Lobachevskii DML: Towards a Semantic Digital Mathematical Library of Kazan University

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Abstract. The digital mathematical library Lobachevskii DML is one of the national initiatives that have emerged in the past decade in different countries of the world. During this time, the formed technical and organizational conditions allowed making mathematicians' dreams of a global World Digital Mathematical Library (WDML) a reality. Following the vision approved by the International Mathematical Union, we started the Lobachevskii DML project in 2017 – the year of the 225-th anniversary of the birth of the brilliant mathematician Nikolai Ivanovich Lobachevskii, the founder of non-Euclidean geometry, the rector of the Kazan University. The main task of Lobachevskii DML project is the development of tools for managing mathematical content, which take into account not only the specifics of mathematical texts, but also the features of processing Russian-language texts. A particular task of creating this digital library is the integration of mathematical resources of Kazan University. Therefore, the original goal of the project was to build up a sound basis for a digital archive comprising the relevant mathematical literature published for 213 years of the existence of Kazan University and stored in the libraries of the University and Kazan. According to our assumption, the digital library Lobachevskii DML should be endowed with all conceivable necessary functions and services, making it a comprehensive and up-to-date live DML, generally respected and used by the local as well as the global mathematical community. From the very beginning, we had in mind that the Lobachevskii DML should constitute a building block for the envisioned global WDML.

In this paper, the results of the implementation of the digital mathematical library Lobachevsky-DML are presented. We describe the purpose of creating this digital library, methods of managing mathematical content based on semantic technologies. The following show how Lobachevskii DML interacts with the information systems of scientific journals. We also present a system of services to support the life cycle of a mathematical document and highlight technologies for supporting new forms of scientific publications and providing integration services with other digital mathematical archives and libraries.

Keywords: semantic technologies, semantic publishing, digital mathematics library, DML, World Digital Mathematics Library (WDML) project, Lobachevskii DML

Introduction

The creation and development of specialized digital libraries (DL) are one of the directions for the formation of a global scientific infrastructure. In the field of mathematics, the problems of integrating knowledge obtained over the entire "printed" period of the development of this science have been considered in a number of projects (see, for example, [1]). Even when such projects were of a local nature, the methods and tools developed during their implementation were oriented towards a comprehensive integration of knowledge (see, for example, [2–4]).

The modern vision of the tasks of forming a global infrastructure of mathematical knowledge is reflected in the documents of the World Digital Mathematics Library (WDML) project [5]. In these documents, it was noted that the leading role in the formation of digital mathematical collections, the accompaniment of their metadata (annotations, key words, etc.) is given by the "smaller" DML.

The present work is devoted to the presentation of Lobachevskii Digital Mathematics Library (Lobachevskii DML, http://www.Lobachevskii-dml.ru/), which we develop in accordance with the basic principles of WDML. The digital mathematical library Lobachevskii DML is another of the national initiatives that have emerged in the past decade in different countries of the world. During this time, the formed technical and organizational conditions allowed making mathematicians' dreams of a global WDML a reality. Following the vision approved by the International Mathematical Union, we started the Lobachevskii DML project in 2017 – the year of the 225-th anniversary of the birth of the brilliant mathematician Nikolai Ivanovich Lobachevskii, the founder of non-Euclidean geometry, the rector (from 1827 to 1845) of the Kazan University. The year 2017 was announced at the Kazan University of as the "Year of N. I. Lobachevskii".

The main task of Lobachevskii DML project is the development of such tools for managing mathematical content, which take into account not only the specifics of mathematical texts, but also the features of processing Russian-language texts. A particular task of creating this digital library is the integration of mathematical resources of Kazan University. Therefore, the original

goal of the project was to build up a sound basis for a digital archive comprising the relevant mathematical literature published for 213 years of the existence of Kazan University and stored in the libraries of the University and Kazan. According to our assumption, the digital library Lobachevskii DML should be endowed with all conceivable necessary functions and services, making it a comprehensive and up-to-date live DML, generally respected and used by the local as well as the global mathematical community. From the very beginning, we had in mind that the Lobachevskii DML should constitute a building block for the envisioned global WDML.

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1 Information Systems in Mathematics

Since inception of the first scientific information systems, the community of mathematicians has been involved in the full cycle of developing such systems, from basic idea to full-scale implementation. Well-known examples are an open source system TeX [6] and commercial systems Wolfram Mathematica and WolframAlpha [7, 8]. With the help of communities of mathematicians, tools for mathematical content management are also actively developed. Examples are MathJax system by American Mathematical Society, information system Math-Net.Ru (http://www.mathnet.ru), developed at the Steklov Mathematical Institute of the Russian Academy of Sciences, and the collection of publicly available preprints arXiv.org (https://arxiv.org/). Now one of the largest digital mathematical libraries is Mizar (http://www.mizar.org/). This is a collection of papers prepared in the Mizar system of formal language, containing definitions, theorems and proofs [9, 10]. Mizar is one of the pioneering systems for mathematics formalization, which still has an active user community. The project has been in constant development since 1973.

At present, scientific research in the field of mathematics is increasingly associated with the use of modern information technologies (cloud, semantic technologies, etc.). These technologies are used in research conducted by distributed scientific groups, the preparation and dissemination of mathematical knowledge in electronic form, the formation of mathematical digital libraries and intellectual processing of their contents. Particular attention is paid to creating a single information space by integrating existing and organizing new digital mathematical libraries (DML). Description of existing digital mathematical libraries with the indication of the purposes and principles of their construction, as well as services for managing scientific content is contained in [11]. Implementation and development of digital mathematical libraries are associated with the development of special tools and the continuous improvement of their functionality.

Since the beginning of the 21st century, a number of developers have created information systems for the management of electronic scientific journals. We compared these systems according to the selected criteria [12]. As a result, the OJS system was recognized as the optimal [13]. We successfully implemented this information platform in the journals Lobachevskii Journal of Mathematics (LJM, http://ljm.kpfu.ru/)/), one of the first Russian electronic mathematical journals, and Russian Digital Libraries (http://ojs.kpfu.ru/index.php/elbib). To manage digital content, we also developed a number of tools that automate a whole series of editorial processes. These include, in particular, the choice of recommendations for the selection of reviewers, style validation of author's documents, search tools, article design services, etc. These tools served as the technological basis for the Lobachevskii DML developed by us (see Section 3).

Let us also pay attention to important results related to the formalization of the of mathematical articles representations. For these purposes, specialized formal languages for the presentation of mathematical texts have been developed (see, for example, [14–18]). These technologies are also used to construct a mathematical ontology and create a semantic search service [19–22].

The above, as well as many other implemented mathematical projects paved the way for the realization of a new idea – the creation of the World Digital Mathematical Library (WDML).

The idea of creating a WDML arose in 2002. The initial aim of this project was digitizing the entire set of mathematical literature (both modern and historical), link it to the present literature, and make it clickable (see [1, 23–28]). As noted in [25], the success of this project and its further impact on mathematics, science and education could be the most significant event after the invention of scientific journals and to become a prototype for a new model of scientific and technical cooperation, a new paradigm for future science in the electronic world. At the same time, the implementation of such a large project will inevitably cause a series of problems. These problems and ways to overcome them were analyzed in [27]. In particular, one of the recommendations was the proposal to develop and coordinate some local projects of creating DML (see ([27, 28]).

Basic plans for the construction of WDML in 2014-2015 were discussed by various mathematical communities and fixed in a number of documents (see [5, 29]). In particular, it was noted that the next step in the development of the WDML project would be building information networks, knowledge-based, which are contained in mathematical publications. Many of the research groups of mathematicians throughout the world took part in the discussion of these ideas, including our group, which represented Kazan University.

In February 2016, in the Fields Institute (Toronto, Ontario) by the Wolfram Foundation, the Fields Institute and the International Mathematical Union working group for the creation WDML, a Seminar on the Semantic Representation of Mathematical Knowledge was organized (https://www.fields.utoronto.ca/Programs/science/15-16/semantic/). Our report on this symposium was devoted to modeling and software solutions in the area of semantic representation of mathematical knowledge [30]. These results correspond to the general ideology of the WDML-project in terms of semantic representation and processing of mathematical knowledge and are a strategic direction of our group's research. In particular, they are connected to the project for the construction of the digital mathematical library Lobachevskii DML, which is described below.

2 Object Approach to the Scientific Digital Content Management

Managing of digital mathematical documents is a unique and complex task. This is due both to the processing of mathematical formulas and to the specific structure of a mathematical document consisting of a logically connected sequence of definitions, theorems, proofs and references. The key idea identified in the WDML project documents is the development of object classes for adequate description and research of mathematical content: a new paradigm for representing digital mathematical content based on elements (classes) and their interrelations is proposed. The selection of classes of mathematical objects and the formation on their basis of ontologies of knowledge areas will allow creating new tools for processing information, in particular, extracting and processing formulas, searching for similar results, and so on.

In our works [31–33], methods of structural analysis of mathematical documents and the selection of objects from them are proposed. In [22, 34], the digital ecosystem OntoMath is described, consisting of ontologies, text analytics tools and applications, designed to control mathematical knowledge. Semantic annotation of mathematical texts is based on the ontology constructed within the framework of the Mocassin project, and ontology of professional mathematics OntoMathPRO [35]. An important application developed on the basis of these ontologies is a special software platform for preparing a mathematical set of related data for publication in the LOD cloud. Another important tool is the semantic search service by mathematical formulas [34]. Another application of the OntoMath ecosystem is a recommendation system for collections of physical and mathematical documents. In particular, for a given document based on selected objects of mathematical knowledge, this system allows you to create a list of "similar" documents (see [36]). These tools are included in the services of the Lobachevskii DML.

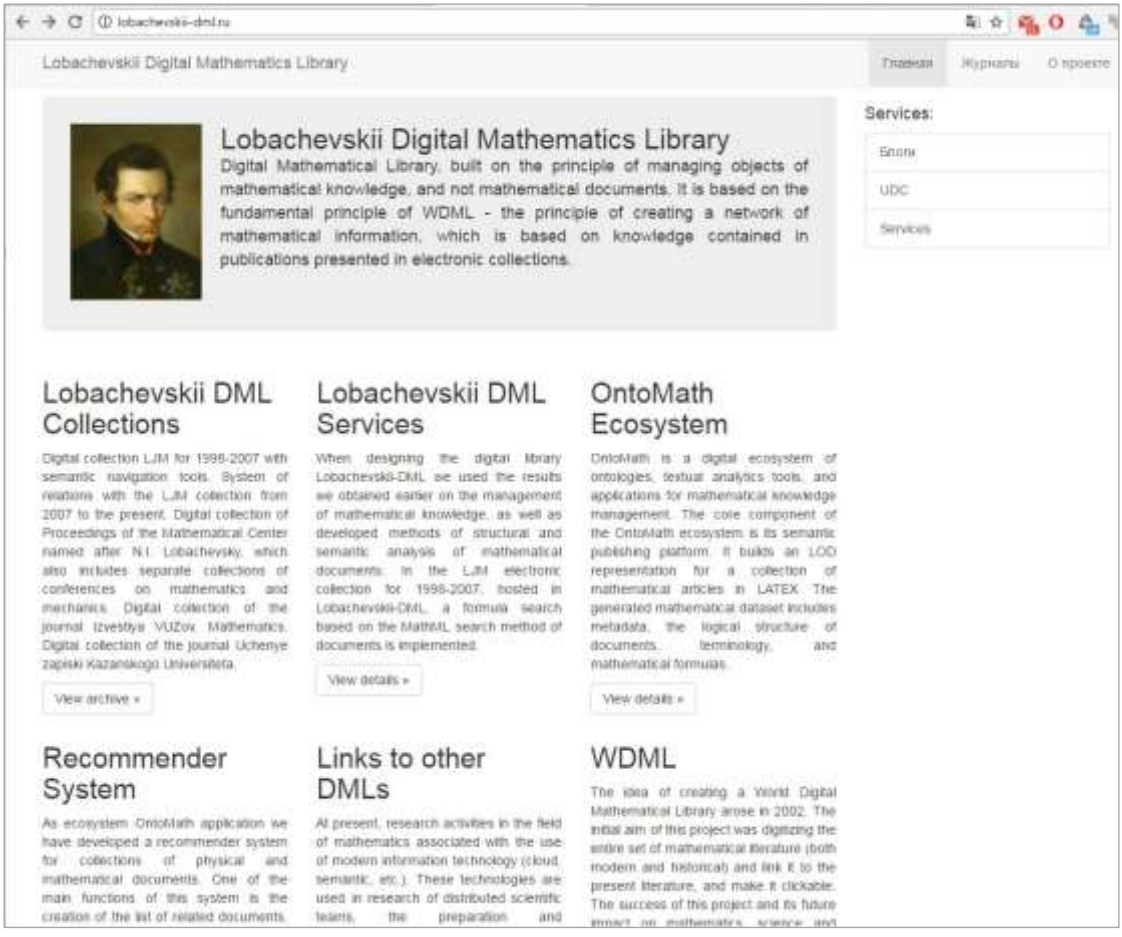

Figure 1 The Lobachevskii DML main page

3 Content, Structure and Services of Lobachevskii DML

3.1 Content and structure of the digital library

Mathematical literature that has been published in Kazan University for more than two centuries of its existence is fairly varied. All these publications have been fully preserved in Scientific Library of Kazan University. The Great Russian scientist N. I. Lobachevskii played a great role in the development of this library. In 1825, he was elected a librarian and managed the library until 1835, combining these duties with the duties of the rector. With him, the scientific foundations of the collection of Library funds were laid, the compilation of single catalogs began, Library has become public, accessible to residents of the city, and a special building was erected for it. Today our library is named after N. I. Lobachevskii. With nearly 6 million publications, it is one of the largest libraries in Russia.

The main goal of creating the Lobachevskii DML was to not only create an archive of specialized literature for mathematics researchers, but also to form an open extensive mathematical library for a wide range of users, possessing a wide range of information processing tools, including search tools. Of course, the basis of the Lobachevskii DML were research journals, as well as selected conference materials and monographs. The main emphasis in the selection of documents was made on the relevance and scientific novelty of materials included in the library.

The informational basis of digital collections in the Lobachevskii DML was printed mathematical books prepared at the Kazan University. At first, these editions were translated into digital format: the result of scanning was a set of pdf-files containing articles from scientific journals, proceedings of conferences, and monographs.

Scientific journals are not only the most important section of the generated DML, but also collections, the easiest to process in DML, because these articles have a uniform structure and a standard set of metadata.

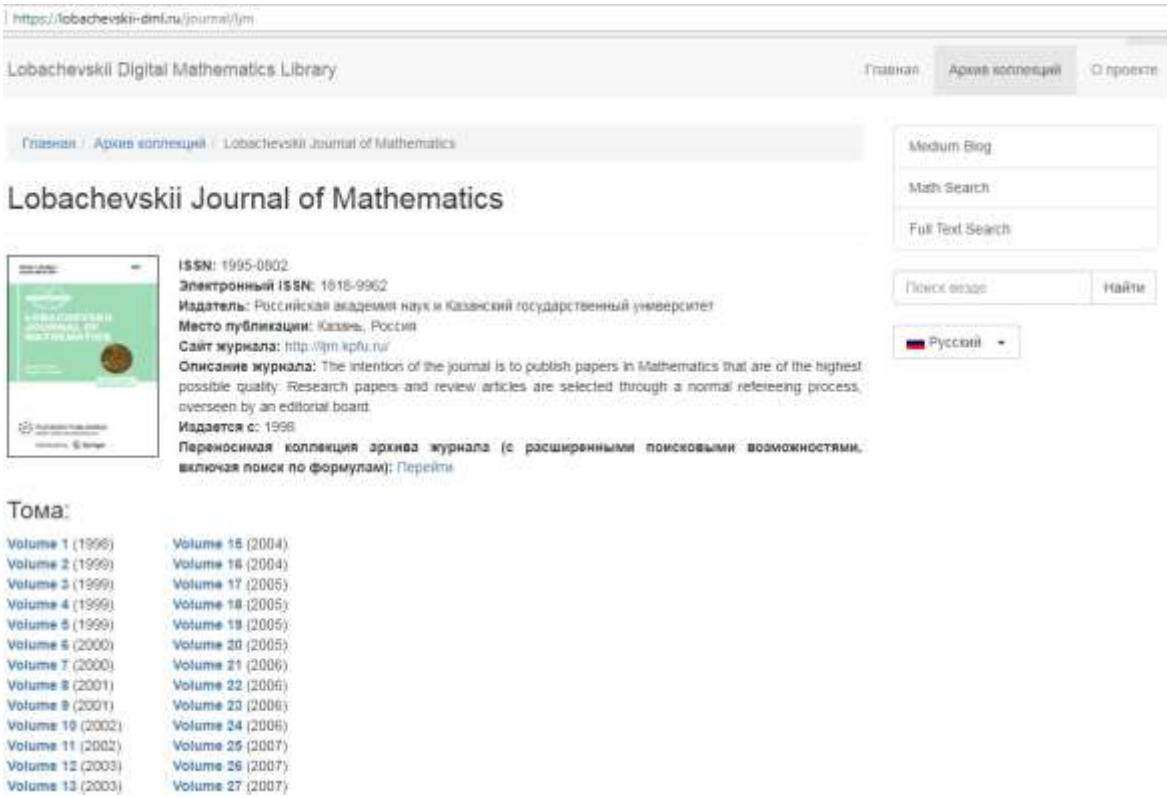

Figure 2 The page of LJM with MathML search tools

Lobachevskii DML structure is as follows:

- the digital collection of articles from the Lobachevskii Journal of Mathematics for 1998–2007 with semantic navigation tools, including search by formulas (see [14]); all the documents of this collection have been translated into the MathML-format (Figure 2);
- the digital collection of LJM articles from 2007 to the present, published by Pleades Publishing LTD and distributed by Springer Science+Business Media LLC;
- the digital collection "Proceedings of the N. I. Lobachevskii Mathematical Center" including materials of international conferences on mathematics and mechanics;
- the digital collection of articles from the journal "Russian Mathematics (Iz. VUZ)";
- the digital collection of articles from the journal "Uchenye Zapiski Kazanskogo Universiteta. Seriya Fiziko-Matematicheskie Nauki (Proceedings of Kazan University. Physics and Mathematics Series).

The digital collections of Lobachevskii DML are shown in Figure 3.

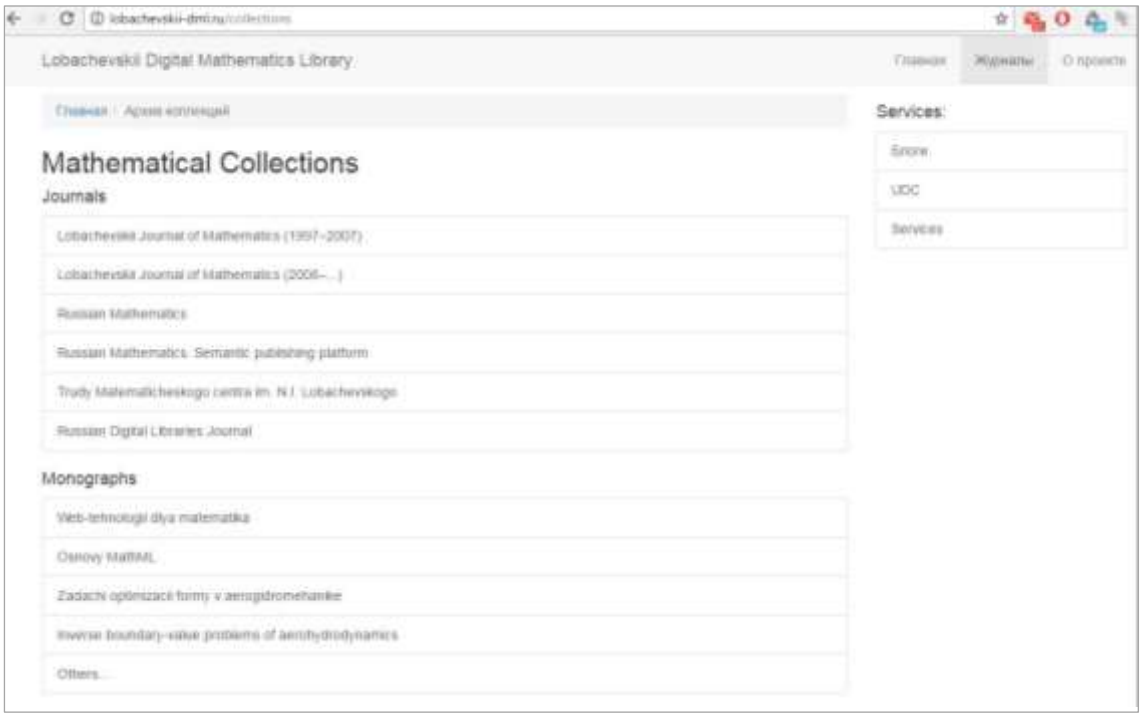

Figure 3 Mathematical collections (https://lobachevskii-dml.ru/collections/)

3.2 Services of Lobachevskii DML

When designing Lobachevskii DML, we used the results we obtained earlier on the management of mathematical knowledge, as well as the developed methods of structural and semantic analysis of mathematical documents [22, 31–36].

For the semantic presentation of documents included in the digital library Lobachevskii DML, we developed an XML-language consisting of a set of tags; the rules for filling them in the form of DTD and XML Schema (see [14]). The XML-file describing each collection of scientific documents was formed in several stages. Each of them assumed the development of a special software tool that eliminates or simplifies the manual processing of a set of digitized documents [31–33, 37, 38]. This XML-file was supplemented with a bibliographic description of the articles contained in the digitized edition (data on the journal number, the title of the conference proceedings, etc.) were added. The most difficult task in this case was the selection of a range of pages for each article included in the publication. Based on the described information, the general file of the processed edition in automatic mode was divided into files containing information about a separate article. Then, in the XML-file that characterizes the collection as a whole, a link to the file describing the article was added.

One of the new search services implemented in Lobachevskii DML is OntoMath Formula Search Engine (http://lobachevskii-dml.ru:8890/mathsearch/). It is a single-page web application that interacts through the SPARQL endpoint with a semantic view of publications using OpenLink Virtuoso (https://virtuoso.openlinksw.com/). This semantic representation is constructed using a semantic publication platform [34]. OntoMath Formula Search finds mathematical formulas containing variables that denote a given mathematical concept. The search is performed in the collection of mathematical documents presented in Lobachevskii DML (Figure 4).

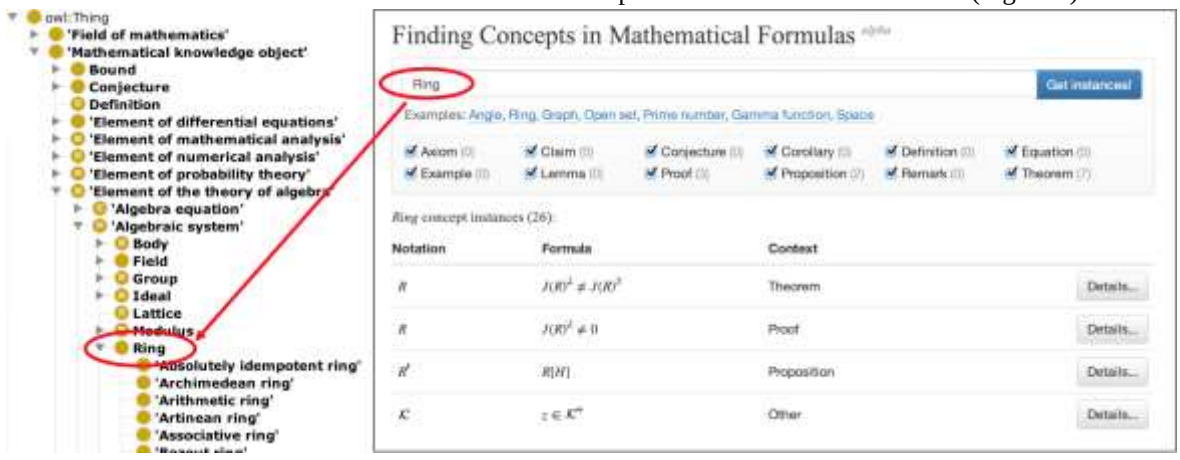

Figure 4 OntoMathPRO Search User Interface

Currently, a new environment of scientific and educational activities is being actively formed, based on the use of Internet technologies. In this regard, along with traditional forms of scientific exchange, focused mainly on printed publications or their electronic versions, new forms of scientific communications are emerging. As the most notable, we note digital presentations as a necessary attribute of reports at scientific conferences, scientific forums and blogs, electronic preprints, webinars and video lectures [39].

The Internet activity of a scientist, often considered as his duty (see, for example, [40]), involves the involvement of all possible means of communication. The use of new forms of scientific exchange should not violate the established traditions of the scientific community, providing for the evaluation of scientific work in the form of peer review, citation system, etc. Consequently, a scientific document of any form should have a bibliographic description and a set of metadata. For example, for "live publications" it is suggested to include in the description the date of the last edition [41]. A successful example of the implementation of the "live publications" model is the Stanford Philosophical Encyclopedia (https://plato.stanford.edu/). All the articles of this encyclopedia were written by specialists in the relevant disciplines and passed the review procedure. The authors maintain the articles up-to-date, periodically updating them. Each new update of the article again undergoes a review procedure, and the history of the publication versions is maintained (it is possible to refer to both the last and any of the previous versions of the article).

Another means of supporting the Internet activity of a scientist are blogs (see, for example, [42, 43]). An example is the blog of modern mathematician Stephen Wolfram (http://blog.stephenwolfram.com/). Another example is the WDML project blog (https://blog.wias-berlin.de/ imu-icm-panel-wdml/). Blogs can be used as a means of organizing open scientific peer review. Such a review, in addition to the traditional one, avoids conflicts of interest and draws a wider circle of experts to the examination. One of the types of open peer review is crowdsourcing-review, in which any representative of the scientific community can take part in the review process.

4 Conclusion

A new digital mathematical library Lobachevskii DML is presented. It is organized based on object management, which corresponds to the paradigm of the World Digital Mathematics Library project. The services for managing mathematical knowledge, implemented in Lobachevskii DML, are described.

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