Neural model based sound coding for cochlear implants

Bernhard Seeber*†[1]

[1]Audio Information Processing, Technical University of Munich – Germany

Abstract

A sound coding strategy for a cochlear implant translates the incoming sound signal into parameters for the electrical pulse pattern to be delivered by the implant, the pulse amplitudes and timings across electrodes. This basic sound coding is accompanied by noise reduction and de-reverberation techniques which clean the sound signal prior to pulse processing, together achieving good performance in many listening situations. Without the explicit noise reduction, the common envelope coding onto fixed, high-rate pulse trains leads to problems with sound localization and listening in situations with noise and reverberation. One reason is seen in the lack of spectral and temporal coding precision due to interaction between stimulation pulses at the electrode-nerve interface and due to using high pulse rates. For example, refractoriness and current-spread across channels make it hard to anticipate which electric pulses will evoke a neural response and thus to code temporal fine structure information.
In recent years, several models for the auditory nerve response to sequential electrical pulsatile stimulation, such as the S-BLIF model (Takanen and Seeber, DOI:10.5281/zenodo.4674564), have been developed, which consider non-linear interactions at the electrode-nerve interface due to adaptation, facilitation and refractoriness. These models compute the probable neural response for a given electrical stimulation sequence.

I will report on a novel approach for a cochlear implant stimulation strategy which deviates from classical deterministic sound coding by using a model to anticipate the nerve's non-linear response. First, the processing order is inverse, as the strategy does not start from the sound. Instead, the nerve's spiking response is the target for which a suitable stimulation sequence needs to be found. A nerve response model is placed in the loop of an optimization strategy which computes the pulse timings, amplitudes and durations needed to evoke a given nerve spike pattern. Different constraints can be implemented by penalizing the distance measure inherent to the optimization strategy, for example to prevent two pulses being placed at the same time on different electrodes or to trade a higher pulse amplitude against placing two or more short pulses which utilize facilitation effects. For example, classical fine structure coding approaches would code a tone into an electric pulse train of constant amplitude with a rate corresponding to the fundamental frequency. Instead, to obtain the anticipated regular spiking response of the nerve, an irregular stimulation sequence is needed which overcomes the refractoriness and other non-linear effects in the electrode-nerve interface. I will show further examples of the optimization and discuss ideas how to overcome the convergence problems posed by non-monotonic changes in the distance measure due to

*Speaker
†Corresponding author: seeber@tum.de

sciencesconf.org:ish2022:383630

the omission of spikes in absolute refractory states. In summary, by basing the cochlear implant strategy on an auditory nerve model and by taking the nerv's response as the target to be achieved, temporal information can be coded in a targeted way over the non-linear electrode-nerve interface.

This work is supported by the Bernstein Center for Computational Neuroscience, Munich, BMBF 01 GQ 1004B.