Stride Ahead on the Way of Architectural Design and Construction Integration

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Abstract: The article deals with the essence and advantage of BIM technology in the optimization of a process of architectural design, features and prospects of IFC-universal object-oriented data format CAD industry. The above examples illustrate ways of cooperation of architects, engineers and other participants in the design and construction of buildings.

Key words: Design · BIM · Integration · IFC

INTRODUCTION

Modern architecture is moving towards free-form complex structures and perfected solutions. Recently, there are a lot of talks about the model approaching to the design that is about building information in modeling-BIM (Building Information Modeling), or, in other words, the virtual buildings.

During its existence, the development of CAD has been the most significant in the architectural design and construction (ADC) and for the last 30 years the programs of simple two-dimensional construction drawings turned into the application of integrated information modeling (BIM). Modern applications provide the integrated BIM solutions for architects and designers. Designed specifically for ADC industry, BIM programs provide real building elements, which are automatically associated with design data having abundance of visualization tools [1].

Analysis of Research and Publications: The basic principle of BIM is that architects can use the 3D-model of a building to extract from it all necessary project drawings and images of buildings, including sections, elevations, details and the element nodes, realistic pictures, presentation materials, as well as the results of calculation and evaluation (Fig. 1).
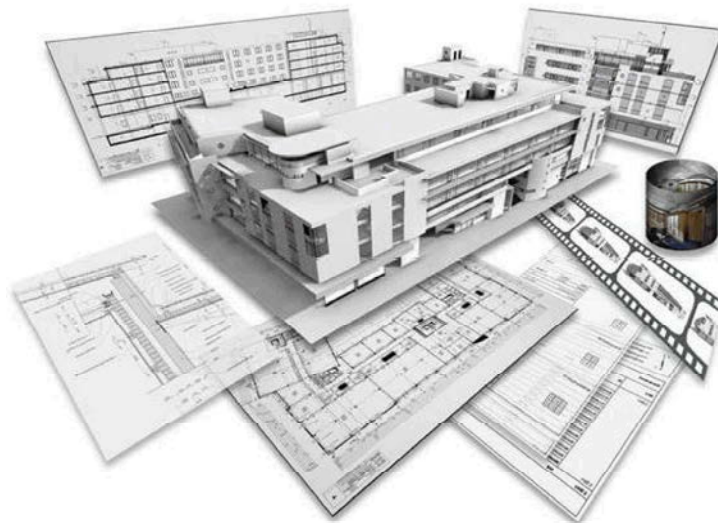

Fig. 1: BIM-virtual basis of architectural design

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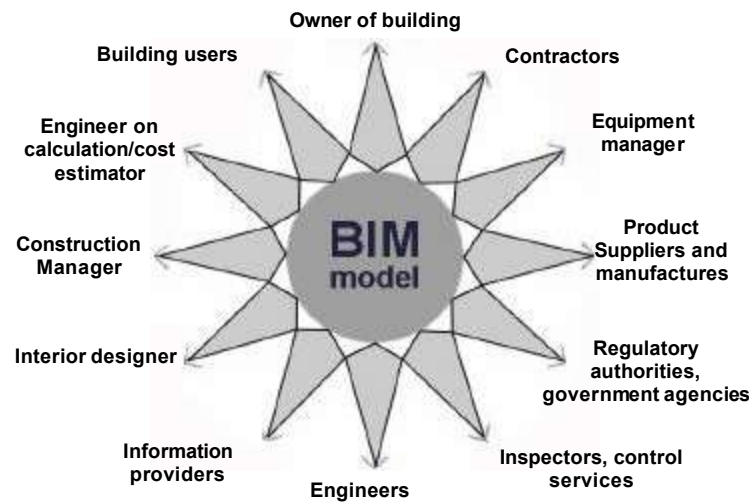
Fig. 2: Participants of collaboration of object design and construction

The most important aspects of the method of BIM include:

- the concept of a single file-the entire building model and all its additional submissions are contained in a single file of a virtual building;
- the use of real architectural elements in the simulation;
- changes made to the model, the impact on all the drawings (and vice versa);
- automated technological process of documentation creation;
- architectural content (libraries);
- attributed to elements an architectural design information about the building;
- generation of additional information (imaging, animation, making calculations, building directory).

CAD industry in construction has chosen to integrate the various disciplines. Cooperation has become the standard mechanism. Only the developed technologies of joint usage of share data may contribute to the maintenance of effective interaction, which is reduced to internal and external collaboration. Identification of its new and effective ways in optimization of the design process and its outcome-remains an urgent task.

BIM programs interact with other branch programs by the use of a variety of established and new types of file formats-DXF, DWG, PDF, DWF, Google Earth, XML, U3D.

To replace the file-sharing data on a bilateral level of lines, hatches, blocks of text, images, at best, inter-dimensional polygonal surfaces, comes universal industry standard, in which building elements retain the original BIM information and only improve in the lifetime of the project.

Shown in figure (Fig. 2) is a scheme which contains a list of major participants in erection of an object.

Architects play an important role in this team, for they are the only ones who all the time coordinate data on the current status of the project to all other participants. If architectural companies fail to adapt to this communication and the centralized world of cooperation, they will not be able to carry out large projects [2], [20].

IAI (International Alliance for Interoperability)-is an alliance of organizations aimed at improving productivity and efficiency in the construction industry and management. Governmental organizations, institutions and major software vendors (Autodesk, Graphisoft, Bentley, Nemetschek and others) are convinced in the need of a universal communications platform data and in the construction industry as well. Many software developers, which support the information data modeling (BIM), the design of buildings and structures, design of equipment for heating, ventilation and air conditioning systems, conducting thermal analysis, the calculations need of material and labour resources, are actively seeking the implementation of IFC support in their software products.

The main advantage of using the IFC (Industry Foundation Classes), developed by IAI, in comparison with other file formats, consists in the processing of BIM data information is stored. That is, all the structural elements of the volume models (constructers) retain its identity and purpose according to the classification of building elements with all its original properties and
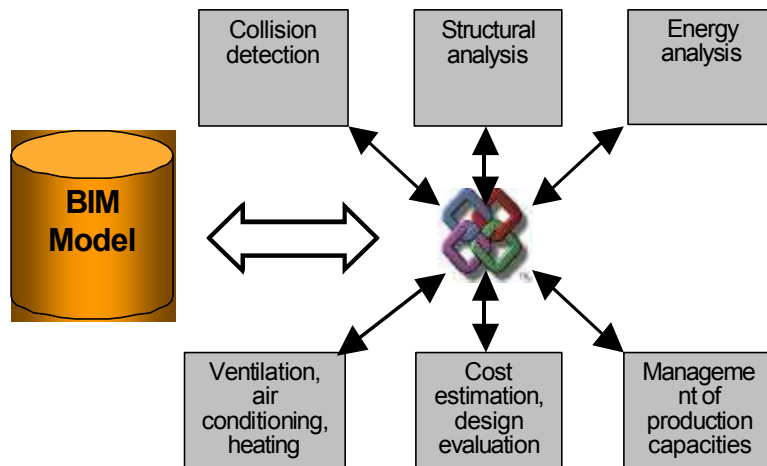
Fig. 3: IFC-modern format of cooperation in CAD

parameters, regardless of the software (medium) environment and performed operations. For example, walls or floors remain walls and ceilings and retain all previously described 2D-and 3D-information after an IFC-file is opened in another application.

- IFC-is a standard universal medium that provides information sharing and interoperability at all stages of constructing of a building.
- IFC-are elements of data that represent parts of buildings or elements of processes and contain relevant information about all of these parts.

IFC is used by programs to build a computer model that contains all the information about the parts of a building and their relationship in order to provide shared access to the model of all project participants.

Today IFC-is a neutral, transparent and object-oriented file format to ensure interoperability in the design and construction industry. It is registered with the International Standards Organization as ISO / PAS 16739. It has several varieties (IFC 2x3, ifcXML and others), also received the encoding ISO [2].

Summary of the Basic Material: BIM model, imported into the external analysis software, provides a wide range of possibilities for the implementation of analytic functions (Fig. 3).

Application of automated methods for coordination of construction for planning construction work offers significant advantages in the stages of modeling, estimating, ordering, procurement and construction management. BIM approach provides optimal shared

environment for both "internal" and "external" specialized applications (design, heating, ventilation, acoustics, electrical equipment, fire equipment, lifting equipment, energy analysis, cost estimation, etc).

For example, VICO Office Suite, based on 5D-model allows estimating the cost of various alternative design solutions. Individual model objects associated with the estimate methods, which describe the methods of their construction and use of resources. Extraction of all the necessary data on the elements of a model with built-in specifications reflects the financial expenditure.

BIM application and coordination of construction, together with tools to identify conflict situations, such as NavisWorks, provide an automatic detection of collisions between the structural components of the project, provides time and space coordination, thus improving the planning process at the construction site and progress made on its work.

Software systems LIRA Soft, SCAD Office, with support from the IFC data format, are a modern tools for numerical investigation of strength and stability of structures and their automated design. It is assumed in the calculation of dynamic and static exposure to modeling a wide variety of structures, systems of reinforced concrete and steel elements of buildings, buildings with brick walls, in accordance with the regulations of the CIS countries, Europe, Africa, Asia and the USA. In the course of the complexes, calculation of a building and its parts with the formation of working drawings and schemes of reinforcement structural elements is executed. In such a case BIM initially serves as the basis for the formation of a design scheme and the completion of the calculation as the medium for further editing.
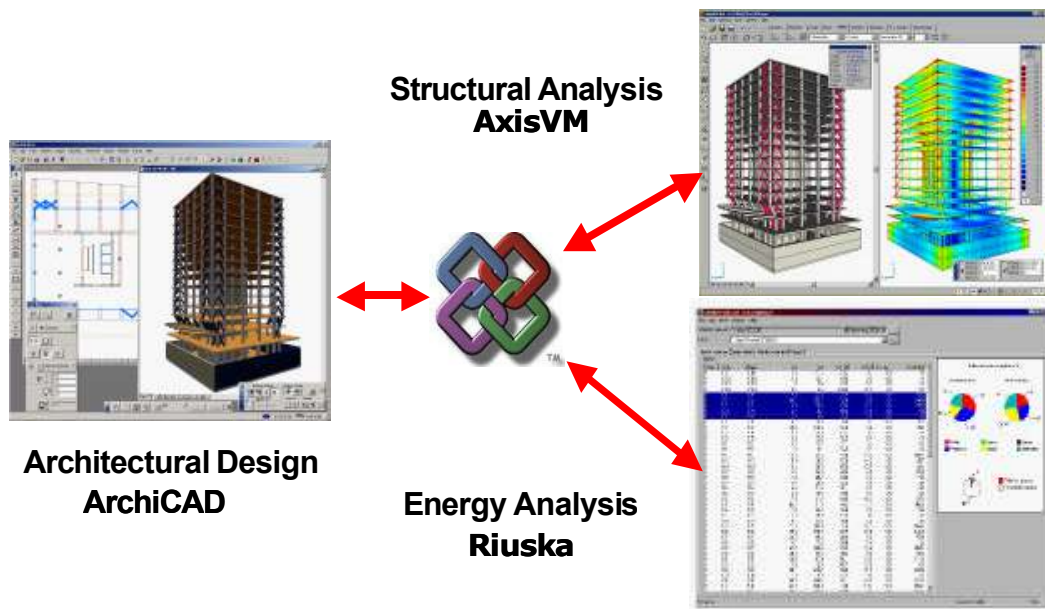
Fig. 4: An example of compatibility of 3D project environment

MagiCAD-is one of the leading CAD software packages for internal engineering systems, based on the support of a single digital model of a building and standard IFC 2x3. MagiCAD contains built-in calculations for selection of sections of pipes, ducts, balancing of a system, acoustic and hydraulic calculations, calculation of heat loss, trace of channels, etc.

Computer simulation of energy consumption within the frameworks in the development of "green projects" and harmonious design is used to estimate the possible energy-saving by the building at all stages of the design process.

Kirksey company has developed a method of a "green building" including the analysis of various performance indicators, which can be easily applied to any project. From the viewpoint of "green" characteristics it is assessed: planning areas, building orientation, landscaping and accounting of day lighting, water consumption and the view for tenants from the premises.

With the BIM model and compatibility with the IFC, serving as the main source of data, such leaders of the energy analysis programs, as Ecotect, EnergyPlus and RIUSKA, allow designers to work in 3D and contain all the necessary tools for creating energy efficient buildings that are shown in (Fig. 4):
- graphical analysis of energy consumption and storage;
- modeling the effects of shadow casting, lighting, acoustics, ventilation and other energy flows;
- results-are load calculations, energy analysis and the indirect effects of the environment.

These applications can be used for optimization of such systems as the consumption of solar thermal and light energy in the initial design stage.

On the same basis, with applications ArchiPHYSIK or Green Building Studio users of ArchiCAD (Allplan, Revit Architecture Suite, etc.) are able to evaluate and compare design alternatives based on the rapid assessment of the performance of the project:

- accurate analysis of operational energy performance of a building, taking into account its individual components and the entire space;
- complete thermal analysis, including the heat transfer coefficient, the diffusion of vapour and temperature amplitude;
- identify detect deviations compared with predetermined values.

All of this changes the essence of energy analysis with a formal procedure for this analysis at the end of the design process, when it is too late to change anything, to the highly effective tool, which supports architects in crucial moments of making the design decisions.

Considerable convenience of modern applications is the ability to quickly visualize and track all the changes in documents of the shared IFC models. In the course of a continuous improvement and additions to a common information model throughout the lifetime of the project, an important link becomes operational monitoring of changes. In particular, when comparing the versions of the models it become important to import only
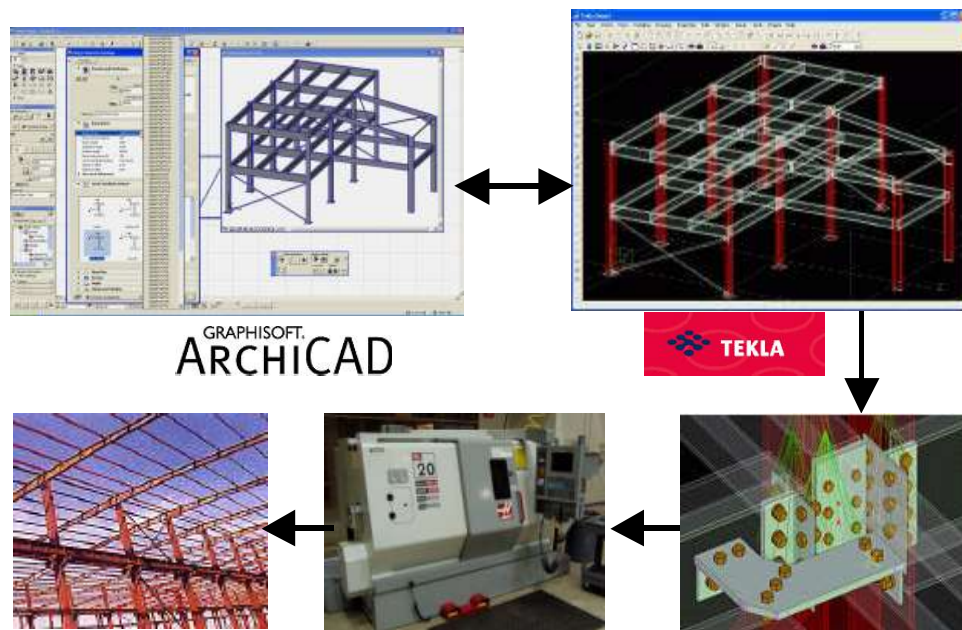
Fig. 5: Technological processes of metal structures production

the differences, reflecting recent changes in the project with the help of colour or other descriptions (such as red-remote, green-corrected, blue-the new elements).

It is difficult to maintain the desired level of freedom of design without the active use of CAD programs and computer-aided manufacturing. CNC machines are capable of producing the most complex building structures with great accuracy, which is achieved in projects using BIM / CAD applications.

Prefabrication of standard building structures requires the integration of design and production. The combination of BIM with CAM programs (computer-aided manufacturing) allows a smooth transition from design to production. Tight integration of BIM and CAM, as a rule, reduces to the technological process, reflecting the six steps of the transition from design to construction [1].

- With the help of BIM a 3D-model of a building is created that most closely approximated to the desired image and structure.
- 3D-data necessary structural components are exported to the CAM application using the format IFC.
- CAM program processes the information and sends it to the CNC machine in its own data format.
- CNC machine creates elements according to the adopted program code.
- Created elements are labelled, packaged and shipped to the site.

- Elements are combined in a design on a construction site in accordance with construction documents created with BIM applications.

As an illustrative example the three cases of the effective integration of BIM and CAM are shown.

BIM and CAM cooperation is a modern technological approach in the design, production and use in the construction of metal structures (Fig. 5). In this case, ArchiCAD finds joint participation in professional software design and analysis of steel structures Tekla; in this case IFC is used as an interface between them. In addition to the significant opportunities for the design and analysis of steel structures (calculation, specification design, cross sections, profiles, nodes), this program has a direct relationship with CNC machines for the production of steel profiles.

Another example reveals the possibility of joining BIM technology to the production of precast concrete products, integrated on the Allplan platform. At factories production mounted and bearing wall panels with the development of the required elements of the fittings, insulation, finishing, delivery and installation on site is launched. In this case, concurrency of different processes is reflected in the following way: the slab is divided into pre-fabricated elements; which are designed for strength and based on the results reinforcing products-mesh and rods are posted, then automatically drawings for the manufacture of prefabricated elements are generated, the received data are transmitted to the machine control

program with CNC welding robots in manufacturing of reinforcing mesh, fixings, controls of concrete pouring and exposure to a subsequent stacking.

Design of a full wooden frame of wooden houses and other items can be obtained directly from the BIM model, using standard ArchiCAD architectural tools.

All elements of the model are identified and data necessary for CNC machine tools, are extracted directly from the BIM with high accuracy and minimal errors. Special extension creates a file that is a source for industrial production. Wood working plants with CNC equipment, produce wooden bearing structures (beams, pillars and rafters), details of floors and roofs and filling of openings. Chance of automatic selection of material and cutting is possible. All of this can be controlled by the CAM program.

CONCLUSION

Thus, the developed BIM applications offer new tools for integrated data exchange, as well as their shared use by all persons involved in the project.

There is a clear trend-the ADC industry is moving from "file system medium" to" data medium ". Stored in the BIM model information could be presented in different file formats for external members of the project. IFC-is a promising universal medium that provides information sharing and interoperability at all lifetime stages of constructing of a building. It becomes logical the appearance of BIM 5D with inclusion of characteristics of time and cost to a model.

Still remains a topical series of problems. Including-full transition to BIM technology in the design of buildings and structures, training personnel to work with new programs, the creation of their projects, templates a n d documentation for new programs, the necessary library base. Expedient is the unification of BIM opportunities in approaching and adaptation of applications to the regional requirements of regulatory permits and features of the calculation base for the analysis of the environmental impact of buildings. A comprehensive introduction and spread of IFC industry universal data format, its improvement, the correctness of the mutual coupling (reading, editing) a single file by various applications will contribute to maintaining the successful coordination of the modern workflow.

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