

---

# Opti-Fox: Towards the Automatic Tuning of Cochlear Implants

---

**Keywords:** cochlear implants, tuning, fitting, modelling, optimisation

**Zoltán Szlávik\***

Z.SZLAVIK@VU.NL

\*VU University Amsterdam, De Boelelaan 1081, 1081 HV Amsterdam, The Netherlands

**Bart Vaerenberg\*\***

VAERENBERG@EARGROUP.NET

\*\*the Eargroup, Herentalsebaan 71, B-2100 Antwerp-Deurne, Belgium

**Wojtek Kowalczyk\***

W.J.KOWALCZYK@VU.NL

**Paul Govaerts\*\***

DR.GOVAERTS@EARGROUP.NET

## Abstract

This paper describes the Opti-Fox project which aims at reducing the need for the presence of experts when fitting cochlear implants to patients.

## 1. Introduction

Hearing is a complex sensory function which converts mechanical waves (sound) to electrical patterns on the auditory nerve. The sound receptor is the inner ear or the cochlea. Each year Europe counts more than 5000 deaf-born babies (i.e., 1/1500 newborns). Not treating these babies leads to deaf-muteness. In adults, the prevalence of “cochlear” hearing loss increases with age, and approximately 20% of 75-year old people have a moderate, and 3% a severe hearing loss. Severe and profound hearing losses can be treated with cochlear implants (CI). When implanting a CI, some 10 to 20 contacts are surgically placed into the cochlea. Within the device, sound is analysed by the external “speech processor” which resembles a classical behind-the-ear hearing aid, and implanted electrodes are then stimulated to generate an electrical field to pass the information directly to the auditory nerve.

The working of a CI is controlled by about 200 tunable parameters that determine the “input-output” behaviour of the speech processor: sensitivity levels at different frequencies, electrical dynamic ranges for each electrode, characteristics of amplifiers, and strategies of stimulating electrodes.

---

Appearing in *Proceedings of the 20<sup>th</sup> Machine Learning conference of Belgium and The Netherlands*. Copyright 2011 by the author(s)/owner(s).

After implantation, CIs need to be programmed or “fitted” to optimise the hearing sensation of the individual patient (Clark, 2003). This is a challenging and time-consuming task that is typically performed by highly trained engineers, audiologists or medical doctors. One of the reasons for this is that the outcome of the optimization process is difficult to measure. Tone and speech audiometry are the only outcome measures that are clinically used all over the world. However, they only measure a marginal aspect of the entire auditory performance, and they hardly allow analytical feedback to the fitter. Therefore, many fitters mainly rely on the patient’s instantaneous feedback. However, since many patients are very young, or may never have been hearing “normally” before, this feedback often relates more to comfort than to intrinsic sound coding accuracy.

As a result, CI centres and manufacturers have developed their own heuristics, usually in the form of simple “if-then” rules that are applied in a very flexible, individual and uncontrollable way. At present, no universal standards or well defined Good Clinical Practice exists to guide the fitters. With more than 200000 CI users worldwide and an annual increase of over 30.000, this becomes an ever-increasing problem and a real bottleneck to further implementation.

## 2. Opti-Fox

Opti-Fox is a project which is funded by a European Commission’s 7th Framework Research for SME grant (7FP-SME 262266). In this project we aim at developing an intelligent, self-learning agent (or system) for CI fitting. We will combine the latest technologies from linguistics, automatic speech recognition, machine learning, and optimization techniques. The con-

sortium consists of SMEs and research institutes from Belgium, the Netherlands and Germany, in close collaboration with the CI manufacturer Advanced Bionics. For more details, the reader is referred to the project's website<sup>1</sup>.

### 2.1. New tests to measure fitting quality

Ongoing research focuses on the development of a new speech understanding test that is language independent, provides automatic scoring by means of Automatic Speech Recognition (ASR) technology, and allows detailed spectral analysis to feed back to the CI fitter. Together with linguists and computational scientists we are developing bin definitions that characterise languages. They will be validated on large corpora of several European languages and they will allow us to draw customised samples for individual patients in such a way that the samples are representative of the entire language in terms of phonetics, typology, morpho-syntax, etc.

We are also developing automated scoring strategies by means of ASR. Different algorithms are being developed and investigated to compare reference utterances with test utterances which may contain errors due to the test person's hearing deficit. In a first stage we have made recordings in 30 hearing volunteers with Flemish, Dutch or German as mother tongue, who were asked to (re)produce about 400 words twenty times, yielding around 240.000 wave-files. This vast dataset will serve the first validation of the algorithms under development. Next stages will include the validation in hearing impaired subjects.

### 2.2. Modelling

By analysing all (both historical and the most recent) data the system will be learning the model of a complex relation between settings of CI device parameters and hearing performance. Our aim is to develop a system that is able to recommend adjustments to device parameters that will lead to the maximal improvement of hearing quality.

The main challenges in modelling, and, subsequently, in tuning a CI device's parameters arise from the following facts: As already mentioned, the number of parameters to be tuned is high (~200) compared to the number of records available in the data collected so far (which is in the order of several thousands). In addition to the parameters of the CI device, one should also consider the differences among patients (e.g., age, speech intelligibility, severity of hearing loss,

etc.). Also, producing new records is a time consuming and expensive task (obtaining one set of exhaustive test results can take up to two hours). An exhaustive hearing test consists of several types of tests (e.g., Audiogram, Phoneme tests), which have several sub-tests (e.g., Audiogram at 1000Hz, 2000Hz, etc.). Currently, the number of all sub-tests is more than fifty. Due to their expensive nature, and sometimes due to assumptions made by experts, some of these tests are not even carried out. Missing values are also routinely present in the input data. In addition, the types and ranges of outcome values are different, e.g., Audiogram measures performance in decibels, values typically ranging from 0 to around 70 for each of the 8 frequencies at which measurement is taken, while a Phoneme score is the sum of 20 binary sub-tests. The various (often asymmetric) error measures that can be defined for (sub-)tests to evaluate model performance complicates modelling even further.

### 2.3. Optimal Tuning

The model provides only a probabilistic approximation of the expected response of a patient to particular parameter settings. Nevertheless, it can be used to compute the most promising configuration that should be tried next. After the evaluation of the recommended configuration by testing the patient, the model could be updated to become more "patient-specific" and, therefore, accurate. Consequently, the updated model can be used to find the next most promising configuration, and so on, until a satisfactory configuration of the CI is found.

## 3. Concluding remarks

An intelligent agent, called FOX, that facilitates CI fitting has been developed, CE marked and is already in use in several CI-centres across Europe (Vaerenberg et al., 2011). The first prototype system of Opti-Fox is expected to be finished around the end of 2011, while the commercial version of the system will be available at the end of 2012.

## References

- Clark, G. M. (2003). *Cochlear implants : fundamentals and applications*, 663–670, 679–683. Springer, New York.
- Vaerenberg, B., Govaerts, P. J., de Ceulaer, G., Daemers, K., & Schauwers, K. (2011). Experiences of the use of FOX, an intelligent agent, for programming cochlear implant sound processors in new users. *International Journal of Audiology*, 50, 50–58.

<sup>1</sup><http://www.otoconsult.com/opti-fox>