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Generating construction schedules through automatic data extraction using open BIM (building information modeling) technology

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ABSTRACT

The architecture, engineering, and construction industries have had rapid technological advancements over the last decade, particularly in the area of building information modeling (BIM). BIM stores all the information of a building and can be leveraged for many new and exciting applications including the generation of quantity takeoffs, 4D scheduling, and building simulations. The main objective in this study is to establish a framework for automating the generation of construction schedules by using data (e.g. spatial, geometric, quantity, relationship and material layer set information) stored in BIM. Using the extracted information, the proposed system in this research creates construction tasks, computes activity durations using available activity production rates, applies sequencing rules, and finally outputs a schedule. To demonstrate the functionality of this framework, a prototype system has been developed to import BIM representations with basic building elements such as slabs, walls, doors, windows, roofs, floors, and ceilings in two story buildings.

1. Introduction

Construction scheduling has come a long way in the last 20 years, a time when many field supervisors felt that using formal scheduling was irrelevant to day to day operations and a time consuming distraction [9]. Since then, it has become an integral part of most construction projects, but remains a time-consuming, error prone and tedious task done manually [5]. As a result a wealth of research was conducting investigating how the process of schedule generation could be improved by automating activity generation, duration estimation and determining sequence logic [5]. However, many of these efforts require substantial manual input including that of the physical model [1]. Recently with the technological advancement and prevalence of building information modeling (BIM) and 3D modeling in the architectural, engineering, and construction (AEC) industries new opportunities exist for improving scheduling processes. By combining the built-in intelligence of BIM with previous research efforts we can further advance the automation of schedules.

Even today, scheduling is still mostly accomplished manually, which can be an extensive and very time consuming process. A reason for this is that this process remains insufficiently supported by software applications [14]. Since it is difficult to interact between scheduling software and BIM, many benefits of the benefits of BIM technology proposed in research papers remain unexploited [15]. Being able to exploit information stored in BIM to assist in generating schedules could help achieve significant time reductions in scheduling compared to traditional manual methods of scheduling. Previous research has demonstrated the feasibility of generating construction schedules for construction process by using the state of the art technologies including BIM, but to date, little work directly focused on this topic and has been able to successfully completely automate this process.

Before BIM technology came into being, there were many attempts to automate the scheduling process. Cherneff et al. [4] and Zozaya-Gorostiza et al. [17] developed systems to integrate CAD with construction schedules using knowledge based systems. Although the research showed the potential to improve productivity in the AEC industry through their proposed approaches, data extraction remained a significant issue [11]. Later Fischer and Aalami [10] and Aalami and Fischer [1], built on this work and devised a method to generate activities and their sequences using construction method templates, CMMT (customizable construction model templates) by generalizing activity elaboration and sequencing knowledge. This allowed activities to be represented at different levels of detail as desired by the target group, but the process still required significant manual input.

Several more recent efforts have attempted to use information stored in either 3D CAD models or BIM for processes related to

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automated schedule generation. Tulke and Hanff [15] demonstrated the viability of using element quantities stored in BIM to generate durations for scheduling tasks using production rates. Their primary objective in this work was not on schedule creation, but rather on using this technique for expediting the 4D simulation process. Later Kataoka [12], conceived the concept of using simple 3D models to generate quantity takeoffs, schedules, and 4D visualizations by creating a structural planning process using the interpretable templates (SPLIT) system. This system takes simple building geometry and applies known construction methods to it and subsequently generates possible building construction configurations [12]. While innovative, this approach focuses on constructing different possible framing systems and comparing schedules generated by using different methods instead of generating schedules for designed structures from BIM. Tauscher et al. [14] proposed a system to semi-automatically generate schedules based on the data extracted from files using the Industry Foundation Classes (IFC) standard. In their work, they used case based reasoning (CBR) to determined task durations based on information retrieved from similar cases. However, the paper did not attempt to elaborate the details of actual outputs of their proposed system [14].

This previous research shows that there is a need for enhanced interoperability between BIM and scheduling software. The related research efforts in this field have demonstrated advancements in utilizing information in BIM or 3D models for scheduling related applications, but comprehensively leveraging of the intelligence of BIM for automated scheduling generation remains to be done. Therefore, in this paper we consider scheduling within the context of building information modeling (BIM) with an end goal of generating a construction schedule through automatic data extraction from a BIM file, focusing on automating physical model input. The individual goals of this research are as follows: firstly, extracting material, location and quantities for all individual elements from BIM and storing the data according to their unique location in the structure(s); secondly, generating activities and durations based on derived building elements, materials, and quantities; thirdly, developing sequencing for activities generated in the second step; fourthly, generating the output of a preliminary schedule in scheduling software compliant formats, and lastly, refinement process to facilitate the data exchange between BIM authoring and scheduling tools. In order to test the feasibility of the proposed approach, a prototype of the framework has been developed and tested in a case study. The BIM-based scheduling was applied to generate the schedule for two small sized buildings in the range of 6000 to 10,000 ft^2 with the basic building components such as slabs, walls, windows, doors, floors, ceilings, roofs and so on. The application can be extended to scheduling of a more complex building with necessary information and sequencing rules provided. The remainder of the paper details the development of the framework, presents a demonstration of feasibility, and concludes with a summary and limitations of the current research.

2. Developing the framework

To address these issues a framework to generate schedules, given a set of sequencing rules, based on BIM has been suggested. The proposed process is deconstructed into five phases: A) construction of the BIM, B) parsing of BIM data, C) transforming of parsed data to activity data, D) generation of schedule, and E) refinement process (Fig. 1).

During BIM creation, in addition to designing all the building elements, the user defines construction work zones (if desired) to prioritize construction of one area over another. This is a way to set construction order if multiple buildings exist or to decompose a large building into several smaller sections. The completed BIM is then exported in the XML variant of the open industry standard Industry Foundation Classes (IFC). IFC is a standard established by the BIM community to allow for model exchange between its various commercial software vendors [3]. The XML schema variant of IFC, ifcXML, is used for the demonstration in this research since it allows for access to more processing tools when compared to STEP files [8]. The prototype system, the implementation of the listed five processes written in the Ruby computer language, then reads and extracts relevant spatial, quantity, material, and relational information of all building elements in each designated work zone. Next, durations and resources related to those elements are calculated and assigned by using production rates stored in a database while considering the user defined sequencing rules. Durations are determined by using production rates from RSMeans [13]. Fig. 2 illustrates the previous descriptions of B) parsing of ifcXML data, C) transforming of parsed data to activity data, and D) generation of schedule in greater detail. This provides a detailed list of the informational requirements for this framework. Lastly, the system writes the schedule in the format of a Microsoft Project file, enabling the user to utilize built-in features in MS Project, such as calculations of early start/finish, late start/finish,

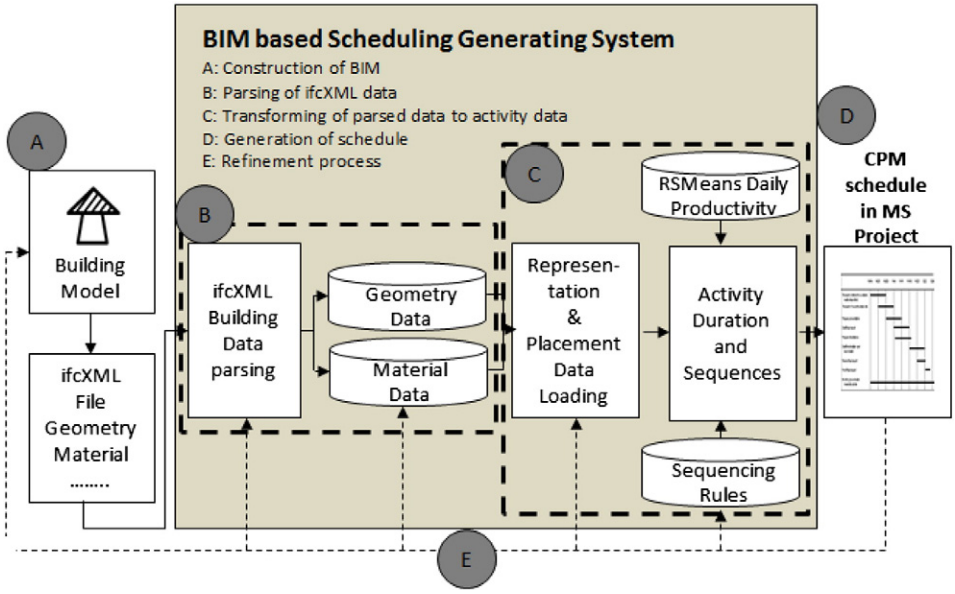

Fig. 1. Methodology flowchart.