A software platform for information conversion from IFC-based architectural model to PKPM structural model

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Abstract
With the emerging use of IFC (Industry Foundation Classes) standard and BIM (Building Information Modeling) technology in the A/E/C (Architecture/Engineering/Construction) industry, the requirements for more effective collaboration between architects and structural engineers have become even more demanding in the current building design field. This paper presents an information conversion platform from IFC-based architectural model to PKPM (Bopomofo acronym, a Chinese building design software) structural model with the aim to enhance effective collaboration at the design phase. To design the framework of the platform, the PKPM structural model and IFC data model are described and analyzed in the research, and mixed program languages such as C++ and FORTRAN are adopted for developing the platform software. The proposed platform can support automatic information conversion from IFC-format architectural model to PKPM structural model, which includes geometrical information, material information, section information and connection attribute information of building elements. A case study is implemented at the end of the paper to illustrate how to use the platform for information conversion. The platform provides a basic tool for PKPM software to support IFC standard.

*Keywords*: IFC standard, PKPM software, collaborative design, architectural and structural model

1 Introduction
In the current building design field, the wide application of IFC (Industry Foundation Classes) standard has effectively facilitated the information exchange and sharing across the project life cycle, which plays a significant role in boosting the sustainable development of the building industry. However, numerous designers still maintain their disciplines’ independence, and different design companies have different software to fulfill their tasks in the Chinese construction industry (Li et al., 2008). IFC is a set of building product model specification developed by the International Alliance for Interoperability (IAI) for product data representation and exchange in the AEC/FM industry (Chen et al., 2005). The IFC standard suitably provides an information exchange and sharing platform, which can couple with the network technology to form a central database server to facilitate information exchange among different participators from various geographical locations (Buildingsmart, 2009). The building software applications supporting the IFC standard are able to exchange and share data with other applications that are also IFC-compliant. (Serror et al, 2008) developed a shared computer-aided structural design (sCAsD) model infrastructure for improving the interoperability between participants in a construction project. (Wan et al., 2004) developed a building model server for...
supporting both IFC-based data integration and transaction-based interoperability between architectural design and structural design applications by analyzing the information requirements of SAP2000 from a software point of view. (Abidemi, et al., 2006) presented a software solution that could reduce initial knowledge requirement for understanding EXPRESS language by providing a .NET class library translation and an implementation view of the IFC model. (Chen et al., 2005) presented an implementation of IFC-based information server for web-enabled collaborative building design between the architect and the structural engineer. (Lee et al., 2003) developed a design information management system (DIMS). (Karola et al., 2002) presented a tool, BSPro COM-Server for easier implementation of IFC files for existing and new software tools. (Faraj et al., 2000) developed a web-based IFC shared project environment (WISPER). In China, (Wang et al., 2004) developed a 4D construction management system based on IFC and engineering information model. (Deng et al., 2005) presented an algorithm for structural model construction from IFC-based architectural model.

Current PKPM software (detailed information about PKPM can be seen in the second section of this paper), a Chinese leading building software which is developed by the China Academy of Building Research (CABR), still does not support information exchange with IFC-compliant architectural model. This paper focuses on the representation rule of IFC data model after a brief discussion of PKPM software and its structural model. To establish an information channel from IFC-based architectural model to PKPM structural model, an information conversion platform is developed. A case study is provided at the end of the paper to illustrate how to use the platform for information conversion.

2 PKPM structural model

PKPM software is developed based on a platform that allows integrating and exchanging information among different modules which include architectural CAD, structural CAD, and HVAC (Heating, Ventilating and Air Conditioning) CAD, etc (China Academy of Building Research, 2009). The structural modeling of PKPM software is mainly implemented by PMCAD (Plane Modeling CAD). PMCAD has convenient and speedy functions for modeling, and it is the core of the structural part of PKPM Software. The objective of our software platform presented in this paper is to implement information conversion from IFC-based architectural model to PMCAD structural model of PKPM.

The PMCAD takes the standard floor of the general structures as its modeling foundation. Its basic assumptions include: (1) columns and walls are laid vertically and have the same height with the structural floor; (2) beams are laid horizontally within the height of the structural floor. Based on the above two assumptions, columns can be located by the nodes, walls and beams can be located by plane grid lines. These greatly simplify the data management of structural model and all the structural elements of the whole standard floor can be located by plane grid lines. In the modeling of PMCAD, the representation of structural elements can be divided into two steps, shape definition and whole localization.

2.1 Shape definition of elements

The elements of the structural model include beams, columns, inclined bracings, walls, and slabs, etc. The shape definition of an element in PMCAD is represented by its geometrical information of section. There are fifteen section types in PMCAD that include rectangle, I-shaped, U-cross, circularity, crisscross, box, etc., which basically cover the needed types for structural analysis and calculation. In PMCAD, the wall and slab are defined together which include the type parameters, thickness, material and so on. Holes also belong to slabs from the broad perspective, but because the position of the hole is defined as a whole conception within the wall or slab, it is equivalent to the block concept of AutoCAD. The section of the hole is defined by using its border points and is
described through a list, and the coordinates of these points are based on the local coordinates of the hole, which means that every hole has its reference location position, and the local coordinate system takes this reference position as the circle center to establish.

2.2 Whole localization of model

The description of the structural model in PMCAD is carried on by relative coordinates. PMCAD uses the unified coordinate system to create a model; it does not only give the origin of the coordinate, the XYZ direction vector, but it also provides a convenient transformation connection for the coordinate system. In PMCAD, the point is established in 3D, it namely contains XYZ coordinate; the localization of elements takes grid lines as reference, and is carried on by the element center and the eccentric centre of grid lines; the localization of wall and slab adopts the grid lines-enclosure as reference, each culmination is described by the relative eccentric center of grid lines nodes; the position of the hole in PMCAD is described by the basic point and rotation angle.

3 IFC spatial structure

The IFC spatial structure is provided by IfcProduct entity, and is defined by IfcSpatialStructureElement (Buildingsmart, 2009). The following four different concepts are subsumed under the IfcSpatialStructureElement entity: IfcProject, IfcSite, IfcBuilding, IfcBuildingStorey and IfcSpace. The four subtypes IfcSite, IfcBuilding, IfcBuildingstorey, IfcSpace are used to represent the levels of the spatial structure. Each concept has: a name (by IfcRoot.Name), a description (by IfcRoot Description), as well as a long name. The name attribute has to be used to store the name of the building, and building storey.

The above different subtypes are contained by each other; they provide a clear hierarchical structure for the building project. Figure 1 shows the spatial structure of a building project. In the spatial structure, the lower the level, the more detailed description of the information is required. The subtype IfcRelAggregates is used to link the instances of IfcProject, IfcSite, IfcBuilding, IfcBuildingstorey, IfcSpace (provided that all levels are applicable).

![Figure 1, Spatial structure of a building project.](image)

In Figure 1, the IfcProject, IfcBuilding and IfcBuildingStorey are mandatory levels for the exchange of complex project data, the IfcSite and IfcSpace represent optional levels (which may be
provided if they contain pertinent data). Each instance of IfcProject, IfcSite, IfcBuilding, IfcBuildingStorey, IfcSpace is connected to other instances of the spatial structure by an instance of IfcRelAggregates, where the single RelatingElement points to the element at the higher level and the 1 to many (1...n) RelatedElements point to the elements at the level of the hierarchy.

4 Information conversion platform

4.1 Objective and structure of platform

The direct objective of the information conversion platform is to automatically translate IFC format data to the compliant data for PKPM structural analysis software. Figure 2 provides a sketched map of the whole structure of the information conversion platform. The data object extracted from IFC project file must be mapped into the corresponding object of PKPM data structure because IFC data model does not keep one-to-one relationship with PKPM data structure. As a result, the data structure must be simplified or optimized according to the characteristics of each data model in the development process of the interface, such as the simplification of the semantic description of the data of IFC and PKPM, and intersection analysis and node optimization of structural elements.

Figure 2, Structure of the information conversion platform.

4.2 Techniques of information conversion from IFC to PKPM

PKPM software is mainly developed by mixed program languages such as Visual FORTRAN and Visual C++. Therefore, the program realization of software platform also adopts a mixed program language. The techniques of program implementation include: (1) Creating hundreds of classes (corresponding with the EXPRESS entities of IFC2×3) in the environment of Visual C++; (2) Writing “Add()” functions, transformation functions, “Construct()” functions and other functions for each class; and (3) Writing "main()" function on the environment of Visual FORTRAN, and creating the implementation function of the main program for the interface software. The role of “Add()” function is to read the entities of IFC project file into the computer memory, and parse the characters of IFC file data stream into provisional parameters which can be understood by the different classes. “Construct()” function can extract the address that corresponds to the object in the computer memory according to the index of provisional parameters, and then provides a value for each address respectively.
The general implementation process of the platform includes the following parts: (1) Read in IFC model. The role of this part is to translate IFC EXPRESS into a language understood by the program; (2) Getting IfcProject. This part acquires information about the project such as name, history, and engineering description and so on; (3) Getting IfcSite. The site information includes: name, longitude, dimensionality, height, address, etc; (4) Getting IfcBuilding and IfcBuildingStorey; (5) Getting IfcBuildingElement. In IFC model, building elements belong to IfcProduct. Therefore, the product information must be obtained firstly when getting the elements’ information. The building elements include: beam, wall, column, slab, door, window, roof, etc.; and (6) Getting IfcUnit.

4.3 Case study

The platform interface is shown in Figure 3. On the right side of the interface, there are vertical menus for converting data information between IFC architectural model and PKPM structural model. There are two important buttons in the conversion menus, “IFC=>PM” and “PM=>IFC”, which are used to extract information between IFC and PKPM. Currently, the functional button of “PM=>IFC” is still under development. Furthermore, other functional buttons such as “IFC tracing”, “IFC detail”, “display model”, “display floor”, etc. are also provided to display the detailed information of the transformed model in the platform. In order to test the implementation performance of the platform interface, a high-rise building is adopted as case study for the interface software. An architectural model of the case is generated by the software of IFC Engine Viewer provided by IFC standard.

Figure 3, Extracting structural model from IFC to PMCAD.

Figure 3 shows the structural model formed by the interface software from the architectural model of the high-rise building. First, designers open the IFC-format file of the high-rise building by clicking the button “IFC=>PM”, and then a structural model is generated automatically and displayed on the interface. The whole process of extraction requires not more than twenty seconds, and contains the basic information including geometrical information, material information, section information and connection attribute information of elements, which are needed for structural analysis of PMCAD. The interface allows the designers to modify and edit the structural model, and furthermore, they can have a closer look of the model by clicking on the zoom button that is found in the tool bar. The
structural model generated by the interface software can provide structural modeling groundwork for the PKPM structural analysis software. The case study shows that the software platform can successfully implement the basic elements’ information conversion from IFC to PKPM.

5 Conclusion

The research on IFC-based information conversion platform can help to facilitate the information exchange among participators in many building design companies. In this paper, a software platform that can automatically convert data information from IFC architectural model to PKPM structural model is developed by using mixed program language such as VC++ and FORTRAN. The scope of the information conversion includes geometrical information, material information, section information, and connection attribute information of elements. Together with the platform, the PKPM structural model and IFC data model are analyzed in this paper. A case study is provided to show how the information is converted from IFC to PKPM by use of the platform interface. The platform provides a basic tool for PKPM software to support IFC standard.

It must be pointed out that the information conversion platform is only our pilot study to facilitate the collaboration at the design phase. The load information and support conditions of structural elements that are important to the structural analysis have not been taken into account in our current platform. Future research will serve to improve the software platform and build a two-way channel for the information conversion between IFC and PKPM.

References


