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A FRAMEWORK AND LANGUAGE FOR COMPLEX ADAPTIVE SYSTEM MODELING AND SIMULATION

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ABSTRACT

Complex adaptive systems (CAS) exhibit properties beyond complex systems such as self-organization, adaptability and modularity. Designing models of CAS is typically a non-trivial task as many components are made up of sub-components and rely on a large number of complex interactions. Studying features of these models also requires specific work for each system. Moreover, running these models as simulations with a large number of entities requires a large amount of processing power. We propose a language, Complex Adaptive Systems Language (CASL), and a framework to handle these issues. In particular, an extension to CASL that introduces the concept of 'semantic grouping' allows for large scale simulations to execute on relatively modest hardware. A component of our framework, the observation module, aims to provide an extensible and expandable set of metrics to study key features of CAS such as aggregation, adaptability, and modularity, while also allowing for more domain-specific techniques.

1 INTRODUCTION

Complex adaptive systems are a type of complex system where entities and the environment are encouraged to adapt and interact with each other in order to achieve desired properties and provide a more realistic abstraction of real-life scenarios. Complex adaptive systems have become ubiquitous in domains such as social networks, supply chains, health-care networks, smart-cities and smart-grids, the "Internet of Things", and the Internet itself (Niazi 2013). Complex adaptive systems must support the concepts of adaptation, modularity, and diversity and contain interactive environments (Holland 2006) . Environments contain other entities and can act as communication mediums that allow for stigmergical interactions, system wide events, and self-organization.

Designing CAS models has been achieved using a variety of languages and frameworks, however, these have been either too domain-specific, or too domain-agnostic. Domain-agnostic attempts have resulted in models that do not adhere to CAS rules, while domain-specific attempts have resulted in developing techniques that are not adaptable to other domains. By introducing a language and framework for modeling CAS, we aim to solve 4 problems. Firstly, provide a standard for CAS modeling and simulation that utilize the above definition of CAS. Secondly, provide a set of tools and metrics to study these models and their myriad properties. Thirdly, allow for large, modular simulations to be executed on relatively modest hardware. Finally, the flexibility of CASL and the observation module allows for the implementation of non-CAS systems, which can then be studied as CAS.

2 CURRENT WORK

We develop a CAS modeling and analysis framework which includes the CASL modeling tool and code generator, the simulator, and an observation tool. Our language, CASL, provides constructs for designing models to capture the salient features of a CAS such as adaptation and modularity, along with other complex systems features such as interactions and behaviors. CASL also requires entities to be defined as either agents or environments. We propose an extension to the language and framework, which requires the model designer to restructure their initial model slightly, by considering the collective relationship between entities. Each collective, or group, consists of agents that have a semantic relationship. As such, we refer to these collectives as 'semantic groups'. This relationship is also dependent on how particular agents are represented and in many cases, how agents are represented can form the basis for their relationship. For example, in an emergency department, a patient has a much stronger relationship with a doctor than a nurse or a pathology technician. This has previously been achieved for models where the environment is represented by two or three dimensional space such as a flock of birds model or a traffic model, and has relied on forming groups based solely on the agent's position in space.

Our prototype framework consists of the CASL modeler, the code generator, a simulator, an observation tool, and an execution database. Once a model is constructed in the CASL modeler, code is generated only if all the required constraints have been adhered to. The generated code is then executed in the simulator, which may require initialization parameters which can be provided by a configuration file. The observation tool is comprised of several modules that analyze various features of a CAS such as aggregation, runtimes, interactions, and domain-specific features. The observation tool is designed to be extensible to allow for new metrics to be added, that may either be designed specifically for the current simulation or for a more domain-agnostic purpose. To aid the observation module, CASL allows for certain model features to be flagged so that these are utilized by a particular metric. For example, an agent may make multiple types of interactions, but only one type is considered useful for study. CASL allows the model designer to flag that particular interaction type for use in an interaction metric.

We are currently implementing and designing new metrics for our observation tool to study key CAS features such as self-organization and aggregation, adaptability, and the effects of modularity on a range of systems. In particular, we are studying two systems in-depth, namely an emergency department and a social network.

3 RESULTS AND CONCLUSION

We have implemented several models in CASL using semantic groups such as Game of Life, Flock of Birds, an Emergency Department, and a social network. Our prototype simulator relies on Repast Simphony for simulation scheduling and our distribution is achieved using parallel processing. For very large models, CASL with semantic groups provides a significant runtime decrease when compared to CASL without semantic groups. A Game of Life model with 160,000 cells was approximately 13 times faster than the equivalent without groups. A Flock of Birds model with 5,000 agents was roughly 18.5 times faster than the non-group equivalent. Furthermore, semantic grouping allowed for executions with more than 10,000 agents to finish, which was not possible using the non-group equivalent. Similar speed-ups have been found in our other implementations.

REFERENCES

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