Title:
Integration of Well-defined BIM External Module with CAD via Associative Feature Templates

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Introduction:
Building information modeling (BIM) has been widely used in modern architecture, engineering, and construction (AEC) industry. BIM software systems can provide engineers, architects, and constructors a 3D visualization of the project and can detect issue, conflict and inference of the design, which will help reduce the project time and lower the overall cost [1]. During concept design, engineers and architects often start with a top-level and large-entity (-scale) design, i.e. the architecture of the overall building form, and then delve into more detailed design models (e.g. with the color of an interior door). The 'detailed design and documentation' [4] is the 3rd level of detail in the BIM system and it provides enough details to get ready for fabrication and manufacturing. Such BIM model contains the precise dimensions, features of the component, quantities and customization information. However, some more in-depth information such as a window's cross-section profile could still be missing. This usually results in the lack of information during the manufacturing process. The authors believe that interfacing CAD (Computer-aided design) and BIM is useful in resolving such information granularity problem. In this extended abstract, BIM/CAD associative feature concept is proposed to manage geometric and semantic associations between BIM and CAD based on a past work [9]. In addition, the authors would introduce the application of data sharing between CAD and BIM to validate the information consistency. By using this new concept, a BIM/CAD integration framework has been developed which can provide both forward and reverse integration [7], generate necessary manufacturing information, e.g. bill of material (BOM) for manufacturers, and support order driven production development.

Main Idea:

Associative feature [9] concept is suggested to interface the BIM and CAD tools in this work, which exchanges data between two different applications and guarantees information consistency. This framework uses Dassault Systèmes SolidWorks as the CAD tool and Autodesk Revit as the BIM system. The research goal is to explore a solution by studying examples of how the systems can be seamlessly integrated and using a generic approach developed for multi-view construction related projects. The general framework of the current research is outlined in Fig. 1.

In this system, after architecture companies negotiate with customers about the final detailed model, the BIM model will be generated and the information will be extracted from the BIM files. Any important information such as quantity, feature, and parametric information will be excerpted and stored in a data set. Customization information will also be synthesized with extracted data to provide a shared database. Then the data set will be mapped into a well-defined CAD template. This external database is designed well enough to cover all types of products which can be made by the manufacturer. The detailed model and BOM can be exported by CAD software, which is essential for the manufacturing process. After verifying the result with standards and design requirements, the BOM is ready to be sent for manufacturing and the information provided by the CAD model can be updated in the BIM system. The BOM then will be sent to enterprise resource planning (ERP) system in which it will cooperate with scheduling and other enterprise data for manufacturing. Finally, the products will be delivered to the customers.

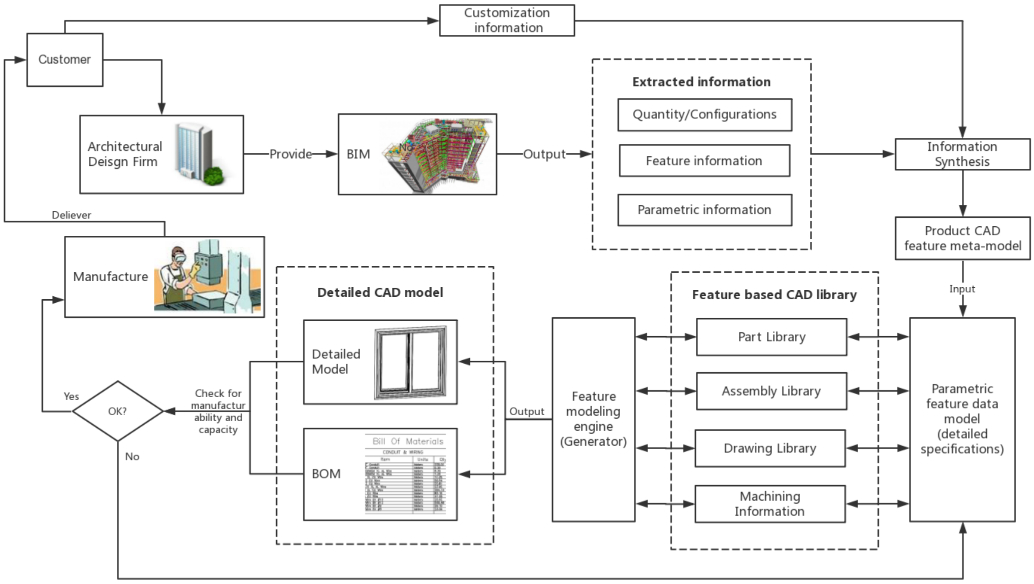


Fig. 1: The general framework of the current research.

Revit uses three important sets of entities in the 3D modeling system: model elements, datum elements and view-specific elements [3]. Each instance, also known as a detail model, is an actual 3D model that is defined and controlled by its family [2]. Inside the building information model, the hosts are the elements mostly built on the construction site such as walls, floors, and ceilings. The components are the attached elements associated with manufactured products that will be installed in a building such as windows, doors, and stairs. The information of those components from a BIM system, however, cannot be directly used to fabricate due to the complex geometry of the manufactured components. Prior to the manufacturing process, detailed 3D models are required to verify the possible interferes of the model and a BOM can provide the required cutting dimensions for the raw materials as well as the information of all components required inside of products for the assembly line. The type and parameters of a BIM window or door feature can be extracted by using Revit API, and then a data set of a separate window or door product CAD model will be generated. In order to realize the automatic interpretation of the CAD result, a series of customized window features are defined such that it corresponds to customer's choices, such as the lamination material of the window frame or the type of grill between the glass. This set of feature properties could not be included in BIM due to its different focus compared to CAD software. The BIM system is designed to embed the objects, create a visualization and input general information into a 3D spatial model [1]. How the proposed feature concept works in the integration system for a sample slider window is shown in Fig. 2.

Inside a window or door manufacturing model, components such as *frames*, *sashes*, and *mullions* can be modeled according to characteristic parameters. Parametric modeling is used when building an external CAD library with SolidWorks. This library uses a feature-object method and has the advantage that it is able to process different parameters with all types of configurations of assemblies included [8]. All the parts are grouped together and formed into series of typical *smart* *types*, e.g. *major/sub -types*, and stored as a supporting toolkit template files for the system [10]. CAD templates also cover associated child templates for drawing, assemblies, and BOMs. They are well-defined and can be generated by running Solidworks application programming interface (API) functions. Based on the input from BIM data set, the requirement and customized specification data structures and associations are embedded into the templates in SolidWorks. The common data model (CDM) has been adopted to map the design-driven semantic parameters and constraints to build the CAD models [5] based on data sharing. When instantiated, the embedded functions then use BIM customer specifications to select and calculate all the required geometrics and analysis parameters according to standard design procedures and building codes. Most decisions and customization steps can be processed automatically.

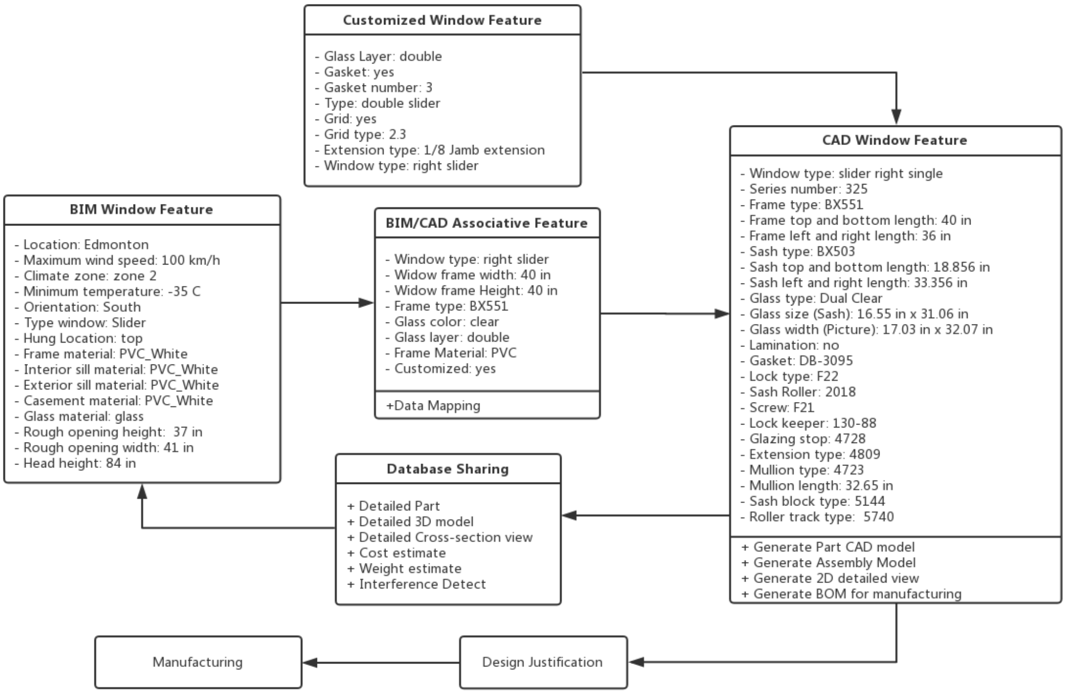
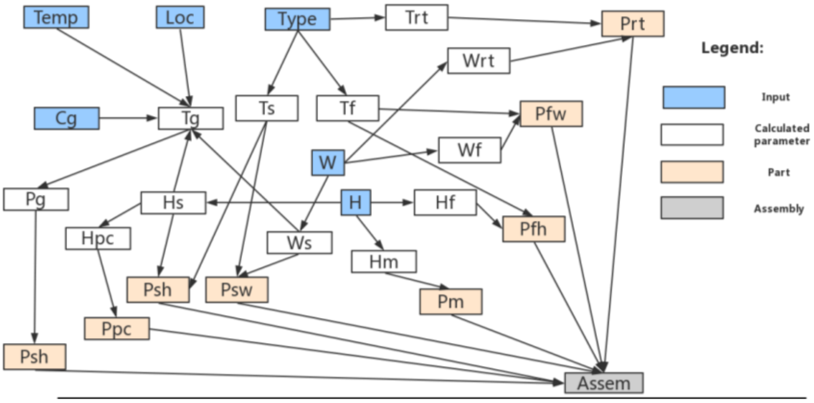


Fig. 2: Semantic associations in BIM/CAD integration referring to window features.

Parameter Symbol	Definition	Calculation	Unit
Hs	Sash left and right length	Hs=H/2-1.675 (H=Height of rough opening)	in.
Hm	Mullion Length	Hm=H-0.85	in.
Tg	Type of glass	By reading location data and customer choice	-
Tf	Type of frame	By reading the type of window chosen by customers	-

Tab. 1: Example representation of the common data model.

For example, the system is able to define the glass type based on the input of location and customer choices. If the parameters are over the limit of fabrication, the system is able to adjust the parameters into suitable ranges and configurations. Tab. 1 shows the sample calculation of how BIM parameters and BIM semantic data integrate with customer requirements. Fig. 3 shows an example of how all the important design parameters affect the development of the design for a single slider window.



Nomenclature			
Temp	Temperature	**Loc**	Location
Cg	Color of Glass	**Trt**	Type of Roller Track
Ts	Type of Sash	**Tf**	Type of Frame
W	Rough Opening Width	**H**	Rough Opening Height
Hs	Sash left and right length	**Ws**	Sash top and bottom length
Pfw	Top and bottom frame part	**Pfh**	Left and right frame part
Pm	Mullion part	**Psh**	Left and right sash part
Psw	Top and bottom sash part	**Assem**	Assembly

Fig. 3: Parameter semantic map for a slider window.

The assembly features are used to associate all the essential characteristics of a supplied product into the CAD assembly [6]. The relationships between the parts and normalized datum are saved into predefined CAD templates, which enables CAD software to generate inserted modular 3D models.

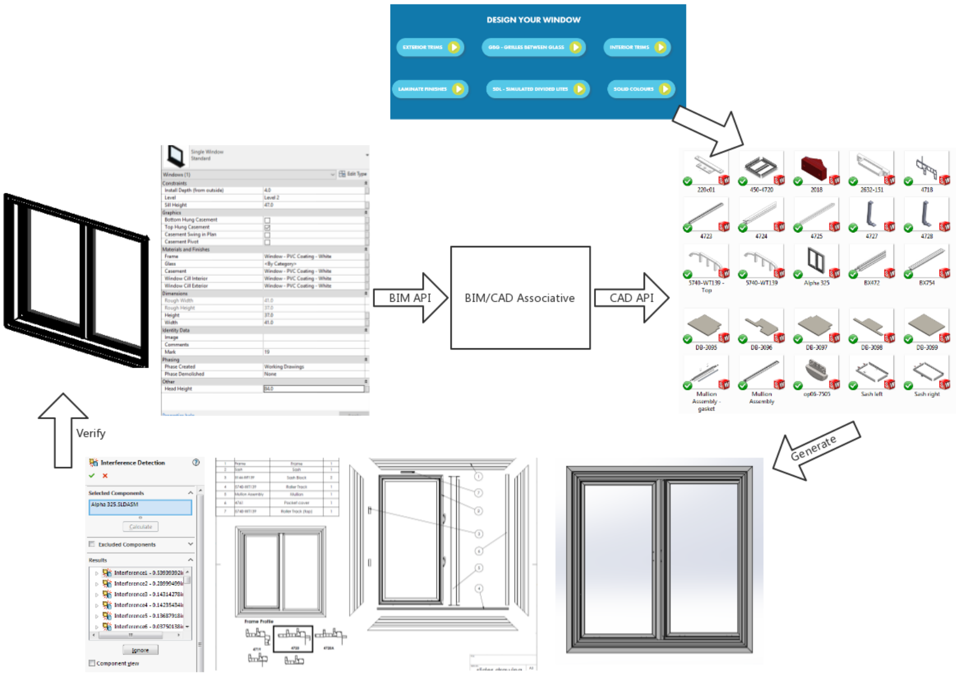


Fig. 4: The case study of a slider window.

By using the proposed BIM/CAD integration mechanism, windows and doors templates can be pre-parameterized to match the existing data scheme from the BIM. The actual CAD models which fulfill the BIM data and customer required data can be generated, including the detailed manufacturing parts and assembly drawings as well as the BOM which provides manufacturers with production specifications. The BOM is further extended to contain all the fabrication information such as dimensioned cutting list which can simplify and accelerate the material preparation process and increase productivity. The CAD part models can also be imported back into the BIM system and help engineers and customers to have a detailed view of the project. Fig. 4 shows a sample procedure of how the BIM/CAD associative feature-based system works with a well-defined CAD library. Customer requirements and BIM parameters are automatically extracted and calculated in an external software which is designed for window design. The software then will match with the type of window inside of the well define CAD library and locate the corresponding part components (frame, mullion, screws and etc.), assembly files, and drawing documents. Next, this software will update all the parameters into the library based on the BIM data and save as new files separately. A new window model built by its prospective parameters then is ready to send back to BIM system. The BOM can be sent to ERP system and lined up for manufacturing.

Conclusion:

This extended abstract explores a BIM/CAD integration system based on the concept of associative features. The authors propose the concept of generating a well-defined CAD template library based on data sharing. A common data model is designed to help integrate information between BIM system, customized data, and CAD software to maintain the consistency and accuracy. The CAD model provides the BOM and cut list for fabrication and transfers back into BIM system to upgrade the details of the building model. A case study is implemented to show the efficiency and reliability of the integrated system. The current research focuses on the framework of the integrated system and authors are not aware of any limitation of the proposed approach. In the future, the prototype of an order driven system using this method will be implemented.

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