A New Metric to Evaluate Auditory Attention Detection Performance Based on a Markov Chain

Simon Geirnaert, Tom Francart, Alexander Bertrand

Evaluating Auditory Attention Decoding

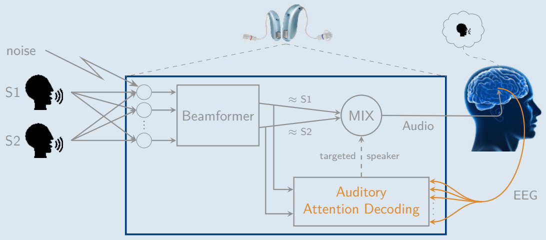
Auditory Attention Decoding

Current hearing aids

✗ lack information on the targeted speaker in a 'cocktail party' scenario

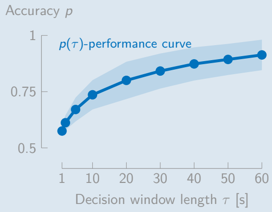
Solution

Auditory attention decoding (AAD) algorithms infer the auditory attention of the user from the electroencephalogram signal



Performance Evaluation

AAD accuracy depends on decision window length ($p(\tau)$-performance curve)



Issues:

- difficult statistical comparison
- contradicting conclusions depending on decision window length
- arbitrary choice of reported decision window length/accuracy

What decision window length is relevant?

Goal

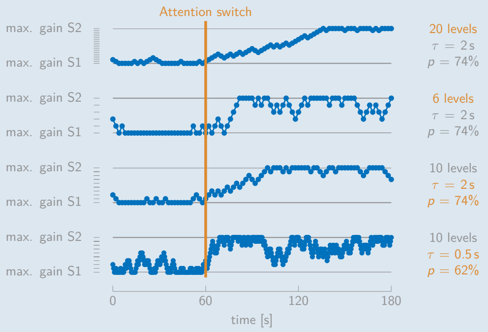
Develop a new single-number performance metric for AAD algorithms that is interpretable in the context of AAD-based adaptive gain control and resolves trade-off AAD accuracy and decision window length

AAD-Based Adaptive Gain Control

Design Adaptive Gain Control System

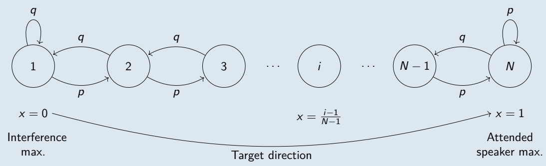
An attention-tracking gain control system has two crucial design issues:

1. How many gain levels should we use?
2. How often should we take a step?



Markov Chain Model

Adaptive gain control system can be directly translated into Markov chain:



Adaptive gain control system	Markov chain
gains	states $x \in [0,1]$
number of (relative) gain levels	number of states N
AAD accuracy	transition probability p
decision window length	step time τ

Two crucial design issues = optimization Markov chain parameters:

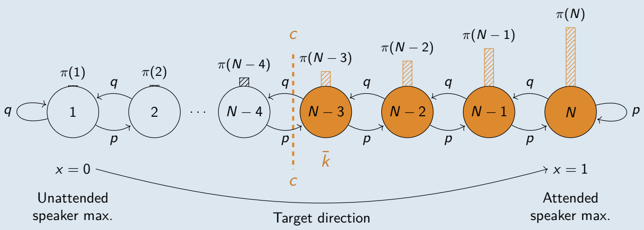
1. Number of states N
2. Optimal working point $(\tau_{\text{opt}}, p_{\text{opt}})$ on $p(\tau)$-performance curve

Optimization Markov Chain Parameters

Optimizing Number of States N

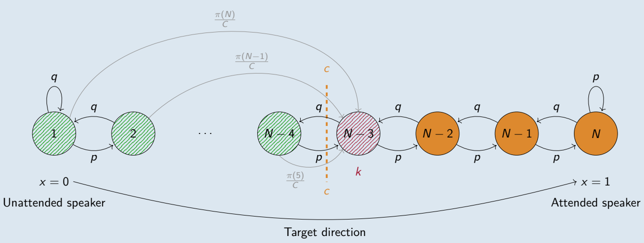
Two design constraints:

- Minimal number of states $N_{\text{min}} = 5$
- Lower bound P_0-confidence interval $\bar{x}$ larger than comfort level c



Finding Optimal Working Point $(\tau_{\text{opt}}, p_{\text{opt}})$

Minimize the expected switch duration (ESD) over the $p(\tau)$-performance curve, with the ESD the expected time needed for a stable gain switch after an attention switch of the user



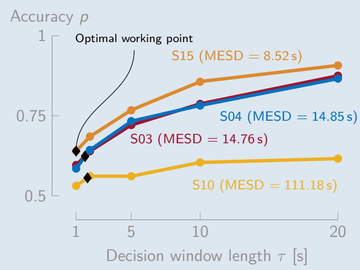
Definition MESD Metric

The minimal expected switch duration (MESD) is the expected time required to reach a predefined stable working region defined via the comfort level c, after an attention switch of the hearing aid user, in an optimized Markov chain as a model for an adaptive gain control system. Formally, it is the expected time to reach the comfort level c in the fastest Markov chain with at least N_{min} states for which $\bar{x} \geq c$, i.e., the lower bound $\bar{x}$ of the P_0-confidence interval is above c:

$$\text{MESD} = \min_{N,\tau} \text{ESD}(p(\tau), \tau, N)$$
$$\text{s.t. } \bar{x} \in [c, 1]$$
$$N \geq N_{\text{min}}$$

Illustration: MESD-Based Performance Evaluation

The MESD, with $c = 0.65$ and $P_0 = 80\%$, applied to the $p(\tau)$-performance curves of an MMSE-based linear AAD decoder applied to four subjects



Conclusion: the relevant working region is at small decision window lengths, despite low AAD accuracy