Developing IFC Standards for Implementing Industrialized Building System Components into BIM Applications

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Abstract. At the present time, construction industry is lacking information concerning predefined IBS geometrics and components which can be used in BIM. In order to integrate IBS with BIM successfully, specific frameworks and standards must be determined, developed and embedded in BIM software. This paper aims at developing Industry Foundation Class standards for IBS components to be integrated and programmed into BIM applications. Among IBS classifications listed in literature, Warszawski classification which is based on geometrical configurations of their main framing components was selected as the target category. Similarly, among this classification, planar or panel system employing planar or panel-shaped elements for floor slabs, vertical supports, partitions and exterior walls was selected for developing IFC standard. The language used for developing IFC algorithm in this paper is Extensible Mark-up Language (XML). It was deduced that XML programming language, because of its flexibility in referring the geometric representation of objects, is absolutely suitable for this type of algorithms. By utilizing XML-based IFC standards, prefabricated components can be standardized, programmed and integrated into BIM software and finally the collaboration process between BIM and IBS can be highly promoted.

Keywords: BIM, Industrialized Building System, Prefabrication, Industry Foundation Class, XML.

1. Introduction

The construction industry and its activities have an important role in socio-economic development, environment, and quality of life. In contrast to its significant impact on national economies and people's lives, the construction industry is typically characterized by labor intensive technology, hard labor conditions, low productivity, and high risks. These problematic business conditions mainly result from the slow integration of technological advances and industrialization principles such as computer-aided construction, automation, standardization, modularization, etc. to the construction industry [1]. The International Council for Research and Innovation in Building and Construction (CIB) in its latest report on industrialized construction linked industrialization with the use of mechanical power and tools, the use of computerized steering system and tools, production in continues process, continues improvement of efficiency, standardization of products, prefabrication, rationalization, modularization and mass production [2].

In the perspective of construction, CIB defined industrialized construction as a generic process of standardization and rationalization of the work processes in the industry to reach cost efficiency, higher productivity and quality. One of the efforts towards construction industrialization in construction is through the introduction of Industrialized Building System (IBS). Rahman and Omar defined IBS as a construction system using pre-fabricated components [3]. IBS employment causes projects to reduce wastage, diminish labor usages, increase equipment involvement and decrease completion time and costs by prefabrication of components, making systematic and mechanized building and using modular coordination. The employment of prefabrication in building has often been hampered by problems of communication between the different parties to its design process--the architect, the structural engineer and the producer of prefabricated elements.

The regular industrialization of a building can be further augmented by the introduction of information technologies in various stages of construction and design. Building information modeling have been gaining acceptance in the construction industry for many applications, such as constructability analyses, design checks, commissioning and life-cycle assessment among others. According to the National Building

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Information Modeling Standard Committee, a building information model (BIM) is defined as "a digital representation of physical and functional characteristics of a facility [4].

In order to integrate successfully IBS with BIM, specific frameworks and standards must be determined, developed and embedded in BIM software. At the present time, the construction industry is lacking information concerning predefined IBS geometrics and components which can be used in BIM. BIM is totally object-oriented software and has a great potential to utilize predefined objects like prefabricated components in its tools. Hence, this paper aims at developing Industry Foundation Class (IFC) algorithms for IBS components to be integrated and programmed into BIM applications.

2. IFC

IFC, as it is today, was originally generated from its use as Foundation Classes for the building Industry. In 1995, a European research initiative agreed to use IFC as a base for representing building industry-specific class diagrams [5]. These diagrams usually refer to a graphic representation of spatial objects and their relationships in a logical view of a system specification. It is a set of entities and their relationships representing a complex data schema. According to IAI, IFC defines data elements that represent the parts of buildings and their spatial relations. In addition to this, they contain relevant information about the spatial extents of the parts. IFCs are used by different computer applications for facility modeling of buildings and sharing information of the models' parts among participants [5]. An IFC schema contains a class diagram that shows the relationship among its entities. It also has an interpretable description of the class diagram with certain constraints enabling the generation of executable codes which can be used in sharing information among several applications. Within the IFC domains, it is important, to avoid any misunderstanding, to note that IFC is neither a software application nor a collection of software components. It is a schema that can be compiled into an executable code or a class library of a programming language that supports information sharing and representation.

3. Research Methodology

IBS has a various different classifications based on material, process and system. In order to narrow down the scope of this paper, among IBS classifications listed by Kamarul Anuar Mohd Kamar et. al [3], Warszawski classification [6] which is based on geometrical configurations of their main framing components, was selected as the target category. It is composed of four main groups of linear or skeleton (beams and columns) system, planar or panel system, three dimensional or box systems and industrialization on site. Therefore, among these groups, planar or panel system which is probably the most widely used types of prefabricated system employing planar or panel-shaped elements for floor slabs, vertical supports, partitions and exterior walls was selected for developing IFC algorithm.

The language used for developing IFC algorithm in this paper is Extensible Mark-up Language (XML). XML has a broader range of supporting utilities and database implementations and is the basis for most ecommerce messages and Web services. By adhering to the IFC content and semantic the XML, community will benefit from an internationally accepted and agreed upon standard for the AEC-FM industry that has already been widely tested in several domains using other representations.

4. Development of IFC algorithm

4.1. Interior and Exterior Walls

Due to similarities between general and digital properties of both exterior and interior walls, only one IFC algorithm developed for them. In order to develop an algorithm, first, the property definition table for walls should be designed. This table tabulated based on IAI standards and ISO 10303-28 [7] (Table 1).

TABLE 1: Property Definition of Wall

Name	Property Type	Data Type	Definition
Reference	Ifc Property Single Value	Ifc Identifier	Reference ID for this specified type in this project.
Is External	Ifc Property Single Value	Ifc Boolean	Indication whether the element is designed for use in the exterior (TRUE) or not (FALSE). If (TRUE) it is an external element and faces the outside of the building.
Extend To Structure	Ifc Property Single Value	Ifc Boolean	Indicates whether the object extend to the structure above (TRUE) or not (FALSE).
Load Bearing	Ifc Property Single Value	Ifc Boolean	Indicates whether the object is intended to carry loads (TRUE) or not (FALSE).

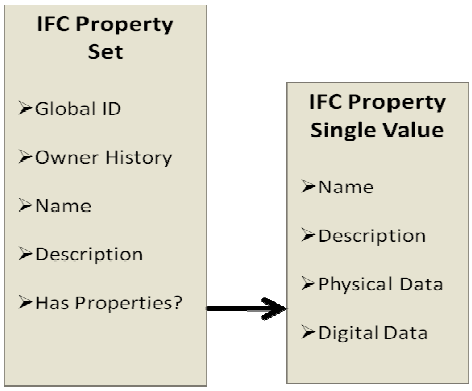

Fig. 1. IFC Property Diagrams

By considering the property definition table (table 1) and property diagram (fig.1) of wall and also ISO 10303-28 [8], the proposed algorithm of IFC in the XML language structure for exterior and interior wall is introduced (Fig 2. a,b).

```
<xs:element substitutionGroup="ifc:IfcObject" name="IfcActor" nillable="true"
type="ifc:IfcActor">
        </xs:element>
        <xs:complexType name="IfcActor">
                <xs:complexContent>
                        <xs:extension base="ifc:IfcObject">
                                <xs:sequence>
                                        <xs:element name="TheActor">
                                                <xs:complexType>
                                                <xs:group ref="ifc:IfcActorSelect">
                                                        </xs:group>
                                                </xs:complexType>
                                        </xs:element>
                                </xs:sequence>
                        </xs:extension>
                </xs:complexContent>
        </xs:complexType>
```

(a)

```
<xs:element substitutionGroup="ifc:IfcGeometricRepresentationItem"
name="IfcAnnotationFillArea" nillable="true" type="ifc:IfcAnnotationFillArea">
</xs:element>
<xs:complexType name="IfcAnnotationFillArea">
        <xs:complexContent>
                <xs:extension base="ifc:IfcGeometricRepresentationItem">
                        <xs:sequence>
                                <xs:element name="OuterBoundary">
                                        <xs:complexType>
                                                <xs:choice>
                                                        <xs:element ref="ifc:IfcCurve">
                                                        </xs:element>
                                                </xs:choice>
                                        </xs:complexType>
                                </xs:element>
                        <xs:sequence>
                </xs:extension>
        </xs:complexContent>
</xs:complexType>
```

(b)

Fig. 2. IFC algorithm for wall: a) IFC object and b) IFC geometrical representation.

4.2. Floor Slab

The last but not least component of planar system is floor slab. For doing this, the property definition table was tabulated based on IAI standards and ISO 10303-28 (Table 2). Then, IFC algorithms based on table 2 and figure 1 was developed for slab (Fig.3).

TABLE 2: Property Definition of Floor Slab

Name	Description	Value Type
Width	Nominal width (or thickness) of the slab. Only given, if the slab is prismatic.	Ifc Quantity Length
Net Area	Total area of the extruded area of the slab. Openings and recesses are taken into account by subtraction, projections by addition. Only given, if the slab is prismatic.	Ifc Quantity Area
Net Volume	Total net volume of the slab. Openings and recesses are taken into account by subtraction, projections by addition.	Ifc Quantity Volume
Net Weight	Total net weight of the slab.	Ifc Quantity Weight

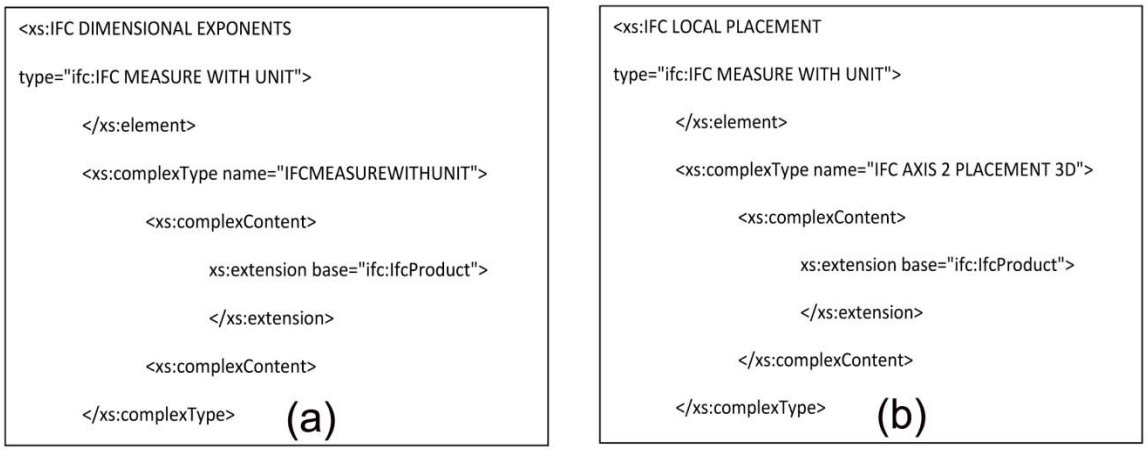

Fig. 3. IFC algorithm for slab: a) IFC dimensional exponents, b) IFC local placement.

5. Conclusion

It is now the responsibility of the wider construction industry and building societies to embrace and further develop this technology to meet the needs of future constructions. A radical improvement of productivity and quality in building construction can be attained only through intensive industrialization, mechanization, automation and computerization of the building process. As conclusion, the IFC standards based on XML language successfully developed for planar system of prefabricated components classified by Warszawski. Due to similarities between general and digital properties of both exterior and interior walls, only one IFC standard developed for them. It was deduced that XML programming language, because of its flexibility in referring the geometric representation of objects, is absolutely suitable for this type of algorithms. To extend the scope of the IBS components to be integrated with BIM in the wider range, it is recommended that the other types of IBS classification such as; “relative weight based categorization” and “the classification based on the production technology” be taken into account in the future studies. By utilizing XML-based IFC standardss, prefabricated components can be standardized, programmed and integrated into BIM software and the collaboration process between BIM and IBS can be highly promoted.

6. References

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