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Integration of ifc objects and facility management work information using Semantic Web

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ABSTRACT

The management of information throughout a building's lifecycle is becoming increasingly important, and building information modeling (BIM) is often used to ensure the interoperability of data. However, BIM-based facility information from the construction phase is difficult to access and use during the operation and maintenance phase. This occurs because the BIM information is not utilized well in facility management (FM). In this research, we propose an approach to effectively manage BIM-based FM information by linking the BIM-based building elements and FM work information in an FM system database. We present a Semantic Web-based FM information system that semantically links BIM data to relevant historical work records. The proposed ontology was evaluated using a sample dataset of the architectural maintenance work records of an office building. Using the proposed approach, facility managers will be able to increase their efficiency in searching related work records that consider shared BIM objects by enhancing the interoperability and accessibility of FM data via the Semantic Web.

1. Introduction

The concept of facility management (FM) is similar to that of building management, both of which are used to operate and maintain buildings. The planning of FM starts with the initiation of construction; then FM information is produced and managed throughout the building's lifecycle. Because FM can be affected by building information throughout the lifecycle, there is a great interest in the management of FM information and the object-oriented performance of FM works through a computerized information management system.

Data interoperability must be ensured through an object-oriented work process that covers the entire lifecycle of the building. To use this approach, especially in the FM area, a standard specification or type of data should be defined for a given facility management system (FMS). To use advanced information management, building information modeling (BIM) ensures coordinated, consistent, and computable building information in the architectural, construction, and engineering (AEC) industry by buildingSMART International [1]. Thus, the schema of industry foundation classes (IFC[1]) was developed as an integrated object data model to systematically and semantically manage a building's elements throughout its lifecycle. Since the IFC schema has semantic data relationships among the building data entities [2], the building data generated and managed in each phase of the lifecycle can be linked not to the internal data entities but to the external heterogeneous database (DB) of the information management system, such as material specifications or actual costs of construction activities.

Although information related to the design and construction of a building could be managed by an international standard, FMS data in the FM area cannot be managed by a public data model because the FMS is used differently by the various FMS scopes and functions in the operation and maintenance (O&M) phase. To define the specification of the data exchange for FMS at the start of the O&M phase, a global development of exchange requirements has been developed for the handover procedure, known as the ‘construction operation building information exchange’ (COBie) system. The COBie schema can be used as a standard data exchange system throughout the building's lifecycle to ensure the interoperability of BIM data for a FMS using a data spreadsheet. However, when the IFC-based BIM data are used with COBie for an FM work, the required FMS data should be managed by an integrated, IFC-based building model with some external data, such as the FM work information, which are managed separately in the FMS DB. Additionally, in the real world, because the data structure of an

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[1] http://www.buildingsmart-tech.org/ifc/IFC2x4/rc4/html/index.htm

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FMS database is not normalized to link the IFC objects or the COBie data as a public data model, the facility manager rarely uses an FMS on the actual job site via the traditional approach without IFC objects or COBie [3]. To increase the usability and accessibility of the object-oriented BIM data in an FMS, the building data, which are generated separately by a heterogeneous data schema, should be integrated semantically to provide object-based FM information that supports BIM-based FM works, such as 3D visualization, review of related work records, and maintenance work management.

Therefore, in this paper, we propose an advanced data management approach to integrate IFC objects, COBie data, and maintenance work information of the FMS DB. In our approach, an ontological system is developed through the Semantic Web to enhance the usability and accessibility of object-oriented information management with FMS. To that end, after analyzing the technical developments of information management in the FM area with BIM and the Semantic Web, we developed an ontology to link the IFC objects with the FM work information of a traditional FMS DB. To evaluate the proposed approach, we collected the historical maintenance work records from a FM company, and used the proposed ontology to semantically link the IFC-based, common BIM files via buildingSMART to the maintenance work records.

2. Technical improvements of information management for FM

The increased use of information technology (IT) and related applications has provided advantages such as improved collection of the data required for FM works and the simplification of the FM work process [4]. According to Jawadekar [5], the development of information management in the FM area was improved with specific IT. As a first step, the computerized information management system could be used for storing FM information, automating data processes, and conducting comprehensive reviews of the physical and functional properties of a facility [6]. The second most important improvement to FM by IT applications is the real-time exchange of data via Web-based information management [7]. Thus, the quality rather than the quantity of FM information became the focus of the facility manager's attention.

To increase the quality of FM information, including BIM data, the FMS must be well developed with precise and valuable data collected by all stakeholders in the previous phases. A variety of approaches can be used to support the FMS by importing and exporting data, such as text, spreadsheets, and relational DB files. Moreover, heterogeneous data are collected by these different methodologies [8]. However, the development of an FMS database still involves some potential problems [9]: 1) the stakeholder's roles and responsibilities for FMS requirements are often unclear; 2) because the applicability and reliability of the data inputted to the FMS DB are often insufficient, the FMS manager are required to repeat previous work in order to develop a FMS DB; and 3) because the requirements of FMS are managed manually based on 2D building information, human error may be introduced to the relationships between FMS requirements.

2.1. BIM-based information management

Various commercial FMS systems use the FM information management tool for BIM. The development of FMS to search for and provide accurate FM information is required in order to increase the type or amount of FM information available to support FM works [10]. To use FMS for efficient information management, the building information entered into the FMS should be organized by semantic relationships among the component data to integrate heterogeneous information. In general, building information has limited heterogeneity because various stakeholders use different software to manage it, but the heterogeneity can be reduced by completing data interoperability with semantic relations [11].

For this reason, a significant amount of research and development has been conducted to ensure the interoperability of FM information using BIM. Kivits and Furneaux [12] analyzed the availability of information from BIM-based FM case studies, and suggested that FM information should be provided more easily and rapidly to facility managers. In addition, FM information should be updated to reflect current status within a single, integrated BIM model in the O&M phase.

McArthur's research [13] identifies improvements in four major areas that are necessary to use BIM in FM works: 1) identification of critical information required to guide operational decisions; 2) high level of effort to create new or modify existing BIM models; 3) management of information transfer between real-time operations and monitoring systems and the BIM model; and 4) the handling of uncertainty based on incomplete building documentation. These four improvements enhance the possibility of using a BIM model in the O&M phase, and the accuracy and consistency of the FM information was verified by three case studies using BIM.

Kang and Choi [14] suggested a BIM-based work scenario in Korean FM practices to support general maintenance works. To validate the proposed scenario, they interviewed a facility manager who had more than 15 years of experience in the management of FM information using BIM, and the manager indicated that the productivity of maintenance work had increased from 25% to as much as 205% as a result of several improvements in requesting, searching, verifying, reviewing, and collecting the required information.

When BIM is used in the design and construction phase of a new construction project, a COBie system may exchange data between phases of a building's lifecycle. COBie is an international standard for the exchange of building information from the design phase to the O&M phase, using a formal spreadsheet [15]. However, when using the COBie sheet for data exchange, the required data should be managed by the integrated, BIM model with some external data. When information managers want to collect FM data using COBie, they must consider external data, such as product data, using a specifier's properties information exchange (SPie) library, which uses buildingSMART as middleware to apply the SPie library to the COBie sheet [16].

2.2. Integrated management using Semantic Web

When automating the process of building information through a computerized DB, two conditions are necessary for semantically-related data interoperability. First, the information must be represented by computerized codes in a programming language. Second, ontology is required to define the relationships among concepts of building information-coded, computerized language [17]. After the development of the World Wide Web (WWW) in the early 1990s, Tim Berners-Lee proposed an extension—the Semantic Web—which can handle Web data without human intervention [18]. Because Web data are currently expressed in human-readable form, computers cannot interpret their exact meaning. To overcome this, Semantic Web data are expressed in a computer-readable format using ontologies, the key technology of the Semantic Web, which are formal and consensual specifications of conceptualizations that provide a shared understanding of a certain domain [19]. Using the ontology that describes various concepts and their relationships, the computer automatically enables reasoning about data from different data sources in order to manipulate relevant data or find new information.

To use BIM-based data relationships in a semantic inference procedure, researchers have converted IFC files to Web ontology language (OWL) for input into Semantic Web applications. Because a BIM model using an IFC is represented in building information as computerized EXPRESS language, IFC-based building information can be defined by OWL-based data and relations with the similarity of the data relationship between IFC and OWL [20]. However, because the IFC schema is described by logic-based EXPRESS, the semantic relationship is limited to the representation and sharing of inferred knowledge. Therefore, awareness is necessary for linking additional semantic information of