Metamodeling and metalearning approaches in inductive modeling tools

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Abstract: **A comparative analysis of terms and tasks of metalearning and metamodeling is carried out. Examples of such tasks, methods and tools for its solution are given. The examples of the application of an inductive approach for the solution of metalearning and metamodelling problems are given.**

Keywords: **metamodel, metalearning, metamodelling, machine learning, inductive modelling, metaknowledge**

I. Introduction

"Meta" means a superstructure over some object. For example metadata is data about data that is some additional generalized data information. Metadata refers to data or information about information. Metaknowledge (in artificial intelligence) is a part of the knowledge base that describes structure of data. The metamodel in computer science is a model that describes another model – transitive relationship between the two models.

Another task with "meta" is metalearning. The basic principle of metalearning is learning to learn. It is used in machine learning in the field of computer science.

The aim of the paper is to analyze the terms and tasks of metalearning and metamodeling and to find out if and why these two problems are different.

Inductive modeling methods are related to methods of extracting knowledge from data. The knowledge extraction based on inductive modeling from data bases is currently one of the deeply analyzed problems.

The generalization of possibilities of constructing models and algorithms based on the inductive approach allows applying the methods of learning and modeling for the purpose of effective solving of model construction and machine learning problems.

II. Concepts of Metalearning and Metamodelling

Metamodeling. It is the analysis of processes [1], design and development of frames, production rules, constraints, models and theories that can be applied to generalized models of intelligent software and information systems.

The term "metamodeling" meet to generalize problems that arise in different industries at all stages: data collection, processing, object management for automation purposes, for simplification and ordering, in order to form a common structure that still has a certain level of flexibility and extensibility.

The main purpose of metamodeling [2] is to describe the data so deeply that they were self-sufficient and allowed the expansion and modification of its structure. A similar property provides software that works with this data. In metamodeling this takes place automatically. Tools based on metamodeling are flexible because they are not written for a particular case of data with a specific structure and with fixed dependencies but work in the general case. Information about the structure of data is read from the metamodel and it is automatically configured for them.

The key issue of metamodeling [3]: how to design the features on which the metamodel is based? These features should combine the characteristics of the set of data and relevant aspects of the model of learning. Characteristics of the data set should not be limited to a simple listing of the number and type of attributes and the number of objects.

Therefore it is unlikely that based on this information it will be possible to forecast something meaningful about the quality of the model.

Two important properties on which metamodeling are based:

- closeness – working with the chosen formal model we will not get beyond its limits;
- completeness of the chosen formal system means that within its framework it is possible to describe all objects from the given set.

Systems based on the principles of the purpose of modeling should have the properties of expandability (adaptability) and universality (community).

Let's consider some real examples of metamodels.

If we have a set of objects one can construct a model of each of them (objects of the same class, close to functions but perform different operations) however it is better to construct a metamodel of this group of objects. This metamodel is a generalized model of this class or group of objects. When we modify this general model by some parameters it will describe any particular object in this group.

If there is a class or a group of objects then it is not necessary to construct models of each but it is enough to construct one generalized model which at some given values of its parameters describes precisely any of the objects in this group or class. Then it will be a metamodel which in its structure actually contains partial models of each particular object of this class.

For example [4] describes metamodel of the iterative algorithm of inductive modeling - one software product which in its structure contains seven programs with different properties, that is, this product is a meta-model of the iterative algorithms of the group method of data handling (GMDH). The metamodel is also a generalized GMDH criterion which includes some group of other criteria [5].

Metalearning. It is a field of machine learning [6] which uses algorithms for automatic learning on metadata about computer experiments. To date this term has not found a standard interpretation but the main purpose of its application is to understand how automatic learning can help in solving learning problems, hence improving the effectiveness of existing learning algorithms or teaching the computer to automatically trigger the learning algorithm itself.

By using a variety of metadata such as learning task properties, algorithm properties (e.g., performance indicators) you can learn how to select, modify or combine different learning algorithms to effectively address learning objectives.

In [7] it is determined that metalearning is the study of fundamental methods that use metaknowledge to obtain effective models and solutions by adapting the processes of machine learning and data processing. Despite the fact that various methods of machine learning and data processing are now available and they can provide good model solutions but it is necessary to develop a methodology for efficient search of the most appropriate model.

Metalearning provides a methodology that allows systems to become more effective due to their experience. In [7] several approaches are discussed to obtain knowledge about the effectiveness of machine learning and algorithms for data search. This knowledge can be reused to select, combine, compile and adapt algorithms and models for faster, more efficient solution to data mining problems. Thus it can help developers improve their algorithms and learning systems.

The authors [8] developed and implemented their own iterative algorithm which can provide in various modifications different variants of algorithms that can work differently and give different models, that is, the purpose of learning is to choose a better algorithm for a specific task.

III. COMPARISON OF THE METALEARNING AND METAMODELING PROBLEM

Are there interactions between metalearning and metamodeling? In general it is obvious that they are different but complementary conceptions.

Modeling is the construction of generalized models of a certain group of objects (software tools, mathematical models, information systems). This metamodel covers a class of objects (informational, physical or mathematical) and in partial cases describes different classes of objects.

If we talk about software metamodels for example a generalized iterative algorithm GIA GMDH [4] allows constructing mathematical models of specific objects (Fig. 1). In order to use this software metamodel it needs to set parameters and we can get a specific model. The learning process of such a metamodel covers the definition of the parameters of the operation of this metamodel. If the control parameters are given (sample length, freedom to choice, number of arguments, class of models, method of estimating parameters, etc.), then we just use a specific algorithm for a particular object.

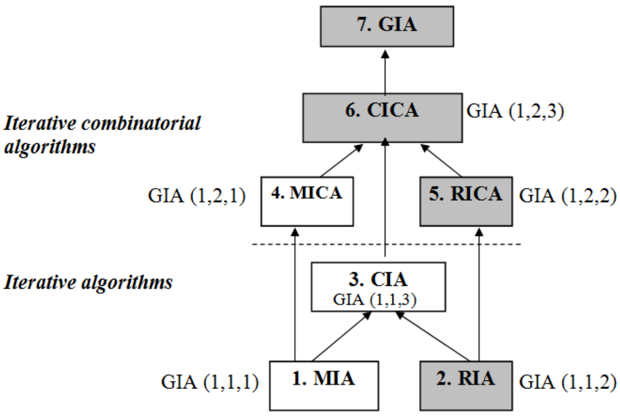

Fig. 1. The generalized iterative algorithm [4]

If you create such a tool that will allow to automatically configure this metaprogram as a metamodel of iterative algorithms, to determine the algorithm that is most adequate to a particular object you need to configure its control parameters and then this will be the learning process. If this learning process uses the preliminary results of a successful or unsuccessful operation of this metaprogram, then this process will be called metalearning.

That is metalearning of a model is the use of a particular algorithm with specified parameters for obtaining a model. When we get a separate model we evaluate the structure and parameters. The choice of structure and model parameters is the learning. If we choose from a complex algorithm, the best or most appropriate values of control parameters, this is already a metalearning, i.e. learning on the results of primary learning.

Simple learning is to run a separate algorithm and get the model. Metalearning means that we choose the best of the algorithms group and adjust its control parameters. This best algorithm with optimal values of control parameters allows one to obtain the structure and parameters of an optimal model for this object.

Thus the tasks of metalearning and metamodeling are substantially different but complementary. If we have a meta-model then we can apply metalearning to best use of this metamodel (for example metaprogram).

Thus each of the modelling specialists works manually with metalearning, combines various possibilities to get the best result. If you develop methods and tools for automatic adjusting these algorithms to find the best solution, this will be the implementation of the principles of metalearning in practice.

IV. INDUCTIVE METHODS AND MEANS OF SOLUTION OF THE METALEARNING AND METAMODELING PROBLEM

The complex developed in [9] can be called a metaprogram. It contains many variants of algorithms that generalize many algorithms and allow the author of the modelling to build his algorithm from the programmed modules of the complex, compare the results with other algorithms and explore its properties.

In [10] the successful solving a modelling problem for complex objects, processes and systems from data substantially depends on the choice of optimum method and consequently from getting acquainted with modelling methods. It is of importance first of all for an expert in data-based modeling domain which should make decisions on what method will be the most effective in a concrete case and also for a user wanting to apply the available modelling methods.

The functional and dialogue structures of integrated complex of tools for investigation and application of modeling methods from data observed on the basis of proposed methodology are developed and realized. The computer toolkit is designed for experimental knowledge discovery on comparative advantages and disadvantages of modeling methods and its components. The computer complex has ability to use recurrent parameters estimation for the purpose of efficiency increasing of modeling methods.

In [4] a generalized iterative algorithm for inductive modeling is developed. It is one software product which in its structure contains seven different software products with different properties and this product is a metamodel of the GMDH iterative algorithms (Fig. 1).

Iterative algorithms capable of working at a great number of arguments but the specific of their architecture do not guarantee model construction of true structure. Presently the classical multilayered iterative algorithm MIA GMDH [11] is most widely known however he has some substantial drawbacks: possibility of loss of informative and/or inclusion of spurious arguments, exponential growth of polynomial degree. The generalized iterative algorithm helps to avoid these drawbacks.

Software framework described in [12] is built on the principle of metamodelling and is intended to implement and run (execute) several GMDH algorithms. A key component of the software framework, distinguishing it from libraries of aggregated functions/methods, is the core implemented according to the object-oriented paradigm.

In [13] the task of metamodeling is explored as one of the tasks of artificial intelligence. The author used methods for solving such specific tasks as: parameter estimation of nonlinear transfer functions by gradient methods; evolving diverse heterogeneous units using genetic algorithms with niching schemes; inductive selection of optimal models (nets) with use of external criteria based on a partition of the given data set; improving the generalization ability of a network system by ensembling a number of models; visualization of useful properties of multidimensional processes due to the evolutionary search based on genetic algorithms with special fitness functions.

Below are examples of the construction of other technologies on the principles of *metalearning* with the use of inductive approach.

In [14] the task of preliminary processing / preparation of data is presented as one of the actual problems in the data mining community. The author concentrates his efforts on construction of a new kind of preprocessing technology: his main goal is providing an automatic transformation the data into form the most suitable for a given classification method to enhance it accuracy.

Carrying out a series of experiments the author [14] tests various combinations of methods of preliminary data processing. Automation of this method is metalearning.

In [8] a systematization of known systems of metalearning was conducted on the basis of developed classification features that take into account the internal organization of systems. The author formulated the requirements for the implementation of the automatic metalearning system, proposed a method for constructing a metalearning system that meets all the requirements formulated and generates metaknowledge accumulation, building on their basis metamodels, selecting the optimal algorithm from a set of available and calculating the optimal parameters for its functioning. The object-oriented architecture of the software platform for the implementation of any of the metalearning systems presented in the systematization has been developed.

In [15] the application of principles of metalearning to optimize the neural network structure of is considered. It is shown that application of variety, ensemble, self-organization and inductive approach are useful for optimizing its structure. The authors combine different types of neurons that are learned by different methods to create a controlled neural network with feedback called Group of Adaptive Models Evolution (GAME).

V. On construction of automated decision support system on inductive, metalearning and metamodeling principles

It is planned to develop an automated decision support system for modeling and forecasting of complex processes built on the principles of inductive approach, metalearning and metamodeling.

Knowledge-based approach will allow using the experience of using inductive modeling techniques in various fields of human activity [16].

The structuring of knowledge obtained as a result of the subject area analysis will enable an interactive or automatic mode to solve the problem of synthesizing the best method or algorithm for each specific modeling application.

The principles of metalearning will allow summarizing this experience in the database and knowledge to formulate rules of decision making in the modelling process.

The metamodeling principles will provide an opportunity to generalize the structure of metadata, that is, to summarize different algorithms and criteria.

Stages or blocks from which the system will be composed [17]: work with various data dases; preliminary data processing, choice of purpose of modeling; preliminary (reconnaissance) analysis of data, choice of object class, class of functions, data transformation depending on the purpose of modeling; formation of the task: the choice of external criteria, the method of estimating parameters, the generator of structures, the formation of the algorithm of the solution, the problem of control parameters; solution of the problem; model creation, validation of the model's adequacy (for example, on the exam), analysis of results, construction of ensemble of models; application of results (Fig. 2).

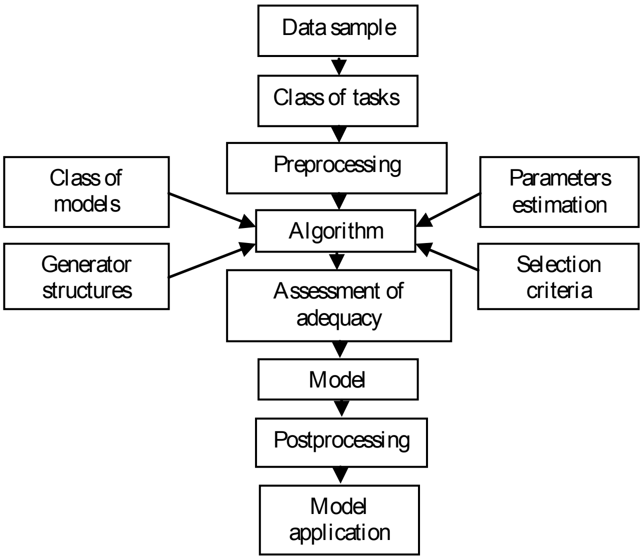

Fig. 2. Scheme of sequential decision making

It is planned to develop such a system on the principles of intelligemt modeling, that is, the construction of models of objects with the use of knowledge and tools that ensure the achievement of quality models at the level of a qualified designer models [18].

VI. Conclusion

The concepts of metalearning and metamodeling are considered. These tasks are compared and their distinctions are shown. Examples of the metamodels application in the field of inductive modeling as well as methods and tools for metamodeling and metalearning are given.

Metamodeling is a generalization of some information about a group of objects in a special model. Metalearning means using the best experience gained to determine the structure and parameters of such model. One can say that metamodeling is a generalization of the metadata structure and metalearning is a generalization the experience of using metamodels.

It is planned to develop a concept and tools based on the inductive approach, which will allow the transfer of the principles of inductive modeling, metamodeling and metalearning to build an automated decision support system accumulated all the acquired experience in the field of inductive modeling of complex processes and systems.

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