The extraction and processing of BIM data

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Abstract. The concept of Smart city includes creating eco-friendly, safe, energy-saving and comfortable human environment. New principles of Smart city management are based on the processing of the information about its status and about functioning of its elements. One of the important elements of the environment are buildings. Modern state of construction engineering is characterized by the transition to BIM technology. Accordingly, the information about the building is represented as its information model. In Russia great attention is given to the research of the effective application of information models throughout the whole life cycle of the construction object. During the process of design, construction and operation of the building there is a need of extraction, analysis and transmission of the data that is stored in the information model. The same problem occurs during the operational management of life support systems of the building. In this paper there is a classification of methods for extracting and processing of the building information model data by means of software Revit. The methods of data processing on the basis of internal software instruments are described. The transmission of data to specialized programs, which allow to analyze the parameters of the building, is discussed. The experience of analyzing the building information model for solving various specialized problems is described. Special attention is paid for extracting and analyzing data by developing additional software modules. The method of writing a macro within Revit project by using a built-in C# code editor is presented. An example of a plugin to create the dll-library for Revit in Visual Studio environment is given. The opportunities of data processing with the help of software Dynamo are analyzed. The advantages and disadvantages of various approaches are discussed.

1. Introduction

The concept of Smart city includes creating eco-friendly, safe, energy-saving and comfortable human environment. New principles of Smart city management are based on the processing of the information about its status and about functioning of its elements. One of the important elements of the environment are buildings. [1, 2]. The widespread interest in Smart City is associated with the ability of producing various positive effects (economic, social, environmental).

Speaking about construction, Smart city is a complex of software and technical solutions and organizational measures aimed to increase the efficient use of all resources (electricity, water, gas, heat, time) and to create conditions for a comfortable stay in the city, living and doing business.

The concept of Smart city includes several areas of construction development. Sustainable urban planning should provide rational infrastructure of the city. It is also necessary to use "green" technologies, based on reduction of harmful emissions, the usage of the most innovative construction technologies and materials and the usage of renewable energy sources [3]. Smart buildings, based on building automation, are also important. This technology provides energy management, monitoring
and sensing of systems of automated data collection, device connectivity, security and other tasks. Thus, the purpose of the usage of all these technologies are environmental sustainability, economic viability, cost-effectiveness, security [4].

An important element of the concept are innovations based on information technology and data analysis. It requires the establishment of progressive IT infrastructure, technologies of monitoring, data collecting, processing and control, and integration of all information systems.

The current state of construction is characterized by the implementation of BIM technology [5]. Building information modeling (BIM) is a digital representation of characteristics of the object, which serves as a source of information about the facility, forming a reliable basis for decisions during the entire life cycle of construction objects. Accordingly, the information about the building is represented as its information model.

During the process of design and construction of the building, there is a need of extraction, analysis and transmission of BIM data. The same problem occurs during the process of operation and control of building life-support systems.

A tool for creating a model is BIM software. There is a number of software products of different vendors (Nemetschek, Autodesk, Tekla, Bently, Graphisoft, Lirasoft, etc.), implementing BIM technology. The formation of the building information model to all software is carried out according to similar algorithms, but each software has its own set of tools. BIM applications enable a visual and quantitative analysis of the parameters of the building [6].

The information model of construction object is based on the three-dimensional model of the building. A three-dimensional model of the building and its elements have not only geometric characteristics. It is possible to create the necessary non-geometric characteristics of any type and to establish relations between them [7]. From the point of view of storage, information model is a structured database, in which all elements have parameters (attributes) describing the geometric, technical, economic and other characteristics of the building required at different stages of its life cycle.

There is an opportunity to provide information in the graphical form and in the form of specifications. The values of the specification parameters can be calculated. However, none of the BIM software can provide solutions to all specialized tasks.

There are two main methods of obtaining additional functions of extraction and processing (analyzing) data [6]: in external software applications and inside the BIM application.

The information model parameters can be analyzed to calculate the strength valuation, to calculate the cost of resources, to provide project management of constructions, etc. This analysis often takes place after the export of the BIM data to specialized software.

If the BIM software and the specialized software are pre-configured for mutual data transmission, the direct transmission of data with a maximum retention of information and relationships is possible. Sometimes the reverse data transfer is also possible.

In other case, the transmission of data is organized on the basis of neutral formats for data transfer. Each BIM software has a set of transmission formats. Among them there are the transmission formats only for graphic information (e.g., dxf, dwg, SAT). There are also formats that convey a more complete set of information about the information model (e.g., RVT, PLA, IFC). Most BIM applications have the ability to upload data in a universal standard for BIM data (IFC) [8,9]. IFC allows to see the contents of the file in ASCII codes, but it has object-oriented structure and does not allow to easily find necessary object parameters. In addition, IFC is not designed for storing information about parameter dependencies between objects in the information model [10].

The data extraction and processing can be implemented with the help of a program-converter [11]. This program usually can be also used for additional data processing (sampling, sorting, systematization, analysis, adjustment, etc.). Data processing can be carried out in BIM software to transfer data in the program-converter, can be carried out during transmission of the data in the target application, after data transfer or in combination of these approaches.

The disadvantage of external data analysis of the building information model in specialized programs is usually the lack of postback data analysis in the information model.
Internal analysis is carried out by adding new functions to extract and process data of the building information model. The results of this analysis also remain inside of the building information model. For programming new functions of extracting and processing data of the information model it is possible to use the native capabilities of the BIM software, as well as the possibility to create macros, plugins and scripts based on the application program interface (API) (Figure 1).

![Figure 1. Methods and tools of BIM data processing](image)

The aim of this work is to use and to analyze methods of expanding the functional capabilities of a BIM application. The objects of research are methods for creating applications for internal data analysis.

2. Materials and methods

The study was carried out by the means of BIM software Autodesk Revit. The software package Autodesk Revit is widespread in the information modelling of buildings due to their functional diversity and the greatest implementation of the concept of BIM [12,13,14,15,16]. Revit software also supports the remote access to BIM data. Revit provides a number of tools for processing graphical and numerical data. There are tools for tabular view and data processing. Based on the known parameters of the model, the new settings can be created and calculated (generated). The information model created in Revit is stored in a closed data format (*.rvt).

The vendors provide the opportunity to manage the Revit model using the classes of Revit API by programming means. Revit API can be used to access the data graphical models (creating, changing and deleting of model elements), to gain access to the parameters of the model (reading and changing properties of model elements), to export model data to other formats, and more. Revit software has a built-in code editor SharpDevelop, which allows to create macros in the C#, Python, visual Basic.NET, Ruby. Macros can be application-level and document-level [17,18].

Revit uses .Net API, which means that any programming language, which uses the framework .Net (C #, VB.NET, F #and others), can be implemented to create plugins. To create a plugin the external programming environment, which supports the development of dll-libraries in .Net framework, such as Microsoft visual Studio, can be used [19].

Another way of extracting and processing of Revit data is Dynamo. Dynamo is a software platform with open source for managing the BIM model. Starting with the 2017 version, it is used in conjunction with Revit. Dynamo provides a visual programming tool. Instead of the complex code it is possible to use ready simple blocks, called nodes, that can be selected from the library and connected with each other according to certain rules. Nodes are written in Design Script language. For more complex user tasks, Dynamo allows writing text scripts (programs) by the means of Python and Design Script [20].
To develop additional functions the task of automated creation of a new BIM parameter was chosen. The value of the new parameter is based on calculations, on processing the values of other parameters and reference data. The solution of the problem is shown on the example of creating hardware specifications for the air ducts of the building (Figure 2).

![Figure 2. Different kinds of metal ducts](image)

Design rules of this specification are regulated by Russian State Standard (GOST). The specification must contain the required field “name and technical characteristic”. This field consists of the name of the element (duct), kind of the element (e.g. round cross section), material of the element (e.g. steel), thickness of the sheet (e.g. 5 mm), dimensions of cross section (d315).

Revit families for ducts do not contain the parameter "name and technical characteristic", therefore it is impossible to use it when creating specifications. However, the family of ducts contain settings such as the family name (stores the type of duct), the width and height or diameter, depending on the type of duct. On their basis it is possible to form part of the new parameter, such as “name”. Technical characteristics (thickness of steel sheet) is determined by reference and depend on the type of duct and its dimensions.

The aim is to create the algorithm of formation of a new option, universal for different types of ducts.

3. Results
The solution of the problem was carried out by four methods: by using the standard tools of Revit, by creating a macro, by creating a plugin, by writing Dynamo-scripts.

3.1. The standard tools of Revit
During the process of solving the problem by standard Revit methods, we used the operations of combining the values of several parameters, addition prefixes and suffixes, logical operations of selection based on the conditions. As the result we created two different algorithm for rectangular duct and round duct. That leads to the formation of two different specifications. We failed to include a calculated portion into the value of the new parameter. This part is carried out in a separate field of specification.

3.2. The macros in Revit
The macro was developed on the basis of the Revit API classes using built-in code editor in SharpDevelop C#. To solve the problem a document-level macro was created. Since the macro is saved inside the project, all users working with project can see this macro and use it (Figure 3).

This method solves the problem in its entirety.
3.3. Microsoft Visual Studio Plug-in
Revit SDK (Software Development Kit) was used as an additional tool for software development. The Revit SDK contains a great set of information concerning the Revit API. It is divided into three categories: documentation, examples and tools. In addition, the Revit SDK contains a customized template for Microsoft Visual Studio (Figure 4).
This method solved the problem in its entirety.

3.4. Visual programming in Dynamo
This problem did not manage to be solved only by means of visual programming and without creating new nodes. The family "duct" is a system one in Revit. An option "family name" is a built-in option (built-in parameter). But there is no standard node to read the embedded parameters, so it is necessary to write a new custom node in Python (Figure 5). Thus, the part of the program is made of nodes, and the part is written in Python. This method solved the problem in its entirety.
4. Discussion
We proposed several criteria to compare methods of creating the algorithm on the base of API: required software, initial settings, level of programming skills, results of code compilation, execution of programs, transportability, restrictions and problems.

| Table 1. Criterion to compare methods |
|--------------------------------------|
|                                       |
| Required software                     |
| Macros in Revit                       | Plugin in Visual Studio               | Dynamo-script                        |
| Software Autodesk Revit. The environment | Software Autodesk Revit. The environment Visual Studio. For convenience two additional applications from Revit SDK can be used: Autodesk Revit LookUp и Add-In Manager | Software Autodesk Revit. Dynamo is an open-source program. Since 2017 Dynamo is the part of Revit |
| SharpDevelop comes as Revit application. As addition, Autodesk Revit LookUp can be used to see information about individual items | | |
| Initial settings                      |
| Define the level of macros. Create module for grouping of macros. Do not required to create a manifest configuration file | Create Visual Studio project. Create links to Revit API projects. Create a manifest configuration file | Do not required |
| Level of programming skills           |
| C# (or Python, or Visual Basic.NET, or Ruby), Revit API classes | C# (or any other languages on .NET platform), Revit API classes | Do not required for visual programming. Python or Design Script for creating user nodes or scripts |
| Results of code                       |
| Macros inside Revit project           | dll-library                           | Code of script.                       |
**compilation**

**Execution of programs**
- From macros manager by Revit interface
- From tab “External” by Revit interface. It is also possible to create a special new button
- By Dynamo interface

**Transportability**
- Application-level macros can not be used in other projects. Document-level macros can be transferred to other projects with considerable restrictions
- By copying the manifest configuration file and dll-library. Can be used for any projects
- By coping *.dyn–file with the script

**Restrictions and problems**
- Increases the file size of Revit project. Transactions are required to be opened and closed within code
- Transactions are required to be opened and closed within code
- There are no ready nodes for all functions of Revit API. Transactions are not required while using nodes

5. Conclusions

BIM technologies are rapidly evolving. However, the software still can not cover the solution of all engineering problems. The use of IFC is a promising and universal method of data transfer. The format requires object-oriented data analysis technologies. The quality of information transmission through IFC is affected by the settings of the export options in BIM applications. Not all the properties of the model can be transferred via IFC.

The software that allows to add new features and tools for internal data analysis of BIM data has big advantages. The choice of the programming method with the goal of expanding the opportunities of BIM software often depends on the skills of the developer. Using the Revit API to develop external applications opens really wide opportunities for expansion of applications, convenience, speed and, as a consequence, productivity in Revit. The problem of analyzing the programming options in Revit is relevant, as the opportunity to assess all the advantages and disadvantages of each method before programming will allow to avoid various kinds of errors and to eliminate problems of porting.

The choice of programming method depends on the complexity of the task, its volume, frequency of usage, distribution among users, and the level of user programming skills. Macros are a good choice for solving local tasks. For creating add-ins that will be used repeatedly and not in the same project it is better to create a project in Visual Studio.

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