Learning with ALeA: Tailored experiences through annotated course material

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Abstract: We present ALeA, an adaptive learning assistant for university courses. The intelligent tutoring system (ITS) provides services for both learners and instructors, based on semantically annotated course material. The system can generate learning tools like flashcards, guided tours, and quizzes, which can be tailored to individual learning progress. Currently, the system is only available for courses from the field of computer science, like artificial intelligence. We plan to expand it for further courses from different fields.

Keywords: learning assistant, self-learning, learning analytics, adaptive learning

1 Introduction

We present ALeA, an Adaptive Learning Assistant and a university course material platform, currently deployed for $\geq$ 1000 students in six computer science courses. ALeA adapts the basic teacher knowledge facets of Shulman [Sh86] and encompasses the components of intelligent tutoring systems (ITSs), namely a student module, an expert module and a pedagogical module as well as the user interface [An90]. A *Content Object Server* provides an ontology of abstract concepts to be learned. These concepts are shareable across courses, subjects, and universities. A *Learning Object Server* provides course material as HTML, ranging from individual definitions, exercises, examples, or explanatory snippets, up to full lecture notes. This material is annotated with references to the ontology from the Content Object Server. A *Learner Model Server* (corresponding to the student model of the ITS), associates learners with their estimated mastery of a given concept; represented as a set of triples $\langle C, D, p\rangle$, where C is a concept, D a cognitive dimension according to Anderson & Krathwohl's revision of Bloom's taxonomy for learning objectives [AK09], and $p \in [0, 1]$ a probability representing the learner's assumed competency.

2 ALeA for learners

ALeA's main features for learners all use the *learner model* to tailor content to the individual student. Every learner model starts out empty. Certain actions in ALeA serve as evidence

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of a student's competence level. They are logged and the learner model is updated for all relevant concepts. For example, incorrectly answering a question about the binomial theorem might also lower a student's score for the related concept of polynomials.

2.1 Dashboard and Course material

The core of ALeA is the course material, in particular lecture notes, slides, and videos. For learner's, a main feature is to access definitions of terms by hovering over them in the text. This way the workflow is not interrupted and students are sure to get the correct definition for their context and do not have to navigate homonyms (e.g. *graph* meaning different things in graph theory or as a representation of a function) or instructor-specific re-formulations.

ALeA can also generate a *learner's dashboard*, which presents the learner's progress in a course based on the learner model. Currently, the dashboard is still under development but all necessary information is available in the system. This dashboard also gives hints on which topics need further study. Based on earlier cohorts, ALeA could even estimate of the learner's preparedness for exams.

2.2 Guided Tours

Guided tours allow learners to generate an individualised mini-course for concepts they do not understand starting with their current level of understanding. Currently, this takes the form of a list of definitions the system assumes the student needs to understand to grasp the final concept (all prerequisites minus those the learner model already knows). We plan to make the guided tours more interactive, presenting one learning object at a time and assessing the learner's progress in the style of a dialogue.

2.3 Flashcards and Quizzes

Quizzes and flashcards are two further self-study tools that are included in ALeA, meant to enhance self-regulated learning [Ba77]. Quizzes are built on rapid feedback enhancing students' engagement and providing immediate feedback [Co08] and flashcards have a direct impact on self-regulated learning [WRP12; ZIP22].

The flashcards are created from the annotated course material and thus provide the content exactly as in the course, at no additional investment for the instructor: For each definition in the material, the system knows the terms defined and the defining text fragments. When learners review a flashcard, they can indicate on a five-point scale to which extent they understand and remember each concept. This self-assessment updates the learner model and determines when to show a card to a student again.

The generation of quizzes is not automatic but requires semantically annotated problems. Each of them carries information about its *prerequisites* and its *learning goals* (a question might be about applying the Pythagorean Theorem and require remembering a theorem about angle sums in a triangle). This allows the system to present students appropriate questions and to track their progress. Currently, we support single-choice and multiple-choice questions and clozes.

3 ALeA for Instructors

The role of the instructor is a dual one in ALeA: they annotate the material to create the domain model and learning objects which induce the learning support services, and they profit from teaching support services resulting from the learner data.

3.1 Domain and Learning Object Modeling

We use the STEX system [MK22] for the annotation of course materials. STEX is a LATEX package that provides macros and environments for embedding markup for knowledge items, learning objects, and their relations. The union of of all concepts introduced in these annotations and their specified relations to each other forms the ontology that the rest of the system operates on. This means there is no necessity to maintain (and ensure compliance with) a separate ontology. This allows easy re-use of concepts but also specification of new concepts or alternative perspectives.

STEX source files are convertible to PDF and the HTML-based OMDoc/MMT format for learning/teaching support services. The MathHub content commons (see `https://gl.mathhub.info`) already provide annotated material for more than a dozen courses as well as domain modules for many topics in computer science and mathematics.

3.2 Course dashboard

Analogously to the learner side, ALeA will provide an *instructor dashboard* for each course. It presents activities and progress of students in a course. This includes the mastery of material covered so far (aggregated from the learner model) now and over time. This constitutes a valuable tool that empowers instructors in evaluating their teaching success. As with the learners, the instructor dashboard indicates exam readiness and which topics are best and least understood.

4 Conclusion and future work

We have presented the main features of ALeA from the learner's and instructor's perspectives. The system features dashboards with an overview of learner progress in the course as well

as study features for individuals. The dashboards as well as the annotated course data are special features which we do not see in other ITSs [AF21; Wa23]. Our next steps are to further improve learner models, to enhance guided tours as educational dialogues and to realize the features we designed prototypes for.

4.1 Acknowledgements

The presented research is part of the VoLL-KI project, supported by the Bundesministerium für Bildung und Forschung (BMBF) under grant 16DHBKI089.

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