HBM-view: Designing a Model Viewing Tool for Behavioral Scientists

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***Abstract*—In this paper we present relevant definitions and design considerations relevant to human-behavior modeling software. The guidelines presented here are based off of a user-survey and expert-panel review performed in development of the BehaviorSim model-building tool designed especially for use in behavioral science. Lessons learned through iterations of this tool and unique considerations for those targeting behavioral scientists are highlighted. Our initial survey of 12 behavioral scientists reveals the diversity of opinions and approaches to behavior modeling within the community and gives context to this emerging area of research. In addition to these guidelines, a theory-agnostic method for defining Human Behavior Models (HBMs) is proposed and techniques for supporting different modeling paradigms within a single user interface are discussed.**

I. Introduction

A. Problem Statement

The increasing prevalence of wearable technologies and user-behavior collection, behavioral researchers are becoming increasingly overwhelmed with data.

State-of-the-art user interface often predicts user behavior in order to preload data or to customize the application. Researchers have seen the potential for optimizing a behavioral intervention to suit not only the user, but also the context. Just-in-Time Adaptive Interventions (JiTAI) promise to provide the optimal nudge at the optimal time to aid users looking to change their behavior Imagine, for example, an anti-stress app which knows not to interrupt your work meetings, but also knows when to play your favorite song to help you relax on the drive home. Or consider a smoking cessation app that knows precisely when and where you are most likely to crave, and distracts you with a game of sudoku before you even realize you were about to want a cigarette. The impending wave of context-aware, affective computing applications seems to be the holy grail of behavior change, but researchers are increasingly finding that our models of human behavior are not ready. The search space of designing an intervention for even a single user can be prohibitively large,

Though the machine learning approaches which are enabling detailed behavior-prediction can be applied to behavioral research problems, the inner workings of these models often do not tell researchers much about how the human system works.

On the other hand, psychological models of human behavior act as a guide for behavioral scientists looking to predict behavior, but are rarely computational in nature - making their application in adaptive systems impossible.

A hybridization of these two approaches may allow researchers to leverage the strength of each as they are applied in adaptive behavioral interventions.

B. Human Behavior Modeling

A Human Behavior Model (HBM) is any computational model which attempts to define the human systems conversion of measurable contextual information into measurable behavior outcome. HBMs are a set which intersects the set of computational cognitive models, both sets include approximations of cognitive processes, but in contrast with cognitive models, HBMs put a greater emphasis on the measurable in and outflows of the human system. Cognitive models traditionally have focused on creating a comprehensible reprentation of cognitive processes, but HBMs have no such restriction and require only that a model define behavioral output as some function of contextual input. Thus HBMs include formulations which may not be considered a cognitive model. For instance, a model which offers little more than statistical relationship between contextual input and behavioral output may be considered an HBM.

For our purposes, we classify HBMs uncovered by our literature review into three classes based on intended application 1) Automation Agents - models developed to act as automated decision agents, 2) Emergent Behavior Studies - models developed to identify emergent behavior of a population, and 3) Cognitve HBMs - models developed for prediction and understanding of an individual's behavior. Note that these categories are not mutually exclusive - a single HBM could theoretically fufill all three roles, but the requirements for each category are quite different, and thus existing models in each category are usually quite different.

* TODO: how do HBMs address the issues raised in above problem statement? * why are they important for the future behavioral research? [?] * how do they fall short?

C. Existing Tools

Our review of existing tools and publications in the area of behavioral modeling has uncovered three types of tools: 1) Dynamical System Modeling Toolkits, 2) Cognitive Architectures, and 3) Agent Modeling Toolkits. Though each approach seeks to address the problem of human behavioral modeling, the intended use of the model is very different. Thus each approach makes an approximation of the human system from a different perspective, and the resulting models show little resemblence. These three types of tools are in partial alignment with the aforementioned three classes of HBMs.

1) Dynamical System Modeling: Works in this group focus on generalized model-building. Applications include network and business analysis as well as semi-physical system modeling. One might be able to use these systems for modeling a human agent, but a more rigid model architecture for organizing the flow of information is needed. One of the contributions of the behaviorSim toolkit is the implementation of a general structure of information flow through a human agent.

Specialized modeling toolkits are often developed to create a variety of more detailed models focused around a single modeling goal. This is precisely the goal of the behaviorSim toolkit. In this search specialized toolkits focusing on neurological simulation, molecular dynamics, product inventory flow, economics, astrophysics, neurological networks, and power system modeling were all encountered in this search. Works on more relevant topics such as social interaction and behavioral modeling are highlighted in the spreadsheet and warrant further investigation.

2) Cognitive Architectures: The next group is a large set of modeling toolkits which aim to create artificial intelligence through the modeling of cognitive processes. Though a well implemented artificial intelligence will serve as an excellent model of human behavior, such an implementation is far from feasible at this time. The behaviorSim toolkit takes a more empirical approach to modeling cognitive functions than existing cognitive architectures.

3) Agent Modeling: Agent modeling has proven useful in many industrial and commercial applications across multiple disciplines. Agent models are generally developed for one of two purposes: 1) to act as an intelligent actor in an automated task, or 2) to observe the emergent characteristics of many interacting agents. The behaviorSim toolkit does not aim to accomplish either of these goals. It is for this reason that the common BDI agent architecture is not suitable for modeling of human behavior based on empirical evidence.

II. Case Studies

Here we present findings from multiple iterations of development of a tool designed to help behavioral scientists forumlate computational models of human behavior. Evaluation at each step of this iterative process involved a small number of testers as guided by http://www.nngroup.com/articles/why-you-only-need-to-test-with-5-users/.

A. Paper-prototype Model-Building Task

A paper prototype served as the first iteration of the model-builder tool. This prototype was simply a quiz-style questionairre which ultimately resulted in a model. This questionairre was tested on small user group of both behavioral scientists and grad students, and was evaluated informally through discussion.

This prototype allowed us to identify the major challenges ahead early on. Namely, we found that careful choice of terminology was important, since some overlapping terms were the cause of significant confusion. Users also found the tasks presented much too challenging and strongly suggested the inclusion of an example model.

B. SBM Questionairre

In the second iteration we focused on a few key elements of the model building process to greatly simplify and shorten the modeling exercise. A context and behavioral outcome based on physical activity were given, and users efforts were focused on defining the inner workings of the human system within these constraints. In this iteration several survey items about the barriers keeping modeling and sim out of behavioral science were added to the questionairre.

Approximately 50 surveys were distributed following presentations on behavioral modeling and simulation at the Society of Behavioral Medicine's Annual Conferece. Out of these, approximately 12 surveys were returned. In general, users still had trouble with modeling exercise. Most did not stray far from the given example, and others provided very different solutions which do not fit the "engineer's view" of the problem.

In the survey questions participants reported that the mathematics and programming concepts required for developing simulateable models were overwhelming, and nearly all participants expressed a desire for increased collaboration between disciplines and software tools to help them apply and validate these methods.

C. behaviorSim Model-Builder v1

The behaviorSim Model-Building tool is a computational model-development environment aimed at behavioral scientists. In this iteration the modeling process is divided into the following five stages:

think - Write out an explanation of your model. How does it work? What are the constructs involved? What kind of information is coming into the model?

draw - Create an "information flow" path diagram to represent your theory. Draw the flow of information between constructs. What are the instreams to each, what are the outflows of each?

specify - How exactly can each construct be calculated from the inflows? Use a fluid-flow analogy or linear combination to define a starting function and then adjust weights, delays, etc until the construct behaves as you think it should. Do lots of thought experiments. What should each step response look like? What should each impulse response look like?