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A framework of information visualization for multi-system construction

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ABSTRACT

Modern buildings usually include multiple systems such as air-conditioning (AC), water supply and gas pipes, sanitary lines, telecommunication systems and security networks. Because these systems are highly interdependent, conventional methods for presenting information, typically a 3D model and a schedule, are insufficient to effectively manage and coordinate various experts working on a project. This research proposes a framework that enables engineers to explore and interact with the information visually. It includes four information views (temporal, hierarchical, relational and spatial), four interaction functions (information exploration, cross-highlighting, time controller, and information extraction) and two display layouts (matrix hardware layout and flexible software layout). A prototype system called Construction Dashboard was implemented following this framework. To validate the effectiveness of the proposed framework we conducted a user test (N = 30) using an example project involving four systems (power, AC, water and computer). Each user answered nine questions related to different management and coordination problems by employing both Construction Dashboard and the conventional method (3D model with a schedule). The results showed that the completion times, for each of the nine questions, to solve these questions are significantly faster when using Construction Dashboard. The success rates to obtain the correct answers are also significantly better in three of the nine questions.

1. Introduction

1.1. Challenges in multi-system construction

Modern buildings are equipped with a diverse range of service systems, such as mechanical, electric, and plumbing (MEP) works, which include air-conditioning (AC) conduits, water and gas pipes, irrigation and sanitary lines, telecommunication and security networks, HVAC and LVAC, fire fighting and fire control, and so forth. Investigators are continuing to add more sensitive regulatory systems in modern buildings to make the living spaces more convenient, comfortable, decorative and safer, as well as energy-saving. However, the multi-system facilities of a building significantly increase the complexity of the planning, design, and construction management processes. Many researchers have also pointed out that coordination is one of the most critical challenges in a project involving multiple systems [1–3].

One such challenge is the identification of the spatial conflicts between systems. In current practice, the pipes and cables are represented using lines. Engineers usually add the symbols and notations to indicate the meaning of each line (i.e. the feature of the pipe or cables). They usually mark lines with different colors to differentiate each of the systems. Although the dimensions are noted on the drawings, engineers still need to imagine the actual space occupied by the cables or pipes. When multiple systems are involved, very often they may miss the conflicts during the design phase which can result in change orders and rework on the construction site.

Another challenge in managing a multi-system project is the scheduling of conflicts. Usually a construction drawing or 3D model presents the final state of a project. The actual assembling sequences require the integration between the spatial and temporal information. This process often relies on engineers' powers of visualization. When more than two systems or two working parties are involved, the conflicts are sometimes very difficult to identify.

A further challenge is that the systems are usually linked to a project milestone. This typically increases the complexity of project scheduling. In most projects involving multiple systems, one or more milestones will be set for each system. The subcontractors need to execute a trial run and a pressure test (or both), to verify the function and stability of the system. Furthermore, the systems are sometimes interdependent. For example, an AC system depends on the power and water systems for cooling. Project managers and engineers need to plan these tasks in advance so that they can promptly deal with any failures during the trial run.

To deal with the management and coordination problem in the increasing number of multi-system projects, engineers need a more powerful tool or method to display the information at different levels of detail. Since projects involve engineers from different backgrounds, the information needs to be presented in a comprehensible way that

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