Assessment and Automated Feedback: a specific implementation.

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Goal

Components

Measuring

- Test bank

work done 1

- Managing info

- Prediction

Future

Abstract

We describe the development of a system for assessment and automated feedback still in progress. This document lists its technical elements as well as the methodology used in its development. The system uses an item bank that assess knowledge and skills in a specific domain. We discuss how an item bank may be revised to be considered reliable. In the current state of the project, the system generates assignments and tests that can be distributed in the printed form or via WEB. The student provides answers to assignments by WEB, the system builds a database of student responses. At full development, the system would use statistical procedures and data mining to draw conclusions about the individual and group's performance. At an advanced stage development, the system could use these findings to suggest additional readings and / or generate specifc assignments for each student. In our case, the system is being used in the Linear Algebra.

Goal

In the context of teaching/learning, the objective is to construct a computer system that can provide individual feedback to the student. Such feedback...

- would make the student more effective. More than just grading the student, also (and more important) stating
  - which concepts/skills are still missing in the student knowledge;
  - which concepts/skills are not still mastered that are important for subsequent topics.
- would make the teacher more effective: Having the topics in which most of the students are having difficulties would provide the data to the teacher in order to redirect the didactic strategy.

Components of the feedback system:

- A data base test bank: A reliable instrument to measure the student knowledge.
- A computer system: An adequate mechanism to manage information involved in the process.
- A predictor: A model to predict the performance of the student in a specific topic when the performance on topics that are prerequisite is known.

Data base item bank

"A reliable instrument to measure the student knowledge".
Item or test bank: A set of problems, questions or items created with the objective to discriminate having or not having the knowledge of a specific topic. Examples:

- Test Bank for Stewart's Calculus Early Transcedentals, 5th Edition. Hardcopy
- Test Bank to Accompany Swokowski's Calculus with Analytic Geometry. Hardcopy
- TestGen Computerized Test Bank for Calculus. Blackboard
- Teaching Calculus with Maple: A Complete Kit. Maple TA
- Maple TA in Blackboard

Important issues in the test bank:

- The number of items should be big enough to reduce the probability that an student be re-exposed to the same specific question: we do not want to measure just memory.
- The set of problems should be highly structured: Every question should have information about
  - the topic being evaluated
  - the level of difficulty
  - discriminating power or index
  - Bloom's Taxonomy Level
  - If applied, the way the question is conveniently solved: graphic/numeric/symbolic
  - If applied, the area of engineering which is related to the question (Mechanics, Physics, Chemistry, Social Science,etc)

  To have in mind: The computer system should be able to re-evaluate a specific student. So, the item bank should be a data base test bank: we should be able to do queries on it. It should be big enough that the queries do not result in a empty set.

Big enough test bank?

A very useful concept: Metha-item.

Similar to algorithmic items in Maple TA: they are questions or items having parameters and a particular algorithm or program code: when a metha item is selected to be part of an assignment, the algorithm is executed in such a way that the parameters take values in some sets of numbers. These values appear in the statement of the problem and in the options (in case of multiple choice questions) . In a simple case, metha-item is a template.

Example

Metha-item: Select the option that contains a primitive to:

$$\int x^a \, dx$$

Choices:

A $x^{a+1}/a+1$

B x^{a+1}

C $(a+1)\,x^{a+1}$

D $a\,x^{a-1}$

Parameters: $\{a\}$

Algorithm: Randomly take a value for a in the set $\{2, 3 \ldots, 10\}$

Hypothesis: All instances of a metha-item are related to the same concept and have the same difficulty.

In our example, a should be different from -1.

"A reliable instrument ..."

Two key elements:

- The reliability is statistically computed.
- The generation of individual assignments is partially based on some randomness.

We need to randomly assign items to students but we also need to track how a given item was solved in order to compute its features (level of difficulty, discrimination power). Such features give us the reliability. Keeping track of which items of the item banck appear in a particular assignment for a student is refered as version control.

Work done about test banks...

- Sets of metha-item bank for some courses:
  - Linear Algebra
  - Elementary Differential Equations
  - Discrete Mathematics (Finite Mathematics)
  - Advanced Mathematics for Engineering
  - Optimization and Linear Programming

  Questions types: Multiple choice, with numeric answer (ex. the value of a parameter that makes singular a given matrix), with a list of numbers as an answer but according to specific order (ex: first row in the inverse of a given matrix), with a list of numbers as an answer but where the order is not important (ex: the eigenvalues of a given matrix). Examples of question types
- Example of metha-item
- Scripts/programs in Mathematica to generate assignments (homeworks and evaluations): LaTeX files and files with the answers key and the info for version control.

An adequate mechanism to manage information

- Data bases are required: the answer key for each assignment (with version control), the responses from the student, the features of each metha-item. (mysql)
- The scripts for grading the assignments (according the version control info and the type of item involved) (php + mysql)
- The scripts for doing the assignments agenda (due dates) (php + mysql)
- The scripts for computing the features of each metha (php + mysql)

Prediction

What seems to be straightforward: The teacher

- states all the concepts and all the processes involved in the course (Topic List), Ex. the first column in this table.
- constructs a network of dependence with the TL: For every element in TL, he/she declares which elements in TL are required. Ex. the second column in this table.
- constructs an item bank according to TL,
- constructs assignments and collect data for computing item features; there are several cycles in this phase in order to get a reliable item bank. An example
- collects data to get grades for elements in TL: it would look like ...

Grading topics

	Elements in TL			
Student	1	2	$\cdots$	k
1	.70	.60	$\cdots$	.80
2	.80	.95	$\cdots$	.50
$\vdots$	$\vdots$	$\vdots$	$\cdots$	$\vdots$

An example (grades are normalized: 1.0 means fully understood)

One assignment may contain items associated with different elements in TL: Even though the student gets just one grade for an assignment, internally the student gets several grades for the elements in TL. A particular case may ocurr when items with different features but associated to the same topic appears in the same assignment. In such case, we compute the student topic grade by using weighted average among the difficulty levels of the items involved.

A simple first attempt for feedback

1. Given each dependence relation stated for the teacher:

$$T_i \text{ depends of } T_{i_1}, T_{i_2}, \ldots, T_{i_n}$$

a) select the corresponding columns on the grade matrix of TL:

Student	T_{i_1}	T_{i_2}	$\cdots$	T_{i_n}	T_i
1	.70	.60	$\cdots$	0.5	.80
2	.80	.95	$\cdots$	0.8	.50
$\vdots$	$\vdots$	$\vdots$	$\ldots$	$\vdots$	$\vdots$

b) search for a mathematical model that predicts T_i:

$$T_i = a_o + a_1 \cdot T_{i_1} + \cdots + a_{i_n} \cdot T_{i_n}$$

2. For a new student who is currently answering an assignment,
   - A get the elements in TL involved in the assignment and grade them,
   - B use the models to predict grades for subsequent elements in TL, (if some TL grades are missing, use averages)
   - C if subsequent element grades are not "acceptable", provide "a feedback"

Level of acceptable grade for a topic? We currently use 0.70 (70 is grade/punctuation for pass a course in our school) but it makes sense to redefine this level using the predicting models for the final topics in the course and trace back to the first ones in chained way.

Feedback?

Currently, the system provides

- the student a list of topics misunderstood; the ones which get a grade that makes the subsequent topics be below of the level of acceptance.
- the teacher an average of students who are below of the level of acceptance for every element on TL. Example

To be done

Even though the time spent in constructing a reliable test bank is really huge (And also, that different teachers work together in such amazing task is a must) too may things are still missing:

- the predictor model is in its very beginings (as it is, it is still quite limited). There are too many options to explore with: Data mining, analytics.
- the way the systems provides a feedback does not correspond to the initial objective, yet.
- the test bank in Mathematica is not an option: In some cases, Math teachers are not fluency in the language of Mathematica.
  Move to other environment could be an option, but it should be easy to implement scripts to do some computations.

```
(* ::Package:: *)
materia = "MA3002";
unidad = 21;
reactivo = 43;
Problema[materia,unidad,reactivo] := False;
Opcion[materia,unidad,reactivo] := False;

(* Algorithm *)
GeneraParametros[materia,unidad,reactivo] :=
   Module[{aux1,aux2,aux3},
      Clear[a,b,c,d,e]; (* Parameters *)
      aux1 = Random[Integer,{2,6}];
      aux2 = Random[Integer,{2,6},{aux1}];
      aux3 = 10*Random[Integer,{2,7}];
      e = Pi*aux3/180;
      a = {aux1, aux2, aux3};
      b = N[Sqrt[aux1^2+aux2^2-2*aux1*aux2*Cos[e]]];
      c = N[Sqrt[aux1^2+aux2^2-2*aux1*aux2*Cos[Pi-e]]];
      b = SELECCIONES[b,c];
   ];
(* Statement *)
Enunciado[materia,unidad,reactivo] :=
  SequenceForm[
  " Sean $z_1$ y $z_2$ dos numeros complejos tales que ",
  EQ["|z_1|=",a[[1]],"\\,\\,\\mbox{ y }\\,\\,|z_2|=",a[[2]]],
  " Determine el m\\'odulo de 1) $z_1 + z_2$ y el de 2) $z_1-z_2$ ",
  " si el \\'angulo entre $z_1$ y $z_2$ es de ",a[[3]]," grados. "
  ];

Opcion[materia,unidad,reactivo,1] := b; (* SIEMPRE LA CORRECTA en 1*)
```

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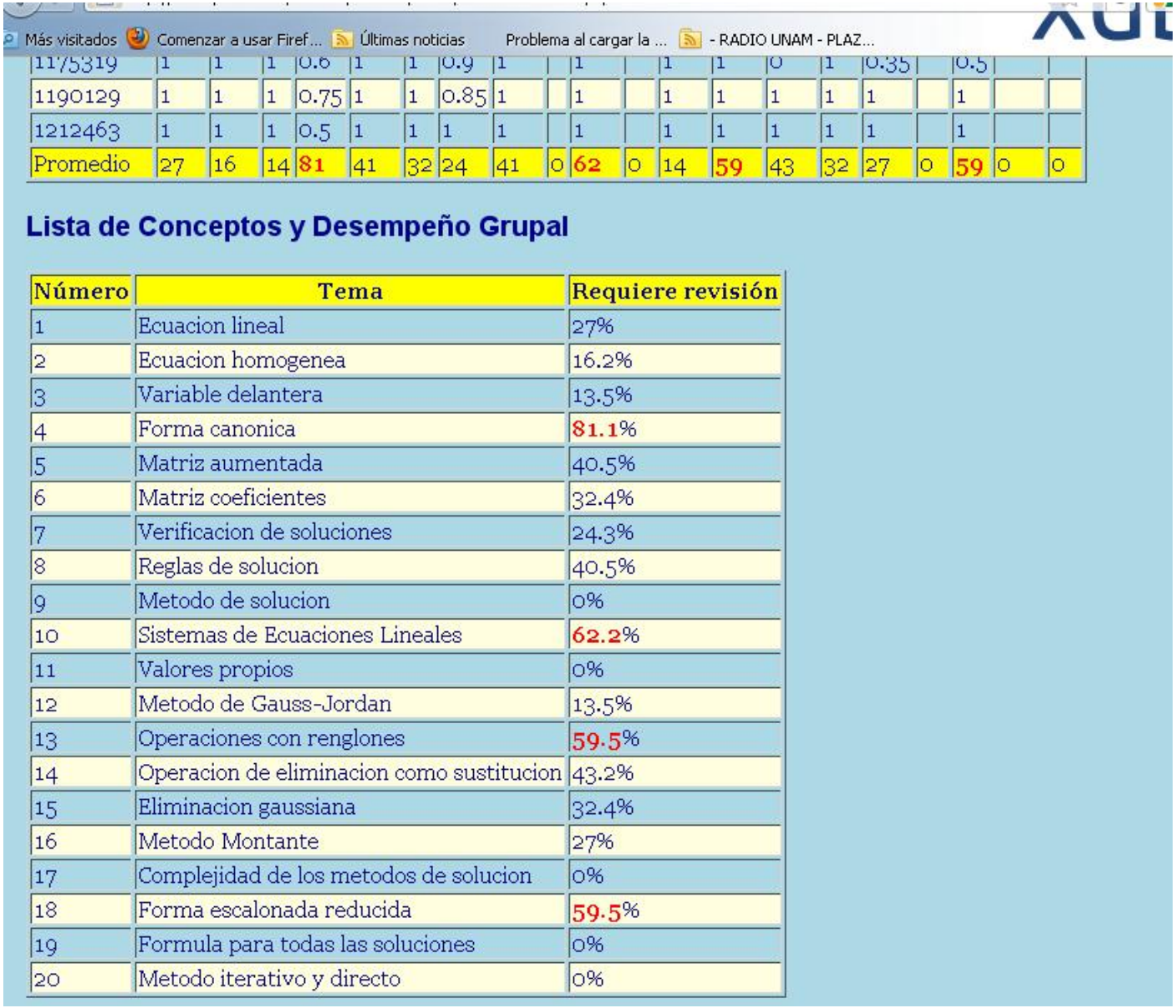

1175319	1	1	1	0.6	1	1	0.9	1		1		1	1	0	1	0.35		0.5		
1190129	1	1	1	0.75	1	1	0.85	1		1		1	1	1	1	1		1		
1212463	1	1	1	0.5	1	1	1	1		1		1	1	1	1	1		1		
Promedio	27	16	14	81	41	32	24	41	0	62	0	14	59	43	32	27	0	59	0	0

Lista de Conceptos y Desempeño Grupal

Número	Tema	Requiere revisión
1	Ecuacion lineal	27%
2	Ecuacion homogenea	16.2%
3	Variable delantera	13.5%
4	Forma canonica	81.1%
5	Matriz aumentada	40.5%
6	Matriz coeficientes	32.4%
7	Verificacion de soluciones	24.3%
8	Reglas de solucion	40.5%
9	Metodo de solucion	0%
10	Sistemas de Ecuaciones Lineales	62.2%
11	Valores propios	0%
12	Metodo de Gauss-Jordan	13.5%
13	Operaciones con renglones	59.5%
14	Operacion de eliminacion como sustitucion	43.2%
15	Eliminacion gaussiana	32.4%
16	Metodo Montante	27%
17	Complejidad de los metodos de solucion	0%
18	Forma escalonada reducida	59.5%
19	Formula para todas las soluciones	0%
20	Metodo iterativo y directo	0%

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- Linear Algebra: Multiple choice/numeric questions; Code for question 1; Code for question 15
- Discrete Mathematics: Item with graphs1 (problem 5); Items with graphs2;
- Linear programming: items with several numbers as an answer. Code for problem 1
- Intro to Complex Variables:items that should be solved by relating lists. Code for problem 1

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