A Project to Compose a Modular AI Certification System in University Education and its inherent chance to verify, validate, and refine AI teaching by AI technologies

Tanja Schramm, Rainer Knauf
Technische Universität Ilmenau
School of Computer Science and Automation
{tanja.schramm,rainer.knauf}@tu-ilmenau.de

Abstract

A current Project of the German Federal State of Thuringia aims at bundling the various AI teaching activities of the involved universities that includes besides technological also social issues. On their way to meet the project objectives, the authors aim at utilizing such unique opportunity to consider the various successful experiences in teaching several AI content issues of the project members to revisit a formerly developed concept of semi-formally representing didactic knowledge and making it a subject of Knowledge Engineering technologies such as consistency issues as well as chances to validate learning paths and refine them based on the validation results. Ideas towards this objective and first results are sketched in this paper.

Introduction

Teaching in general, and AI teaching in particular, suffers from a lack of an explicit and adaptive didactic design. In particular, university education suffers from that, because university teachers are mostly not equipped with meta-knowledge to teach their expertise appropriately. To overcome this drawback, it is useful, to provide them a mean to compose their didactic design.

A prerequisite to meet this goal is a formal model of didactic design such as our formally developed concept of storyboarding (Jantke and Knauf, 2005) or others such as (Düsterhöft and Thalheim 2001), for example, which were driven by slightly other purposes but are not very much specific to the instructional design process (Briggs et al. 1992) (Rothwell and Kazanas 2004).

The storyboarding concept is setting the stage to apply Knowledge Engineering Technologies to verify, validate, and refine the didactics of teaching AI. Moreover, based on such a model, didactics can be refined to overcome revealed weaknesses or (meta-) learn from proven excellence based on students' storyboard paths and their related learning success in terms of their achieved learning results.

The paper is organized as follows. The next section outlines the scope of the project to bundle, coordinate and refine AI teaching activities within the involved German universities. Section three sketches the Storyboarding concept that was formerly developed by (Jante and Knauf 2005) and successive refined to become a tool for university education, see (Knauf et al. 2010) and (Tsuruta et al. 2013), for example. Based on this formal representation, section four introduces measures to formally verify such storyboards by checking their consistency. As a first possible inference technology on such storyboards, which reveals knowledge that was not represented explicitly within the storyboard, section five sketches the idea of a heritance concept within the hierarchy of nested graphs, which is adopted from the old idea of object oriented programming in Software Engineering. To "force" storyboard authors to compose logically consistent storyboards, we introduce a set of legal operations to systematically construct storyboards in section six. A first activity to storyboard a particular AI course of one of the authors is described in section seven along with some first insights according the usefulness for both the project objectives and chances and limitations to verify, validate, and refine these storyboards. Finally, section eight summarizes the introduced concepts along with an outlook of their application to handle the knowledge and experiences to teach AI that is collected within the mentioned project in particular and generally in teaching AI.

The ThINKI project

The joint project "Thuringian Initiative for AI in University Studies" (ThINKI) is an educational program of two universities in the German Federal State of Thuringia that aims at covering the complete range of AI technologies and applications in science and technology that addresses divers target audiences with different perspective on AI to gain a deeper understanding of AI by integrating and further developing teaching contents and a certification program for graduate students of various study paths. Besides the technical and mathematical issues, it also includes social, ethic and judicial aspects of developing upcoming AI systems.

Within this project, the authors of the present paper aim at (1) providing an ontology of the very diverse AI approaches that are researched, developed, applied and taught at the involved universities of the German Federal State of Thuringia, (2) revising own AI contributions to these processes to fit into the context of the entire project, (3) developing a system of AI expertise certifications of the various needs and desires of diverse stakeholders in various granularities. Additionally, we also like to use this opportunity of AI teaching revision for another purpose beyond the original project's objectives, namely considering AI technologies such as Knowledge Engineering and Data Mining to handle the Knowledge on teaching AI issues. Among the project partners, there is a huge source of AI teaching experience. Thus, it is a good opportunity for a meta level of AI, namely *using AI for teaching AI*. As a (semi-) formal basis for it, we revisit our formerly developed Storyboarding concept (Jantke und Knauf, 2005) of representing didactic knowledge illustrated in the next section.

Storyboarding

Storyboarding as a mean to model learning processes has been considered since the end of the 90th. We sketched former works and its pros and cons in former papers such as (Jantke and Knauf 2005), (Knauf et al. 2010) and (Tsuruta et al. 2013). This storyboard concept is built upon concepts which enjoy (1) *clarity* by providing a high-level modeling approach, (2) *simplicity*, which enables everybody to become a storyboard author, and (3) *visual appearance* as graphs. We define a storyboard as follows:

- *A storyboard is a nested hierarchy of directed graphs with annotated nodes and annotated edges.*
- *Nodes are scenes or episodes.*
- *Scenes denote leaves of the nesting hierarchy.*
- *Episodes denote a sub-graph.*
- *Additionally, there is exactly one Start- and End- node to each (sub-) graph.*
- *Edges specify transitions between nodes. They may be single-color or bi-color.*
- *Nodes and edges have (pre-defined) key attributes and may have free attributes.*

The interpretations of these terms are described after presenting a small example. For exemplification, Figure 1 shows a top level storyboard on one of our papers. This storyboard reflects the fact that different readers trace the paper in different manners according to their particular interests, prerequisites, a current situation (like being under time pressure), and other circumstances. In the example, the alternative paths may be driven by the reader's role as follows:

- Members of Ilmenau research group may skip the *Introduction* and *Summary and Outlook* and the section on the *Storyboarding* concept, since they are familiar with it.
- The Tokyo research group may also skip the *Introduction* and *Summary and Outlook* as well as the section on the *Dynamic Learning Need Reflection System*, because they are familiar with it.
- Referees, on the other hand, (hopefully) want to read all sections. After reading the *Summary and Outlook*, they can read the *Acknowledgements* and *References* in any sequence. They don't have to read the *Acknowledgements*, but they should read the *References* at least.

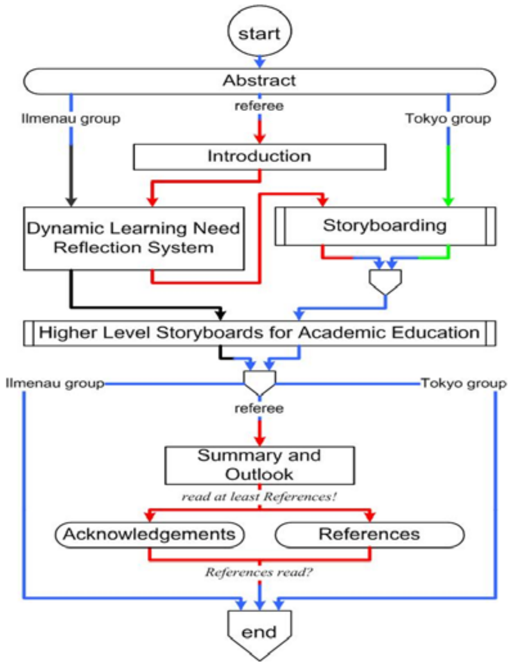


Figure 1: An exemplary storyboard

A storyboard can be traversed in different manners according to users' interests, objectives, and desires, didactic preferences[1], the sequence of nodes (and other storyboards) visited before (i.e. according to the educational history), available resources (like time, money, equipment to present material, and so on) and other application driven circumstances. Our storyboards are interpreted as follows:

- ***Scenes** denote a non-decomposable learning activity that can be implemented in any way, for example the presentation of a document, the opening of a learning tool that (e.g., an URL or an e-learning system) or an informal description of the activity.*

[1] For example, in the authors' experience, some students understand better by providing them illustrations, others by providing a small example and others by providing formal descriptions.

- ***Episodes*** *are defined by their sub-graph.*
- ***Graphs are*** *interpreted by the paths at which they can be* ***traversed****.*
- *The* ***Start Node*** *of a (sub-) graph defines the starting point of a legal graph traversing.*
- *The* ***End Node*** *of a (sub-) graph defines the final target point of a legal graph traversing.*
- ***Edges*** *denote transitions between nodes. Outgoing edge must have the same color as the incoming edge by which the node was reached. If there is a condition specified as the edge's key attribute, this condition has to be met for leaving the node by this edge.*
- ***Key attributes of nodes*** *specify application driven information, which is necessary for all nodes of the same type, e.g. actors and locations.*
- ***Key attributes of edges*** *specify conditions, which have to be true for continuing traversing on this edge.*
- ***Free attributes*** *may specify whatever the storyboard author wants the user to know: didactic intentions, useful methods, necessary equipment, or the like.*

A storyboard is a semi-formal knowledge representation for the didactics of a teaching subject and thus, a firm base for processing, evaluating and refining didactic knowledge. This concept allows for deeply nested structures involving different forms of learning, getting many actors involved and permitting a large variety of alternatives. The emphasis of this concept - driven by the goal of dissemination - is on simple storyboards designed quickly by almost anyone and without any particular (and expensive) software tool, but standard software tools instead. This is an intended difference to all the modeling approaches so far, which are driven by software technology.

Node types, their visual appearance, their behavior on double click, and their behavior when following a hyperlink are as described in Table 1 and edge types in Table 2.

On a first view, this purpose is similar to the purpose of traditional storyboards that are produced for shows, plays, theater games or movies, i.e. visual arts. Basic differences of our storyboards to those used to "specify" a show are:

- the primary purpose (learning vs. entertainment),
- the degree of formalization, and, as a consequence of being semi-formal,
- the obligation of everything above the scene level, and
- the opportunity to formally represent, process, evaluate, and refine our storyboards, which does not apply at all to storyboards in visual arts.

In fact, the latter is due to the degree of formalization and the chances to make AI methods of Knowledge Engineering are deepened in the following sections of the present paper.

Table 1 Node Types

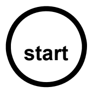
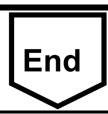
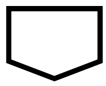
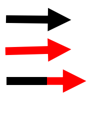
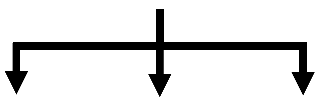
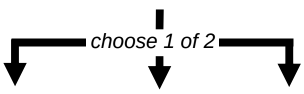
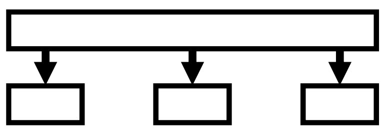
	Scene	Episode	Start	End	Reference
Symbol					
Interpretation	Subject	subject composition (core, course), defined by a sub-graph	start of graph path	end of graph path	re-entry after return from a sub-graph
Behavior on double click	▪ *open document* ▪ *nothing, if verbal activity description*	*opening the related sub-graph*	*not meaningful*	*jump to the related Reference Node of the related super-graph*	*not meaningful*
Behavior on hyperlink	▪ *opening a document* ▪ *visiting a website, if URL* ▪ *opening the mail tool, if email address*		*not meaningful*		

Table 2 Edge Types

	Simple edge	Fork	Fork with conditions	Alternatives
Symbol				
Interpretation	defines a unique successor node	defines several successor nodes, which have to be traversed independently from each other in any sequence or parallel	defines several successor nodes, which have to be traversed independently from each other according to the specified condition	defines several successor nodes, out of which exactly one has to be traversed

Formal Verification of Storyboards

As a first measure to make our semi-formal representation of teaching knowledge storyboarding a subject of Knowledge Engineering (KE) technologies, we introduce its formal verification in this section.

Verification methods that are possible thanks to the level of formality are the following consistency tests:

(1) A *Hierarchy Completeness Test* includes issues like

- Does every episode have exactly one related graph?
- Does every (non-top) graph have exactly one related episode node in exactly one related super-graph?

(2) A *Path Completeness Test* considers issues like

- Does every traversing path terminate? In other words: Is the End Node reachable on every possible path in each (sub-) graph?
- Is each node reachable from the Start Node in each (sub-) graph?

(3) A *Node Soundness Test* checks well-known automata consistency issues.

- Are alternative outgoing edges (of the same beginning color) logically consistent in terms of being free of contradictions and logically complete?

(4) An *Edge Color Test* can check the interdependencies of incoming/outgoing edges

- Is there a unique start color? In other words: Is there a unique (beginning) color of the start-node outgoing edges?
- Is there at least one outgoing edge with the same (beginning) color for each incoming edges (finishing) colors?

Automatic heritance of Annotations in the Nested Graph Hierarchy of Storyboards

As a second measure to make our semi-formal representation of teaching knowledge storyboarding a subject of Knowledge Engineering (KE) technologies, we introduce the heritance of annotations within in the nested graphs:

(1) In some applications it makes sense to inherit annotations from nodes (both scenes and episodes) to their related super-graph, e.g. Material that are used to teach a particular lecture is also material to teach the complete subject the lecture is part of.

(2) It also may be useful to inherit the arithmetic sum of a key annotation of all nodes to the related super-graph, e.g.

- an upper limit of the time needed to teach a subject can be estimated by the sum of its components (lectures) or
- a maximum cost of a university study can be estimated by the sum of the fees for all recommended subjects.

(3) Moreover, it might be useful to inherit the maximum value of a key annotation of all odes to the related super-graph. The educational difficulty (basic/easy, medium, advanced, very difficult) of a study needs to be communicated as the maximum value of all mandatory subjects.

For purposes like these, an appropriate inheritance method (out of a library of available methods) could be selected for each key annotation.

Operations to Construct Legal Storyboards

As a third measure to make our semi-formal representation of teaching knowledge storyboarding a subject of Knowledge Engineering (KE) technologies, we introduce a formal method that ensures he construction of storyboards that are logically consistent and free of anomalies.

An operation set that makes sure the resulting storyboard is syntactically a graph is described as follows and explained by an appropriate drawing:

(1) Adding an empty path

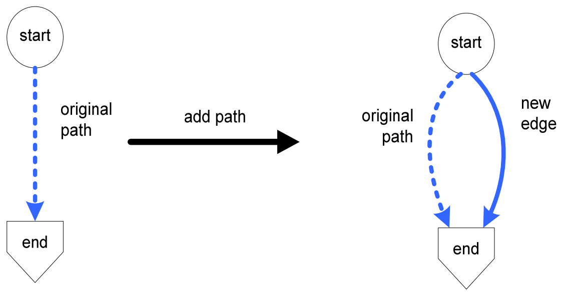


Figure 2: Adding an empty path

(2) Adding a node into a path

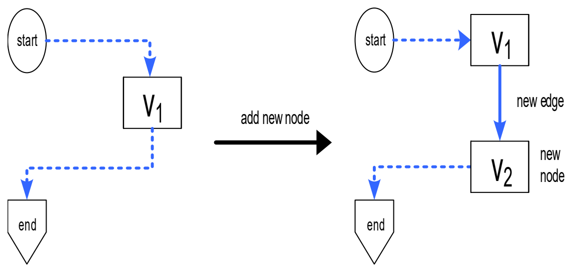


Figure 3: Adding a node

(3) Turning a scene to an episode

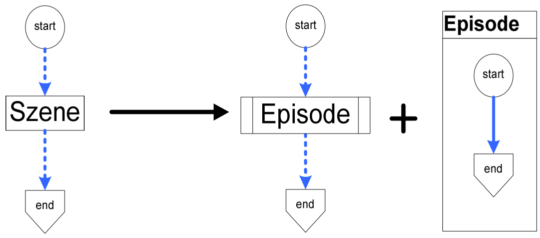


Figure 4: Turning a scene to an episode

(4) Adding a concurrent path that includes a node

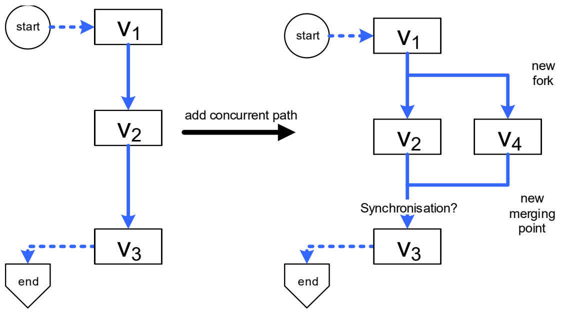


Figure 5: Adding a concurrent path

(5) Merging (equivalent) nodes

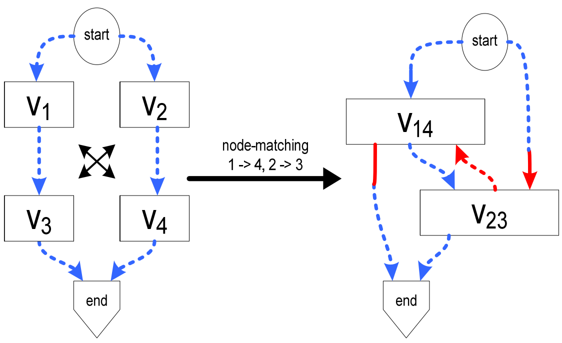


Figure 6: Merging nodes

Of course, for each of the above mentioned operations a related undo-operation needs to be provided.

Storyboarding a Particular AI Course

For illustration of storyboarding one of our AI courses, Fig. 7 shows a storyboard on the lessons on deductive inference within a course on Inference Methods of one of the present paper's authors.

Fig. 8 zooms the episode about the most general unifier towards its related subgraph. At this point, students are provoked by us by providing a simple (counter-) example of a deduction chain by using Robinson's resolution calculus that can never end up by the ultimate goal of the empty clause. By discussing this problem, the students should come up on their own with extending the resolution accordingly to rescue the completeness of the inference calculus by introducing the factorization rule.

Surely, those graphs could be composed by using the above mentioned set of storyboard construction operations.

These example storyboard fragments illustrate the modular character of storyboarding, which provides the chance to develop the didactics of each module and each level of granularity independently from each other.

Moreover, by storyboarding the didactic of teaching particular topics according to the various points of view of different target audiences can be managed.

Currently, the storyboard on this course is under use by our students and we are tracing their paths and analyzing their submitted homework and examination materials. This date will form the base for possible upcoming changes including refinements of the storyboards.

In the context of the entire ThINKI project, the authors aim at convincing content providers of other topics in teaching AI to adopt our storyboarding concept as well and, most important, to model the didactics with respect to the different needs of different target audience, which seems to be the ultimate crux when integrating AI teaching approaches provided by different teachers from different scientific backgrounds and with different educational objectives.

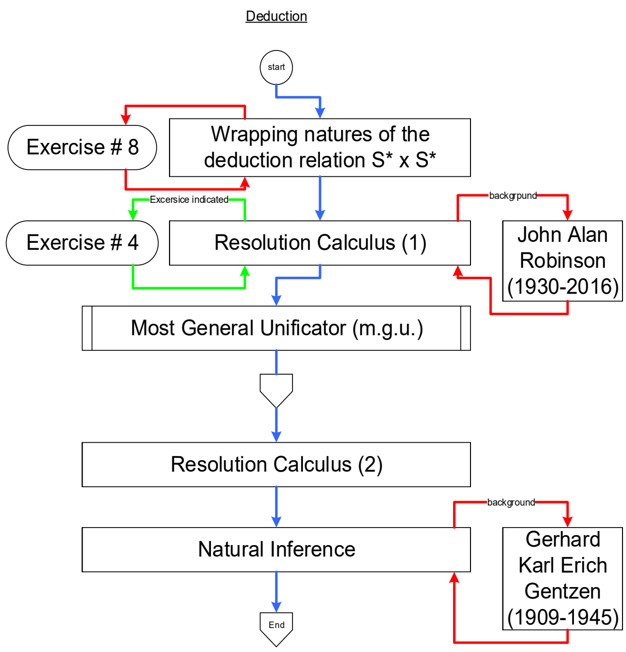


Figure 7: Storyboard of the Episode "Deduction" in our Course on Inference Methods

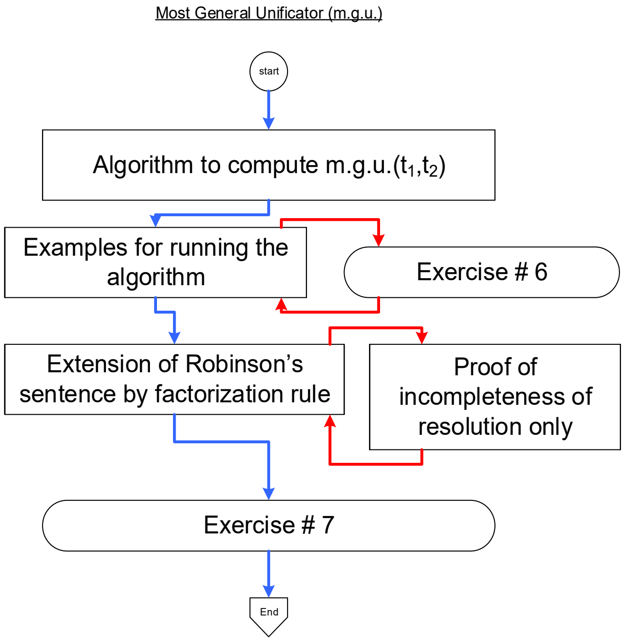


Figure 8: Storyboard on computing the m.g.u. and extending Robinson's sentence to keep the completeness of the deduction calculus

Conclusions and Outlook

The paper introduced an approach semi-formally represent the didactics behind teaching AI issues. This work aims at applying Knowledge Engineering technologies such verification in terms of consistency checks, validation in terms of associating the learning success to learning paths as well as refinement of storyboards based on the validation results.

An issue that is still not solved yet is the representation of the didactic of teaching particular topics according to the various points of view of different target audiences, but we are quite sure that this can be solved due to the expressive power of our storyboards, in particular by more extensively using colored edges.

Moreover, we think about including other verification issues than just logic consistency, which should be related to the learning content.

An important issue for acceptance of AI in application scenarios and research and thus, in university teaching, as well, is its feature to be explainable. Anything that appears mystic is not worth to be considered at all. In fact, the authors of (Arnold et al. 2022) showed that (1) learning with and from an Explainable AI (XAI) by means of exploration, collaborative experimentation, and interrogation does really work and, more important (2) "bears the potential of impact on the learners' opinions about the relevance of explainability" (Arnold et al. 2022) and sketches one of our ultimate objectives when teaching AI. Explainability needs to be reflected by our storyboards explicitly by a set of typical "explanation patterns" that could probably be provided in a related library of storyboard templates.

An interesting validation issue of upcoming work is modelling typical learning traits of students, classifying the students according to such traits and performing the validation according to these user models specifically for the various student types.

Acknowledgements

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