Hearing Aid Fitting With a Genetic Algorithm*

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* Patent pending.

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- ...and many others

Motivation

- Increasing hearing aid processing power enables sophisticated signal processing with many (interacting) parameters.
  - Even after initial prescriptive fitting, parameters must be further optimized subjectively.
  - Simultaneous adjustment of several parameters yields too many settings to be tested.

Motivation

- The genetic algorithm (GA) is a promising solution.
  - Allows automated, in-field…
    - fine tuning of prescriptive parameters and
    - search for good subjective parameter settings

Background: Genetic Algorithms

- GAs borrow biological concepts such as natural selection, mutation, and crossover
- Parallel search
  - Refines a “population” of solutions
- Stochastic
  - Solutions chosen randomly for refinement, with higher quality solutions more likely to be chosen
  - Refinement method chosen randomly: global and local search
- Can work well on multimodal and discontinuous surfaces

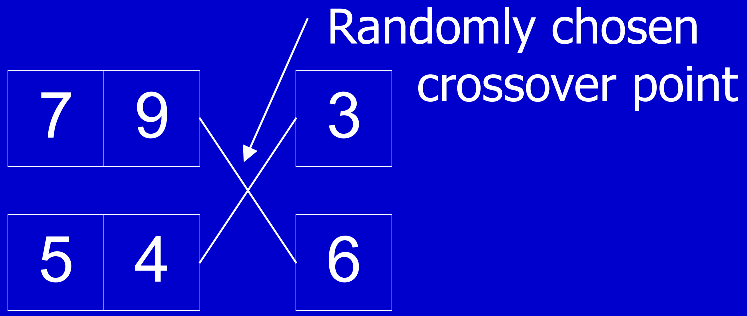
Crossover and Mutation

3 parameters

7	9	3

5	4	6

2 genes or hearing aid memories



7	9	6

5	4	3

New genes

7	9	6

Original gene

+2	-1	0

Random mutation

9	8	6

New gene

Background: Adaptive Fitting

- Neuman *et al.* (1987): Compared 3 adaptive methods
  - Simplex, double elimination, and iterative round robin
- Takagi and Ohsaki (1999)
  - GA hearing aid fitting in compressive amplification space, level × frequency → level, sum of 2-D Gaussian distributions
  - Population size 20
  - 5-level absolute scale

Background: Adaptive Fitting

- Improvements beyond (Neuman, 1987)
  - Cope with higher dimensionality (3-6^+ vs. 2)
  - Cope with multiple local optima
  - Combine attributes of multiple genes/memories
- Improvements beyond (Takagi, 1999)
  - Switched from absolute scaling to paired comparisons (dominance judgments) for easier in-field use

Methods

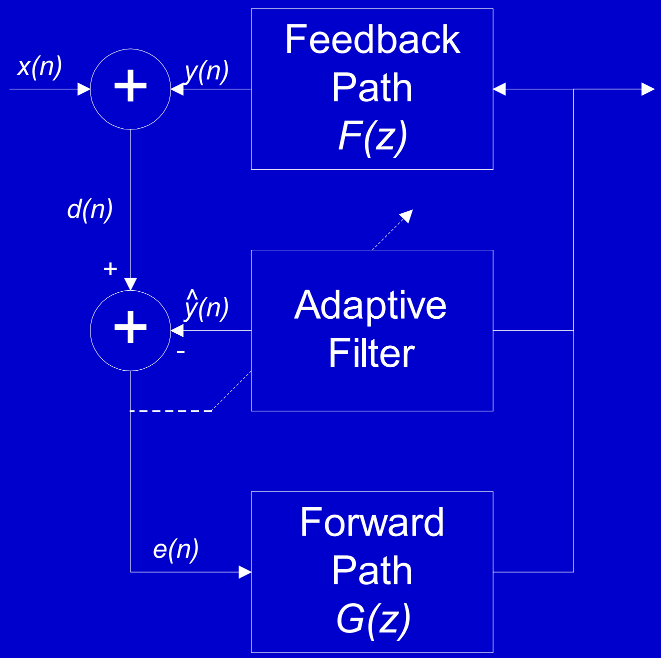
- Inferencing via paired comparisons
- Data collected
  - Alternatives in each pair
  - Decisions
  - Listening time
  - GA actions

Methods: Portable Prototyping Device and User Interface

- Motorola 56303 DSP
  - Up to 66 MHz
  - 8 k × 24 b on-chip RAM
- 32 kB non-volatile, field-writable memory
- 2-color LED
- Connects to custom ear modules
- Runs for about 4 hours on 3 AAA batteries

Methods: Feedback Canceller Fitting

- Cancel acoustic feedback using a digital filter
- NLMS filter
  - L – filter length
  - α – adaptation time constant
  - ρ – update decimation factor



Methods

- Subjects
  - 8 experienced hearing aid users w/ mild/moderate losses
  - 8 normal hearing
- Instructions
  - Toggle between 2 genes/memories
  - Create feedback (subjects were told how to do this)
  - Evaluate cancellation **and** sound quality/artifacts
  - Make a selection (algorithm then chooses 2 alternatives for next comparison)

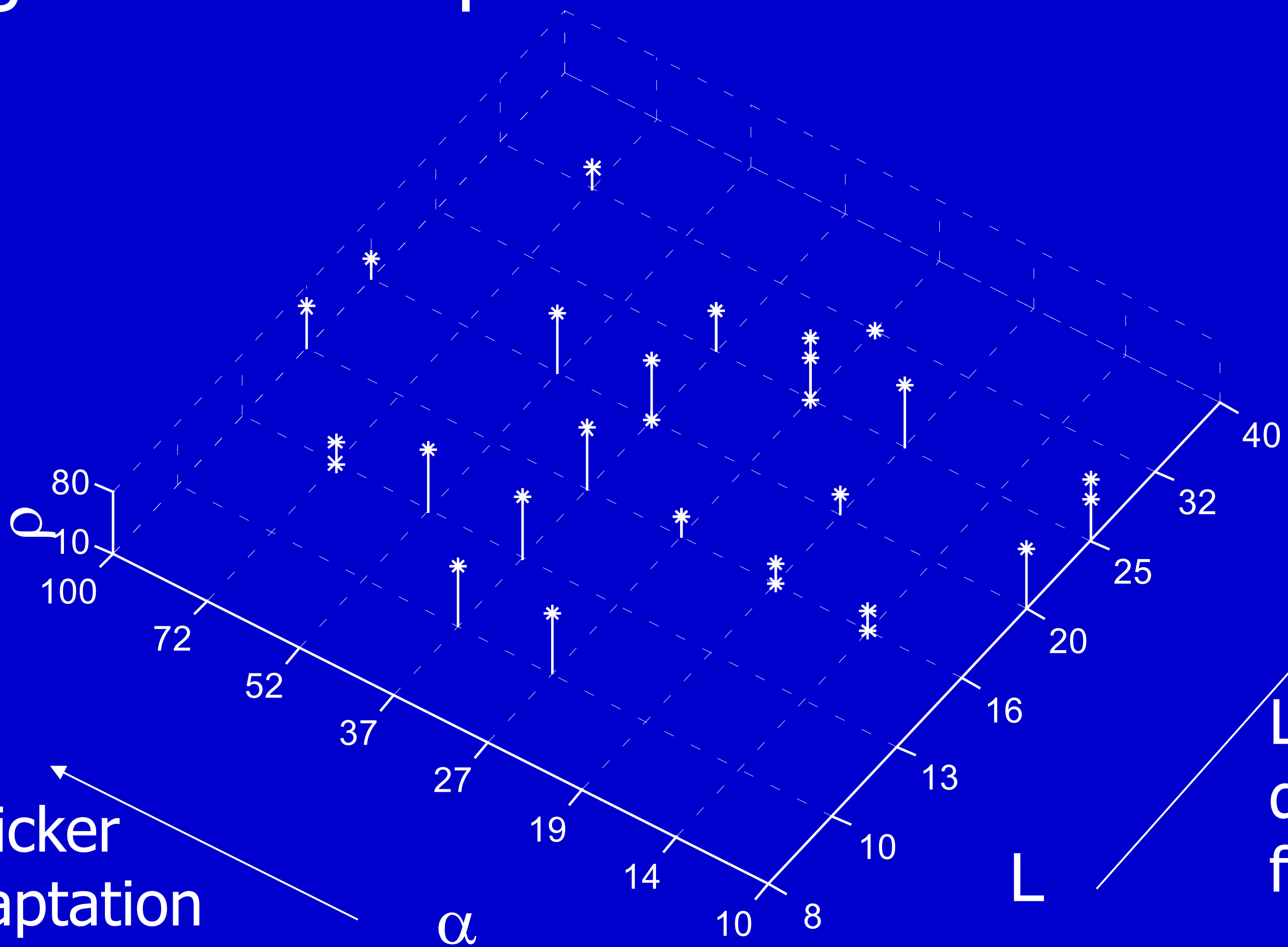
Results: Measures of Success

Type	Examples	Pros	Cons
Objective / Direct	Gain margin	Direct, rigorous	Limited scope
Indirect / ensemble	Population variation	Derivable, simulatable	Abstract, indirect

Results: Favorite Solutions for Hearing Impaired

- Average of 50 comparisons

Less frequent filter updates



Quicker adaptation

Longer digital filters

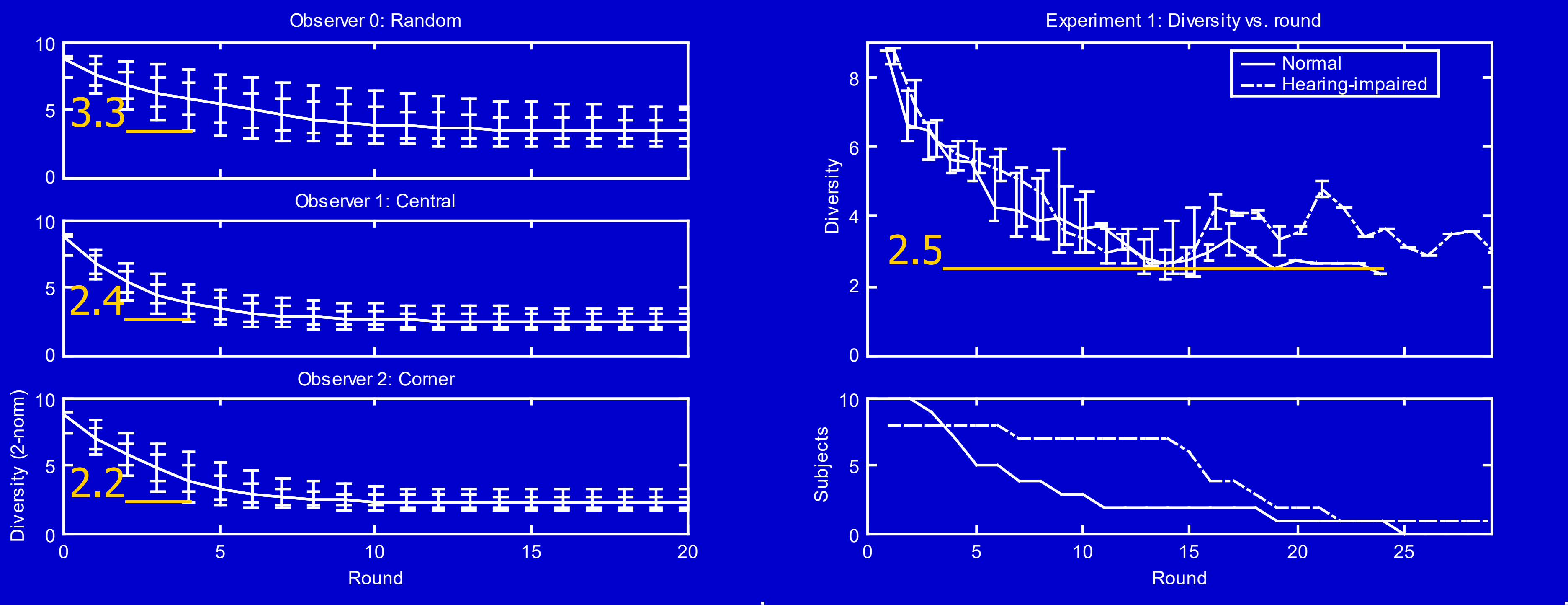
Note: f_s = 20 kHz

NLMS Gain Margins for Hearing-Impaired Subjects

Subject	1.0 kHz	1.6 kHz	2.5 kHz	Mean
I1	6.1	13.3	10.6	10.0
I2	10.0	10.1	13.3	11.1
I3	16.8	11.2	7.1	11.7
I4	11.6	14.4	10.9	12.3
I5	15.0	19.4	18.0	17.5
I6	12.4	12.9	13.9	13.1
I7	12.0	14.0	11.0	12.3
I8	15.3	14.3	12.5	14.0
Mean	12.4	13.7	12.2	12.8

Diversity for Feedback Canceller Fitting Experiment

- Ensemble performance is closer to simulated perfect rational observers than to random observers

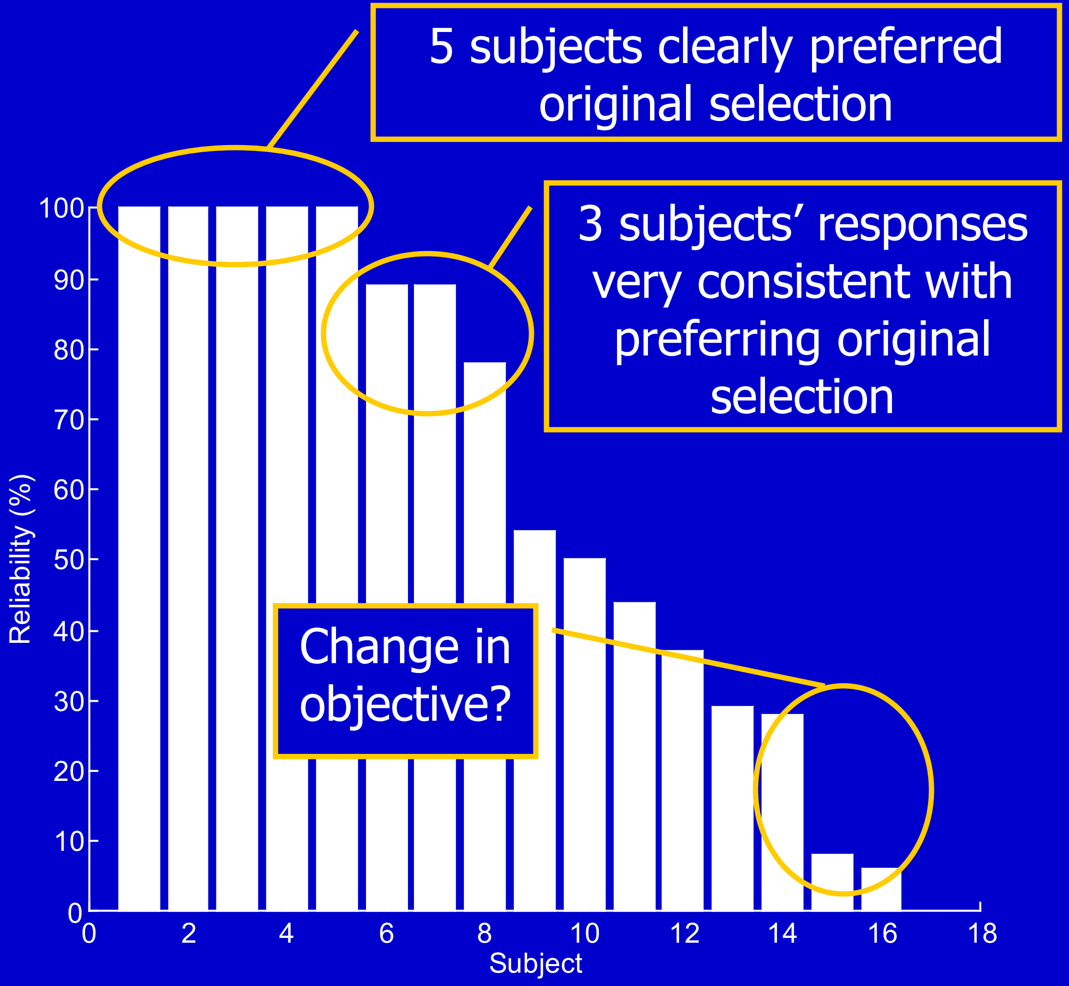


Feedback Canceller Fitting Follow-up: Reliability

- Each subject compared his or her favorite setting and 4 settings representative of the favorites across all subjects
- Total of 20 comparisons
- Subjects indicated preference
- Subjects ranked similarity on a scale of 1 (“clearly different”) to 5 (“identical”)

Feedback Canceller Fitting Follow-up: Reliability

- An "optimal" ranking of the alternatives was determined for each of the 16 subjects based on their responses



Multiband Expansion Fitting

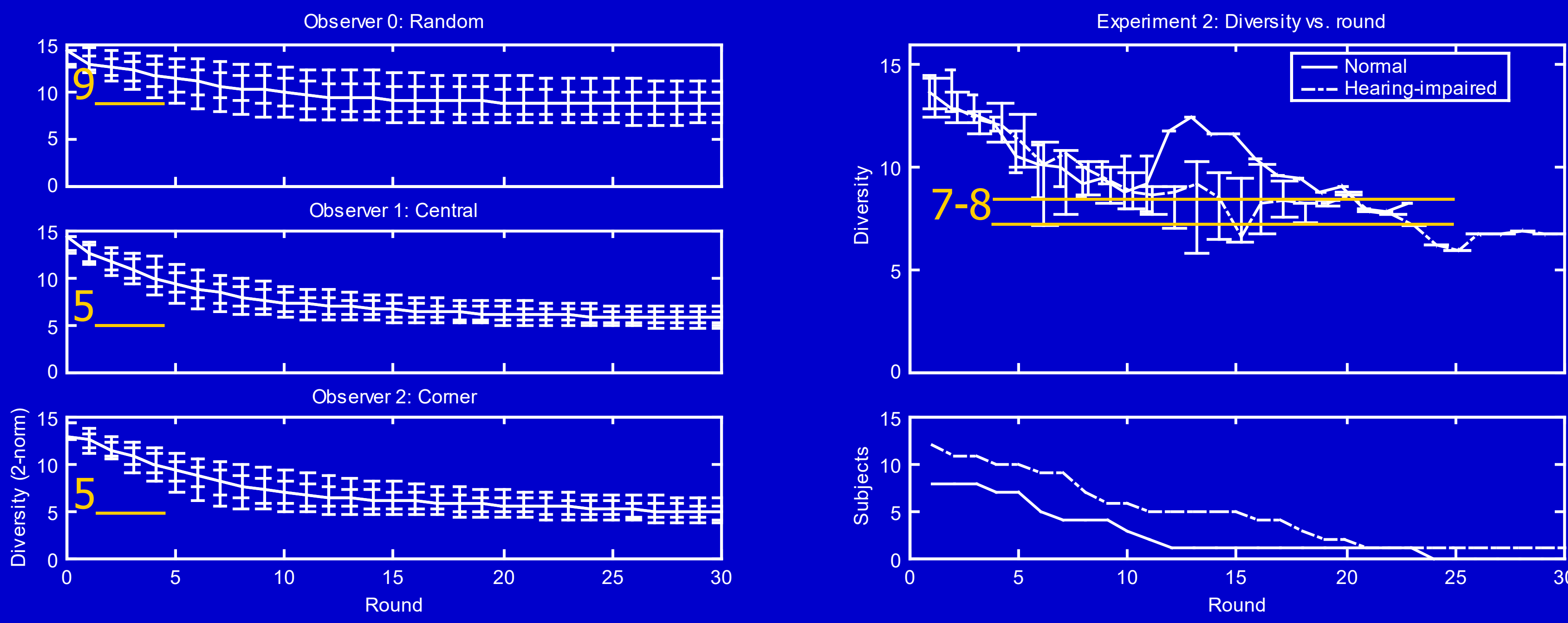
- Goals
  - Test the method at higher dimensionality
  - Test with an idiosyncratic component
- We experimented with slow acting expansion, on which much less prior work has been done and which seems to primarily affect subjective quality.
- 8 hearing-impaired and 8 normal hearing subjects

Multiband Expansion Fitting: 6 Parameters Varied

- Expansion ratios in 3 bands
- Signal level estimation time constant
- 2 parameters controlling expansion thresholds in 3 bands

Diversity for Multiband Expansion Fitting Experiment

- Ensemble performance is between simulated perfect rational observers and random observers.



Repeatability for Multiband Expansion Fitting Experiment

- Four HI subjects reran the experiment from different initial populations. Each subject's favorite solutions from both runs were compared.
- For each parameter, we computed a statistic measuring the difference between the solution for run 1 and run 2.
- Even though many runs were short, 2 parameters were controlled with 80% confidence.

Param.	Dev.	p
time const.	1.42	0.8
mid-band XR	1.66	0.8
Exp. thresh.	1.94	0.7

Summary and Conclusions

- First experiment – feedback cancellation
  - Most users found reliable settings
  - Preferred settings varied greatly between users, but all provided roughly equivalent gain margin
  - Non-random performance
- Second experiment – multiband expansion
  - Users found repeatable settings for 2-3 parameters
  - Results not as strong as in first experiment due to increase in complexity and parameter space oversampling (JNDs larger than estimated)

Future Directions

- Future work suggested by experimental results
  - Choosing optimal mutation rate (fixed or adaptive)
  - On-line adaptation of coarseness of parameter tilings in response to observed discrimination ability
  - Enhancing inferencing method to use some redundancy might improve performance for highly error-prone subjects
- Focus has been on in-field optimization, but the method could also be used:
  - Clinically
  - Or, for complete self-fitting of hearing aids