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Dynamic Construction Visualizer

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DYNAMIC CONSTRUCTION VISUALIZER

THE NEED

Discrete-Event Simulation (DES) is a powerful objective function evaluator that is well suited for the design of construction operations. Simulation results typically include the cost and time of construction as well as resource utilization rates, waiting time and length at queues, etc. The results usually point out important parts of the operations with potential for improvements that may result in cost or time savings. Systems such as STROBOSCOPE are currently available that permit the modeling of construction complex construction operations in detail. These systems can provide detailed information about construction operations such as resource utilization, resource idleness, operation bottlenecks, production rates, and the resulting expected cost before commencing actual work in the field.

Notwithstanding these facts, there has been limited use of discrete-event simulation in planning and analyzing construction operations. Discrete-event modeling is an inherently complex activity that is both a science and an art. The modeling of a construction operation requires the description, in the language of the simulation modeling system, of mental plans that are often complex and elaborate. Differences between the mental plan and the operation actually modeled in a first attempt are ubiquitous. Verification is the process by which the model creator looks at what has been actually modeled, compares it to what was intended, and updates the model to accurately reflect the intention.

The developer of the computer simulation model, however, may have misconceptions about how the actual operation will take place in the field. Thus, a model may not be an accurate representation of reality despite proper verification by its developer. Such errors cannot be discovered by verification because the model indeed reflects what the model creator intended. The aim of Validation therefore is to determine whether simulation models accurately represent the real-world system under study. This is typically carried out by consulting people who are intimately familiar with the operations of the actual system, but who are not necessarily proficient in simulation.

Simulation models are termed as Credible when the models and their results are accepted as being valid, and are used as an aid in making decisions. In the case of both verification and validation, the inner workings of a model and its output need to be communicated to others for discussion and input, and in a way that is both

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comprehensive and comprehendible. Construction simulation tools typically provide results in the form of numerical or statistical data. However, they do not illustrate the modeled operations graphically in 3D. This poses significant difficulty in communicating the results and workings of simulation models, especially to persons who are not trained in simulation but are domain experts. Decision makers often do not have the means, the training and/or the time to verify and validate simulation models based solely on numerical output. Potential practitioners are therefore always skeptic about simulation analyses and have little confidence in their results. This lack of credibility is one of the major deterrents of the widespread use of simulation as an operations planning tool in the construction industry.

The design and analysis of construction operations using simulation makes sense only if the insights gleaned are used in making decisions and increasing understanding (i.e., they are credible). The lack of credibility in a simulation model is directly related to the inability to effectively communicate its results and internal logic. There is clearly a need to communicate simulated operations in a way that can conspicuously help in verify, validate, and therefore accredit simulation models. Visualizing simulated operations can be an effective means of achieving this.

It is a generally accepted fact that visually presented information is understood and grasped more easily than any other form of communication. The need to visually communicate simulated operations is more relevant in the context of construction because construction operations analysts (e.g., superintendents) typically do not have the necessary training in simulation to allow them to validate simulation results based on tables and charts.

The Technology

The Dynamic Construction Visualizer (DCV) is general-purpose 3D visualization system that allows simulation model developers to animate modeled operations with chronological and spatial accuracy in 3D virtual space. The system is independent of any particular simulation-modeling program or CAD modeling software.

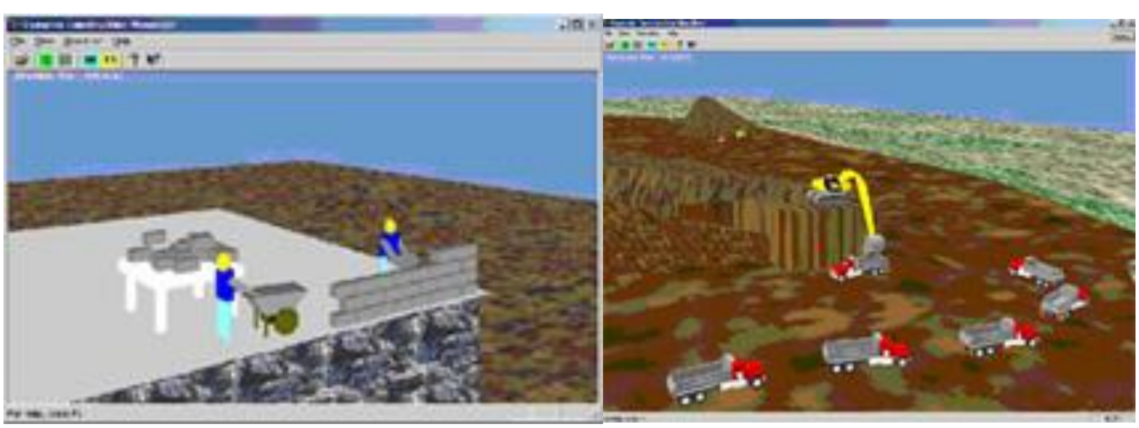

Figure 1 Example of 3D visualization

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DCV language files unambiguously describe the spatial configuration of modeled systems with the passage of time. The DCV is as a "post-simulation" visualization engine that possesses the following characteristics:

- Maintains an independent simulation clock, the speed of which can be controlled by the viewer depending upon the animation speed desired.
- Allows the user to navigate easily in 3D virtual space and place himself/herself at any desired vantage point by controlling the camera using the keyboard or the mouse.
- Allows the user to jump ahead or back to any desired location in the simulation by specifying a future or past time value.
- Permits the viewer to start and pause the animation at any time to make static observations in the modeled system.

Simulated operations are visualized in 3D by processing sequential, time-ordered animation commands written in the DCV language. The animation commands are contained in an ASCII text file hereinafter referred to as the trace file. DCV trace files are meant to be generated by simulation software. Any simulation software capable of writing custom text output during a simulation run can generate the trace files automatically. These include most of the programmable generic and special-purpose simulation languages as well as high-level programming languages such as BASIC, FORTRAN, C and C++. Non-language based simulation software may also be adapted to generate trace files during a simulation run.

The DCV uses 3D models of all pertinent resources and system entities to depict the simulated operations and the evolving product in 3D. The DCV system does not possess any built-in 3D model building capability. Instead, required 3D models of system entities can be imported from a wide variety of 3D CAD modeling software. The DCV provides direct support for the VRML file format. Geometry files from practically every 3D modeling program (e.g. AutoCAD™, MicroStation™, 3D Studio™) can be easily exported or converted into VRML format.

Benefits

Realistic 3D visualization of simulated construction operations can provide valuable insight about construction operations that are otherwise non-quantifiable and presentable. Volumes of data that take hours to review can be communicated in a few seconds. For instance, many techniques are available to simulation analysts to perform verification (e.g., looking at simulation logs). However, a visualization of what occurred in the simulation model can reveal such errors very quickly. Similarly, communicating the working of simulation models to domain experts through visualization can allow errors in logic to be easily identified and corrected, and allows planning groups to participate in discussions aimed at improving the plan.

Operations Level visualization can be potentially utilized in many ways in construction practice and education. Using available CAD models of infrastructure and the resources, it can be possible to re-create

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in a virtual world what happened in the past (trace-driven simulation) or what may happen in the future (by showing what was simulated by a simulation model). These visualizations can be very realistic, with accurate depictions of construction sites, infrastructure, equipment, and atmospheric conditions (visibility, fog, rain). Historical (from past data) and predicted (from simulations) animations can be in compressed or expanded time. A 20 second incident could be studied in very slow motion. General operations, in contrast, could be animated in fast motion so that several hours of operations are viewed in a few minutes. In general, the value of visualizing construction at the Operations Level can be tremendous. Being able to visualize construction sequences and operations can result in tremendous savings in money and time and help to keep projects on schedule. Visualizing construction operations in 3D can permit the complete subjective analysis of the construction process. Construction subtleties such as maneuverability problems at loading and dumping areas in earthmoving operations, the restricted visibility of the crane operator in steel girder erection, overcrowding in particular work zones due to simultaneous execution of different trades in building construction, and a host of other safety problems such as potential collision between two machines can easily be deciphered by visualizing the actual construction operations that lead to the completion of the constructed product.

In addition, 3D Visualization can allow the validation and verification of operational concepts, enable checking for design interferences and overall constructability review and the sharing of project information. It can also enable the testing and validation of construction sequences, checking for physical clashes of moving pieces and enable communication/coordination among multiple project participants.

Status

The DCV has been used to visualize several simulated operations both within and outside the realm of construction. The first figure above presents an animation snapshot of the main loading area in a modeled earthmoving operation. The alternate loading area is also visible in the background. In this animation, the viewer is able to observe the accumulating trucks waiting to be loaded, the trucks maneuvering to get into position under the excavator, the excavator digging the earth and loading the trucks until they are full, the trucks traveling to the dumpsite, accumulating to enter the dump area, backing up and tipping their load, and then returning to the loading site to begin another cycle.

Barriers

- The application of the technology requires developing 3D cad models for the process to simulate.
- Some operations are difficult to be described: the flow of concrete from pump into forms, the deformation of the terrain as an excavator digs the earth, etc.

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Reviewers

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