Artículo de investigación

Metamodelling in the information field

Метамоделирование в информационном поле

Recibido: 19 de agosto del 2019 Aceptado: 16 de octubre de 2019

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Abstract

The article studies metamodelling in the information field. Specifics of metamodelling are described. Three basic interpretations of metamodelling are shown. The features of metamodelling in information technologies and information field are presented. A functional difference between the information space and the information field is specified. The article studies metarelations in the information field. Three information situations characterizing metarelations are considered: sequence, transformation, and generalization. The differences in metarelations between an object and a metamodel and between a model and a metamodel are described. The article shows the relation scheme in the system "object – model – metamodel". The scheme of metatheory formation is presented. The principles of metamodelling in the information field are revealed. The article proves that a metamodel in

Аннотация

Статья исследует метамоделирование в информационном поле. Раскрывается специфика метамоделирования. Показаны три основные интерпретации метамоделирования. Показана особенность метамоделирования в области информационных технологий и информационного поля. Отмечено функциональное различие между информационным пространством и информационным полем. Статья исследует мета отношения в информационном поле. Рассмотрены три информационные ситуации, характеризующие мета отношения: ситуация следования, ситуация трансформации, ситуация обобщения. Показано различие отношений мета отношений между объектом и мета моделью и между моделью и мета моделью. Статья раскрывает схему отношений в системе «Объект – модель -

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the information field is a model of information construction. A new concept of information metamodelling is introduced.

Key Words: Modelling, information field, model, metamodel, information construction, artificial intelligence, information relations.

метамодель». Дана схема формирования мета теории. Раскрываются принципы метамоделирования в информационном поле. Статья доказывает, что метамоделью в информационном поле является модель информационной конструкции. Вводится новое понятие информационное метамоделирование.

Ключевые слова: моделирование, информационное поле, модель, метамодель, информационная конструкция, искусственный интеллект, информационные отношения.

Introduction

Metamodelling is a promising direction in the modelling of complex systems, category theory, artificial intelligence technologies, and information technologies (Atkinson, Kuhne, 2003; Wang, Shan, 2007; Atkinson, Kuhne, 2001). The information field is a field for obtaining information about surrounding objects (Tsvetkov, 2014b). Unlike the information space, the information field is informative. The main function of the information space is coordination. The information space determines spatial relations. The main function of the information field is to inform about the content of the field function at a given point of the field (Kulagin, 2016).

Since modelling in the information field is one of the types of information technologies, metamodelling in the information field is also information technology. Therefore, the information method acts as the methodological basis of the metamodelling theory. In theoretical terms, metamodelling is based on the fundamental mathematical principles of metatheory.

Literature review

The concept of metatheory was proposed first by D. Hilbert (1979) in his works on the substantiation of classical mathematics by the proof theory. This direction is called metamathematics (Robinson, 1963; Goldblatt, 1974) and currently, it is intensively developing (Hájek, Pudlák, 2017).

The prefix meta (Greek μετα – after, following, across, behind) has the original meaning: to follow something, transfer to something, change of a state, transformation from one state to another.

In modern terminology, the prefix meta is used to define not only the sequence but also generalization. It is used for such objects and systems, which, in turn, serve for study, description or modelling of other objects or systems. In scientific terminology, such concepts as metatheory, metalanguage, metasystem, metamathematics, metainformation, metadata, metaknowledge, metamodel, metatask, etc. are widely used. This article considers theoretical and methodological aspects of metatechnologies in modelling regarding the information field.

Methods

General description

Studies in modelling and information technologies were used as materials. Methods included system analysis and synthesis, information field theory, comparative analysis, mathematical logic, qualitative analysis, and artificial intelligence methods.

The methodology is based on three basic principles and three types of metamodels. The first principle of the methodology is the concept of information field, in which the objects are located. There are relationships between objects in the information field. In the information field, information interactions take place. The information field is characterized by heterogeneity. The second principle of the methodology is the information situation model. The information situation includes an object and objects and factors interacting with it. It describes a homogeneous part of the information field around an object. The third principle of the methodology is associated with the expansion of the concept of metamodel, which is usually considered only as a generalization.

In this paper, metamodelling depends on the information situation. In different information situations, metamodels have different types. In the information field, prefix, infix and postfix types of metamodels are distinguished. Prefix metamodels are characterized by the situation and the process of following. Infix models are characterized by a situation of the transformation of objects and models; the transformation process is characteristic of them. Postfix metamodels are characterized by the generalization process. Based on the basic metamodels, various designs and combinations of models are built. Based on basic metamodels and principles, the relationship between the models and the original object is investigated.

Metarelations in the information field

The information relations exist and are applied in the information field and information technologies. As applied to metamodelling, information metarelations can be distinguished between an object and a metamodel and between a model and a metamodel. In information technologies and, in particular, in modelling, information metarelations, according to J. Clear (Hájek, Pudlák, 2017; Clear, 1990), have different semantic meanings for different information situations between an object and a metamodel.

Situation 1. The prefix meta shows the sequence relation. If there is an original object (OO), then a metamodel (MM) is an object that is observed after OO. Consequently, MM can be determined only after OO is defined. Thus, OO is a prerequisite for MM. The sequence relation is expressed by implication; therefore, there is the following for situation 1:

OO→MM

The binary sequence relation Re can be introduced. In this case, the sequence relation can be described as follows:

OO, Re, MM (1)

The expression (1) describes the sequence relation. It is necessary, but not sufficient for the formation of the metamodel of the object. The expression (1) is read from right to left. MM is preceded by OO.

Situation 2. The prefix meta shows the relation of transformation or information morphism (Okhotnikov, 2017). If OO is an original, then metamodel is MM* object that shows that OO changes and acts as an object summarizing all the changes that occur. The symbol "*" indicates the possible multiplicity of the result of the transformation. However, OO serves as a general name reflecting the changes. The transformation has many variants; thus:

OO→MM*1
OO→MM*2
OO→MM*3

The binary transformation relation Rt can be introduced. In this case, the transformation relation can be described as follows:

OO, Rt, MM* (2)

The expression (2) describes the transformation relation. It is not necessary, but not sufficient for the formation of the object metamodel. It characterizes the possibility. The expression (2) is read from left to right, as OO is unique and there can be many MM*. OO can be transformed into several MM*.

Situation 3. The prefix meta shows the generalization relation. If OO is an original object and can be represented by a certain number (number of instances) of OO, including instances OO1, OO2, OO3, and OO4, which differ from each other in individual features. In this case, it can be said that the original object has general features (of class) and individual features. In this case, between MM' and the objects OO1, OO2, OO3, and OO4, instances of the class of the original object and generalization relations are established. MM' is defined as a generalization of instances of OO.

OO1→MM'
OO2→MM'
OO3→MM'
OO4→MM'

The binary relation Ro can be introduced. It possible to describe the situation as follows:

OO, Ro, MM' (3)

The expression (3) describes the generalization relation. It is necessary, but not sufficient for the formation of the object metamodel. The expression (3) is read from right to left since MM' is unique and there can be a lot of OOe. MM' summarizes the instances of OOe. Case 3 shows a selection of generalization. MM' has general features and excludes individual ones. In the information field of the situation 3, the concept of the information construction corresponds. In the category theory of MM', the concept of category corresponds. The basis for the building the metamodel will be as follows:

OO, Re, Ro, MM’ (4)
or
OO, Re, Rt, Ro, MM’ (5)

The expressions (4) and (5) describe a direct metamodel of the object.

System "original – model – metamodel"

The metarelations in the system "object – metamodel" are considered; it is possible to go to the relations in the system "original – model – metamodel". Let OO be an original object, M – a model of an object, MM^M – a metamodel of the model M, MM – a metamodel of the original. Thus, with the transfer to models, there will be two metamodels: an object metamodel and a model metamodel. A model M and a metamodel MM can be obtained per object.

Conclusion. Not every model of M object is a metamodel.

MM model, presented as a metamodel of OO object, is what takes place after OO, i.e. the original object is a prerequisite to the metamodel of MM object. There is a sequence feature for the object. MM^M model, presented as a metamodel of M model, is what takes place after M, i.e. the object model precedes the metamodel of MM^M model. There is a sequence feature for the model. Based on the above considerations, it follows that the concept metamodel, as applied to models connecting several models through replacement procedure, includes four features of this concept:

1. The object metamodel can be defined only after the types of original objects, replaced by the metamodel, are defined;
2. The model metamodel can be defined only after the types of object models, replaced by the metamodel, are defined;
3. The model metamodel describes the transformation – replacement – of one model with another;
4. The model metamodel has a high level of abstraction. The level of its abstraction is higher than the levels of individual models. Fig. 1 shows the system "object – model – metamodel".

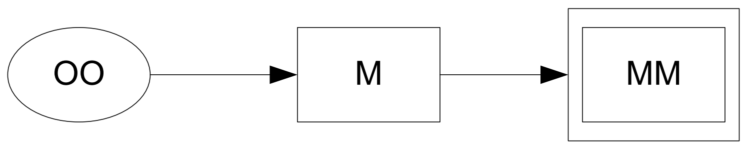

Figure 1. The scheme of the relations in the system "object – model – metamodel".

Fig. 1 shows a scheme of the relations between an object (OO), a model (M) and a metamodel (MM) as "one to one". In practice, several models can correspond to one object. That is, between them, there is a "one to many" relation. This case is shown in Fig. 2a.

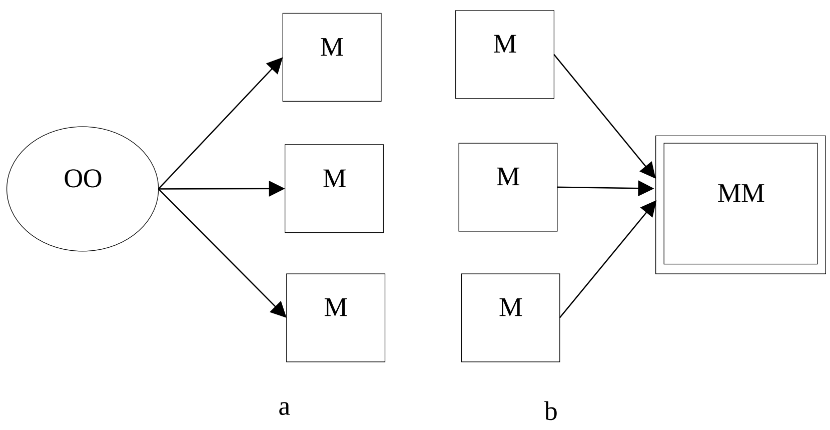

Figure 2. The relation "one to many" and the relation "many to one".

ISSN 2322- 6307

Fig. 2b shows the "many to one" relation. It means that with one MM, several models of M objects can correspond. These models are the basis for its formation. Two situations are possible. The first information situation in Fig. 2b corresponds to the case when all different M models describe one OO object. In this case, MM can be either a metamodel of models or an indirect metamodel of an object. The second information situation corresponds to the case when different models describe different objects.

Results and discussion

One of the applications of metamodelling is the development of new theories. In Fig. 2b, MM can be either a theory of models or a theory of the behavior of objects. In practice, MM can often be a particular theory. There can be a situation when a new metamodel, which will be a metatheory, is built on the basis of metamodels (Hjørland, 1998; Figueroa, 2014) (Fig. 3).

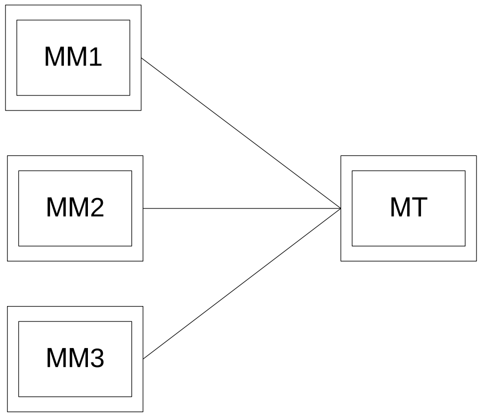

Figure 3. Building a metatheory based on the generalization of metamodels.

In Fig. 3, MT denotes a metatheory. Logically the process of building a metatheory looks as follows:

$MM1 \wedge MM2 \wedge MM3 \wedge \wedge MMi \rightarrow MT$ (6)

MMi correspond to metamodels of different quality, which, however, describe related objects (of the same class), phenomena, or processes. The distinction between related and connected should be emphasized. Related models may be connected. This is a sufficient condition for their generality and belonging to one phenomenon. Connectedness is not a sufficient condition since qualitatively different processes and objects belonging to different classes and different hyperobjects of the world views can be connected (Tsvetkov, 2014a). Connectedness is not necessarily a genetic generality.

In information technologies and computer science, all processes occur in the information field. The feature of the information field is the use of special models: information model, information situation model (Tsvetkov, 2017b), information unit model (field element) (Tsvetkov, 2014d; Ozhereleva, 2014), information construction model (Tsvetkov, 2014c, Chekharin, 2014). There are information relations in the information field. In the information field, models obtained by measurements and observations are divided into primary and secondary models. In other words, they can be defined as parameter and information unit models. Fig. 4 shows the transformation of an original or primary model into an information unit model.

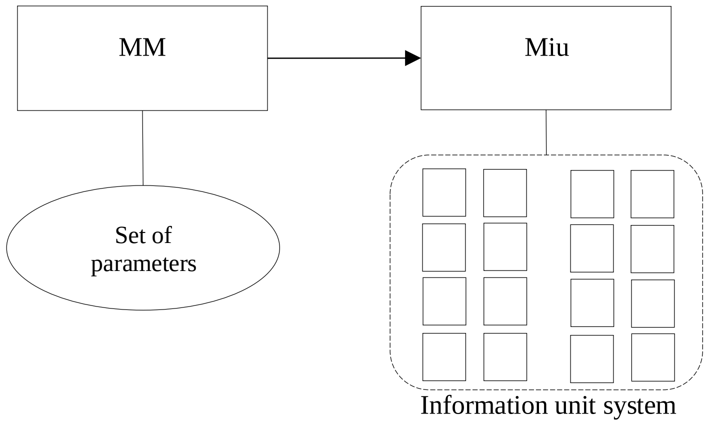

Figure 4. Decomposition in the information field.

In Fig. 4, MM is a measuring model, which is obtained on the basis of receiving information or measurements. Miu is a model built on the basis of information units. Logically, the process of building a secondary model looks as follows:

MM = Miu (Iu1∧ Iu2 ∧ Iu3 ∧ ∧ Iui) (7)

In the expression (7) Iu is information units of the information unit system. A part of these units is included in the model, like a part of words of a language is included in a real text.

A measuring model contains a set of parameters and relations between them. Some connections and relations may be implicit. The model based on the use of information units is structured and systematized. This is due to the fact that information units are always included in a system. They are part of the system and provide a systematized and systematic description of the model.

An example can be a cryptographic message. The original message has parameters, but not systematized or structured. Decoding or deciphering defines a system of information objects, which is detailed by information units. In a text, the information units are words and symbols. In the program description, the units are operators and operands. Decoding defines a structured and systematic model of a text message.

The feature of the information field is that in many cases the role of the metamodel is played by the information construction (IC). Fig. 5 shows the scheme of building the metamodel in the information field.

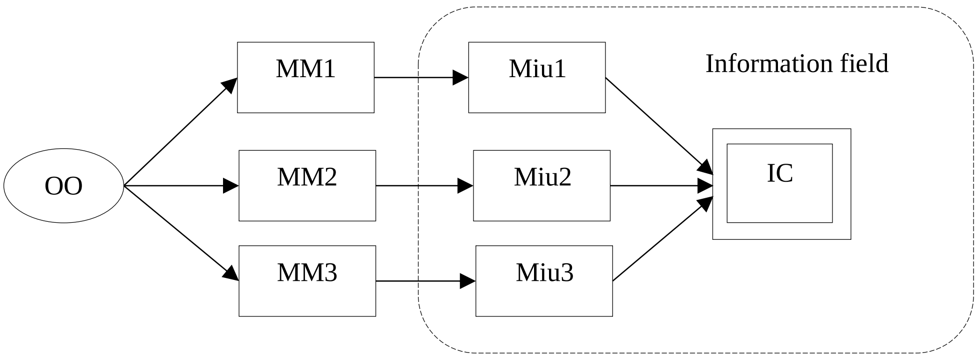

Figure 5. Building information construction as a metamodel.

In general, the process of building a metamodel in the information field can be described by the following expression:

OO→MM→Miu→IC(Iu1(Information unit)∧Iu2∧Iu3∧∧Iui) (9)

In the expression (9), it is emphasized that the metamodel (IC) has a clear structure of information units, which are the units of the information field.

The measurement or research of an object leads to the building of a set of primary models, which can be called measuring or research (MM). They contain sets of parameters and descriptions connected in an arbitrary way, depending on the technology and research methods. At the second stage, the measuring models are transformed into Miu, which have internal structure and external systematization. In some cases, Miu are classified objects.

The use of information units as the basis of structural building of Miu makes it possible to connect the models at the level of their structure. This increases control of the modelling process and increases its reliability. At the last third stage, the information construction (metamodel) is formed on the basis of a generalization of systematized Miu. The information structure as a metamodel is more structured and systematized in comparison with conventional metamodels due to the use of an information unit system.

The metamodelling theory is an important section of the modelling theory and system analysis. Recently, the tendency towards engineering-based modelling and a general understanding of basic concepts, such as model and metamodel, has become a key problem (Kühne, 2006). Despite the fact that these concepts have been widely used for a long time, there is still no consensus about when exactly these concepts should be used. In the information field, this direction is supplemented by information unit models, information situations, and information constructions. The information construction is a conceptual model and can be considered as a metamodel.

Metamodelling in the information field is more structured and systematized. However, from the point of view of the modelling process, it is more complex.

Conclusions

Metamodelling in the information field integrates the information modelling, modelling and metamodelling. Beyond the framework of this article, there is an analysis of the information situation model, which under certain conditions can act as a metamodel. The information construction, due to its generalized description, is always a metamodel. The information situation may or may not be a metamodel depending on actual conditions. In general, this study gives reason to introduce a new term for modelling in the information field – information metamodelling. A metamodel in the information field represents a type of information construction or information situation. This simplifies the process of metamodelling in the information field. The information metamodelling is metamodelling using models of information units and information constructions. It allows creating a more structured and systematized metamodel and developing internally structured metatheory. In computer science, a metatheory (Hjørland, 1998; Shaitura et al., 2017, 2018) is under development and requires further research.

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