Automation in Construction 55 (2015) 15–24

Contents lists available at ScienceDirect

Automation in Construction

journal homepage: www.elsevier.com/locate/autcon

Automated generation of shop drawings in residential construction

Juan D. Manrique [a], Mohamed Al-Hussein [b], Ahmed Bouferguene [c], Reza Nasseri [d]

[a] Stuart Olson Dominion Construction Ltd, 12836 146 Street NW, Edmonton, AB, Canada T5L 2H7
[b] NSERC Industrial Research Chair in the Industrialization of Building Construction, Department of Civil and Environmental Engineering, Hole School of Construction Engineering, 3-014 Markin/CNRL Natural Resources Engineering Facility, Edmonton, AB, Canada T6G 2 W2
[c] Campus Saint-Jean/University of Alberta, Edmonton, AB, Canada T6C 4G9
[d] Landmark Group of Builders, #301, 1103 95 Street SW, Edmonton, AB, Canada T6X 0P8

ARTICLE INFO

Article history:
Received 29 November 2012
Received in revised form 24 November 2014
Accepted 4 March 2015
Available online 11 April 2015

Keywords:
Algorithm Optimization
Automation
Computer Aided Drafting (CAD)
Computer Models
Frame design
Quantitative analysis
3D Analysis
3D models
Wood structures

ABSTRACT

The residential construction industry relies mainly on elementary two-dimensional (2D) design and shop drawings. Building Information Modeling (BIM) and parametric design have proven to be an effective technology for integrating design and construction while maintaining low cost and producing more benefits to owners, designers, and builders. However, architects, engineers, and designers may lack the time and resources needed to generate accurate BIM models or to be able to use the model information to benefit the construction process. In this paper, we propose a methodology for the automation of shop drawings for the wood-framing design of residential facilities based on a parametric model that is incorporated into a 3D-CAD model. The proposed methodology is tested in a number of virtual scenarios within the CAD environment, and is implemented as a computer program referred to in this paper as FRAMEX, a tool developed using Visual Basic for Applications (VBA) as an add-on to AutoCAD. FRAMEX adopts the guidelines at the foundation of BIM technology to generate shop drawings in which the information is consistent at every level of detail, from the studs to the panels to the home where all the panels are joined to form a single entity. It also reduces the time required for drafting design by automating the process based on 3D-CAD and parametric modeling.

© 2015 Elsevier B.V. All rights reserved.

1. Introduction

At present, automation of design is the best strategy in the building manufacturing industry to reduce construction costs during procurement and assembly, as well as to reduce material waste and through-put time. Providing design information and allowing end-users to manipulate this information can translate to benefits during the construction process. Automation of design eliminates the need for designers to spend time ensuring that all the information has been incorporated into the Issued For Construction (IFC) drawings or construction shop drawings [1]. The quest for accurate drawings becomes even more crucial given the shift toward off-site construction as a production paradigm [2] which led to an increasing amount of products for the home building industry being efficiently manufactured in shops. To achieve this efficiency, it is thus imperative that the shop drawings have minimal to zero errors in order to prevent unnecessary delays in the production lines. In fact, to ensure a global operation efficiency, the personnel involved in the production must be able to access accurate and up-to-date information in order to respond in a timely manner to changes in design [3,4]. In the construction industry, building information modeling (BIM) has emerged as a framework of choice for integrating information pertaining to all components of a given project. As a result, a change to any part of the design triggers a series of events which update the information of all relevant components, e.g., building materials, cost, scheduling, impact on the environment, (provided these models are available in BIM as implemented by the given organization). In this respect, the National Institute of Building Sciences (NIBS) has provided a comprehensive definition of BIM: [5] "A digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM process to support and reflect the roles of that stakeholder. The BIM is shared digital representation founded on open standards for interoperability". BIM technology offers a framework in which models can be integrated (as needed) in order to allow accurate information sharing and collaboration among stakeholders. However, in the context of the construction industry, evidence shows that BIM has not been utilized to its full capabilities [6], even though the interconnection between the underlying models allows stakeholders to assess at a glance the impact of a decision on the project as a whole. It is

E-mail addresses: jdm19@ualberta.ca (J.D. Manrique), malhussein@ualberta.ca (M. Al-Hussein), ahmed.bouferguene@ualberta.ca (A. Bouferguene), rezan@landmarkgroup.ca (R. Nasseri).

http://dx.doi.org/10.1016/j.autcon.2015.03.004
0926-5805/© 2015 Elsevier B.V. All rights reserved.

important to note that, depending on the needs and the goals targeted by a given organization, BIM can be implemented at different levels of complexity by including specific model entities. In the context of this paper, the objective is to showcase the benefits of parametric modeling [7–11] for the production of accurate shop drawings from which precise material take-off lists are generated and further processed to produce cutting layouts. It should be noted that parametric modeling, which links objects by using logical relationships, is well adapted to BIM technology. BIM technology in turn, as specified in the above definition, interconnects all the physical and non-physical components of a project in order to ensure consistent information project-wide. As a result of adopting BIM as the underlying paradigm for this research, it is possible to integrate different models, including a stock cutting algorithm which produces cutting layouts from material with nominal sizes (as found in the market) that satisfy demands while minimizing waste. In order to achieve interoperability, albeit at an elementary level given the prototype nature of this research, the models developed in this work which output the outcome required by the end-user are implemented as add-ons within a CAD environment. As a result, even though emphasis was not heavily put on interoperability, which could be achieved (if necessary) by following the IAI Industry Foundation Classes-based guidelines for representing objects, FRAMEX instead capitalizes on the portability of formats such as DWG, DXF and DGN (which generally are supported by CAD environments) to exchange information with other applications. This strategy not only allows manipulation of the BIM models in a CAD environment, but also permits access to software functionalities that make the construction aspect more efficient and affordable [12]. The software employed for BIM implementation must also be capable of representing reality with minimal effort from the end-user, thus facilitating a drafting design process that is prompt, accurate, and inexpensive [13].

Currently, the precision and accuracy of construction drawings (2D- or 3D-CAD) is dependent on the designer's technical competence and experience, a reality which may result in expensive design billing hours, a lack of proper documentation, or an accentuated need for specialized trade personnel and training support. Indeed, drawings for the home building industry are often produced in a CAD environment and inherently do not allow for interconnectedness between the design elements, thereby leading to inconsistent information. As a result, construction drawings have historically lacked quality and accuracy. Traditionally, this particular issue is partially solved by relying heavily on the expertise of those involved in the process: (i) designers, who strive to ensure that the information conveyed by the drawings is consistent for each element separately, as well as jointly when these elements are assembled into a monolithic functional system, and (ii) tradesmen, who are required to possess the know-how of their respective trades in order to resolve issues related to under-detailed or inconsistent information such as the absence of material take-off lists, absence of cutting layouts to minimize waste, or information rendered out-of-date because changes in design were not propagated to all relevant elements. Although building manufacturing offers advantages as a means to automate processes [14–16], users are still required to design specific modeling components from scratch. In fact, many generative design tools developed to date are restricted to a limited number of design issues or to only a portion of the design process [17], making the drafting design stage an expensive, disjointed, and tedious process. Although attempts have been made to automate construction processes, the majority of automated construction research and development has been bottom-up from the construction/engineering side rather than top-down from the design side [18].

The research presented in this paper focuses on the automation of construction drawings for wood framing design based on the platform construction method. The methodology is developed in a CAD environment through the use of parametric modeling, and concentrates on the upstream construction process (the design stage). The proposed methodology takes into account the use of several architectural housing models (see Fig. 1 for an example). These 37 housing models are all developed using BIM technology which analyzes models using a predefined set of logic-decision rules built in FRAMEX. FRAMEX is designed to automatically generate a set of shop drawings that incorporate the construction parameters and restrictions, i.e. framing rules. We also describe the advantages of utilizing BIM, with a focus on improving the building manufacturing process by pre-fabricating construction components in order to improve quality control, enhance productivity, reduce the need for highly qualified labor, and minimize material waste [19].

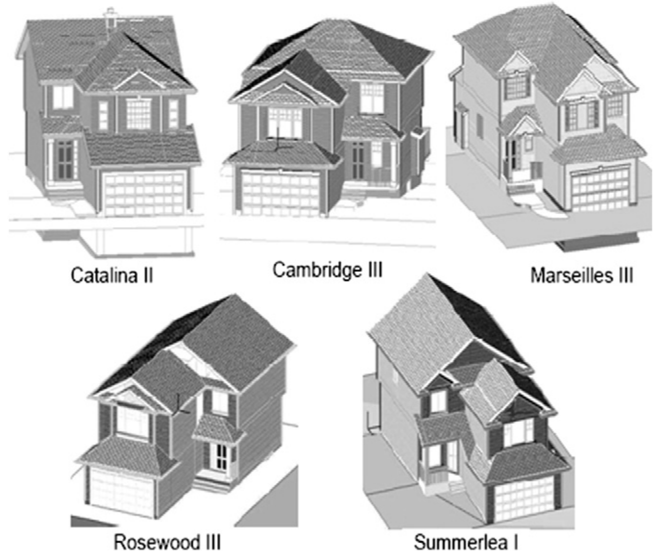

Fig. 1. Architectural models.

2. Methodology

The methodology follows the procedure shown in Fig. 2, where three processes are identified (initial stage, analysis stage, and output stage).

During the initial stage, each wall assembly is classified based on its functionality under different layer names. This classification is made according to the specific wall structural behaviors of five different types of walls assemblies: Exterior Bearing walls (EB), Exterior Non-Bearing walls (ENB), Interior Bearing walls (IB), Interior Non-Bearing walls (INB) and Mechanical walls (M), as summarized in Fig. 3.

For each element in the assembly that includes the wall, such as doors, windows, columns, and beams, it is necessary to use information and knowledge from the structural designer and from trades in the field in order to ensure a practical representation of the information in a parametric algorithm within FRAMEX, as presented in a 3D-CAD. The components that make up the wall are drafted in the 3D model with their final dimensions, which requires considerable effort and precision from the drafting designers. The maximum error allowed for design is set to 3.18 mm (1/8 in); this low allowable error is needed to accommodate the cutting technique utilized at construction sites, including the thickness of the cutting blade. (The advantages, disadvantages and challenges of this procedure are explained under the "Benefits and Constraints" section of this paper.) FRAMEX is designed to treat the provided information for its intended purpose. For instance, information from the beam/joist layout determines the location of all columns, beams, and stud-spacing for the mechanical walls. FRAMEX also specifies the structural behavior of the different types of walls. Windows, doors, and wall connections are framed according to the platform-framing construction method (see Fig. 4).

Download English Version:

https://daneshyari.com/en/article/246427

Download Persian Version:

https://daneshyari.com/article/246427

Daneshyari.com