Simulation

Special Issue Editorial

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Special issue: Distributed and real-time simulation of next-generation complex systems

In an era where our world is shaped by increasingly intricate systems, from interconnected smart grids to intricate biological networks and virtual replicas of physical entities known as digital twins, the complexities of these systems have surpassed the capabilities of conventional simulation approaches. The SIMULATION special issue titled ''Distributed and Real-Time Simulation of Next-Generation Complex Systems'' confronts this challenge head-on by exploring innovative methodologies poised to revolutionize how we model, understand, and optimize such multifaceted systems.

These complex systems, prevalent across diverse domains such as transportation, industry, biology, social interactions, and more, exhibit dynamic behaviors that defy simplistic linear models. Traditional simulation methods, relying on centralized, offline, and deterministic approaches, struggle to capture the adaptive, nonlinear, and emergent nature of these systems.

Recognizing this pressing need for more effective tools, the special issue embarks on a journey to explore distributed and real-time simulation as promising alternatives. These approaches harness the advancements in computing, communication, and sensing technologies, paving the way for simulations that are not only more scalable and efficient but also remarkably realistic. They allow us to navigate the complexities of these systems by integrating different perspectives, capturing various aspects, and accommodating interactive scenarios involving human-in-the-loop or hardware-in-the-loop components.

Through a collection of five research papers, this special issue ventures into showcasing the latest techniques and applications in distributed and real-time simulation. These papers serve as a window into the evolving landscape of simulation methodologies, providing insights into how these approaches can model, analyze, and optimize complex systems that transcend multiple domains, scales, and levels of abstraction.

Initially, P. Andelfinger and A.M. Uhrmacher (Synchronous speculative simulation of tightly coupled agents in continuous time on CPUs and GPUs) address the problem of simulating agent-based models in continuous time using parallel discrete-event simulation methods. The paper argues that traditional methods based on logical processes and time-stamped events are not suitable for models that involve frequent and instantaneous interactions among tightly coupled agents, such as those expressed in the domain-specific language ML3. Hence, it proposes a novel synchronization method that uses synchronous optimistic rounds to allow direct agent interaction and limit the agent state history. Through implementations of the method for both CPUs and GPUs, performance is evaluated on a variant of the susceptible-infected-recovered network model evidencing a high speedup and scalability compared to traditional methods, and being able to handle dynamic topologies and fine-grained interactions efficiently.

F. Bhering et al. (Network performance estimator with applications to route selection for IoT multimedia applications) presents MAPE, a per-flow estimator based on a deterministic discrete-event simulation for multimedia traffic in wireless networks. The estimator uses a deterministic simulation approach that considers the characteristics of multimedia traffic, such as interference and multirate flows. The paper shows that the estimator can provide accurate and timely estimates of throughput, packet loss, and delay for each flow. The paper also shows that the estimator can be used to select optimal routes for video transmission in IoT scenarios. The paper compares the estimator with other simulators and shows its advantages in terms of speed and accuracy.

The article by G. Davidson et al. (A methodological approach for modeling the spread of disease using geographical discrete-event spatial models) proposes a new methodology for modeling infectious disease spread using geographical models. The methodology uses Cell-DEVS and JSON to create cellular models that capture the spatial dynamics of disease transmission over different regions. The paper shows how the methodology can be used to develop various versions of a compartmental model that consider different factors, such as movement restriction, asymptomatic population, and vaccination stages. By calibrating the baseline model using real data from Ontario, authors demonstrate the advantages of the methodology in terms of adaptability, prototyping, and prediction.

M. O'Connor et al. (Low-latency GNSS multipath simulation and building wall detection in urban environments) present a scalable real-time multipath simulator for improving the navigation accuracy of autonomous driving in urban environments. The simulator uses 3D building information and GNSS signals to simulate the effects of signal distortions and reflections caused by buildings. The simulator uses GPUs and a load balancer to achieve low latency and high efficiency. The paper shows that the simulator can reduce the positioning error by more than half in most cases compared to non-multipath processing.

The paper also proposes a new method for detecting walls using GNSS signals to deal with incomplete or erroneous 3D building information.

Finally, T. Potuzak (Improved methodology for assessment of communication protocols for distributed road traffic simulation) proposes an improved methodology for testing and comparing different high-level communication protocols for micro-scale (or microscopic) distributed road traffic simulations. The methodology considers the performance, applicability, and scalability of the protocols, as well as the error introduced by lossy protocols. The methodology uses a scoring system to rank the protocols based on various features of the simulation, such as network topology, traffic scenario, and communication frequency. The paper shows how the methodology can help to design or improve a distributed road traffic simulation by choosing the best protocol for a given situation. Furthermore, the paper presents a case study where the methodology is applied to several protocols developed by the authors.

The special issue aims to offer valuable insights into the potential and diversity of distributed and real-time simulation for next-generation complex systems. It serves as a platform to showcase the capabilities of these simulation methods while highlighting the challenges that persist and the wide array of opportunities available for future research and advancements in this burgeoning field. By emphasizing both the current accomplishments and the room for further growth, it encourages exploration and innovation to refine these methodologies and address the complexities of modern complex systems more effectively.

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