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A PETRI NET BASED METHOD FOR THE EARLY VERIFICATION & VALIDATION OF A SIMULATION STUDY IN CONSTRUCTION MANAGEMENT

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ABSTRACT

A simulation study in construction management is business information that supports decision-making activities in construction planning and scheduling. To be confident in the various results of a simulation study, it is intuitive to be confident first in the collected simulation model inputs. This paper proposes properties to verify and validate simulation model inputs. The proposed V&V (Verification and Validation) properties are registered in a method that navigates an automatically generated project network. The project network is modeled as a marked graph Petri net. The method inspects the Petri net's transitions and collects the needed information according to the properties. The validity of the method is confirmed by an in-house building construction project where errors and semantic mistakes in the building project's model inputs were detected.

PROBLEM DESCRIPTION AND SOLUTION

Building construction projects are complex because of the unique characteristics of each new building facility in addition to the corresponding unique surrounding construction conditions. The use of simulation in construction management allows decision-makers to analyze the project unique and dynamic processes rather than to guess the project schedule based on experience. This results in examining different resource allocation strategies and in highlighting the risks of various project schedule alternatives before starting the real execution of the building project.

After gathering the required simulation model inputs, these inputs will be executed by a simulation environment. Based on the project's objectives, a large number of possible project schedule alternatives will be generated (Samkari et al. 2012). The project's objective is to increase the utilization of the production resources with respect to the contract's absolute and relative deadlines, while decreasing both the project's makespan and costs. However, to what extent can decision-makers be confident in those simulation results and thus remain in control of the decision-making process? It is intuitive that the completeness and correctness of the simulation results are realized only if the completeness and correctness of the simulation model inputs are confirmed regardless of how rich the model is (Bengtsson et al. 2009).

Generally, the simulation results are represented as Gantt diagrams that are time schedules, and as computer animations after linking the 3D-CAD (computer-aided design) objects with construction activities of a time schedule. Those representations assist in principle the decision support process in finding the best time schedule (simulation result). In contrast, these representations and diagrams do not aim and are not designed to detect errors in the time schedule caused by errors in the simulation model inputs.

In order to enable building construction practitioners to use simulation effectively in their business, simulation model inputs must be verified and validated first. The authors defined several V&V properties

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and classified them as stated in Rabe et al. (2009). A subset is listed in table 1. These properties enable achieving better comprehension of the model inputs. For example, model inputs are checked as follows:

- Incorrect quantities of building elements gathered from a CAD or BIM (building information model) environment;
- Errors in the defined process data, e.g., incorrect interdependencies among production activities and incorrect performance rates; and
- Semantic mistakes, e.g., *starting to construct the internal block walls of the building before starting with the external reinforced concrete walls*.

Additionally, some properties help in understanding the size of the project under simulation, e.g., finding the key production resources and determining the longest and shortest execution paths.

Table 1: a subset of suggested V&V properties that are applicable in construction management

V&V criterion	Property	Description
Completeness	Project's coverage	Checks whether all building component types, e.g., wall and column, are assigned a construction method and thus will be constructed.
Accuracy	Execution cycles	Checks for any existing cycles in the definition of the interdependencies among the construction activities.
Plausibility	Best practice 1	Examines whether a window will be built or not unless all structure works are completed within the floor, or the whole building.
Clarity	Project complexity	Represents the complexity of the project morphological structure.

In order to check the model inputs, the properties are registered in a method that navigates a marked graph Petri net and inspects its transitions. With regard to the V&V stage, the use of a Petri net has no advantages over other graph based representations. As for simulation, a marked graph Petri net is a persistence net that allows representation of concurrency. Moreover, the use of tokens in a Petri net provides dynamic links between conditions and tasks (Sawhney 1997). This is actually what makes a Petri net model most preferred in this research project.

The in-house application of the method to the simulation model inputs of a four story nursing-house project resulted in the early detection of errors and semantic mistakes that were not apparent. As a main conclusion, the proposed early V&V method made it possible to confirm that the simulation model is not incorrect before running the simulation. Moreover, it saved the decision-maker from the time consuming *try and error* loop; thus it saved the cost of multiple executions of the same simulation study.

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