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Generation of a construction planning from a 3D CAD model

Bauke de Vries [a,*], Jeroen M.J. Harink [b]

[a] Department of Architecture, Building and Planning, The Eindhoven University of Technology. P.O. Box 514, 5600 MB Eindhoven, The Netherlands
[b] BAM Utiliteitsbouw, Advies and Engineering. P.O.Box 54, 3980 CB Bunnik, The Netherlands

Abstract

In construction planning practice, increasingly 4D CAD system are applied for construction analysis and communication. Normally the planning expert is responsible for relating building components to construction activities. In this article we describe a method for automated generation of the construction planning. An algorithm is presented that derives the construction order from a solid model of the building. Experiences from a pilot study illustrate the differences between the real planning and the generated planning, and they show the limitations of the current implementation. Finally an outlook is presented on a more advanced planning system that includes contractor's specific knowledge for more accurate results.

Keywords: 4D CAD; Construction management; Construction analysis; Automatic planning

1. Introduction

Traditionally, construction planning is a critical factor in building management. The construction planner, employed by a building contractor is a person with much experience in building construction who knows how to estimate the required labour and equipment from a building design. Using this knowledge a construction planning is created as the leading schedule for other derived plans such as transport, measurement, safety, etc. Project plans are constructed completely manually or using a specific tool like MS project® or Primavera®.

Due to the critical factor of the planning, many research efforts have been directed to simulation of the building process based on the planning, to visually or computationally search for conflicts or errors [1,2]. From this research, 4D CAD systems have emerged, like InVizn®, Navisworks® and 4D Suite®. These systems support the planner by relating building components from a 3D CAD system to construction activities from a project planning system, using a graphical interface. The construction process can then be simulated by executing the planning and the user can visually check how the process proceeds. 4D CAD systems can be used for construction analysis and communication. Experiences in practice by Clayton [3] and Broekmaat [4] have learned that 4D CAD reduces the number of activities on the critical path, distributes the equipment more evenly, allows for more flexibility in time and reduces planning mistakes.

Even when using 4D CAD systems, the planning expert still plays a crucial role, as he manually relates building components to construction activities and visually tests whether problems occur during the construction process. 4D CAD systems do not bear any knowledge about the construction process itself. More advanced systems support collision detection, but there is no mechanism for expressing constraints and dependencies, and to test whether they are violated in the construction process.

In our research project we took up the challenge to automate the planning process, being well aware that a completely automated procedure is probably not feasible. However, this proposition allows us to investigate which construction knowledge can be derived from common sense or physical laws, which knowledge is construction method dependent, which knowledge is building component dependent and which knowledge cannot be described by the previous methods and thus remains for further investigation or in the hands of the planning expert. For knowledge representation we initially follow a computational approach to research how far this method can bring us in producing a reliable planning. A limited pilot study is executed to test the results against current planning practice. In this paper we report on construction

* Corresponding author. Tel.: +31 40 2472388; fax: +31 40 2450328.
E-mail address: b.d.vries@bwk.tue.nl (B. de Vries).

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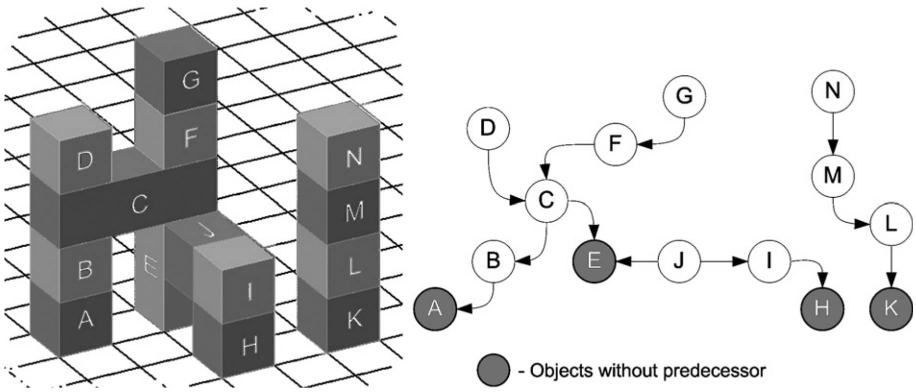

Fig. 1. 3D grid and graph schema.

algorithms we investigated and how well they performed. Finally we will discuss which deviations were found and how we think we can extend our system to produce a more reliable planning.

2. Construction algorithms

A construction algorithm encapsulates construction knowledge. Construction knowledge can be divided in knowledge about structural behaviour and knowledge about construction methods. Structural behaviour is determined by physical laws, and construction methods are determined by the building products and the construction equipment. For now, we assume that the construction method is fixed, which does not mean that our automated planning can handle only one construction method. We will come back to this issue in the discussion section. Given the construction method, there are still many construction orders possible. In this section we will discuss which computation methods are available for calculating the construction order of building components and how these methods perform.

An excellent overview of ordering methods is presented by Johnson et al. [5]. They differentiate between ordering by element type, by elevation, by joint configuration, and by tracing from foundation. The authors were not able to identify an algorithm that worked in a consistent, generalized manner. The methods flawed for special cases. They conclude that only Finite Element Analyses can solve this problem. In our project we take a different approach. We do not aim at an abstraction for structural analysis, but for construction analysis. Therefore we have researched algorithms that analyze the topology of a building construction. Before that we will briefly discuss the basic principles for 3D geometry representation of building components, since this representation strongly affects the algorithmic approaches.

2.1. 3D representations

In building practice line drawings are still widely used. Recognition of building components from line drawings is in its infancy and is not considered in this research. Increasingly, architectural and engineering offices produce 3D models using surface modelling and/or solid modelling. With solid modelling, structural properties such as inertia and volume are readily available. CAD systems typically contain a library of building components that can be adjusted to the designer's needs. Building components (e.g. wall) can provide additional (e.g. material) and derived data (e.g. surface area).

2.2. Construction order analysis

Instead of calculating the vertical load distribution to find out which component bears another component, it is also possible to use the geometric data of the model. More specifically the topology of the building can tell which component is on top of or next to another component. Under the assumption that a 3D CAD model is available, we investigated two approaches for construction order analysis, namely 3D box representation and 3D solid representation. The analysis results in a directed graph, stored in a log file. In this graph the nodes represent the building components and from each node the edges point at components that are underneath or besides.

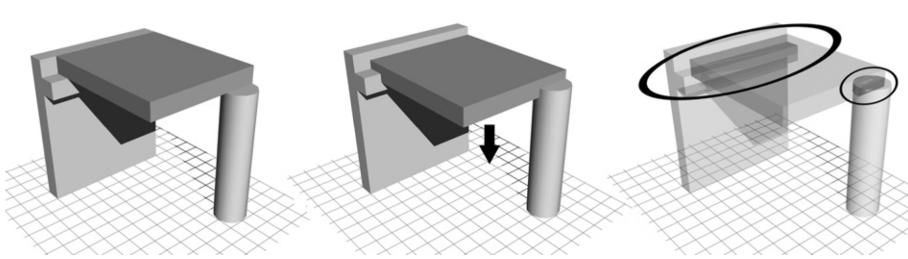

Fig. 2. 3D solid displacement and intersection.