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CONCEPTUAL MODELING FOR SIMULATION MODEL REUSE

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ABSTRACT

This doctoral research focuses on the development of a methodology for guiding simulation model reuse from the conceptual modeling stage. In simulation studies, neither the benefits of model reuse nor the important role played by conceptual modeling, are new. However, most of the focus in the existing approaches has been so far on the reuse of code or, where they integrate the reuse of conceptual models, lacks strong enough empirical evidence of the extent to which they indeed work or not. This PhD dissertation addresses both these gaps by proposing and validating a five-stage decision-making process template (discussed in a separate paper at this conference) and a step-by-step detailed method (still work in progress) to guide simulation practitioners in evaluating which of the past models they have access to should be reused in a new study, which model components should be reused, and how exactly.

1 INTRODUCTION

Simulation modeling is widely used to analyze complex systems, predict outcomes, and support decision-making. Despite various levels of automation existing in practice to support decision-making by simulation professionals, developing and validating simulation models remains a time-consuming and costly process. For a long time, the reuse of existing simulation models has been proposed to alleviate the weight of project costs through enhancing productivity and maintainability in simulation studies (Sargent et al. 1986). Among the earliest contributions in this direction is the Conical Methodology proposed in Nance (1994), an object-oriented approach that helps to improve the understandability and maintainability of 'knowledge' models, which can be achieved through hierarchical development and standardized documentation.

In recent years, there has been growing recognition of the importance of reusing conceptual models. These define the objectives, scope, and requirements of the simulation, and ensure that the model aligns with the stakeholders' needs and expectations (Robinson 2015). As such, the reuse of conceptual models offers significant advantages, including improved model validity, reduced development time, and enhanced adaptability to new contexts. However, the lack of structured methodologies for conceptual model reuse has been a significant barrier to its broader adoption (Balci et al. 2017). To address these challenges, this PhD research proposes novel methodological guidance for simulation conceptual model reuse, which rests on: a structured approach to model reuse, an emphasis on validation steps, the integration of practical tools, and the sharing of empirical evidence about the pros and cons of the method, grounded in a stream of simulation projects mostly in the area of airport operations.

2 METHODOLOGICAL CONTRIBUTIONS

This research puts forward two contributions of a methodological nature. Firstly, it developed and validated a template for decision-making around the main modeling and validation steps that characterize simulation studies. This is intended as a generic model of the modeling and validation process as such, and is discussed in a separate paper at this same conference.

Secondly, this research developed and validated a detailed step-by-step method that spells out each of the steps in the generic model in the form of a learning system, following the structure and guidelines of Soft

System Methodology (SSM). The method helps simulation modelers to structure the problem and facilitate the integration of reusable components into new models, which are validated for accuracy and relevance to the new simulation context. By iteratively refining the conceptual model through (where needed) stakeholder discussions and subject-matter expert validation, the methodology ensures that the reused components align with the specific requirements of the new simulation study. Where existing models only include software code, the method integrates reverse engineering techniques to help identify the underlying conceptual structures in the existing code, before these are decomposed into reusable conceptual model components to be taken to further development.

3 EMPIRICAL WORK, SO FAR

We have developed and tested the above decision-making process over the past six years, in just over a dozen research and consultancy projects, all focusing on the area of airport airside operations management. These projects have explored various perspectives, including those of the airport operator, air traffic services provider, airline, and ground handling service providers, and have included airports of different sizes across the UK, often in collaboration with or sponsored by relevant organizations.

All our projects have involved simulation components, primarily using DES/ABS (Discrete-Event Simulation/Agent-Based Simulation) hybrid models. In response to specific project requirements, some models were further hybridized with Metaheuristics, Reinforcement Learning, and Constraint Programming (Gök et al. 2023). Additionally, some projects employed a simulation optimization approach, predominantly using sim-heuristics. The result of the application in several case studies has shown that the decision-making process template and model reuse detailed method are effective in facilitating model reuse at the conceptual level, especially for the less experienced simulation modelers, to whom the methodological aid provides clarity of scope and timed sequence of steps needed for a successful project that relies on older conceptual models and software code.

4 MOVING FORWARD

Still Remaining before the completion of this doctoral research project are additional empirical testing of both the decision-making process template and the detailed method. In particular, we are planning to work on workforce planning problems that share only some of the features of the one we have recently addressed in the airport industry, but in a different industrial sector (public transport in urban areas). This is meant to stretch the testing of our method beyond the industrial context in which all projects have taken place so far. This way we are hoping to understand better where our method may start to fail to provide the time and cost savings that generally come with model reuse.

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