# RuleML-based mechanism of building information models verification

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**Abstract.** The issues of automated verification of design results based on information models have been raised recently by scientists and specialists from different countries, including the Russian Federation. Interoperability of expertise based on information models of objects should be provided using open formats for the presentation and exchange of the data. Each software that performs the functions of information modeling, as a rule, stores the results of the work in files of its proprietary format. IFC allows exchanging information about the geometry, attributes and relationships between the elements of information models of capital construction, that is, provides the transfer of all types of information stored by the information model. The MVD (Model View Definition) format is used to specify the subset of data volume that is used to solve a particular problem. RuleML is a system of families of modeling languages web of rules designed for the purpose of uniform presentation and exchange of the main types of web rules and logic between different platforms. BCF (BIM Collaboration Format) is an open standard maintained and distributed by buildingSMART that allows for various information modeling applications sharing information about issues related to IFC models that were previously shared by project participants.

## 1 Introduction

The issues of automated verification of design results based on information models have been raised recently by scientists and specialists from different countries, including the Russian Federation. The most urgent need to develop appropriate approaches at the country level became after the publication in July 2018 of the Government of the Russian Federation instructions aimed at ensuring the modernization of the construction industry and improving the quality of construction until July 2019 [1]. The key requirements of this order were to ensure the transition to the life cycle management system of capital construction projects through the introduction of information modeling technologies, the development of appropriate information modeling standards, training of specialists in this field. In July 2019, the town-planning Code of the Russian Federation [2] was amended, which established an information model as a form of design documentation when submitting documents for examination.

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These and other factors require the development and adoption of appropriate approaches to automate the examination process using information models. Now, a number of methods and corresponding software tools have been developed, but they are localized for a specific country [3, 4]. This complicates their adaptation for the Russian Federation. At the same time, more and more projects are carried out with the involvement of specialists from different countries, and therefore the formation of a variety of approaches, including at the level of verification of information models, prevents interoperability, which is known to be formed at three levels: technical, semantic and organizational.

The aim of this study was to develop an approach to the verification of information models of construction facilities, based on the available open standards to ensure technical interoperability.

## 2 Materials and methods

Interoperability of expertise based on information models of objects should be provided using open formats for the presentation and exchange of the following data:

- information model data;
- machine-readable rules;
- results of information model verification.

This study proposes the use of a number of open standards developed and supported by the buildingSMART Alliance, which is common practice. However, at the level of this organization has not yet fixed the appropriate standard for the presentation of requirements for information models in machine-readable format. In his earlier research [5], the author proposes and justifies the use of the rule ML modeling language for these purposes. A brief description of each of the standards used will be given below.

### 2.1 Format of presentation of information models data

Each software that performs the functions of information modeling, as a rule, stores the results of the work in files of its proprietary format. In order to provide machine-readable information on the construction and operation of buildings and structures, as well as for the exchange of construction data, an open standard IFC (Industry Foundation Classes, industry base classes) has been developed, which is currently maintained and updated by buildingSMART. IFC allows exchanging information about the geometry, attributes and relationships between the elements of information models of capital construction, that is, provides the transfer of all types of information stored by the information model. [6, 7]

The IFC 4 standard with Appendix 2 and amendment 1, developed by buildingSMART, is fixed in ISO 16739-1: 2018 "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries-Part 1: Data scheme" and its Russian counterpart GOST R 10.0.02-2019 / ISO 16739-1: 2018 "System of standards for information modeling of buildings and structures. Industry base classes (IFC) for the exchange and management of data on construction sites. Part 1. Data scheme» [8, 9]

### 2.2 Format of representation of subsets of information models

Experts involved in the project (architects, structural engineers, building systems engineers, facility managers, and so on) have different responsibilities, experience, and needs in creating and using data about capital construction projects. However, they must share this information among other members of the project team to perform various tasks. The MVD (Model View Definition) format is used to specify the subset of data volume that is used to

solve a particular problem. MVD can cover almost the entire scheme (for example, to archive a project), or be more specific as a pair of object types and related data (for example, to determine the price of a curtain wall system). [7]

The MVD standard is also supported by buildingSMART and is referred to in ISO 16739-1: 2018 "Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries - Part 1: Data scheme" and its Russian counterpart GOST R 10.0.02-2019/ISO 16739-1:2018 "building information modeling standards System. Industry base classes (IFC) for the exchange and management of data on construction sites. Part 1. Data scheme» [8, 9].

### 2.3 Format of representation of machine-readable rules

RuleML is a system of families of modeling languages web of rules designed for the purpose of uniform presentation and exchange of the main types of web rules and logic between different platforms. [12]

RuleML covers a wide range of rules, including declarative and imperative rules, which are implemented in the Deliberation RuleML and Reaction RuleML families respectively, and the Consumer RuleML family represents their integration. [13] Figure 1 shows the structure of the RuleML language.

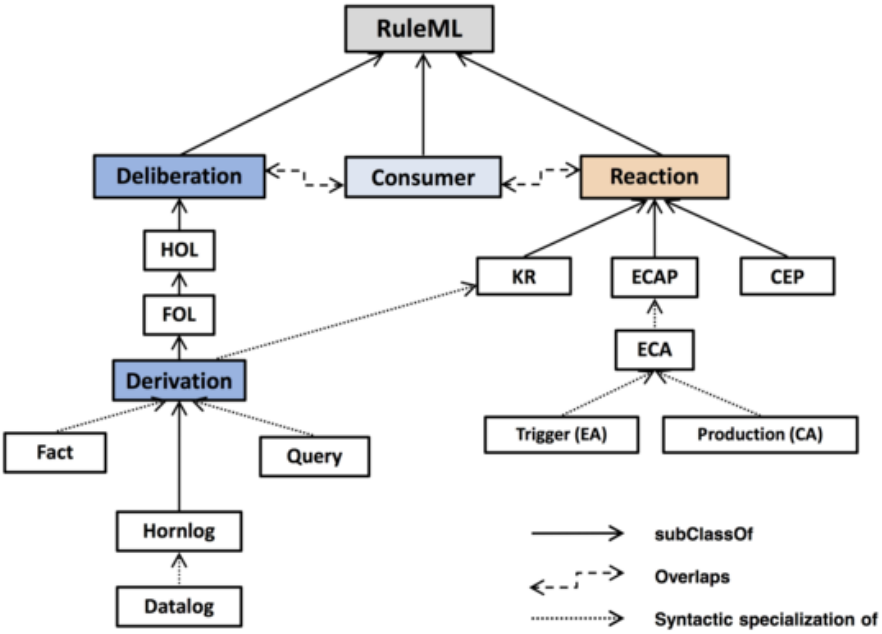


**Fig. 1.** Structure of RuleML [13]

Since the provisions of building regulations, in fact, represent a description of what should be a building or structure, the meaning they are closer to the group of declarative rules. That is why the family of Deliberation RuleML will be considered in this study. This family is based on the logic of the highest order, which, in turn, is based on the logic of the first order. For further reasoning, we find some equivalents for the elements of Deliberation RuleML in terms of first order logic. Special constructs are used to identify elements within the rule base that separate their contents from the rest of the text by using the appropriate start and end tags of the statement.

**Table 1.** Correlation between elements of "Deliberation RuleML" and terms of the first order logic

| | |
|---|---|
| <Assert>-</Assert> | Tags for positive expressions. |
| <Atom>-</Atom> | Tags for atomic formulas of expression |
| <Rel>-</Rel> | Tags for predicates of atomic formulas |
| <Ind>-</Ind> | Tags for subject constants |
| <Var>-</Var> | Tags for subject variables |
| <And>-</And> | Tags for conjunction (binary logical multiplication) |
| <Or>-</Or> | Tags for disjunction (binary logical addition) |
| <Neg>-</Neg> | Tags for logical negation |
| <Implies>-</ Implies> | Tags for implication, which include prerequisite <if>-</if> and conclusion <then>-</then>. |
| <Forall>-</Forall> | Tags for universal quantifier |
| <Exsist>-</ Exsist> | Tags for the quantifier of existence |

### 2.4 Format of submission of comments on the results of the audit

BCF (BIM Collaboration Format) is an open standard maintained and distributed by buildingSMART that allows for various information modeling applications sharing information about issues related to IFC models that were previously shared by project participants. [7]

BCF works by passing data from one application to another in XML format, which are contextualized problem information directly referencing the PNG representation, IFC coordinates, and BIM elements via the IFC GUID. [7]

There are two different ways to use BCF – through file sharing or through a web service. The file-based sharing process is relatively simple and familiar to most users. Bcfzip-file is passed from user to user, edited, and returned. As an alternative to the file workflow, there is a RESTful web service-based API mode for BCF. In this case, the exchange of information takes place through a BCF server, which can be simultaneously an information modeling server that stores all BCF data and allows project participants to synchronize the creation, editing and management of BCF files in one centralized location. [7].

## 3 Results

The method of verification of information models of construction objects is based on the open standards described above, and consists of the following stages:

1. Formation of verification rules based on the rules modeling language.
2. Formation of requirements for filling the information model.
3. Obtaining requirements for the content of the information model.
4. Prepare an object model that provides the necessary information for validation.
5. Preliminary verification of the model for completeness for the main stage of verification.
6. Formation of lists of model validation rules depending on the type of object to be verified.
7. Implementation of the rules, that is, directly verification.
8. Creation of a report on the results of verification of the information model.

This technique has the following distinctive features:

− simplicity of rules formation for the subject specialist, ease of making changes to the rules, cross-platform, their connection with the source text of the normative document, the ability to describe an unlimited range of requirements, including unlimited nested conditions;

- possibility of automatic extraction of requirements to availability of elements and attributes of information models, and completeness of the last at the expense of the received form of representation of rules for the subsequent organization of preliminary check on completeness of model;
- ability to perform the necessary and sufficient amount of checks for a particular object due to the presence of the stage of formation of lists of rules;
- use of open standards (IFC, RuleML, MVD and BCF).

The key feature of this technique is the algorithm of formation of rules for checking information models of construction objects, which is its basis. This algorithm is based on the rule ML modeling language and includes three stages, shown in figure 2.

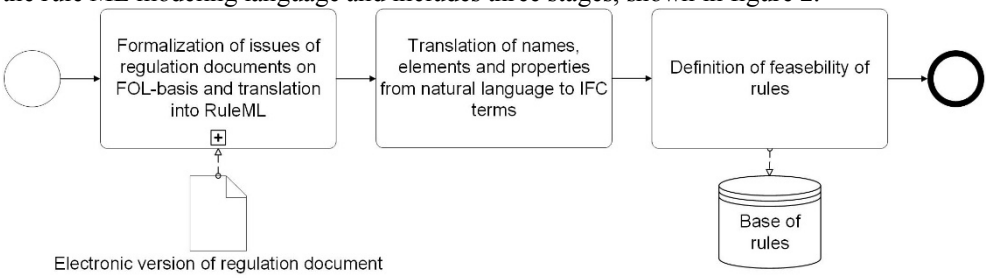


**Fig. 2.** Algorithm of formation of rules of verification of information models of construction objects based on language of modeling of rules

The first stage of the algorithm contains several sub-steps, that are shown in figure 3.

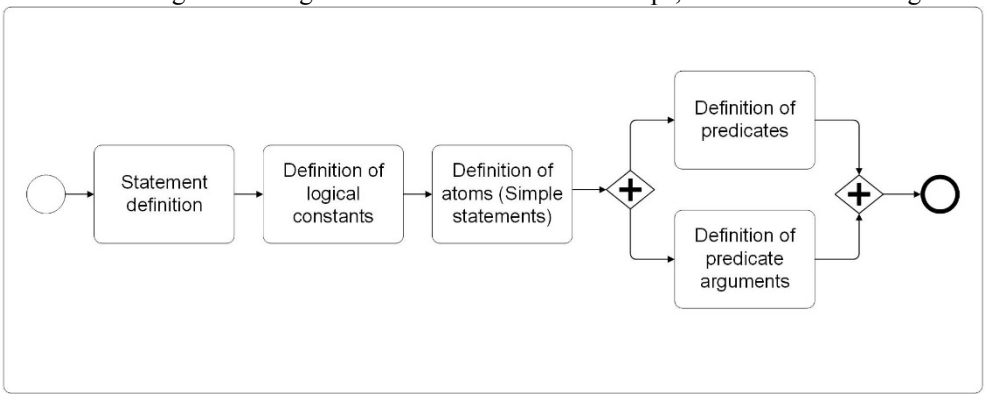


**Fig. 3.** Detailing of the first stage of the algorithm of rules formation verification of information models of construction objects on the basis of the rules modeling language

A detailed description of this algorithm and methodology is given in the author's study [12].

## 5 Conclusions

The article offers the method of verification of information models of construction objects on the basis of language of modeling of rules. In addition, this methodology is based on other currently approved open international standards, namely: IFC, MVD and BCF. The developed method is a unified approach both to the organization of examination of project documentation and to internal checks of information models within the project organization. The algorithm underlying this technique allows you to perform an effective translation into machine-readable format of any requirements, and in particular the

requirements of regulatory documentation. In further articles, the author plans to describe the practical application and implementation of this algorithm and methodology.

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