INTERACTIVE MATHEMATICS QUIZMAKER AND THE ONLINE MATHEMATICS PLACEMENT EXAMS

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Introduction

By the mid-1990's, the increasing availability of networked computer system allowed assessments and educational tutorials to be delivered online in multiple forms. However, it has been and continues to be widely acknowledged that online assessment in mathematics discipline faces a number of challenges. Those challenges include:

- Input of mathematical expressions;
- Storage and delivery of assessment on different computer platforms;
- Capture, grading, storage, authentication, and verification of students' responses;
- Collation, analysis and return of results;
- Feedback availability;
- Assigning partial credit; and
- The cost of implementation.

In an effort to resolve some of these issues, numerous existing commercial software such as Scientific Notebook, Maple/Maplets, and MapleTA have been developed for online exam creation and grading. However, according to [Allen, 2003], none reaches the critical demands of assessment in mathematics. Specifically, assessment created by Scientific Notebook functions on its own separately installed browser, not on common web browsers – Internet Explorer, Netscape or Mozilla. Maplets require Maple software to generate questions as well as to verify responses but do not have the ability to capture nor store students' responses. Assessments created by MapleTA efficiently meet most of the challenges of online assessment in mathematics except the capacity to assign partial credit, and the cost of implementation increases with the number of the users. Other software from publishers such as Thomson (iLRN) and Wiley (eGrade) are propriety. As well, there are other commercial software tools such as Respondus that work within course management systems. Therefore, there is clearly a need for a low or no cost alternative that can address the many difficulties in online mathematics assessment. Moreover, it should be appropriate for use with large-scale testing bases. In fact, besides those mentioned above and others [Allen, 2003], there is available a competitive option.

Interactive Mathematics QuizMaker (IMQ)

IMQ is non-commercial software. It runs on an Apache Tomcat server, which the students can access using any common web browser. IMQ uses Maple on the server as the engine for mathematical execution and language implementation. It affords the numerous types of questions, multiple-choice, multiple-response and short-answer, combined with random generation and immediate feedback. The distinguishing feature of IMQ is its use of Maple kernel for performing computations and verifying responses without the requirement of Maple on the client computer. Mathematical formulae are converted to HTML which can be viewed by any browser without the use of Java Applets or any special plug-ins. With mathematics typography and answer checking resolved, it allows a capacity for assigning partial credit by several different methods. It also enables an extensive interaction between the instructor and the students via the detailed grade reporting and progress monitoring. IMQ has a built-in authentication system that allows the student to access the assessment task with protected password. Regarding the input of mathematical expressions, IMQ allows students to type their answers as text base with the use of Maple syntax. For example, the answer $3x^2$ can be entered as 3*x^2. Moreover, IMQ has the ability to detect the syntax error entering by the student and generate a message to suggest the correct or appropriate syntax. Hence, the student can validate the answer entering before submitting it for grading.

Questions creations

IMQ questions are written using a mark-up language incorporating elements of Maple procedure and LaTeX code. Each line of the question begins with a flag. Some of the major flags include:

Flag	Characteristics
t>	Generates text, as seen by the student.
a>	Provides the correct answer to the question.
h>	Indicates that the attached statement(s) will be executed by Maple invisibly (i.e. without showing the result to the student).
c>	Specifies a list of responses for multiple-choice item.
p>	Displays either Maple expression or plots generated by Maple.
s>	Specifies an answer-testing procedure.
v>	Specifies the value (or the weight) of the question.
sb> and se>	Declares the beginning and the end of the solution or feedback.
local>	Declares the local variables for each question.

forbid> forbids the students from using the Maple commands to execute the answer.

description> includes the description of the question which will not be seen by the student

Following is an example of a simple multiple-choice item with a manually-coded answer:

```
t> What is $@(sin)^(2)@(x)$ + $@(cos)^(2)@(x)$ ?
c> MC(-1, 1, Pi, -Pi, 0)
a> 1
```

The first line with the "t>" flag asks IMQ to display the question, the second line with the "c>" flag lists all the choices to be seen by the students, and the third line with the "a>" flag tells IMQ the correct choice. This correct choice is used to assign the credit, and it will not be seen by the students. Here is the output of the question:

What is $\sin^2(x) + \cos^2(x)$?

A ○ -1

B ○ 1

C ○ π

D ○ $-\pi$

E ○ 0

If the multiple-choice is not considered as a type of formative assessment question, IMQ strongly encourages a more realistic example of short-answer item that can be graded by Maple:

```
t> Differentiate the function $@f(x)@ = @x^5@$ with respect to $x$.
forbid> Diff, diff
a> value(diff(x^5,x));
end>
```

The question is formatted as:

Differentiate the function $f(x) = x^5$ with respect to x.

Answer: [ ]

Similar to the multiple-choice, the first line asks IMQ to display the question. The second line with the "forbid>" flag prevents the students from using the Maple

differentiate command to obtain the answer. The third line tells IMQ to compare the student's answer with the correct answer generate by Maple.

In order to prevent cheating between students, IMQ allows item randomization, through an additional parameter set. Though the item is randomly generated, the grading procedure functions in the same manner as the grading procedure for a non-randomized item. Furthermore, the specific feedback and actual solution can also be generated for each item. The following example illustrates the random feature with feedback:

```
description> Indefinite integral of a random polynomial of the form
$@(x-a)^n@$.

#local> a,n,f,J,F,x
h> a:=nzrand(-9..9);
   n:=rnd(2..8);
   f:=(x - a)^n;
   J:=Int(f,x);
   F:=value(J);
#note> sprintf("%A", J=F)
forbid> Int, int

t> Evaluate the following integral
p> J
a> value(J);

sb>
t> Let $$@u@ = @x-a@$$  So $dx=du$.  The integral becomes
  $$@Int(u^n,u)@ = @u^(n+1)/(n+1)@ $$
se>
```

An example of the output from this code is:

Evaluate the following integral $\int (x-9)^5 dx$

Answer:

Grading procedure and partial credit

By default, each IMQ question is weighted as one point; and of course, the weight can be changed as desired. On homework or practice tasks, the student is (optionally) penalized 10% each time a wrong answer is submitted, but he/she is allowed to rework the problem. For a multiple-response item, the student obtains full credit for each correct less 10% for each incorrect submission at each trial. For a short-answer item, the grading procedure allows IMQ to check and assign credit not only for the exact matching answer but also for the mathematical equivalent answer. Checking mathematically equivalent answers is carried out within Maple by algebraically comparing the input answer with the model answer.

The custom grading procedure defined by the instructor allows IMQ to assign partial credit for each portion of the student's answer. The rubric for assigning partial credit can be as detailed as desired. The following is an example of an item with custom grading procedure that asks IMQ proportionally deduct some certain points for each incorrect portion of the answer:

```
h>a:=rnd(1..5)();
  b:=a+rnd(1..3)();
t> Give an example of a cubic polynomial $p(x)$ with the following
properties: \\
t> $p(0)=1 $ \\
t> $p(x)=0 $ at $x$=@a@ and $x$=@b@ \\
ap>$p(x):=$
v> 10
s>[proc(ans) local points;points:=5;\
  if not `aim/Testzero`(subs(x=0,ans)-1) then\
   printf("Your polynomial fails to satisfy $p(0)=1$");\
   points:=points-1; fi;\
  if not `aim/Testzero`(subs(x=a,ans)) then\
   printf("Your polynomial fails to satisfy $p(x)=0$ at $x$=%g",a);\
   points:=points-1; fi;\
  if not `aim/Testzero`(subs(x=a,ans)) then\
   printf("Your polynomial fails to satisfy $p(x)=0$ at $x$=%g",b);\
   points:=points-1; fi;\
  if not `aim/Testzero`(degree(ans,x)-3) then\
   printf("Your polynomial is not a cubic");\
   points:=points-2; fi;\
  points;\ end , (1-x/a)*(1-x/b)*(1-x)]
end>
```

Interactive Mathematics QuizMaker and the Online Placement Exams

Besides the creation of online assessments for use by the pre-service and in-service teachers at Texas A&M University, IMQ has been used for the development, implementation and administering a large-scale placement exam at Bowling Green State University (BGSU) since June 2003. Approximately 5,500 new students take online placement exams every school year at BGSU. The exams include questions ranging from arithmetic, algebra, geometry, trigonometry, and probability, to pre-calculus. Along with the mathematical portion, the online placement exams also include a survey to collect student background information, feedback, and the name of the college and department the student applied for. The IMQ database system allows the exam results and survey records to be accessed electronically by the college and the department that the student has designated. At the same time, this data is collected, analyzed, stored and accessed by the administration and records office on the BGSU campus. In addition, IMQ is also currently used for creating online assessments in various courses such as calculus, discrete mathematics, algebra and geometry for pre-service and in-service teachers. Requests for more information regarding IMQ can be directed to the authors at dnguyen@bgsu.edu or at dallen@math.tamu.edu.

Reference

Allen, G. D. (2003). A Survey of Online Mathematics Course Basics. *The College Mathematics Journal, 34* (4).