Design and Implementation of MAML

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Abstract: At ICCM (Internet Computing and Computer Mathematics) lab in Lanzhou University, we are developing MAG (Mathematics Assessment Grid) System to integrate the mathematical question resources on Internet into a very large, open and virtual questions library. As part of the project, Mathematics Assessment Markup Language (MAML), which is used to encode questions, test papers and their description information, has been designed. The MAML, defined by XML, provides well-defined elements that can be used together with SVG and MathML for representing questions and test papers. It is easy to search and transfer questions in MAML on Internet. MAML can also be used in E-Learning and E-Testing system. Presentation information and description information of a question are encoded as well as the content of a question. The users can embed a well-formed question in MAML into XHTML page. The client side is only a browser with plugins for MAML, MathML and SVG. To implement MAML, we are developing an online editor (MaEdit) which is based on MAML, MathML and SVG. The users can edit a question in GUI mode or coding mode. The editor can transform a question between these two modes automatically. In this editor, the users can edit the text, mathematical formula and SVG graph of a question. Graph in other types such as bitmap, gif, jpeg can also be inserted into the question. After editing, the users can save the question which is represented by MAML, MathML and SVG into a database or as a file.

1. Background

The Internet advent gave a powerful communication structure to easily access to any kind of information and knowledge, and E-learning [1] can be defined as 'learning that is accomplished over the Internet, a computer network, via CD-ROM, interactive TV, or satellite broadcast'. While various methods have been used to display mathematical formulae in Web pages and to make simple mathematical computations accessible via CGI programs or X Windows, a general and effective system for accessing, producing, and delivering mathematical content is still the subject of research and development. Researchers of the W3 Consortium (W3C) and other institutes are working to make the publishing of mathematical materials documents on the Web more convenient and easy. MathML [2] is an XML application for markup of mathematical expressions that supports both presentation encoding (display layout) and content encoding (computation semantics).

Mathematics education using the Web is increasingly popular and important in these days. Web-based learning can extend the reach of education and significantly broaden its impact and influence. So, Institute for Computational Mathematics (ICM/Kent) has developed WME [3, 4, 5, 6,

7] (Web-based Mathematics Education) as a distributed system for supporting, enhancing, and delivering mathematics education at all levels.

In fall 2004, we introduced WME to China. We have ported WME to a site in Lanzhou University and performed research on how well WME may work in China and what can be learned about the relocatability, configurability, internationalization, and interoperability of the WME site and the WME components.

In this work, we found that teachers and students take more care of test and assessment because test and assessment are more important in China. On one hand, the teachers have limited questions in different types. They have to spend much time in looking for and choosing the appropriate questions to make test papers. On the other hand, there are large numbers of mathematical questions on Internet. Our interest is how to make use of the resources on Internet. So we decided to develop MAG (Mathematics Assessment Grid) [8] at ICCM lab in Lanzhou University. To do this, we must establish a standard for describing a mathematical question and a test paper. As part of the project, Mathematics Assessment Markup Language (MAML), which is used to encode questions, test papers and their description information, has been designed.

In Rice University, USA, Elizabeth Bartmess and co-workers have designed QML1.0 (Questions Markup Language) [9] for encoding questions. However, QML has no description information markup elements and test paper markup elements. So it cannot be used in MAG.

2. INTRODUCTION TO MAG AND MAML

MAG is a grid system that integrates the mathematical question resources on Internet into a very large, open and virtual library. The main data sources of MAG are MAML-based Web pages and isomerous databases on Internet. Files in other types on Internet can also be data sources of MAG if they can be translated into MAML automatically. The users can login MAG to search questions on certain subject and make a test paper. MAG is transparent to the user. What the user needs to do is just sending key words to MAG. MAG searches the appropriate questions by specific algorithm from data sources on Internet automatically. Then it translates questions in other types into questions in MAML. MAML (Mathematics Assessment Markup Language) is at the core of MAG framework.

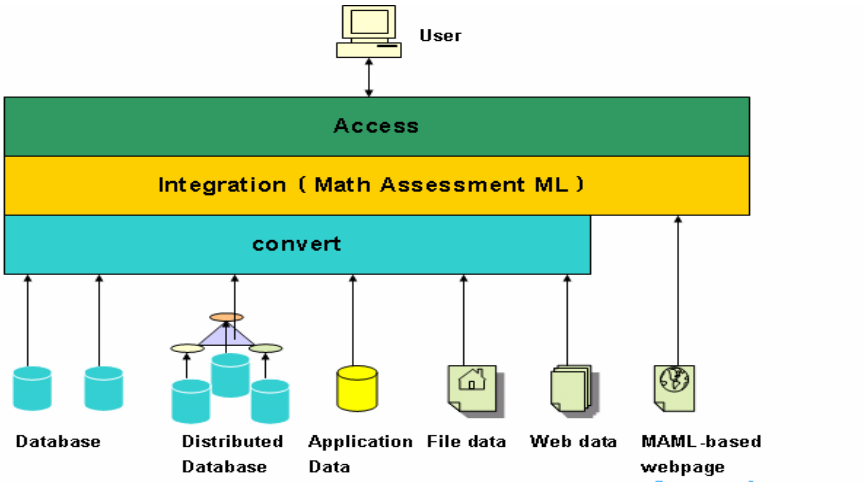

Figure 1. Architecture of MAG

Nowadays, mathematics questions and test papers on Internet are in several types, such as Web pages, word documents, PDF files, or stored in databases. Due to the lack of description

information, it is difficult to search a question that is in one of these types. It is also difficult to make a test paper with these questions. In the past years, E-learning and E-testing have developed quickly. There is still no standard method to describe a mathematical question and test paper. The questions in special types cannot be shared in E-testing systems.

We are now working on MAML, which is used to encode questions or test papers and their description information. It provides well-defined *question elements* and *paper elements* that can be used together with XHTML and MathML for describing a question or a test paper. It is easy to search and transfer questions in MAML on Internet. MAML can be used to encode questions or test papers not only in Web pages, but also in E-learning and E-testing systems. All systems can share questions and test papers that are in MAML. The requirements of MAML can be listed as follows.

- Encode content of mathematical questions and papers
- Encode description information of mathematical questions and papers
- Being compatible with XHTML, MathML and SVG [10] for intermixed usage
- Facilitate conversion to and from questions in other types automatically or manually
- Facilitate to edit
- Allow marked-up pages to be delivered to regular Web browsers for end-user viewing
- Provide for extensibility

3. Overview of MAML Elements

All MAML elements are classified into three groups: *test paper markup elements* which are used to describe an examination paper, *question markup elements* which are used to describe a question and *presentation markup elements*. MathML markup elements and SVG markup elements can be embedded into MAML.

We classify all questions into 5 types: one choice, multiple choices, fill-in-the-blank, true or false and essay questions. A question can be divided into two parts: the content of the question and the description information of the question. The content of a question is in these types: text, figure (SVG or other type picture) or formula in MathML. What we will do is encoding both the content and the description information.

The examination papers are in two types: the standard blank papers the teachers make and the papers for students to take a test. We may only have one copy of the blank paper. But we must apply a copy of the paper to every student in E-testing. The paper contains not only the questions but also the information of the student and the answers of the student.

All elements are listed as follows.

Paper markup elements

<paper> <pdescription> <ptitle> <psubject> <pstarttime> <pendtime> <psite> <pdifficulty> <pscore> <pspecification> <pschool> <pgrade> <pclass> <pname> <pstudentid> <psection>

Question content markup elements

<questionset> <question> <qdescription> <qbody> <qchoice> <qtext> <qblank> <qmathml> <qsvg> <qimage> <qtocorrect> <qparameter> <qkey>

Descriptive markup:

<qtopic> <qcorrectness> <qdifficulty> <qrscore> <qanswer> <qscore>

Presentation markup elements

<qrow> <qbr>

Besides these elements, there are about more than 100 attributes which are used to describe the style of the paper and question.

We created the MAML DTD that defines the syntax of MAML elements.

Appendix A is an example of test paper in MAML.

4. Processing of MAML

We can embed MAML into a XHTML document. But the browser cannot process the MAML markup directly. So we must translate the MAML into regular Web page before the browser deals with it. We have two choices: translating it on server side or translating it on client side. One of our main aims is to make it convenient to the user to search questions on Internet. If we translate MAML on server side, what the user got is just the translated document without MAML markup. Therefore, the user cannot search the questions by the description information of questions. So we translate MAML on client side because in this mode, the user can search the questions in MAML by the description information. Mathematical expressions in MathML are displayed either by MathPlayer or directly by the MathML-enabled Web browser. A browser with plugin SVGViewer can display SVG graph well.

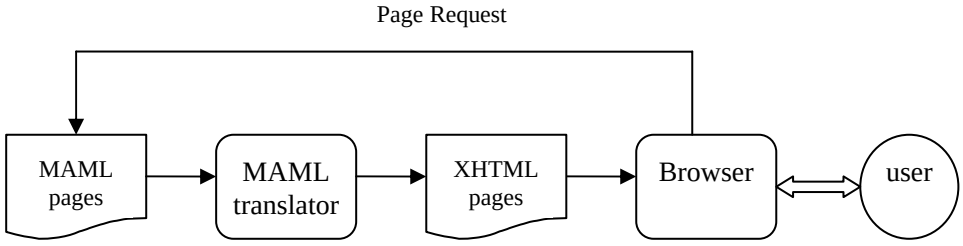

Figure 2. Processing of MAML

5. MaEdit

MaEdit is a Web-based mathematical question editor which is under development in ICCM lab. With a convenient visual user interface, you can create and edit mathematical test questions and papers in this editor. MaEdit can run within any standard Web browser which supports JavaScript and DOM. The functionalities of MaEdit are listed as follows.

- Create and edit a question in GUI mode
- Load MathEdit [11] to edit mathematical expressions of a question and insert the retrieved mathematical expressions (in MathML) into MAML
- Load GeoSVG [12] to draw figures of a question and insert retrieved mathematical graph (in SVG) into MAML
- Edit a question in coding mode (MAML, MathML and SVG code) directly
- Add and update the description information of question
- Save the question in MAML automatically

The characteristics are as follows.

- Complete Web Orientation. MaEdit is a web-based visual mathematical question editor
- Edit in GUI mode or coding mode. The editor can transform a question between these two modes automatically
- Abundant media types

MaEdit is implemented in Ajax [13]. Users don't need to install any software. A Web browser

with plugins of MathPlayer, SVGViewer and MAML translator is enough. In this editor, the users can edit content and description information of a question. The editor can also load MathEdit and GeoSVG to edit mathematical formula and SVG graph of a question. Graph in other types such as bitmap, gif, jpeg can also be inserted into the question. After editing, the user can save the question which is in MAML, MathML and SVG into database or as a file.

In ICM/Kent, a Web-based authoring tool, GeoSVG, which makes the creating of interactive geometry and other mathematics lessons simple, has been developed. In ICCM, we are developing a Mathematical expression editor, MathEdit. We have designed APIs in MaEdit to GeoSVG and MathEdit. Users can edit mathematical expressions and draw figures by these tools.

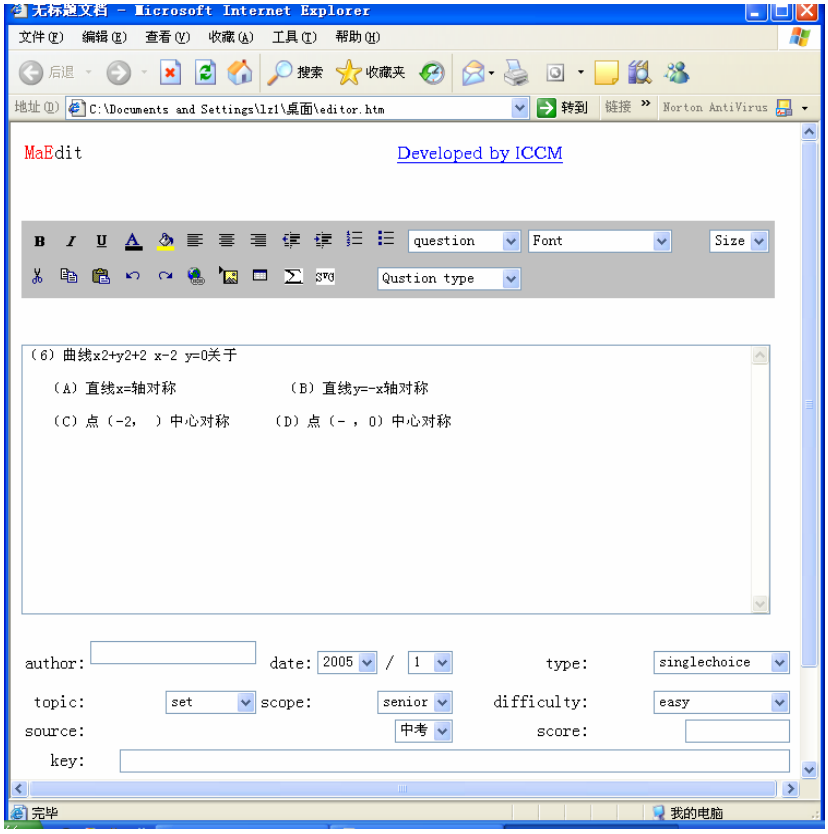

Figure 3. MaEdit

6. Future Work

The MAG Framework and MAML is an ambitious vision and there is much work ahead.

- Develop MAG software.
- Develop interfaces to several famous questions libraries for MAG. The users can search questions in these libraries by MAG.
- Research on the feasibility of transforming questions in MS Word document, PDF document and HTML text into questions in MAML automatically.
- Develop a paper assessment system which can do assessment automatically. The students can sit take the test wherever they have a browser with several plugins as mentioned.

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APPENDIX A: AN EXAMPLE OF MAML

This is a paper of City Uiversity, London on algebra.

CITY UNIVERSITY
London
Part I Examination
Algebra
13 June 2003 5:00 pm – 7:00 pm
Time allowed: 2 hours
Full marks may be obtained for correct answers to
ALL of the SIX questions in Section A
and
TWO of the THREE questions in Section B.
Do not attempt more than TWO questions from Section B.

Section A

Answer all questions from this section. Each question carries 8 marks.
1. Show that every non-zero complex number has a unique multiplicative inverse. That is, show that for given x and y real, there is precisely one real pair a and b such that

$$(x + iy)(a + ib) = 1.$$

Recall that Z denotes the set of integers. Find all elements of the subset of the complex numbers given by $\{a+ib \mid a, b \in Z\}$ with the property that the inverse of the element lies in the same set.
…

Section B

Answer two questions from this section. Each question carries 26 marks.
…

8. (a) Show that if A is an invertible matrix and b a constant vector then the equation Ax = b has a unique solution vector x.
(b) Work out the determinant of

$$A = \begin{pmatrix} 1 & 2 & 1 \\ 3 & 0 & -1 \\ 1 & -4 & -3 \end{pmatrix}$$

by direct computation. Note that

$$(2,-1, 1)A = (0, 0, 0)$$

Use this fact to verify your answer for the determinant by a logical argument (i.e. without computation).
(c) For the matrix A above solve

$$A\underline{x} = \begin{pmatrix} 1 \\ 4 \\ 2 \end{pmatrix}$$

Recall that if A is not invertible, as here, then there may be multiple solutions, or no solution, to Ax

= b, depending on the vector b on the right hand side. (You may assume that we are in the former case here... Although you are welcome to check this for yourself.) Recall also that if there are two distinct solutions (u and v say, then u + k(u - v) is also a solution for any scalar k. Express your answer for the general solution in the form

$$\underline{x} = \underline{x_1} + k\underline{x_0}$$

where k is an arbitary real value. Verify that $A\underline{x} = \underline{0}$ and $A\underline{x_1} = \begin{pmatrix} 1 \\ 4 \\ 2 \end{pmatrix}$.

Now, we encode this paper into MAML.

```
<paper id = “613.102”>
   <pdescription>
      <ptitle>Part I Examination</ptitle>
      <psubject>Algebra</psubject>
      <pstarttime>13 June 2006 5:00 pm</pstarttime>
      <pendtime>13 June 2006 7:00 pm</pendtime>
      <pschool>CITY UNIVERSITY LONDON</pschool>
      <pspecification>
       Full marks may be obtained for correct answers to ALL of the SIX questions in Section A
       and TWO of the THREE questions in Section B. Do not attempt more than TWO questions
       from Section B.
      </specification>
   </pdescription>
   <psection id=”A” name=”SECTION A”>
      <pspecification>Answer all questions from this section. Each question carries 8 marks.
       </pspecification>
       <question title =”1” type=”essay”>
          <qbody>
         <qtext>Show that every non-zero complex number has a unique multiplicative inverse. That
               is, show that for given x and y real, there is precisely one real pair a and b such that (x
               + iy)(a + ib) = 1. Recall that Z denotes the set of integers. Find all elements of the
               subset of the complex numbers given by
          </qtext>
          <qmathml>
             <math xmlns="http://www.w3.org/1998/Math/MathML">
               <mo>{</mo>
               <mi>a</mi>
               <mo>+</mo>
               <mi>bi</mi>
               <mo>&#x2223;</mo>
               <mi>a</mi>
               <mo>,</mo>
               <mi>b</mi>
               <mo>&isin;</mo>
               <mi>&Zeta;</mi>
               <mo>}</mo>
             </math>
```

```
            </qmathml>
          <qtext> with the property thatthe inverse of the element lies in the same set.
          </qtext>
        <qbody>
      </question>.
…
</psection>
<psection id=”B” name=”SECTION B”>
    <pspecification>    Answer two questions from this section. Each question carries 26 marks.
   </pspecification>
   <questionset title=”8”>
       <question title=”(a)” type=”essay”>
          <qtext>Show that if A is an invertible matrix and b a constant vector then the equation Ax
             = b has a unique solution vector x.
          </qtext>
       </question>
       <question title=”(b)” type=”essay”>
          <qtext>
            Work out the determinant of
          </qtext>
          <qmathml>
             <math xmlns="http://www.w3.org/1998/Math/MathML">
                <mi>A</mi>
                <mo>=</mo>
                <mrow>
                   <mo>(</mo>
                   <mtable>
                      <mtr>
                         <mtd>
                            <mn>1</mn>
                         </mtd>
                         <mtd>
                            <mn>2</mn>
                         </mtd>
                         <mtd>
                            <mn>1</mn>
                         </mtd>
                      </mtr>
                      <mtr>
                         <mtd>
                               <mn>3</mn>
                          </mtd>
                          <mtd>
                             <mn>0</mn>
                          </mtd>
                          <mtd>
                             <mo>&minus;</mo>
```

```
                        <mn>1</mn>
                      </mtd>
                    </mtr>
                    <mtr>
                      <mtd>
                        <mn>1</mn>
                      </mtd>
                      <mtd>
                        <mo>&minus;</mo>
                        <mn>4</mn>
                      </mtd>
                      <mtd>
                        <mo>&minus;</mo>
                        <mn>3</mn>
                      </mtd>
                    </mtr>
                  </mtable>
                  <mo>)</mo>
                </mrow>
              </math>
            </qmathml>
            <qtext> by direct computation. Note that
              <qrow style = “align=center”>(2,-1, 1)A = (0, 0, 0)</qrow>
            Use this fact to verify your answer for the determinant by a logical argument (i.e. without
            computation).
            </qtext>
          </question>
…
        </questionset>
      </psection>
</paper>
```