Predicting Individual Human Reasoning: The PRECORE-Challenge

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Short Summary

Most computational models of cognition are based on aggregate data. In recent years, skepticism about group-to-individual generalizability has begun to emerge (Fisher, Medaglia, & Jeronimus, 2018). Simultaneously, results have shown that the current state in modeling reasoning is approaching a ceiling caused by the focus on aggregation (Riesterer, Brand, & Ragni, 2018). The time is ripe to adopt a new perspective on the challenge of cognitive modeling: how to model the individual reasoner. In addition to explaining aggregate data from training datasets, computational cognitive models can adapt to an individual by integrating knowledge about past responses into the prediction mechanism. This workshop will tackle conceptual, computational, theoretical, and methodological challenges in modeling individual reasoning behavior. A recent methodological advancement in assessing both aggregate and individual reasoning behavior, the Cognitive Computation for Reasoning Analysis (CCOBRA) framework, will be used to propose a new competition for theory-driven computational models of individual reasoning behavior. This workshop, and its underlying theoretical challenge, invites participants from cognitive science, AI, and all related fields to learn to build computational models of individual reasoners.

Core challenge: Modeling individuals

How can cognitive scientists build robust simulations of individual reasoners? This workshop will address the theoretical and methodological challenges in developing PREdictive, individualized COgnitive models of REasoning – the PRECORE Challenge. An orthodox methodology for fitting cognitive models to a dataset concerns a two-fold procedure: a given cognitive model's parameters are set by learning to predict the outcomes from a training dataset, and then it is applied to a novel dataset that the model never encountered before. The methodology is often used to build models of aggregated behavior form multiple individuals, but in principle, it can be applied to assessing individual reasoning behavior as well. The Cognitive Computation for Behavioral Reasoning Analysis (CCOBRA) framework is a benchmarking tool implemented in Python that actively integrates the individual human into the prediction loop. At its core lies a close connection to psychological experiments. Models are expected to simulate the experimental procedure for individual participants. They are presented with the same task in the same sequence with the same response options. By providing precise responses to individual tasks, models are evaluated based on their predictive accuracies. In the CCOBRA framework, computational models are supplied with the true response, both in the training phase, as well as in the evaluation phase; in this way, models can learn a default set of parameter settings in training and then be used to detect individual strategies in reasoning in the evaluation phase to refine their predictions further. Models are allowed to train on a dataset consisting of tasks and the actual human responses of individuals not present in the evaluation data. Additionally, after predicting the response to a task, they are presented with the true response and thus allowed to adapt to an individual participant. Hence, CCOBRA extends the traditional cognitive modeling problem by moving beyond the level of aggregates. As a result, the challenge for computational cognitive models is more difficult, but the payoffs are greater, i.e., they can lean to the development of robust computational models of individual reasoning strategies and adapt to the constraints of individual reasoners.

Models are ultimately compared via their predictive accuracy on unseen data. If a model manages to hit the true response more often than another model, the CCOBRA framework assigns it a higher score. The framework operates in a domain-agnostic fashion, i.e., it is compatible with computational cognitive models based on symbolic, probabilistic, connectionist, or hybrid approaches. Hence, computational cognitive models in the CCOBRA framework are assessed and compared on a fair and neutral ground. The only requirements imposed by CCOBRA is an implementation based on Python and the capability of generating a precise prediction for a given task. The problem of overfitting will be tackled by computing the final evaluation scores on previously unreported data. Higher predictive scores in the CCOBRA framework correspond directly to a better grasp of the processes underlying an individual human reasoner's cognitive system. The project is entirely open-source and accessible via Github[1].

[1] https://github.com/CognitiveComputationLab/ccobra

Benchmarking data and example model implementations can be found in the repository. A companion website[2] exists which allows to quickly upload and evaluate model implementations without the need to install the framework.

A domain-general challenge

Cognitive scientists have built computational models that simulate a wide variety of reasoning behavior, e.g., reasoning about syllogisms, reasoning about relations, reasoning about sentences and propositions, and reasoning about causation. Theorists have built computational models of reasoning in only some of these domains – and they've constructed models of individual reasoners in only one of them. Hence, the challenge of analyzing individual reasoning behavior is acute. This workshop, and its underlying benchmarking methodology, seeks to develop domain-general solutions for developing models of individuals. Consider the domain of syllogistic reasoning, for instance. Syllogisms are problems built from categorical assertions of the form "All of the As are Bs" and "All of the Bs are Cs". Reasoners deduce conclusions from syllogisms by comprehending two premises responding to the prompt: "What, if anything, follows?" Most reasoners generate spontaneously generate a conclusion of the form "All of the As are Cs" to the two premises above. As a recent meta-analysis shows, some syllogisms are easy, and some are difficult (Khemlani & Johnson-Laird, 2012). The same meta-analysis showed that twelve theories syllogistic reasoning had difficulty explaining the variation reasoners exhibit. The problem is endemic to computational models of reasoning: many of them perform well on aggregated data, but they they are unable to account for the individual differences that become relevant when attempting to predict how individual reasoners respond to various problems (Riesterer et al., 2018). Models in all reasoning domains are presently have an upper bound by the most frequent response.

Goals and Scope

The central goal of the workshop is to encourage and enhance cognitive modeling of syllogistic reasoning on an individual level and discussions by researchers of such diverse fields of cognitive science as psychology, AI, linguistics, and philosophy. Participation is possible by any of the following: Presenting a 15 minutes talk about cognitive modeling (please send us an email by July, 1), submitting a model for the modeling task in CCOBRA, discussing statistical analysis of aggregated vs. individual reasoning, or providing any insights in the discussion for advancing the current state of modeling beyond the level of aggregate syllogistic data.

Workshop Organization

Marco Ragni is a DFG-Heisenberg fellow and associate professor at the technical faculty of the Albert-Ludwigs-University Freiburg and leads the Cognitive Computation Lab. His research interests include qualitative spatio-temporal reasoning, knowledge representation and reasoning, cognitive modeling, and complex cognition with a special focus on analyzing why and how human reasoning often deviates from classical logical approaches.

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[2] http://orca.informatik.uni-freiburg.de/ccobra/