REDUCING WASTE IN CONSTRUCTION THROUGH HIERARCHICAL CONTROL CONCEPTUAL MODELLING FRAMEWORK

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ABSTRACT

Discrete-Event Simulation is an event-driven simulation in which a real dynamic process is imitated as it progresses over time. It has been recognized as a powerful technique for the quantitative analysis of complex construction operations. The two main DES strategies for modelling construction operations are Process Interaction (PI) and Activity Scanning (AS). Although each strategy has its own advantages and disadvantages, some researchers illustrated that AS is a more natural and effective strategy than PI for simulation modelling of construction operations. Nevertheless, neither PI nor AS are able to accurately represent a real system in terms of dispatching and resource allocation. This potentially avoids accurate assessment of waste from construction operations. Recently, a hybrid strategy combining features of both AS and PI, called Hierarchical Control Conceptual Modelling (HCCM) has been presented that uses hierarchical control structures as a more general, flexible and powerful tool to define DES models. On the other hand, dynamic Three Dimensional (3D) visualisation adds significant credibility to DES models by facilitating verification and validation. This is especially true in construction, where decision makers in the field are typically experts in their domain but are not generally proficient in simulation itself. In this regard, some research has integrated DES modelling and 3D visualisation so that (1) simulation and animation run concurrently and in a manner that allows interaction with the animation to affect the course of events in the simulation; and (2) simulation and animation run in the same virtual environment avoiding errors and misconception between the model and the animation. However, the potential of this technology to be applied into specific production problems such as reduction of production waste has received little attention. In this research, 3D visualisation is utilised for verification and validation purposes. The aim of this research is to introduce the HCCM framework for DES modelling in construction. Applying the HCCM framework to a DES model is visually demonstrated through a case study of waste reduction from construction operations. FlexSim, a powerful DES modelling package based on both PI and AS is utilised to model the construction operations as it enables visualizing and handling highly dynamic, complex systems. The control policies of the HCCM framework allows development of what if scenarios for very specific production problems in construction, enabling precise modelling of dispatching systems and resource allocations in a user friendly environment. 3D visualisation, mainly achieved by the use of dispatchers and transporters, enables decision makers to unambiguously understand production logic and so, better plan and control construction operations. Preliminary results demonstrate waste reduction from a construction case study.

KEYWORDS: 3D Visualisation, Discrete-Event Simulation, Environment, Hierarchical Control Conceptual Modelling, Waste
INTRODUCTION

Discrete-Event Simulation (DES) is an event-driven simulation approach in which a real dynamic process is imitated as it progresses over time. DES models describe time-driven systems, where state variables change instantaneously at separate points in time [1]. The main goals of DES are to: 1) identify problematic areas in a current or proposed system; 2) implement “what if” experiments; and 3) optimize (production) system performance. Optimization is achieved by changing model input parameters such as: work shifts; routes for material; and available storage; to improve performance metrics that may include: throughput under average and peak loads; utilization of resources; queue lengths at work locations; and work-in-process. DES is not only able to model complex systems with highly dynamic decision rules and relationships between different entities and resources, but can also explicitly address system uncertainty [1]. Furthermore, the value of DES lies in its ability to capture the variability of events instead of using mean values as model inputs, restricting the need for assumptions. DES is also able to provide transparent information for decision makers by means of animated graphic interfaces [2]. Last but not least, DES has been recognized as a powerful technique for the quantitative analysis of complex construction operations [3].

The two main DES strategies for modelling construction operations have been Process Interaction (PI) and Activity Scanning (AS). A PI model is defined from the point of view of the entities that flow through the system. These entities typically arrive, undergo some processing where they capture and release scarce resources, and then they leave the system. In contrast, AS models are defined from the point of view of the various activities that are performed and focus on identifying these activities and the conditions under which they take place [4]. Although each strategy has its own advantages and disadvantages, some researchers illustrated that AS is a more natural and effective strategy than PI for simulation modelling of construction operations [4]. Recently, a hybrid strategy combining features of both AS and PI, called Hierarchical Control Conceptual Modelling (HCCM) has been presented that uses hierarchical control structures as a more general, flexible and powerful tool to define DES models. HCCM introduces requests, which generalize the concept of a process, and controlled behaviour, a generalization of conditional behaviour. By combining and centralizing these concepts a much bigger focus on dispatching and resource allocation can be applied [5].

On the other hand, dynamic Three Dimensional (3D) visualisation adds significant credibility to DES models by facilitating verification and validation. This is especially true in construction, where decision makers in the field are typically experts in their domain but are not generally proficient in simulation itself. In this regard, some research has integrated DES modelling and 3D visualisation so that (1) simulation and animation run concurrently and in a manner that allows interaction with the animation to affect the course of events in the simulation; and (2) simulation and animation run in the same virtual environment avoiding errors and misconception between the model and the animation. However, the potential of this technology to be applied into specific production problems such as reduction of production waste has received little attention. In this research, 3D visualisation is utilised for verification and validation purposes.
PROBLEM STATEMENT

Current modelling strategies in construction are not able to accurately represent a real system in terms of dispatching and resource allocation. This potentially avoids accurate assessment of waste from construction operations.

RESEARCH AIM

The aim of this research is to introduce the HCCM framework for DES modelling in construction. Applying the HCCM framework to a DES model is visually demonstrated through a case study of waste reduction from construction operations.

RESEARCH METHODOLOGY

The methodological steps of this research are: (1) describing general model, assumptions and simplifications; (2) defining high level HCCM including structural view, behavioural view, high level entity definition, high level activity definition and control view; (3) defining low level HCCM including input/output definition, detailed entity definition, detailed activity, event and process definition, and detailed control definition; (4) development of the HCCM model in FlexSim as defined in 2-4; (5) verification and validation of the HCCM model through 3D visualisation; (6) implementation of improvements to reduce waste and simulation output analysis and; (7) highlighting strengths of the HCCM by comparing it to pure PI/AS.

RESEARCH SIGNIFICANCE AND EXPECTED FINDING

The control policies of the HCCM framework allows development of what if scenarios for very specific production problems in construction, enabling precise modelling of dispatching systems and resource allocations in a user friendly environment. 3D visualisation, mainly achieved by the use of dispatchers and transporters, enables decision makers to unambiguously understand production logic and so, better plan and control construction operations. Preliminary results demonstrate waste reduction from a construction case study.

REFERENCES