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A web-based platform for the simulation–optimization of industrial problems

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ABSTRACT

This study presents a platform for industrial, real-world simulation–optimization based on web techniques. The design of the platform is intended to be generic and thereby make it possible to apply the platform in various problem domains. In the implementation of the platform, modern web techniques, such as Ajax, JavaScript, GWT, and ProtoBuf, are used. The platform is tested and evaluated on a real industrial problem of production optimization at Volvo Aero Corporation, a company that develops and manufactures high-technology components for aircraft and gas turbine engines. The results of the evaluation show that while the platform has several benefits, implementing a web-based system is not completely straightforward. At the end of the paper, possible pitfalls are discussed and some recommendations for future implementations are outlined.

1. Introduction

The use of a simulation in combination with an optimization algorithm, so called simulation–optimization, is a commonly used technique in industry today, to find the best parameter values for a system or a process. Simulation applications have traditionally been provided as desktop systems, but during the last few years the interest for web-based simulation has grown. "Web-based simulation" does not have an exact meaning, but is a broad term including various approaches to integrate the web with the field of simulation. Byrne, Heavey, and Byrne (2010) states that web-based simulation "*... can be defined as the use of resources and technologies offered by the World-Wide-Web (WWW) for interaction with client and server modelling and simulation tools*". Page and Opper (2000) provide another definition, stating that the web-based simulations "*... denote the invocation of simulation programs over the Internet, specifically through a web browser*".

Compared to classical desktop systems, several advantages with web-based systems can be identified:

- *Accessibility* – a web-based system is accessible from anywhere with an internet connection, and not only from the specific computer that has the simulation system installed. This also means that a web-based system allows access outside normal business hours.
- *Scalability* – web-based systems allow for the dynamic provision of computing resources (Rabinovich & Spatscheck, 2002) and are thereby able to handle an increasing number of simulation/optimization requests without performance degradation.
- *Portability* – a web-based system can be run in any web browser on any operating system, without requiring recompilation (Suh, 2005). It is not only limited to a traditional computer, but can be run on any device that has a web browser (e.g., a mobile phone or an iPad).
- *Maintenance* – the maintenance of web-based systems is easier, since they do not have to be installed in each client's computer. Updates are made through a server and reach the clients instantly, eliminating virtually all on-site maintenance and allowing for a frequent update scheme.
- *Controlled access* – through user logins, a web-based system allows for the configuration of user groups with different privileges based on work tasks. The privileges can be easily changed on the server, instead of updating the client computer.
- *Licensing* – simulation software licenses are usually very expensive, and a traditional simulation system is often required to have one license installed in each computer that runs the system. With a web-based system, the number of licenses can be significantly reduced, since the simulation is located in a common infrastructure.

Although web-based simulation has obvious advantages and is a concept that has been discussed in the simulation research community for 15 years, the field is still in its infancy (Byrne et al., 2010; Fishwick, 1996). While the field has started to grow during

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the last few years, there are still only a small number of real-world applications of web-based simulation (Byrne et al., 2010). There are even fewer studies of integrating optimization with a web-based simulation system; less than a handful can be found in the literature. This study aims to add to this number, by presenting a new web-based platform for simulation–optimization. Contrary to existing, similar platforms, the one proposed specifically targets industrial, real-world problems. Since the design of the platform is generic, it is thereby possible to apply to most simulation–optimization problems, including for example manufacturing scheduling, engineering design, operational planning, and resource allocation. In the implementation of the platform, modern web techniques, such as Ajax, JavaScript, GWT, and ProtoBuf, are used. The platform has been tested and evaluated on a real industrial problem of production optimization at Volvo Aero Corporation, a company that develops and manufactures high-technology components for aircraft and gas turbine engines. The results of the evaluation show that while the platform has several benefits, implementing a web-based system is not completely straightforward.

The remainder of the paper is organized as follows. Section 2 presents existing web-based platforms for simulation–optimization that have been used as reference and inspiration. Section 3 provides a description of the design and implementation of the new platform. The application and evaluation of the platform on the industrial optimization problem at Volvo Aero Corporation is presented in Section 4, which is followed by an analysis in Section 5. Finally, Section 6 summarizes the conclusions from the study.

2. Related work

This chapter presents existing web-based platforms for simulation–optimization, described in the literature, and discusses their strengths and weaknesses.

2.1. Existing web-based platforms for simulation–optimization

A review of the literature reveals only a few papers that discuss web-based simulation–optimization. An early study on the subject

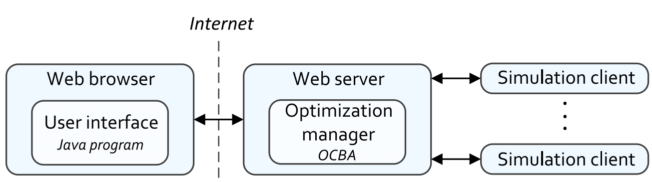

Fig. 1. Web-based simulation–optimization platform proposed by Luo et al. (2000).

was presented by Luo and his colleagues in 2000 (Luo, Chen, Yücesan, & och Lee, 2000) and describes a general platform for web-based simulation–optimization that is based on Java. The platform consists of three parts: a web browser, a web server, and a number of parallel simulation clients (Fig. 1, freely from Luo et al., 2000).

The user interface is the Java program started by a web-browser. Through the user interface, it is possible to set up, run, and view simulation–optimization experiments. Optimizations are performed using an algorithm called Sequential Algorithm for Optimal Computing Budget Allocation (OCBA) and run by an optimization manager. The optimization manager, which is located at a web server, is also responsible for distributing simulation jobs among the clients and collecting the results.

Luo et al. evaluate their platform on a number of theoretical queuing problems. There are two main objectives of the evaluation: (a) to study the reduction in execution time accomplished by the distributed client, and (b) to study the network delay caused by communication with the clients. The results of the evaluation show that the total execution time decreases with an increased number of clients, but the network traffic significantly impedes the results when the clients are distributed over the internet.

A more recent study on web-based simulation–optimization is presented by Yoo, Cho, and Yücesan (2009). The design of this platform, which is implemented partly using Java and partly using the .NET framework, is shown in Fig. 2 (freely from Yoo et al., 2009). The platform is similar to the one proposed by Luo et al. (2000) in that both implement an OCBA-based optimization algorithm and a distributed architecture for parallel simulation evaluations. Two main differences are: (a) Luo et al. use a web page as user interface instead of a Java program, and (b) Lou et al. utilize a database for storing and retrieving optimization results, which is not done by Yoo et al. (at least not described in the paper).

The optimization manager holds an intelligent algorithm that evaluates feasible regions within the search space, chooses the most promising region, and partitions the search space. The results are stored in a central database and made available to the simulation clients. Contrary to the platform described by Luo et al. (2000), the simulation clients have a certain degree of intelligence by holding an OCBA algorithm. The OCBA algorithm performs experiments at the simulation client, based on the information provided by the optimization manager. The results from the simulation clients are stored in the central database, which becomes the single point of interaction between the optimization manager and the simulation clients. The database has a web interface which allows communication over the internet.

Yoo et al. (2009) evaluate their proposed platform using a theoretical AGV control problem. However, the evaluation is only performed with respect to optimization algorithm behavior, and only

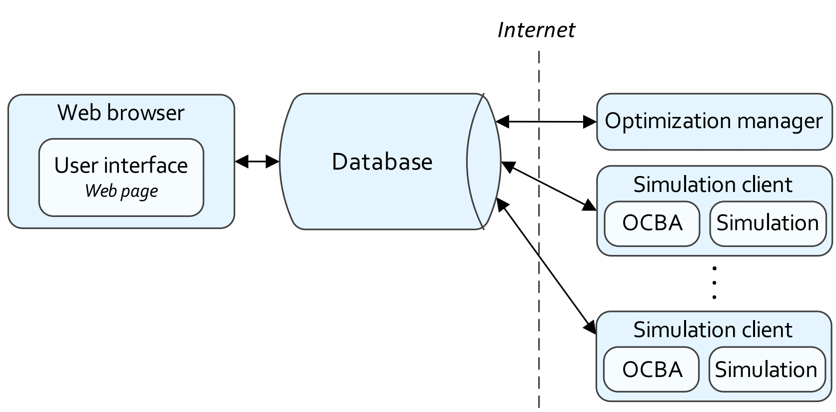

Fig. 2. Web-based simulation–optimization platform proposed by Yoo et al. (2009).