LIFE CYCLE MANAGEMENT OF CONSTRUCTION FACILITIES

УПРАВЛЕНИЕ ЖИЗНЕННЫМ ЦИКЛОМ ОБЪЕКТОВ СТРОИТЕЛЬСТВА

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Creating a Tool for Transforming Digital Requirements when Uploading Digital Information Models in IFC Format

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Abstract

Introduction. Modern computer-aided design (CAD) systems make use of digital information models (DIM) depending on the aims of a project. According to the Decree of the Government of the Russian Federation No. 614, Section 7, Subsection D, the use of information modeling technologies (IMT) does not always imply designing a DIM. However, making sure DIM attribute data are in compliance with a customer's requirements or those of expert evaluation remains time-consuming and prone to technical errors. The relevance of the study is due to the need automated DIM parameter matching based on the technical specification requirements, which would reduce time costs and improve the quality of uploading the model. The study looks into the problem of the lack of tools for automated parameter matching based on machine-readable requirements. The aim of the study is to develop an application providing programmatic comparison of CIM attribute data in compliance with the technical specification requirements.

Materials and Methods. The software solution is being developed for a range of CAD systems, such as Renga Professional, CADLib "Model and Archive", Autodesk Revit. The article examines methods for generating parameter matching files specifically for Renga Professional. Throughout the study the following software was used: Renga Professional, Visual Studio Code, BimVision. In order to develop the application and algorithms, the Python programming language was used with the following libraries: PyQt6, openpyxl, et_xmlfile.

Research Results. A software solution has been developed that enables one to automatically match the DIM attribute data with the specified ones based on machine-readable requirements. The application provides the conversion of machine-readable requirements into a machine-readable DIM attribute data mapping file. Testing has shown a reduction in the time required to create parameter matching files in comparison with manual file generation. The resulting tool has the flexibility of implementation allowing one to upload existing requirements, as well as create one's own and use them while uploading a model.

Discussion and Conclusion. From a practical standpoint the resulting application is highly significant for an investment and construction project, where, while designing a DIM in compliance with the current regulations, it is necessary to make use of an open standard for the data presentation format - Industry Foundation Classes (IFC). The application allows one to minimize routine operations while designing a DIM from a proprietary format into the IFC format. The research is promising as its future directions include expanding the functionality to be able to work with additional data formats and integration with other BIM platforms. The research results contribute to the development of methods for automated processing of DIM requirements.

Keywords: automated mapping, mapping, parameter matching, Python, machine-readable requirements, IFC, IDS

Создание инструмента для преобразования цифровых требований при выгрузке цифровых информационных моделей в формате IFC

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Аннотация

Введение. Современные системы автоматизированного проектирования (САПР) используют цифровые информационные модели (ЦИМ) в зависимости от задач проекта. Согласно Постановлению Правительства Российской Федерации № 614 ч. 7 п. Д. применение технологий информационного моделирования (ТИМ) не всегда подразумевает формирование ЦИМ. Однако процесс соответствия атрибутивных данных ЦИМ требованиям заказчика или экспертизы остается трудоемким и подверженным техническим ошибкам. Актуальность исследования обусловлена необходимостью автоматизации сопоставления параметров в ЦИМ с требованиями технического задания, что позволит сократить временные затраты и повысить качество выгрузки модели. Исследование затрагивает проблему отсутствия инструментов для автоматизированного сопоставления параметров на основе машиночитаемых требований. Цель работы — разработка приложения, обеспечивающего программное сопоставление атрибутивных данных ЦИМ согласно требований технического задания.

Материалы и методы. Программное решение разрабатывается для разнообразных САПР систем, таких как Renga Professional, CADLib «Модель и Архив», Autodesk Revit. В статье будут рассмотрены методы формирования файлов сопоставления параметров именно для Renga Professional. В процессе выполнения работы было использовано следующее программное обеспечение (ПО): Renga Professional, Visual Studio Code, BimVision. Для разработки приложения и алгоритмов применялся язык программирования Python со следующими библиотеками: PyQt6, openpyxl, et_xmlfile.

Результаты исследования. Разработано программное решение, позволяющее автоматически сопоставлять атрибутивные данные ЦИМ с заданными на основе машиночитаемых требований. Приложение обеспечивает преобразование машиночитаемых требований в машиночитаемый файл сопоставления атрибутивных данных ЦИМ. Тестирование показало сокращение времени создания файлов сопоставления параметров по сравнению с ручным формированием файлов. Разработанный инструмент обладает гибкостью внедрения и позволяет как загрузить существующие требования, так и создать собственные и использовать их при выгрузке модели.

Обсуждение и заключение. Реализованное приложение обладает высокой практической значимостью для инвестиционно-строительного проекта, где при формировании ЦИМ в соответствии с действующими нормативными актами необходимо использовать открытый стандарт для формата представления данных — Industry Foundation Classes (IFC). Приложение позволяет минимизировать рутинные операции при формировании ЦИМ из проприетарного формата в формат IFC. Перспективы исследования включают расширение функционала для работы с дополнительными форматами данных и интеграцию с другими BIM-платформами. Результаты работы вносят вклад в развитие методов автоматизированной обработки требований к ЦИМ.

Ключевые слова: автоматизированное сопоставление, мапирование, сопоставление параметров, Python, машиночитаемые требования, IFC, IDS

Introduction. Modern computer-aided design systems (CAD) [1] have a key role to play in designing and maintaining a digital information model (DIM) [2] at the stages of the life cycle of a construction object [3]. The development of a range of automation and optimization methods helps to reduce the time spent on routine operations, improve the quality of a project and mitigate the human error factor. The relevance of the research is due to the growing complexity of projects calling for a high implementation quality, as well as the need for all DIM components to be in compliance with the regulatory standards, technical specifications and expert evaluation requirements.

The scientific obstacle lies in the lack of automated parameter matching solutions in DIM in the process of unloading. A range of CAD systems, such as Autodesk Revit, Renga Professional, Model Studio "Building Solutions", etc., only

provide methods for manually configuring parameter matching rules, which impacts time and thereby financial costs. In CAD systems produced by CSoft, there are simplified methods for matching parameters based on a table of all existing model attribute parameters, but the necessary ones have yet to be selected manually. There are no ready-made solutions available for automating the conversion of machine-readable requirements into machine-readable files for matching attribute data in DIM.

The aim of the study is to create a ready-made product for parameter automation based on machine-readable requirements provided by the customer or expert evaluation in the technical specification. To this end, the following problems are to be solved:

1. Analysis of the structure of machine-readable DIM requirements.

2. Development of algorithms for data collection from machine-readable requirements.

3. Development of algorithms for generating parameter matching files for diverse CAD systems.

4. Testing algorithms for the correctness of data collection and file generation.

The novelty of the research lies in creating algorithms for processing machine-readable requirements for DIM followed by formation of attribute data matching files based on the collected information for both domestic and foreign software in a single software solution.

Materials and Methods. The object of the study was digital information models formed at the stage of the life cycle of a building "Design" (Table 1) in compliance with Decree of the Government of the Russian Federation of 05/17/2024 No. 614 Section 7 Subsection d [4]. The following software solutions were used:

1. BimVision is a software package for viewing uploaded DIM in IFC format.

2. Renga Professional is a national BIM system for integrated building design and DIM upload into IFC.

3. Visual Studio Code is a development environment where the program code was written and the algorithms were debugged.

Table 1

Practical significance of the tool being developed in the life cycle of an object

Phases	PRE-INVESTMENT			INVESTMENT					POST-INVESTMENT	
STAGES	PRODUCT DESIGN	PREPARING THE LEGAL PAPERWORK	INVESTMENT	ENGINEERING EXPLORATION	DESIGN	TENDER	CONSTRUCTION AND ASSEMBLY	OBJECT COMMISSIONING	OPERATION	DEMOLITION
STAGES	Designing technical and economical indicators; Project budgeting	Legal paperwork; Technical conditions	Concept project design; Budgeting; Project work budgeting	Conducting engineering exploration	Designing project paperwork; Project work expert evaluation	Detailing project solutions; Detailing estimated project costs; Designing target power spots	Starting construction and assembly; Performing construction and assembly; Funding construction and assembly	Object commissioning; Funding construction and assembly; Paperwork termination	Operation	Operation

Python was chosen as the programming language due to its flexibility to various tasks and support of a wide range of libraries. The main libraries used in the project are

1. PyQt6 is a library for creating a graphical user interface (GUI).

2. Openpyxl is a tool for working with Excel files.

3. Et_xmlfile is a tool for working with XML data.

The application was developed based on modern programming paradigms [5]. The entire program code is based on the object-oriented programming (OOP) approach [6] (Fig. 2) allowing one to structure the code in the form of classes based on their methods and data processing logic. An event-oriented model [7], characteristic of the PyQt6 library, was used for the implementation of the graphical interface (Fig. 3). This enabled user actions to be associated with the corresponding class methods by means of the mechanism of signals and slots.
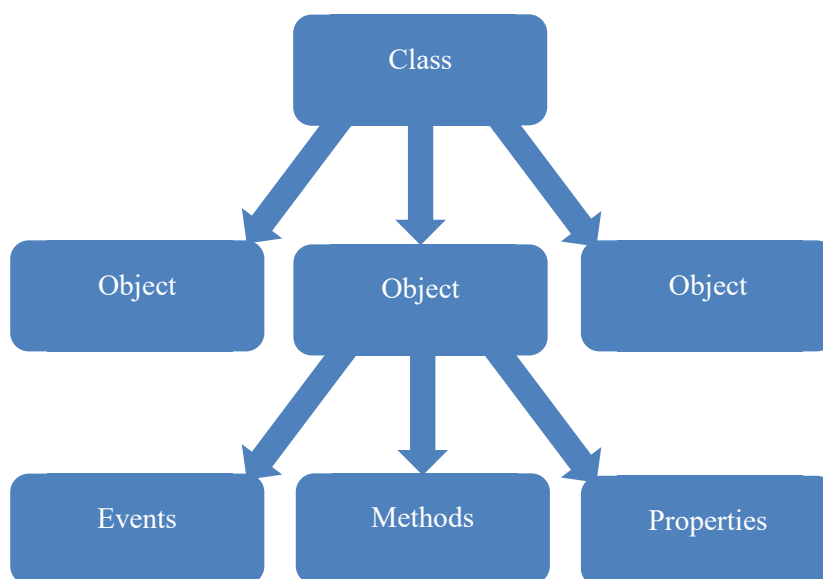
Fig. 2. OOP scheme
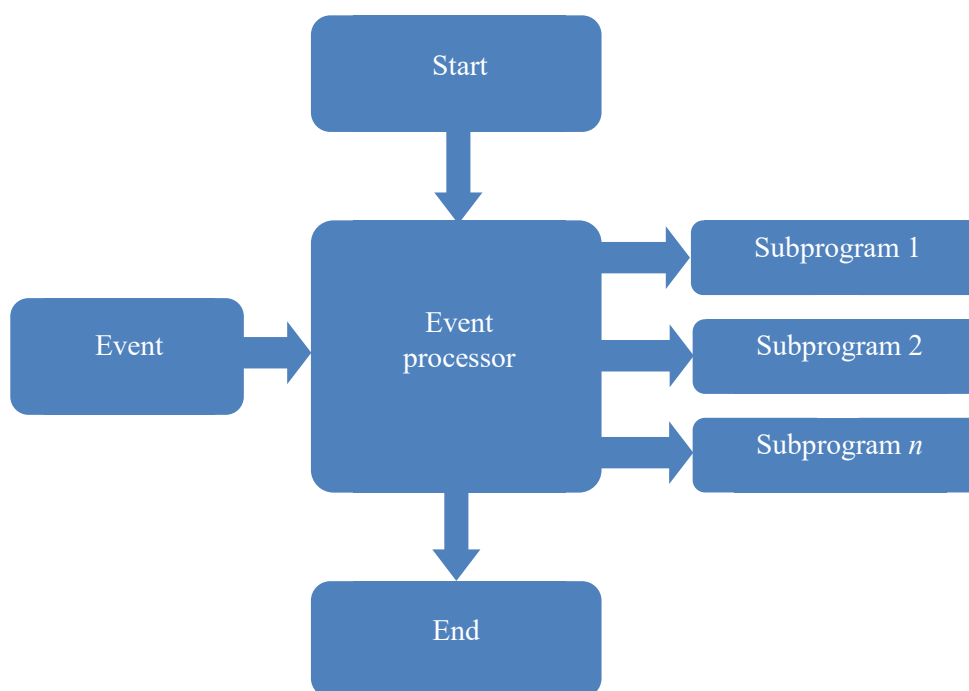
Fig. 3. Event-driven model scheme

The main research material is the machine-readable format of the requirements for filling attributive data, the CIM IDS file. Using data processing and sampling algorithms, it is from the IDS file that all the necessary information about the requirements for the digital information model is extracted. Later, using algorithms, a parameter matching file is generated based on the IDS file samples.

Life cycle management of construction facilities

Research Results. This research enabled us to develop a software solution for the problem of automating the comparison of parameters of digital information models in compliance with the machine-readable requirements of the technical specification. In the process of analyzing the life cycle of the building and considering the stage when the digital information model is formed, a wide range of errors were identified while checking the DIM against the expert evaluation requirements. One of the most common errors is incorrect matching of the DIM parameters in a proprietary format while uploading a model into the international Industry Foundation Classes (IFC) format [8]. IFC is a standard developed by buildingSMART International designed for information exchange among construction participants. The IFC model is a collection of a geometric model in a proprietary format and the attribute data of this model (Fig. 4).
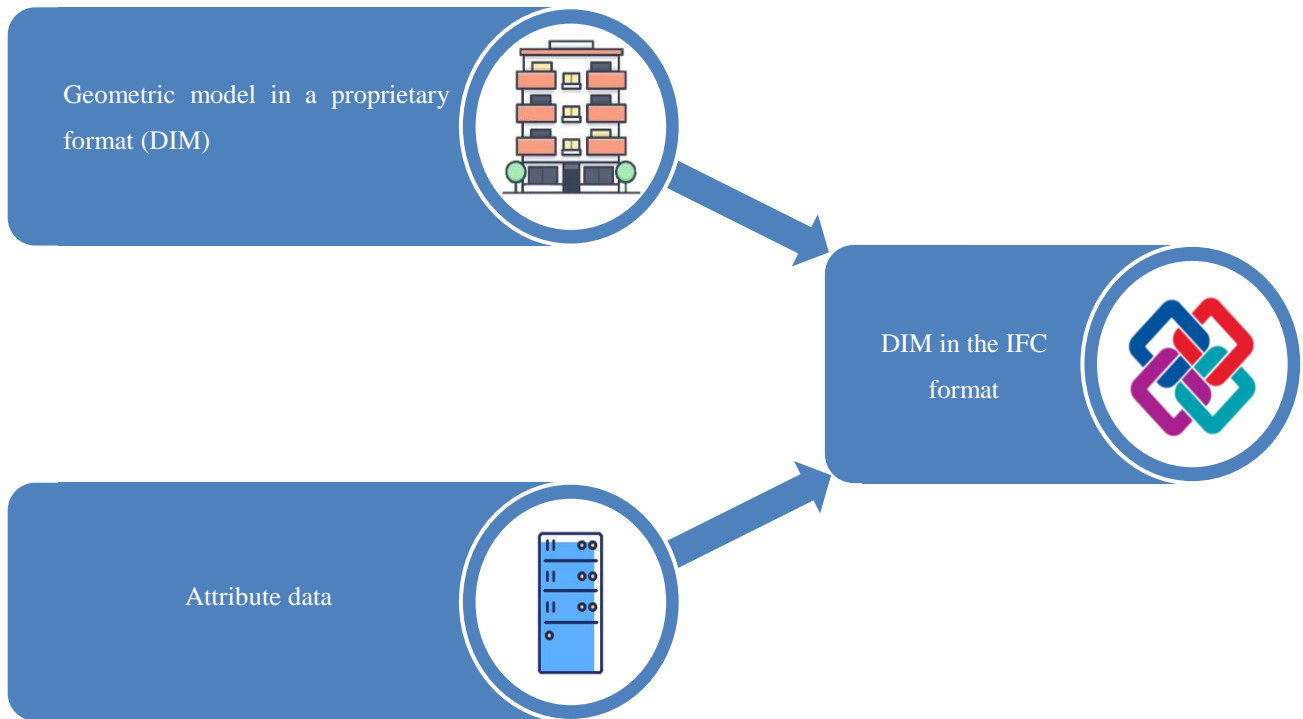
Fig. 4. IFC-model design scheme

While investigating the models that failed the examination by means of BimVision, it was found that the main error made while exporting the model to the IFC format was incorrect attribute data names in the parameter matching file caused by the human factor. The solution is to create a software product that allows one to automate and eliminate the human factor of making mistakes in writing the parameter matching file.

Before writing the basic algorithm for generating the parameter matching file, it is essential to decide where all the necessary data will be extracted from. At the moment, there is already an international data transmission format in a machine-readable representation in the form of XML markup, where all the necessary requirements are stored. This is the Information Delivery Specification (IDS) [9] — a standard from buildingSMART International that automates the formation of requirements for model exchange. By studying the structure of the IDS file, it can be clearly identified where in the file all the necessary data is located (Fig. 5). Each aspect of the attribute parameter group (IFC class, attribute data group name, and attribute data name) is located under its own tag in the IDS file. Having written algorithms and using the existing library for working with XML markup (et_xmlfile), all the necessary information is automatically searched for in the file by tags and create a "dictionary". The "dictionary" acts as a repository for all the parameters of machine-readable requirements.

```xml
<?xml version="1.0" encoding="utf-8"?>
<ids xmlns:xs="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:sch
  <info>
    <title>Требования к элементам ЦИМ (Архитектурные решения)</title>
    <copyright>Отдел ТИМ, СПб ГАУ "ЦГЭ"</copyright>
    <version>3.1</version>
    <description>ЦГЭ.ЦИМ.3.0 Часть 3. АРХИТЕКТУРНЫЕ РЕШЕНИЯ</description>
    <author>bim@spbexp.ru</author>
    <date>2024-12-09</date>
    <purpose>Проверка атрибутивного состава, по требованиям СПб ГАУ "ЦГЭ"</purpose>
    <milestone>Проектирование</milestone>
  </info>
  <specifications>
    <specification name="Таблица 3.А.3 – Имена атрибутов для элемента «Стена» (IfcWall)" ifcVersion="IFC4" ide
      <applicability minOccurs="1" maxOccurs="unbounded">
        <entity>
          <name>
            <xs:restriction base="xs:string">
              <xs:enumeration value="IFCWALL" />
              <xs:enumeration value="IFCWALLTYPE" />
              <xs:enumeration value="IFCWALLSTANDARDCASE" />
              <xs:enumeration value="IFCWALLELEMENTEDCASE" />
            </xs:restriction>
          </name>
          <predefinedType>···
          </predefinedType>
        </entity>
      </applicability>
      <requirements>
        <property cardinality="required" instructions="Указывается номер корпуса, в котором находится элемент.
          <propertySet>
            <simpleValue>Местоположение</simpleValue>
          </propertySet>
          <baseName>
            <simpleValue>Номер корпуса</simpleValue>
          </baseName>
        </property>
        <property cardinality="required" instructions="Указывается номер секции, в которой находится элемент.
          <propertySet>
            <simpleValue>Местоположение</simpleValue>
          </propertySet>
          <baseName>
            <simpleValue>Номер секции</simpleValue>
          </baseName>
        </property>
```

Fig. 5. Machine-readable format of the expert evaluation requirements

Further development includes the formation of a parameter matching file. In order to create it, it is essential to investigate the structure of the standard parameter file provided by the CAD documentation. In our case, the standard attribute mapping file for Renga Professional will be considered [10]. It is an XML-marked file that stores basic information about the file itself (file name, creator, version, file type) and all the necessary information for parameter matching and exporting DIM to IFC (Fig. 6*a*).

There are 3 ways to generate parameter matching files:
1. Forming a file based on the names of the properties.
2. Forming a file based on the GUID numbers of the properties.
3. Generating a file using the Renga API.

Next, the algorithm for forming a file based on property names will be considered. This method is the most effective one as there is no need to interact with Renga Professional project files, and it also ensures the user that their data will not be used without them knowing.

The attribute data mapping file itself has the JSON format, which is an advantage as the standard Python libraries already know how to work with this file format. The program algorithms structure all the data based on the previously created "dictionary", and the program outputs a ready-made attribute data mapping file in a necessary extension (Fig. 6*b*).

a)   *b)*

Fig. 6. File for mapping export parameters to IFC for Renga Professional:
a — standard mapping file; *b* — matching file based on the expert evaluation requirements

The final stage of the development of a ready—made solution is the creation of a clear and simple graphical user interface (GUI). All the necessary buttons have been added to upload the IDS file and create a parameter mapping file for Renga Professional.

Discussion and Conclusion. The aim of the study has been achieved by creating algorithms for processing and analyzing IDS files and generating structured parameter matching files for exporting CIM to the IFC format.

The developed application eliminates the manual generation of attribute data matching files minimizing the risk of errors related to the human factor, as well as reduces the time for the CIM export operation to IFC.

Testing on a variety of different machine-readable requirements in the IDS format and also templates provided by the IDS format developers dispalyed correct operation of data extraction algorithms and generation of parameter matching files.

The software solution involves further development with other CAD systems. The generated parameter matching files for Autodesk Revit and CADLib "Model and Archive" are being actively tested.

Collecting data from human-readable formats (PDF, xlsx) using artificial intelligence (AI) is one of the pillars of software solution development.

The study contributes to developing methods for automating BIM processes indicating the efficiency of developing solutions for automating routine tasks. The software solution can already be employed as a ready-made solution for a limited number of CAD systems.

In conclusion, the developed tool makes it possible to improve the quality of DIM formation. There will be focus on the flexibility of the software solution for a wide range of CAD systems and the integration of AI to work with diverse formats of human-readable requirements.

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YE Chmir: scientific supervision, revision of the manuscript, correction of the conclusions.

AV Shilo: development of the idea, project supervision, revision of the manuscript.

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