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Logic for ensuring the data exchange integrity of building information models

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ABSTRACT

Industry domains require distinct data and structures of building information models developed and tailored for their disciplines. To seamlessly exchange the building information models, Industry Foundation Classes (IFC), which is one of neutral formats, has been broadly used the architecture, engineering and construction, and facility management industries. Model views definitions (MVD), which is one of the IFC sub-schemas used by domain experts and BIM software vendors, consists of IFC-mapped data exchange requirements of each domain and helps software vendors develop IFC import and export features that allow project participants share and exchange BIM information. Because of the heterogeneous translation processes and structures of IFC interfaces according to model views, their validation is imperative to ensure the integrity of BIM data and maintain a consistent data exchange environment. To accomplish this objective, this paper suggests a new approach to evaluating BIM data in accordance with diverse requirements of MVD. Since MVD entails various types of data exchange specifications, this research examines their embedded checking rule types and categorizes corresponding implementation scenarios. In addition, this paper involves rule logic and IfcDoc-based BIM data validation developed based on the logical rule compositions of identified rules types and checking scenarios. This approach is expected to support sharing consistent BIM data sets and confirming the quality of received data pertaining to the syntax and semantics of a targeted model view.

1. Introduction

There is a significant and growing demand for diverse aspects of design and construction data to be shared among project participants throughout entire design and construction processes. The sharing differs according to the roles of participants, contractual agreements, project stages, mandated performance levels, building codes, and contextual issues at hand. Some shared exchanges and their associated concerns are known before the outset of a project, but because of a different scope of each project, there are still several troublesome issues in collaboration, cooperation, and communication during project phases. For example, an architect, a structural engineer, and a constructor require different software to create, manipulate, analyze, and apply building data and their distinct data models for achieving their particular objectives. These heterogeneous information and data must be maintained consistently in diverse types of domains, phases, and software for sharing a correct set of data models referred as to synchronization. However, with the increasing number of requirements in complicated projects, building data cannot be easily coordinated and shared among domain professionals [8,15]. To address the disfunctional situation, the importance of a neutral format that is able to support importing and exporting building model data between various building information modeling (BIM) authoring tools and applications has been increasingly recognized.

One of the most popular neutral formats broadly used in the architecture, engineering and construction, and facility management (AEC-FM) industries is Industry Foundation Classes (IFC) [11]. Diverse industries, such as the Precast/Pre-stressed Concrete Industry (PCI) and the American Institute of Steel Construction (AISC), have already applied the IFC schema as a primary neutral BIM data exchange format to their data exchange processes. But, in order to reliably use such data exchanges, potential users need to have a high level of confidence that the exchanges translate their product model data completely and accurately. Since BIM data exchanges using a neutral format must support complete and robust import and export of product model data without geometrical and semantical translation errors or omissions, validation of BIM data exchanges is critically needed prior to project application.

The development projects of IFC data exchange specification and processes for the Precast/Pre-stressed Concrete Industry (PCI), the American Concrete Institute (ACI), and American Industry of Steel

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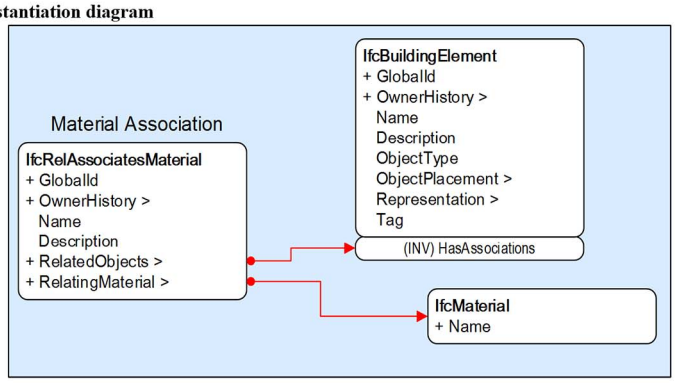
IFC Release Specific Concept Description (IFC 2x3)

Precast Piece Material Association

Reference	PCI-061	Version	1.1	Status	Draft
Relationships	Assigns material to either precast or non-precast elements.				
History	Developed Fall, 2009, revised for submission November, 2012				
Authors	Ivan Panushev, Chuck Eastman (chuck.eastman@coa.gatech.edu)				
Document Owner	Precast/Prestressed Concrete Institute				

Instantiation diagram



Implementation agreements

Attribute	Implementation agreements
GlobalId	Must be provided
OwnerHistory	Must be provided, but may contain dummy data
Name	Optional
Description	Optional
RelatedObjects	Must be subtype of IfcBuildingElement.
RelatingMaterial	Must be the IfcMaterial

Fig. 1. An IFC-native BIM data binding document regarding the precast piece material association.

Construction (AISC), allowed authors to examine and develop a solid checking method and process for ensuring consistent data exchanges of BIM product models using the IFC format in these domains. In addition, the authors collected a variety of specifications of the distinct domain data exchanges and the translation requirements of their IFC-mapped native objects extracted from the IFC data exchange process development of the PCI. This paper shows the identified types of product data exchange requirements, the rules of IFC data translation and exchange, the scenarios of each rule checking process, and the logic of their checking implementation. Based on these findings, the validation features of IfcDoc have been developed with the collaboration of the authors and Tim Chipman who is an owner of Constructavity. The detailed information of IfcDoc is described in Section 5.

2. Industry Foundation Classes and model view definitions

Among neutral formats for AEC/FM and civil infrastructure industries, IFC has been extensively employed and studied by industry experts and researchers with the goal of accomplishing desired BIM data exchanges between heterogeneous BIM authoring and application tools [21]. The specifications and the data structures of IFC are defined in the EXPRESS language along with modeling constructs, data exchange definitions, and syntactic and semantic requirements [4]. The IFC schema, which can be referred to as a baseline library, encompasses geometrical, syntactical, and semantical requirements and specifications of BIM data exchanges.

To implement this IFC schema, software developers of BIM authoring tools and professionals of building and civil infrastructure industries have been actively involved in the development processes of the IFC sub-schemas for each discipline, which select and assemble parts of the specification of the IFC schema needed to develop IFC-binding processes of each domain knowledge and native BIM authoring tool object data. This IFC sub-schema also referred to as a model view definition (MVD), represents interoperable requirements of IFC-based BIM data exchanges of specific domains [17]. In other words, the MVD specifications should be sufficient for the needs of import and export of IFC product data of diverse BIM authoring and application tools. The BIM data exchanges encompass predefined syntactic and semantic requirements that are supposed to be implemented by BIM software developers for a binding process of IFC and native model data [22]. Each data exchange during the design and construction phases requires distinct specification sets of BIM model exchange. The scope and the size of MVD are generally determined by types of domains, required information of pertinent professionals and types of domain-specialized BIM software and applications.

MVD consists of a series of specification units referred to as the ‘concept’, which encompasses the specifications and implementation agreements of IFC data exchanges required for one or more entities, their attributes, and relationships [12,19]. The specifications of IFC translation implementation specified in a concept document provide software developers with IFC and native objects binding rules according to necessary attributes of IFC entities, relationships, and properties defined for unique domain knowledge [14]. The crucial functionality of the concept is reusability that allows each concept to be iteratively applied to develop diverse MVD specifications across several domains [12]. Fig. 1 is the concept document of the PCI pertaining to the precast