Mathematical Formalization and Parameter Estimation for Cognitive Models with Instance-based Learning

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Abstract: Quantitative analysis and modeling of higher-order cognitive processes, e.g. problem solving, for patients with cognitive deficits like schizophrenia can lead to a more efficient diagnostic of their cognitive performance and a better understanding of the transformation of the underlying cognitive processes.

Most cognitive models contain adaptable parameters, which can be used to adopt the model's behavior to individual differences. This flexibility, however, makes it difficult to intuitively understand the model behavior because of the wide range of possible parameter combinations. Thus, in order to investigate the dependence of the model's behavior from the parameters, systematic methods are necessary, but have not been applied to such models yet.

We choose a derivative-based optimization approach, which makes it possible to deal with more complex processes. This approach requires a mathematically tractable formulation of cognitive models, however. We used the cognitive architecture ACT-R as a framework for cognitive models and implemented models with instance-based learning, which allows the transfer to similar tasks.

As the ACT-R architecture unfortunately contains many logical statements and absolute value expressions, we smoothened those non-differentiabilities and generated a time-discrete formulation. With a modular Python implementation of this reformulation, we conducted simulations including stochastic components and parameter sensitivity analyses for several models.

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