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3D-Planning of construction site equipment based on process simulation

T. Horenburg, J. Wimmer, S. Kessler & W. A. Günthner
Institute for Materials Handling Material Flow Logistics, Technische Universität München, Germany

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The equipment of a building site as a link between planning and realisation assures high productivity by optimzing material flow and efficiency of expensive machines.

There have been approaches in research to plan the building site virtually using software-tools and to create transparency for later processes within work preparation. A concept exists to manage resources and areas for repetitive floors in multistory projects based on a project plan (Thabet et Beliveau, 1997). Yet another approach consists in dimensioning objects of building site equipment using rule-based algorithms and loading them into a 3D-model (Lennerts, 1999). Further research determines the layout of tunnel projects using a genetic algorithm, which evaluates hard and soft constraints to realise an optimal arrangement of the equipment objects (Zhou et al., 2009).

Approaches existing so far consider static periods, such as approximate construction phases. Hence there is a new status of the building site equipment created for each phase and tested on averaged system loads. This facilitates a macroscopic optimisation of the layout, however, without considering individual fluctuating material flows. A 3D-visualisation of realistic material flows enables a clearly arranged planning, in which effects of changes in the layout can be easily analysed. By using process simulation for illustrating construction progress and processes, realistic material flows can be determined. The simulation is based on the layout of the equipment combined with the workflow and the building site model, which, for instance, results in an optimal execution sequence for building site processes (Beißert et al., 2008). Hence the material flow for every individual layout can be used to optimise utilisation of space and equipment, such as storage areas or tower cranes. As a result of implementing the construction site equipment to the simulation environment – unlike common CAD-systems – various analysises of material flow such as Sankey-diagramms or bottleneck analysis are possible. Based on the process simulation significant evaluations such as capacity utilisation of equipment objects are generated separately for every construction phase. The current layout can be validated regarding an optimal material flow and efficiency of individual functional surfaces by a sufficient number of simulation experiments. Rearrangement processes can be planned respectively resulting in an optimal layout based on realistic material flows.

For this purpose a 3D-model of the building site is imported in the simulation environment. Furthermore events are created within an imported Gantt-chart, which defines the individual construction phases. These events are located each at the start and end of every process step. Besides the imported models and the project plan a library of intelligent objects for building site equipment is provided. The library contains individual modules that can be combined with other modules via defined interfaces. Further attributes (e.g. time and costs of the equipment) such as 2D- and 3D-CAD-models and functions of common building site equipment are stored for every simulation object. Additionally, the objects are adjustable during time. Changes in size and position can therefore be represented, which is particularly interesting for variable areas such as storage spaces. The different attributes refer to typical characteristics of the particular object such as size and capacity of storage areas or the rotational and lifting speed of cranes. The building area is managed by background routines, so that areas can not be occupied simultaneously by several processes.

The building site equipment can be changed for every event of the imported Gantt-chart. The respective layout configuration is recorded and during simulation experiments the equipment objects are specified according to the determined layout and the current event. In this approach the building site is to be equipped based on a 2D-plan and set up depending on delivery and storage strategies. A 3D-model is parallely used for the equipment of the building site and the entire layout is updated automatically as soon as a module of the library is integrated. It is therefore possible to perform a three dimensional verification of the equipment objects without additional work and expenses. Events are based on individual progress of the Gantt-chart and hence chart-updates do not affect the site equipment.

The presented method of solution to improve the building site equipment is realised in Siemens Plant Simulation. The created library for an efficient 2D/3D planning of building sites is exemplarily realized for specific objects such as storage and installation areas, construction roads, tower cranes and containers. The modules are functionally embedded in the simulation and controlled by easily comprehensible dialogs.

The allocation of space at the time assigned by an active event is performed by the planner. During the periods between events, idle space is available for the resource management and can be allocated respectively. Resource management records allocated areas, type of equipment and utilisation and can be used depending on the plan's level of detail. As soon as the material flow on the real construction site differs from the simulated, a new simulation run can be performed using actual data. It is conceivable to integrate algorithms for optimising layouts into the simulation tool such as a genetic algorithm for the planning of the temporary equipment objects. It is also possible to consider security-relevant aspects by integrating specific rules into the simulation tool.

The integration of the building site equipment in a simulation environment does not only serve as preparatory module for the process simulation, but is also basis for an unobstructed material flow at the construction site. The approach mentioned above provides a tool to plan the construction site layout manually depending on the accuracy of the project plan, the precise layout results from the simulation according to the required degree of detail.

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