Creating a hearing aid app for smartphones

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# Motivation and introduction

Elder people generally suffer from hearing loss. To solve the issue, most of them buy hearing aids. Such devices are often expensive and involve regular hearing care. On the other hand, most people already own a smartphone which is equipped with a microphone and the possibility to connect headphones. Although the acoustics of the microphones in smartphones are by far worse than the acoustics of professional grade hearing aids, smartphones are often cheaper and easier to set up than traditional hearing aids which might represent a good first step for many people in the world of hearing aids.

This paper focuses on the creation of the HearingAid app, an Android app that allows users to record the smartphone’s microphone input, amplify and play it back in real time over the user’s headphones. While being aware of the limitations imposed by the device hardware and by the Android platform, the app aims to be as good as a professional hearing aid on supported devices.

# Overview over hearing impairment

Hearing loss affects every patient differently. While most patients are affected as a sign of aging, some patients acquire their impairment through genetical disorders. In any case, hearing aids can only offer help in case of partial hearing loss, meaning that the patient is still capable to hear sounds that exceeds a certain threshold in volume. While all humans have that so called absolute threshold of hearing, which describes the minimum volume a sound must have to be perceived, patients who suffer from hearing loss have a threshold which is significantly higher than the one of the average human being.

While the absolute threshold of hearing (ATH) describes the lower bound of the hearing range of a human being, the threshold of pain describes the level of loudness at which the patient feels pain, thus representing the higher bound of the hearing range. In general, hearing impaired patients maintain their threshold of pain while their ATH rises (Kießling 2001). The actual value of both, the ATH and the threshold of pain vary from person to person and also depend on the frequency of the sound (Kießling 2001).

# Overview over the operating principles of a hearing aid

## Volume compression

In general, hearing aids aim to amplify the sound a patient would hear. Most relevant sounds (speech, music, warning signals) are in a frequency range between 500 and 6000 Hz. Due to the above stated fact that the patients ATH rises while the threshold of pain doesn’t, hearing aids perform volume compression (a large range of volume is mapped on a smaller range of volume). Sounds below the patient’s ATH are amplified while making sure that no sound exceeds the threshold of pain. On the other hand, hearing aids must preserve the perception of volume (louder sounds must be perceived louder). That means that hearing aids cannot simply amplify all sounds by the same amount (risk to exceed the threshold of pain) and cannot amplify all sounds to the same volume neither (perception of volume would be lost). To accomplish this, hearing aids generally know their user’s ATH and threshold of pain and calculate the amount by which a sound must be amplified for each sound individually depending on its frequency and volume.

## Amplification algorithms

# Sound latency

While the volume by which a sound is amplified hugely impacts the user’s comfort, sound latency does even more. Users will start to notice sound delays if the latency is more than 10 ms (Superpowered Inc. 2017) and will get seriously distracted at higher latencies. According to our own field measurements, latencies of more than 50 ms make conversations impossible. While one might still be able to hear the conversation partner, it will become difficult for the user to speak because he will hear his own voice delayed by the very same latency. Due to this, hearing aid hardware and algorithms must be built to process sound in 10 ms or less. This is easy for hearing aid manufacturers as they are constructing their own hardware and have the budgets for more expensive hardware, engineered for the exclusive purpose of sound processing. On smartphones, this is even a bigger issue than the acoustics of the microphone as smartphone hardware is built for general purpose and not necessarily optimized for low latency. Also, smartphone CPUs have several tasks at once (responding to calls, responding to user input, execution of other apps running in the background) while hearing aid hardware solely processes the sound.

# Introduction to the Android application framework

## Basic framework

Apps on the Android platform are generally built using the Java language. This comes with many advantages: Developers do not need to worry about memory management since Java is garbage collected. Because Java runs on the so-called Java Virtual Machine[[1]](#footnote-1), it is cross platform which removes the effort of compiling a program for every CPU architecture available on the market.

The advantages aside, the Java platform also brings several disadvantages. Firstly, the JVM slows the program down by design as it has to translate every instruction of the virtual CPU to instructions for the real CPU. Furthermore, as Java is mostly Just-in-time compiled (JIT compiled), the JIT compiler also takes up time to compile. Thirdly, when the garbage collector becomes activated, the application is halted for several milliseconds until the garbage collector finishes its work.

All those factors lead to applications written in the Java language to be slower. While this does not matter in usual usage cases[[2]](#footnote-2), it does in the case of this app as it directly impacts sound latency, which is a crucial factor of success as mentioned above.

## Android Native Development Kit

As there are many other use cases which require low latency, several application developers have requested Google (the main manufacturer of Android) to allow execution of so-called native code. Native code are instructions that are executed directly on the device’s CPU instead of being executed on the JVM. This eliminates the JVM software layer but also removes all the advantages that come with the use of the JVM. Usually, native code is written in C++ and compiled into assembler code for each platform that the app will be able to run on.

Google made interoperability between native code and Java code easy by offering the so-called Android Native Development Kit (NDK). The NDK offers all tools required for native development (compiler, framework classes). To transfer information between native code and Java code, the NDK utilizes a concept that is already present in Java, the Java native interface (JNI). The latter allows information (commands, strings, numbers, …) to be transferred from Java to native code and vice versa. In general, all code that affects the view of an Android application is written in Java while backend code is written in C++. A controller class written in Java is responsible for the transfer of data and commands from and to C++.

Literature

Kießling, Jürgen (2001): Strategien zur Anpassung von Hörgeräten. In: *EINBLICKE - Forschungsmagazin der Carl von Ossietzky Universität Oldenburg* 2001 (33). Online verfügbar unter http://www.presse.uni-oldenburg.de/einblicke/33/7kiessling.pdf, zuletzt geprüft am 20.01.2018.

Superpowered Inc. (2017): What Developers Can and Cannot Do to Lower Android Audio Latency. The Android Audio Low Latency Primer to Android’s 10ms Problem. Superpowered Blog. Online verfügbar unter http://superpowered.com/android-audio-low-latency-primer, zuletzt geprüft am 20.01.2018.

1. A software layer that emulates a virtual CPU and translates the instructions of the virtual CPU to instructions for the real hardware CPU. [↑](#footnote-ref-1)
2. Users won’t matter if their navigation app takes 5.0 seconds to calculate a route or 5.1 seconds [↑](#footnote-ref-2)