Densifying the Sparse Cloud SimSaaS: The need of a Synergy among Agent-directed Simulation, SimSaaS and HLA

3 AUTHORS:

Tiago Azevedo
University of Porto
4 PUBLICATIONS **3** CITATIONS

SEE PROFILE

Rosaldo J. F. Rossetti
University of Porto
134 PUBLICATIONS **419** CITATIONS

SEE PROFILE

Jorge G. Barbosa
University of Porto
65 PUBLICATIONS **263** CITATIONS

SEE PROFILE

Densifying the sparse cloud SimSaaS: The need of a synergy among agent-directed simulation, SimSaaS and HLA

Tiago Azevedo, Rosaldo J. F. Rossetti, Jorge G. Barbosa

Artificial Intelligence and Computer Science Lab
Department of Informatics Engineering
Faculty of Engineering, University of Porto, Portugal
{*tiago.manuel, rossetti, jbarbosa*}*@fe.up.pt*

Abstract: Modelling & Simulation (M&S) is broadly used in real scenarios where making physical modifications could be highly expensive. With the so-called Simulation Software-as-a-Service (SimSaaS), researchers could take advantage of the huge amount of resource that cloud computing provides. Even so, studying and analysing a problem through simulation may need several simulation tools, hence raising interoperability issues. Having this in mind, IEEE developed a standard for interoperability among simulators named High Level Architecture (HLA). Moreover, the multi-agent system approach has become recognised as a convenient approach for modelling and simulating complex systems. Despite all the recent works and acceptance of these technologies, there is still a great lack of work regarding synergies among them. This paper shows by means of a literature review this lack of work or, in other words, the sparse Cloud SimSaaS. The literature review and the resulting taxonomy are the main contributions of this paper, as they provide a research agenda illustrating future research opportunities and trends.

1 INTRODUCTION

Modelling & Simulation (M&S) is widely used in real scenarios such as traffic and transportation networks, where making physical modifications could be highly expensive, dependent on political decisions and very disruptive to the environment. Its uses could be decision making and what-if analysis, performance optimisations, testing and training, making M&S methodologies a huge need for Universities and companies worldwide.

Nowadays, there is a new paradigm called Simulation Software-as-a-Service (SimSaaS) where simulation software is used in the form of services, thanks to the latest evolutions in cloud computing and Software-as-a-Service (SaaS). Instead of having the simulation software installed on their own computers, researchers could take advantage of the huge amount of resource that cloud computing provides.

Even so, studying and analysing a problem through simulation may need several simulation tools, with different resolutions and domain perspectives, hence raising interoperability issues that could not be trivial to solve.

IEEE has already a standard for interoperability among simulators named High Level Architecture (HLA). HLA is covered by many works in the literature. Moreover, the multi-agent system approach has become recognised as a convenient approach for modelling and simulating complex systems (Moya and Tolk, 2007). Indeed, many researchers have developed work regarding agents.

This paper shows that the M&S community did not make a complete jump from the simulations in the local machines to the simulations in the cloud offered in the form of services. To prove such an assertion, we conducted a literature review to make the body of knowledge of the current synergy among agent-directed simulation, SimSaaS and HLA.

The literature review was conducted using the methodological and systematic framework proposed by (vom Brocke et al., 2009). It is not important in the context of this paper to explicitly describe all the phases. Yet, some considerations must be made. The databases sources selected were Scopus, Engineering Village and ACM. These databases are commonly known to contain vast work and have been used by many researchers in software engineering.

The queries made to the databases sources were based in four main keywords: SimSaaS, Cloud Computing, HLA and agents. It is considered a time frame from 2004 to 2015. The evolution of knowledge and technology in the software engineering field is tremendous every year. Thus, a time frame of a decade seems enough.

This paper will start to briefly explain some preliminary background concepts regarding the agent-oriented paradigm, HLA and cloud for a better understanding of the scope of this work. After that, the results of the literature review are broadly indicated and a taxonomy of the research work is presented. The literature review and resulting taxonomy are the main contributions of this paper, as they provide a research agenda illustrating future research opportunities and trends.

2 PRELIMINARY BACKGROUND

For the sake of clarification in future references, this section will briefly describe what is the agent-directed simulation paradigm, the HLA standard and the cloud paradigm.

Yilmaz and Ören (Yilmaz and Ören, 2007) indicated that the agent-directed simulation paradigm consists in three main areas: (1) simulation for agents (simulation of agent systems, that is, the simulation model is one or more agents), (2) agent-based simulation (model behaviour generation or monitoring of this process by using agents) and (3) agent-supported simulation (improving simulation by using agents as support facilities). There are several researchers which consider *agent simulation* and *agent-based simulation* the same principle as they do not take into account the contribution of agents in model generation. In this work, it is adopted the same perspective in which the two principles are seen as the same.

In order to have a structural basis for interoperability among simulators, IEEE developed HLA, a software standard that provides a common technical architecture for distributed M&S. A federate is the name given to every participant of the simulation, whereas each one can interact within a federation. Communication between simulators is possible thanks to a Run-Time Infrastructure (RTI). HLA baseline components are: (1) Federate Interface Specification (IEEE, 2010c); (2) Framework and Rules (IEEE, 2010a); and (3) Object Model Template (OMT) Specification (IEEE, 2010b). The first is a definition of the services that each federate can use for communication. The second is a set of rules that ensure the proper interaction within a federation. The latter is a specification of the format and syntax of the data that is exchanged among federates.

Cloud computing is a fresh and on-going recent buzzword where more and more work is being done not only in the industry but also among academics. Nonetheless, there is no general consensus on an unambiguous definition (Geelan, 2009). A problem in defining cloud computing is that it overlaps with other domains in distributed systems. Foster et al. (Foster et al., 2008) define the fields of distributed systems according to scale and domain (application-oriented versus service-oriented). Web 2.0 covers the spectrum of service-oriented applications, opposing to the Supercomputing and Cluster Computing, which have been more focused on traditional local applications. Cloud Computing lies at the large-scale side, being more scalable than Grid Computing. Grid Computing overlaps with all these fields, and because of that it is normal to exist wrong definitions.

Despite the overlapping of cloud computing with other domains, it is possible to distinguish it from grid computing. Indeed, there are three aspects that are new in cloud computing (Armbrust et al., 2010): (1) the appearance of infinite computing resources available on demand; (2) the elimination of an upfront commitment by cloud users; and (3) the ability to pay for use of computing resources on a short-term basis as needed. Two new buzzwords emerged from Cloud Computing, trying to extend it even further: Fog Computing (Bonomi et al., 2012) and Cloud 2.0 (Miluzzo, 2014). Concluding, we adopt the definition provided by The National Institute of Standards and Technology (Mell and Grance, 2011): *Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.*

3 AN UNEXPLORED CLOUD SIMSAAS

This section will show the unexplored Cloud SimSaaS by means of a literature review. It starts by referring SimSaaS and Cloud generically, following the HLA standard and the agent-directed simulation topics.

In our research, it was clear that SimSaaS is a very modern topic. The great majority of the papers were published after 2011 and the first ones do not directly use the term *SimSaaS*, vaguely mentioning

simulation and *web*. Although there is an increasing number of works per year, papers about SimSaaS are not many. Nevertheless, they are wide concerning the domains of application. It is possible to see works in the biomedical domain (Sawicki et al., 2012), in crowd and pedestrian field (Wang and Wainer, 2015) as well as works regarding ontology learning (Wang and Wainer, 2014), traffic and transportation (Härri et al., 2010), scheduling parallel discrete event simulation jobs (Liu et al., 2012a) and a cloud simulation in manufacturing (Taylor et al., 2014a), just to cite some.

Beyond these specific domain works, there are also some generic ones concerning frameworks for development, for example (Tsai et al., 2011) (Guo et al., 2011). Moreover, Cayirci refers to SimSaaS using the term *Modelling and Simulation-as-a-service* (MSaaS). He clarifies MSaaS, including top threats (Cayirci, 2013c). He also talks about the notions and relations of accountability, risk and trust modelling (Cayirci, 2013a), as well as MSaaS composition in multi-datacenter or multi-cloud scenarios (Cayirci, 2013b). Cayirci is not the only one using the term MSaaS: (Siegfried et al., 2014) illustrate potential benefits that may be achieved by MSaaS and challenges that remain to be solved.

Since cloud simulation started to be studied, an overall picture took some time to arrive. So, in 2012 Liu et al. (Liu et al., 2012b) proposed a general architecture of cloud simulation in the form of a SaaS type cloud. Figure 1 summarises the main blocks of this architecture. The simulation services which are offered through a website to very different users, are divided into three self-explanatory groups: Modelling as a Service, Execution as a Service and Analysis as a Service. All these services are possible due to the physical and virtual resources in the bottom, as well as the so-called Cloud Operating System which manages and connects the baseline infrastructure to the top.
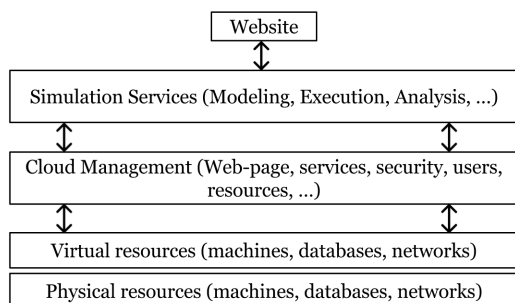

Figure 1: The main blocks of the Cloud Simulation general architecture (Liu et al., 2012b)

Although HLA has already been used in a variety of works like agent-based simulations, there is almost no clear references about interoperability among simulators when talking about SimSaaS. A first approach in extending HLA to support grid-wide distributed simulation dates back to 2005 (Xie et al., 2005).

A very relevant work from 2012 discusses how HLA can be integrated with Service Oriented Architecture (SOA) in the context of a smart building project (Dragoicea et al., 2012). The Simulation Engine Service is exposed by RESTful services. Inside this Engine, there is also a RESTful API that exposes access to the RTI's federation management and deals with the creation, initialisation, deletion, starting, stopping, and execution of simulations. Still in this context, the authors refer another paper (Wang et al., 2008), where a comparison between HLA and SOA concluded that:

- HLA has good interoperability, synchronization and effective and uniform information exchange mechanism between the communicating components (federates), but lacks several features of web services, such as: the integration of heterogeneous resources, web-wide accessibility across firewall boundaries;

- SOA benefits from loose coupling, component reuse and scalability but lacks a uniform data exchange format and time synchronization mechanisms;

- The combination of HLA and SOA can extend the capabilities of the two technologies and thus enable integrated simulated and real services.

Like HLA, the agent-directed simulation paradigm is used in a huge variety of fields but, when it comes to SimSaaS, few examples exists. Nevertheless, already in 2006, it was mentioned the importance of agents on simulation by exploring the relationship of software agents to simulation and games (Yilmaz et al., 2006).

Some authors (Tolk and Diallo, 2010)(Tolk et al., 2011) defend that most of the current simulation interoperability standards are inadequate as they just support the federation by focusing on information exchange without providing the necessary introspective. HLA provides more flexibility as it only standardises how to structure the data, not the exchanging of information. However, the focus remains on the information exchanged within a system. Consequently, a formal approach to simulation interoperability using agent-supported simulation tries to solve this problem.

JAVA Agent DEvelopment Framework (JADE) is a common software framework that simplifies the implementation of multi-agent systems. Web Services Integration Gateway (WSIG) is an add-on for JADE

which performs two-way translations between service requests and responses and JADE agent requests and responses. Thanks to this, it was possible to design a service-oriented simulation software framework as part of a broader approach towards generating improved levels of actionable views of situation awareness (Shao and McGraw, 2009).

Shao and McGraw referred that the great benefit of using JADE as the underlying agent development framework is that JADE agent entities can invoke web service functionality hosted outside the JADE run-time environment using normal JADE agent protocols, and that external entities can invoke JADE agent functionality from outside the JADE environment using normal web service protocols. Although the framework is very relevant, the applications were not in the cloud nor in a grid.

A truly implementation of agents in the cloud showed that agent-based M&S can benefit a lot from cloud computing, making it easier to have more accurate and faster results, as well as timely experimentation and optimisation (Taylor et al., 2014b). Even so, agent-based M&S in the cloud may be highly complex due to the very different clouds, cloud middlewares and service approaches.

Federated simulation environments have some limitations in supporting dynamic model and simulating updating, as it was pointed in 2004 and 2006 (Yilmaz et al., 2006). An example is HLA federation development, as it requires complete specification of object models and information exchanges before the simulation begins. It was also argued that there is a fundamental roadblock because of a lack of machine processable formal annotations describing behaviour, assumptions and obligations of federates.

4 TAXONOMY OF THE RESEARCH WORK

SimSaaS is a trendy term which has been growing considerably in recent years. Thus, it is the ideal time to take advantage of this hype. However, there are some concerns: there is a lack of automation and integration of tools in M&S (Wang and Wainer, 2015), and research dissemination methods suffer as they do not allow publishing simulation code and scripts along with the published paper (Sliman et al., 2013).

Herewith, HLA is another term referenced a lot in the literature since the first complete version (HLA 1.3) was published in 1998, but once again, when it comes to SimSaaS, almost nothing focuses on this and there is few work regarding extension of HLA to allow simulation services in general and in the cloud.

Indeed, HLA solely has some disadvantages (Yilmaz et al., 2006)(Tolk and Diallo, 2010).

In a 2014 panel about the future of research in M&S (Yilmaz et al., 2014) it is referred as a future research topic the distribution of SimSaaS in the cloud. So, once more SimSaaS is still mentioned as an unexplored area, now specifically in distributed simulation.

Although a truly implementation of agents in the cloud showed that agent-based M&S can benefit from cloud computing (Taylor et al., 2014b), there is a lack of work putting together agents and cloud in order to support SimSaaS.

Summing up all the discoveries of the described literature review, it is possible to see a lot of gaps in the literature concerning SimSaaS, SimSaaS in specific domains of application, SimSaaS in the cloud, HLA in the cloud, solutions to HLA restrictions, agents to support SimSaaS and agents in the cloud. As the metaphor in the title of this paper tries to address, SimSaaS in the cloud is currently too sparse since it has so many gaps in research. It is necessary to make it less sparse (densifying) in order to augment the scientific and technological knowledge among researchers in the field.

Densifying the sparse cloud SimSaaS is not just putting together cloud and SimSaaS, but also the synergies among them and agent-directed simulation and HLA, which could bring so many advantages. Fog Computing and Cloud 2.0, which were previously mentioned, could also help in this evolutionary process. Concluding, making these synergies a reality will be the front research opportunities for the next years.

A taxonomy of the research work could make the gaps identified and the research agenda for the next years more clear. Figure 2 illustrates the taxonomy in the form of a Venn Diagram. Every work is about M&S, more precisely SimSaaS. So, there are works that simply mention SimSaaS. Then, inside SimSaaS topic, research can focus on Cloud, HLA or Agent-directed simulation. In the particular case of Agent-directed simulation, there is a subset regarding Agent-supported simulation. As some works can address more than just one term, the representation in the form of a Venn Diagram was chosen to illustrate these possible synergies.

The presented taxonomy could be used as a conceptual framework for future developments. Researchers should look to these opportunities in the scientific community to orient their work, taking advantage of the benefits that this trends can give to their daily investigations.
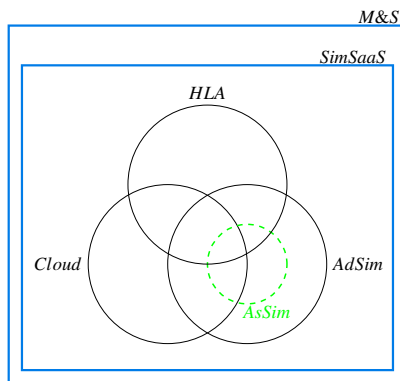
(AdSim: Agent-directed Simulation, AsSim: Agent-supported Simulation)

Figure 2: Diagram representing the taxonomy of the research work

5 CONCLUSIONS

This paper started to briefly expose important concepts for a better understanding of its contents. After that, a literature review is presented, focusing in four distinct yet related topics: SimSaaS, Cloud Computing, HLA and Agents. Finally, a taxonomy of the research work is presented in the form of a Venn Diagram for a clear visualisation about which topics can (and should) have synergies among them. This taxonomy could be used as a conceptual framework for future developments.

With the front research opportunities for the next years and current research work identified, we hope this paper can leverage the scientific activity in the field, with researchers actually finding it useful to make the jump to the cloud. That jump will bring advantages not only to each researcher in particular, but also to the overall simulation scientific community seeking for more knowledge.

ACKNOWLEDGEMENT

REFERENCES

Armbrust, M., Fox, A., Griffith, R., Joseph, A. D., Katz, R., Konwinski, A., Lee, G., Patterson, D., Rabkin, A., Stoica, I., et al. (2010). A view of cloud computing. *Communications of the ACM*, 53(4):50–58.

Bonomi, F., Milito, R., Zhu, J., and Addepalli, S. (2012). Fog computing and its role in the internet of things. In *Proceedings of the first edition of the MCC workshop on Mobile cloud computing*, pages 13–16. ACM.

Cayirci, E. (2013a). A joint trust and risk model for MSaaS mashups. pages 1347–1358, Washington, DC.

Cayirci, E. (2013b). Configuration schemes for modeling and simulation as a service federation. *Simulation*, 89(11):1388–1399.

Cayirci, E. (2013c). Modeling and simulation as a cloud service: A survey. pages 389–400, Washington, DC.

Dragoicea, M., Bucur, L., Tsai, W.-T., and Sarjoughian, H. (2012). Integrating HLA and Service-Oriented Architecture in a Simulation Framework. In *Proceedings of the 2012 12th IEEE/ACM International Symposium on Cluster, Cloud and Grid Computing (Ccgrid 2012)*, CCGRID '12, pages 861–866, Washington, DC, USA. IEEE Computer Society.

Foster, I., Zhao, Y., Raicu, I., and Lu, S. (2008). Cloud computing and grid computing 360-degree compared. In *Grid Computing Environments Workshop, 2008. GCE'08*, pages 1–10. IEEE.

Geelan, J. (2009). Twenty-one experts define cloud computing. *Cloud Computing Journal*, 4:1–5.

Guo, S., Bai, F., and Hu, X. (2011). Simulation software as a service and Service-Oriented simulation experiment. pages 113–116, Las Vegas, NV.

Härri, J., Killat, M., Tielert, T., Mittag, J., and Hartenstein, H. b. (2010). DEMO: Simulation-as-a-service for ITS applications. Taipei.

IEEE (2010a). IEEE Standard for Modeling and Simulation (M &S) High Level Architecture (HLA)– Framework and Rules. *IEEE Std 1516-2010 (Revision of IEEE Std 1516-2000)*, pages 1–38.

IEEE (2010b). IEEE Standard for Modeling and Simulation (M &S) High Level Architecture (HLA)– Object Model Template (OMT) Specification. *IEEE Std 1516.2-2010 (Revision of IEEE Std 1516.2-2000)*, pages 1–110.

IEEE (2010c). IEEE Standard for Modeling and Simulation (M&S) High Level Architecture (HLA)– Federate Interface Specification. *IEEE Std 1516.1-2010 (Revision of IEEE Std 1516.1-2000)*, pages 1–378.

Liu, X., Qiu, X., Chen, B., He, Q., and Huang, K. (2012a). Scheduling parallel discrete event simulation jobs in the cloud. volume 2012, London.

Liu, X., Qiu, X., Chen, B., and Huang, K. (2012b). Cloud-based simulation: The state-of-the-art computer simulation paradigm. In *Proceedings of the 2012 ACM/IEEE/SCS 26th Workshop on Principles of Advanced and Distributed Simulation*, PADS '12, pages 71–74, Zhangjiajie. IEEE Computer Society.

Mell, P. and Grance, T. (2011). The NIST definition of cloud computing.

Miluzzo, E. (2014). I'm Cloud 2.0, and I'm Not Just a Data Center. *Internet Computing, IEEE*, 18(3):73–77.

Moya, L. J. and Tolk, A. (2007). Towards a taxonomy of agents and multi-agent systems. In *Proceedings of*

the 2007 spring simulation multiconference-Volume 2, pages 11–18. Society for Computer Simulation International.

Sawicki, B., Chaber, B., Starzyński, J., and Szmuro, R. (2012). Internet application concept to trivialize EMF biomedical computing. *COMPEL - The International Journal for Computation and Mathematics in Electrical and Electronic Engineering*, 31(4):1190–1197.

Shao, G. and McGraw, R. (2009). Service-oriented Simulations for Enhancing Situation Awareness. In *Proceedings of the 2009 Spring Simulation Multiconference*, SpringSim '09, pages 48:1–48:7, San Diego, CA, USA. Society for Computer Simulation International.

Siegfried, R., Van Den Berg, T., Cramp, A., and Huiskamp, W. (2014). M&S as a service: Expectations and challenges. pages 248–257. SISO - Simulation Interoperability Standards Organization.

Sliman, L., Charroux, B., and Stroppa, Y. (2013). A new collaborative and cloud based simulation as a service platform: Towards a multidisciplinary research simulation support. pages 611–616, Cambridge.

Taylor, S., Kiss, T., Terstyanszky, G., Kacsuk, P., and Fantini, N. (2014a). Cloud computing for simulation in manufacturing and engineering: Introducing the CloudSME simulation platform. volume 46, pages 89–96, Tampa, FL. The Society for Modeling and Simulation International.

Taylor, S. J. E., Anagnostou, A., Kiss, T., Terstyanszky, G., Kacsuk, P., and Fantini, N. (2014b). A Tutorial on Cloud Computing for Agent-based Modeling & Simulation with Repast. In *Proceedings of the 2014 Winter Simulation Conference*, WSC '14, pages 192–206, Piscataway, NJ, USA. IEEE Press.

Tolk, A. and Diallo, S. Y. (2010). Using a Formal Approach to Simulation Interoperability to Specify Languages for Ambassador Agents. In *Proceedings of the Winter Simulation Conference*, WSC '10, pages 359–370. Winter Simulation Conference.

Tolk, A., Diallo, S. Y., Padilla, J. J., and Herencia-Zapana, H. (2011). Model Theoretic Implications for Agent Languages in Support of Interoperability and Composability. In *Proceedings of the Winter Simulation Conference*, WSC '11, pages 309–320. Winter Simulation Conference.

Tsai, W.-T., Li, W., Sarjoughian, H., and Shao, Q. (2011). SimSaaS: Simulation Software-as-a-service. In *Proceedings of the 44th Annual Simulation Symposium*, ANSS '11, pages 77–86, San Diego, CA, USA. Society for Computer Simulation International.

vom Brocke, J., Simons, A., Niehaves, B., Riemer, K., Plattfaut, R., and Cleven, A. (2009). Reconstructing the Giant: On the Importance of Rigour in Documenting the Literature Search Process. In *Proceedings of the 17th European Conference on Information Systems*, Verona, Italy.

Wang, S. and Wainer, G. (2014). Semantic Mashups for Simulation As a Service with Tag Mining and Ontology Learning. In *Proceedings of the Symposium on Theory of Modeling & Simulation - DEVS Integrative*, DEVS '14, pages 25:1–25:8, San Diego, CA, USA. Society for Computer Simulation International.

Wang, S. and Wainer, G. (2015). A Simulation As a Service Methodology with Application for Crowd Modeling, Simulation and Visualization. *Simulation*, 91(1):71–95.

Wang, W., Yu, W., Li, Q., Wang, W., and Liu, X. (2008). Service-oriented High Level Architecture. In *Proceedings of the 2008 Summer Computer Simulation Conference*, SCSC '08, pages 16:1–16:12, Vista, CA. Society for Modeling & Simulation International.

Xie, Y., Teo, Y. M., Cai, W., and Turner, S. J. (2005). Servicing Provisioning for HLA-Based Distributed Simulation on the Grid. In *Proceedings of the 19th Workshop on Principles of Advanced and Distributed Simulation*, PADS '05, pages 282–291, Washington, DC, USA. IEEE Computer Society.

Yilmaz, L., Ören, T., and Aghaee, N.-G. (2006). Intelligent agents, simulation, and gaming. *Simulation & Gaming*, 37(3):339–349.

Yilmaz, L. and Ören, T. I. (2007). Agent-directed simulation systems engineering. In *Proceedings of the 2007 Summer Computer Simulation Conference*, pages 897–904. Society for Computer Simulation International.

Yilmaz, L., Taylor, S. J. E., Fujimoto, R., and Darema, F. (2014). Panel: The Future of Research in Modeling & Simulation. In *Proceedings of the 2014 Winter Simulation Conference*, WSC '14, pages 2797–2811, Piscataway, NJ, USA. IEEE Press.