

Verifying the compliance of personalized curricula to curricula models in the semantic web

Matteo Baldoni, Cristina Baroglio, Alberto Martelli,
Viviana Patti, and Laura Torasso
Dipartimento di Informatica
Università degli Studi di Torino

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Overview

- **Focus: verifying the compliance** of **specific curricula** (personalized sequences of learning resources in the SW) w.r.t abstract specifications of **curricula models**
- **Learning resources in the semantic web**
 - adding a semantic layer to the description of learning resources accessible over the internet (RDF, LOM)
 - enabling the application of **automated reasoning techniques** for personalized use and reuse (-> REVERSE).
- **Approach:** combining
 - lesson learnt in the community of traditional educational systems (especially for what concerns the re-use of learning resources)
 - New possibility of running reasoning techniques developed in AI over the semantically annotated learning resources
- **A step further:** previous work on reasoning about actions for dealing with curriculum sequencing personalization functionality

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Overview

- Our contribution: verification technique that can be profitably combined with curriculum sequencing personalization functionality

- **KR issues:**

- action methaphor for learning resources
 - annotation of learning resources -> prerequisites-effects at the knowledge level;
- specific curricula: sequence (first step) -> output of personalization
- Curricula models

- **temporal projection + model checking** techniques from AI: checking compliance of specific

- possible **implementation** in a unified framework: SPIN; DEMO available

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Motivating use cases


- Compliance verication: when it can be useful?
- Practical cases where the need of personalizing learning resource sequencing w.r.t. to the student desire has to be *combined* with the ability to check that the result of personalization fit some abstract constraints, possibly imposed by a third party.
- **Use case:** a given University could certify that the specific curricula that it offers for achieving a certain educational goal -that built upon the local university courses- respect some European schemes defined at the abstract level of competence.
- Automatic checking of compliance combined with curriculum sequencing techniques could be useful for implementing processes like cooperation in curriculum design and **curricula integration** which are actually the focus of the *Bologna Process*, promoted by the EU ministers responsible for higher education:

"Curriculum design means drawing up of a **common study path** aimed at reaching the educational goals that have been jointly defined. In these schemes the **partners offer specific segments which complement the overall curriculum designed**"

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SW & Personalization

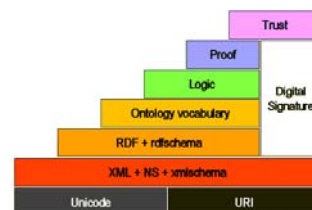
- The **Semantic Web** is concerned with adding a computer-interpretable semantic level to resources that are accessible over the internet in order to enable sophisticated forms of automatic use and reuse.
- Especially with the development of peer-2-peer e-learning architectures, also **learning resources** can be considered as resources that are accessible over the internet
- The introduction of **machine-processable semantics** makes the use of a wide variety of reasoning techniques possible -> 
- ...thus widening the range of the forms that personalization can assume.
- Given a proper semantic markup we can apply reasoning techniques to support automated and personalized learning resource discovery, selection, composition...
- So far, reasoning in the Semantic Web is mostly reasoning about knowledge expressed in some ontology

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SW & Personalization

- The ontology layer is the highest layer of the Semantic Web tower that can be considered as quite well assessed.
- But personalization may involve also other kinds of reasoning and knowledge representation, that conceptually lie at the logic and proof layers of the Semantic Web tower
- What kinds of knowledge and what kind of reasoning are necessary for performing personalization?
- This is an open question! Which personalization feature? Application domain?
- Results and tool from KR & AR community can be adapted
- Reasoning about action and change
- Verification of temporal properties by model checking techniques



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Lesson learnt

- combining
 - **lesson learnt in the community of traditional educational systems (especially for what concerns the re-use of learning resources)**
 - the new possibility of running reasoning techniques developed in the AI community over the semantically annotated learning resources
- Wide literature on Adaptive Hypermedia applied to educational issues
 - common goal: using knowledge about the learning domain, the student, learning strategies (and so on...) in order to support flexible, personalized learning and tutoring

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Lesson Learnt: the knowledge level

- to keep separate
 - **knowledge entities** (competences) and , i.e. some identifiable piece of knowledge related to the learning resources,
 - **information entities** (that is the actual learning resources).
- to define at the knowledge level, a set of learning dependencies = the dependencies among knowledge entities
- Given such a separation
 - associating to each learning resource a set of competences that describe it -> semantic metadata
 - **personalization component**
 - using **knowledge** associated to the learning resource **&** a representation of the user **learning goal &** of the **user knowledge**, for performing the **personalization tasks like for example curriculum sequencing**

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Lesson Learnt: the knowledge level

Personalization task:

- **curriculum sequencing:** one of the technologies used in Web-based education for supporting adaptation and guidance, where an *optimal* reading sequence through a hyper-space of learning objects is to be found
 - different methods on how to determine which reading (or study) path to generate in order to support in the best possible way the learner navigation through the hyper-space.
 - **generated sequences** fit the user requirements and characteristics, based on the available learning resources

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Lesson Learnt: the knowledge level

Advantages

- it is closer to human intuition
- easy reuse of the learning objects: the same learning object will be automatically taken into account by the personalization component whenever a competence that is supplied by it is necessary during the sequencing process
- it fits with the idea of semantic annotation of learning resources
- it enables the application of reasoning processes for implementing sequencing
- which semantic annotation at the knowledge level for learning resources? -> KR issue connected with the reasoning I want to apply

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Previous work: resources as actions

- **action metaphor**: a learning resource is an **action** with
 - a set of **preconditions** (knowledge that is necessary for using the learning object)
 - a set of **effects** (the supplied knowledge).
- an action can be executed given that a set of conditions holds; by executing it, a set of conditions will become true; **in the same way** a learning resource can profitably be used if the learner has a given set of prerequisite knowledge; by using it, the learner will acquire a new set of knowledge.
- a reasoner uses such descriptions & the **user learning goal & user knowledge profile** (expressed at the knowledge level) for performing the **sequencing task**.
 - the WLog system [Baldoni, Baroglio, Patti, AIRE 2004, Kluwer]
 - ...in the semantic web [Baldoni, Baroglio, Patti, Torasso, EAW 2004]
 - integration into the Personal Reader Framework (Hannover - REWERSE) -> **work in progress**

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Previous work: WLOG

- **reasoning techniques** from reasoning about actions:
 - Planning for sequencing: reasoning about the dynamics of the learning objects outcomes and preconditions and generating sequences of learning objects for achieving the learning goal.
 - temporal projection for validation of user-given curricula
 - temporal explanation (in case of validation failure)
- **sequencing** by refining learning strategies (schemas)
 - described on the basis of the defined knowledge entities
 - reasoning technique: procedural planning
 - reasoner is implemented in the logic language DyLOG [Baldoni, Giordano, Martelli, Patti, AMAI 2004, Kluwer]

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Integrating a new verification task

- A step further...given a semantic annotation of the resources based on the metaphor of resources as actions (unified framework), we focus on a new kind of reasoning:
- *compliance* verification of personalized curricula w.r.t. a curricula model
- **Personalized curricula:** learning paths through learning resources personalized w.r.t. specific user need, e.g. they could be the result of a curriculum sequencing method that exploits the planning techniques of previous work
- **Curricula models** specify general rules for building such paths
 - They can be interpreted as constraints expressed in terms of knowledge elements or concerning features that characterize the resources.

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Compliance verifications means

- Checking if
 - the resources are sequenced in such a way that their preconditions are respected
 - the learning goal is achieved in the end, and
 - along the sequence the constraints imposed by the model are satisfied.
- Which KR that for dealing with the outlined task?
 - (A) Specific curricula building on top of semantic learning resources
 - (T) Curricula Models and (G) Learning Goal
- Which techniques for performing the comparison of courses to constraint-based schemas and checking compliance

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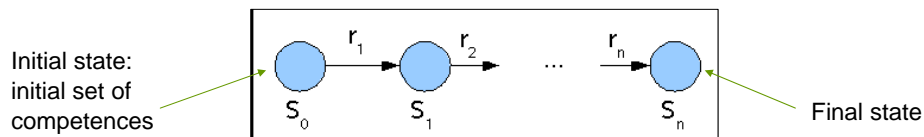
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KR - A: specific curricula

- A specific curriculum is a sequence of learning resources/actions r_1, \dots, r_n
- Resources are actions with preconditions and effects -> semantic annotation in RDF or LOM

ACTION: db for biothec(),

PREREQ: relational db, EFFECTS: scientific db



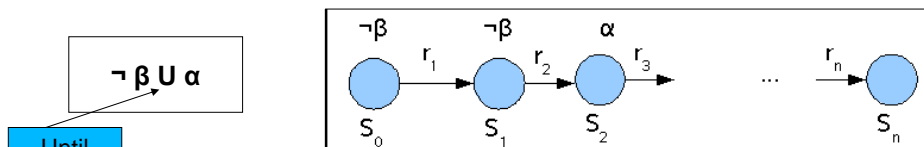
- Assumption: competences can only be added to a state after executing the action of attending a course (reading a learning material).
- Intuition behind: no new course will ever erase from the students memory the concepts acquired in previous courses, thus knowledge grows incrementally.

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KR - T: curricula models

- a curriculum model is a set of *temporal constraints* on action paths defined on the basis of knowledge elements -> independent from specific resources
- restricting the set of possible sequences of resources, by imposing constraints on the order by which knowledge elements are added to the states
 - “a knowledge element A is to be acquired before a knowledge element B”
 - “a knowledge element A is guaranteed to be acquired”...
- Expressing temporal constraints on action paths in Linear Time Logic (LTL)
 - Intuition behind: “is the property of interest true for all the possible executions of a model (the specific curriculum -> linear sequence)?”



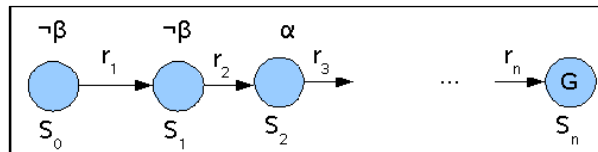
- Example: β can hold only after α becomes true. If β becomes true before S_2 , the constraint is violated by the sequence

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KR - G: learning goal

- A learning goal is a set of knowledge elements
- We expect the learning goal holding in the final state of every curriculum that matches the model



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Reasoning: compliance verification

- checking whether the specific curriculum respects the model
- I must check
 - that the sequence r_1, \dots, r_n is sound w.r.t. the precondition and effect relations specified in the Action model A ,
 - that the sequence allows reaching the goal G , and that
 - the sequence respects the temporal constraints in T
- Intuition: combining temporal projection & model checking

$$A \models_{AL} G \text{ after } r_1, \dots, r_n \quad (*)$$

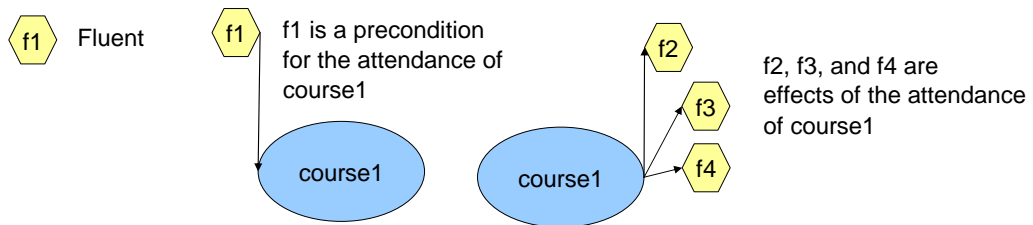
where AL is any action logic that supports temporal projection, and

$$r_1, \dots, r_n \models_{LTL} T \quad (**)$$

where LTL is a linear-time temporal logic.

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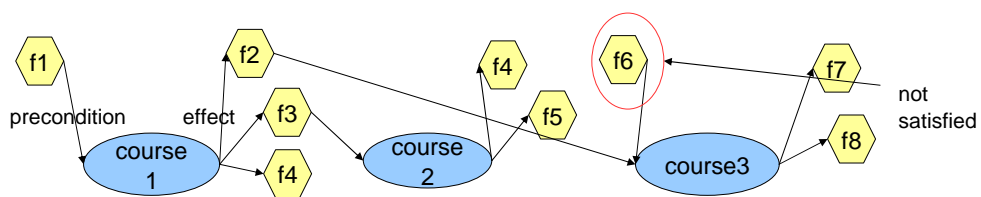
Notation



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Curriculum 1

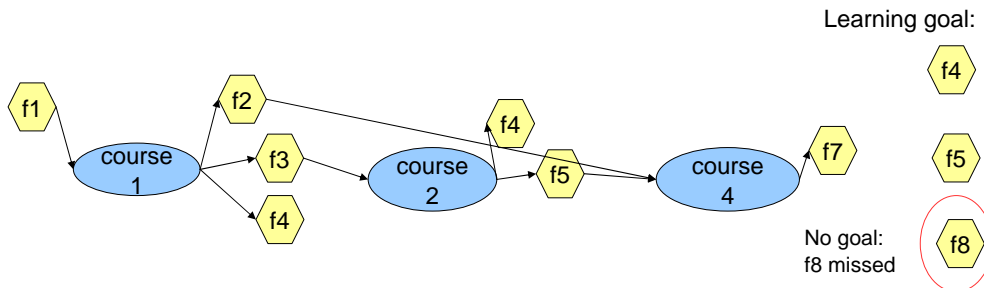


- Curriculum 1 does not pass the temporal projection test because the precondition "f6" does not hold.

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Curriculum 2

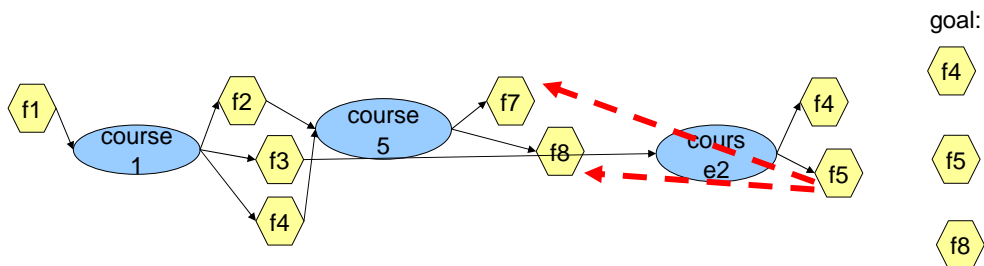


- Learning goals: f4, f5, f8
- This curriculum does not pass the temporal projection test because the learning goal does not hold at the end of the execution of "course1, course2, course4".
- In particular, "f8" does not hold.

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Curriculum 3

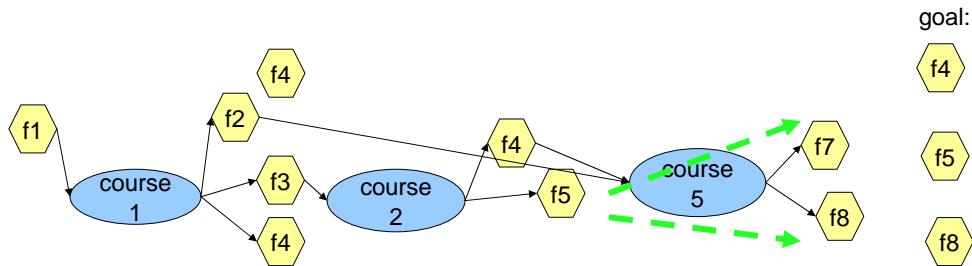


- Curricula model - constraints: $\neg f7 \text{ U } f5$, $\neg f8 \text{ U } f5$
- This curriculum passes the temporal projection. However, it do not satisfy the temporal constraints " $\neg f7 \text{ U } f5$ " and " $\neg f8 \text{ U } f5$ " that the model imposes.

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Curriculum 4



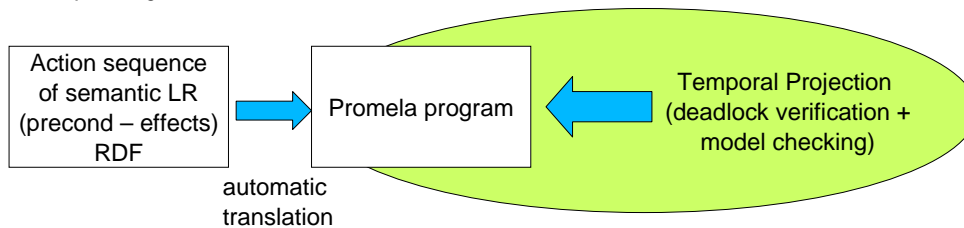
- Curricula model - constraints: $\neg f7 \text{ U } f5, \neg f8 \text{ U } f5$
- This curriculum passes the temporal projection phase and it satisfies the temporal constraints " $\neg f7 \text{ U } f5$ " and " $\neg f8 \text{ U } f5$ ".

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Implementation

- Aim: exploiting **existing technology and languages** for developing a system that can perform the compliance verification
- Semantically annotated resources -> RDF;
- knowledge elements for describing effects, preconditions, goals as terms of a shared vocabulary (simplest form of ontology)
- Model checker: SPIN
 - Tool used for checking if a finite state system (described in Promela) complies to some specification (described in LTL)
 - Algorithm based on the exploration of the state space
- Approach explored: integrating the temporal projection reasoning capability into the model checker SPIN



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Implementation

- **Steps:**
 - Translating the specific curriculum to be checked into the model checker representation language -> Promela
 - actions: transitions that modify the value of knowledge elements (->boolean variable)
 - Specifying temporal constraints: LTL formulas making use of such boolean variables
 - Run the model checker SPIN:
 - Temporal projection -> deadlock verification algorithm of SPIN
 - Model checking algorithm for checking the temporal constraint
- DEMO on the example available
- <http://www.di.unito.it/~alice/ccompliance/>

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Conclusion and Future

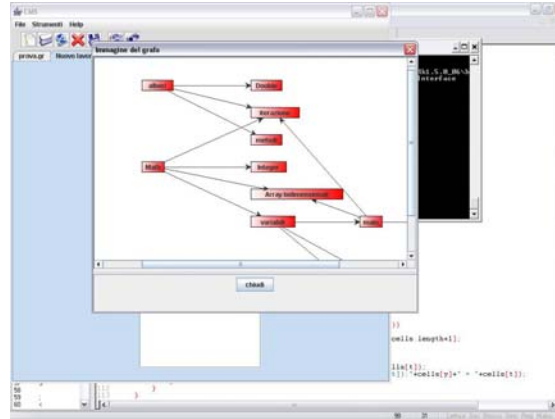
- KR: Two-level representation of curricula, aimed at capturing the distinction between specific curricula and models of curricula defining general rules or constraints to be satisfied
- Approach: verifying the compliance of a curriculum to a model by exploiting reasoning techniques that combine temporal projection and model checking and a possible implementation
- Relevance: the possibility of verifying the compliance of curricula to models is important in those applicative contexts where the need of personalizing learning resource sequencing w.r.t. to the student desire has to be combined with the ability to check that the result of personalization w.r.t. some abstract models.
- compliance verification is **complementary** w.r.t the capability of applying planning techniques for building from a set of available resources, personalized curricula aimed at reaching a given learning goal.
- **Future**
 - Hierarchies of knowledge elements (instead of plain vocabularies)
-> opens the way for integration of ontological reasoning techniques
 - Checking complex specific curricula, containing tests or branching points (exemple SCORM manifests) instead of simple sequences

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Future: on the practical side ...

- Elisa
Chiabrando
Master student



- Question: integration in the personal reader framework (Hannover – REWERSE) as an additional service complementary w.r.t the curriculum sequencing personalization service?

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