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An Aspect-Oriented Approach to Large-Scale Urban Simulations

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ABSTRACT

Within the Modeling and Simulation (M&S) field, a major challenge that lies ahead is integrating massively complex urban simulations. The urban environment is a multifaceted model with many components, such as transportation, land use, and water and power distribution. To produce a high fidelity simulation of a city, all components should interact as they do in the real world. Furthermore, an urban simulation should be within an ecosystem of cities, states, and nations.

This study presents an aspect-oriented approach for designing distributed simulations that achieves 2 goals: 1) enables M&S experts to focus on the simulation, not on the platform or on interoperability; and 2) is scalable in terms of simulated entities and models. A middleware called Urban Simulation Platform is proposed, using an aspect-oriented approach to interface between the well known High Level Architecture interoperability standard and the traditional simulation design.

1 INTRODUCTION

Effective policy making is largely responsible for planning the cities of the future, and M&S plays a major role in the policy decision making process (Waddell and Ulfarsson 2004). The major challenges of urban simulation derive from the tremendously complex and diverse models of cities' infrastructure systems (e.g. transportation, water distribution, and land use). Transportation and traffic alone have an extensive body of research, and require a tremendous computational power to simulate the volume of vehicles of a real city. Simulating multiple infrastructure systems and enabling their interaction requires an astounding amount of computing power.

Distributed simulations are an effective of way of obtaining the computing power necessary for such large scale simulations. However, distributed simulation design remains a challenge for M&S practitioners, in most part due to the technical complexity and too low cost-benefit ratio for industry adoption (Boer et al. 2006). This study proposes a middleware solution named Urban Simulation Platform (USP) with the purpose of reducing the overhead of designing and implementing distributed simulations. USP utilizes the High Level Architecture (HLA) protocol for interoperability, and presents an interface that is simulation oriented, abstracting the complex details of distributed systems.

2 PRIOR AND RELATED WORK

The fundamental concept behind USP derives from our previous work: the Distributed Scene Graph with Microcells (DSG-M) (Valadares et al. 2014). DSG-M is a distributed virtual environment architecture that achieves scalability by employing a space and functional criteria for simulation distribution. Each simulator is responsible for a functional part (e.g. physics, scripts, data persistence) of the whole simulation in an enclosed region of the virtual space. DSG-M was shown to successfully scale up a distributed virtual environment even under worse workload conditions. The successful use of functional partitioning used in DSG-M inspired its use for the broader field of distributed simulations.

The software engineering community has formalized several paradigms that assists developers in building large and complex software. Functional partitioning, as done in DSG-M, is similar to the paradigm of Aspect Oriented Programming (AOP) (Kiczales et al. 1997). AOP addresses cross-cutting concerns: properties that fulfill a requirement that cannot be cleanly encapsulated in a procedural manner (i.e. in functions, methods, and procedures). The encapsulation of cross-cutting concerns in modules are named *aspects*. This study traces a parallel between both fields, in which infrastructure systems are seen as aspects of the urban simulation.

3 CURRENT WORK

DSG-M established that encapsulating simulations as aspects was not only possible, but effective. This study proposes to design and build an Urban Simulation Platform (USP) that achieves 2 goals. First, it enables scalability for simulating multiple infrastructure systems of a complex urban environment with high fidelity. Second, it reduces the overhead of designing urban simulations by modularizing each infrastructure system as an independent aspect of the urban simulation. Ideally, USP should be capable of enabling interactions between simulations that were independently developed with little effort.

The first part of this study is a proof of concept using an urban simulation project called Mobdat. Mobdat connects 3 aspects of an urban simulation that were independently developed: traffic, virtual environment interface, and social interactions.

The Mobdat project provides the perfect opportunity to demonstrate the proposed USP. The first task was to convert Mobdat to HLA, which has already been done, with source code available at http://github.com/arthur00/urbansim. The current phase is designing the USP library based on the converted Mobdat to HLA in a way that is aspect-independent. Currently, each aspect has its own converted library that enables interoperability of the urban simulation. The last step will be evaluation: determine to what degree this study has achieved the 2 goals set out in the design phase.

Evaluation will consist of measuring two points: scalability of aspects and number of simulated entities. Increasing number of entities is evaluated in terms of performance: how many entities can be simulated until the distributed simulations drops below a pre-defined threshold? The second part is number of aspects. To measure scalability of aspects, multiple aspects will be implemented, and static code analysis of source code tangling will be used to measure how independent aspects are of each other and of the platform. Code tangling is measured with the **aspect code fraction** metric: the ratio of lines of code in an aspect that are related uniquely to the aspect. Some metrics have already been extracted for the DSG-M project, which successfully exposed a large amount of code tangling between DSG-M and its antecessor, DSG.

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