Chapter VIII

Modeling Cognitive Agents for Social Systems and a Simulation in Urban Dynamics

Yu Zhang
Trinity University, USA

Mark Lewis
Trinity University, USA

Christine Drennon
Trinity University, USA

Michael Pellon
Trinity University, USA

Phil Coleman
Trinity University, USA

Jason Leezer
Trinity University, USA

ABSTRACT

Multi-agent systems have been used to model complex social systems in many domains. The entire movement of multi-agent paradigm was spawned, at least in part, by the perceived importance of fostering human-like adjustable autonomy and behaviors in social systems. But, efficient scalable and robust social systems are difficult to engineer. One difficulty exists in the design of how society and agents evolve and the other difficulties exist in how to capture the highly cognitive decision-making process that sometimes follows intuition and bounded rationality. We present a multi-agent architecture called CASE (Cognitive Agents for Social Environments). CASE provides a way to embed agent interactions in a three-dimensional social structure. It also presents a computational model for an individual agent's intuitive and deliberative decision-making process. This chapter also presents our work on creating a multi-agent simulation which can help social and economic scientists use CASE agents to perform their tests. Finally, we test the system in an urban dynamic problem. Our experiment results suggest that intuitive decision-making allows the quick convergence of social strategies, and embedding agent interactions in a three-dimensional social structure speeds up this convergence as well as maintains the system's stability.

INTRODUCTION

In social environments, people interact with each other and form different societies (or organizations or groups). To better understand people's social interactions, researchers have increasingly relied on computational models [16, 40, 41, 42]. A good computational model that takes into consideration both the individual and social behaviors could serve as a viable tool to help researchers analyze or predict the complex phenomena that emerge from the interactions of massive autonomous agents, especially for the domain that often requires a long time to evolve or requires exposing real people to a dangerous environment. However, efficient, scalable, and robust social systems are difficult to engineer [3].

One difficulty exists in modeling the system by holding both the societal view and the individual agent view. The societal view involves the careful design of agent-to-agent interactions so that an individual agent's choices influence and are influenced by the choices made by others within the society. The agent view involves modeling only an individual agent's decision-making processes that sometimes follow intuition and bounded rationality [29]. Previous research in modeling theory of agents and society in a computational framework has taken singly a point of view of society or agent. While the single societal view mainly concentrates on the centralist, static approach to organizational design and specification of social structures and thus limits system dynamics [12, 16, 35], on the other hand, the single agent view focuses on modeling the nested beliefs of the other agents, but this suffers from an explosion in computational complexity as the number of agents in the system grows.

Another difficulty in modeling theory of agent and society exists in quantitative or qualitative modeling of uncertainty and preference. In the case of quantitative modeling, the traditional models like game theory and decision theory have their own limitations. Game theory typically relies on concepts of equilibria that people rarely achieve in an unstructured social setting, and decision theory typically relies on assumptions of rationality that people constantly violate [27]. In the case of qualitative modeling, there are three basic models: prescriptive, normative and descriptive [31, 37]. A prescriptive model is one which can and should be used by a real decision maker. A normative model requires the decision maker to have perfect rationality, for example, the classical utility function belongs to this category. Many normative theories have been refined over time to better "describe" how humans make decisions. Kahneman and Tversky's Prospect Theory [18, 34] and von Neuman and Morgenstein's Subjective Utility Theory [36] are noted examples of normative theories that have taken on a more descriptive guise. One of the central themes of the descriptive model is the idea of Bounded Rationality [29], i.e., humans don't calculate the utility value for every outcome; instead we use intuition and heuristics to determine if one situation is better than another. However, existing descriptive methods are mostly informal, therefore there is a growing need to study them in a systematic way and provide a qualitative framework in which to compare various possible underlying mechanisms.

Motivated by these observations, we have developed a cognitive agent model called CASE (Cognitive Agent in Social Environment). CASE is designed to achieve two goals. First, it aims to model the "meso-view" of multi-agent interaction by capturing both the societal view and the agent view. On one hand, we keep an individual perspective on the system assumed by the traditional multi-agent models, i.e. an agent is an autonomous entity and has its own goals and beliefs in the environment [5, 43]. On the other hand, we take into account how agent's decisions are influenced by the choices made by others. This is achieved by embedding agents' interactions in three social structures: group, which represents social connections, neighborhood, which represents space connections and network, which span social and space categories. These three structures reproduce the way information and social strategy is passed and therefore the way people influence each other. In our view, social structures are external to individual agent and independent from their goals. However, they constrain the individual's commitment to goals and choices and contribute to the stability, predictability and manageability of the system as a whole.

Our second goal is to provide a computational descriptive decision model of the highly cognitive