Enhancements of Discrete-Event Simulation for Modeling Construction Operations

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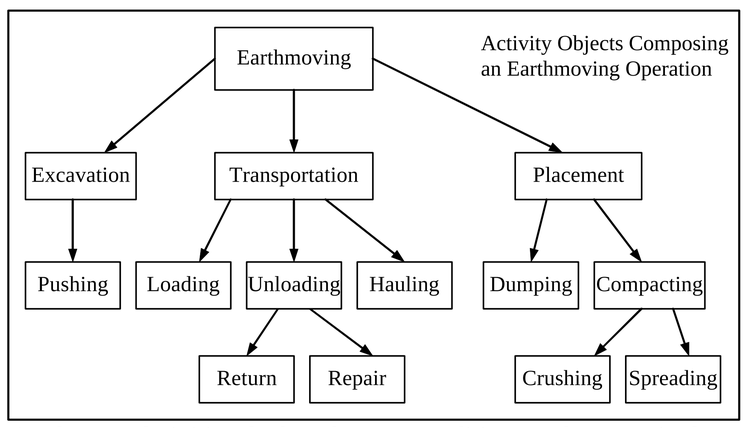
Introduction and Background

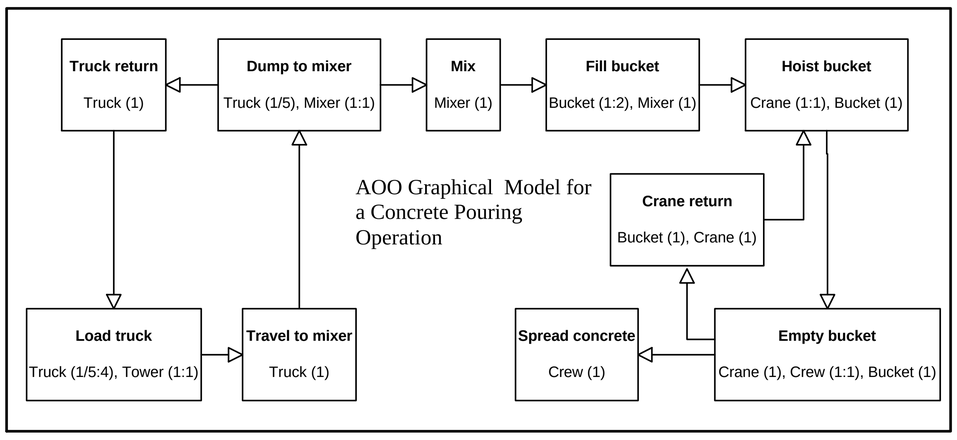
The simulation technology, which advances with the computer technologies, has become one of the important tools in the analysis of construction systems. The simulation techniques allow users to test and evaluate different control strategies in an inexpensive way, which have been proven to be effective tools for improving construction process planning. Since 1970s, some general discrete-event simulation tools such as SLAM II have been applied to the study of construction processes. In addition, some discrete-event simulation tools that are especially for the construction field have been developed, e.g. CYCLONE, COOPS, and CIPROS, etc. However, the widespread application of the simulation techniques to construction has been impeded by some limitations, which can be classified into the following aspects:

Difficulties in modeling due to the complex simulation strategy and graphical representation- modeling works may be tedious and error-prone due to the requirement of programming techniques that normally take users much time to learn. These problems will be serious when simulation users lack adequate simulation knowledge.
Difficulties in model verification and validation- verification of the simulation model and results are crucial but most systems lack an easy-to-use method to accomplish these.
Lack of flexibility in modeling- some activities can start under flexible conditions and there exists subjectivity in assessing and monitoring the quantities of resources to activate an activity. Therefore checking the quantities of resources is carried out under a vague or imprecise environment, especially when these resources are flexibly demanded.
Lack of dynamic decision-making modeling in allocating limited resources to one of multiple resource-competing activities.

The goal of the study is to explore some methods to resolve the above problems for construction, in which some simulation-related methodologies such as object-oriented approach, fuzzy set theory, and animation are utilized.

Activity Object-Oriented (AOO) Modeling and Simulation Strategy

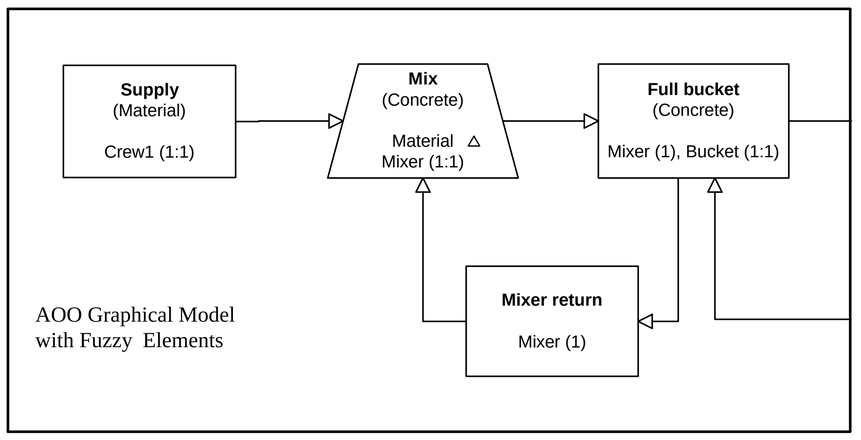


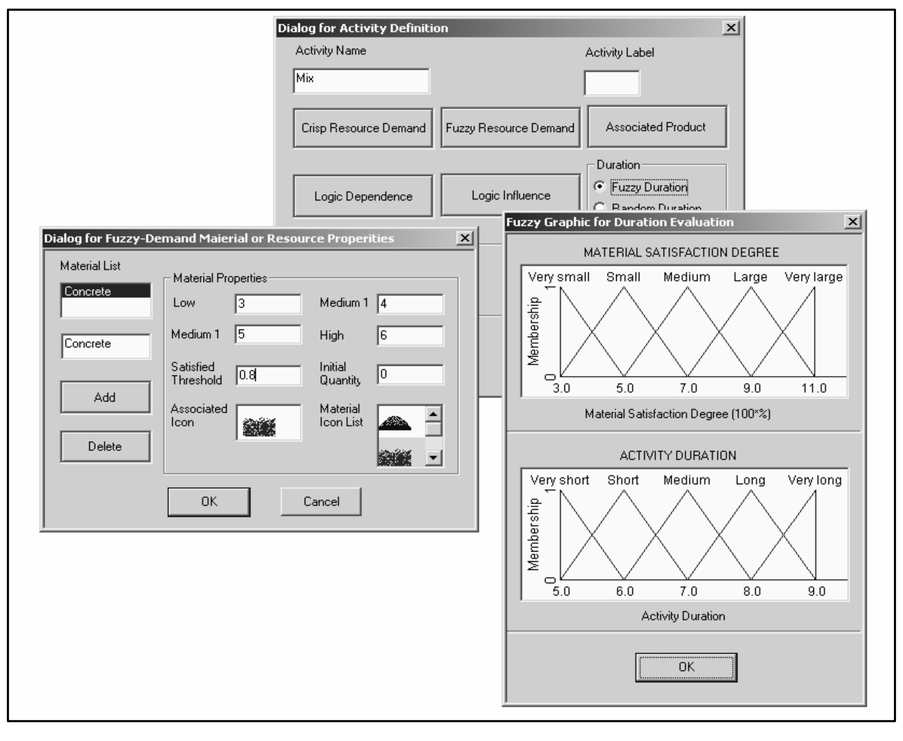


Object-oriented approach enables the generation of the user interface of software that has a close correspondence with reality and is user-friendly. A construction process contains a series of activities. These activities may be sequentially or simultaneously initiated when the start conditions such as required resources (e.g. crew, equipment and material) and logical dependencies (e.g. upon the completion of the preceding activities) are satisfied. These activities will be terminated in due time and the involved resources will be released so as to serve other activities. Some activities may be repetitively initiated when their start conditions are satisfied again. A construction process can be abstractly assumed to be composed of a series of activities, that is, the activities can be viewed as the essential elements of a construction process. Therefore when applying the object-oriented modeling for the construction process, the activities can be chosen as the objects and other elements such as the entities constituting the start conditions of the activities, e.g. required resources and logical dependencies, can be assumed to be the attributes of the activity objects.

Fuzzy Logic Control of Construction Activities

The flexible demands on resources for the activation of an activity could lead to variability in the actual quantities of resources to complete the activity each time it is executed. The variance of the involved quantities of resources contributes to the uncertainty in activity duration and, in general, there is a non-linear functional relationship between the duration and the involved quantities of resources. Some uncertainties can only be described through the imprecise or vague linguistic terms, i.e. “about” or “enough,” instead of the precise mathematical forms. Fuzzy set theory provides a means to describe uncertainties in linguistic terms and fuzzy logic is used to handle the relevant operations under fuzzy environments. The application of fuzzy logic to discrete-event simulation in dealing with uncertainties in resource requirements and activity duration is adopted. The demands on resource quantities are assumed to be flexible and described by the fuzzy sets in linguistic terms. The controlling of activity activation is modeled through the fuzzy logic, which is also utilized to determine the varying duration that has a non-linear relationship with the involved quantities of resources. The AOO simulation is enhanced with such modeling capabilities.





Animation for AOO Simulation

Difficulties in modeling have limited the widespread application of the simulation technology in construction. First, the modeling process is error-prone due to mistaken definition or input of the relevant attributes or parameters, leading to logical inconsistencies in the simulation model. Secondly, verification of the simulation model and validation of the simulation results are not easy. Lastly, it is not easy to fully understand the dynamic or stochastic features of the system being modeled and interpret the simulation results in the forms of statistics, especially when the system is a very complex one. Computer animation is an alternative to handle the above problems.