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METALEARNING AS ONE OF THE TASK OF THE MACHINE LEARNING PROBLEMS

The concepts of metalearning as one of the tasks of machine learning are considered. The basic principles of metalearning g and examples of solving problems of machine and metalearning in various fields of human activity are given. It is planned for a decision support system construction based on an inductive approach for complex processes modeling and forecasting.

Keywords: *machine learning, metalearning, inductive modelling, decision support.*

Introduction

Machine learning is a branch of artificial intelligence. Its main idea is that the computer does not just implement a pre-written algorithm, but learns how to solve this problem.

The field of machine learning today is one of the most relevant areas at the intersection of information technology, mathematical analysis, and statistics. Machine learning methods are increasingly used to solve a variety of problems, ranging from traffic congestion analysis to self-driving cars. More and more tasks are being shifted to self-learning machines. Very often machine learning methods are being incorporated into electronics, which a person uses every day without even knowing that he uses machine learning methods every day.

Today in the field of machine learning, a huge number of methods have been developed that differ in their features and areas of application. Many simple approaches have been created that can be widely applied in various fields of human activity.

However, the construction of machine learning systems requires a huge amount of time of highly professional specialists both in the field of artificial intelligence and in the subject area to which this technology is applied. A promising area for the further development of the field of machine learning is automated machine learning. This will significantly reduce the share of human participation in the creation of artificial intelligence systems.

Metalearning is one of the tools of machine learning when the accumulated experience in solving learning problems in a certain area of human activity is implemented in a specific algorithm with the goal of transferring human experience to a machine.

Machine Learning Problem

Machine Learning (ML) is an extensive subsection of artificial intelligence that studies the methods of constructing algorithms that can be learned [3], i.e. exploring methods that allow computers to improve their performance based on experience. A characteristic feature of ML methods is not a direct solution to a problem, but learning in the process of applying solutions to many similar problems [1]. To build such methods, mathematical statistics, numerical methods, optimization methods, probability theory, graph theory, various techniques for data handling in digital form are used.

TThe name ML was proposed by Arthur Samuel in 1959, which the question of Alan Turing: "Can machines think?" replaced with the question "Can machines do what we can (as thinking entities)?" [7].

There are two types of learning. Inductive learning is based on the identification of general patterns from particular empirical data (case-based learning or learning from examples). Deductive learning involves formalizing expert knowledge and transferring it to a computer in the form of a knowledge base. Deductive learning is usually referred to as the field of expert systems, so the terms machine learning and case-based learning can be considered synonymous.

Machine learning is at the intersection of mathematical statistics, optimization methods, and classical mathematical disciplines; it also has its specifics related to problems of computational efficiency and retraining. Many inductive learning methods have been developed as an alternative to classical statistical approaches. Many methods are closely related to Data Mining.

The most theoretical sections of machine learning are combined in a separate direction, which is called the Computational Learning Theory (COLT).

Machine learning is not only mathematical but also a practical, engineering discipline. Pure theory, as a rule, does not immediately lead to methods and algorithms that are applicable in practice. To make them work well, additional heuristics have to be invented to compensate for the inconsistency made in the theory of assumptions with the conditions of real problems. Almost no research in machine learning is complete without an experiment on model or real data, which confirms the practical working capacity of the method.

Machine learning includes, but is not limited to, neural networks and deep learning. This is the ability of a computer to display or do something that it is not programmed for, using experience received in this field. Generalize the experience of solving many previous tasks with the help of a approach – metalearning. Let us consider in more detail the metalearning and what tasks it solves.

The task of Metalearning

Metalearning is a field of machine learning [1], in which automatic learning algorithms on metadata about computer experiments performed are used. The main purpose of its application is to understand how automatic learning can help in solving learning problems, therefore, to increase the efficiency of existing learning algorithms or to learn how to automatically call a learning algorithm.

You can learn to choose, change or combine different learning methods to effectively solve the learning problem using various metadata, such as the properties of the learning task, the properties of the algorithm (for example, performance indicators). Metalearning facilities are tools that allow you to implement the accumulated experience in solving a problems in a specific area in a specific algorithm that will continue to self-learn.

In [8], it is declared that the problem of choosing a suitable prognostic model (or combination of models) solved taking into account the field of application. The end-users often lack not only the experience needed to choose the right model, but also the availability of many models for trial and error. The solution to this problem is achieved by creating metalearning systems that provide automatic and systematic user guidance by matching a specific task with a suitable model (or combination of models).

Authors [9] described the creation of self-adaptive learning algorithms that dynamically improve their properties by accumulating meta-knowledge. Paper contains an overview of metalearning tasks. Despite the different views and directions of research, the question remains: how can we use meta-knowledge about learning to improve the performance of learning algorithms? It is clear that the answer to this question is key to the development of the industry and continues to be the subject of intensive research.

In [4] metalearning is defined as a field of research that solves the problem of learning, the purpose of which is to develop models that can learn new skills or quickly adapt to new conditions with a minimum of learning examples. This not only significantly speeds up and improves the solution of these problems, but also allows us to replace manually developed algorithms with new automated approaches based on data.

The goal is to learn models of various learning problems so that they can solve new learning problems with only a small number of learning examples, i.e. concentrate on finding independent models.

Properties of metalearning algorithms:

- learn faster;
- generalize the result to many tasks;
- adapt to environmental changes.

Thus, it is possible to solve any problem using one model, however, metalearning should not be confused with one-time learning.

In [5], it is stated that the application of machine learning to a specific problem call the questions that are typically solved with the help of personal experience, premonitions, critical situations, trial and error; for example, choosing an adequate machine learning algorithm or corresponding parameters for such an algorithm.

It is shown that the difference between metalearning and traditional machine learning is only in the amount of data analyzed. Traditional learning, also known as basic learning, focuses on one specific task, for example, when a specific disease is detected, each instance will consist of features that describe one patient in a way that facilitates the machine learning algorithm to determine if someone has from patients, this disease or not. At the meta level, learning takes place on several tasks, so questions go from forecasting whether a new patient has this disease or not, to what is the best algorithm for forecasting whether a patient has a disease or not (choice of algorithm); or how to optimize the performance of a parameterized disease detection algorithm (hyperparametric tuning); at this meta level, instance is a task. To select an algorithm, information is used that characterizes each task: statistical data (average for the features: average value, standard deviation, asymmetry) to take into account all previous experience of different tasks.

In [6], it was shown that metalearning problem, also known as “learning for learning”, is designed to develop models that can learn new skills or quickly adapt to new conditions with the help of several learning examples. There are three general approaches:

1) to study the effective distance metric (based on metrics);

2) use a (recurrent) network with external or internal memory (based on the model);

3) to explicitly optimize the model parameters for quick learning (based on optimization).

A good machine learning model often requires learning with lots of patterns. People, conversely, learn new concepts and skills much faster and more efficiently. Metalearning consists of the construction of metamodels that can adapt well or generalize new tasks that have never been encountered during learning. The adapted model can solve new problems, which is why it is called learning. Tasks can be any clearly defined family of machine learning tasks: controlled learning, case-based leaning, etc.

In [7], the concept of metalearning was assigned to the field of data mining forecasting, combining forecasts of various models. It is often used if the models included in the project are of different types.

For example, we have three different classifiers, linear discriminant analysis and neural networks. Each of them calculates the predicted classification for the cross-checking sample, from which the general criterion of agreement can be calculated (for example, the proportion of classification errors). Experience shows that a combination of forecasts of several methods gives a more accurate forecast than that obtained from any single method. Predictions of various classifiers can be used as input to the metalearning procedure, which will allow us to combine forecasts to create the best classification. For example, the predicted classifications of the three classifiers, the linear model and neural networks can be used as input variables in the metaclassifier of neural networks, which will try to find the correct combination of predictions from different models from the data to achieve maximum classification accuracy.

You can repeatedly apply the metalearning process, using the results of the previous step as input at each step; however, in practice, such an exponential increase in the amount of data processing to obtain an accurate forecast gives less and less benefit with each step.

Application Machine Learning for the Real Task Solving

In [10] the reviewed machine learning methods for classifying large volumes of satellite data. Particular attention is paid to deep architectures, in particular neural networks, which at the moment is the most powerful and accurate method for recognizing visual images. The main advantages of deep learning methods over traditional approaches to classification problems that have been used over the past decades and are based on expert knowledge to extract features from input data are determined.

SAS company named the planet's most comfortable cities, a list of which was compiled using machine learning algorithms [11]. To compile the rating, data were used on nearly 150,000 settlements in 193 countries. The machine learning algorithm has identified many criteria — from climatic indicators, the number of events to the number of trees on the streets and the prices of certain products. The choice of which criteria to use was made automatically — analysts only interpreted quantitative indicators and characteristics. Based on meta-criteria, the most comfortable city was determined.

In [12], a systematic review and meta-analysis were carried out to diagnose any symptom of the disease using medical imaging and histopathology materials, and the accuracy of diagnosing Machine learning algorithms is used for visual recognition. A model of deep learning was created, created thanks to advances in the architecture of parallel computing, which made an important breakthrough in the competition of large-scale visual recognition.

The author [13] approves that generalization is the most fundamental concept of machine learning. If the information on which the spam filter SpamAssassin has learned is generalized to your mail messages, you will be satisfied; if not, you will start looking for the best spam filter. However, relearning is not the only possible reason for the poor quality of work on new data. Perhaps SpamAssassin programmers used training data that is not representative of the email messages that come to you. Fortunately, this problem has a solution: take other training data with the same characteristics as your mail. Machine learning is a wonderful technology that allows you to adapt the program behavior to specific circumstances, and many mail spam filters allow learning on user data.

It is said in [14] that machine learning surrounds you everywhere, although you may not be aware of this. Thanks to machine learning, the search engine understands which results (and ads) to show in response to your request.

When you look at mail, most of the spam goes past you because it was filtered using machine learning. If you decide to buy something on Amazon.com or look at Netflix to watch a movie, the machine learning system will helpfully suggest options that you may like. With machine learning, Facebook decides which news to show you, and Twitter picks the right tweets. Whenever you use a computer, it is very likely that machine learning is involved somewhere.

Mobile phones, in general, are full of learning algorithms that tirelessly correct typos, recognize voice commands, correct data transfer errors, read barcodes and do many other useful things. The smartphone even learned to guess your next action and give useful tips. For example, he will tell you that the meeting will begin later, because the plane on which your guest should fly is delayed.

Machine learning can be thought of as turned inside programming, in the same way as the square root of the opposite of the construction of the second degree, and integration back differentiation.

Inductive Approach for the Metalearning Task Solving

Below are examples of constructing other technologies based on the principles of metalearning using an inductive approach.

In [16, 17], systematization of well-known metalearning systems was carried out on the basis of the developed classification features that take into ac-

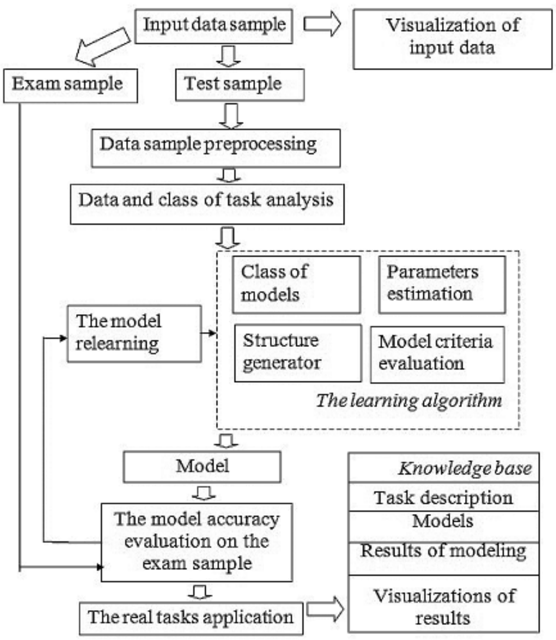

Fig. A block diagram of a metalearning solution based on an inductive approach

count the internal organization of the systems. The author formulated the requirements for the implementation of an automatic metalearning system, proposed a method for constructing a metalearning system that meets all the stated requirements and generates meta-knowledge accumulation, builds meta-models on its basis, selects the optimal algorithm from the set of available ones and calculates the optimal parameters for its functioning.

An object-oriented architecture of the software platform was developed to implement any of the metalearning systems presented in the systematization.

In [18, 19], the problems of metamodeling and metalearning based on an inductive approach are compared: metamodeling is a generalization of some information about a group of objects in a particular model, and metalearning is the use of accumulated experience about the best way to determine the structure and parameters of such a model. It is shown that the generalized iterative algorithm GIA GMDH [20] allows you to build mathematical models of specific objects. 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 determination of the operating parameters of this metamodel.

The authors plan to develop an automated decision support system for modeling and predicting complex processes, built on the principles of an inductive approach, meta-learning and metamodeling.

Structuring the knowledge obtained as a result of the analysis of the subject area will allow interactively or automatically solving the problem of synthesis of the best method or algorithm for each specific modeling application.

The principles of metamodeling will make it possible to generalize the structure of metadata, that is, to generalize various algorithms and criteria.

The figure shows a block diagram of a metalearning solution based on an inductive approach.

Stages or blocks from which the system will be composed [20]: work with various data-bases and knowledges bases; data preprocessing, selection of class of task and data analysis; preliminary (reconnaissance) data analysis, selection of an object class, function class, data conversion depending on the purpose of modelling; task formation: selection of external criteria, parameter estimation methodology, structure generator, solution algorithm formation, parameter management task; solution; creating a model, checking the adequacy of the model (for example, in an exam), analysing the results, building many models; application of the results.

Dividing the data sample into two parts (testing and exam) makes it possible to evaluate the resulting model on new independent data that were not used in the construction of the model. The metadata containing learning results is entered into the knowledge base.

Conclusion

Methods and tools of machine learning allow you to teach a computer how to solve problems, similar to how people doing this.

The principles of meta-learning will allow you to summarize a person's experience in a database and knowledge to formulate decision-making rules in the modeling process.

Using the experience of solving many problems allows you to build a system on the principles of metalearaining. It is planned to develop such a system using an inductive approach and experience in solving many applied problems based on this approach. A block diagram of the solution to the problem of the metalearning method based on the inductive approach is developed.

REFERENCES

1. Machine learning, [cited 2017 Oct. 16]. Available from: https://en.wikipedia.org/wiki/Machine_learning https://ru.qwe.wiki/wiki/Meta_learning_(computer_science)
2. Machine Learning — Mashinnoye obucheniye. https://www.it.ua/ru/knowledge-base/technologyinnovation/ machine-learning. (In Russian).
3. Machine Learning. http://www.machinelearning.ru. (In Russian).
4. Gupta, A. An Introduction to Meta-Learning. https://medium.com/walmartlabs/an-introduction-to-meta-learning-ced7072b80e7.
5. What is meta-learning in machine learning? https://www.quora.com/What-is-meta-learning-in-machine-learning.
6. Meta-Learning: Learning to Learn Fast. https://lilianweng.github.io/lil-log/2018/11/30/meta-learning.html.
7. Meta Learning. http://statsoft.ru/home/textbook/glossary/GlossaryTwo/M/MetaLearning.htm.
8. Brazdil, P., Giraud-Carrier, Ch., Soares, C., Vilalta, R., 2008. "Metalearning: Applications to Data Mining", Springer Publishing Company, Incorporated, pp. 11–31. doi:10.1007/978-3-540-73263-1.
9. Vilalta,P., Drissi, Y., 2002. Perspective view and overview of meta-training, artificial intelligence. Overview, 18 (2), 77–95. https://doi.org/10.1023/A:1019956318069
10. Lavrenyuk, M.S., Novikov, O.M. Ohlyad metodiv mashynnoho navchannya dlya klasyfikatsiyi velykykh obsyahiv suputnykovykh danykh. System Research & Information Technologies, 2018, № 1, pp. 52–71. DOI: 10.20535/SRIT.2308-8893.2018.1.04. (In Ukrainian). https://doi.org/10.20535/SRIT.2308-8893.2018.1.04
11. Methodology for comparing machine learning algorithms based on meta-learning. https://www.rfbr.ru/ rffi/ru/project_search/o_2037109. (In Russian).
12. Liu, X., Faes, L, at all., 2019. A comparison of deep learning performance against health-care professionals in detecting diseases from medical imaging: a systematic review and meta-analysis. https://www.thelancet.com/ journals/landig/article/PIIS2589-7500(19)30123-2/fulltext. DOI: https://doi.org/10.1016/S2589-7500(19)30123-2
13. Flach, P., 2012. "Machine learning: the art and science of algorithms that make sense of data", Cambridge University Press, 2012, 396 p.
14. Domingos, P., 2015. The Master Algorithm: How the Quest for the Ultimate Learning Machine Will Remake Our World. USA: Basic Books, 352 p.
15. Named the most liveable cities on Earth. https://www.avianews.com/world/2018/04/ 10/best_cities_to_live/. [Названы самые удобные для жизни города на Земле] https://www.avianews.com/world/2018/04/ 10/best_cities_to_live/. (In Russian).
16. Orlov A.A., 2014. "Avtomaticheskaya sistema meta-obucheniya s podderzhkoy vybora optimal'nogo algoritma resheniya zadachi i vychisleniya optimal'nykh parametrov yego funktsionirovaniya". Izvestiya Tomskogo politekhnicheskogo universiteta, 5 (324), pp. 57–70. [Орлов А.А. Автоматическая система мета-обучения с поддержкой выбора оптимального алгоритма решения задачи и вычисления оптимальных параметров его функционирования. Известия Томского политехнического университетаб №5 (324). С. 57-70.] (In Russian).
17. Orlov, A.A., 2014. "Models, algorithms and software platform for implementing meta-learning based on the method of group accounting of arguments", Avtoref. dis. by specialty 05.13.18 Tomsk, 24 p. [Орлов А.В. Модели, алгоритмы и программная платформа для реализации мета-обучепия на основе метода группового учета аргументов. Авореф. дис. Специальность 05.13.18 Томск, 2014. 24 с.] (In Russian).
18. Savchenko, Y., Stepashko, V., 2018. "Metamodeling as a way to universalization of inductive modeling tools". 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT 2018 – Proceedings. pp. 444–447. https://doi.org/10.1109/STC-CSIT.2018.8526582
19. Savchenko, Y., Stepashko, V., 2018.Metamodeling and Metalearning Approaches in Inductive Modelling Tools. Preprint. https://easychair.org/publications/preprint/6L1W.
20. Stepashko, V., Bulgakova, O., Zosimov, V. "Construction and Research of the Generalized Iterative GMDH Algo-rithm with Active Neurons". In: Advances in Intelligent Systems and Computing II / N. Shakhovska, V. Stepashko, Editors, AISC book series, v. 689, Berlin: Springer, 2017, pp. 474–491. https://doi.org/10.1007/978-3-319-70581-1_35.

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МЕТАНАВЧАННЯ ЯК ОДНА З ЗАДАЧ МАШИННОГО НАВЧАННЯ

Вступ. Сьогодні кожного з нас оточує велика кількість пристроїв, які полегшують нам взаємодію з зовнішнім середовищем. Все більше своїх функцій людина намагається передати комп'ютеру, смартфону та іншим приладам. Практично всі ці пристрої використовують методи та засоби машинного навчання. Для розв'язання задач машинного навчання використовують засоби математичної статистики, чисельних методів, методів оптимізації, теорії ймовірностей, теорії графів, а також різні технології роботи з даними в цифровій формі. Використовуючи методи машинного навчання, можна навчити комп'ютер робити речі, на які він не запрограмований, закладаючи в нього знання в певній галузі.

Мета статті — дослідити задачу метанавчання серед задач машинного навчання, використавши отримані результати для розробки системи підтримки прийняття рішень в задачах моделювання та прогнозування складних об’єктів із застосуванням індуктивного підходу.

Результати. Досліджено задачу метанавчання як одну з задач машинного навчання. Виділено основні принципи метанавчання та наведено приклади застосування машинного навчання та метанавчання в реальних задачах. Використовуючи різні метадані, такі як властивості завдання навчання, властивості алгоритму (наприклад, показники ефективності), можна навчитися вибирати, змінювати або поєднувати різні методи навчання для ефективного розв'язання задач навчання.

Огляд показав, що різниця між метанавчанням і традиційним машинним навчанням полягає тільки в обсязі аналізованих даних. Традиційне навчання, також відоме як базове навчання, зосереджено на одній конкретній задачі. На метарівні навчання відбувається перехід від прогнозування стану конкретного об'єкта, до того, який алгоритм є найкращим для прогнозування стану цього об'єкта. Проаналізовано застосування індуктивного підходу при розв’язанні задачі метанавчання та наведено приклади такого застосування.

Висновки. Проведений аналіз показав, що задача метанавчання є удосконаленням досвіду людини при розв'язання задач, які він у вигляді бази знань передає комп’ютеру для того, щоб на основі певних моделей та правил можна було розв'язувати складні задачі машинного навчання. Планується розробка системи прийняття рішень на основі метанавчання для задач моделювання та прогнозування складних об’єктів застосовуючи індуктивний підхід.

Ключові слова: *метанавчання, машинне навчання, індуктивне моделювання, підтримка прийняття рішень.*

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МЕТАОБУЧЕНИЕ КАК ОДНА ИЗ ЗАДАЧ МАШИННОГО ОБУЧЕНИЯ

Цель статьи — исследовать задачу метаобучения как одну из задач машинного обучения и использовать полученные результаты для разработки системы поддержки принятия решений в задачах моделирования и прогнозирования сложных объектов с использованием индуктивного подхода. Проанализировано применение индуктивного подхода при решении задачи метаобучения и приведены примеры такого применения. Анализ показал, что задача метаобучения является усовершенствованием опыта решения задач человека в виде базы знаний, которые он передает компьютеру для того, чтобы тот мог бы решать сложные задачи машинного обучения.

Ключевые слова: метаобучение, машинное обучение, индуктивное моделирование, поддержка принятия решений.