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SEMSim Cloud Service: Large-scale urban systems simulation in the cloud

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ABSTRACT

Large-scale urban systems simulations are complex and with a large number of active simulation entities the computational workload is extensive. Workstation computers have only limited capabilities of delivering results for large-scale simulations. This leads to the problem that many researchers and engineers have to either reduce the scope of their experiments or fail to execute as many experiments as they would like in a given time frame. The use of high-performance computing (HPC) infrastructure offers a solution to the problem. Users of such simulations are often domain experts with no or little experience with HPC environments. In addition users do not necessarily have access to an HPC. In this paper we propose an architecture for a cloud-based urban systems simulation platform which specifically aims at making large-scale simulations available to typical users. The proposed architecture also addresses the issue of data confidentiality. In addition we describe the Scalable Electro-Mobility Simulation (SEMSim) Cloud Service that implements the proposed architecture.

1. Introduction

Urban processes have been the subject of many simulation studies in the past. This includes topics that cover diverse aspects of urban life, such as climate science (e.g., urban heat island effect [1]), energy studies (e.g., smart grids [2] or vehicle-to-grid [3]), health (e.g., pandemics [4]), social science (e.g., crowd evacuation [5]), and transportation (e.g., public transport [6] and traffic management [7]) to name only a few. Agent-based models are commonly used for simulating urban processes, such as transportation for example, and are often the only feasible way to study the urban systems of interest. With an increasing interest in city science and research, we expect to see more such simulation studies in the future.

Large-scale agent-based simulations, i.e., simulations that include several hundred thousand agents, can be compute intensive which is the reason why they are ideally performed on high-performance computing (HPC) systems. Domain experts (e.g., transportation engineers), who are the typical users of simulation tools, may not have access to in-house HPC resources and/or may not have the necessary skills to work with an HPC system. With the onset of cloud computing this situation is rapidly changing. HPC resources are now readily available via cloud computing providers such as the

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Google Compute Engine (GCE)[1] or Amazon EC2.[2] Given the availability of HPC resources, we expect to see more cloud-based simulation services to emerge. It has been shown [8] that the move to using cloud-based simulation hardware can offer opportunities for vertical and horizontal scaling of hardware resource usage at runtime and is an interesting field of research that we want to address in this paper.

With large-scale simulations being migrated to the cloud, users will have to face new challenges including (but not limited to):

- Usability – Graphical user interfaces of many simulation software tools have been designed for use on workstations by a single user. Although existing user interfaces can be re-used even if the simulation is executed in the cloud, it would be better to think about more suitable user interfaces that are specifically designed for cloud-based simulation services. User interfaces should be able to not directly communicate with the simulation but rather through a defined API over the internet. This enables many different UIs for different aspects of the same simulation (e.g., configuration, visualization, data analysis).
- Data Confidentiality – Virtually all urban systems simulations rely on a large amount of data (e.g., road network data, population data, traffic data, cell phone activity data). This data may be sensitive and data providers may not permit the use of cloud-services due to concerns regarding confidentiality.

In this paper we introduce a general architecture for cloud-based simulation services that addresses the two issues mentioned above. In addition, we introduce the Scalable Electro-Mobility Simulation Cloud Service (SEMSim CS), a proof-of-concept implementation of the proposed general architecture. SEMSim CS is used in the context of electromobility research in order to help answering questions regarding the impact of the introduction of electric vehicles into an existing transportation system and energy infrastructure of a mega-city such as Singapore. We evaluate the performance of the SEMSim CS on a typical cloud-based virtual machine (VM) and compare it to the performance on a dedicated HPC machine.

2. Related work

2.1. Web-based and cloud-based simulations

Web-based simulations have been used in the scientific community for many years. Most of the early applications of combining the web with simulations consisted of providing collaboration platforms or independent front-end interfaces [9,10]. These systems offered interfaces in the form of web-applications or thin-clients for controlling simulations. Other simulation support systems distribute simulation jobs over a network of computing centers [11] for load-balancing or load optimization. For collaboration between different institutions web-based repositories and interfaces for consolidating the modeling efforts have always been popular [10].

The question of Modeling & Simulation as a Service (MSaaS) was surveyed by Cayirci [12]. In the survey MSaaS is defined as a "model for provisioning modeling and simulation services on demand from a Cloud Service Provider (CSP)". It is furthermore defined that a user of such simulation systems should not be responsible for the maintenance, licensing of software or scaling of infrastructure. The survey largely focuses on the security, privacy and trust concerns connected with using cloud computing as a vital back-end of simulation experiments. The security concerns discussed by Cayirci are the ones defined by the Cloud Security Alliance for general cloud computing instances [13]. Those are then evaluated and reduced to risks which are of concern for MSaaS. Cayirci concludes that it comes down to trust between the experimenter and the different CSPs and a possible lock-into a specific CSP.

Guo et al. [14] tried to develop a service specification of how a simulation software as a service (SSaaS) and service-oriented simulation experiments should be formally specified. They give a formal description of how service-oriented experiments can be expressed as well as how formal descriptions of a SSaaS can be given. This approach helps to produce a meta-model for simulation experiments.

Cloud-based services have been very successful for Web 2.0 applications as a back-end for mobile applications. There are some commercial applications available that offer SSaaS. The research project CloudSME[3] is concerned with the use of cloud-based simulations for the manufacturing and engineering industry. This project has shown it potential for being a viable option to be used for cloud-based modeling and simulation [15]. SimScale[4] and AutoDesk[5] both offer simulation services for computer aided design models. The simulation services include simulation-based tests for fluid-dynamics, structural mechanics and thermal evaluation on digital prototypes. The *Altair Simulation Cloud Suite*[6] allows researchers and engineers in that have a CAD and CAE work flow for their simulations to move it completely to a cloud based solution. This allows users to import their CAD models into the browser based interface and allows a off-site simulation life cycle management, leveraging on their

[1] https://cloud.google.com/products/compute-engine.
[2] https://aws.amazon.com/ec2.
[3] http://cloudsme.eu.
[4] http://www.simscale.de/.
[5] http://www.autodesk.com/products/sim-360.
[6] http://www.altair.com/simulation-cloud/.

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