Using intelligent adaptive assessment models for teaching mathematics

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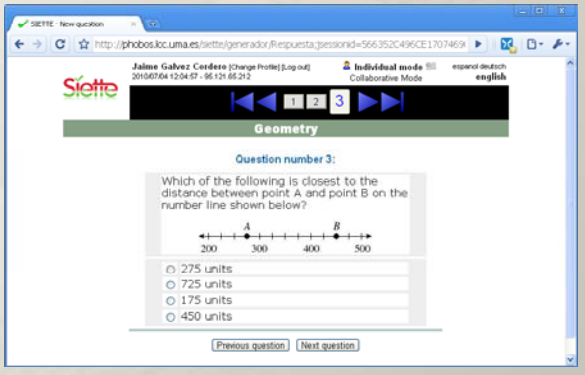
Motivation

- Teaching / assessment of students using:
  - Artificial Intelligence + psychology theories + computer science
- Typical ways of assessing student's knowledge with Computer Adaptive Systems (CAS)
  - Questions
    - Multiple choice
    - Fill in the blank
- Typical use of CAS for learning
  - Theoretical material
  - Other learning material in Mathematics domain
    - Videos
    - Demonstration step by step

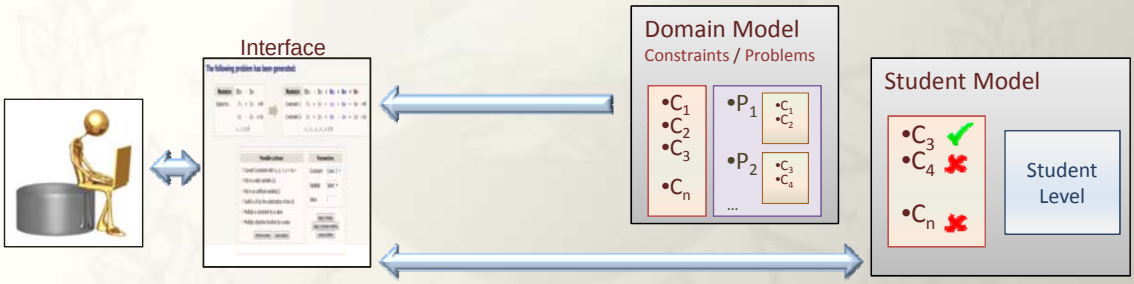


The problem to overcome

- Teaching / assessment is focused on declarative knowledge rather than procedural knowledge
  - Tasks with a solving process involved
  - Traditional CAS Mask or eliminate real application of procedural knowledge
  - Difficult to assess this type of knowledge using CAS
- Solution:
  - Use of problem solving learning approaches
    - Learning by doing
    - Adaptation to individual needs
  - Inconveniences:
    - Use of the systems which are normally used for learning purposes to assess student's knowledge

Constraint-Based Modelling (CBM)

- Methodology for building problem solving learning environments
  - Based on Ohlsson's theory of learning from performance errors
  - Efficient and effective approach :
    - Pattern matching process in an inference engine
  - The base is a set of principles that cannot be violated by any solution to the problem



- Domain principles = Constraint = Inference rule

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If  Relevance_condition = state X
And Satisfaction condition
Then
    Error treatment
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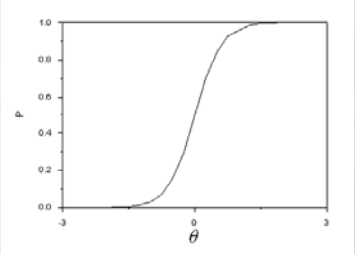
- Main problem is that estimation of student's level is based on heuristics

Item Response Theory (IRT)

- Well-founded test theory for measuring individual traits such as knowledge level (θ)
- Item Characteristic Curve (ICC): describes the relationship between the probability of answering an item (or question) correctly and the student's knowledge level
  - It is modeled from prior student's data
  - The most commonly used function to this end is the 3 parameter logistic (3PL)
  - This curve has to be inferred statistically in a process called calibration



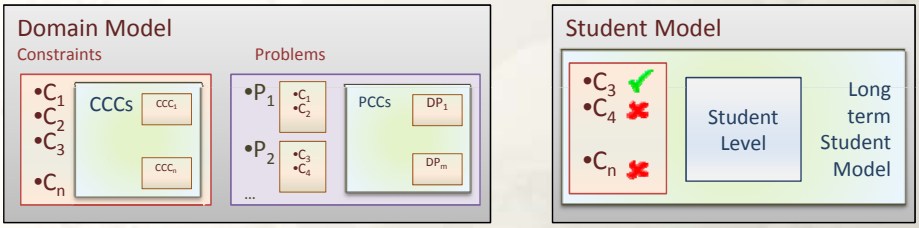
- Main advantage of IRT:
  - Data-driven and well-founded technique
  - Invariance
- Disadvantage:
  - Used only for declarative tasks such as test questions

What do we propose?

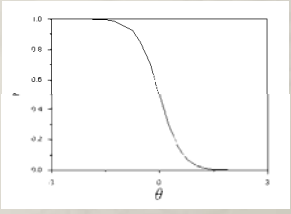
- A new assessing model by combining CBM with IRT
  - Assessment of students in problem solving environments
  - Students will be assessed through just a few problems
  - Using formal methods to improve CBM estimations and therefore learning process **adaptation**
- Overcoming existing difficulties when integrating both approaches:
  - Using a technique for a different purpose than the one for which it was developed
    - CBM is an approach for tutorial purposes
    - IRT evidences are just the answer to the items
- Solution:
  - Correspondence between IRT and CBM

Using CBM and IRT

- Proposed architecture for the CBM + IRT diagnosis model:

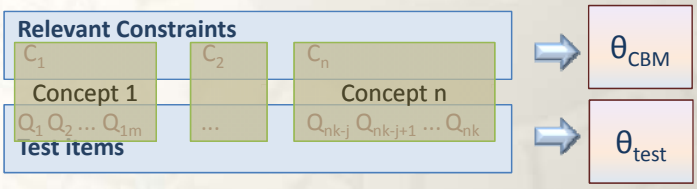


  - Constraint Characteristic Curve (CCC): It quantifies the probability of violating a constraint according to the student's knowledge level
    - Like ICCs, CCCs have to be calibrated
  - Problem Characteristic Curve (PCC)
    - Inferred from combination of CCCs
  - Long term student model
    - Updated according to IRT
    - It uses the CCCs of the relevant constraints of the domain



Current state

- Evaluation of our model:
  - In two different domains:
    - Complex and ill-defined tasks
    - Well-defined domain with simple tasks
  - We have collected data from real students
  - The assessment of our proposal has been compared with declarative assessment of same related concepts

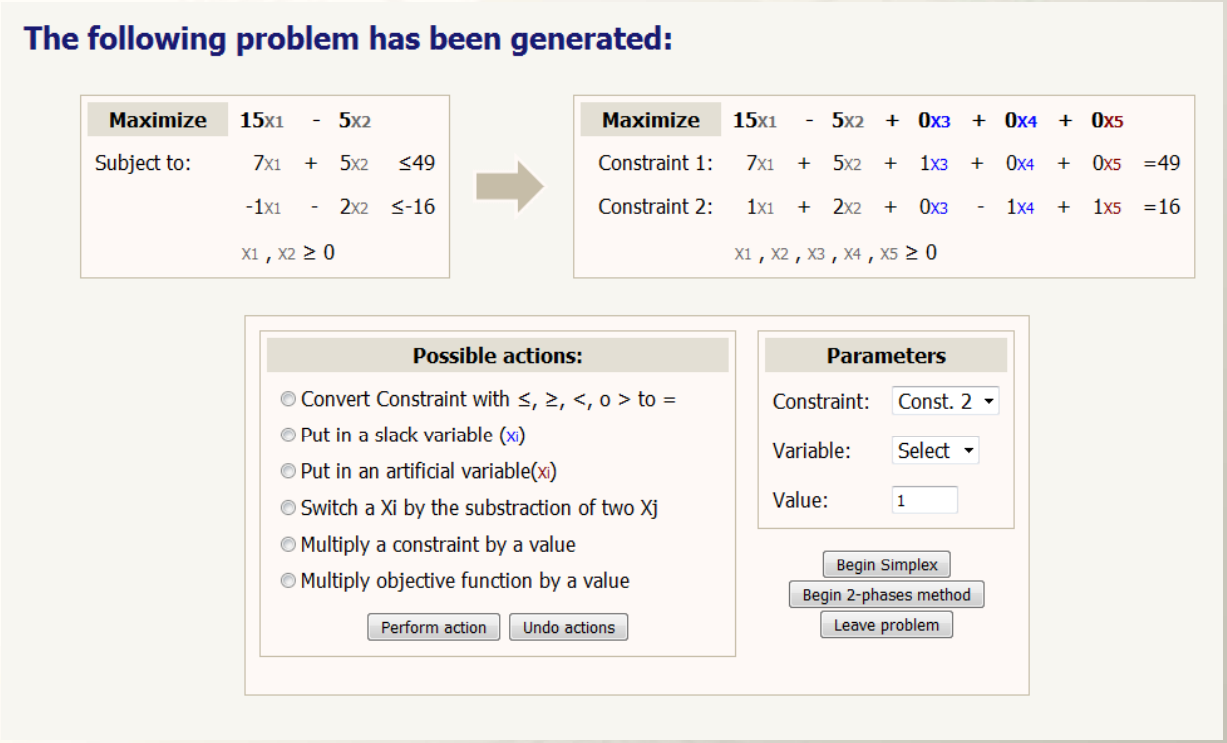


- Validity of CBM + IRT for assessment:
  - It is possible to assess students in a problem solving environment
    - Result of procedural assessment is equivalent to declarative assessment for a certain set of procedures / concepts

The Simplex tutor

- Linear optimization domain
  - Simplex and two-phases algorithms
  - Well-defined and reduced domain
    - < 20 constraints
    - The number of steps is known a priori:
      - Simplex has 3 steps (one of them is iterative)
      - Two-phases method has 4 steps (one of them is iterative)
    - The ways to achieve a correct solution state are limited
- Web application using Jboss Rules inference engine where:
  - Teachers can:
    - Define problems
    - Inspect students' results
  - Students can:
    - Put their knowledge into practice by solving problems assigned by teachers

The Simplex tutor interface



The Simplex tutor interface (2)

Previous | Iteration 3 (Phase 2) | Next

		Ci=	15	-5	0	0
Base	CB	P0	P1	P2	P3	P4

Constraints violated:

- Vector entering the base: It hasn't been correctly selected the vector enterning the base
- Basic entering vector: There is not a base formed by entering this vector
- Vector leaving the base: It hasn't been correctly selected the vector leaving the base
- Negative Po: There is some negative Po

Perform linear combination

Const. 1 = -5 Const. 2 + 1 Const. 1

Combine

Basic changes:

Get in P 1 Get out P 3

Next iteration | Undo actions

Simple solution

Unlimited solution

Infinite solutions

Leave problem

The Simplex tutor interface (3)

To solve the problem it is required to write the final solution.
Result values can be consulted in the final table after the iterations.

Final table:

Iteration 4		Ci=	15	-5	0	0
Base	CB	P0	P1	P2	P3	P4
P1	15	2	1	0	2/9	5/9
P2	-5	7	0	1	-1/9	-7/9
		Zi= -5	0	0	35/9	110/9

Solution values

Optimal value of the function: -5

Optimal solution point: (X1= 1 ,X2= 0)

Finish problem

Leave problem

Conclusions and Future work

- Proposal using CBM + IRT for teaching / assessing students
  - Supply weaknesses of traditional approaches for assessing procedural knowledge
  - Generic approach
- Advantages:
  - Assessment of real procedural knowledge
  - Our assessment technique leads to accurate and invariant estimations (improvement on CBM estimations)
  - Teaching is improved by a better adaptation
  - Few problems instead of long tests
- Future work:
  - Adaptive problem selection based on IRT-based adaptive tests
  - Comparison with other methodologies for building learning environments
  - Project DEDALO starting in September 2010:
    - Applying our approach to mathematics domain
      - Study fields of application
      - Developing a system for teaching mathematics
    - Testing the approach with a huge amount of real students
    - Study assessment improvement by using other AI techniques

Thank you for your attention

Any question ?

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