

Math Indexer and Searcher Web Interface

Towards Fulfillment of Mathematicians' Information Needs

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Abstract. We are designing and developing a web user interface for digital mathematics libraries called WebMIaS. It allows queries to be expressed by mathematicians through a faceted search interface. Users can combine standard textual autocompleted keywords with keywords in the form of mathematical formulae in \LaTeX or MathML formats. Formulae are shown rendered by the web browser on-the-fly for users' feedback. We describe WebMIaS design principles and our experiences deploying in the European Digital Mathematics Library (EuDML). We further describe the issues addressed by formulae canonicalization and by extending the MIaS indexing engine with Content MathML support.

Keywords: search interface, math-aware search, digital mathematical library, formulae canonicalization, WebMIaS, MIaS, EuDML, MathML.

1 The Need for a Math-Aware Search Interface

Scalable search facilities now have the status of killer application on the web and are in high demand among the users of digital mathematics libraries (DML). There are some papers in DMLs which contain more formulae than words. With this in mind, we are designing and implementing the math-aware search engine, Math Indexer and Search (MIaS) [8] supporting a presentation form of mathematics, since the vast majority of scholarly literature in math has only been available in optically recognized presentation formats.

MIaS has been developed primarily for use in EuDML [1]. Since there is no established math-aware user interface, we were faced with the task of designing and implementing one. To gain acceptance across the wider community of potential DML users, the main design goal was ease of use. Having the entry barrier as low as possible is important for attracting new users.

The only available formulae search which does not have format of sources of documents under control was `LaTeXsearch.com` interface by Springer. It allows only one \LaTeX formula as a query. As the same formula can be written in many ways in \TeX , string hashing is used to match the query with formulae in documents written in \LaTeX . While most mathematicians are used to writing a query in \LaTeX , there are problems with this approach as formulae similarity cannot be defined as a metric on \LaTeX formulae strings. Other qualities of formulae, such as their structure should be taken into

account, as well as textual phrases denoting the content sought. Furthermore, allowing users to type longer \LaTeX formulae with immediate visual feedback simplifies the use.

For EuDML, we have added on-the-fly rendering of math, as autodetected in \LaTeX and MathML formats. We have added facets for searching in different document fields [6]. Most importantly, we have had the privilege of mining EuDML search logs for user search scenarios which has shown how users have striven to find the information they require. For example, an interesting observation was that Content MathML has started to appear in the math search box. New \LaTeX XML converter [4] allows the development of new corpora of math texts with math representation in both Presentation and Content MathML, an example of which is the database available for NTCIR-10 Math Task [5] (100,000 arXiv documents). The most challenging problems have included the normalization of math notations coming from different sources, typically a typed or copy-pasted query, and heterogeneous document formats. Development of a robust math canonicalizer emerged as a must for the success of the new math search paradigm to be supported by the DML search user interface.

2 User Interface for Math Information Retrieval

Users are accustomed to forming search strategies with minimal effort using words as queries for documents represented as bags of words. For EuDML we have designed an advanced search form

<http://eudml.org/search>

to allow faceted searches with one facet designed for inputting math formulae. On

<http://mir.fi.muni.cz/webmias>

we maintain a link to the latest version of the development version of WebMIaS to discuss possible DML users' search migration paths and strategies, and to get feedback from the user community. The WebMIaS search interface in Figure 1 observes several design principles and qualities:

formulae in \TeX . Mathematicians know and use compact \LaTeX math notation. Auto-detection of MathML is also in place. To convert \LaTeX queries into MIaS-supported MathML, we switched the converter from Tralics to \LaTeX XML, which is able to convert the user input into mixed Presentation-Content MathML.

on-the-fly formulae rendering. Formulae rendering allows quick feedback when writing the query—users know what they want when they see it. Robust live rendering of copy-pasted MathML is provided means of MathJax. Users are also warned when writing an invalid \TeX query.

pop-up help. Pop-up windows inform users about the interface.

domain-specific auto-completion. Frequent collocations and terms from the DML domain are suggested for text queries.

facets. Adding facets allows natural filtering (by language, author, . . .) of search results to achieve high precision.

snippets with query coloring. Snippets are shown in hit lists. Matched words and formulae are colored in the snippets for a quicker first look evaluation of the results.

scoring and debugging. Scoring of computed relevance to a query is shown for every hit. In the development interface, one can deduce document score computation.

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WEBMIaS
 MATH INDEXER AND SEARCHER

Match of the following rules

Contains the following formula:

k/H_0^2

Rendered: k/H_0^2

Search using: Search in: Verbose output:

Total hits: 16, showing 1-16. Core searching time: 246 ms Total searching time: 745 ms

[Exact solutions of embedding the 4D Universe in a 5D Einstein manifold](#)
 ... where $\Omega_k = k/H_0^2$ and ... $\Omega_m = C/H_0^2$, and ... Exact solutions of embedding the 4D Universe in a 5D Einstein manifold ... Provided that the induced matter is described by a perfect fluid with density
 score = 1.171408
 f085122.xhtml - cached XHTML

[Giant Vortex Lattice Deformations in Rapidly Rotating Bose-Einstein Condensates](#)
 ... suggesting the vortex density ℓ/R_0^2 to be the dominant factor determining the variation of giant vortex core oscillation frequencies. ... (larger ℓ/R_0^2) the core oscillates rapidly, but with increasing core size the oscillation frequency slows, and approaches the value of the breathing mode, as the size of the giant vortex approaches that of the condensate itself. Giant Vortex Lattice Deformations in Rapidly Rotating Bose-Einstein Condensates ...
 score = 0.5382766
 f076410.xhtml - cached XHTML

[Topological phases and circulating states of Bose-Einstein condensates](#)
 ... $2 \times (v/a_0) \left(\frac{a_0^2}{\lambda} \right) / (a_0 \rho \bar{v})$... $\frac{N_e e}{\rho_0^2} = -\frac{2}{a_0 \rho} \times \frac{1}{\rho_0} \times \left(\frac{a_0}{\lambda_e} \right)^2 \times \frac{e}{a_0^2}$... Topological phases and circulating states of Bose-Einstein condensates ... However, somewhat surprisingly, the realization and the detection of a vortex state ... is the linear charge density along the wire.
 score = 0.29080945
 f027503.xhtml - cached XHTML

[Expansion of a Bose-Einstein Condensate in the Presence of Disorder](#)
 ... $\frac{d}{dt} = \frac{d}{dt} - \frac{v}{c}$... Expansion of a Bose-Einstein Condensate in the Presence of Disorder ... describes the density of the particles in ...
 score = 0.23334973
 f086100.xhtml - cached XHTML

Fig. 1. WebMIaS user interface

Mining the EuDML and WebMIaS query search logs reveals quite different, often contradictory user demands. While some users prefer exact searches of visually remembered formulae, others demand semantic specification of terms representing them. For example, we got a request to constrain a search to $E = mc^2$, where m represents mass. The first request could be fulfilled by an exact Presentation MathML retrieval. However, the latter needed semantic tagging which is usually absent in full-text XMLs and may only be approximated by indexing disambiguated Content MathML.

For testing the search behaviour we indexed 100,000 math papers from the NTCIR-10 Math task [7]. To formulate queries containing math, it emerged that new strategies will have to be developed. It can be expected that it will take some time before math search users learn them. To find the balance between word and math search and between exact, proximity and subtree search, several MIaS indexing parameters have to be set. These parameters differ from collection to collection. Currently set parameters are being evaluated for the current collection.

As MathML created by different content generators such as InftyReader, Tralics, or L^AT_EX_{ML} differ significantly. To prevent the rapid growth of the math index containing mathematical formulae [8], their *canonical representations* with the same meaning need to be chosen and indexed. As the results produced by available normalization tools for MathML were not reliable enough, we concluded that it was necessary to develop our own normalization tool that would become part of both indexing and searching in the (Web)MIaS system [2].

To help us to see the changes made by the normalization tool we are generating HTML reports of its inputs and results. Samples of these reports are available for a DML-CZ paper. The \LaTeX source code of the paper was transformed to XHTML+MathML by several tools. Examples of normalized MathML can be seen for Tralics and \LaTeX XML¹.

When querying using math formulae [3] one has to decide on the *formulae similarity metrics* to allow not only exact formulae matches. Subformulae, formulae expressed in different notation or even similar formulae with different variables need to be considered as hits with lower scores. These metrics are used for weighting similar formulae in documents in the same way that *term frequency* is used for weighting standard word hits.

The link to the WebMIaS interface provided above also shows our development tools that allow us to debug MIaS indexing and querying. With the verbose output enabled, the computation process of document scores can be inspected to see how words and (sub)formulae affect the ranking. The option to take only Presentation MathML, only Content MathML or both into account is also available. Even though Content MathML may give better, semantically related results most of the time, there are cases where visual fidelity is sought and Presentation MathML is preferred.

In addition to the web user interface, it is also possible to use WebMIaS remotely via web services: its general usage is described in the OpenSearch standard. Details of API and WebMIaS OpenSearch description document can be found on the WebMIaS home page above. The web services are particularly useful for remote automated searching, as for example, for the purposes of system evaluation or for a programmable search.

3 Conclusions and Future Work

We have described the WebMIaS math-aware user interface designed to allow searching DMLs with keyword and formulae faceted searching. It has been applied in the EuDML project to the users' satisfaction. Further deployment of the WebMIaS user interface is in preparation for further DMLs as DML-CZ or arXiv.

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