Rule based building components for modular coordination

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Abstract

As the utilization of Building Information Modeling (BIM) increases in the built environment sector, the need to add domain specific knowledge into the BIM authoring tools also increases. This research is focused on the development of a rule-based BIM application which allows a designer to create parametrically enhanced rich models and perform modular coordination (MC). Through this development a designer is able to perform standardization and dimensional coordination system to size and locate building objects in a modular reference frame. The object level development is focused on incorporating rules for sizing and placing the building components according to MC standards. Integration of rules of MC with BIM applications enhances the design process and allows users to automate some tedious modelling activities that do not require design expertise. The development of rule based smart building objects utilizes the parametric modelling capabilities of BIM authoring tools in conjunction with visual programming tools to enhance the modelling process. The first part of the work is concentrated on the modelling process of parameter based prefabricated building components customizable under rules specified in the MC standards. In conjunction with this the development of modular reference frame which can be used to align the modelled objects in a 3D space was also performed in this research. The presented work describes the customization of BIM authoring tool for modelling a residential facility using axial planning of structural elements and illustrates ease and assistance offered to user with an example. In the prototype system the user is guided by some specific rules and elements while allowing sufficient options to develop variegated configuration and modules with rule-based prefabricated components. The integration of design rules of MC standards with BIM application will be influential in radical increase in the use of digital modelling and design of built environment particularly in the prefabrication industry.

Keywords: modular coordination; BIM applications; customization; rule based BIM objects; parametric modelling.

1. Introduction

The design process of built environment can be described as handcraft which requires “manual expression” of designer’s expertise [1]. It is an information intensive, iterative [2], evolutionary and complex process [3], [4]. One of the oldest industry still utilizes the traditional project delivery approach in which raster documents are shared among project participants. The inefficiencies of traditional 2D paper based approach are now well documented as well as understood. A minor change in design invokes either updating all models and drawings or there will be inconsistency and lack of coordination [5]. Moreover, 2D drawings are the only way of information exchange among the professionals [6] and the coordination among the participants to convey the correct and complete information depends solely on the expertise of the designer. So, when the designers engage himself in high value adding tasks such as decision making, analysis of alternatives, experimentation with shapes; he is also responsible for low value production related tasks such as data processing, information retrieval, design documentation and coordination.

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The induction of Building Information Modelling (BIM) technology has enabled the industry to mobilize resources from production oriented tasks to expertise driven tasks [7]. Because of its model-centric and object-driven core, BIM by its very nature reduces the low value production related activities performed by the designer. So, in a way BIM is positively changing the balance between high-value decision making efforts and low-value production oriented efforts. The customization of design tools can make the process more efficient and reduce the efforts expended by designers on repetitive and redundant tasks.

With the aim of customizing BIM tool to ease the modelling process, the research was conducted to understand the process and methodology of enriching BIM authoring tools with domain specific information and knowledge to assist the designer in enhancing value-creation in the design process” By utilizing the concept of rule-based modifications to BIM authoring tools for modular coordination, this research work demonstrates the “computer as an agent” [8] construct. Exploiting parametric modelling feature of BIM application, this study explores possibility of developing rule based smart building objects for associating modular coordination rules. The aim of integrating modular coordination rules will be to assist users during the modelling process which can be extended further for improving overall design process.

2. BIM Authoring Tools for Modular Coordination

The BIM practice allows design team to shift the efforts to early stages, hence making the value adding decision more viable [9]. On the other hand, modular coordination enables co-operation among designers and other stakeholders via dimensional coordination. Alongside BIM, modularization and off-site fabrication are the enabling concepts and practices have significant impact on US construction industry [10]. Moreover, BIM and modular coordination enhance the design and construction process by improving the communication among the project participants [11]. The pre-project planning and coordination issues among professionals has created the need of implementing BIM on complex projects [12]. BIM practice organizes the activities like planning, design-analysis, development of drawings, fabrication schedule, construction schedule etc. Also the proliferation of model-driven fabrication, BIM applications have increased reliability on prefabrication techniques [13]. In a way, BIM practice has potential towards increased use of pre-fabricated modules and also modular coordination [14].

3. Review of Literature

BIM can be defined as a process of creating and updating building model for analyzing it in virtual environment at each stage of building life cycle [15]. In other terms, it is a process of creating an intelligent and computable 3D data set [14]. BIM authoring applications provide an enabling platform for generating, updating and sharing building information data in efficient manner [15]. In the BIM process, the building data is stored digitally at single place which can be used for documentation activities, eliminating the need of several information resources for different activities, reducing the consistency issue. However, the efficient use of these modelling application can be realized only when the models are developed at appropriate level of detail [16]. These applications have potential to reduce efforts required for production oriented tasks such as visualization, quantity take off and information exchange. Computer Aided Design (CAD) applications allow users to create building model which is more or less geometrical representation of elements [17]. While BIM allows object-oriented modelling and represents elements as virtual building objects [18] [19], offers an enabling platform for integrating domain specific constraints and logic. Sometimes, BIM applications are considered evolved version of CAD tools for modelling buildings [20] and described as CAD + specifications [21].

Modular coordination is a dimensional coordination and standardization system for sizing the building components and placing them within a reference system [22]. It has a three-dimensional integer lattice acting as a reference and module as the smallest unit [23]. Prefabrication and industrialized production systems use this dimensional coordination to optimize the number of different sizes [24], reduce on-site waste and ease interchangeability of components.

Parametric Modelling in BIM Applications – The visual, thermal or mechanical properties of building objects are defined using variable known as parameters. Parameters are also useful in defining geometrical relationship among objects such as alignment, separation etc. [25]. Moreover, using explicit mathematical expression, parametric modelling features allow to integrate domain specific knowledge [26]. Parameters allows regeneration of geometry
based on geometrical constraints [27]. The predefined set of rules for modelling building facility using parameters in BIM authoring tools reduce modelling and technical flaws [28]. BIM tools reduce errors through automated design verification. 3D design capabilities and distributed intelligence of BIM applications offer an integrated and automated design environment, which can reduce errors through automated design verification [29].

4. Research Methodology

As illustrated in Figure 1, the research involves study of several modular coordination standards and examination of modelling process in BIM authoring application. Then comes the object level development stage where various rules to be incorporated are listed. Alongside this, various options available in BIM authoring tools which can be used to incorporate these rules are also analyzed. After this, several building components such as doors, windows, wall panels etc. are developed with parametrical constraints so that these objects are customizable under modular coordination standards. Rules such as alignment, 5 mm rule and tolerance are incorporated as geometrical constraints while others are suggestive in nature. Modular reference frame can be created using the parametric and generative capability of BIM tools. The object developed in the previous step are also intended to improve the overall design process such as design documentation, visualization, quantity take-off and information sharing which are not in the scope of this paper.

5. Development of Smart Modelling Elements

The design or modelling for modular coordination starts with creation of a three dimensional integer lattice termed as modular reference frame. This frame consists of reference planes spaced at a distance of module or multi-module. The prefabricated building components can be placed in the project referencing to these planes. As explained in figure 2, visual programming tool has been used to generate modular reference frame. Based on the sizing rules for modular coordination, customizable rule based smart building objects are developed. For placing the building objects, there are reference planes associated with the objects which will interact with modular reference frame and guide the modeler to place it in the project.
6. Modular Reference Frame

As we can learn from modular coordination standards and design practice, the reference frame is the starting point of design process. For creating reference frame, the user requires planes represented by lines along x-, y-, z- directions. The study utilizes visual programming tool for this activity as it is sequential and based on predefined logic.

6.1. Generation of Modular Reference Frame

A visual program has been developed to generate the grid of reference lines and levels. As explained in figure 3, the first part generates the list of values which can be used as multi-module, then it takes input from the user to select appropriate value for the project. After user input, the program performs simple mathematical operations and in the end it generates lines which can be converted into column grids. Similar to this, another visual program has been developed to generate the levels which will provide reference in the z-direction.

6.2. Aligning Planes/Lines

In this study, axial placement has been taken into consideration to place structural objects. As shown in figure 4, during the modeling process of building objects, reference planes are created. These reference planes can be used to align it to the modular reference frame. Several modular coordination details such as joints, 5mm rule for structural elements and tolerance for various elements are captured during modeling process with the help of reference planes and lines.

7. Prefabricated Smart Building Objects

Before a designer can embed the domain specific knowledge or rules, there is a need to develop the building objects with geometrical constraints, parameters and construction details. In this study, several prefabricated building objects such as wall panels, slab panels, doors, windows, stairs etc. are developed. As expressed in figure 5, various rules for sizing the components according to modular coordination rules have been identified, then different options have been used to incorporate those rules as discussed in subsequent sections.
7.1. Assistive Messages

This option can be used to display assistive information to the user, when there is a deviation from modular sizes. As explained in figure 6, assistive messages are created during the modelling process of object. Then a visibility parameter has been associated with the text message. The value of visibility parameter depends on a conditional statement which allow it to appear in the project environment when there is a deviation from standard sizes.

The Preferred Dimensions for Length are:
300, 600, 900, 1200, 1500, 1800, 2100, 2400, 2700, 3000, 3300, 3600, 3900, 4200, 4500, 4800, 5100, 6000, 6600, 7200, 7800, 8400, 9000, 9600
Please select from given values.

7.2. Adjusting Parametric Values using Visual Programming

The visual programing tool can be used to modify value of parameter for particular building object. As explained in figure 7, a visual program can be developed first to generate values then associating that value with suitable parameter. A list of values can be used to guide the user about dimensions possible for the parameters.
7.3. Size Catalog (Doors/Windows)

This is suitable option when there are several combinations of values for parameters are possible for door and windows under modular coordination rules. Spreadsheet application can be used to generate suitable set of values for parameters. The “type catalog” option can be used to create combination of length and height for doors & windows possible under modular coordination rules. As explained in figure 8, the object is developed which has geometrical components controlled by parameters, then the values of these parameters can be controlled using separate .csv file.

8. Conclusions

The BIM tools allow the design team to incorporate domain specific knowledge to ease the modelling process. The parametric modelling feature enables the user to create geometrical constraints and easily manipulate the design alternatives within set of standards. Various options to adjust the parametric values make the modelling process more flexible. The research can be extended to improve design activities such as quantity take-off, documentation and information sharing by incorporating identity parameters. The identity parameters can be associated with the building objects to enhance and streamline the design process. Moreover, other domain specific knowledge such as acoustical design, building byelaws etc. can also be incorporated. The objective of such rule based objects is to increase knowledge resource or built-in intelligence of BIM tools.

References
