THE WORLD DIGITAL MATHEMATICS LIBRARY: REPORT OF A PANEL DISCUSSION

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Abstract. A summary of the Panel Discussion of the World Digital Mathematics Library held at the 2014 International Congress of Mathematicians in Seoul, South Korea, on August 20, 2014.

1. Introduction

The increasing ubiquity of the World Wide Web in the waning years of the twentieth century inspired the vision of a World Digital Mathematics Library (WDML), containing digitized versions of the entire corpus of mathematical research literature, both contemporary and historical, in a distributed system of interlinked repositories. The unique attributes of mathematics, including the eternal validity of mathematical results and constructions, make the WDML especially compelling. More than just a collection of digitized research papers and books, the WDML will include the abilities to search, link, annotate, index, classify, mine, compute, etc., that will form a wide ranging toolbox of applications that incorporate the desirable features of, but go beyond the current capabilities of MathSciNet, zbMATH, Google Scholar, Wolfram Alpha, etc., and thereby foster the next generation of mathematical research and its manifold applications. Moreover, a commitment to openness, ensuring that the WDML is freely accessible throughout the worldwide research and education communities, lies at the heart of this vision.

The WDML vision was codified by the General Assembly (GA) of the International Mathematical Union (IMU) who, in 2006, endorsed a statement, *Digital Mathematics Library: A Vision for the Future*, [7], of the Committee on Electronic Information and Communication (CEIC) that "... endorses this vision of a distributed collection of past mathematical scholarship that serves the needs of all science, and

The moderator is grateful to James Davenport for taking notes, to Thierry Bouche and Patrick Ion for help with the text, and to the ICM2014 Team for recording the panel session, which can be found on YouTube [13]. A permanently archived version of this video will appear subsequently on the IMU website.

encourages mathematicians and publishers of mathematics to join together in implementing this vision."

While digitization projects gained momentum and scope in the intervening years [21], while a number of "local" initiatives, such as the European Digital Mathematics Library (EuDML) [8], Math-Net.Ru [16], and several country-based DML's (e.g., DML-CZ [5], DML-PL [20], NUMDAM [17]) have demonstrated proof of (at least some aspects of) the concept, and while some of the required software tools are under active development by a number of groups, both academic and commercial, the overall implementation of a truly Global Digital Mathematics Library has remained tantalizingly out of reach. Nevertheless, several recent developments have rekindled expectations that we may at last have both the means and the will to realize the WDML within the near future. These developments include:

On June 1-3, 2012, the CEIC organized a Symposium on *The Future World Heritage Digital Mathematics Library* that was held at the U.S. National Academy of Sciences and involved over 50 participants from throughout the world. The meeting was supported by a grant from the Alfred P. Sloan Foundation. Participants, keynote talks, position statements, panel discussions, breakout sessions and more can all be found on the Conference Wiki [24].

In conjunction with the NAS Symposium, the Sloan Foundation further funded a broad-based committee to write the report *Developing a 21st Century Global Library for Mathematics Research*, that explores the practical mechanisms, challenges, and capabilities that are required for the realization of the WDML. The report was published by the US National Research Council in March, 2014, [6].

On August 17, 2014, in conjunction with the International Congress of Mathematicians in Seoul, South Korea, the IMU and CEIC hosted a meeting of a select group of 21 experts to plan the next practical steps towards the construction of the Global Digital Mathematical Library (GDML). As a result, a smaller eight person working group (WG) under the sponsorship of the IMU, was created. The WG members are Patrick Ion, chair (USA), Thierry Bouche (France), Bruno Buchberger (Austria), Michael Kohlhase (Germany), Jim Pitman (USA), Olaf Teschke (Germany), Stephen Watt (Canada), and Eric Weisstein (USA). The WG is charged with the tasks of designing a road map for the practical next steps towards the GDML, determining its organizational structure, prioritizing the different requirements for its implementation, estimating an incremental budget, both start-up and

sustaining funds, and fostering the writing of proposals to funding organizations, with the goal that these next steps will be realized before the end of 2014.

2. Statements by Panelists

As an outgrowth of the preceding developments, a Panel Discussion on the World Digital Mathematics Library was organized by the CEIC, and held at the 2014 International Congress of Mathematicians in Seoul, South Korea, on August 20, 2014. The invited panelists were:

- Thierry Bouche, Université Joseph Fourier, Grenoble, France
- Ingrid Daubechies, Duke University, USA
- Gert-Martin Greuel, University of Kaiserslautern, Germany
- Patrick Ion, Mathematical Reviews, USA
- Rajeeva Karandikar, Chennai Mathematical Institute, India
- June Zhang, Peking University, China

The moderator was:

- Peter Olver, University of Minnesota, Minneapolis, USA

To focus the panel discussion, the following questions were circulated in advance to the invited panelists and to the audience.

(1) How would you define the WDML?
(2) What is the user base that should be targeted ?
(3) What are the main features expected from a WDML?
(4) In existing systems, what would you identify as good practices (respectively bad practices)?
(5) How can the community engage with existing stakeholders (publishers, societies, universities, funders) so as to keep the central WDML entity lean enough to be sustainable?

The ensuing discussion is summarized below. The proceedings began with short presentations by each panelist in turn, which were then followed by questions and comments from the audience and responses by the panel.

Peter Olver initiated the discussion with some remarks on the vision and history of the WDML, and where we currently stand, summarizing the points outlined in the introduction to the present article. The World Digital Mathematics Library is a vision which started gathering steam in the late 1990's. The IMU signed on as an early proponent of this vision, and a document supporting the WDML prepared by the CEIC was endorsed by the Executive Committee and the General Assembly in 2006, [7]. The basis of the WDML is to have access to the world's mathematical literature, in a *searchable*, *linked*, *computable*,

indexed, etc., form. A variety of relevant resources and background materials can be found on the CEIC portion of the IMU website, [11]. However, there have been some significant advances and initiatives in the last couple of years, and the intent is that this Panel will help set in motion the next steps necessary to the realization of the WDML.

Various regional initiatives exist, and thus prove, to some extent, the overall concept. However, a truly global digital library remains to be realized. In 2012, the CEIC organized a meeting at the U.S. National Academy of Sciences funded by the Sloan Foundation, [24], which was followed by the writing of a report, issued by the US National Research Council in March, 2014 [6]. The meeting on Sunday at ICM2014 and formation of a Working Group mentioned above was summarized; see also Patrick Ion's contribution below. The support and publicizing of this initiative by the mathematical world at large is needed, so that we will be able to go to funding agencies, the community, private foundations, etc. to seek the required support. Indeed, the stars seem to be aligning now, and it would be a shame not to take advantage of the moment.

Ingrid Daubechies began the presentations by commenting that she is very enthusiastic about the prospects for a WDML, and, while not an expert herself, in the remaining months of her Presidency will continue to foster the realization of the WDML vision.

Rajeeva Karandikar then addressed the Panel Briefing questions as follows:

(1) The WDML should aim to be a one-stop virtual location for all the needs of a mathematician as far as literature is concerned — where they can search and retrieve archival material, find researchers currently working on similar subjects, or in other areas in mathematics that use research on a theme of interest.
(2) Research mathematicians and Ph.D. students in mathematics form the initial target user base. Eventually, this will include scientists/engineers using mathematical results for research and development, students, historians, the educated citizen, etc.
(3) The main features expected from a WDML are:
    - Search and retrieval of original content *permanently* available.
    - Provide access at either no cost or minimal cost to the end user/institution.
    - Include journals and research monographs; maybe later other books.

- Provide, to a user, names of people working in an area or who use work in an area.

(4) Not enough exposure to comment, presuming that the question is about existing DML's. There is a plethora of bad practices in the publishing world, but we all know them already.
(5) The goal is to enlist mathematics departments to participate in the setting up of a distributed WDML, and thereby avoid major investment in hardware. Mathematicians need to impress on publishers that things are going to change, whether they like it or not. In particular, publishers will have to adjust to much lower revenues. Once the project gets underway and funding agencies see the benefits, we can then persuade them to help fund the WDML activity going forward.

For this to work, we have to digitize older material and bring it into the digital library. We also need to ensure that henceforth the research work funded by public funds does not end up under the copyright restrictions imposed by commercial publishers.

Further remarks:

- I endorse the statement in yesterday's Publishing Panel, calling on all publishers to allow open access to all papers after at most a five-year window, and hand over the material to the WDML to make it accessible to the community. The IMU should start by setting a deadline (e.g., December 31, 2014) for implementation, after which the community will not co-operate with recalcitrant publishers by declining to submit manuscripts, serve on editorial boards, referee papers, etc.
- The publishing metadata should be openly licensed, and not proprietary to the MathSciNet/Zentralblatt systems as it is at present. The mathematical societies must be convinced to join in the enterprise, and we do not want to lose their support.
- I agree with Ingrid Daubechies' blog post of 2012 that Editorial Boards should become independent societies that then sign licensing agreements with publishers to assume ownership of their journals. It will be hard for one or two individual boards to do this, but acting collectively could put significant pressure on publishers to agree to this new arrangement.
- All new research work should appear on an open archive, under a Creative Commons license. In this way, publishers will no longer have an exclusive control over the material.
- Most of the discussion has been centered on journals, but we should also consider books, especially research monographs.

> Most authors do not write research books for money and would be happy to put their works in the public domain

To quote Peter Olver, [18]: "The time is ripe for a radical rethinking of the traditional academic model for scholarly communication within mathematics. ... If we are not properly engaged, the future will be decided for us and, almost certainly, will not be to our liking."

June Zhang introduced herself as a librarian not a mathematician. She gave an introduction to the China Academic Library and Information System (CALIS), a public information system for higher level teaching and research, which has been funded by the Chinese Government since 1988. Phase 3 (the current phase) is funded with 200M RMB in government support. There are currently 1200+ member libraries and 250+M resources. The principal goals of CALIS are :

- To promote, maintain and improve resource sharing;
- To organize libraries to build the Chinese Academic Digital Library (eduChina);
- To provide information services at a high academic level for teaching and research;
- To extend cooperation nationally and internationally.

CALIS provides seven primary services:

(1) Academic search engine (eDu);
(2) Inter Library Loan and Document Delivery Services (eDe);
(3) Reference Service (eWen);
(4) Union Catalogue Service;
(5) Foreign Language Journals Service;
(6) Imported Database Management;
(7) Training and Certification.

The CALIS digital library system structure has four basic layers:

(1) Basic infrastructure: hosts, servers, database, storage, security, mid-level software;
(2) Resources: knowledge base, databases, reports, courses, bibliographic information, navigation;
(3) Applications: including support applications such as data management and service applications such as document delivery, interlibrary loan, full text service, communication service, etc.;
(4) Digital Library Portal: designed for the end users, who in turn help decide on the desired portal functions.

Standards run through the whole process of constructing the Digital Library, including metadata schema, technical schema, and many interoperability standards. Maintenance of data and systems is the most

important aspect once the library is constructed. Organization and management is another essential long-term component. All service and development of the Digital Library are governed by the CALIS management group in the administrative center in Peking University. CALIS currently contains:

- 140+M books, including 0.25M Chinese language mathematics and 0.1M other language mathematics;
- 228 Chinese Mathematics journals, 1130 other mathematical journals, and 604 open access journals;
- 46M dissertations, including 32,763 Chinese language mathematics and 16,929 other language mathematics

CALIS members contribute all their metadata and holdings information. CALIS cooperates with the Korean Education and Research Information Service (KERIS) and with the Japanese National Center for Science Information System (NACSIS).

Gert–Martin Greuel began by stating that this is a very important panel for the community, and it needs to address difficult details. The panel should talk about mathematical knowledge, which is a very complex system, but still *primarily* based on scientific publications, although software, databases, etc. also exist. Mathematical knowledge may be considered as a continually growing huge building in which it is necessary that each floor is reached and no stone is lost. Thus, unlike other sciences, in mathematical research the literature plays a very important role due to the timeliness and validity of its achievements, that are mainly preserved in the scientific literature. Mathematical knowledge does not become obsolete, so the entire literature must be available to the research mathematician and user of mathematics. The published research literature is the principal component and should be the starting point of a WDML, but this is not all and we should be open to other types of resources in the future.

Further points:

- Much of the literature has been digitized, but this has been done by different sources, commercial and non-commercial, to different standards, and with different licensing conditions.
- We need to think of the architecture for the WDML, which is not just a repository of digitized mathematics, but also semantic tools will be needed later on in more and more sophisticated ways.
- Stephen Wolfram noted that this is a $100M project, and this cannot be done by volunteers. We have to come to grips with the issues of long term maintenance.

- We also have to think about content, e.g. border sciences such as biology, computer science, etc.
- Searching, computing, indexing, linking, and the like will be important.
- There are many commercial copyright interests, who will not give their content for free. We have to engage them, and the best we can hope for is a reasonable moving wall.
- Archiving requires longer term evaluation and design, as well as long-term funding.
- We have to cope with growth of the literature: zbMATH now records 120K items/year; arXiv has an even steeper growth rate with no flattening seen yet.
- High quality and specific metadata, with mathematical search options is important, semantic content analysis, author disambiguation and author profiles.

Recall the IMU/CEIC requirement: Each article should include a separate list of references with links to the indexing databases Mathematical Reviews and Zentralblatt. Mathematical Reference Databases have several advantages:

- provide identifiers for the indexed mathematical literature;
- ensure completeness of the mathematical literature;
- have high quality and well-structured metadata, as well as math-specific search options;
- are restricted to the mathematical literature, and hence have little extraneous noise;
- include semantic content analysis (MSC, keywords, abstract, reviews);
- provide linking of information, e.g., full texts if available, references, etc.;
- provide author disambiguation and author profiles.

Mathematical Reference Databases are also engaged in the development of necessary tools for the WDML and hence can provide core services for the WDML.

- deciding continuously what to index, i.e., what is math literature?
- development of metadata schemes for mathematical publications;
- maintenance of the Mathematics Subject Classification (MSC);
- form pilot partners for the use of the methods for publishing and presenting mathematical knowledge, e.g., use of MathML as presentation format.

Thierry Bouche began with a quote by Jean–Pierre Serre:

> Mathematicians just make their results available to everyone as if they were on shelves waiting to be fetched.

Note that digital libraries don't currently have the good features (well-organized, permanent, etc.) of paper libraries. Digital power tools can, and should, be opening new paths for research and serendipity.

Mathematical validated literature never becomes obsolete. (Old results are not superseded by newer ones: they are their foundation, full proofs are sometimes never written twice!) The mathematical literature is valid only as a whole, building a wide network of references, and useful to other sciences in an asynchronous fashion. The mathematical corpus is the set of all (potentially) referenceable published works. It must be carefully archived, indexed, and preserved, and must be widely accessible over the long term.

We thus need a reference library, which should be

- comprehensive
- up-to-date
- well organized
- long lasting
- widely open
- easy to use for non-mathematicians
- and digital, with power tools opening new paths for research and serendipity!

The European Digital Mathematics Library (EuDML) has finished a three-year 1.6M euro funded project, which has now become a follow-up unfunded consortium under the auspices of the European Mathematical Society (EMS).

In a nutshell, we produced

- A critical mass in content, approximately 6% of the mathematical corpus.
- A cooperation network.
- A math-savvy fully functional digital library, with MathML metadata, math mining, MSC, links to/from math databases.
- A good looking Web site with unique navigation tools adapted to our user community.
- Internal and external deep interlinking, MSC browsing, reference lookup.
- A number of productivity and interoperability devices enabling the main service, some production ready, some more experimental.

- EuDML initiated organizational model and policies, under the strong control of science through EMS.

The three-point EuDML policy is that the content be:

(1) Scientifically validated, and published in final form;
(2) Physically hosted at one of the partner institutions;
(3) Openly accessible after a reasonable moving wall: 0–5 years.

We now understand the basic layer, and scaling from 6% to 30% of Mathematical Corpus is at hand. But the most pressing demand from mathematicians is 100% of the Corpus. The gaps are items that are not digitized, or not professionally digitized, missing item-level metadata, inability to harvest existing metadata, or metadata that the content owner does not agree to provide. All these are surmountable, but require some effort — technical, legal, political — and support from the community [4].

To ensure stability, we need a distributed and replicated physical archive. Correctness matters to us, so it is of high importance to let intelligent agents generate derived mathematical knowledge that would be machine readable for enhancing service (spontaneous crowdsourcing, OCR, structure/semantics recognition, ...) but this process should be transparent to the users and never hide the original, unmodified sources. We are talking of an infrastructure for research that will be the daily working tool of mathematicians worldwide. What is really needed is long-term institutional support just like your university or department library today!

Patrick Ion just retired from near 30 years at Mathematical Reviews. He was heavily involved in TEX, MSC, etc., and served as co-chair of the W3C Math WG that produced the standard MathML, that is now a recognized part of HTML5.

At the first ICM in 1897 there was a session under the chairmanship of Peano concerned with questions of how to encode mathematical knowledge, [22]. Indeed it was in connection with such efforts that Peano developed his axioms for the natural numbers. At the 1928 ICM in Bologna there was active discussion of how to provide comprehensive bibliographic resources for mathematics to everyone [1]. Now the IMU sees the possibility of realizing the current dream of a Global Digital Mathematical Library or World Digital Mathematical Library.

The adjective digital is important here as it is the new digital technologies that allow better access to the resources of mathematical knowledge than ever before. We are in the presence of a transformative technology, and we can capitalize on it to everyone's benefit. I can imagine that in 16th century Europe, or even earlier in 14th

century Korea [10], when printing from metal type was a brand-new technology, people saw the possibilities of the new forms of book for the recording and dissemination of knowledge. That they were right we all now know. That sort of opportunity is open to us again now.

The adjective global is important too. We all think the truths of our subject to be global, independent of location in this world. We think of ourselves as a world-wide community. This is well demonstrated by our being gathered at the ICM from over 120 countries. A GDML can have a global reach as a result of the digital technology mentioned, particularly the internet. It will be a shared global good. We can hope for global support for the idea and expect that there can be contributions to a GDML from all over the world. It will provide benefits all over the world. The earliest mathematical artifact some think to be from Ishango in Congo, [9]; perhaps this GDML can be a help in Africa. But as Adrian Paenza emphasized in his Leelavati Prize lecture at ICM2014, [12], the main goal has to be to offer solutions to problems that the people you serve want solved. We think of ourselves as a world-wide community, so a GDML can have a global reach, thanks to digital technology.

IMU President Ingrid Daubechies and Chair Peter Olver of the IMU's CEIC took the initiative to work toward a WDML or GDML through consultations with a broad expert group. This culminated in comprehensive report from a Workshop at the US National Academy of Sciences, [6]. Now a small working group of eight persons, which I am to chair, has been given the task of making, by the end of this year, concrete proposals for work setting up a GDML. Then resources can be found, so to speak, to virtually break ground on building a GDML.

The GDML WG represents a variety of backgrounds and interests and is about as international as 8 people can be, if where their careers have carried them is taken into account. They are united by a belief that there are opportunities for building a GDML to serve the mathematical community and disseminate mathematical knowledge as widely as it is needed, and by a wish to make that happen starting now. The WG will of course be calling upon the expertise of the community, about the square of 8 in size, that Ingrid Daubechies and Peter Olver have been consulting, as well as on many others. The WG's activities will be reported on through the IMU's CEIC web site and we, of course, will be happy to hear from the community of ideas for services a GDML may provide and what problems it may solve. We expect that realizing a GDML will naturally involve both the academic and industrial mathematical communities and collaboration with those who have served it well for a long time — very importantly the publishing

business world-wide. The WG's goal is to get GDML projects defined and started in comparatively short order.

I see essentially four facets to the GDML initiative:

- Community aspects;
- Literature aspects — relatively well-understood after EuDML's efforts, but essential;
- Knowledge management aspects — less well-understood;
- Administrative aspects — June Zhang has described the scale.

They are all discussed in the NRC report. The WG is to make concrete what's suggested there on all four fronts.

Some parts of a GDML require work that is understood, or already done in part, but that just takes much time and effort to complete. Other parts require serious investigation and prototyping which also takes time, even nowadays, although the general ideas may seem clear. The WG is made up of members who think now is the time to realize the new opportunities for a GDML. We all believe that now is the time to *do* this.

3. Audience Questions and Comments

Following the presentations by the panelists, the audience was given the opportunity to ask questions and make comments.

Marie Farge, France, began by stating that we have given our copyright away. There are different traditions under a variety of national laws: copyright, author right, etc.. The kind of copyright agreements we sign with some publishers are illegal under French law. So we should talk to good lawyers on an international level about this issue, and in this way we can put pressure on the publishers to release the copyrights. Ingrid Daubechies answered that this was duly noted, and that we should involve a very good international lawyers early on.

Mina Teicher, Israel, asked how far back are you going to go — 19th century, 18th, 16th? Several on the Panel answered in principle as far as we can. We should start with the more easily accessed material, e.g. older uncopyrighted material should be more readily available.

Alexey Ustinov, Russia, remarked that many of the digital libraries in Russia, which are very good, are illegal! Gert-Martin Greuel emphasized that everything the WDML does has to be legal.

Gerhard Paseman, USA, asked about the political implications of a WDML. The publishers are very good at lobbying the government, and might influence the funding of mathematics were such a digital library

to affect their business. Ingrid Daubechies replied that in some countries, including US, there are legal obligations to ensure that publicly-funded research is publicly-accessible. Countries are passing laws to ensure this. Paseman replied that that doesn't address the issue. Suppose we had such a library — how would that affect government funding in the future. If the AMS sees a decrease in their revenue as a result, they may ask government only funds those researchers who published with them. Daubechies said the publishers have not seen a decrease in revenue from implementing a moving wall, and Gert-Martin Greuel said that publishers may well profit from implementing a moving wall. Moreover, once a digital library is in place with structured metadata, which is the hard part, and basic services, publishers will be able to make use of that to enhance their own web pages, offer additional services, etc. Peter Olver added that representatives from the US National Science Foundation (NSF) and the German Deutsche Forschungsgemeinschaft (DFG) attended the 2012 NAS Workshop, and were very supportive of the effort.

Gizem Karaali, USA, said that the Mathematical Association of America (MAA), as the result of an initiative by the educational directorate of NSF, created a mathematics digital library, Math-DL, as a component of the National Science Digital Library. Her question was if the WDML is mainly geared towards research, how do you see your work combining with educational needs? Rajeeva Karandikar replied that in the long term the WDML would include educational components, but in the short term the emphasis should be on research. Gert-Martin Greuel brought up the issue of digital identifiers, such as DOI. Lack of digital identifiers for everything makes extending the WDML into educational material much more of a challenge. Marie Farge remarked that something along these lines has already been started in the US.

Thomas Banchoff, USA, former president of the MAA, stated that the MAA has placed all of its publications on JSTOR with a moving wall. JSTOR treats mathematics education as seriously as mathematics research. He then asked how JSTOR fits into the WDML initiative. Gerhard Paseman noted that he has to pay for JSTOR. Peter Olver said that a danger is that JSTOR recopyrights material in that it charges users to access its corpus. Thierry Bouche said that, given the extent of its holdings, if it weren't subscription-based, JSTOR would be close to what we want. On the other hand, it has no mathematics specificity, so that all the enhancements we envision related to mathematical knowledge do not exist on JSTOR. He also remarked that, since the tragic 2013 death of Aaron Swartz, JSTOR has modified its

copyright procedures. Patrick Ion added that JSTOR is very successful at many things. The original mission of JSTOR was to avoid having to construct more library buildings, and the Mellon Foundation decided that the $90 million it provided in funding was the cheaper alternative to the library shelf space people were demanding. However, the mission of JSTOR is very different from the WDML, and the mathematics that they have, while very good, is rather inaccessible, even to those with good subscriptions. While they have a good business model, they aren't a simple model for a GDML. Banchoff asked if this is going to complicate the WDML plans. Ion replied that he didn't think so because JSTOR journals can be redigitized or access can be negotiated with JSTOR or publishers.

Marie Farge asked that, since you want to make it free, what's your business model? Peter Olver answered that, as Stephen Wolfram said in Sunday's meeting, the WDML is a public good, not a business, and so there is no business model. We do, however, need a sustainability model. Thierry Bouche asked what is the business model of your institution's library? There is a lot of money going to university libraries that could go towards the WDML. Gert-Martin Greuel added that this is a difficult question. Having accurate and complete metadata that is secure, archived, etc., could be of interest to commercial publishers, who could help support the WDML consortium to help enhance their own services. Governments could use it to evaluate their own researchers. But we do not want to require Universities to buy subscriptions. Ingrid Daubechies said that there is currently a lot of money going into assembling and providing access to literature through libraries, but there are major challenges for the administrative and community aspects. There are certainly money streams that could be used when it makes sense to everyone. Marie Farge then added that having free access will boost industry, and their demand for mathematics and mathematicians, as well as aiding retired mathematicians and young students.

An unidentified questioner asked whether you can look at other models that exist, iTunes, Napster etc., which are successful in their own way. Patrick Ion agreed and pointed to music indexing services, such as MusicBrainz.org. Peter Olver added that, while the discussion has concentrated on getting access to the mathematical literature, the WDML is more than just a collection of papers, books, etc. and will include applications allowing one to search for theorems and ideas, determine whether something you found is in related to results in an old paper in a different area, various indices of concepts, theorems, formulas, and so on.

Another unidentified questioner then asked how do we follow up on today's Panel? Peter Olver announced that a blog concerning the WDML will be hosted by the CEIC, starting soon after the end of the Congress, and available on the CEIC website [14]. The initiative will require community input and community buy-in. Indeed, without the support of the mathematics community, the WDML will not succeed.

A questioner from Mumbai, India, asked whether the WDML will have some form of quality control. Many open access journals take money from authors to publish and are sheer junk and will publish anything people pay for. Mathematicians shouldn't have to pay for publishing since it brings corruption into the system. The WDML should set up some form of standards. Thierry Bouche replied that this is not an easy question. In EuDML, there is an advisory board linked to the European Mathematical Society which makes an effort to enforcee quality standards, but this is not necessarily perfect. Gert-Martin Greuel added that zbMath and Math Reviews do check for quality every year when deciding which journals to index. This is difficult, but needs to be done. The questioner then asked whether we can put a stop to author-pays journals. Greuel said that zbMath stops indexing substandard journals. Peter Olver recommended the IMU/CEIC produced a document on best practices for journals [3]. This concluded the proceedings.

4. Conclusion

As a result of the Meeting and the Panel, the IMU has initiated a WDML blog [14], to provide a forum for ongoing discussion of the emerging WDML. A key conclusion of the panel discussion, coupled with contemporaneous developments, is that there is now real potential for significant near-term progress on the realization of the WDML.

References

[1] R.C. Archibald, Plans for reviving Bibliotheca Mathematica, in:*Atti del Congresso Internazionale dei Matematici, Bologna 3-10 Settembre 1928*, vol. 6, pp. 473–474; see `http://www.mathunion.org/ICM/ICM1928.6/`

[2] J. Ball and J. Borwein, ACCESS: Who gets what access, when and how?, MSRI Digitizing Mathematics Workshop, 2005. `http://www.mathunion.org/fileadmin/CEIC/Publications/MSRI.pdf`

[3] Best Current Practices for Journals, International Mathematical Union, 2010. `http://www.mathunion.org/fileadmin/CEIC/bestpractice/bpfinal.pdf`

[4] T. Bouche, The Digital Mathematics Library as of 2014, *Notices Amer. Math. Soc.* **61** (2014) 1085–1088.

[5] Czech Digital Mathematics Library, `http://dml.cz`

[6] *Developing a 21st Century Global Library for Mathematics Research*, The National Academies Press, 2014.
[7] Digital Mathematics Library: A Vision for the Future, International Mathematical Union, 2006, http://www.mathunion.org/fileadmin/CEIC/Publications/dml_vision.pdf
[8] The European Digital Mathematics Library, https://eudml.org
[9] http://en.wikipedia.org/wiki/Ishango_bone
[10] http://en.wikipedia.org/wiki/Jikji
[11] http://www.mathunion.org/ceic/resources/icm-2014-panels/
[12] http://www.youtube.com/watch?v=Te4iO6jkuG0
[13] https://www.youtube.com/watch?v=OERXmv2oIyU
[14] The IMU WDML Blog, 2014– , http://blog.wias-berlin.de/imu-icm-panel-wdml/
[15] A. Jackson, The Digital Mathematics Library, *Notices Amer. Math. Soc.* **50** (2003) 918–923.
[16] Math-Net.Ru, http://www.mathnet.ru
[17] NUMDAM: Recherche et téléchargement d'archives de revues mathématiques numérisées, http://www.numdam.org
[18] P.J. Olver, Journals in Flux, *Notices Amer. Math. Soc.* **58** (2011), 1124–1126.
[19] J. Pitman and C. Lynch, Planning a 21st Century Global Library for Mathematics Research, *Notices Amer. Math. Soc.* **61** (2014) 776–777.
[20] The Polish Digital Mathematics Library, http://pldml.icm.edu.pl
[21] U. Rehmann, DML: Digital Mathematics Library, http://www.mathematik.uni-bielefeld.de/∼rehmann/DML/dml_links.html
[22] E. Schröder, Über Pasigraphie, ihren gegenwärtigen Stand und die pasigraphische Bewegung in Italien, in: *Verhandlungen des ersten Internationalen Mathematiker–Kongresses in Zürich vom 9. bis 11. August 1897*, pp. 147-162; see http://www.mathunion.org/ICM/ICM1897/
[23] Some Best Practices for Retrodigization, International Mathematical Union, 2006. http://www.mathunion.org/fileadmin/CEIC/Publications/retro_bestpractices.pdf
[24] Symposium Wiki for The Future World Heritage Digital Mathematics Library, held at National Academy of Sciences, 2012. http://ada00.math.uni-bielefeld.de/mediawiki-1.18.1/index.php/Main_Page

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