Social Network Analysis Applied to Agent-Based Modeling to Understand Social Withdrawal as an Emergent Property

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Abstract

Behavioral sciences are divided into two main categories: neural (information sciences) and social (relational sciences). Here we developed a new approach to join both categories by the social network analysis applied to agent-based modeling approach (which we used in a previous work to study biological and artificial multi-agent system). The neural category is represented by using an evolutionary robotics (ER) approach in agent-based modeling (based on previous studies of Candadai et al. (2019) and extending them using more embodied agents to compare the measures of internal neural complexity) and the social category is represented by social network analysis applied to social networks constructed from the agent-based model. This approach might be useful for understanding human behavior. In this paper we specifically focus on social withdrawal, which can be defined as a social phenomenon where an individual chooses not to interact with his/her peers. Our proposal is to study it from the perspective of complex systems and we will use this approach to test the hypothesis that social withdrawal can be understood as an emergent property of a complex system of embodied agents by varying the possible scenarios and measuring the interaction and isolation entropies as an index of internal complexity.

Introduction

Social network analysis (SNA) and agent-based modeling (ABM) have been useful tools to understand complex systems, however, there have been few studies using these two approaches in combination. Reséndiz-Benhumea et al. (in press) have applied SNA to ABM in order get new insights on the emergent properties of a complex system. They studied task allocation as an emergent property of swarm robotics inspired by ant foraging behavior. This approach might be well suited to understand human behavior, such as the social phenomenon known as social withdrawal.

Behavioral sciences

Behavioral sciences focus on cognitive processes within individuals and behavioral interactions between groups of individuals in a social system. These are divided into two main categories: neural (information sciences) and social (relational sciences). The former category is aimed at the information processing carried out by cognitive individuals embedded in social environments, this includes, for example, psychology, cognitive science and neural networks; while the latter category is aimed at interactions and relationships between cognitive individuals in a social system, this includes, for example, agent-based models, social networks and dynamic network analysis (Samantaray, 2017).

Evolutionary Robotics (ER) approach

Evolutionary robotics (ER) has been used as a scientific tool for studying minimal models of cognition. This approach allows to generate simulation models for experimental setup, where, generally, the behavior of each agent is determined by a continuous-time recurrent neural network (CTRNN) (Beer, 1995) and optimized by using an evolutionary algorithm (Harvey et al., 2005; Froese and Di Paolo, 2010).

Social interaction

Following ER methodology and an enactive approach of social interaction, Candadai et al. (2019) proved that interaction increases the complexity of an agent's neural activity and revealed that this cannot be achieved in isolation. They performed experiments on agent-based modeling and measured neural entropy as an index of internal complexity in different interaction conditions: by artificially evolving interacting pairs of agents (interaction entropy) and by artificially evolving isolated agents in the environment (isolation entropy). Furthermore, they measured the interaction entropy of an agent in the presence of agents under "ghost" condition, which means they were not able to mutually interact with each other. This led to a loss of internal complexity of "live" agents and proved that active interdependent interaction enhances their neural complexities.

Social withdrawal and isolation

Social withdrawal and isolation are defined as limitations in social interaction. The first one is characterized by the voluntary decision of the individual not to interact with others (associated to internal factors). On the other hand, the second one occurs when the others do not want to interact with the individual (associated to external factors). If not treated properly, both phenomenon can lead to depression, relationship difficulties and internalizing behavior problems, that can get worse later (Rubin and Coplan, 2004; Starr and Dubowitz, 2009). In this study, we are interested in understanding social withdrawal as an emergent property of a complex system of embodied agents in order to get insights that could help to reintegrate the affected agents.

Methods

We are going to use our model as opaque thought experiment, as defined by Di Paolo et al. (2000). Essentially, this perspective will help us make conceptual advances in our thinking about the space of possibilities.

Our proposal consists in joining the two categories of behavioral sciences, i.e. neural (information sciences) and social (relational sciences), by the SNA applied to ABM approach. The neural category will be represented by the ER approach in ABM, where, neural controllers of each agent will be modeled as CTRNN and its parameters will be optimized by using an evolutionary algorithm (extending the work of Candadai et al. (2019)). The social category will be represented by SNA applied to social networks constructed from the ABM (extending the work of Reséndiz-Benhumea et al. (in press)). This integration will lead to get new insights on the emergent properties of the complex system.

Briefly, we are going to replicate and extend the work of Candadai et al. (2019) by adding more embodied agents to the system, measuring and comparing the neural complexity under diverse conditions and scenarios. The simulated model will consist in a 2-dimensional environment and simulated mobile robots inspired by Di Paolo's acoustically coupled agents (Di Paolo, 2000). Agents' neural controllers will be modeled as CTRNN.

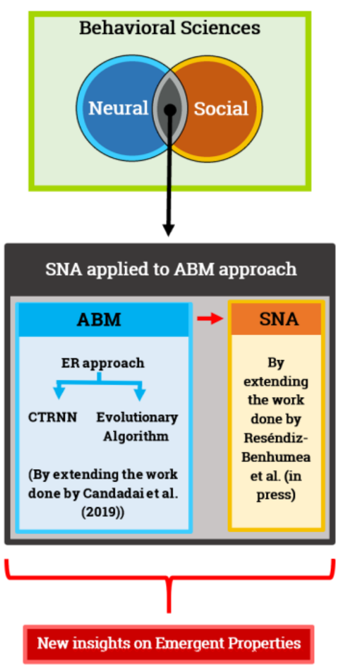

Figure 1: Proposed approach for studying social withdrawal in the context of complex systems. It will consist in joining the two categories of behavioral sciences by SNA applied to ABM approach in order to get new insights on emergent properties.

These embodied agents are going to be artificially evolved. Then, the obtained data related to interactions and neural complexity will be used to construct social networks. We will apply social network analysis to them in order to, finally, get the emergent properties of the system (extending the work of Reséndiz-Benhumea et al. (in press)). This approach is shown in Figure 1.

Although cognitive complexity has often been associated with brain size, an increase in brain size is neither a necessary nor a sufficient condition of cognitive complexity. We aim to show this by demonstrating that in our model the complexity of neural activity can be increased by social integration via embodied interaction. And, then, within this context, we ask whether this mechanism of social integration can scale with group size. Perhaps some agents will be less integrated, and we can investigate what effects this might have on their cognitive complexity by analyzing their neural activity.

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