variability introduced by individual differences in ear morphology, emphasizing the need for designs that accommodate a range of ear shapes and sizes. [OW12] [YLW23]

In tandem with these studies, there has been rigorous development and evaluation of localization algorithms and methodologies. Beamforming, recognized for its computational efficiency [Lyl+15], underwent critical evaluation to determine its precision in complex auditory scenarios. The Inverse Boundary Element Method (Inverse BEM) [SH01] was also explored, with discussions centered on its algorithmic structure and potential applicability in modeling sound leakage. A significant contribution to this body of work was the study ”Sound leakage investigation of ANC headphones using particle velocity sensors” [MYF20] This research provided a comparative evaluation of traditional microphone measurements and Intensity techniques, offering insights into the relative accuracy with the use of 3d scanner in cooperate with intensity scanning method.

Despite the comprehensive nature of existing research, there is an identified gap: the integration of 3D point cloud scanning with traditional sound localization methodologies. This intersection presents an opportunity for further research, aiming to combine the benefits of both techniques to address the challenges of headphone sound leakage more effectively.

1.3 Problem statement and Research goals

The central research question guiding this study is: Can a solution be developed to accurately identify sound leakage from headphones using a combination of 3D LiDAR scanning and beamforming methods?

Addressing this question is pivotal for several reasons. Sound leakage in headphones not only compromises acoustic fidelity but also has broader implications for noise reduction, user privacy, and overall user experience. Current methodologies, while insightful, either lack the precision or efficiency required for comprehensive real-world applications. Thus, the problem at hand is not just to identify sound leakage but to do so in a manner that is both accurate and efficient.

This research aims to bridge this gap by proposing a novel approach. By integrating 3D LiDAR scanning with beamforming methods, the study seeks to harness the strengths of both techniques. While 3D LiDAR scanning offers detailed spatial information, beamforming provides rapid and efficient sound localization. The synergy of these methods has the potential to revolutionize the way sound leakage is studied and addressed.

1.4 Empirical considerations

This research is conducted in collaboration with HBK, which provides access to specialized equipment including a microphone array and the HATS-head and torso simulator. These tools are essential for capturing accurate sound leakage patterns from headphones.

For the 3D modeling aspect, data will be captured using the Microsoft Azure Kinect and processed using open-source tools, notably Open3D. The goal is to integrate the data from the microphone array with the 3D modeling data to produce a visualization of sound source localization coordinates.

Algorithm development is a significant component of this research. The algorithms, designed for reconstruction and localization, will be developed across platforms such as Python, C++, and Matlab. Given the constraints of the project, the primary role of the sound source localization algorithm is for validation, and further refinement may be required.

The research may utilize the facilities of the DTU laboratory for specific experimental tasks. While the collaboration with HBK provides access to equipment, the research remains primarily academic, focusing on understanding and addressing headphone sound leakage.

Intellectual Property Rights (IPR) are a consideration due to the collaborative nature of the project with HBK. Clear agreements on ownership and rights will be established to avoid potential conflicts.

CHAPTER 2

Plan

This chapter outline the entire plan for the Thesis work, including a Gantt chart demonstrate the ideal timeline of project. This section also contains a risk assessment.

2.1 Gantt Chart

Figure 2.1 shows a timeline of this project, formed in .

2.2 Risk Analysis

A risk analysis identify the top-4 or so risks that can really upset the entire project. Typical risk factors are often those that are not under control. The Risks of this project are

Table 2.1: Risks. 1:low risk, 5:high risk of delays.

#	Title	Description	Risk	Week
R_1	4 Explain and implement algorithm	low risk, simplify the problem will mitigate it.	2	4
R_2	10 Measuring with new instrumets and collecting data	High risk, might delayed depending on previous progress	4	6
R_3	11 Prepare simulate data and ground-truth data	This is high risk, data might not accurate enough to represent ground-truth	4	4
R_3	21 Modification	middle risk, might need previous writing part finish eariler	3	7

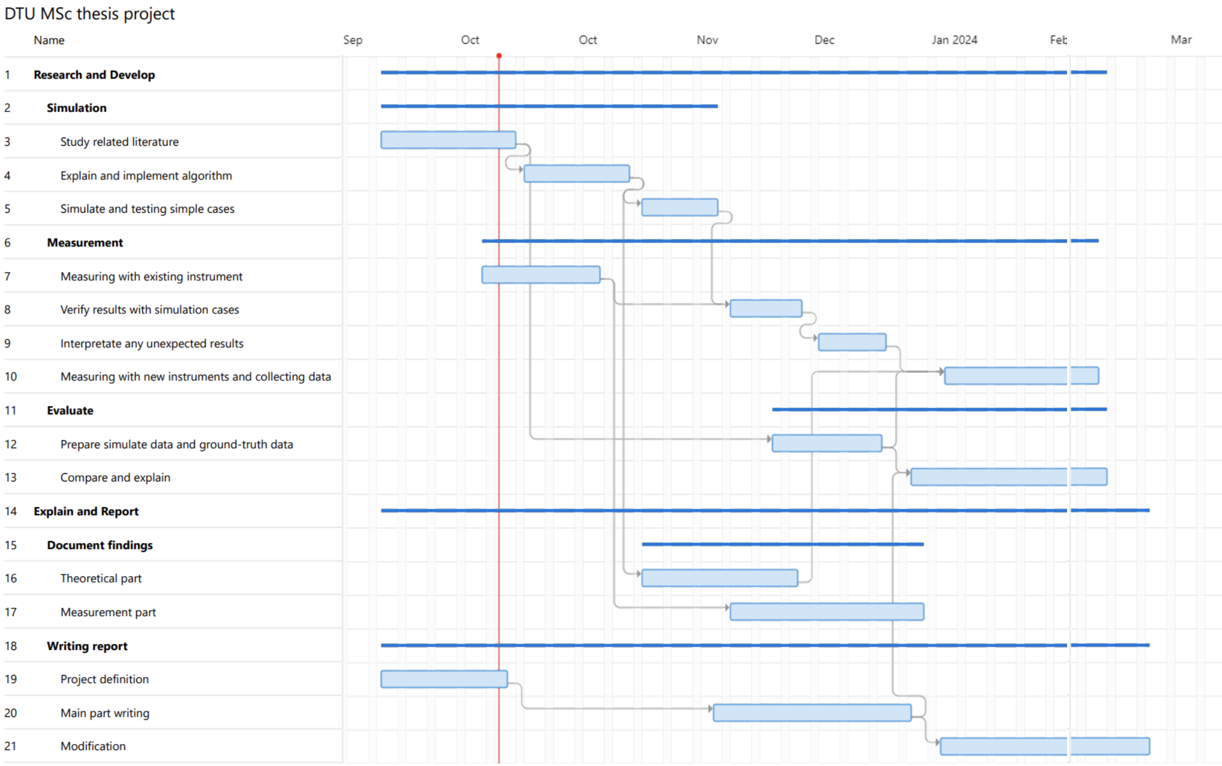

Figure 2.1: The Gantt chart for this thesis.

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