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Research on Parametric Component Library of Prefabricated Building Based on IFC Standard

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Abstract. Prefabricated components, as the basic unit of prefabricated buildings, play a decisive role in the quality and cost of the building. At present, the data format and information storage mode of the component model are diversified, which causes the project information to be effectively shared and exchanged, and the phenomenon of information islands is formed. Aiming at this problem, this paper proposes the construction scheme of BIM-based modular building parameterized component library through the comprehensive application of IFC standard and information integration technology, and verifies the component model information extension and component library construction scheme based on IFC standard through examples. Feasibility, providing a reference for standardizing and unifying BIM software data standards.

Keywords: BIM component library, collaborative filtering recommendation algorithm, IFC, prefabricated building, WebGL

1 Introduction

Prefabricated building is one of the main ways to realize the industrialization of buildings. It is a modern construction method integrating integrated design, industrial production, mechanized installation, information management, integrated decoration and intelligent application [1]. The goal of BIM technology is synergy. The core is information sharing and exchanging, and the basis is data standards. The development of IFC (industry foundation classes) standards solves the problem of data sharing and exchanging between BIM software [2]. BIM is the key technology and the best platform for the realization of the prefabricated building system. The application of BIM in the process of prefabricated building construction is conducive to the refinement of the process and the efficiency of information management, and effectively promote the transformation and upgrading of China's construction industry [3]. At present, the research on applying BIM technology to prefabricated building information management mainly includes Vanlande et al. [4] proposed to apply IFC standard for information storage and data processing in project design and construction stage to improve the efficiency of information sharing, but There is no explanation for the method of storing information. Opitz et al. [5] pointed out that the traditional semi-structured and unstructured documents are associated with the component model to realize the information integration of the construction project in the whole life cycle, but the method of extracting the component information is not explained. Redmond et al. [6] use XML or its subset of SML to extend IFC capacity, but the technical requirements for users are higher. There is less research on the establishment of a library of fabricated building components based on the IFC standard. Therefore, there is an urgent need to make up for the gap in the research of the fabricated building component library based on the IFC standard, and to standardize the expression of component information by the IFC standard.

At present, the existing component libraries at home and abroad include New Zealand Product Spec, the UK's National BIM Library, and China's large-scale database of housing and urban and rural

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construction products. However, these component libraries are mainly for the data format of proprietary software, the number and types of information are small, the classification ability of information needs to be improved, and the information mobility is not high. Based on the above problems, it is proposed to build an assembly building component library based on IFC standard, and promote the integration of design, production and construction through this library, and reduce the long-term fragmentation of the parties, the program is seriously out of line, and lack of information sharing and communication between upstream and downstream. The research idea of this paper is to solve the problem of information storage and data processing required by the component model for each participant of the project based on the information description and extension mechanism of the IFC standard. The improved collaborative search recommendation algorithm is used to implement the intelligent retrieval recommendation function of the platform to the component; Finally, through the construction of the Web-side platform, the functions of reading, saving, extracting, integrating and expanding structured IFC model data and unstructured document data are realized.

2 Component Model Expression Method Based on IFC Standard

The IFC standard was developed and gradually refined with reference to the STEP standard and is defined in the EXPRESS language. The latest version of the IFC4 standard contains a large number of class definitions, with 755 entities, 418 attribute sets, and 390 data types [7]. The IFC architecture is divided into four layers: the resource layer, the core layer, the shared layer, and the domain layer. Each concept layer defines a series of entity objects. The entity objects of each layer establish a reference relationship through the relationship object. When all the entity objects in the concept layer establish a reference relationship, the entity objects in the high level can refer to the same level or low. Entity objects in the hierarchy, prohibiting entity objects in the lower level from referring to entity objects in the higher level.

In the entity class defined by the IFC standard, the information of the component object mainly includes geometric information, relationship information, and attribute information. The geometric information includes position and expression. The relationship information includes not only the reference relationship between the component object and the related resource, but also the membership relationship and connection relationship between the component object and other objects. The attribute information is mainly used to assist in describing the component related parameters.

The component objects derived from the entity IfcProduct all have geometric information describing the shape and position. The EXPRESS-G icon defined by IfcProduct is shown in the Fig. 1. The object location (ObjectPlacement) and expression (Representation) properties in the entity definition are inherited from IfcProduct. The relationship information between component objects and between different objects is abstracted into the concept of objects. The relationship between component entities is established through the relationship object (IfcRelationShip). The acquisition of the overall information tree of the component object is achieved by filtering and extracting the relationship information. The information of the component entity itself is described by attribute definition, and the attributes used for information description can be divided into three definition forms: direct attribute, inverse attribute and derived attribute.

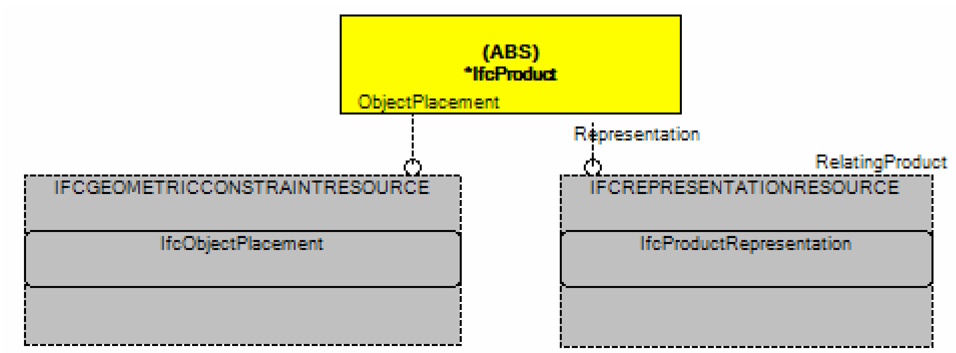


Fig. 1. EXPRESS-G chart of IFCProduct

3 Parametric Model of Fabricated Building Components

3.1 Parameterized Model Information Demands Analysis

The designer models the structure through the modeling software, creates the building structure, builds a whole building structure by using beams, plates, columns and other components, and calculates the structural load of the model. The benefit of applying BIM software is the ability to split the model according to the characteristics of the prefabricated building and to specify the components that can be industrially produced. Parametric model is made for the specified component. The parametric model of the fabricated building component mainly includes geometric information attributes, non-geometric information attributes and exclusive information attributes [8]. The geometric information attributes mainly include the geometrical dimensions and positioning information of the components; the non-geometric information attributes mainly include the key parameters of the steel structure of the components, fire performance, material information, etc. the exclusive information attributes mainly include the material suppliers, manufacturers, and price of the components, component connection and installation methods, information required for operation and maintenance.

3.2 Component Model Extension Mechanism Based on IFC Standard

Since the entity types and attributes given in IFC's data model are not perfect, The domain level is lack of entity information. Therefore, the entities involved in the information requirements of the fabricated building components cannot be fully represented, Entities in the standard domain layer needed to be extended. There are three extension methods based on the IFC model, which are extension methods based on IFC Proxy entities, extension methods defined by entities, and extension methods based on attribute sets. Based on the parameterized model information requirement analysis, the fabricated building component adopts the attribute value based on expansion method to increase the component attribute information. The extended process is shown in Fig. 2.

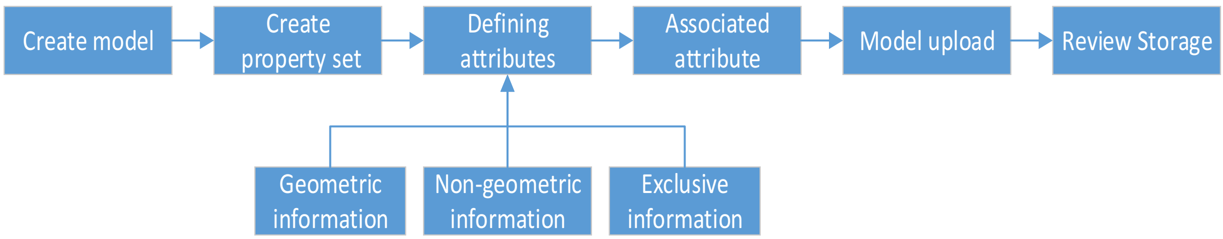


Fig. 2. Extension process based on attribute values

After the geometric information, non-geometric information and exclusive information of the fabricated building component are set, the attribute information and the component need to be associated with each other before expression. For example, material information, the relationship of the material is expressed by the entity IFC Associates Material, the attribute of the entity Related Objects points to the associated entity, and the attribute Relating Material points to the material information. The basic attribute information of the component is associated by IFC Defines By Properties, the attribute of the entity Related Objects points to one or more associated objects, and the Release Property Definition points to the attribute set [9]. The relationship is shown in Fig. 3. Through the IFC standard, the information required by the participants of the prefabricated building project Is integrated into the parameterized component model of the modular building, so that the extended IFC standard entity can better express the different information needs of the project participants, So as to improve the construction quality and reduce the production cost of assembly building in the whole life cycle management process of assembly building.

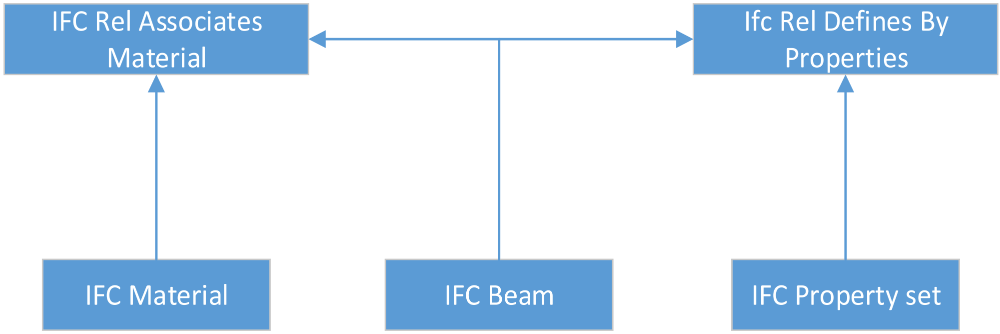
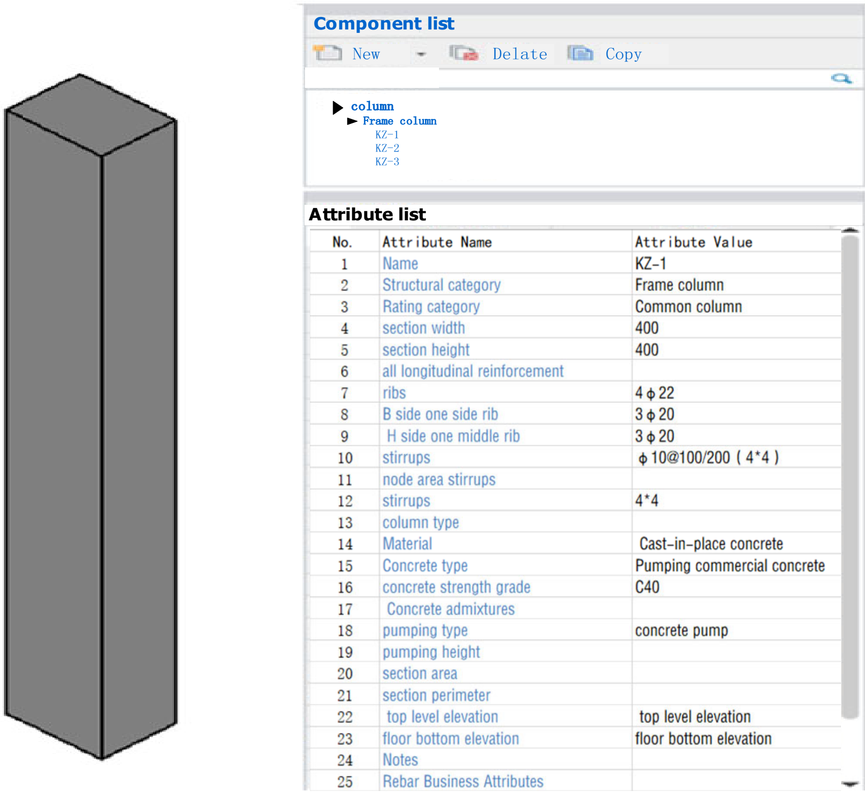


Fig. 3. Component-based expression based on IFC standard

3.3 Extension of the Component Model Based on IFC Standard

Taking prefabricated concrete columns of prefabricated buildings as an example, the parametric model should contain five dimensions of component size, material, mechanical properties, assembly method, and engineering project, each of which contains its corresponding parameter information. The size label is mainly responsible for controlling the dimensional information of the concrete part of the component (including the length, width and height of the concrete component dimensions) and the position information (the position of the component in the project model). After selecting the material information of the component, the preliminary model view of the component is obtained by inputting the corresponding parameters. As shown in Fig. 4 build model view.



No.	Attribute Name	Attribute Value
1	Name	KZ-1
2	Structural category	Frame column
3	Rating category	Common column
4	section width	400
5	section height	400
6	all longitudinal reinforcement	
7	ribs	4ϕ22
8	B side one side rib	3ϕ20
9	H side one middle rib	3ϕ20
10	stirrups	ϕ10@100/200 (4*4)
11	node area stirrups	
12	stirrups	4*4
13	column type	
14	Material	Cast-in-place concrete
15	Concrete type	Pumping commercial concrete
16	concrete strength grade	C40
17	Concrete admixtures	
18	pumping type	concrete pump
19	pumping height	
20	section area	
21	section perimeter	
22	top level elevation	top level elevation
23	floor bottom elevation	floor bottom elevation
24	Notes	
25	Rebar Business Attributes	

Fig. 4. Component model view

When the preliminary model of the completed component is established, made the component is deepening design, and the content of the deepening design mainly includes the arrangement of the steel bar and the embedded component. The main contents of the steel bar label are the information of the distributed steel bars and the stressed steel bars of the laminated floor, including the concrete protective layer, the steel bar diameter, the steel bar protective layer, the steel bar spacing and the steel bar extension length parameters; the embedded part label information mainly includes pipes and equipment.

Pre-buried size, location and other information, convenient for manufacturers to produce. As shown in Fig. 5 Component model reinforcement configuration.

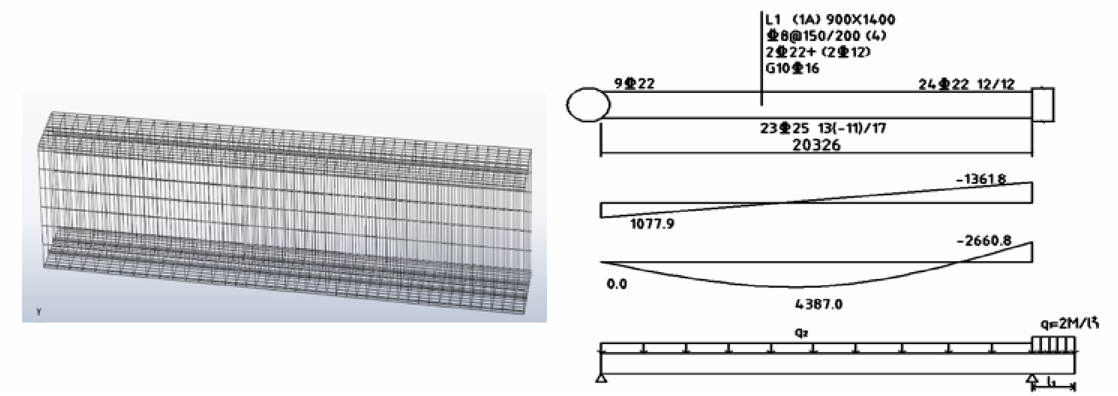


Fig. 5. Component model reinforcement configuration

4 Design of Fabricated Building Component Library Based on IFC Standard

4.1 Platform Architecture of the Assembled Building Component Library

Establishing an assembly-based building component library system based on the IFC standard allows the user to obtain the obtained information with the corresponding authority. The integration, coordination and scalability of the system are used to realize the extraction of component information and resource sharing. And Improve the efficiency and accuracy of prefabricated building designs. As shown in Fig. 6 the architecture of the fabricated building component library system based on IFC technology is the data layer, the service layer, the transport layer and the application layer from bottom to top.

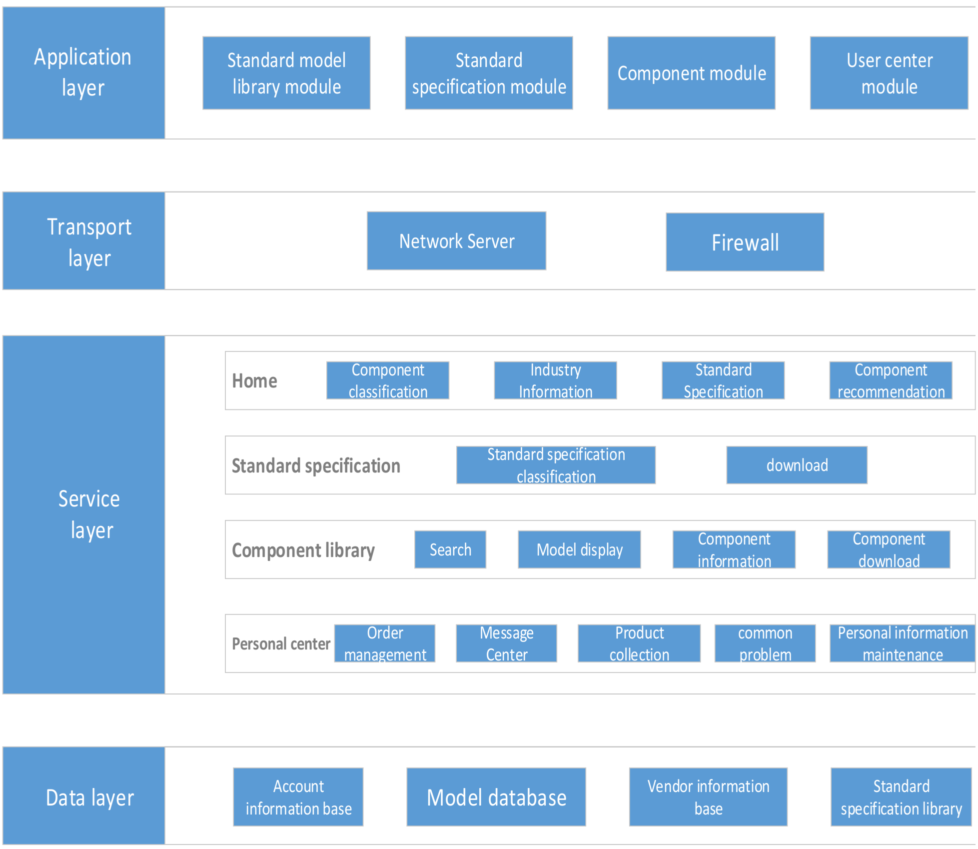


Fig. 6. Assembled building component library platform framework

The data layer can be divided into Database of account information, database of model, database of vendor information and standard specification library according to the content, and is responsible for storing various information resources. The database can be accessed or updated according to the SQL command sent by the superior, and the corresponding data information can be fed back to the user according to different access requests [10]. Because the component model stores more formats, The single volume of component data is smaller and the entire graphics data volume is larger, the relational database is difficult to perform. In order to meet the complex and variable data structure storage requirements of the building database, the system adopts the DB+Spark structure. As shown in Fig. 7, through the various types of data and the relationship between the data, It solves problems in 3D geometric data, document data, structured data, relational data storage and management issues.. Compared with the traditional relational database, the database supports flexible data structure storage methods to process 3D geometric data faster; compared with the document database, it occupies less storage space.

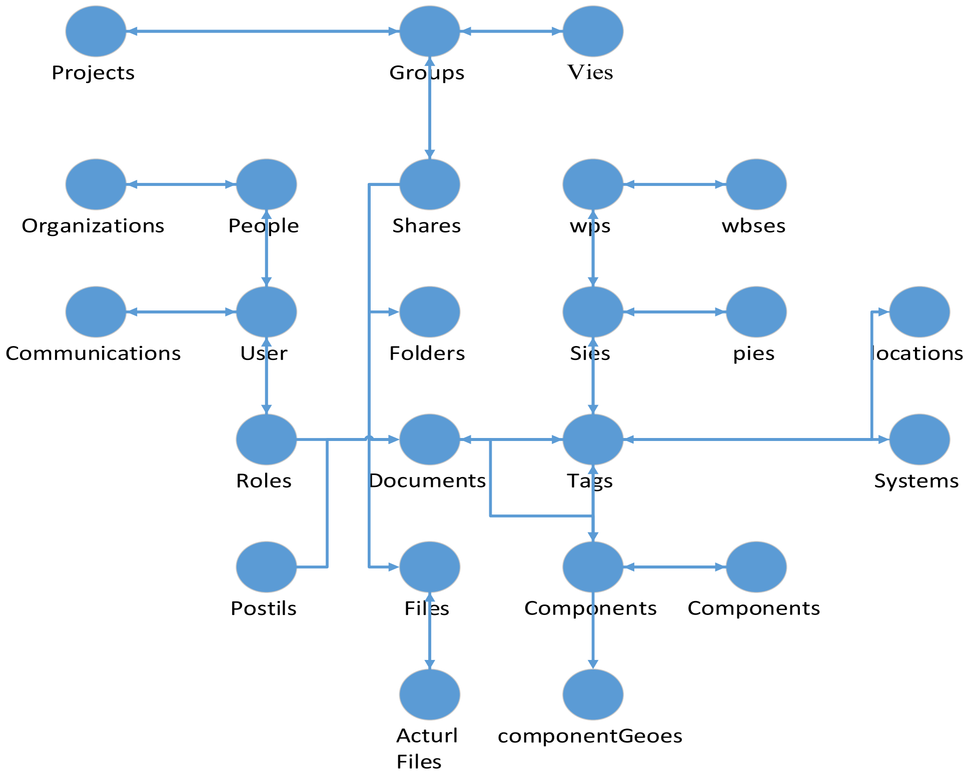


Fig. 7. Schematic diagram of component library data relationship

The application layer request is converted by the http transport protocol via the web server and then transmitted to the database layer for data processing, and the result is fed back to the user application layer. The service layer is mainly a behavior module for managing Information of BIM product library, including user management, component information uploading, component model visual browsing, component query, and component management. The component product entry means that the user uploads the component information to the component library through the webpage uploading method, and the uploading mode supports the uploading of the single or batch file; The fund-raising operation means that the user can download the component data to the PC and provide it to the BIM software after the user passes the authority authentication.

4.2 Personalized Recommendation Algorithm Research

The personalized recommendation function of the fabricated building component library refers to recommending different content information for different users. When selecting which recommendation algorithm to use, it is necessary to comprehensively consider the accuracy, efficiency, rationality and other elements of the recommendation. The modules of the personalized recommendation system can be divided into three parts: input, output and implementation of the recommendation algorithm [11]. There are two main categories of personalized recommendation algorithms, one based on the memory (based type) and the other based on the model (model-based) type. The memory-based type is further divided into user-based and item-based algorithms. The assembly-type building component library system uses the item-based recommendation algorithm. Its basic working idea is to first calculate and analyze the behavior history data of all users of the system, and calculate the similarity between components based on these data, and finally will be with the user before. Like the product similar to the product recommended to this user. At the same time, in view of the sparse data of the existing component library, the classification of the components is added to calculate the similarity between the components.

The methods for calculating similarity mainly include cosine-based cosine-based, correlation-based correlation-based and adjusted-based similarity calculation. The system uses the correlation-based similarity calculation method, that is, to calculate the Pearson correlation between two vectors. The formula is as follows:

$$sim_1(i_1, i_2) = \frac{\Sigma_{u\in U}(R_{u,i} - R_i)(R_{u,j} - R_j)}{\sqrt{\Sigma_{u\in U}(R_{u,i} - R_i)^2} \times \sqrt{\Sigma_{u\in U}(R_{u,j} - R_j)^2}} \quad \textbf{(1)}$$

Where, Ru, i represents the score of the component i by the user u, and Ru, j represents the average of the scores of the i component.

The components that are not scored by the user can be predicted based on the similarity between the calculated components, and the weighted summation method is used here. First, the weights of the components that have been evaluated by the user u are weighted and summed. The weights are the similarities between the same components and components of each material, and then all the similarities of the components are added and the average value is obtained. Finally, according to the formula calculating the score of the user u on the component. The formula is as follows:

$$sim_2(i_1, i_2) = \frac{\Sigma_{all\ similar\ items, M}(S_{i,M} * R_{u,M})}{\Sigma_{all\ similar\ items, M}(|S_{i,M}|)} \quad \textbf{(2)}$$

Where Si, m is the similarity between component i and product M, Ru, m represents the scoring of component M by user u.

Considering that the item-based recommendation is influenced to some extent by the component information content, the component classification information measures the similarity of the content in the content to some extent. Therefore, in this paper, the classification information of the component is used to replace the similarity in the component information content, and the component similarity is calculated by the classification information of the component. The formula is as follows:

$$sim_3(i_1, i_2) = \frac{1}{|c|}\sum_{j=c} c_{i1,j} \times c_{i2,j} \quad \textbf{(3)}$$

|C| indicates the total number of classifications on the entire data set, C indicates the classification set on the item, Ci1, j indicates whether the item i1 belongs to a certain class, and if the member belongs to a certain category, the value is 1, otherwise 0.

According to the above analysis, component-based similarity can be obtained from three aspects, and then averaged to obtain the final inter-component similarity.

$$sim(i_1, i_2) = \frac{sim_1(i_1, i_2) + sim_2(i_1, i_2) + sim_3(i_1, i_2)}{3} \quad \textbf{(4)}$$

4.3 Web-based Component Model Visualization Display

WebGL is a technology for drawing, displaying 3D graphics and supporting interactions in a browser. It is a lightweight subset of OpenGL that allows developers to embed interactive 3D graphics that support hardware acceleration directly in the browser. The advantage of this technology is that its program runs in the browser, no need to install any special plug-ins or library files, just need to write the functions to be implemented into a JavaScript program and give it to the browser to run 3D graphics programming

[12]. Developers can take full advantage of the browser features and use the common Web technology to complete the release of the component 3D graphics program.

This paper mainly describes the visualization method from modeling and file uploading to data collection and graphics processing. The modeling and file reading analysis process is mainly through 3D modeling of the example building, then the model file conversion is unified into the IFC format, and further converted into an OBJ file, which is used as an external calling file of the webpage. Render the display model in the browser by calling the JavaScript-based WebGL executable file. The geometrical information extraction of the component is realized by the model loading method based on the component geometric multiplexing algorithm. The triangular mesh model is applied for display, and the built-in GLSL ES shader language of WebGL is used to finally realize the Web-3D browsing and interaction of the BIM model [13].

4.3.1 Model loading Method Based on Component Geometric Multiplexing Algorithm

Regardless of the complexity of the shape of the 3D model, most of the basic units that make up the model use triangles, so the loading and rendering of the 3D model requires matrix-by-vertex, piece-by-piece matrix operations. For the building information model display system in the actual project, if such a large number of operations are all processed by the CPU, due to the design goals and working methods, it is impossible to ensure the rapid calculation of the model data efficiently, which will affect the model fluency of the show. In the system using WebGL 3D visualization technology, the program assigns these computational tasks to the GPU. GPU has unique advantages for large-scale data operations with uniform types and weak interdependencies, and can well handle the building information model display process. The matrix operation greatly improves the efficiency of program execution and data processing, and ensures the smoothness of the 3D model display.

4.3.2 Research on Rendering of Triangular Mesh Model

There are 7 basic graphics that WebGL can draw directly, other more complex models are composed of these basic graphics. As shown in Fig. 8, gl.POINTS represents the point in space, gl.LINES represents the line segment in space, gl.LINE_STRIP represents a set of connected line segments, gl.LINE_LOOP represents a set of line segments that end to end, gl.TRIANGLES represents A separate triangle in space, gl. TRIANGLE_STRIP represents a triangle forming a band in space, and gl.TRIANGLE_FAN represents a triangle forming a sector in space.

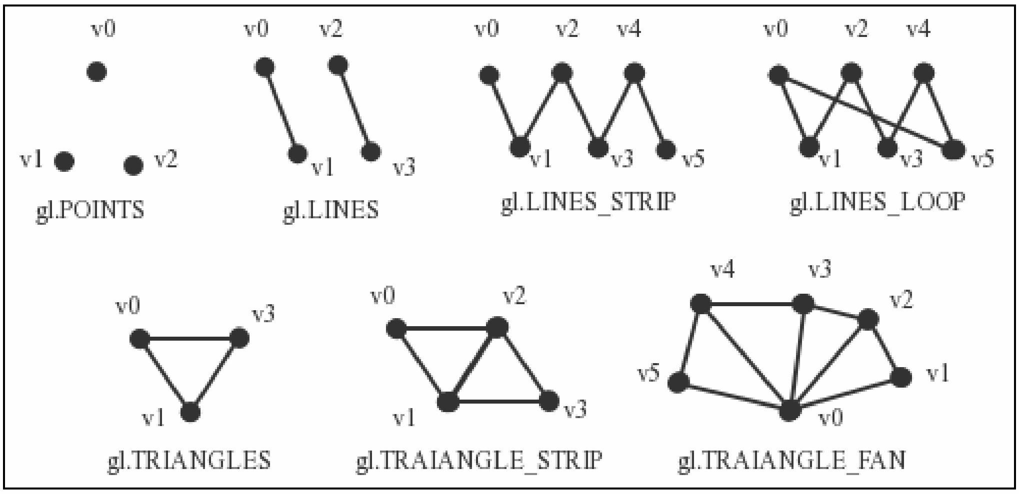


Fig. 8. Predefinition of WebGL basic graphic

After geometric data processing, the geometric information of the components are represented by the triangular mesh model, so each triangle element that makes up the object can be drawn one by one to draw the entire three-dimensional object [14]. First, the geometric data of the component is obtained through the network request, and then the information such as the vertex coordinates, the index, the normal, the appearance, the color, the transformation matrix, and the like of the component are extracted and extracted from the geometric data.

As shown in Fig. 9, the corresponding vertex shader program is defined according to the data, compiled and passed to the GPU. The GPU executes the shader program one by one according to the obtained vertex data, completes the matrix operation of the coordinates, and generates corresponding vertex coordinates. The vertex shader applies a projection matrix to convert the three-dimensional world coordinates into screen coordinates. After the primitive is generated, the corresponding color shader program is defined by color, light, etc., compiled and passed to the GPU for fragment coloring, and the fragment shader rasterizes the fragment, and judges the fragment to be rendered according to the depth and Determine the color of each tile.

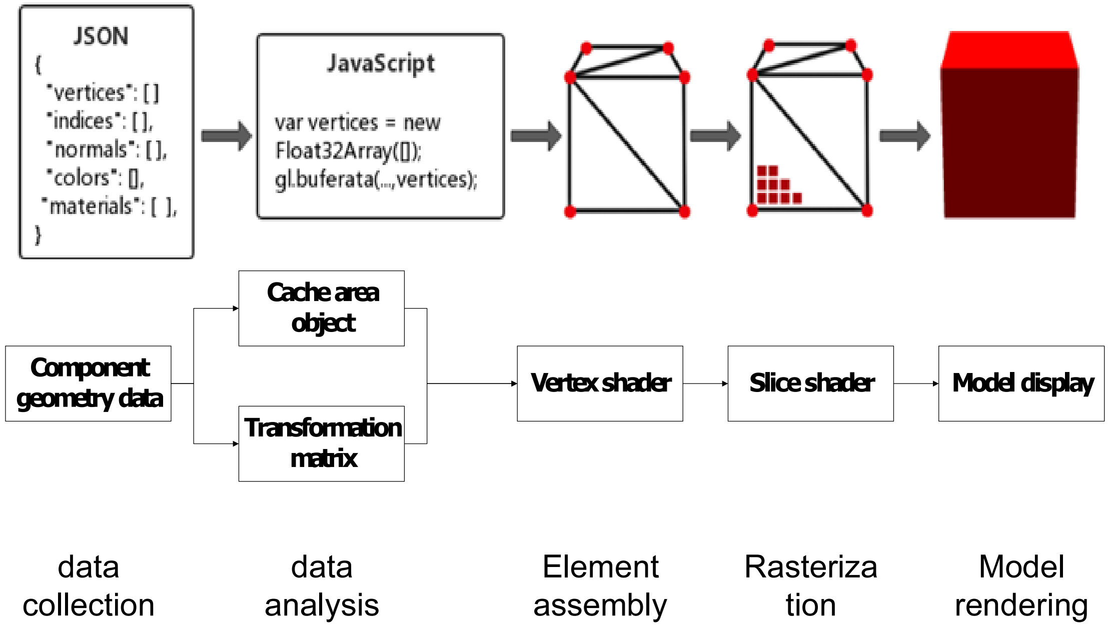


Fig. 9. Flow chart of model rendering

4.3.3 GLSL ES Language and Shader Research

The GLSL ES language is a derivative of the OpenGL shader language. Its target platform is consumer electronics and embedded devices. Currently, this shader language is widely used in image processing and data computing [15]. As a strongly typed language, shader programs written in that language require attention to variable types. Similar to the C language program, the shader program starts execution from the main function. The language supports vector and matrix types, which are ideal for graphics processing tasks. The language defines and supports a large number of functions to complete data operations. The function categories and related information are shown in Table 1.

Table 1. GLSL ES function definition

Function category	Function function	Number of functions
Angle and trigonometric function	Angle and trigonometric correlation operations	36
Exponential function	Exponential operations such as power and logarithm	28
General function	General operations such as absolute value, rounding, and modulo	73
Geometric function	Geometric operations such as length, distance, and cross product	29
Matrix function	Matrix multiplication	3
Vector function	Comparison, component, etc. vector operations	45
Texture query function	Texture operations such as texture coordinates and texture reading	12

In 3D scenes, drawing lines with only lines and colors is not enough to meet the needs. It also requires the shader to efficiently perform variable factors such as illumination and perspective transformation to provide various rendering effects. This is also the data that WebGL calls the GPU to perform and the key to computing and implementing 3D scene construction. Shaders are divided into vertex shaders and fragment shaders. Vertex shaders are programs used to describe vertex information such as position coordinates and colors. A fragment shader is a program for processing pieces of information such as lighting and coloring. An example of the program for the two shaders is shown in Fig. 10.

```
//Vertex Shader
var VSHADER = "" +
    "void main() {\n" +
    "Position = vec4(1.0, 1.0, 1.0, 1.0); \n" +// Vertex coordinate information
    "} \n";

//Fragment Shader
var FSHADER = "" +
    "void main() {\n" +
    "FragColor = vec4(1.0, 1.0, 1.0, 1.0); \n" +// Chip color information
    "} \n";
```

Fig. 10. Shader program example

There are two processes of primitive assembly and rasterization between the vertex shader and the fragment shader. The function of the primitive assembly process is to assemble the isolated vertex coordinates into triangle primitives. As shown in the vertex shader program shown in Fig. 10, the Position parameter is the input data of the primitive assembly process, passing through the vertex shader.

5 Conclusion

Based on the research of IFC standards and the information needs analysis of the participants of the project, this paper proposes the construction plan of the assembled building component library based on IFC standard. Taking prefabricated components as the core, according to the system framework design and development, the key technologies needed for the realization of the system are studied, and the concrete and feasible methods are put forward, and the design, production, transportation and construction information of the assembly-type construction project are realized. Efficient use. At present, the component library does not fully support the IFC standard on the data interface, which makes the IFC model have missing information and error phenomenon in the software input and output process, so it needs constant optimization and improvement in function. In the later stage, real-time monitoring of components was realized by using GIS and RFID technology. Set port docking production and construction data in the component library, so that the component production and construction site are synchronized with the component library 3D model display module, and provide framework design support for component refinement and automated assembly.

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