



BIM-based framework for automatic scheduling of facility maintenance work orders



Weiwei Chen^a, Keyu Chen^a, Jack C.P. Cheng^{a,*}, Qian Wang^b, Vincent J.L. Gan^a

^a Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong

^b Department of Building, School of Design and Environment, National University of Singapore, 4 Architecture Drive, Singapore

ARTICLE INFO

Keywords:

Automatic scheduling
Building information modeling
Facility management
Facility maintenance management
Facility maintenance path planning

ABSTRACT

Although more than 65% of the total cost in facility management (FM) comes from facility maintenance management (FMM), there is a lack of efficient maintenance strategies and right decision making approaches to reduce FMM costs. Building information modeling (BIM) has been developed as a potential technology for FMM in buildings. This study proposes an FMM framework based on BIM and facility management systems (FMSs), which can provide automatic scheduling of maintenance work orders (MWOs) to enhance good decision making in FMM. In this framework, data are mapped between BIM and FMSs according to the Industry Foundation Classes (IFC) extension of maintenance tasks and MWO information in order to achieve data integration. After bi-directional data transmission between the BIM models and FMSs, work order information is visualized in BIM via API to identify components that have failed. Second, geometric and semantic information of the failure components is extracted from the BIM models to calculate the sub-optimal maintenance path in the BIM environment. Third, the MWO schedule is automatically generated using a modified Dijkstra algorithm that considers four factors, namely, problem type, emergency level, distance among components, and location. Illustrative examples are given in the paper to validate the feasibility and effectiveness of the proposed framework in indoor and outdoor 3D environments.

1. Introduction

Facility management (FM) is an integrated approach for an organization to operate, maintain, improve and adapt its buildings and infrastructures in a way such that the primary objectives of the organization, occupants, owners and facility managers are supported [1]. FM comprises various areas, but it is facility maintenance management (FMM) that constitutes most (65%–85%) of the total costs incurred by FM activities [2]. Facility maintenance activities can be supported by computerized maintenance management systems (CMMSs) and facility management systems (FMSs) as fundamental information sources, providing FM staff (facility managers and maintenance workers) with a wealth of support-related information as well as assisting management in decision making. Currently, many CMMSs and FMSs, such as ARCHIBUS [3], EcoDomus [4], Maximo [5] and FM system [6], are available on the market. They can be used to manage the building maintenance process and to provide a better organized information platform. However, solutions for automatic information capture and data analysis are still limited in CMMSs and FMSs. Specifically, most of the current existing systems cannot provide automatic scheduling of a large

number of maintenance work orders (MWOs). On the other hand, the effective management of facility maintenance relies heavily on continuous and reliable information of asset inventory, condition and performance [7]. However, traditionally, FM staff use 2D drawings to search for information, such as the dimension, material and location of building elements. It is not only time-consuming, but also difficult for FM staff to obtain accurate information from 2D drawings. Thus, innovative approaches are needed to improve information transfer and retrieval for supporting FMM.

Building information modeling (BIM) is a new approach to building design, construction and facility management. In BIM, a digital representation of the building process is used to facilitate the exchange and interoperability of information in digital format [8]. BIM creates a digital database of all assets of a building and can support virtual 3D coordination of construction and operational activities, including FM. Volk [9] suggested that BIM can contribute to FM both as an information source and as a repository for supporting the planning and management of building maintenance activities in both new and existing buildings. BIM concepts, tools, workflows and their underpinning open standards (e.g. Industry Foundation Classes (IFC)) [10] and data

* Corresponding author.

E-mail address: cejcheng@ust.hk (J.C.P. Cheng).

structure specifications (e.g. Construction Operation Building information exchange (COBie)) [11] offer the means to support the exchange of information throughout the lifecycle of a building.

The objective of this study is to propose an integrated BIM-FM methodology framework to improve the efficiency of FMM. The proposed framework is developed based on BIM technology and existing FMSs, allowing FM staff to access accurate information and automatically obtain MWOs scheduling. In addition, the framework can visualize corresponding MWOs in BIM models, allowing FM staff to make better scheduling decisions. This paper is organized as follows. Section 2 reviews literature on (1) IT-based FMM, (2) facility information management and BIM-based data integration, and (3) maintenance work order scheduling. Section 3 proposes a BIM-based FMM framework by presenting its (1) as-built BIM model preparation and data integration, (2) identification of failure components, (3) maintenance path planning method, and (4) a work order scheduling algorithm. Section 4 shows the feasibility and efficiency of the proposed BIM-based FMM framework using two illustrative examples. Section 5 concludes the study and elaborates on future work.

2. Literature review

2.1. IT-based FMM

CMMSs are traditionally utilized by facility maintenance organizations to record, manage, and communicate daily operations, and can be deployed for (1) asset management, (2) inventory control, (3) generation of service requests, (4) managing work orders of different types, and (5) tracking the resources (time and costs) of services and materials used to complete work orders [12]. Another technology used in FMM is computer aided facility management (CAFM) systems or FMSs, which integrates Computer-Aided Design (CAD) graphics modules and relational database software to provide various facility management capabilities, including space management [13]. It also provides a means to collect data from a variety of sources and links it to other systems (such as CMMS) or to human transfer processes. There are two major problems in current FMSs: (1) CMMSs/FMSs cannot provide automatic maintenance work order scheduling, and (2) it is difficult for FM staff to access accurate information.

In recent decades, BIM has been increasingly used for FM, because BIM facilitates collaboration among different people and information integration during the O&M phase, and BIM is also beneficial for processing the large sets of complex information typically associated with maintaining building assets. Implementing BIM in FM also allows asset owners to formulate intelligent decisions on facility related activities, and to consequently optimize maintenance scheduling and space utilization planning [14]. Some early studies [5,9–14] on BIM-based FMM have shown how BIM may enhance FMM activities. Hassanain et al. [15] have proposed an IFC-based data model for integrated maintenance management for roofing systems. Hassanain et al. [16] presented a general object-oriented schema for asset maintenance management that supports information exchange from the construction stage to the O&M stage. However, no visualization function was considered in the study. A case study on the Sydney Opera House demonstrated some existing FM systems (such as Mainpac [17], HARDCAT [18] and TRIM [19]) for facility information management, and illustrated the research value that IFC and BIM can support data consistency and information interoperability in FM. Furthermore, the case study showed that BIM can help FM staff to perform visual decision making in FM [8,20]. However, immature data formats and data exchange policies made the data export process rather time consuming. Later on, Lin and Su [21] developed a mobile- and BIM-based integrated visual FMM system, and the system included functional modules for (1) information and report management, and (2) facility monitoring through visualized and colorized BIM models. However, it did not provide any decision making functions for maintenance

scheduling. Stakeholders are yet cautious about implementing BIM in the FM industry, and most functions, such as information querying and work order scheduling, are still performed manually [22,23]. The interoperability problem of BIM-FM integration and automatic decision making for maintenance management need to be further explored.

2.2. Facility information management and BIM-based data integration

Information is critical for efficient and effective building maintenance and daily operations [1]. However, during O&M, more than 80% of the time is used to look for relevant information, due to lack of data integration. As BIM provides a comprehensive information system that captures information on all related building components, this essential and relevant information, such as geometric and semantic information, can be efficiently gathered and retrieved in a BIM environment. Ding et al. [24] further reinforced these findings and revealed that BIM reduces time for updating FM databases by 98%. A tremendous amount of building information is collected over the lifecycle of a building. However, data flow from the design stage to the operational stage is still not seamless and data loss may occur. Teicholz [25] reported a few issues concerning data loss and data integration including: (1) inconsistent naming conventions, (2) no universal standards for facility information requirements, (3) inadequate data categorization in BIM and CMMSs/FMSs, (4) poor information synchronization, and (5) a lack of methodology to capture existing facilities and assets. In addition, there is a shortage of a scalable framework to efficiently manage information related to FM. In order to solve the data integration problem between BIM and CMMSs/FMSs, researchers have applied two standards, namely COBie [11] and IFC [10]. COBie is an information exchange specification for the life-cycle capture and delivery of information needed by facility managers [11]. The COBie standard helps to improve the handover of asset related data via the BIM models to the facility managers and/or owners of a building [8,26]. With COBie standard, stakeholders are able to store maintenance information in BIM in a structured way, and thus in a valuable form of facility documentation [27]. This improvement is achieved by the standardization of data management in COBie for improved interoperability between BIM and CMMSs/FMSs [28]. In addition, the IFC standard is an object-orientated 3D vendor-neutral BIM data format for geometric and semantic information of building objects. The IFC standard has been used as the generic file format for transferring information from BIM models into CMMSs/FMSs, due to the lack of interoperability between existing CMMSs/FMSs and the growing number of commercially available BIM packages [23]. Information extension of the IFC data model is necessary to store facility information in a BIM model. Lucas et al. [26] proposed an object-oriented product model in the context of developing a healthcare facility information management framework, in order to help facility managers to better manage facility lifecycle information. Many researchers [2–8,20] have studied BIM-based facility information management and data integration between BIM models and FMSs, but they have yet to consider how to map data seamlessly without losing any data between BIM models and CMMSs/FMSs. Therefore, this study leverages COBie and extends IFC to achieve data mapping and data integration between BIM and FM.

2.3. MWO scheduling

MWO scheduling refers to the scheduling of a series of maintenance tasks to fulfill certain requirements. There are two key steps in managing MWOs, namely, prioritization and scheduling. Some researchers have applied equipment classification systems, preventive maintenance (PM) scheduling models, and work-order management systems for prioritizing repair requests for industrial facilities and manufacturing companies [29,30]. For example, Xu et al. [31] proposed an agent-oriented approach to manage work orders for circuit breaker maintenance. Hamdi et al. [32] designed an intelligent healthcare

Download English Version:

<https://daneshyari.com/en/article/6695519>

Download Persian Version:

<https://daneshyari.com/article/6695519>

[Daneshyari.com](https://daneshyari.com)