Fast Model-Based Fitting through Active Data Selection

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Abstract

THE current trend of model-based fitting refers to setting hearing aid tuning parameters (e.g. compression ratios, thresholds and time constants) to values that maximize a utility metric averaged over a representative database. As a rule, a large set of preference data for an individual patient is needed to train his unique utility model. Clearly, this is a situation that is not conducive to an efficient audiology practice. In this paper, we report on a novel approach to accurate model-based fitting that needs few measurements from an individual patient. Our method is based on the observation that, for fitting purposes, we are not interested in an accurate utility model for all possible tuning parameter values. Instead, we are only interested in the values for the tuning parameters that maximize the utility model.

Problem Statement

- Given is:
  1. a patient
  2. a Hearing Aid (HA) algorithm $y = H(x, \theta)$ with tuning parameters $\theta \in \Theta$.
  3. a database $\mathcal{X} = \{x_1, \ldots, x_K\}$ of interesting sound samples.
- The (fitting) goal is to find the most preferred parameter value $\theta^* \in \Theta$ for a patient, relative to database $\mathcal{X}$, subject to minimal burden on the patient.
- Example: (10 dim.) $\theta = [\underbrace{CR, TA, TR, CT}_{\text{agc}}, \underbrace{G_{min}, TA, TR, VAD}_{\text{noise suppr.}}, \underbrace{\Delta f, \Delta t}_{\text{analysis}}]$ and 5 interesting values (very low, low, medium, high, very high) per parameter. Let $\mathcal{X}$ consist of 5 minutes of audio data.
  - One sure Solution method: we present the HA-processed database $\mathcal{X}$ to the patient, for every candidate parameter value θ in Θ, and request his 'satisfaction rating'. Pick the parameter θ^* with largest rating.
  - This fitting algorithm takes $\frac{5^{10} \times 300}{3600 \times 24 \times 365} \approx 93$ years!
- If we want to lessen the burden on the patient (yes we do), we will inevitably be left with uncertainty about the optimal parameter values.
- In this poster, we report on ongoing research to do fitting (ie, finding θ^* *and an estimate of its uncertainty*), while limiting patient burden to about 15 simple listening events.

Approach

We have developed a model-based optimization approach (called: HearClip) where measurements on patients (e.g. audiogram, SNR loss, preference listening tests) are converted to preferences for HA tuning parameters without loss of information See Fig.1).

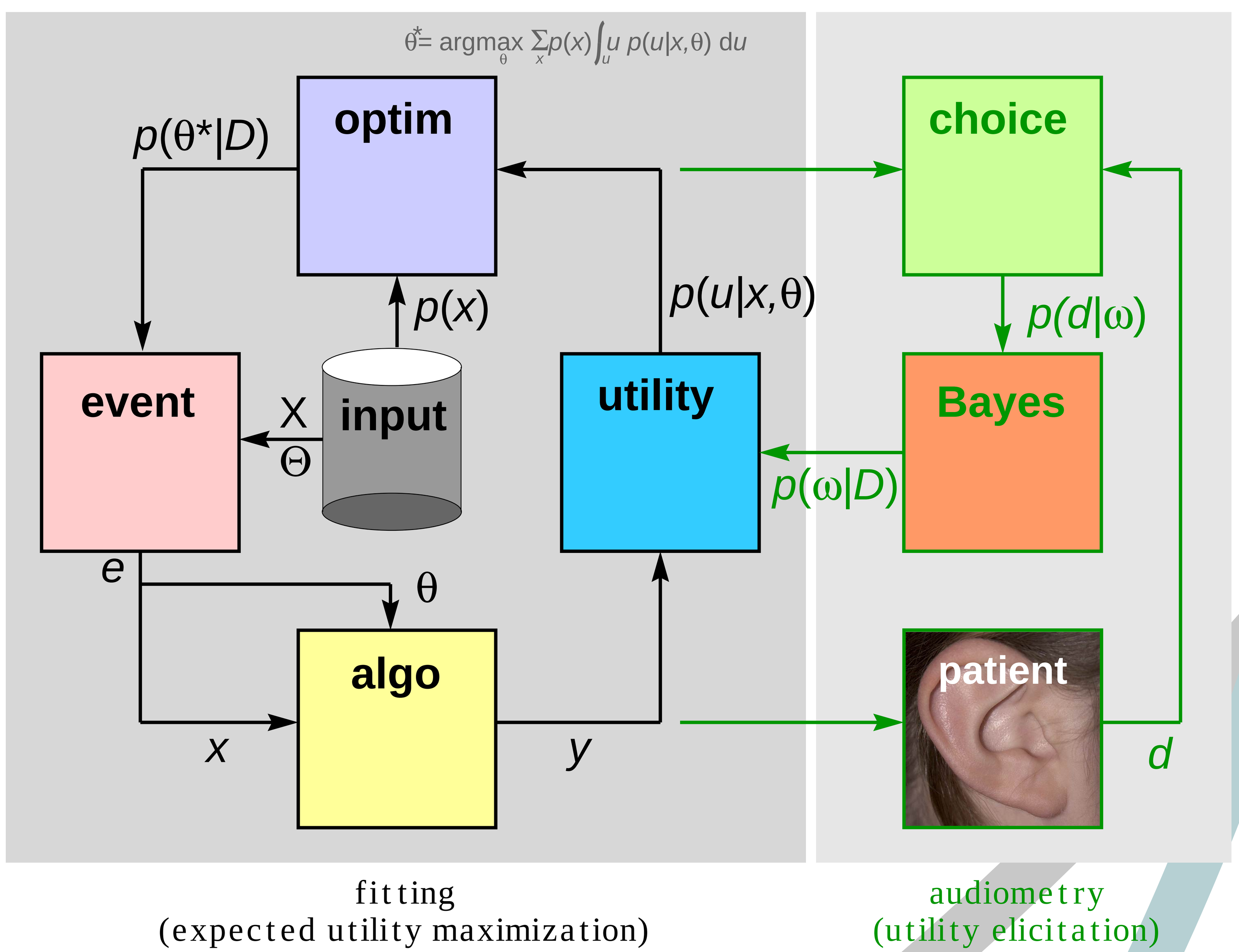


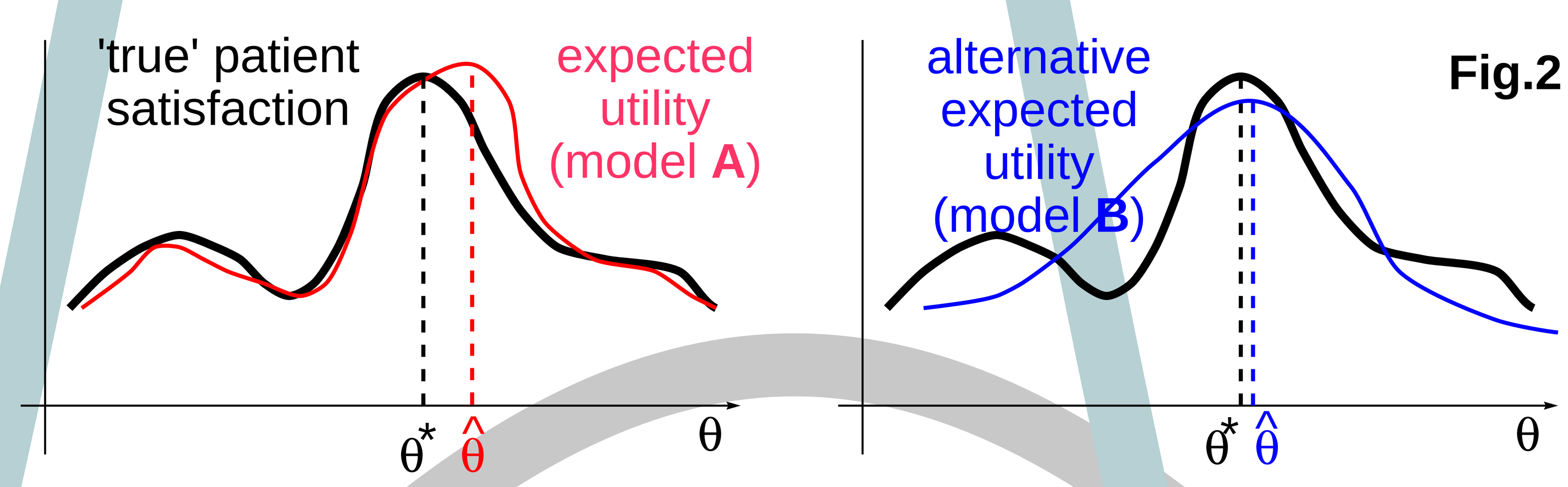
Figure 1: *Flow diagram for fitting based on the HearClip model.*

- **(utility elicitation)**. First, a utility model $u = U(y, \omega)$ is trained to predict patient satisfaction ratings. See also work on quality/intelligibility models by, a.o., Kates/Arehart (this conf.) and database collection by Houben et al. (this conf.).
- **(expected utility maximization)**. Next, the expected utility (sum of utilities over database $\mathcal{X}$) is maximized w.r.t. θ.
- We use a completely probabilistic (Bayesian) modeling approach to properly account for all uncertainties and response inconsistencies, thus supporting active selection of listening events that are most informative for utility elicitation and/or expected utility maximization (see next section). +
- **(personalization)**. The utility function will not be accurate for each unique patient. Therefore, during the optimization stage, in areas of large uncertainty about the expected utility, we allow maximal 15 direct patient evaluations for personalized optimization.
- Total patient burden of this fitting algorithm is now maximal 15 evaluations.

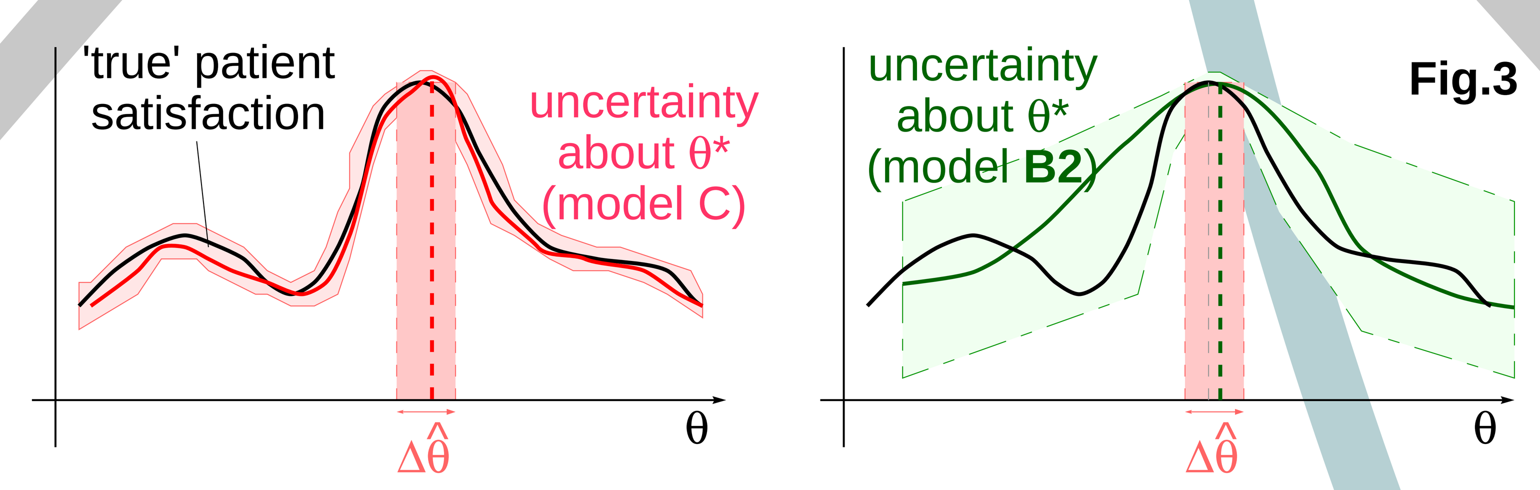
Active Data Selection

The number of requested patient evaluations can be drastically reduced on the basis of the following observations.

- All utility function evaluations can be executed before the patient enters the clinic.
- Bayesian approach allows to pick at any time the most informative next listening experiment.
- We do not care about the shape of the expected patient satisfaction function away from the maximum location. Fitting is an optimization rather than a regression problem. $\Longrightarrow$ we can use a much simpler response surface function for optimization (see Fig.2).



- Since we are only interested in accuracy around maximum utility, we do not need to spend computational resources on reducing uncertainty away from the maximum (see Fig.3).



Experimental Validation

Simulations of experiments are ongoing. Early results indicate that personalized optimal fitting is possible with very few pairwise comparative evaluations on a given patient. Active data selection reduced our dataset of 576 stored comparisons to less than 15, while predictive performance stayed the same. Ask me for more recent results and details.

acknowledgments

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