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Erratum

Logic for ensuring the data exchange integrity of building information models

Yong-Cheol Lee[a,*], Charles M. Eastman[b], Wawan Solihin[b]

[a] Department of Construction Management, Louisiana State University, Baton Rouge, LA, USA
[b] College of Design, Georgia Institute of Technology, Atlanta, GA, USA

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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 in the architecture, engineering and construction, and facility management industries. Model view definition (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 model 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 the new approach to evaluating BIM data in accordance with diverse requirements of MVD. Since MVD entails various types of data exchange specifications, this research study 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 a 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 the 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 the 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 this disfunctional situation, the importance of a neutral format that can 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 the complete and robust import and export processes of product model data without geometrical and semantical translation errors or

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* Corresponding author.
E-mail address: yclee@lsu.edu (Y.-C. Lee).

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omissions, validation of BIM data exchanges is critically needed prior to project application.

The development projects of IFC data exchange specifications and processes for the Precast/Pre-stressed Concrete Industry (PCI), the American Concrete Institute (ACI), and American Industry of Steel Construction (AISC), allowed authors to examine and develop the 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 development of the IFC data exchange standard for PCI. This paper shows the identified types of product data exchange requirements, the rules of IFC data translations and exchanges, 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 Constructivity™.

2. Industry foundation classes and model view definition

Among neutral data exchange formats for the 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 adopt 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 BIM authoring tools' native 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, MVD specifications should be sufficient for the needs of import and export processes 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 data exchanges. 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 a 'concept', which encompasses the specifications and implementation agreements of IFC data exchanges required for one or more entities, their attributes, relationships, and properties [12,19]. The specifications of IFC translation implementation defined in a concept document provide software developers with IFC and native object binding rules according to necessary each IFC entity's attributes, 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 one concept document of the PCI MVD pertaining to the precast piece material association. This concept document declares that IfcBuildingElement must refer the IfcRelAssociatesMaterial entity for providing material information: IfcRelAssociatesMaterial must entail values or relationships for the following required attributes: GlobalId, OwnerHistory, RelatedObjects, and RelatingMaterial. This concept is reusable by the several subtypes of IfcBuildingElement such as IfcBeam in order to define their material relationships.

End-users can regard IFC files as translated data of BIM models based on a set of concepts of predefined MVD. Considered another way, MVD consists of imperative criteria to be employed not only for IFC/BIM data binding but also for evaluation of IFC instance files pertaining to accuracy and consistency of data translation and exchanges. Even though IFC users have experienced several limitations and problems in BIM data exchange because of unexpected geometrical deformations and information omissions, no approach completely and robustly supports the validation according to MVD specifications or their embedded criteria. A means of checking IFC instance files about conformity to model views will help BIM software vendors obviously identify hidden problems of IFC and native BIM data binding and indirectly evaluate the importing and exporting translation processes of their IFC interfaces according to specifications of a targeted model view [25,26].

With this objective, this paper provides the identified types of MVD specifications and suggests checking logic and processes for validation of IFC instance files. The authors generalized the requirements of the PCI MVD and developed frameworks for concept-based modularized validation. In addition, this paper proposes an innovative approach to the MVD validation of an IFC instance file using the IfcDoc tool, which was originally developed for MVD documentation. This tool has been used to develop the specifications of the IFC 4 schema and the documents of several model view definitions such as Construction Operations Building Information Exchange (COBie). It also serves as a foundation platform that contains MVD rule checking features [3]. In addition, this paper contains the discussions of the complicated structure of a modularized checking system and the limitations of model view-based validation.

3. Related efforts and research

To ensure the accuracy of IFC and BIM data translation, a mapped IFC instance file must be evaluated according to its assurance of compliance with assigned MVD specifications. Even though several approaches have been studied and developed for validation of an IFC instance file regarding MVD, how accurately the IFC interfaces of BIM software implement their import and export features for IFC and BIM native data bindings still has significant limitations. The primary reason for these limitations resides on the lack of a robust checking approach that can accurately evaluates an IFC instance file about whether it thoroughly fulfills both syntactic and semantic requirements defined in MVD. As a result, software vendors and domain professionals have manually assessed the IFC instance files translated by their IFC interfaces to keep track of syntactic and semantic compliance, geometrical and topological issues, and other technical problems of their BIM authoring tools. To ameliorate this time-consuming and tedious process, there have been previous research efforts for checking an IFC instance file according to diverse aspects of MVD specifications.

With regard to the semantic checking of an IFC instance file against MVD, buildingSMART International launched the global testing and documentation server (GTDS), which is the web-based checking platform [2]. The GTDS has an objective to evaluate the IFC import and export features of BIM software using their IFC instance files [10]. In other words, software developers employ the GTDS for validating their IFC instance files exported from their software. Since most of BIM authoring tools export IFC instance files using the IFC coordination view version 2.0 (CV 2.0), an agreed broad subset of the IFC 2 × 3 schema specified through the agreements of the groups of buildingSMART International, the GTDS evaluates them according to CV 2.0 [1]. If they satisfy all of the requirements defined in CV 2.0, they can receive a certification guaranteeing the robustness of IFC translation features of their software according to CV 2.0 [16]. However, the GTDS supports evaluating an IFC interface only regarding CV 2.0. Because several industry domains have developed their distinct model views for