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Multiple Levels of Cognitive Modeling within Agent-Based Modeling

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1. Introduction

We are conducting basic research on the factors affecting the rise of conflict among peoples in an environment with multiple societies, cultures, and biomes. The decisions that some agents make are more likely to have a significant impact on the trajectory of our simulation than those of other agents. This implies that the fidelity of the decision-making process needs to be high in some cases in order to achieve cognitive plausibility and model accuracy. However, to use cognitively-plausible architectures such as Soar (Newell, 1990) or ACT-R (Anderson et al., 2004) to provide such high fidelity for all agents becomes computationally intractable. To meet our needs, we use a hybrid approach.

Our approach is to use agent-based modeling (Epstein, 2002; Luke, Cioffi-Revilla, Panait, Sullivan, & Balan, 2005) and to vary the sophistication of the agents' decision making process with the agent's level within the simulation's hierarchy of agents. This extended abstract describes our approach, results, and future work using an existing simulation.

2. Heterogeneous Agent-Based Modeling

We are building on RebeLand, an agent-based model of conflict developed by Claudio Cioffi-Revilla and Mark Rouleau (2009). RebeLand is a model of an isolated island populated by agents representing civilians and governments embedded within a governance hierarchy. Government agents perform administrative tasks in one of three distinct governance levels within the lone state of RebeLand: the state, the city, and individual level (i.e., police units). Civilian agents represent members of the general population that, when sufficiently aggrieved with their government, become rebel forces. RebeLand provides a laboratory to experiment with the complex social and environmental conditions leading to the generation and/or suppression of civil unrest. We describe below three levels of cognitive complexity and the modeling approaches we have implemented.

3. Many Simple Agents

At the lowest level of cognitive plausibility is the modeling of the general population. Individual agents simulating farmers are each represented by a small number of variables maintained from step to step and a small number of variables used only within a step. Examples of cumulative variables are wealth, employment status, and support for government. Variables that are memory-less include sufficiency of food resources and the threshold to rebel. These values are derived from the environment but are affected by decisions made by the city and state governments.

4. Some Rule-Based Agents

At the middle level are far fewer agents modeled using rules implemented in code: mobile rebels agents and the police forces created to combat them. Their behavior, specifically, direction of movement, interactions, and other behaviors are represented by rules. Rebels move toward geographic resources, the city center, or randomly, based on nearby events. Police forces generally approach rebel agents in their visual sensor range. The interactions, i.e., combat, between rebel and police forces reduce their respective numbers based on relative strengths.

5. Few Cognitive Agents

At the top level are the government decision makers. City-level decision makers are currently the most complicated agents and posses the most cognitively plausible modeling. These agents are more complicated in that they make decisions that affect citizens directly (such as decisions on tax rates, distribution of food and benefits to citizens) and decisions that affect citizens indirectly (the management of economic, environmental, and security issues). City decision makers use their tax base and state financial support to produce public policy in an effort to dampen the adverse affects of social and environmental issues upon the general population. Economic (i.e. inflation or unemployment) and environmental (i.e. flood or drought) issues are generated using an exponential decay function with Power Law-derived duration and severity values. In a tranquil governance climate, city decision makers possess all the resources needed to prevent rebellion. Whereas, in an extremely harsh scenario, resources are severely limited and government agents typically fail to placate their citizens, police units become overwhelmed, the state typically falls, and regime change results.

The other government decision maker is the state government agent. This agent currently plays a very limited role in routine government decision-making. The state is simply responsible for the redistribution of city revenue (through taxation) from cities possessing a surplus to cities in need of financial support.

Our current system uses rules implemented in code and bounded rational calculations to provide agents at this level with greater cognitive faculties. Greater cognitive faculties permit the exploration of complex problems beyond the current scope of RebeLand, such as ethnic tension amongst political units.

6. Results, Discussion and Future Work

The current RebeLand model exhibits regime change under a range of conditions with most agents modeled using ordinary differential equations, some modeled as rules implemented in code, and a few with rules and bounded rational calculations. Our future work is to (1) simplify the rules such that a basic rule interpreter can be used rather than code so that non-programmers can work with the models and (2) to model government decision-makers as individuals using a more cognitively plausible architecture. These advancements to RebeLand serve to capture more of the social and cognitive nuances involved in the production and management of civil unrest.

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JEFFREY K. BASSETT is a PhD student in Computer Science, Volgenau School of Information Technology and Engineering, George Mason University. Most of his research to date has focused on using Evolutionary Computation as a learning technique, with particular emphasis on using rule-sets to represent behaviors in teams of robots.