Institution: BRUNEL UNIVERSITY (H0113)

Unit of Assessment: 11 – Computer Science and Informatics

Title of case study: High Performance Simulation techniques to reduce industrial production and logistics costs through better management

1. Summary of the impact (indicative maximum 100 words)

The research has enabled industrial simulation users to investigate and develop larger scale systems *faster* and *cheaper* and thus to explore a *wider* variety of cost-saving options with more *precision*, and industrial simulation providers to offer new high-performance simulation (HPS) products and services. As a direct result of this work: Ford has made £150,000 cost savings in consultancy and significant process improvements to engine manufacture globally; Saker Solutions (UK SME) has created the first ever HPS system for production and logistics; Sellafield PLC has used this system to make significant process improvements and savings in the management of nuclear waste reprocessing of around £200,000 per year; and Whole Systems Partnership (a UK SME) used a spin-off from this research to generate a £200,000 per year revenue stream from interoperable healthcare decision support systems. Globally, several other companies are adopting the standardisation efforts and other outcomes of the research as the foundation for future innovation.

2. Underpinning research (indicative maximum 500 words)

Discrete-event simulation is used to investigate and improve planned or existing industrial production and logistics systems (e.g., car engine manufacturing plants, nuclear waste disposal, etc.). However, the state-of-the-art of simulation technology limits the size of system being studied and the amount of investigation that can be done in a project. Models are also costly to develop, so it is desirable to reuse models as 'building blocks' in analysing larger systems. For example, an engine manufacturing system model might be composed of several reused interoperable models that represent the production of engine blocks, camshafts, assembly lines, etc. Reusing these models to compose a larger model clearly saves costs as there is significant investment in each individual model. There are, though, major barriers to such composability and interoperability that limit the size of model that can be developed. Simulations also take time to run (minutes to hours depending on complexity/size), and a systematic investigation could require many thousands of simulation runs (and therefore potentially thousands of hours). In practice, projects have limited time and budgets, so only a subset of simulation experiments can be carried out in a specific project/context, limiting the quality of study outcomes as a result.

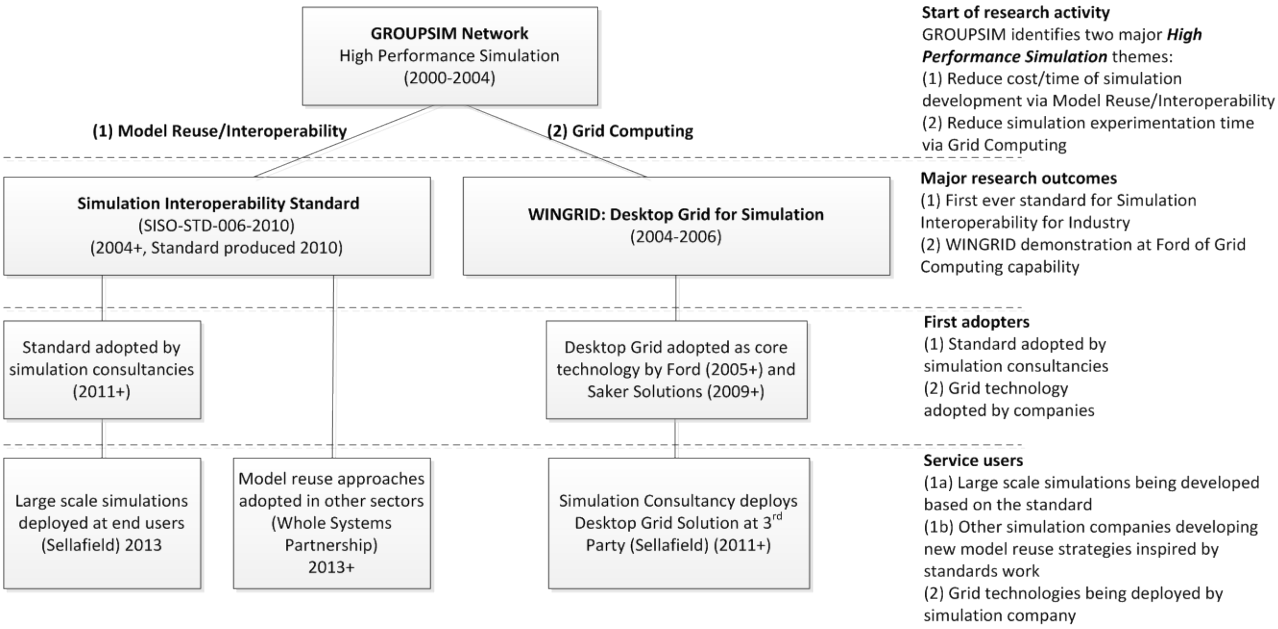
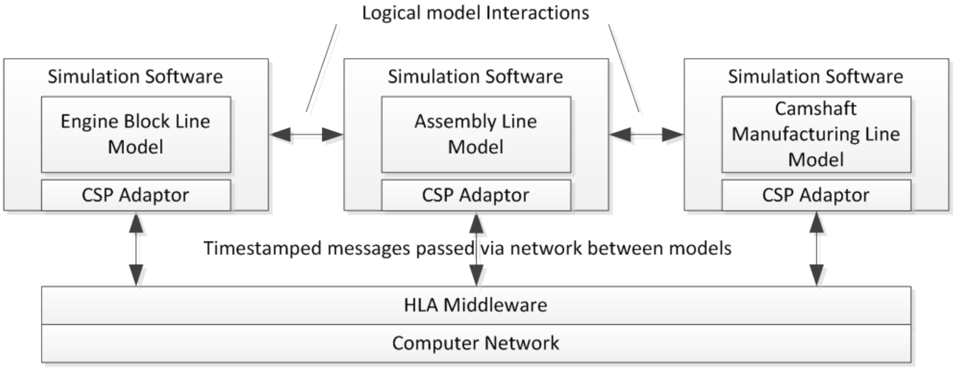


Figure 1: High Performance Simulation Impact Overview

Solutions to the above problems were evident in other simulation domains, but did not exist for industrial discrete-event simulation users. In 2000, Taylor (a Senior Lecturer at Brunel at the time, now a Reader) led the EPSRC Network GROUPSIM (EPSRC GR/N35304, 2000-2004) to investigate methods to transfer these innovations into this industrial simulation sector to make a step change in the state-of-the-art. These High Performance Simulation techniques have two major complementary themes: (1) techniques to reduce the cost and time of simulation development and (2) techniques to reduce the time of simulation experimentation. The path to impact of the research is shown in Figure 1.

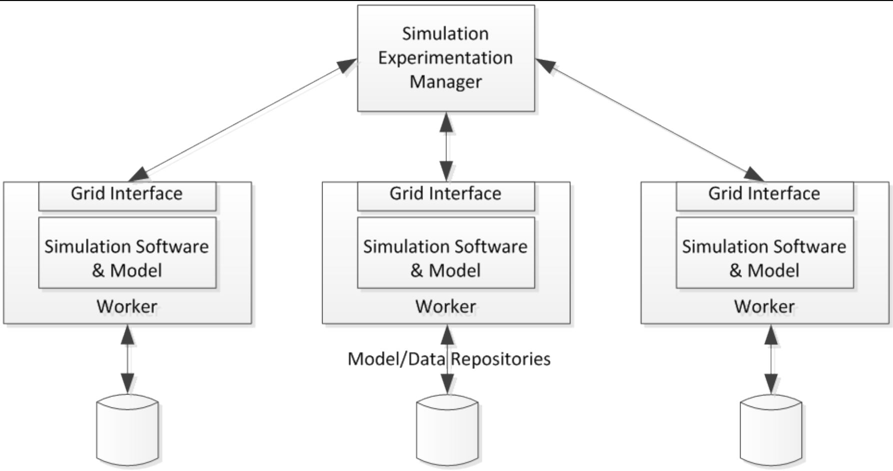
(1) The defence simulation sector had successfully created an approach to model reuse that linked together (interoperated) models over a computer network (Figure 2) and thus made major cost savings in model development by reusing previously developed models. This was based around the IEEE 1516 High Level Architecture (HLA) standard for simulation interoperability. GROUPSIM identified that there were major barriers to using the HLA and related software (middleware) for production and logistics simulation and that further standardisation was needed. In 2004, Taylor led this standardisation effort by creating the international COTS Simulation Package Interoperability Standards Development Group under the US-based Simulation Interoperability Standards Organization (SISO). In 2010, derived directly from concepts introduced by Taylor in GROUPSIM, he developed the world's first standard in this area, the *Standard for COTS Simulation Package Interoperability Reference Models* (SISO-STD-006-2010) (validated by SISO standards development process following repeated community balloting). This is being used, for example, to underpin large-scale simulation of nuclear waste management at Sellafield (developed by Saker Solutions) and has been adopted by several companies (e.g., AEGIS Technologies (USA), PITCH (Sweden), Simul8 (UK) and D-SIMLAB (Singapore)). To demonstrate the approach and to avoid proprietary model and data issues, a generic healthcare-based production and logistics simulation was also created with related software developed to support simulation interoperability by Taylor and Mustafee (PhD Student, then Research Fellow, at Brunel 2004-9; now a lecturer at the University of Exeter) (e.g., simulation software adaptors developed for the well-known Simul8 software). A novel model reuse strategy has also been developed with Whole Systems Partnership under a Knowledge Transfer Programme (Taylor as lead academic) for Systems Dynamics Decision Support in Healthcare (KTP008757) (Manpower capability planning) (currently deployed at Trent Strategic Health Authority).



Example: Three previously developed models are reused as a single large model by passing timestamped messages representing logical model interactions through HLA Middleware via a computer network. The simulation software is modified to interface with the HLA Middleware (Simulation software (CSP) Adaptors).

Figure 2: Model Reuse Via Simulation Interoperability

(2) In other areas, Grid Computing (the use of multiple computers to speed up applications) has had a major impact. However, at the time, Grid Computing technologies could not be easily utilised by most simulation software used for production and logistics simulation. To demonstrate how Grid Computing could be used in this area, Taylor with Mustafee developed WINGRID (2004-2006) – the WINDOWS-based Desktop Grid for Simulation (Figure 3). This was successfully deployed at the Ford Motor Company's Dunton Engineering Centre (Brentwood, Essex) to investigate engine system manufacturing worldwide. At Ford this system has evolved and is now a core simulation technology. Experience from this work led to the development of SAKERGRID which supports high speed simulation at Saker Solutions, a UK simulation consultancy with a wide range of production and logistics projects. SakerGrid has, in turn, been deployed at Sellafield to support the high speed simulation of nuclear waste management.



In WINGRID (and decendents) the key issues were that industrial simulation software experimentation was sequential, only ran under WINDOWS and had to be correctly installed and licenced. . To overcome these a simulation experimentation manager would be built that could take each experiment, package it into a job and send it to a worker (three shown, n possible). A worker would be a WINDOWS PC with the simulation software installed and licenced. A worker would receive the job via a dedicated Grid interface, load a designated model and run it with data and parameters as specified in the job file. Results would be returned to the manager for compilation.

Figure 3: WINGRID Desktop Grid Architecture

3. References to the research (indicative maximum of six references)

[1] Taylor, S.J.E., Turner, S.J. and Strassburger, S. (2010). Standard for COTS Simulation Package Interoperability Reference Models (SISO-STD-006-2010), Simulation Interoperability Standards Organization, Orlando, Florida, USA.

[2] Taylor, S.J.E. Developing Strategies and Infrastructure for Collaborative Simulation Modelling (GROUPSIM). EPSRC (GR/N35304).

Publications

[3] Taylor, S.J.E., Turner, S.J., Strassburger, S. and Mustafee, N. (2012). Bridging The Gap: A Standards-Based Approach to OR/MS Distributed Simulation. *ACM Transactions on Modeling and Computer Simulation*. 22(4). Article 18. http://dx.doi.org/10.1145/2379810.2379811

[4] Mustafee, N., Taylor, S.J.E., Katsaliaki, K., Dwivedi, Y.K. and Williams, M. D. (2012). Motivations and Barriers in using Distributed Supply Chain Simulation. *International Transactions in Operational Research*. 19(5): 733–751. http://dx.doi.org/10.1111/j.1475-3995.2011.00838.x

[5] Mustafee, N. and Taylor, S.J.E. (2009) Speeding up simulation applications using WinGrid. *Concurrency and Computation: Practice and Experience*, 21 (11), 1504-1523. http://dx.doi.org/10.1002/cpe.1401

[6] Katsaliaki, K., Mustafee, N., Taylor, S.J.E and Brailsford, S. (2009). Comparing Conventional and Distributed Approaches to Simulation in a Complex Supply-Chain Health System. *Journal of the Operational Research Society*. 60, pp. 43–51. http://dx.doi.org/10.1057/palgrave.jors.2602531

4. Details of the impact (indicative maximum 750 words)

The GROUPSIM Network began work that has led to major innovations in High Performance Simulation for industrial discrete-event simulation users and is facilitating the investigation and development of larger scale systems *faster* and *cheaper* and now allows a *wider* variety of cost-saving options to be explored with more *precision*. It also has made it possible for industrial simulation providers to offer new high-performance simulation (HPS) products and services. As shown in Figure 1, these innovations have two major complementary themes: (1) techniques to reduce the cost and time of simulation development (Model Reuse and Interoperability) and (2) techniques to reduce the time of simulation experimentation (Grid Computing). The impact of each theme is detailed below.

The standardisation efforts involved in (1) began in 2004 with the formation of the standards development group (CSPI PDG) at SISO and produced the first standard in 2010. The standard is now being gradually adopted by the international practitioner community and is being used to guide the development of large-scale manufacturing simulations. Saker Solutions was involved in the development of the standard and is now using the standard to create a large-scale simulation of nuclear waste reprocessing at Sellafield PLC which has led to “major cost savings” (see corroborating source S1). This is the first time that Sellafield has been able to comprehensively study the major elements of waste management as a whole system and is a direct output of both the standard and the standardisation process. Examples of practitioners adopting the standard internationally are: AEGIS Technologies (a USA SME specialising in defence simulation), PITCH (an SME based in Sweden that develops large scale simulations), Simul8 (a UK SME that sells one of the most well-known simulation software) and D-SIMLAB (a Singapore SME specialising in aircraft maintenance logistics). (Corroborating source S2 from Mark Elder, Chairman of Simul8, is representative of this adoption, “*Without this we and the whole simulation industry would still be operating in an isolated way*”).

The Grid Computing development work in (2) has been adopted by several simulation users. At the Ford Motor Company’s Dunton Engineering Centre (Brentwood, Essex) simulation is used to design engine manufacturing facilities worldwide and for process improvement in day-to-day operations by studying different machine configurations, buffer capacities, changeover Schemes, etc. Brunel and Ford developed various High Performance Simulation solutions for implementation in Ford’s Power Train Manufacturing simulation team. Ford has adopted and built new high performance simulation systems in conjunction with Lanner Group (a simulation consultancy SME). Ford now uses significantly more simulation in this area and has saved an estimated £150,000 in consultancy cost during the REF period and, according to Ford’s Technical specialist, a significant undisclosable sum due to process improvements as a result of that extra experimentation (see corroborating source S3). Dunton leads simulation activities in this area worldwide and this work has therefore affected production teams at Ford’s engine manufacturing facilities across the world (UK, USA, Mexico, Spain, South Africa and Brazil) (see corroborating source S3).

Experiences from this enabled Taylor to lead the development of SAKERGRID (in 2010) with Saker Solutions (one of around 10 UK SMEs specialising in simulation), Grid Computing software supporting high speed experimentation and test/build development. Saker Solutions employs 12 people (annual turnover £1 to £2 million) in the UK and works with many UK companies using simulation to study a wide range of manufacturing, production and logistic problems. SAKERGRID has been used to significantly improve the quality of Saker’s simulation projects and is saving around £20,000 per annum in terms of project time saved at Saker (£80,000 over 4 years) (see corroborating source S1). Saker Solutions has now implemented SAKERGRID (in 2011) within the Sellafield Ltd Operational Research Group (around 25 members) where the tool has been used since to support over 10 major projects in the last year. The expected direct savings in this financial year at Sellafield Ltd are approximately £200,000 with substantial additional savings expected in subsequent years. Of course, in addition there are unquantified savings arising from the reduced turnaround time of experimentation enabled by the use of SAKERGRID which both reduces project lead time and increases the number of scenarios which can be examined (see corroborating source S4).

In terms of products and services, Saker Solutions is now able to offer new high-speed products and services based on this work. Saker Solutions is the first to offer these in a comprehensive manner. This has had a ‘ripple effect’ in the community and has led to at least one further innovation due to the impact of these advanced in simulation technology state of the art. This took the form of a Knowledge Transfer Partnership (KTP) between Whole Systems Partnership and Brunel University (Taylor). Whole Systems Partnership is a small consultancy with a £300,000 per year turnover that develops healthcare decision support solutions. The results of the KTP are a (from 2013 onward) £200,000 per year revenue stream using reusable Systems Dynamics models for decision support in manpower capability planning in the NHS (see corroborating source S5).

5. Sources to corroborate the impact (indicative maximum of 10 references)

S1 – Letter received from Managing Director, Saker Solutions
S2 – Letter received from Founder and Non-executing Chair, Simul8 Corporation
S3 – Letter received from Simulation Technical Expert, Ford Motor Company Ltd.
S4 – Letter received from Project Leader, Sellafield Operational Research Group
S5 – Letter received from Managing Director, The Whole Systems Partnership