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EVOLVING AGENT COGNITION WITH NETLOGO LEVELSPACE

Bryan Head[1,3], Arthur Hjorth[2], Corey Brady[2], and Uri Wilensky[1,2, 3]

Center for Connected Learning and Computer-Based Modeling
[1]Dept. of EECS, [2]Dept. of Learning Sciences, [3]Northwestern Institute on Complex systems
Northwestern University, 2133 Sheridan Rd, Evanston, IL 60208, USA

ABSTRACT

Any agent-based model (ABM) involving agents that think or make decisions must inevitably have some model of agent cognition. Often, this cognitive model is incredibly simple, such as choosing actions at random or based on simple conditionals. In reality, agent cognition can be complex and dynamic, and for some models, this process can be worthy of its own dedicated ABM. The LevelSpace extension (Hjorth, Head & Wilensky, 2015) for NetLogo (Wilensky 1999) allows NetLogo models to open instances of other NetLogo models and interact with them. We demonstrate a method for using LevelSpace to simulate agents with complex, evolving cognitive models. We give the agents in a NetLogo predator-prey model "brains," themselves represented as independent instances of a NetLogo neural network model.

1 INTRODUCTION

ABMs have proven to be a powerful tool for analyzing complex systems (Epstein 1999; Macal & North 2008). Much of their power derives from the fact that they allow modelers to examine the relationships between two levels of a system: the agent level and the aggregate level. However, while ABMs have historically been restricted to two levels, complex systems are generally comprised of many different levels. For instance, agent cognition is generally represented using abstract data structures rather than by leveraging the powerful visual and conceptual advantages of ABM. NetLogo LevelSpace solves problems like this by allowing many NetLogo models to interact in Multi-Level Linked (MLL) model systems, each model of which may independently exhibit emergent behaviors, nested within the larger complex system.

2 LEVELSPACE

LevelSpace allows NetLogo models to open instances of other NetLogo models. Once open, the parent model may then send commands and reporters to its child models to manipulate and retrieve information from them. These commands and reporters can be arbitrary pieces of NetLogo code and may take arguments, so that a parent model can send information about its own state to its child models. Finally, LevelSpace models can be chained: the child models may themselves use LevelSpace to open up and interact with instances of other models, enabling MLL systems with arbitrarily many nested levels to be created.

While LevelSpace itself is fairly simple in concept, it opens up a wide range of possible MLL system architectures. For instance, it allows modelers to connect related but separate models, such as a traffic model, a model of climate change, and a model of an ecosystem. It also allows hierarchical MLL systems, such as a model of the air transportation network connecting models of cities with airports. Finally, LevelSpace may be used to create models in which agent cognition is itself modeled as an ABM, as is demonstrated here. We accomplish this by creating two ABMs: one model represents an agent's cognition (in this case, a neural network model), the other contains the agents themselves (a predator-prey model).

3 MLL SYSTEM DESIGN

Our MLL system is based on the Wolf Sheep Predation model found in the NetLogo Models Library (Wilensky 1997). Wolf Sheep Predation is a basic predator-prey model consisting of wolves, sheep, and

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grass. Wolves eat sheep and sheep eat grass. Both may starve to death and both may reproduce when they have eaten a sufficient amount. Grass regrows at a specified rate. In the original model, wolves and sheep move in a random direction every tick of the simulation, regardless of their surroundings.

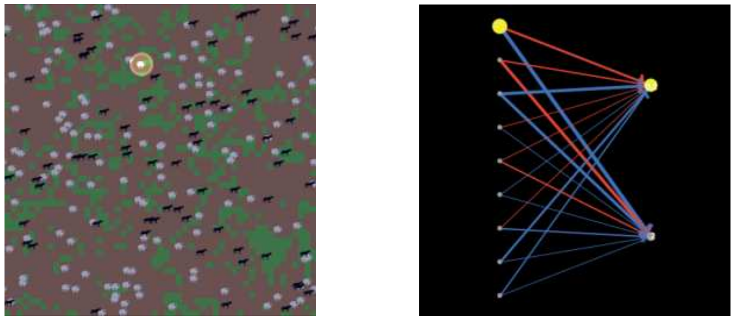

Figure 1: Left: The predator-prey model in the middle of a run with a sheep highlighted. Right: The highlighted sheep's neural network from the same moment. Red links are excitatory, blue inhibitory. Thickness indicates weight.

In order to give the agents more sophisticated behavior, we built a feed-forward, artificial neural network model in NetLogo to act as the agents' cognitive, stimulus-response model. It is a complete model that may be used on its own or integrated into other models using LevelSpace. Users may specify the number of layers, the number of nodes in each layer, and the weights of connections between the nodes.

In the predator-prey model, wolves and sheep each have their own instance of the neural network model. As animals are born and die, instances of the neural network model are created and destroyed. In order to be controlled by its neural network, an animal encodes stimuli from surroundings as a list of booleans, sends this list to the neural network's input layer, and then reads the resulting state of the neural network's output layer to determine its response. In order to allow for evolution, newly-born animals inherit the weights of their parent's neural network, mutating each weight by a small amount.

Because each of the animals' neural networks is a full-fledged NetLogo model, it can be easily visualized and interacted with, even while the predator-prey model is running. Thus, modelers can see exactly how a given agent's neural network responds to the agent's environmental stimuli.

4 CONCLUSION

LevelSpace opens up new possible architectures for agent-based modeling through MLL Systems. In particular, it enables the powerful technique of implementing agent cognition as a separate ABM integrated within a higher level system, as demonstrated here. This allows modelers to leverage the advantages of agent-based modeling in working with cognitive models. Just as the transition from equation-based models to ABMs enables more intuitive design, implementation, and visualization, so too does the transition from abstract representations of agent cognition to MLL-based representations.

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