Automated course configuration based on automated planning: framework and first experiments*

Carla Limongelli[1], Andrea Sterbini[2] & Marco Temperini[3]
[1] *DIA, Università Roma Tre, Italy*
[2] *DI, Università di Roma "La Sapienza", Italy*
[3] *DIS, Università di Roma "La Sapienza", Italy*

Abstract
The work presents an application of automated planning to the process of course configuration. *Configuring* a course means to build a course based on the effective needs of the specific learner. The course is built by selecting and sequencing learning objects (*learning components*) from a repository. Parameters in that process are the *starting knowledge* that the learner already possess and the *target knowledge* that is expected to be gained through the course.

In order to have more powerful ways to reason on its properties and structure we propose to treat this problem as a planning problem: a configuration is a *plan*, a component is an *action* in the plan; required/acquired knowledge are modeled, resp., as action preconditions and postconditions. The *initial state* of the plan encodes the student's starting knowledge, while the *goal* of the plan encodes the course target knowledge.

We have run a short experiment on a class of 26 third-year undergraduate students, regularly attending the course of *Algorithms and Data Structures*.

1 Introduction

In this paper, we extend the original framework proposed in [1, 2] and use automated planning to implement the configuration process. As a matter of fact, with *automated planning* we can easily obtain several alternative configurations for the same course or to verify the consistency of sets of learning components.

*contact author: Carla Limongelli limongel@dia.uniroma3.it

We show how the configuration of a course can be defined in terms of a planning problem, how the specification of learning components can be manipulated to feed the planning process and how the solution of such process can be interpreted as the specification of a configuration (or, the solutions can be used as alternative courses, each one responding to the intended learner's need).

A short experiment, run on a class of 26 third-year undergraduate students, shows the applicability and the success of this approach.

2 The Logical Framework

We recall the basic definitions introduced in [1, 2] for course configuration.

Definition 1 (Knowledge item) A *knowledge item* is an expression meaning the (sufficient) knowledge about a certain topic.

Definition 2 (Component) A component C specifies a *teaching contents* which may be included in a course about a given notion/aspect/technique/teaching-aim. The component also specifies which knowledge is required to understand the teaching contents of the component and which knowledge is gained by going through the teaching content.

id (*component identifier*);

rk (*required knowledge*) The knowledge required to take the component, expressed as a set of knowledge items to be possessed before taking the component;

tc (*teaching contents*) Teaching resources used in the component (hypertext, hypermedia, guided exercises, plain exercises for self evaluation, plain exercises to be evaluated by the tutor, final tests for self evaluation, final tests to be evaluated by the tutor);

ak (*acquired knowledge*) The set of knowledge items which are gained by studying the component.

Once the *starting knowledge* of a given student has been defined (e.g. through an initial test), together with the *target knowledge* that should be reached about the topic, a course can be *configured* for the student, i.e. especially adapted for his/her case.

A course tailored to the peculiar needs of a given student is a *configured course*, where all the components needed to satisfy the target knowledge requirements are sequenced according to their prerequisites.

3 Course Specification = Planning Problem

The generation of a course can be seen as a planning problem. A planning problem is characterized by:

the description of the initial state: in this case the initial state is represented by all the knowledge the student already has in the specific field: the *Starting Knowledge*;

the description of the executable actions and their effects: each action represents a didactic module (with the specific *Required Knowledge*, and the effects represent the knew knowledge acquired once that the module has been studied: the *Acquired Knowledge*;

the description of the goal: it is represented by all the knowledge that the student has to acquire after the entire course: the *Target Knowledge*.

As a particular kind of planning problem, the generation of a course shows the following characteristics:

- everything is known: the environment is accessible;
- the environment is deterministic: actions effects are known;
- the environment is static: during the plan generation the environment does not change.

Under the above conditions, the solution found by a planner guarantees the goal reachability, starting from the description of the initial state and applying some of the actions. Moreover, in our course configuration problem, the plan comes out to be complete and consistent.

In a complete plan the goal G and the actions preconditions are supported by the initial state and by one or more actions in the plan.

Notice that in our case we never loose knowledge: fluents can only become true and they do no longer change.

4 The System

The core of our system uses the planner Blackbox [3]. Blackbox is a planning system based on the "planning as satisfiability" approach: it translates planning problems, written in PDDL, into boolean satisfiability ones; then it tries to solve them by means of different powerful SAT engines. It is one of the most popular planners and it is available under different platforms. These characteristics made us to choose Blackbox as a planner to implement course configuration.

In general a Didactic Course is constituted by two (pddl) files [5], the problem and the domain specification. The problem specification contains: the student's Starting Knowledge, and the Target Knowledge of the course (see Fig. 1).

```
(define (problem PROBLEM-NAME)
    (:domain DOMAIN-NAME)
    (:init STARTING-KNOWLEDGE)
    (:goal TARGET-KNOWLEDGE))
```

Figure 1: The general structure of the problem definition file.

The domain file represents all the modules in the course i.e. a list of components, represented by different actions. This file is unique for the course (see Fig. 2).

```
(define (domain COURSE-NAME)
        (:requirements :strips :typing :equality)
        (:types knowledge) %% not necessary at the moment%%
        (:predicates SET-OF-KNOWLEDGE-ITEMS
        ...)
        (:action MODULE-1
            :parameters (?k - knowledge)
            :precondition (set of required knowledge for the module-1)
            :effect (set of the acquired knowledge for the module-1)
        )
        ...
        (:action MODULE-n
            :parameters (?k - knowledge)
            :precondition (set of required knowledge for the module-n)
            :effect (set of the acquired knowledge for the module-n)
        )
)
```

Figure 2: The general structure of the course. Each module is represented by an action.

The planner takes these two input files and produces a plan that represents a set of didactic modules that the student has to learn in order to reach its target knowledge.

5 Experiments

We have run a short experiment on a class of 26 third-year undergraduate students, regularly attending the course of *Algorithms and Data Structures*.

Our aim was to test if and how the personalization is effective on the the students' learning process and satisfaction. Components have been defined to cover a 3-hours section of the face-to-face course (an *introduction to graphs*). Two groups of students have been selected: the first group was ready to study that section on line; the second was the reference group, attending face-to-face lectures. At the beginning and at the end of the section the students answered two short tests: the first one aimed at assessing their starting knowledge and at configuring each course; the second one aimed at evaluating their final knowledge on *introduction to graphs*.

In appendix we show an example of a possible plan generated by Blackbox. Figure 4 shows the problem specification obtained from an initial test, figure 5 shows a snapshot of the domain, i.e. the specification of all the available components, and 6 shows the configuration generated by the planner.

The results of the initial and final assessments are reported in figure 3, that shows the gap between the initial (light blue) and final (blue) outcomes for the on-line students, confirming the effectiveness of the on-line course. In appendix we show also the questionnaire delivered to the students at the end of the course to evaluate

the perceived effectiveness of the method. The final average results scored by the two tested groups is 8.60/10 for the reference group vs. 8.06/10 for the on-line group. Both the perceived quality of the course and the results of the assessment tests show that the method is effective as much as the face-to-face teaching.

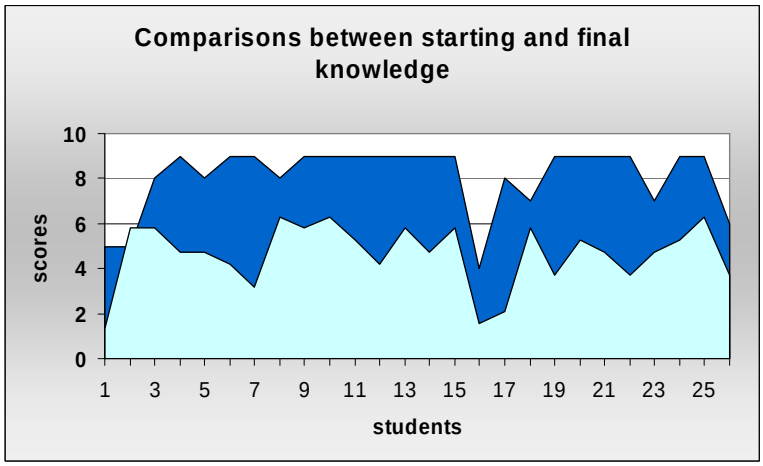

Figure 3: Comparison between the initial (light blue) and final (blue) tests, on-line group.

References

[1] A. Sterbini and M. Temperini, *A logical framework for course configuration in e-learning*, Proc. International Conference on Information Technology Based Higher Education and Training (ITHET) 2003, Marrakech, Morocco, 2003.

[2] A. Sterbini and M. Temperini, *Design and implementation of a logical framework for course configuration in e-learning*, Proc. International Conference on Computers and Advanced Technology in Education (CATE) 2003, Rhodos, Greece, 2003.

[3] H. Kautz and B. Selman. *BLACKBOX: A new approach to the application of theorem proving to problem solving*. In Working notes of the AIPS-98 Workshop on Planning as Combinatorial Search, pages 58–60, 1998.

[4] A. Sterbini and M. Temperini *Course configuration via logic and graphic tools*, in Proc. Int. Conf. on Web-based Education (WBE04), Feb. 2004.

[5] M. Ghallab, A. Howe, C. Knoblock, D. McDermott, A. Ram, M. Veloso, D. Weld, and D. Wilkins. Pddl—the planning domain definition language, 1998.

6 Appendix

```
(define (problem sample)
  (:domain introduzione-ai-grafi)
  (:objects k - knowledge)
  (:init (and (grado k) (componente-connessa k)
              (ciclo k) (intro-rappresentazione-grafo k)))
  (:goal (and (dfs k) (bfs k)))
)
```

Figure 4: Problem description: the student has basic notions about graphs and their representation and should learn depth-first and breadth-first searches.

```
(define (domain introduzione-ai-grafi)
    (:requirements :strips :typing :equality)
    (:types knowledge)
  (:predicates
    (grado ?k - knowledge)
    (componente-connessa ?k - knowledge)
    (ciclo ?k - knowledge)
    (rappresentazione-grafo ?k - knowledge)
    (bfs ?k - knowledge)
    (dfs ?k - knowledge)
    ...
  )
...
(:action id10
 :parameters   (?k - knowledge)
 :precondition (rappresentazione-grafo ?k)
 :effect       (lista-di-adiacenza ?k)
)
(:action id11
 :parameters   (?k - knowledge)
 :precondition (lista-di-adiacenza ?k)
 :effect       (matrice-di-adiacenza ?k)
)
(:action id12
 :parameters   (?k - knowledge)
 :precondition (and (matrice-di-adiacenza ?k)
                    (lista-di-adiacenza ?k))
 :effect        (complessit ?k)
)
(:action id13
 :parameters   (?k - knowledge)
 :precondition (complessit ?k)
 :effect       (richiami-complessit ?k)
)
(:action id14
 :parameters   (?k - knowledge)
 :precondition (and (complessit ?k)
                    (richiami-complessit ?k))
 :effect       (intro-ricerca ?k)
)
(:action id15
 :parameters   (?k - knowledge)
 :precondition (intro-ricerca ?k)
 :effect       (bfs ?k)
)
(:action id16
 :parameters   (?k - knowledge)
 :precondition (bfs ?k)
 :effect       (dfs ?k)
))
```

Figure 5: Snapshot of the domain describing the course components to the planner.

```
1 (id10 k) // Adjacency lists
2 (id11 k) // Graph representation: Adjacency matrices
3 (id12 k) // Graph representation: Representation complexity
4 (id13 k) // References on asymptotic complexity
5 (id14 k) // Search algorithms: introduction
6 (id15 k) // Breadth first search
7 (id16 k) // Depth first search
```

Figure 6: A plan generated form the previous problem and the course domain.

How did you find the usage of the course material?							
Very easy	25%	**Relatively easy**	**67%**	Relatively difficult	8%	Very difficult	0%
Did you receive adequate help during the course?							
Yes	**50%**	Partially	38%	No	13%		
If you needed help, from whom you have got assistance?							
Colleagues and/or other course participants	37%	**Documentation**	**47%**	With email or Internet discussions	16%	Other	0%
Did you experience technical troubles with the material or the software used in the course?							
Often	13%	**Sometimes**	**38%**	**Rarely**	**38%**	Never	13%
How do you rate the didactic load of the lessons?							
The lessons were too long	0%	The lessons were too short	9%	**Evenly distributed among lessons**	**52%**	Some lessons were too long, while other were too short	39%
Did you find useful this course to study for the written exam of 19/11/04?							
Yes, it was useful; I only had to do the exercises	33%	No, I had to re-study the whole course	4%	**Partially useful; I had to fill holes in the course material**	**46%**	I haven't yet taken the exam	17%
Apart from the textbook, did you need the help of the transparencies used in class?							
Only to check that the topics were the same	**58%**	No, I didn't use them	25%	Yes, because I did find some topics unclear	17%		
The graphic presentation of the topics and the page format were pleasant to see?							
Yes, very much	21%	**Enough**	**71%**	Not much	8%	Not at all	0%
Do you judge sufficient the links among the course topics?							
Yes, very much	17%	**Enough**	**83%**	Not much	0%	Not at all	0%
Motivation/interest to follow the course							
Very high	17%	High	38%	**Relatively high**	**46%**	Relatively low	0%
Where did you normally was while participating to the course?							
At home	42%	University / Workplace	8%	**In both places**	**50%**		
Did you enjoy participating to this course?							
Very much	13%	**Yes**	**79%**	Not much	8%		
The course has been mainly:							
Superior to my expectations	13%	**In line with my expectations**	**75%**	Inferior to my expectations	13%		
How did you find the experiment of attending an "open and at distance" course?							
Very well	17%	**Partially well**	**79%**	Not well	4%		
How do you judge this course, compared to the "traditional" courses that you had taken?							
Very much more effective	0%	More effective	17%	**Equally effective**	**61%**	Less effective	17%
Which one of the following aspects has been useful in this learning experience?							
Opportunity to choose the place to take the lessons and study	25%	**Opportunity to choose the time to take the lessons and study**	**71%**	Information completeness	0%	Sharing informations with other on internet	4%
Which one of the following aspects has been bad in this learning experience?							
To be isolated	17%	Needing more support and encouragement to study	17%	**Absence from the course of the informations that I needed**	**35%**	Electronic support tools (email, newsgroups ...) insufficient	9%
Would you consider the idea of taking other courses like this one?							
Yes	**50%**	No	4%	Perhaps	46%		
Regarding the tests/exercises done during the course							
They were not sufficient to check my intermediate preparation	25%	**They were sufficient to check my intermediate preparation**	**42%**	I would have preferred that they were all self-evaluation tests	4%	I would have liked that they were corrected by the teacher via email	29%
They were mainly:							
Difficult	0%	Relatively difficult	8%	**Relatively easy**	**67%**	Easy	21%
How do you judge the final evaluation test?							
Very difficult	0%	Difficult	4%	Relatively difficult	42%	**Relatively easy**	**50%**

Figure 7: Final questionnaire (more frequent answers are highlighted).