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Application and support for high-performance simulation

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High-performance simulation that supports sophisticated simulation experimentation and optimization can require non-trivial amounts of computing power. Advanced distributed computing techniques and systems found in areas such as High-performance Computing (HPC), High-throughput Computing (HTC), grid computing, cloud computing and e-Infrastructures are needed to provide effectively the computing power needed for the high-performance simulation of large and complex models. In simulation there has been a long tradition of translating and adopting advances in distributed computing, as shown by contributions from the parallel and distributed simulation community. This special issue brings together a contemporary collection of work showcasing original research in the advancement of simulation theory and practice with distributed computing. This special issue is divided into two parts. This first part focuses on research pertaining to high-performance simulation that supports a range of applications, including the study of epidemics, social networks, urban mobility and real-time embedded and cyber-physical systems. Compared to other simulation techniques, agent-based modeling and simulation (M&S) is relatively new; however, it is increasingly being used to study large-scale problems. Agent-based simulations present challenges for high-performance simulation, as they can be complex and computationally demanding, and it is therefore not surprising that this special issue includes several articles on the high-performance simulation of such systems.

Contributed papers

Zou et al. study the simulation of epidemics, such as severe acute respiratory syndrome (SARS) and H1N1 influenza. The scale of these potential disasters and the response time needed to simulate and plan for epidemic prevention and control demands high-performance simulation. Previous work has investigated this on general-purpose central processing unit (CPU)-based platforms. However, as the authors identify, there are new opportunities to execute such simulations on high-performance computation clusters composed of sophisticated general-purpose graphics cards (GPGPUs); towards this, the authors investigate optimization techniques for implementing an epidemic model on a cluster with GPGPUs. Two theoretical issues are explored: the efficient implementation of this form of simulation on GPGPUs and the minimization of communication latencies to improve scalability.

Hou et al. use parallel discrete event simulation to investigate large-scale social networks in an attempt to better understand complex social phenomena. The authors identify that current simulation environments for social studies are mostly sequential and may be limited when social networks grow to a certain size; sequential simulation environments do not usually support large-scale network simulation, which may comprise of millions of entities, and in such cases parallel and distributed processing seem to be the only alternative. The authors propose a large-scale M&S framework for social networks (SUPE-Net), which is based on a parallel discrete event simulation environment (YH-SUPE) for massively parallel architectures. The framework is designed as a layered architecture with utilities for network generation, algorithms and agent-based modeling. To evaluate the framework the authors execute the susceptible–infected–recovered (SIR) epidemic model on large-scale networks using a supercomputer. Results indicate that SUPE-Net achieves a satisfactory speedup as more computing resources are used.

Zia et al. address the complexity and scale of urban mobility. Social agents are difficult to model as they exhibit complex behavior, they exist in settings that can demand various levels of abstraction and they frequently require real spatial and population data for agent representation in models. In this study, the authors propose an agent-based parallel geo-simulation framework of urban mobility. They use a high-quality raster map of a city in Europe and convert it into cellular automata (CA). The fine-grained CA supports pedestrian mobility and can be extended to support other mobility modes. The urban mobility simulation is performed on a shared memory

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multiprocessor with 2048 cores. The authors present an analysis of the simulation efficiency and agent behavioral response for an emergency scenario.

Collier and North discuss the development of parallel agent-based modeling and simulation (ABMS) with Repast for High-performance Computing (Repast HPC). Repast HPC is intended to leverage the computing capability that is increasingly being made available on HPC platforms and make this accessible for large-scale ABMS. The authors describe the implementation of Repast HPC as a useful and usable framework, a complete agent-based M&S platform developed explicitly for large-scale ABMS. Benchmark runs using an example Repast HPC rumor-spreading application are performed on IBM Blue Gene/P supercomputers and experiments show that Repast HPC's components scale reasonably well.

Cordasco et al. also explore high-performance agent-based simulation but from a different perspective. In an attempt to create a usable and portable solution, the authors adopt a framework-level approach to create D-Mason, a parallel version of the Mason toolkit for multiagent simulation, to distribute simulations on several (heterogeneous) machines. The use of D-Mason at a framework level proves itself effective as it enables the researchers using the framework to be only minimally aware of the fact that the simulation is running on a distributed environment; further, the solution does not require a researcher to rewrite simulation code but still benefits from the seemingly transparent distribution of computational work among machines whose idle CPU time is harvested. Results are presented that show that D-Mason allows large-scale agent-based simulations to be executed – simulations that would otherwise have been impossible to execute on Mason because of CPU and/or memory requirements.

Pfeifer et al. discuss the challenges of real-time embedded and cyber-physical systems to M&S. These challenges come principally from the need to preserve event causality among simulators with different models of computation, signals, criterion for time advancement and levels of abstraction. SimConnect and SimTalk are presented as enabling heterogeneous, distributed, hardware/software co-simulation with a simplified backplane approach, wherein co-simulation backplanes are independent software or hardware agents that distribute information among process-separated simulators; they may also control and coordinate simulator time advancement for synchronization. Application of the tools to the coordination of three different simulators (TExaS, Ngspice and Simulink) is presented to simulate closed-loop, hardware/software-based, Proportional-Integral-Derivative/Pulse-Width-Modulated control of a direct current motor. Results demonstrate coordination between simulators with configurable tradeoffs in speed versus accuracy.

The first part of the special issue concludes with a paper on a distributed virtual environment (DVE) by Li et al. In a DVE participants located in different places may observe inconsistent views of the simulated virtual world due to message delay and loss in the network. The authors propose a compensatory update scheduling algorithm to compensate for the impact of message delay and loss on consistency in the DVE. Experiments using real traces of a racing car game are conducted to evaluate the proposed algorithm and it is shown that if the condition derived in the authors' theoretical analysis is fulfilled, the compensatory algorithm can fully compensate for the impact of message delay and loss on consistency.

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Guest editor profile

Dr Navonil Mustafee is a lecturer in the University of Exeter Business School. He is based at the Centre for Innovation and Service Research (ISR), which is a multidisciplinary research center that aims to bring academic rigor to the challenges of managing service organizations. He has research interests in distributed systems and M&S. He has applied distributed computing technologies such as grid computing and parallel and distributed simulation to execute large and complex simulations in application domains such as healthcare and banking. His current research explores the use of multiple operations research techniques and hybrid-simulation in the operations context. He publishes in both computing and operations research/simulation journals, including *Concurrency and Computation: Practice and Experience*, *Simulation: Transactions of the Society of Modelling and Simulation International, Journal of the Operational Research Society, International Transactions in Operational Research* and *ACM Transactions on Modelling and Computer Simulation*. He is/has been the guest editor for special issues in journals such as the *Journal of Enterprise Information Management, Journal of Simulation* and *Concurrency and Computation: Practice and Experience*. He has served as the co-program chair for the UK Operational Research Society's 55th Annual Conference (OR55) and is the program chair for the 2014 Spring Simulation Multi-Conference.

Dr Simon J E Taylor has been an academic for over 20 years. He is the Founder and Chair of the international COTS Simulation Package Interoperability Standardisation Group at the Simulation Interoperability Standards Organization. He is the co-founding Editor-in-Chief of the *Journal of Simulation*. He was Chair of the Association for Computing Machinery's Special Interest Group for Simulation (2005–2008). He is a Reader in the School of Information Systems, Computing and Mathematics at Brunel University (UK) and leads the ICT Innovation Group. He has published over 150 research articles as well as attracting over £1M in research grants in computer simulation and distributed computing, some of which has led to major cost savings in industry. He has enthusiastically taught hundreds of computing students at undergraduate and postgraduate levels. His recent work has focused on the development of cloud-based high-performance simulation for industry and the development of e-Infrastructures in Africa.