IMAGE-GUIDED FREQUENCY-PLACE MAPPING IN COCHLEAR IMPLANTS

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1. Introduction

- Multi-channel cochlear implants (CI) leverage frequency based cochlear tonotopic mapping to map acoustic information to the cochlear place of stimulation which is primarily determined by electrode locations.
- Despite the fact that electrode locations within the cochlea are unique to each patient, the acoustic frequencies assigned to the electrodes by the CI processor are determined generically.
- Suboptimal electrode array placement, variations in insertion depth, and exact positioning and proximity of electrodes to nerve fibers can all result in a mismatch between the intended and actual pitch perception.
- **We propose a novel, image-guided CI processor programming strategy to select more optimal, patient-specific frequency assignments which helps to minimize sub-optimal frequency-place mapping distortions in CIs.**

2. Proposed algorithm

- The proposed strategy utilizes pre and post implantation CT scans of recipients' cochleae to determine precise spatial location of electrodes and the corresponding neural stimulation sites [1].
- Using spatial location of electrode contacts, we generate a user-customized frequency-place function by modifying the frequency characteristics of the filterbanks of CI sound processor.
- This is achieved by maximizing the frequency match at lower frequencies (frequency range of first three formants), and introducing mild compression as needed to avoid truncation (e.g., due to shallow insertion). Mid and high frequency bands are assigned conventional logarithmic filter spacing [2].
- The frequency space is divided into 4 sub-bands and following rules are applied to determine filter frequency boundaries:
  - w_0 = [0.1–0.5] kHz, w_1 = [0.5–1.0] kHz, w_2 = [1.0–3.0] kHz:
    - Maximize frequency matching in w_0, w_1, and w_2
    - Mild compression in w_1, if needed, to avoid truncation
    - At least 2 analysis filters in w_1
  - w_3 = [3.0–8.0] kHz:
    - Logarithmically spaced filters

[1] Noble, J. H., *et al.*, "Image-guidance enables new methods for customizing cochlear implant stimulation strategies," *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, vol. 21, issue 5, pp. 820 - 829, 2013.
[2] Ali, H., *et al.*, "Image-guided customization of frequency-place mapping in cochlear implants," *IEEE Int. Conf. on Acoustics, Speech and Signal Processing, ICASSP'15*, Brisbane, Australia, April 19-24, 2015.

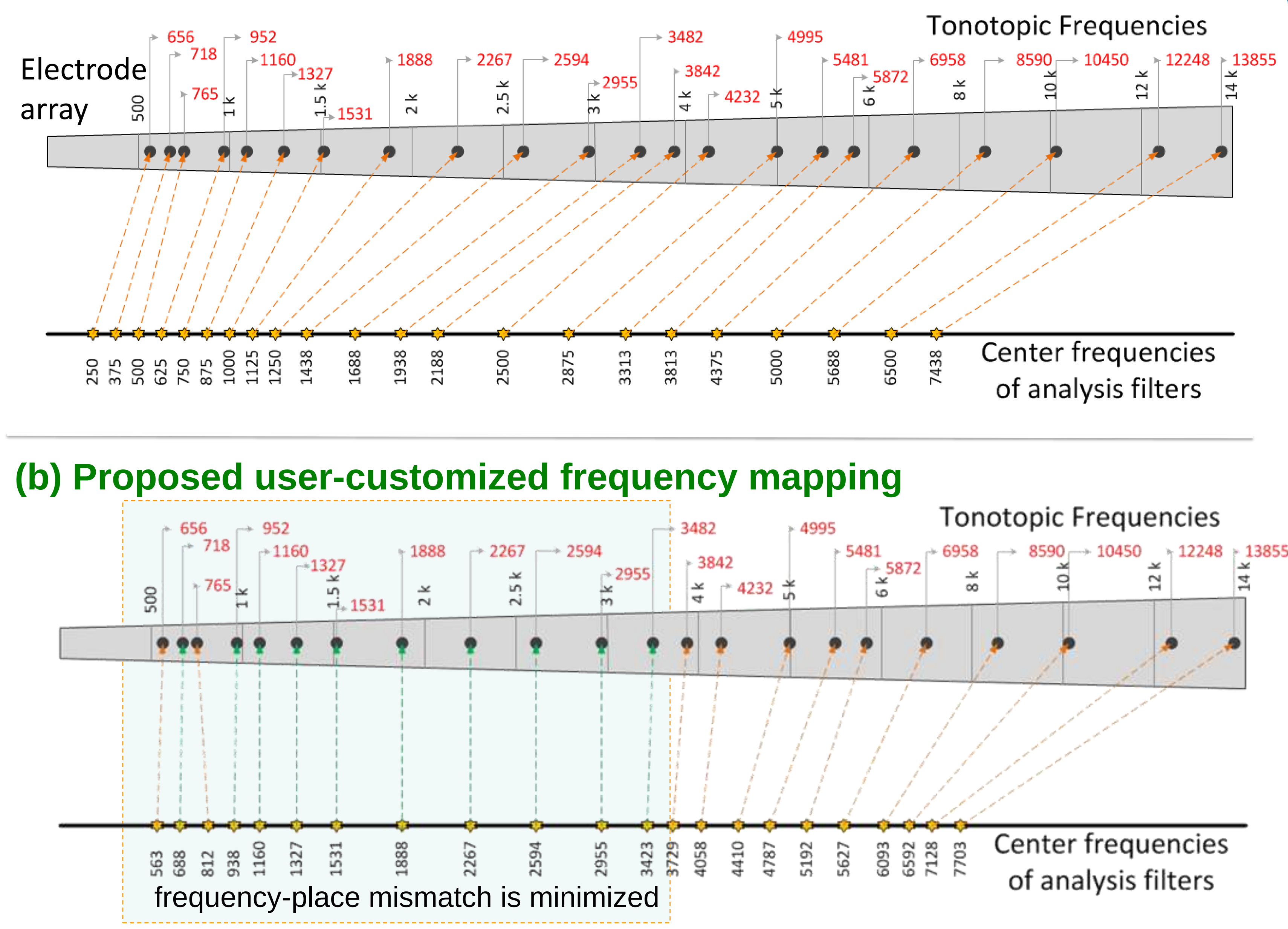

Fig. 1: An example of frequency-place mapping in (a) clinical processors, and (b) using proposed mapping strategy (figure not to scale).

3. Method

- Vocoder-based simulation of CI signal processing was used to evaluate the efficacy of the proposed technique.
- 42 normal hearing users participated in the study.
- 14 unique frequency-place maps of actual CI users tested. Each map was tested with 3 participants and results were averaged.
- Speech recognition was assessed using four sets of test materials: vowels, consonants, IEEE sentences in quiet, and in +10 dB SNR.
- 4 mapping conditions were tested:
  - **Cond. 1: Ideal CI position, default filters**
    - Analysis filters = default ACE, Synthesis filters = default ACE
  - **Cond. 2: True CI position, default filters**
    - Analysis filters = default ACE, Synthesis filters = image-based filters
  - **Cond. 3: True CI position, proposed filters**
    - Analysis filters = custom filters, Synthesis filters = image-based filters
  - **Cond. 4: True CI position, exactly matched filters**
    - Analysis filters = image-based filters, Synthesis filters = image-based filters

4. Results

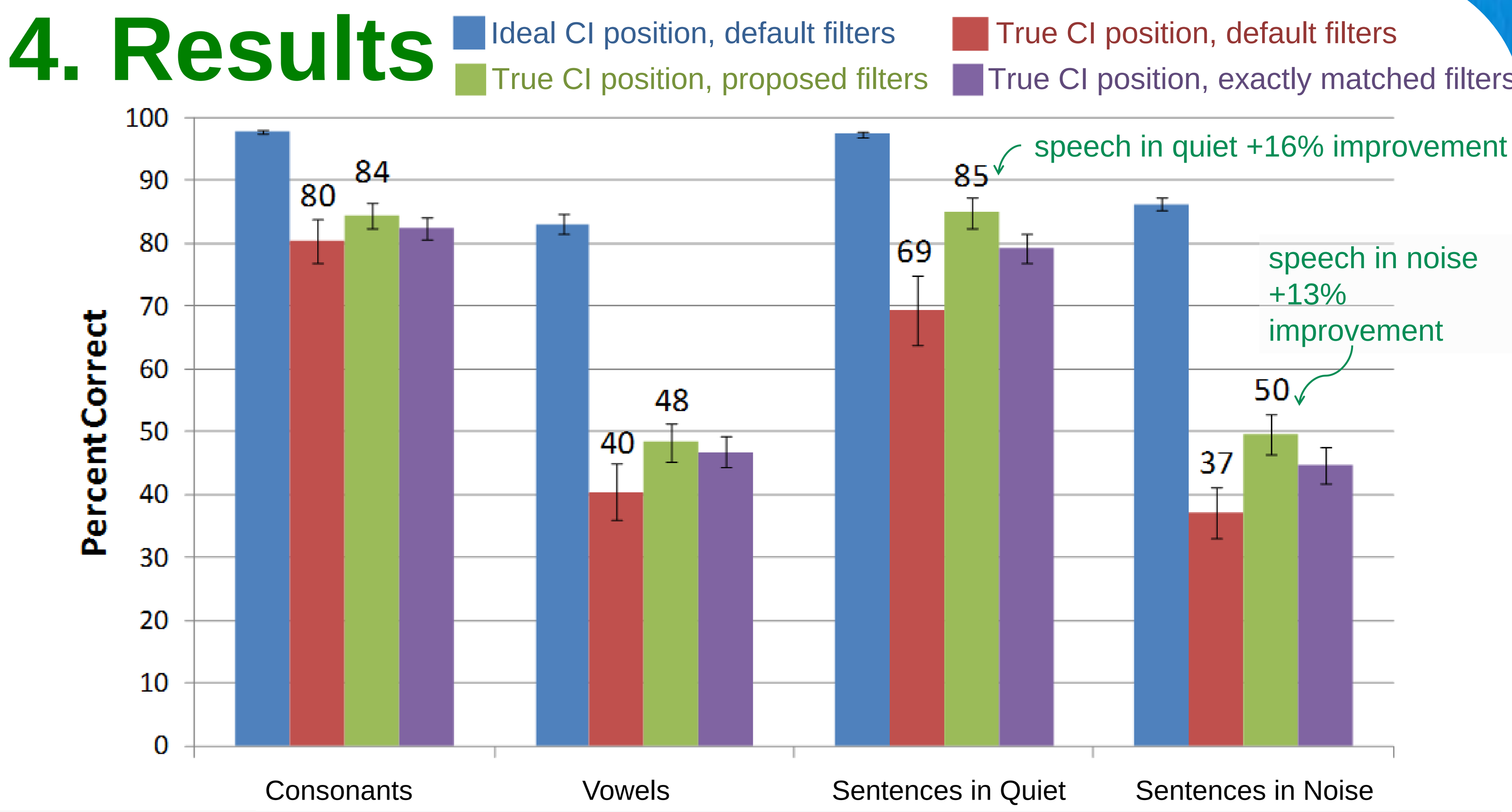

Fig. 2: Percentage correct scores for speech recognition in different test conditions – Simulation data from 42 normal hearing individuals.

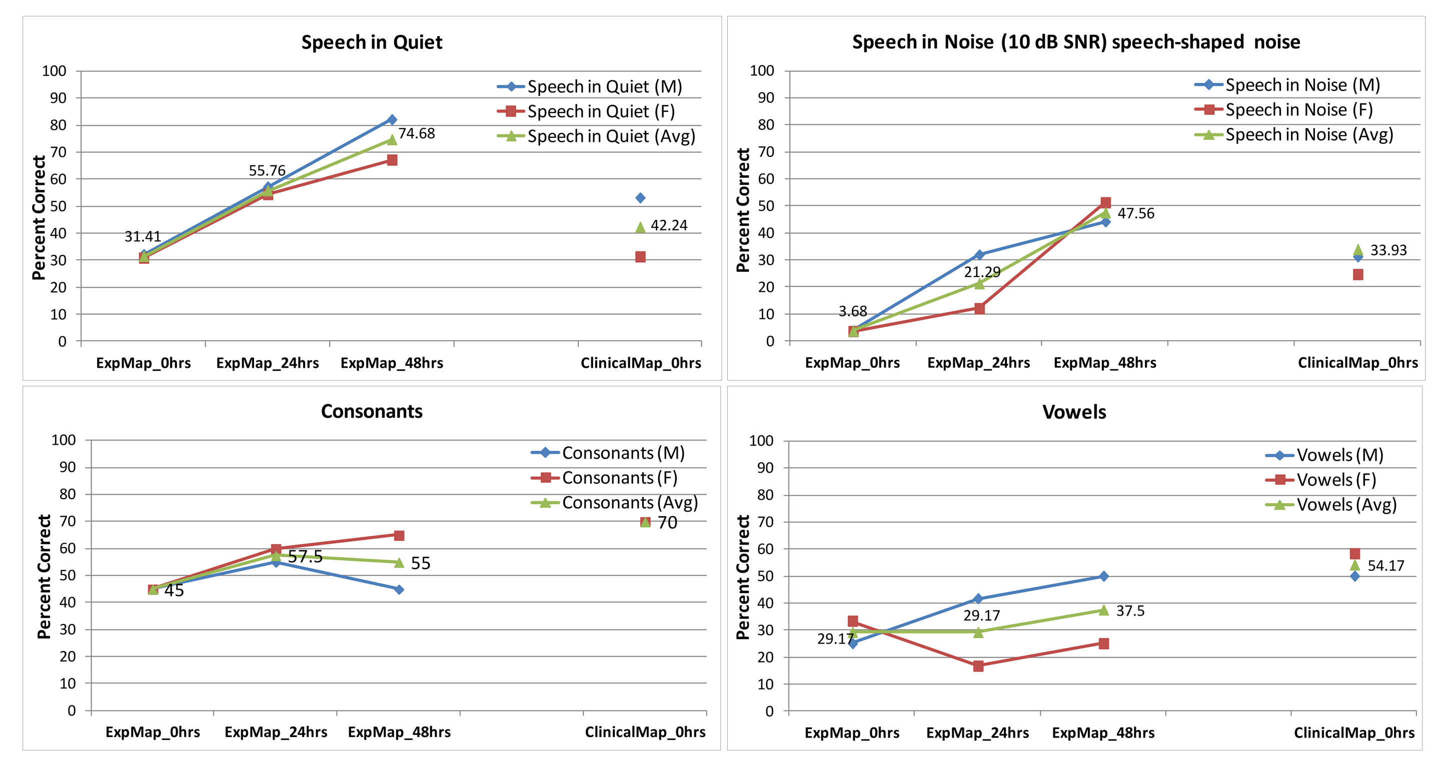

Fig. 3: Pilot data from 1 CI user tested over a period of 48 hours.

5. Conclusions

- Lack of knowledge on the spatial relationship between electrodes and stimulation sites has resulted in a generic ***one-size-fits-all*** frequency mapping paradigm with the hope that CI users will learn to adapt to the incorrect frequency locations of stimulation.
- The proposed solutions optimize sound processing and fitting based on an individual's cochlear physiology and true location of electrodes.
- The current data suggest that user customized frequency maps can potentially aid in achieving higher asymptotic performance and possibly faster adaptation to electric hearing.

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