\chapter{Introduction}

\label{sec:introduction}

Hearing impairment has become a common phenomenon, which is problematic because a significant part of communication is speech. Hearing is necessary both professionally and for personal communication. The degradation of quality of life(\ac{qol}) due to hearing loss is undetermined \cite{qol\_reduction\_due\_to\_hearing\_loss}, although the general consensus is that hearing impairment reduces QoL.

Hearing loss (HL) is a phenomenon measured on a continuous scale, and the threshold at which hearing impaired commences remains under debate in the research community \cite{prevalence\_hearing\_loss\_at\_europe}. In terms of years of life with the impairment, HL is the second most common disability. In 2012, the World Health Organization estimated that 360 million people (5.3\% of world population) have disabling hearing impairment. For adults aged 55--74, over 30\% have lost more than 30dB in their better ear \cite{prevalence\_hearing\_loss\_at\_europe}. However, 80\% of adults that need hearing aids (HAs) do not use them \cite{unused\_hearing\_aids}, and those that do use such aids acquire them only after suffering HL for over 10 years \cite{hearing\_aids\_early\_screening}. The reasons listed in \cite{unused\_hearing\_aids\_table2} indicate that 15\%--30\% of patients who do not use HAs do not benefit from the devices and 22\%--52\% suffer from noisy background.

For children, multiple longitudinal studies have measured HA effectiveness, and the adoption of early screening and intervention ensures that children receive HA and cochlear implants at a very young age. Parallel research on children with normal hearing (\ac{cnh}) show that the amount of vocal input affects language development: researchers have assumed that, given vocal input, children will uptake the information. However, this assumption fails for children that are hard of hearing (\ac{chh}) because the difficulty of understanding in noisy environments or low-power speech leads to variable uptake and reduced vocal input. In addition, the auditory degradation varies but includes low-pass filtering and spectral reduction that causes final ``s’’ to be inaudible, thereby eliminating the experience of many morphemes \cite{APHC}. Multiple causes are responsible for varied auditory uptake, including distance to the parent, noise from the environment, and HA fit. Some studies have found that CHH with HAs have a linguistic development one standard deviation below the norm for their age, with the age at which the HA is fit not being predictive \cite{OCELHA}. Despite the controversy about HA effectiveness for CHH, several studies have found that audibility assistance increases language comprehension for school-aged children \cite{Stiles\_SII,TIHASLDCH}, although not to level of CNH. Other studies show that HAs contribute significantly to language understanding \cite{ADEAC}. This unclear picture suggests that more-precise measurements are needed to test the effectiveness of HAs and that better fitting methods are required.

Hearing Aids are adapted to the user by examining the patient hearing threshold for pure tones and testing speech discrimination in a quiet environment. The user then gets a prescription and returns at a later date to report their experience and make adjustments. This process can be reiterated several times because no objective method exists to test the effectiveness of a HA prescription.

To address this situation, \citealt{Barzelay2011} simulated the cochlear model in the time domain; however, the simulation was implemented on a CPU and is too slow. Thus, a real-time solution requires massive parallel computation. \citealt{Saboddd2013682} implemented part of the cochlear model on a commodity GPU, but solution remained excessively slow. Therefore, we implemented the entire cochlear model on a GPU, including the hearing-level inference and how the HA prescription affects the model.

The remainder of this thesis is organized as follows: \cref{sec:human-ear-anatomy-model} describes the cochlear model simulated by our program. \cref{sec:gpu\_architecture} compares different generation of NVidia architectures and their effect on program performance. \cref{sec:parallel\_input\_generation} describes parallelization for signal and noise at various power levels. \cref{sec:cochlear\_model\_optimization} describes the improvement of the algorithm \cite{Saboddoron20131215} and the performance for multiple execution profiles. \cref{sec:neural\_response\_calculation} presents the calculation of the auditory nerve response from the basilar membrane velocity. \cref{sec:jnd\_calculation} discusses the parallel algorithm to calculate \ac{jnd} directly on a \ac{gpu} from the auditory nerve response. \cref{sec:hearing-aids-effectiveness} describes how to use this program to diagnose patients and fit HAs. Finally, the results are given in \cref{sec:results} and the conclusion in \cref{sec:conclusions}.