Research on BIM sub-model data of construction engineering based on MVD

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Abstract: BIM technology has been widely applied to various stages of construction projects in China. The data required at each stage and scenario of construction projects varies, necessitating the definition of target BIM data according to data needs. When BIM software generates IFC models, different MVD templates can be configured to output BIM sub-models. To study the characteristics of data configuration for different MVDs, this article takes construction projects as an example and designs an analysis experiment for BIM sub-model output based on MVD. It analyzes the differences and characteristics of IFC model data from both the overall project level and the professional component level according to key indicators, with the aim of providing references for construction project personnel to select matching MVDs, ensuring the effectiveness of BIM sub-models, and meeting the needs of business scenario applications.

Keywords: Construction Engineering, BIM, IFC, MVD, Sub-model

1. Introduction

In today's construction industry, the application of Building Information Modeling (BIM) technology has become a key factor in driving the improvement of project efficiency and quality. With the continuous maturation and popularization of BIM technology, its application throughout the entire lifecycle of construction projects has become increasingly widespread, playing an indispensable role from design and construction to operations and management. However, due to the varying data requirements at different stages and scenarios of construction projects, how to efficiently extract and output sub-models from BIM models that meet specific needs has become an urgent issue to address. This paper aims to explore and analyze BIM sub-model output strategies based on Model View Definition (MVD), in order to provide scientific data selection and model output references for construction project personnel, ensuring the effectiveness of BIM sub-models and their adaptability to business scenario applications.

2. Research background

Building Information Modeling (BIM) technology has been widely applied to various engineering projects in China. As BIM technology is deeply integrated into different stages of engineering projects, a wealth of BIM model data resources have been accumulated. According to the data requirements of various business scenarios, it is necessary to transfer BIM models between different business scenarios [1]. Currently, complete BIM models are often used for data sharing and exchange. Due to the generally large size of BIM model files and the varying data needs of different business scenarios, the original BIM models may contain redundant data that is not required by the scenarios, leading to low efficiency in the sharing and exchange of complete BIM model data [2]. Therefore, it is necessary to first parse the complete BIM models, extract the required data based on scenario demands, and output sub-models corresponding to the scenarios. Considering that the parsed BIM model data needs to be applied in different software systems, this study adopts the open and neutral international standard Industry Foundation Classes (IFC) as the main format for BIM model parsing and output.

Research on extracting required data from complete models to form sub-models has been conducted by scholars both domestically and internationally. The international consortium building SMART International, based on its research of IFC, has studied and released the Model View Definition (MVD) standard. MVD is

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primarily used to specify which data are included in the IFC schema implemented by software. Models output based on MVD are sub-models of the complete model, and the MVD standard mainly extracts and outputs target data of BIM models from a software technology perspective. Wang Renchao et al. [3] proposed a concrete dam construction simulation model based on MVD, processing and outputting IFC model data according to IDM information interaction requirements. Ming xing [4] defined the conversion requirements for architectural and structural models based on MVD, researching data processing algorithms for extracting structural information from architectural models based on MVD. Chen Yuan et al. [5], according to the needs of progress management, used MVD for modular description, researching the development method of construction project progress management information models based on IFC/IDM/MVD.

Table 1: Explanation of MVDs for Experimental Testing

Group	MVD Name
T1	IFC2x3 Coordination View 2.0
T2	IFC2x2 Coordination View
T3	IFC2x3 Basic FM Handover View
T4	IFC4 Reference View
T5	IFC4 Design Transfer View
T6	Shenzhen IFC

Table 2: Data Analysis of BIM Sub-models under Different MVDs

Group	IIFC File Size (MB)	Number of IFC Entities	Total Number of Property Sets	Total Number of Properties	Total Number of Relationship Entities
T1	140.3	2306775	90684	225277	113710
T2	175.8	2924649	99113	250597	122190
T3	140.3	2306857	90684	225281	113710
T4	106.9	656987	83412	225138	106322
T5	92.9	1364351	83444	225171	106469
T6	43.1	283802	15552	25914	104351

Table 3: IFC Expressions of Component Types under Different MVDs

<table>
<tr><th>Group</th><th>Wall</th><th>Door</th><th>Air Handling Unit</th><th>Pipe Elbow</th></tr>
<tr><td>T1</td><td rowspan="3">Ifc Wall Standard Case</td><td rowspan="6">Ifc Door</td><td rowspan="6">Ifc Building Element Proxy</td><td rowspan="3">Ifc Flow Fitting</td></tr>
<tr><td>T2</td></tr>
<tr><td>T3</td></tr>
<tr><td>T4</td><td>Ifc Wall</td><td rowspan="3">Ifc Pipe Fitting</td></tr>
<tr><td>T5</td><td>Ifc Wall Standard Case</td></tr>
<tr><td>T6</td><td>Ifc Wall</td></tr>
</table>

At present, some BIM software has set up different configurations for IFC output modes [6], such as IFC2x3 Coordination View 2.0, IFC4 Design Transfer View, etc. Each mode corresponds to an MVD setting, which outputs IFC model data for different scenario requirements. Engineering personnel generally use the default mode of BIM software to output IFC models, which may result in model data that does not

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match the scenario requirements, leading to data loss, distortion, and other issues [7]. This study takes construction projects as an example and designs an experimental scheme for BIM model output under different MVDs, analyzing the characteristics of BIM model data output for construction projects under various MVDs.

3. Experimental plan design

3.1. Plan design

Considering the characteristics of construction engineering, to comprehensively study the data features of BIM sub-models output under different MVD configurations, this paper selects a certain construction project's basement as a test case. The model was created by Revit software, with the original BIM model file size being approximately 152MB, including various professional components such as architecture, structure, and electromechanical. Considering the needs of different application scenarios in construction engineering, this plan mainly selects different MVDs for output testing, as shown in Table 1. Among them, the Shenzhen IFC standard and its tools have been released, which is an expansion and improvement based on IFC4.1. Therefore, the output of Shenzhen IFC is also one of the MVDs tested.

3.2. Indicator design

To analyze the differences in BIM sub-model data output by different MVDs, the analysis is mainly conducted from the overall project level and the professional component level. At the overall project level, the main indicators include IFC file size, the number of IFC entities, and the total number of property sets; at the professional component level, based on the professional division of construction engineering, typical components such as walls, doors, air handling units (equipment-level components), and pipe elbows (pipeline-level components) are selected to analyze indicators such as the object type, geometric expression, property information, and relationship information of professional components.

4. Analysis of experimental results

4.1. Overall project level

Table 2 organizes the indicator conditions of BIM sub-models under different MVDs.

4.1.1. Correlation between IFC file size and IFC entity count

In terms of IFC file size and the number of IFC entities, there is a basically positive correlation between the two, that is, the larger the file, the more IFC entities it contains. Among them, the BIM sub-model file of Test Group T2 is the largest, while that of Test Group T6 is the smallest. Analyzing the reason, the IFC version corresponding to Test Group T2 is IFC2x2. Compared with versions such as IFC2x3 and IFC4, IFC2x2 is still immature in expressing various professional components and their information of engineering projects, often using complex expression methods for definition, such as using faceted representation for geometric bodies. In IFC4, various complex geometric expression methods such as Ifc Advanced Brep have been added, which can parameterize the definition of complex geometric bodies according to certain logical relationships. Compared with other IFC versions, the IFC files output based on the Shenzhen IFC standard have been lightweighted by methods such as lossless compression and de-redundancy, reducing the amount of model data.

4.1.2. Property sets and counts in MVDs

In terms of the total number of property sets and properties, the number of Ifc Property Set and Ifc Property Single Value exported under each MVD configuration is essentially the same, with T6 having the least.

4.1.3. Relationship entity counts in MVDs

In terms of the total number of relationship entities, the quantity of relationship entities exported under each MVD configuration is roughly the same. With the upgrade and optimization of IFC versions, the expression of relationship information for various components in the project has become increasingly

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refined. The IFC2x2 model contains the most relationship information, while IFC4 contains the least, which is in line with its developmental trend.

4.2. Professional component level

This plan selects typical components of construction engineering projects, such as walls, doors, air handling units, and pipe elbows, as test cases. The following text will conduct a comparative analysis on indicators such as the type, shape, properties, and relationships of the components.

4.2.1. Component types

Table 3 organizes the types of BIM sub-model test component entities output under different MVDs. For common types of components, such as walls and doors, the output IFC component types are essentially the same, with Ifc Wall Standard Case and Ifc Wall both capable of representing wall components, the former being a subclass of the latter. For components with complex shapes or specific functions, if there is no corresponding IFC component entity expression, a proxy entity Ifc Building Element Proxy is generally used, such as the IFC expression for air handling units. As the IFC standard evolves, some professional components have been refined in newer IFC versions, such as the IFC expression for pipe elbows, which is IfcFlowFitting in IFC2x2 (T2) and IFC2x3 (T1, T3), and Ifc Pipe Fitting in the IFC4 version.

4.2.2. Component geometry

The geometric shapes of components involve applications such as quantity surveying, professional coordination, and structural safety. In this plan's test components, both geometrically regular and irregular components were selected as test cases. Table 4 summarizes the IFC expressions used for the geometric shapes of the test components.

From Table 4, it can be seen that the IFC standard has different expression methods for components with different geometric appearances. For geometrically regular components, such as wall components, the extruded solid Ifc Extruded Area Solid is mainly used for expression. At the same time, IFC data analysis shows that several extruded solids can be combined to form complex components, such as air handling units. Analysis of the IFC expression of the geometric shape of the air handling unit reveals that its geometric shape is formed by the Boolean operations of several extruded solids Ifc Extruded Area Solid. For irregularly shaped components, such as pipe elbows, earlier IFC standard versions mainly used the faceted brep Ifc Faceted Brep for expression, which increased the number of IFC expression statements and led to larger IFC files. With the development of the IFC standard, geometric expression entities with certain logical relationships have been gradually adopted. Therefore, in the geometric expression of pipe elbows, the IFC4 (T4, T6) standard uses the triangulated face set Ifc Triangulated Face Set for expression. Figure 1 analyzes the logical relationship of the Ifc Triangulated Face Set IFC expression.

Table 4: Geometric IFC Expressions of Components under Different MVDs

<table>
<tr><th>Group</th><th>Wall</th><th>Door</th><th>Air Handling Unit</th><th>Pipe Elbow</th></tr>
<tr><td>T1</td><td rowspan="5">Ifc Extruded Area Solid</td><td>Ifc Extruded Area Solid、Ifc Faceted Brep</td><td>Ifc Extruded Area Solid</td><td rowspan="3">Ifc Faceted Brep</td></tr>
<tr><td>T2</td><td>Ifc Faceted Brep</td><td>Ifc Faceted Brep</td></tr>
<tr><td>T3</td><td>Ifc Extruded Area Solid、Ifc Faceted Brep</td><td rowspan="4">Ifc Extruded Area Solid</td></tr>
<tr><td>T4</td><td>Ifc Extruded Area Solid、Ifc Triangulated Face Set</td><td>Ifc Triangulated Face Set</td></tr>
<tr><td>T5</td><td>Ifc Extruded Area Solid、Ifc Advanced Brep</td><td>Ifc Surface Curve Swept Area Solid</td></tr>
<tr><td>T6</td><td>Ifc Triangulated Face Set</td><td>Ifc Triangulated Face Set</td><td>Ifc Triangulated Face Set</td></tr>
</table>

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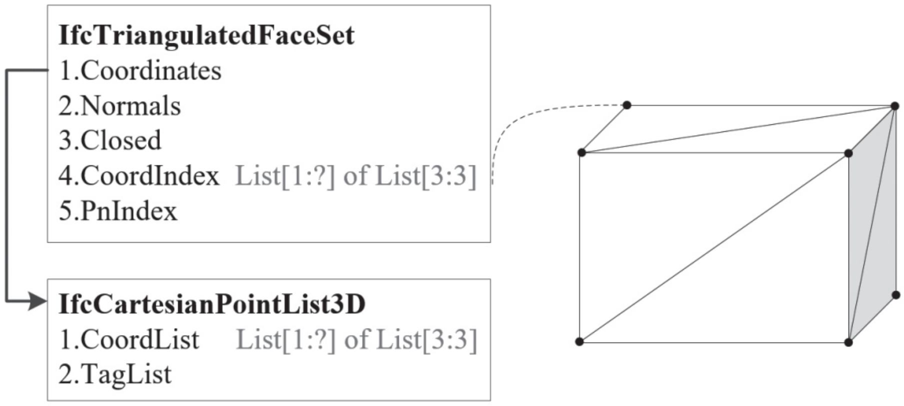

Figure 1: Geometric Expression Relationship Based on Ifc Triangulated Face Set

4.2.3. Property information

In the IFC standard, property information carried by components is mainly expressed through property sets Ifc Property Set and property items Ifc Property Single Value. This plan statistically analyzed the situation of property items Ifc Property Single Value contained in each test component. The statistical analysis shows that the number of property information carried by the test components is basically the same, and the property values are essentially consistent, ensuring the accuracy and completeness of the information of the test components.

To analyze the overall situation of property information in BIM sub-models under different MVDs, Figure 2 shows the situation of property sets Ifc Property Set and property items Ifc Property Single Value in the BIM sub-models. The number of property sets Ifc Property Set and property items Ifc Property Single Value in test groups T1 to T5 is roughly the same. In test group T6, the number of property sets and property items is much less than in other test groups. Analysis of the IFC data of test group T6 shows that the same Ifc Property Set and Ifc Property Single Value are indexed by multiple IFC entities, while other test groups have a one-to-one indexing relationship. Therefore, it can greatly reduce the amount of IFC statements and improve the expression and processing efficiency of IFC data.

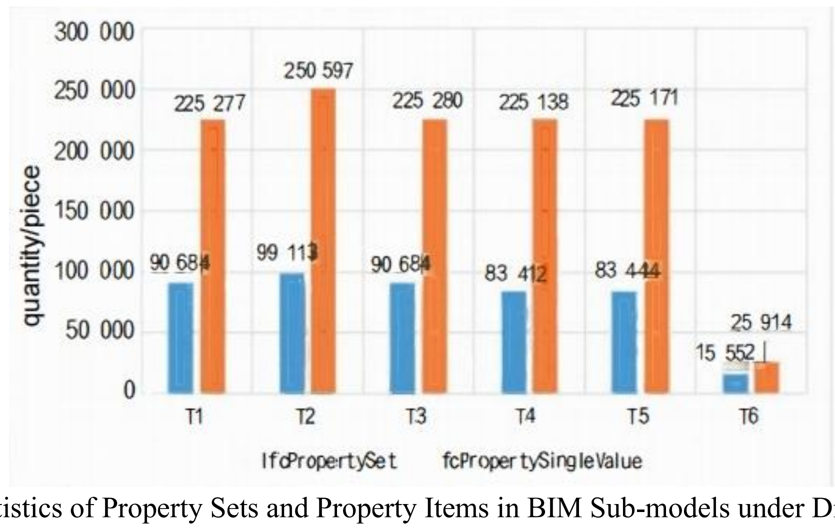

Figure 2: Statistics of Property Sets and Property Items in BIM Sub-models under Different MVDs

4.2.4. Association relationships

In this plan, door components are set within wall components, having a containment association relationship, and there are also connection relationships between wall components. Mechanical and electrical facilities such as air handling units and pipe elbows not only have system grouping relationships but also typically have upstream and downstream interface relationships. Table 5 summarizes the IFC expression of the association relationships between the tested components.

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Table 5: IFC Expressions of Component Association Relationships under Different MVDs

		T1	T2	T3	T4	T5	T6
Component	Relationship Category	Ifc Rel Voids Element					
		Ifc Rel Connects Path Elements					—
Component	Relationship Category	Ifc Rel Fills Element					
		Ifc Rel Assigns To Group					
Component	Relationship Category	Ifc Rel Connects Port To Element					Ifc Rel Nests
		Ifc Rel Assigns To Group					
Component	Relationship Category	Ifc Rel Connects Port To Element					Ifc Rel Nests

Based on IFC data analysis, there is no direct association between wall components and door components; instead, they are associated through the opening element Ifc Opening Element. This is beneficial for calculating the actual opening sizes of wall components and facilitates the flexible configuration of wall openings. For mechanical and electrical specialties, systems are generally composed of multiple mechanical and electrical facilities to perform a specific function. Therefore, when creating mechanical and electrical BIM models, a system Ifc System is formed, and all components of the system are typically associated in the IFC file by Ifc Rel Assigns To Group. In test group T6, Ifc Rel Nests is directly used to associate the inlets and outlets of components, which is conducive to analyzing the transmission paths of media within the components.

5. Discussion of experimental results

In the horizontal aspect, the test groups T1 to T6 cover different versions such as IFC2x2, IFC2x3, and IFC4. Looking at the different versions, the newer versions are more refined in terms of component types and geometric expressions, adding dedicated component entities for the characteristics of various professions. For instance, the IFC4 version introduces Ifc Pipe Fitting to represent pipe elbows. Especially in terms of geometric expression, the newer versions have established more entity expressions with logical relationships, preserving the geometric features of components to the greatest extent and also being more concise in terms of data volume, reducing file size. For example, the IFC4 version introduces advanced geometric expression entities such as Ifc Triangulated Face Set and Ifc Advanced Brep.

In the vertical aspect, the study focuses on different model views such as Coordination View, FM Handover View, Reference View, Design Transfer View, and Shenzhen IFC.

5.1. Coordination view: Multidisciplinary foundation

Coordination View serves as the foundational version for collaboration among architecture, structure, and MEP disciplines, encompassing the necessary information for each specialty. Notably, IFC2x3 Coordination View 2.0 is the version currently supported by most BIM software [8], meeting the needs of early BIM applications.

5.2. FM handover view: Facility info management

FM Handover View includes not only the basic elements of engineering projects but primarily describes the management requirements for facility and equipment information.

5.3. Reference view: 3D coordination for Multi Disciplines

Reference View supports 3D coordination among various disciplines. This view exports various components, which are often expressed using triangulated face sets, to meet the purposes of geometric appearance reference.

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5.4. Design transfer view: Geometric analysis focus

Design Transfer View is primarily used for computational analysis in design, supports data transfer, and focuses on geometric feature parameters, such as the newly added Ifc Advanced Brep, Ifc Surface Curve Swept Area Solid, and other geometric expression entities.

5.5. Shenzhen IFC: Enhanced national standard compliance

The Shenzhen IFC standard is developed based on the national standard "Building Information Model Storage Standard" (GB/T51447—2021) and is optimized to meet the expression of information from various professions. During the testing process, the IFC models exported based on Shenzhen IFC have been optimized in terms of file size, information expression, and geometric expression.

6. Conclusion

To analyze the differences and characteristics of BIM sub-models output based on different MVDs, this paper takes construction projects as a case study and conducts research and analysis on IFC models generated under various MVDs. Starting from the overall project level and the professional component level, the analysis focuses on key indicators such as component types, shapes, properties, and relationships. The experimental results demonstrate that there are differences in the IFC models generated due to the varying data requirements of different MVD settings, including file size, component types, information carried, and expression methods. To meet the data needs of different business scenarios, engineering personnel should combine the characteristics of different MVDs and configure the required IFC model data through various MVD outputs.

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