INFORMATION SOCIETY TECHNOLOGIES
(IST)
PROGRAMME

Project IST-2001-33562 MoWGLI

Report n. D0.b
First Self-Assessment Report

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Project Acronym: MoWGLI
Project full title: Mathematics On the Web: Get it by Logic and Interfaces
Proposal/Contract no.: IST-2001-33562 MoWGLI

Contents

Note

There is a fair amount of overlapping between this document and the first Project Progress Report. As a consequence several sections are duplicated in both documents.

1 Project Roles and Bodies

The Project has a richly articulated management structure. Following the discussion during the Kick-off meeting in Golm, the main roles have been attributed as follows:

Project Manager Prof.Andrea Asperti, University of Bologna.

Dissem. and Exploit. Manager Prof. Bernd Wegner, Technical University of Berlin.

Work-package Leaders

- **Project Management** A. Asperti (Bologna).
- **State of the art and Req. Analysis** H. Geuvers (Nijmegen).
- **Transformation** C. Sacerdoti Coen (Bologna).
- **Metadata** E. Melis (DFKI).
- **Interfaces** L. Pottier (INRIA)
- **Distribution** M. Kohlhase (DFKI)
- **Testing and Validation** H. Geuvers (Nijmegen)
- **Information Dissem. and Exploit.** B. Wegner (AEI)

The main management bodies are the Project Coordination Committee (PCC) and the Project Exploitation Board (PEB).

The **Project Manager** chairs the PCC. The mandate of the PCC is to represent the Project, report to the Commission, monitor overall performance of the project, ensure accomplishment of the technical objectives, administer project resources and monitor project spending. The PCC is composed by the following people: A. Asperti (chair), M. Kohlhase , H. Geuvers, B. F. Schutz, C. Loiseaux, C. Rideau.

The **Exploitation Manager** chairs the PEB. The PEB is responsible for coordinating dissemination and exploitation activities, promote project visibility and acceptance of project results. The PEB is composed by the following people: B. Wegner (chair), A. Asperti, M. Moschner, H. Geuvers, C. Loiseaux, H. Herbelin.

1.1 Consortium Agreement

The Consortium Agreement has been largely discussed and duly signed on July 15 2002. Due to the absence of major industrial partners in the Consortium, and the no-profit nature of the Project, all partners agreed on a “light”version, proposed by INRIA and already used in the past for other EU-projects with a similar nature and composition.

1.2 Project Meetings

All partners regularly met in internal meetings during the first reporting period. Other meetings have been already planned for the rest of the Project. The following meetings have been held:

Potsdam MoWGLI Spin-off Meeting, 15-17 march 2002.
16 participants, so reparted: UNIBO (2), INRIA (4), DFKI (1), KUN (2), MPG (6), Trusted Logic (1).

Eindhoven 17-19 July 2002.
18 participants, so reparted: UNIBO (4), INRIA (3) DFKI (3), KUN (6), MPG (2).

Saarbrücken , 16-17 December 2002.
15 participants, so reparted: UNIBO (3), INRIA (1) DFKI (6), KUN (4), MPG (1).

Bologna , 18-19 February 2003.
17 participants, so reparted: UNIBO (6), INRIA (3) DFKI (4), KUN (2), MPG (2).

There have been also several personal visits or bilateral meetings among project partners, in particular:

- George Goguadze and Paul Libbrecht (Saarbrücken) visited Bologna on 20-27 June 2002.
- Michael Kohlhase (Saarbrücken) visited Bologna on 25-28 September 2002.
- Claudio Sacerdoti-Coen (Bologna) visited INRIA Sophia-Antipolis on 6-13 July 2002.
- Hanane Naciri (INRIA Sophia-Antipolis) visited Bologna on 11-15 November 2002.
- Michael Kohlhase (Saarbrücken) visited Bologna on February 14-15 2003.

2 Information Flow

In order to enhance the flow of information inside the project, a Web-site, a CVS repository and dedicated mailing-lists have been set up.

2.1 MoWGLI Web-site

Quite an effort has been devoted to the architectural design and implementation of the MoWGLI Web-site (`http://www.mowgli.cs.unibo.it`). Usability and extensibility have been favoured w.r.t. aesthetic principles.

All the gathered information is stored in valid XML files and the Web pages are automatically generated from the XML data by means of XSLT. As a consequence, the DTDs force the consistency and completeness of the entered data and the stylesheets allow to data-mine the stored information in the most effective way, adding new views not conceived when the Web site was designed for the first time. For example, from the list of known events of interest to MoWGLI is easy to automatically extract the list of deadlines, ordered by date.

The site has two main parts, a public one and a private one. The public part contains detailed information on the project workplan, all the already released deliverables and publications and up to date information on all the workshops and conferences of interest to MoWGLI users and developers. The private part (member area) provides on-line archives of the mailing lists, minutes or reports from the MoWGLI meetings, and all the other information that have no public interest.

The state of advancement of the project is easily grasped in the Deliverable section, where all deliverables are listed, and made available in postscript and pdf format upon completion.

2.2 The CVS repository

The Web site is mainly used as a storage of stable, important information. Instead, for the development of the deliverables, our main tool for exchange of information between the participants is the CVS repository, which also has a public read-only area and a private area. This way, not only the final outcome of our work, but also the intermediate steps and important discussions can be recorded and monitored.

Of course the CVS repository is also essential for the collaborative development of all the software components of MoWGLI.

2.3 Mailing Lists

Two mailing lists have been created:

mowgli-dev (`mowgli-dev@cs.unibo.it`). The mowgli-dev mailing list is essentially devoted to technical discussion and development. It is currently composed by 20 members, comprising all developers of the MoWGLI system.

mowgli-adm (`mowgli-adm@cs.unibo.it`). This is a restricted mailing list, devoted to administration.

Both mailing lists and their respective archives are accessible from the MoWGLI Web-site (in a password protected member area). Figure 1 shows the flow of information on the mowgli-dev mailing list during the last year.

	UNIBO	INRIA	DFKI	KUN	MPG	Trusted Logic	Total
march	2	1	1	0	1	0	5
april	4	0	1	1	3	0	9
may	34	6	15	11	10	4	80
june	28	3	18	3	13	0	65
july	44	9	26	8	12	0	99
august	4	1	2	1	1	0	9
septermber	12	2	7	0	4	0	25
october	35	0	17	0	17	4	73
november	10	2	3	4	1	5	25
december	1	1	4	0	4	0	10
january	23	1	11	2	6	0	43
february	6	0	2	1	0	0	9
Total	203	26	107	31	72	13	452

Figure 1: e-mail messages on the mowgli-dev mailing list

The figures in table 1 only account for the global information flow. Bilateral e-mail exchange cannot be traced and documented so easily. However, there has been a lot of bilateral communication between Bologna and INRIA about the exportation module of Task 2.1. Despite the low traffic generated on the mailing list, Trusted Logic contributed as well during this phase, and in many other relevant aspects.

3 Workplan

According to the contractual workplan, the following Workpackages have been activated so far:

WP0 Project Management
WP1 State of the art and Requirements Analysis
WP2 Transformation
WP3 Metadata
WP4 Interfaces
WP7 Information Dissemination and Exploitation

WP1 was meant to be reasonably short; apart from a few topics requiring a deeper analysis (Tasks 1.3-5), this phase was meant to rapidly reach a good level of inter-operability among the different sites.

Most part of the work was based on the possibility to have at our disposal, and as soon as possible, large collections of documents encoded with semantic markup. One strategy we meant to pursue was to import material (e.g. journal articles) written in LaTeX. However, the first prototype of the authoring tool was only scheduled for month 18.

A more rapid way to get meaningful repositories of fully structured mathematical knowledge was by exporting them from the available libraries of Logical Frameworks and Proof Assistants (Task 2.1). This was our **first Milestone**: after six months from the beginning of the project we expected to have a first prototype of the Exportation Module and a first draft of the Document Type Descriptor for the low, logical level.

At this point we meant to start the study of the intermediate format of the information, and the implementation of the stylesheets performing the transformation (tasks T2.2-3). The completion of this work, expected for month 12, was our **second Milestone**.

Our **third Milestone** was the possibility of disposing as soon as possible of good presentational engines for Mathematical Markup (task 4.1).

In parallel with these transformation issues, we also started the study and classification of metadata, and their concrete modeling.

Summing up, at the end of first year we planned to have three major achievements:

1. the full library of the COQ Proof assistant exported into a suitable application independent XML dialect;

2. a bunch of stylesheet performing the transformation to intermediate representation, both for formulae and proofs;

3. a prototype MathML-viewer.

3.1 Overview of the progress

We are particularly satisfied by the work done so far. All Milestones have been successfully accomplished, respecting the prefixed timetable. All deliverables, listed in Figure 3.1 have been submitted in due time, or within a short delay (in this case, usually, with previous notification and agreement by the - former - PO).

n.	Deliverable Title	WP no.	Lead Partic.	Estim. person-month	Type	Secu-rity	Deliv. month
0.a	Self-Assesment parameters and criteria.	0	UNIBO	2	R	Pub	6
0.b	First Self-Assesment Report	0	UNIBO	1	R	Pub	12
1.a	Preliminary Report on Application Scenarios and Requirement Analysis	1	KUN	6	R	Pub	3
1.b	Structure and Metastructure of Mathematical Documents	1	DFKI	8	R	Pub	6
1.c	Distributed Digital Libraries: development, archiving, retrieving.	1	MPG	6	R	Pub	6
2.a	XML Exportation Module(s)	2	INRIA	4	P	Pub	6
2.b	Document Type Descriptors	2	INRIA	2	R	Pub	12
2.c	Stylesheets to Intermediate representation (formulae)	2	UNIBO	7	P	Pub	12
2.d	Stylesheets to Intermediate representation (proofs)	2	UNIBO	9	P	Pub	12
3.a	Report on Metadata for Mathematical Libraries	3	DFKI	9	R	Pub	12
3.b	Metadata Model	3	DFKI	11	R	Pub	12
4.a	First Prototype implementation of Rendering Engines for MathML	4	UNIBO	16	P	Pub	12
7.a	Dissemination and Use Plan	7	MPG	3	R	Pub	6
R =Report, *P* =Prototype, Pub=Public							

Figure 2: List of all deliverables for the first reporting period

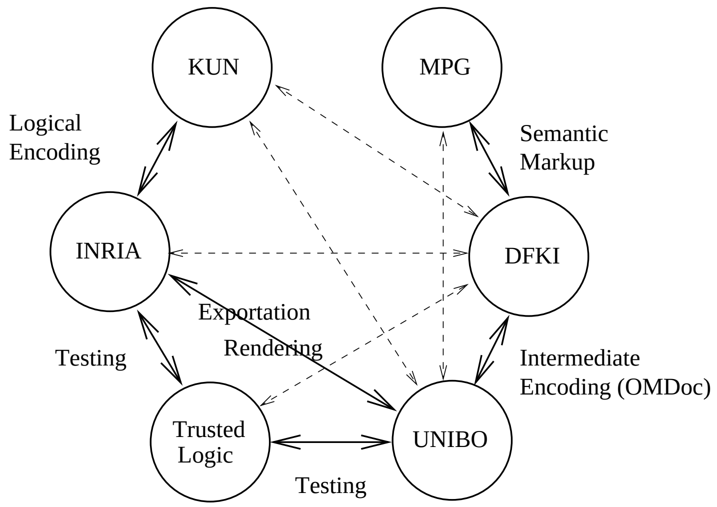
Although the validation WP did not start yet, all software which has been produced has been largely tested for its compliance to expected objectives and requirements. In particular, Trusted Logic ... The following is the list of Deliverables for the period covered by this report.

So far we did not met major (unexpected) technical challenges, and no re-targeting of the Workplan for the next reporting period is expected.

4 Project Synergy

Figure 4 describes the main synergies between the different partners, up to now (thick lines). The dotted lines represent the prospected cooperations for the next reporting period. In particular, there has been a strong interaction on the following themes:

Exportation UNIBO and INRIA strictly collaborated at Task 2.1, in order to develop the



module for exporting the mathematical libraries of the COQ Proof Assistant into a suitable XML dialect. The module is currently a standard library of COQ.

Math-ML Rendering Engines There has been a deep know-how exchange between UNIBO and INRIA on Task 4.1, about rendering engines for MathML that resulted in the convergent development of two prototypes.

OMDoc A deep, major revision of the content markup for the proof and the macrostructure levels of OMDoc has been jointly done by UNIBO and DFKI. The work should result in a new version of OMDoc (Version 2.0), to be released around april 2003.

Semantic Markup DFKI also provided support and knowhow assistance to the development of the semantic markup under investigation at MPG (that should eventually be some variant of OMDoc).

Testing Anticipating part of the activities relative to Task 6.2, Trusted Logic managed to install most of the software components under development in MoWGLI. They also produced an XML version of the formal models of the JavaCard virtual machine, using the XML exportation module of Coq developed in MoWGLI, as well as XML documents giving explanations in informal style about the models. At every key notion introduced in this document, a link to the formal definition of the model (namely Coq constants) is issued. This document can be translated into an HTML document, which allows an easy navigation through both formal and informal notions. The activity of Trusted Logic produced already important feed-back to the developers about the concrete rendering and management of notions.

Logical Encoding Following some rendering problems raised by UNIBO, there has been an intensive collaboration between Nijmegen and INRIA aimed to solve a few foundational problems of the mathematical formalization in COQ (especially related to the sort of constructive proofs). This interaction also leaded to the creation of a small task-force among COQ developers, aimed to the discussion of the problems of mathematical development (`mathincoq@pauillac.inria.fr`).

For the next reporting period, we plan to have many additional synergies among project partners, especially due to the beginning of the validation phase:

Active Math Following the work under development at DFKI, we plan to have direct collaborations between all sites involved in validation activities (Nijmegen, MPG and Trusted-Logic) and DFKI.

Presentational Stylesheets UNIBO will tightly work with DFKI at the development and documentation of presentational stylesheets (similarly expecting feedback from all partners involved in validation).

5 Cost Breakdown

There has been a certain degree of underspending by all sites with an Additional Costs Funding Regime. This looks in part phisiological to this kind of regime. The main source is the cost category of Personnel, and it is typically explained by a delay in activating the contracts (either by lack of a suitable candidate or for administrative reasons). This was in particular the case of MPG and, especially, KUN. In the latter case a candidate for the research position offered on MoWGLI funding has only been found at the beginning of february 2003. This has not caused a sensible delay in MoWGLI's activity, since the work expected from KUN (mostly requirement analysis, for the first reporting period) has been taken in charge by the permanent staff of the University. Also, the low costs of KUN for Travel and Subsistence is mainly due to the location of the first MoWGLI meetings (Golm, Eindhoven and Saarbrucken), relatively close to Nijmegen.

The underspending of Bologna in the category of Durable Equipement is due to an original mistake in the proposal: in fact, in the cost-statement, we only charged the amount of the equipment cost relative to the reporting period (that looks the correct practice), while in the contract we charged the full cost on the first year.

	UNIBO		INRIA		DFKI		KUN		MPG		Trusted Logic		Total	
Cost Category	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act	Est	Act
Personnel	15604	12950	37521	45248	85462		36803		42348	21612	8000	7544	225738	
Durable equip.	10000	1521	0	0	1736		0		0	0	0	0	11736	
Subcontracting	0	0	0	0	0		0		0	0	0	0	0	
Travel and subs.	7500	7769	7232	10537	8000		10000		8000	3897	2000	0	42732	
Consumables	0	0	0	0	0		0		0	0	0	0	0	
Computing	0	0	0	0	0		0		0	0	0	0	0	
Prot.of know.	0	0	0	0	0		0		0	0	0	0	0	
Other costs	5500	5179	220	781	0		0		500	0	1000	0	6220	
Subtotal	38604	27419	44973	56566	95198		46803		50848	25509	11000	7544	286426	
Overheads	7721	5484	63630	65895	68370		9361		10170	5102	6400	6035	165652	
Total	46325	32903	108603	120461	163568		56164		61018	30611	17400	13579	452078	

Figure 3: Costs in Euro for the reporting period: 03/2002-03/2003

6 Dissemination of Results

The Dissemination of Results is progressing particularly well, especially thanks to the intensive work of Prof.Bernd Wegner, Chair of the Project Exploitation Board.

The following is a list of the main talks and presentations of the Project held at International Events:

- 16.3.-21.3.2002. New York, Ann Arbor, ILIAC Workshop at Queens Borough Library, Plenary lecture by B.Wegner, addressing MoWGLI among others.
- 15.5.-21.5.2002 Madrid, invited lecture by B.Wegner at CINDOC, addressing MoWGLI among others.
- 8.6.-15.6.2002. Sudak, Crimea, Crimea 2002. Talk on MoWGLI by B.Wegner.
- 23.6.-26.6.2002. Znoimo/CZ, annual meeting of the Union of Czech Mathematicians and Physicists. Plenary lecture by B.Wegner, addressing MoWGLI among others.
- 4.7.-11.7.2002. Úbeda, International Conference on Approximation Theory Plenary lecture by B.Wegner, addressing MoWGLI among others.
- 21.8.-1.9.2002. Beijing, ICM 2002, Satellite Conference on EIC in mathematics. Talk on MoWGLI by B.Wegner.
- 23.9.-30.9.2002. Novosibirsk, ElPub 2002. Plenary lecture by B.Wegner, addressing MoWGLI among others.
- 11.10.-20.10.2002 Dubna, RCDL 2002, Plenary lecture by B.Wegner, addressing MoWGLI among others.
- 21.11.-22.11.2002 Trieste, First European Workshop on MathML and Scientific e-content. Abdus Salam International Center for theoretical physics. Talk on MoWGLI by A.Asperti.

Similarly, Scientific and Technological aspects of the Projects have been submitted to International Conferences, testifying the high technical quality of the work performed so far. The following is a list of main scientific publications related to MoWGLI for the first reporting period:

1. A.Asperti, M.Kohlhase. MathML in the MoWGLI Project. Second MathML International Conference, Chicago, USA, June 2002.
2. A.Asperti, B.Wegner. MoWGLI - A New Approach for the Content Description in Digital Documents. Proceedings of the 9-th International Conference on Electronic Resources and the Social Role of Libraries in the Future. Section 4, Volume 1, Autonomous Republic of Crimea, Ukraine.
3. A.Asperti, F.Guidi, L.Padovani, C.Sacerdoti Coen, I.Schena. Mathematical Knowledge Management in HELM. First International Workshop on Mathematical Knowledge Management, RISC-Linz, Austria, September 2001. Accepted for publication in Annals of Mathematics and Artificial Intelligence, Special Issue on Mathematical Knowledge Management (to appear).

4. G.Goguadze, E.Melis, P.Cairns. Problems and Solutions for Markup for Mathematical Examples and Exercises. Proceedings of the Second International Conference on Mathematical Knowledge Management (MKM03), LNCS n.2594, Bertinoro (Italy), February 2003.

5. F.Guidi. Searching and Retrieving in Content-based repositories of Formal Mathematical Knowledge. Ph.D. dissertation, Department of Computer Science, University of Bologna. January 2003.

6. M.Kohlhase, R.Anghelache. Towards Collaborative Content Management and Version Control for Structured Mathematical Knowledge. Proceedings of the Second International Conference on Mathematical Knowledge Management (MKM03), LNCS n.2594, Bertinoro (Italy), February 2003.

7. H.Naciri, L.Rideau. Formal Mathematical Proof Explanations in Natural Language Using MathML: An Application to Proofs in Arabic. Second MathML International Conference, Chicago, USA, June 2002.

8. H.Naciri, L.Rideau. Affichage et diffusion sur Internet d'explications en langue arabe de preuves mathmatiques. Proceedings of the 6th African conference on research in computer science CARI'2002, Yaound, Cameroun, October 2002.

9. L.Padovani. A Standalone Rendering Engine for MathML. Second MathML International Conference, Chicago, USA, June 2002.

10. L.Padovani. On the Roles of LaTeX and MathML in Encoding and Processing of Mathematical Expressions. Proceedings of the Second International Conference on Mathematical Knowledge Management (MKM03), LNCS n.2594, Bertinoro (Italy), February 2003.

11. L.Padovani. MathML Formatting. Ph.D. dissertation, Technical Report UBLCS-2003-3, Department of Computer Science, University of Bologna. January 2003.

12. C.Sacerdoti Coen. From Proof-Assistants to Distributed Libraries of Mathematics: Tips And Pitfalls. Proceedings of the Second International Conference on Mathematical Knowledge Management (MKM03), LNCS n.2594, Bertinoro (Italy), February 2003.

13. I.Schena, F.Guidi. A Query Language for a Metadata Framework about Mathematical Resources. Proceedings of the Second International Conference on Mathematical Knowledge Management (MKM03), LNCS n.2594, Bertinoro (Italy), February 2003.

14. F.Wiedijk.Comparing mathematical provers. Proceedings of the Second International Conference on Mathematical Knowledge Management (MKM03), LNCS n.2594, Bertinoro (Italy), February 2003.

Finally, as an integrated part of the dissemination policy for MoWGLI we should recall the organization of the second International Conference on Mathematical Knowledge Management, held in Bertinoro (Bologna - Italy), in February 2003. The proceedings of the Conference, which contain many works endorsed by MoWGLI, have been published by Springer-Verlag in the Lecture Notes in Computer Science Series (LNCS n.2594).

7 WorkPackages' evaluation parameters and assessment criteria

7.1 Transformation

This work package was devoted to the complex issue of transforming a low level, content description of mathematics (understandable by automatic applications for the mechanization of mathematics) into a human-readable presentational format. It covered both statements and proofs.

The transformation process has been decomposed in a sequence of intermediate steps, for modularity reasons. The first phases of this process, covered by the first reporting period, were the XML Exportation module from the internal format of the COQ Proof Assistant to XML, and the stylesheet for transforming the low-level formal encoding into a suitable intermediate representation (mostly based on OMDoc and MathML-content).

The deliverables fall in three categories:

1. XML exportation module for the COQ Proof Assistant (D2.a).
2. XSL Stylesheets and DTS's (D2.b-f).
3. Tools for automatic extraction of metadata (D2.g).

7.1.1 XML exportation module for the COQ Proof Assistant

The Exportation Module is currently a Coq standard contribution, included in the official distribution of Coq, which adds new commands to export to XML theorems and definitions. The Makefile of Coq and the utility `coq_makefile` are also modified to easily allow to export in a batch process the whole standard library of Coq and all future contributions. The XML output is valid with respect to DTDs we jointly provided. The design of the DTD was by itself a major accomplishment, likely to become a standard reference in the design of similar tools for different Proof Assistant applications.

The module has been successfully exploited for the exportation of the full Coq library into XML. The exportation process requires 3h 35m on a 1.8Gh Pentium IV processor with 512Mb of RAM and produces 1.13Gb of XML compressed files.

In order to check that all the relevant logical information has been exported a completely new Proof Checker has been developed in Bologna (an important and time-consuming task not listed among MoWGLI's activities). The whole library has then be successfully re-checked for internal consistency.

In conclusion, according to our own evaluation parameters, the task has been *very successful*.

7.1.2 XSL Stylesheets and DTS's

The low-level DTD's developed for the exportation module of Coq faithfully reflects the foundational logical system used by this application, namely a version of constructive Type Theory known as the Calculus of Inductive Constructions.

In passing from this level to a presentational markup, it looks natural, both for modularity and interoperability reasons, to pass through an intermediate "content" representation. For the encoding of Mathematical *expressions*, we just adopted MathML-content, a recent recommendation of the World Wide Web Consortium. Because of the peculiarity of the mathematics in the Coq library, we extended MathML content markup using the facilities offered by the MathML `csymbol` element.

The intermediate format for proofs, logical items (theorems, lemmas, examples, and so on) and more generally for the macrostructure of documents, was far less evident, and required a really deep investigation effort. We eventually agreed on a largely revised version of OMDoc, that should become official with the forthcoming release of this specification (OMDoc 2.0, expected for april 2003).

More than 5000 lines of XSLT have been written, organized in about 20 files covering different aspects and part of the mathematical notation.

The application of the stylesheet, even on very large proofs, just takes a few seconds, testifying the actual feasibility of this technology (that was one of our main evaluation criteria).

Trusted Logic already started to experiment the overall architectural design of the transformation process, in relation with their formal models of the JavaCard virtual machine. In particular, they wrote XML documents giving explanations in informal style about the models; at every key notion introduced in this document, a link to the formal definition of the model (namely Coq constants) is issued. This document can be translated into an HTML document, which allows an easy navigation through both formal and informal notions. This work, even if quite preliminary (the validation WP6 has not started yet, according to the Workplan), has already proved the good degree of use extensibility and customization of our approach (again, this was one of our prospected evaluation criteria).

Summing up, our preliminary evaluation of the task is extremely positive. A more precise and detailed evaluation will be only possible at the actual completion of the WorkPackage, in conjunction with the validation activities.

7.2 Metadata

The tasks about metadata proved to be more challenging than expected, especially because of the very different perspectives the partners of the projects have on their documents, and what functionalities should be supported by the metadata. We had extensive discussions on the mailing list, and eventually decided to organize a dedicated meeting on this topic, held in Saarbrücken, which was also open to external participants. The discussions lead to a clarification of the different positions and of the problems to be addressed.

In our analysis we have considered both Web-standards metadata models (Dublin Core), and also more specific markup languages that are targeted to particular mathematical applications (OMDoc). We realized that the wide range of mathematical applications makes unfeasible the definition of a unique metadata model, hence extensibility and customization have been taken into account.

According to the parameters and criteria adopted in the self-assesment document D0a, the actual evaluation of the model can only be done after the implementation of the searching tools and an extensive validation.

7.3 Interfaces

This Work-Package was devoted to the design and the implementation of the interfaces to the library, covering rendering, browsing, searching and retrieving functionalities. For the first reporting period, the only Task concerned was the design and implementation of MathML-rendering engines (Task 4.1).

7.3.1 MathML rendering engine

The efforts devoted to the fulfillment of this WorkPackage resulted into the development of two prototype engines for the rendering of MathML presentation markup. The engines can be used as components for the development of larger applications involving browsing and searching through libraries of mathematical documents.

One of the prototypes (`GtkMathView`) has been developed in C++ and exposes a GTK+ interface. It is thus suitable for the creation of applications that are based on the GTK+ (`http://www.gtk.org`) graphical framework. Apart from the GTK+ interface, a PostScript interface is also available, which allows the exportation of MathML documents into PostScript. This allows embedding rendered MathML documents into larger PostScript or PDF documents. The quality of the PostScript rendering is comparable with that achievable with TEX/LATEX(in fact, the John Wiley & Sons, Inc. publisher has adopted the PostScript exportation interface of `GtkMathView` for rendering MathML markup to be included in several on-line encyclopedias and textbooks). The other prototype has been developed in Java, and is thus a more natural choice for the development of Java applications.

Even though the two rendering engines have been developed separately and in different languages, a lot of effort has been spent trying to identify and implement the common functionalities that a potential user expects to find in this kind of components. Report D4.a details about such functionalities and shows sample applications and scenarios when using the components.

Despite their status of "prototypes," the two engines have been extensively tested. The first obvious, straightforward testbench is given by the official MathML testsuite which is available at the Math Working Group Web side (`http://www.w3.org/Math`). Although these tests has been successfully passed except for a few isolated cases, we have to report that the testsuite is under development and still fairly small. In fact, most of the features tested are related to not-so-important aspects of MathML such has the handling of colours and spaces. Furthermore, the vast majority of tests regards very small formulas, hence the testsuite does not provide a sensible feedback on the behaviour of the components when they are used to render unusually large mathematical documents such as those resulting from proofs and statements exported from the Coq library (that is, exactly the class of documents we cope with in the context of MoWGLI). We also have to report that *most* the existing MathML implementations fail to render MathML documents with large numbers of nested tables, or require far from acceptable rendering times.

In conclusion, this work package has delivered two rendering engines for MathML that are highly competitive and performant if compared to the existing implementations, and also allow the user a higher degree of customizability. As of now they are also the only possible choices for effectively rendering the kind of mathematics that can be extracted from the Coq library and transformed into MathML. With respect to the self-assessment criteria, we regard them as being *very successful*.