From Simulation to Digital Twins of Socio-Economico-Techical Complex Systems

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The integration of DevOps methodologies with agent-based modeling tools represents a revolutionary shift in simulating collective behaviors in complex systems. Utilizing multi-agent simulation (MAS) tools, this fusion offers a detailed view of the dynamic interactions among agents, thereby enhancing our understanding and ability to optimize emergent properties of systems. These tools are crucial across a wide range of fields, from socio-economic systems and biological ecosystems to urban planning, demonstrating their extensive utility and impact.

DevOps cycles play a critical role in MAS by enabling continuous integration and deployment. This aspect is vital for adapting to the evolving demands of complex system analysis and supports a cyclical development and testing process. Such practices facilitate on-the-fly refinements of simulations, significantly boosting the models' efficiency and effectiveness.

Typically, the process starts with the conceptualization of system dynamics, followed by iterative development cycles. Each cycle rigorously tests and refines agent behaviors through simulations, greatly benefiting from DevOps practices such as automated testing and continuous feedback loops. This ensures that the simulations are both robust and relevant.

The applications of MAS are extensive, spanning urban planning [1], healthcare systems [3], and intelligent farming [5]. Future research aims to boost the scalability and efficiency of these simulations, integrate advanced AI techniques, and enhance user interfaces, thereby broadening the accessibility of these powerful tools.

A pivotal advancement in MAS is the shift from basic modeling to the development of digital twins, which incorporate artificial intelligence and real-time evolution into agent behaviors. Digital twins are virtual counterparts of physical systems that evolve in parallel with their real-world analogs. They provide essential real-time analytics and decision support for managing complex systems like smart cities or advanced manufacturing processes, facilitated by MAS that models detailed agent interactions and behaviors. New methodologies have been developed to handle the transition from simulation to a digital twin, like DTOps (see figure 1).

Nevertheless, digital twins based on MAS encounter significant hurdles, particularly in accurately modeling the full complexity of socio-economic systems [4]. The unpredictable nature of human behavior and the myriad variables in these settings mean that even sophisticated MAS may not capture all dynamics completely. Moreover, the computational demands of simulating each agent and their interactions can pose scalability challenges. The integration and maintenance of diverse, accurate, and timely data sources are crucial for the digital twins' effectiveness and reliability.

In conclusion, while the integration of DevOps methodologies with MAS considerably enhances the modeling and analysis of complex systems, the shift towards digital twin technology introduces new challenges and opportunities. These digital twins offer unparalleled real-time insights and predictive capabilities but also require meticulous management of model fidelity, computational resources, and data to fully harness their potential.

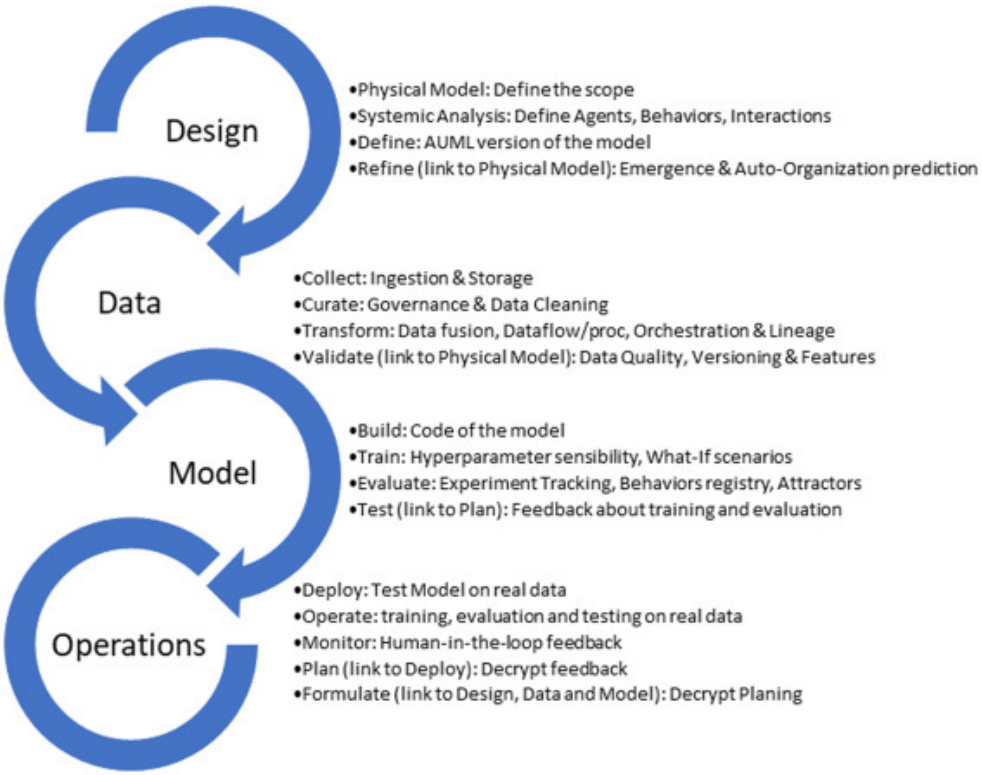

Figure 1: DTops methodology [2]

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