

Digital ecosystem ontomath: Mathematical knowledge analytics and management

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Abstract

© Springer International Publishing AG 2017. A mathematical knowledge management technology is discussed, its basic ideas, approaches and results are based on targeted ontologies in the field of mathematics. The solution forms the basis of the specialized digital ecosystem OntoMath which consists of a set of ontologies, text analytics tools and applications for managing mathematical knowledge. The studies are in line with the project aimed to create a World Digital Mathematical Library whose objective is to design a distributed system of interconnected repositories of digitized versions of mathematical documents.

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Keywords

Digital libraries, DML, Formula search, Information retrieval, Linked data, Mathematical content search, Ontology, OntoMath, Semantic search, WDML, World digital mathematical library

References

- [1] Knuth, D.E.: The TeX Book. Addison-Wesley Publishing Company, Reading (1986)
- [2] Wolfram, S.: A New Kind of Science. Wolfram Media Inc., Champaign (2002)
- [3] Wolfram, S.: An Elementary Introduction to the Wolfram Language. Wolfram Media Inc., Champaign (2015)
- [4] Chebukov, D.E., Izaak, A.D., Misurina, O.G., Pupyrev, Y.A., Zhizhchenko, A.B.: Math-Net.Ru as a digital archive of the russian mathematical knowledge from the XIX century to today. In: Carette, J., Aspinall, D., Lange, C., Sojka, P., Windsteiger, W. (eds.) CICM 2013. LNCS (LNAI), vol. 7961, pp. 344–348. Springer, Heidelberg (2013). doi: 10.1007/978-3-642-39320-4_26
- [5] Carette, J., Farmer, William M.: A review of mathematical knowledge management. In: Carette, J., Dixon, L., Coen, C.S., Watt, Stephen M. (eds.) CICM 2009. LNCS (LNAI), vol. 5625, pp. 233–246. Springer, Heidelberg (2009). doi: 10.1007/978-3-642-02614-0_21
- [6] Lange, C.: Ontologies and languages for representing mathematical knowledge on the semantic web. Semant. Web 4(2), 119–158 (2013). doi: 10.3233/SW-2012-0059
- [7] Ion, P.D.F.: Mathematics and the world wide web. In: Carette, J., Aspinall, D., Lange, C., Sojka, P., Windsteiger, W. (eds.) CICM 2013. LNCS (LNAI), vol. 7961, pp. 230–245. Springer, Heidelberg (2013). doi: 10.1007/978-3-642-39320-4_15
- [8] Kohlhase, M.: Mathematical knowledge management: transcending the one-brain-barrier with theory graphs. Newslett. Eur. Math. Soc. 92, 22–27 (2014)
- [9] Elizarov, A., Kirillovich, A., Lipachev, E., Nevzorova, O., Solovyev, V., Zhiltsov, N.: Mathematical knowledge representation: semantic models and formalisms. Lobachevskii J. Math. 35(4), 347–353 (2014). doi: 10.1134/S1995080214040143
- [10] Naumowicz, A., Korniłowicz, A.: A brief overview of M. In: Berghofer, S., Nipkow, T., Urban, C., Wenzel, M. (eds.) TPHOLs 2009. LNCS, vol. 5674, pp. 67–72. Springer, Heidelberg (2009). doi: 10.1007/978-3-642-03359-9_5

- [11] Bancerek, G., Byliński, C., Grabowski, A., Korniłowicz, A., Matuszewski, R., Naumowicz, A., Pak, K., Urban, J.: Mizar: state-of-the-art and beyond. In: Kerber, M., Carette, J., Kaliszyk, C., Rabe, F., Sorge, V. (eds.) CICM 2015. LNCS (LNAI), vol. 9150, pp. 261–279. Springer, Cham (2015). doi:10.1007/978-3-319-20615-8_17
- [12] Elizarov, A.M., Lipachev, E.K., Malakhaltsev, M.A.: Web technologies for mathematicians: the basics of MathML. In: A Practical Guide. Fizmatlit, Moscow (2010). (in Russian)
- [13] Kohlhase, M.: An Open Markup Format for Mathematical Documents (Version 1.2). LNAI, vol. 4180. Springer, Heidelberg (2006). <http://omdoc.org/pubs/omdoc1.2.pdf>
- [14] Iancu, M., Kohlhase, M., Rabe, F., Urban, J.: The mizar mathematical library in OMDoc: translation and applications. *J. Autom. Reason.* 50(2), 191–202 (2013). Springer
- [15] Kohlhase, M.: Semantic Markup in TeX/LaTeX. <http://ctan.altspu.ru/macros/latex/contrib/stex/sty/stex/stex.pdf>
- [16] Dehaye, P.-O., et al.: Interoperability in the OpenDreamKit project: the math-in-the-middle approach. In: Kohlhase, M., Johansson, M., Miller, B., de Moura, L., Tompa, F. (eds.) CICM 2016. LNCS (LNAI), vol. 9791, pp. 117–131. Springer, Cham (2016). doi: 10.1007/978-3-319-42547-4_9
- [17] Elizarov, A.M., Kirilovich, A.V., Lipachev, E.K., Nevzorova, O.A.: Mathematical knowledge management: ontological models and digital technology. In: CEUR Workshop Proceedings, vol. 1752, pp. 44–50 (2016). <http://ceur-ws.org/Vol-1752/paper08.pdf>
- [18] Staab, S., Studer, R. (eds.): Handbook on Ontologies. Springer, Heidelberg (2003). (Republished in 2009)
- [19] Briscoe, G., De Wilde, P.: Digital ecosystems: evolving service-oriented architectures. In: Conference on Bio Inspired Models of Network, Information and Computing Systems. IEEE Press (2006). arXiv:0712.4102v6. <https://arxiv.org/pdf/0712.4102v6.pdf>
- [20] Digital Ecosystem Convergence between IT, Telecoms, Media and Entertainment: Scenarios to 2015. http://www3.weforum.org/docs/WEF_DigitalEcosystem_Scenario2015_ExecutiveSummary_2010.pdf
- [21] Amritesh, C.J.: Digital ecosystem for knowledge, learning and exchange: exploring socio-technical concepts and adoption. In: Basile Colugnati, F.A., et al. (eds.) OPAALS 2010. LNICST, vol. 67, pp. 44–61. Springer, Heidelberg (2010)
- [22] David, C., Ginev, D., Kohlhase, M., Corn, J.: eMath 3.0: building blocks for a social and semantic Web for online mathematics & elearning. In: Mierluş-Mazilu I. (ed.) Proceedings of the 1st International Workshop on Mathematics and ICT: Education, Research and Applications, pp. 13–23. Conpress, Bucureşti (2010). <http://kwarc.info/kohlhase/pmalog10.pdf>
- [23] David, C., Ginev, D., Kohlhase, M., Matican, B., Mirea, S.: A framework for semantic publishing of modular content objects. In: CEUR Workshop Proceedings, vol. 721, pp. 1–12 (2011). <http://ceur-ws.org/Vol-721/paper-03.pdf>
- [24] Kohlhase, M., Cornelii, J., David, C., Ginev, D., Jucovschi, C., Kohlhase, A., Lange, C., Matican, B., Mirea, S., Zholudev, V.: The planetary system: web 3.0 & active documents for STEM. In: Sato, M., Matsuoka, S., Sloot, P.M., Dick Albada, G., Dongarra, J. (eds.) Procedia Computer Science (4) (Special issue: Proceedings of the International Conference on Computational Science), pp. 598–607. Elsevier (2011)
- [25] Bouche, T.: Digital mathematics libraries: the good, the bad, the ugly. *Math. Comput. Sci.* 3(3), 227–241 (2010). doi:10.1007/s11786-010-0029-2
- [26] Sylwestrzak, W., Borbinha, J., Bouche, T., Nowinski, A., Sojka P.: EuDML – towards the European digital mathematics library. In: Sojka P. (ed.) Towards a Digital Mathematics Library. Paris, 7–8 July 2010, pp. 11–26. Masaryk University Press, Brno (2010). http://dml.cz/bitstream/handle/10338.dmlcz/702569/DML_003-2010-1_5.pdf
- [27] Bouche, T.: Towards a World Digital Library: Mathdoc, Numdam and EuDML Experiences. UMI, La Sapienza, Roma (2016). <http://www.mat.uniroma1.it/sites/default/import-files/biblioteca/SEMINARIO2016/bouche.pdf>
- [28] Elizarov, A., Lipachev, E., Zuev, D.: Mathematical content semantic markup methods and open scientific e-journals management systems. In: Klinov, P., Mouromtsev, D. (eds.) KESW 2014. CCIS, vol. 468, pp. 242–251. Springer, Cham (2014). doi:10.1007/978-3-319-11716-4_22
- [29] Elizarov, A.M., Zuev, D.S., Lipachev E.K.: Open scientific e-journals management systems and digital libraries technology. In: CEUR Workshop Proceedings, vol. 1108, pp. 102–111 (2013). <http://ceur-ws.org/Vol-1108/paper13.pdf>
- [30] Elizarov, A.M., Zuev, D.S., Lipachev, E.K.: Infrastructure of electronic scientific journal and cloud services supporting lifecycle of electronic publications. In: CEUR Workshop Proceedings, vol. 1297, pp. 156–159 (2014). http://ceur-ws.org/Vol-1297/156-159_paper-23.pdf
- [31] Elizarov, A.M., Zuev, D.S., Lipachev, E.K.: Electronic scientific journal management systems. *Sci. Tech. Inf. Process.* 41(1), 66–72 (2014). doi:10.3103/S0147688214010109
- [32] Elizarov, A.M., Zuev, D.S., Lipachev, E.K., Malakhaltsev, M.A.: Services structuring mathematical content and integration of digital mathematical collections at scientific information space. In: CEUR Workshop Proceedings, vol. 934, pp. 309–312 (2012). <http://ceur-ws.org/Vol-934/paper47.pdf>

- [33] Elizarov, A.M., Lipachev, E.K., Haidarov, S.M.: Automated processing service system of large collections of scientific documents. In: CEUR Workshop Proceedings, vol. 1752, pp. 58– 64 (2016). <http://ceur-ws.org/Vol-1752/paper10.pdf>
- [34] Jackson, A.: The digital mathematics library. Not. AMS 50(4), 918–923 (2003). <http://www.ams.org/notices/200308/comm-jackson.pdf>
- [35] The Digital Mathematical Library Project. Status, August 2005. <http://www.math.uiuc.edu/~tondeur/DML04.pdf>
- [36] Digital Mathematics Library: a Vision for the Future. International Mathematical Union (2006). http://www.mathunion.org/fileadmin/IMU/Report/dml_vision.pdf
- [37] Tondeur, P.: WDML: the world digital mathematics library. The evolution of mathematical communication in the age of digital libraries. In: IMA Workshop, December 8–9 (2006). http://www.math.uiuc.edu/~tondeur/WDML_IMA_DEC2006.pdf
- [38] Pitman, J., Lynch, C.: Planning a 21st century global library for mathematics research. Not. AMS 61(7), 776–777 (2014). <http://www.ams.org/notices/201407/rnoti-p776.pdf>
- [39] Developing a 21st century global library for mathematics research. Washington, D.C.: The National Academies Press, Washington, D.C. (2014). arxiv.org/pdf/1404.1905, <http://www.nap.edu/catalog/18619/developing-a-21st-century-global-library-for-mathematics-research>
- [40] Olver, P.J.: The world digital mathematics library: report of a panel discussion. In: Proceedings of the International Congress of Mathematicians, 13–21 August 2014, Seoul, Korea, Kyung Moon SA, vol. 1, pp. 773–785 (2014)
- [41] Elizarov, A.M., Zhiltsov, N.G., Kirillovich, A.V., Lipachev, E.K., Nevzorova, O.A., Solovyev, V.D.: The OntoMath ecosystem: ontologies and applications for math knowledge management. In: Semantic Representation of Mathematical Knowledge Workshop, 5 February 2016. <http://www.fields.utoronto.ca/video-archive/2016/02/2053-14698>
- [42] Todeschini, R., Baccini, A.: Handbook of Bibliometric Indicators: Quantitative Tools for Studying and Evaluating Research. Wiley-VCH Verlag (2016)
- [43] Nevzorova, O.A., Birialtsev, E.V., Zhiltsov, N.G.: Mathematical text collections: annotation and application for search tasks. Sci. Tech. Inf. Process. 40(6), 386–395 (2013)
- [44] Nevzorova, O., Zhiltsov, N., Zaikin, D., Zhibrik, O., Kirillovich, A., Nevzorov, V., Birialtsev, E.: Bringing math to LOD: a semantic publishing platform prototype for scientific collections in mathematics. In: Alani, H., et al. (eds.) ISWC 2013. LNCS, vol. 8218, pp. 379–394. Springer, Heidelberg (2013). doi:10.1007/978-3-642-4135-3_24
- [45] Kamareddine, F., Wells, J.B.: Computerizing mathematical text with mathlang. Electron. Notes Theor. Comput. Sci. 205, 5–30 (2008)
- [46] Solovyev, V., Zhiltsov, N.: Logical structure analysis of scientific publications in mathematics. In: Akerkar, R. (ed.) Proceedings of the International Conference on Web Intelligence, Mining and Semantics (WIMS 2011), vol. 21, pp. 1–9. ACM DL (2011). doi: 10.1145/1988688.1988713
- [47] OWL 2 Web Ontology Language. RDF-Based Semantics (Second Edition). W3C Recommendation 11 December 2012. <https://www.w3.org/2012/pdf/REC-owl2-rdf-based-semantics-20121211.pdf>
- [48] Nevzorova, O., Zhiltsov, N., Kirillovich, A., Lipachev, E.: OntoMath ontology: a linked data hub for mathematics. In: Klinov, P., Mouromstev, D. (eds) KESW 2014. CCIS, vol. 468, pp. 105–119. Springer, Heidelberg (2014). doi:10.1007/978-3-319-11716-4_9
- [49] Elizarov, A.M., Lipachev, E.K., Nevzorova, O.A., Solov'ev, V.D.: Methods and means for semantic structuring of electronic mathematical documents. Doklady Math. 90(1), 521–524 (2014). doi:10.1134/S1064562414050275
- [50] Elizarov, A.M., Kirillovich, A.V., Lipachev, E.K., Zhizhchenko, A.B., Zhil'tsov, N.G.: Mathematical knowledge ontologies and recommender systems for collections of documents in physics and mathematics. Doklady Math. 93(2), 231–233 (2016). doi:10.1134/S1064562416020174