Towards a Design Pattern Language to Track Students’ Problem-Solving Abilities

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This paper is a first contribution towards a set of Design Patterns to track Usage of Learning Systems that is the focus of the DPULS JEIRP in the context of Kaleidoscope network. In our multidisciplinary team AIDA we are particularly involved in problem based learning environments and cognitive diagnosis. We implemented various systems for different domains, different types of students and institutions. BSMod [1] is a generic system using Bayesian Networks for student modelling; so far it analyzes a sample collected by Pepite [2]. Combien? [3] is a software to learn problem-solving methods in combinatorics at high school level, it collected six hundred of students’ answer to exercises. Diane [4] is a diagnosis system for arithmetical word problems in elementary schools; it works on one thousand two hundred students’ tracks. Java Course [5] is an on-line introductory course on Java programming for second year university students, it analyzes one hundred students’ logs and students’ answers. Pepite is a diagnosis system to support teachers in monitoring algebra learning in secondary schools, so far it collected and analyzed a sample of exercises worked by three hundred secondary school students. We also experienced trace analyses from four hundred logs of students connected to Wims [6], a server of math exercises at university level.

For each experience, researchers analysed usage tracks and problem-solving answers or performance. These tracks are diverse and recorded data are different. According to experienced systems, a detailed analysis of students’ answers is processed on-line and the result is recorded in the tracks or it is processed after the student session. The analysis is fully automatic or human supported.

Based on our diverse experiences, we present a first draft of design pattern language to track students’ problem-solving abilities to be discussed in the AIED 2005 workshop. To begin with, we used the Alexander’ format of design pattern description [7].

Figure 1 is a synthetic view of the design pattern in relation with the process of tracks’ analysis. Then, we present each design patterns and their dependence diagram.
Figure 1: Tracks’ synthetic process Design Patterns

CONTEXT
Students use a system to solve problems

USAGE DATA
Trails + Answers

ADDITIONAL DATA
• Tasks model
• Domain model
• Model of competence
• Typologies of errors
• Predefined set of stereotypes

Detailed Analysis
Of each answer or exercises
(Immediate or delayed)

Automatic Grading of Student’s Answer

Synthetic Analysis
Of a set of answers, exercises
or a whole course session
(Delayed)

Set of codes for each answer

Synthetic Analysis

Individual student’s profiles

Classification

Classification of Students

Cognitive map of the class

Student’s stereotype

Displaying data

Displaying the Diagnosis

OBJECTIVE
System or teacher monitors learning
Designer improves the system

Legend

Static Data
Dynamic Data

Output
Input
<table>
<thead>
<tr>
<th>Name</th>
<th><em>Automatic Grading of Student's Answers</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Your system records students’ answers to problems where students can build their own solution. A task model is available.</td>
</tr>
<tr>
<td>Problem</td>
<td>How to automatically grade the student's answer to a problem? Or if it is not possible, how to support human grading?</td>
</tr>
<tr>
<td>Motivation</td>
<td>You want to know if the student answered the questions correctly. You want an automatic ranking (as much as possible).</td>
</tr>
</tbody>
</table>
| Forces                   | - Answers expressed by students are very different according to domain diversity and to students’ cognitive diversity.  
- The more freely the answer is expressed, the more difficult is the grading  
- Except on very specific exercises, it is impossible to predict all types of answers |
| Solution                 | Several approaches can be used and combined.  
If you can define a set of predefined solutions, you can use a pattern matching approach.  
If the answer is expressed in a formal language, you can use specific software to assess its correctness such as a compiler, a theorem prover, a Computer Algebra System (CAS), SQL engine etc.).  
If the answer is expressed in natural language, you can use natural language processing tools but very often, you will need a human assessor. |
| Examples                 | Diane, Wims, Java Course, Combien, Pépite. |
| Actors                   | Teacher, Tutor, Researcher, Student (auto-evaluation). |
| Related Patterns         | *Detailed Analysis* |
Displaying the Diagnosis

Context
You already have conducted a requirements analysis with the different categories of actors. Your system analysed the student’s tracks. Your system now has rich information about students problem solving skills and you wish to make available the results of the analysis for the different type of actors.

Problem
How to display the analyses of the traces? How to make them usable and understandable?

Motivation
To improve learning activity, actors need a multidimensional point of view on student’s features, a report of his/her strong and weak points in a preset categorization of competence, on overview on the whole class competence.

Forces
- There are many and diversified data to display.
- The different actors don’t have the same requirement.
- The displaying must suit the expectations of the users.

Solution
Each type of user needs an adequate presentation.

First, you have to structure the results from the different actors’ point of interest. For example, a teacher may need to access the student’s grades (success, failure or partial failure) and the success rates on the various abilities. Another teacher may want to see the learning strategies and the cognitive map of the class. A researcher might wish to display the all catalogue of answers to a specific exercise or statistics about success rates on a question. A student may need to display his/her grades.

Second, you have to choose an adequate presentation or interaction model. You can represent the student’s characteristics weaknesses and strong points with a representation by text, histogram or diagram. The interaction model could include browsing functionalities to verify or modify the automatic diagnosis. It could data base queries.

It is important to let users adapt the display to their needs, but it is also important to set default parameters for occasional users.

In our experiences, users need views on the student activity with different level of abstraction. It is important to give an overview and let the possibility to have more details or explanation on how this overview was build. The overview is needed for strategic decision-making. Details are required to understand better the synthetic view, to correct it or to take tactical decision.

Examples
Diane, Wims, Combien, Pépite, Java Course.

Actors
Teacher, Tutor, Students, Researcher.

Related Patterns
Synthetic Analysis, Classification of Students
<table>
<thead>
<tr>
<th>Name</th>
<th>Detailed Analysis</th>
</tr>
</thead>
</table>

**Context**
The student answered a question or solved a single exercise. The answer is recorded as well as usage data (time spent, the incurred actions, the help requests, etc). A task model, a model of competence, typologies of exercises and typologies of errors are available.

**Problem**
How to analyze the answer of a student to a given question?

**Motivation**
You want to analyze, correct, comment on or classify the student’s answer.

**Forces**
- The answer can take a multitude of forms and its interpretation can set many problems (typing errors, incomprehension of the system).
- Analysis is a very complex process.
- It is necessary to pay attention to bad interpretations or errors of manipulation.

**Solution**
This detailed analysis is immediate or delayed. An immediate assessment is carried out when the answer is given. In this case the system often gives an immediate feedback to the student and this feedback is recorded along with the answer, its assessment, the time, etc.

This delayed detailed analysis occurs when during the problem solving session the systems collects students’ answers and usage data but they are analyzed after the session.

The analysis depends on the actors’ objectives. Actors may need success rates, grades or might wish a more precise analysis on resolution strategies or how much time the student spent before validating his answer, etc.

Answers analysis can be automated, human, or supervised. From the different models (competence, task), and predefined typologies (exercises and errors), you build grids of analysis for each exercise and implement procedures or heuristics to carry out a full or partial analysis.

Then, you can build a system using these heuristics to analyse the strategy of resolution. Thus, you determine competences that were used by the student to answer. But you have to remember that hesitations and errors hold a significant part in the analysis of the student, it is possible to see strong point and weakness to propose some remedial action.

The teacher carries out the human analysis. The analysis is supervised when the teacher or a researcher is needed to complete or correct or modify the software analysis.

**Examples**
Diane, Logic-Tutor, Combien, Wims, Pépite, Java Course.

**Actors**
Teacher, Tutor, Researcher.

**Related Patterns**
*Automatic Grading of Student's Answers, Synthetic Analysis.*
<table>
<thead>
<tr>
<th>Name</th>
<th>Synthetic Analysis</th>
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</thead>
<tbody>
<tr>
<td>Context</td>
<td>You collected the student’s answers to a set of questions, exercises or to a whole course. The detailed analysis of each answer was carried out. A domain model, a model of competence, and typologies of errors and exercises are available.</td>
</tr>
<tr>
<td>Problem</td>
<td>How to get an overview of the whole activity of the student?</td>
</tr>
<tr>
<td>Motivation</td>
<td>Fine-grained analysis does not facilitate decision-making. Strategic decision-making requires a high level description of student’s activity: To monitor learning or to improve their course, teachers need a synthetic view on the student learning activity and an account for the student’s evolution. Thus, you want to define the main features of the student’s competence.</td>
</tr>
</tbody>
</table>
| Forces   | • Trade offs have to be found between synthetic view and account for diversity, complexity and evolution of student’s activity  
• Main dimensions of analysis are different for different actors  
• A pedagogical, didactical, or cognitive model is required to define the main dimensions to synthesize the analysis |
<p>| Solution | The synthetic analysis is always delayed because it requires detailed analyses of every answer during the whole session. From the domain model or the model of competences, you have to define main dimensions to account for clusters of abilities or success rates or errors. For example, you could decide to determinate the student’s evolution on a special competence during the course, or on his/her strong points and weaknesses, etc. Then you will find recurring abilities or errors in detailed analyses using a typology of exercise or errors. For instance, if your dimension of analysis is “to solve difficult exercises” you will calculate how many difficult exercises the student solved or tried. If your dimension of analysis is “usage of algebra”, you will find that a student does use algebra to prove relation or sometimes or always. Finally, you may classify the student in comparison with others (their class mates, a priori classification see; pattern Classification of students) |
| Examples | Bsmod, Wims, Pepite, Diane |
| Actors   | Teacher, Tutor, Researcher, Student |
| Related Patterns | Detailed Analysis, Displaying the Diagnosis, Classification of Students |</p>
<table>
<thead>
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<th>Name</th>
<th>Classification of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Your system built a synthetic analysis of learning activity for every student’s in a whole class or course. Teachers or educational researchers defined a set of students’ stereotypes.</td>
</tr>
<tr>
<td>Problem</td>
<td>How to draw up an assessment of the class or a representation of the whole class activity? How to categorize type of students in the class?</td>
</tr>
<tr>
<td>Motivation</td>
<td>You want a cognitive map of the class built from the data collected on individuals. To monitor learning or to improve a course, teachers need to classify the usage of learning materials and to group students according their performance or abilities.</td>
</tr>
</tbody>
</table>
| Forces        | • There are different individuals’ characteristics, which must be preserved.  
                • There are many different ways of grouping students according to actors’ needs. |
| Solution      | You have to specify a classification of students. By a statistical, empirical or theoretical analysis you can define clusters of students and characterize these clusters. Thus, each cluster defines a stereotype.  
                Stereotypes can be very simple (low achieving, regular, high achieving students), multidimensional (ranking students on a multidimensional scale) or describing usage (player, systematic learner, butterfly etc.)  
                Then, you classify each student in a stereotype. Several techniques are available: decision trees, rates and thresholds etc.  
                Finally, you display a map of the class. For instance, you display each stereotype with the students’ names if the teacher wants a grouping of his/her students or you display charts with the number of students by stereotypes. |
| Examples      | Pépite, Java course, Wims. |
| Actors        | Teacher, Tutor, Researcher. |
| Related Patterns | Synthetic Analysis, Detailed Analysis, Displaying the Diagnosis |
References


Web sites:
http://www.math-info.univ-paris5.fr/combien