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ScienceDirect
International Journal of Project Management 27 (2009) 532–542
International Journal of Project Management
www.elsevier.com/locate/ijproman

Construction schedule review in GIS with a navigable 3D animation of project activities

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Received 11 February 2008; received in revised form 27 June 2008; accepted 17 July 2008

Abstract

This paper presents a Geographic Information Systems (GIS) based navigable 3D animation of project activities to visualise and review a construction project schedule as an alternative to the existing 4D CAD tools. Most of the commercial tools allow planners to build a 4D model but lack features like generation and manipulation of developed 4D model on a single platform. To facilitate the 4D model manipulation, both 3D model and the project schedule are developed within GIS. However, models generated by using popular commercial tool like *y* and the schedule generated in *Primavera* or *Microsoft Project* can also be utilised within the proposed approach. The animation of the project activities utilises dynamic linkage between activities of the schedule and the corresponding 3D components, thus, allowing detection of missing activities and logical errors in the project schedule. The database management capabilities of GIS are also utilised to maintain and update the construction resource database to facilitate the project planning. Most of the existing 4D technologies do not have project management capabilities and are used mainly for planning and design phases of a project. GIS based approach suggested in this paper may be used as the project management tool at any stage of the project. Along with 'what' is to be built 'when', a navigable 3D GIS based animation conveys 'where' in the space and offer powerful schedule visualisation, planning and querying capabilities.

Keywords: Geographic Information Systems; 4D construction management; Scheduling; Project management

1. Introduction

Critical Path Method (CPM) has significantly contributed to construction project scheduling process by providing start/finish time, total/free floats and critical path activities. In addition, CPM schedule is a vital source for delay impact analysis in the time related claims. The CPM schedule provides non-spatial information that lacks in spatial aspect of the construction project. To have the spatial aspect, planner uses 2D drawings and associates components of the drawing with the related activities present in the CPM schedule. The absence of dynamic linkage between the activities of CPM schedule and corresponding components of a 2D drawing makes it difficult to check the schedule completeness [1]. Due to the difficulty in mentally linking each component of a 2D drawing with corresponding activity of the CPM schedule, the schedule interpretation varies with individual project team member. The schedule interpretation also depends on the level of experience, knowledge and individual perspective of the project participants. Therefore, it becomes difficult to understand, communicate and discuss whether a problem exists in the schedule or not. Any missing activity or logical error in the CPM schedule may pose a serious problem for the successful completion of the project [2].

Such shortcomings of the scheduling tools together with the advances in digital technologies have motivated various research and development efforts to develop new construction process planning techniques in order to enhance the visualisation of construction sequence [3]. The 3D CAD

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doi:10.1016/j.ijproman.2008.07.004

technologies available to Architecture, Engineering and Construction (AEC) industry have allowed researchers to combine it with the CPM schedule that leads to the development of 4D CAD [1]. 4D CAD allows the planner to visualise the construction process in a way, as it would actually be built. Koo and Fischer [1] suggested that 4D CAD model increases the comprehensibility of the project schedule and allows the user to detect the potential problems such as scheduling conflicts, examining constraints and to evaluate alternative construction methods prior to the construction. The 4D visualisation technique provides an effective means to communicate temporal and spatial information to the project participants. Visualisation of construction plan allows the project team to be more creative in providing and testing solutions by means of viewing the simulated time-lapse representation of the corresponding construction sequences and prompting the users to think about all missing details [4–5].

The 4D CAD systems lack construction specific components such as scaffolding and other temporary works integrated in the 3D model. This lack of planning for temporary structures may affect the safety, quality and productivity. In view of these practical deficiencies, virtual reality (VR) technologies were used in construction control [5–6]. Simulation of construction progress in a VR space enables preliminary examination of construction methods or procedures by visual inspection of construction progress. A VR based system suggested by Huang et al. [3] generates, reuses and modifies 3D models of building components, construction equipment, temporary works as well as labour force. These systems make 4D models more complete by adding temporary works and their activities to set and dismantle them. It allows planner to review the construction process planning and analyse the workspace layout more efficiently. Waly and Thabet [7] developed an integrated virtual planning tool called the Virtual Construction Environment (VCE) which allows a project team to undertake rehearsals of major construction processes and examine various execution strategies before actual construction work.

Despite a lot of researches in 4D CAD and VR technologies their use is not very common in AEC industry. These tools are somewhat difficult to use and the floor level visualisation provided by them is not easy to customise [8]. Existing 4D CAD/VR systems are unable to aggregate and distribute the information between spatial and non-spatial databases. The 4D CAD tools are based on object-oriented concepts and are used primarily for planning, design phase and appraisal types of analysis [9]. Most of these tools have an ad hoc modelling approach that makes it difficult to update and maintain these systems. Furthermore, 4D CAD models have a single level of detail, which hinders the collaboration among general contractors and sub-contractors as well as very few of these models support computer based cost and safety analysis [9].

To improve the construction planning efficiency, Koo and Fischer [1] suggested that 4D construction management in AEC industry requires a tool that can manipulate the CPM schedule and 3D components in a single environment. These two essential components cannot be manipulated in a single environment in the existing 4D CAD/VR based construction management tools. GIS that combines CAD like spatial data editing capabilities with database management system seems to have the potential to solve this problem [10]. GIS improves the construction planning and design efficiency by integrating spatial and non-spatial documents of the construction project in a single environment.

The construction project information such as drawings, specifications and CPM network/bar-chart required during planning are generally available in different forms, thus making it difficult to integrate information during the planning phase. GIS, appears to have the potential of integrating such project specific spatial and non-spatial information together [10]. Moore [11] argued that the incorporation of 4D technology into the area of GIS will improve its analytical power. The researches in the last decade indicate that GIS can be used effectively to meet different construction project requirements [12–13]. It is used in AEC industry to handle various construction project requirements such as data management, integrating information, route design, complex visualisation, quantity takeoffs, construction cost estimate, site layout, construction planning, etc. [14]. Heesom and Mahdjoubi [15] suggested that most of the 4D CAD simulations are used for schedule visualisation purposes only, whereas very few offer the ability to carry out analytical tasks on the developed 4D model. On the other hand, GIS provides spatial analysis tools along with the visualisation capabilities [10]. GIS provides the abilities to model complex topographical condition and planning the access routes to the construction sites that is not possible in 4D CAD/VR. It can also be used to find the shortest path to the construction site in the complex transportation networks [13]. GIS along with Geographic Positioning Systems (GPS) may be used to control the various operations at construction site on real time basis.

The study by Poku and Arditi [9] used *AutoCAD* and *Primavera* to generate construction design and schedule respectively and manually transferred the information from *Primavera* and *AutoCAD* to *ArcView*. This manual transfer of information creates a difficulty in its practical applications. The CPM schedule (generated in *Primavera*) requires frequent revisions during construction stage and need to be linked/unlinked many times with/from the components of a 3D model to correct the construction sequence, thus, making it a time consuming process. Another limitation of the system proposed by Poku and Arditi [9] is that, if it does not provide the desired construction sequence, the schedule generated in *Primavera* cannot be corrected in *ArcView*. Also, the geometrical editing of 3D components (developed in *AutoCAD*) is not possible in *ArcView*, if required at schedule correction stage.

This paper discusses a GIS based approach to develop a 3D model of the building as well as CPM schedule to facilitate the manipulation of both on a single platform as an