ActiveMath: System Description

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ActiveMath [2] is a web-based, user adaptive learning environment that employs content encoded in a semantic XML-representation of mathematical knowledge and integrates several mathematical service systems.

The ActiveMath system dynamically generates interactive (mathematical) documents according to the user's capabilities, content needs, and presentation preferences and provides a generic distributed architecture and facilities for a user interaction with (mathematical) service systems. It supports instructional as well as exploratory learning and leaves freedom of navigation and responsibility to the user. A demo is available at `http://www.activemath.org/demo`.

Currently, ActiveMath integrates the following components: a session manager, the knowledge base, a course generator, a user model, a pedagogical module, and deduction and computation service systems such as the proof planner of ΩMEGA [3] and Computer Algebra Systems (CAS). The components can communicate over the Internet by a standardized XML-RPC protocol. Requests of the user and (in the other direction) HTML-pages are communicated via a web-server. The course generator requests and processes information from the knowledge base, from the user model, and from the pedagogical module to generate a document adapted to the user's goals, preferences, and knowledge. Information about the user's actions, such as the time intervals of her reading a concept or the success of solved problems, is passed from the session manager to the user model (as well as from the proof planner and CAS to the user model), where it is used for updating.

1 Knowledge Representation

Our knowledge representation is based on `OMDoc` [1], an extension of the `OpenMath` standard. `OMDoc` encodes the semantic of mathematical objects as well as metadata and mathematical facts such as theorems, definitions, proof methods, and proofs and includes natural language formulations as well as formal (`OpenMath`) objects. `OMDoc` uses a semantic XML-based representation of mathematical knowledge that provides an *ontology* for the content of the course which is indispensable for a reuse of teaching material and for a combination of material from different sources. Operations such as copy&paste, e.g., pasting a formular selected within a learning document into a CAS, can realised easily. For an adaptive learning environment, additional – in particular pedagogical – metadata than those provided by `OMDoc` are necessary. Therefore, we have extended `OMDoc` by metadata that express pedagogical properties and relations.

2 Course Generation

The course generation dynamically constructs a course that suits the learner's goals (e.g. to learn everything needed to understand the mathematical concept *groups*), preferences (e.g., colorful presentation), and mastery level.

The course generators uses an expert system to dynamically assemble the course for each user according to the given pedagogical rules and user model. For instance, one rule determines that if the user wants to prepare for an exam and her knowledge of the current concept is low, then several exercises with increasing difficulty are presented. Other rules specifiy what a generated learning document should look like so that the learner is able to achieve a specific learning outcome, for instance being able to enumerate the learned concepts or to apply them during problem solving.

The document generation process has several stages: (1) Mathematical content is retrieved from the knowledge base. All items on which a requested concept depends are collected. (2) The collection of content items is then processed according to the information in the user model and the pedagogical module. This step returns an instructional graph of ids of `OMDoc` elements. (3) The instructional graph is linearized, and finally (5) the session manager fetches the actual `OMDoc` content for each item in the linearized instructional graph. Filters (e.g., XSL style sheets) transform the `OMDoc` content to HTML or PDF.

3 External Systems

An external system acts as an expert service in the learning environment. The benefit of integrating it is manyfold. (1) Expert services allow the user to explore a problem interactively. (2) It allows the user to focus on a particular skill to solve a specific problem. For example, the user of the system should not fail to calculate the limit of a function just because he cannot find the factorization of a polynomial; a computer algebra system may serve this task. Similarly, the user should not fail to find the overall proof just because he cannot prove a simple subgoal. It may suffice from a pedagogical point of view that the user suggests some intermediate goals that should be provable and a proof planner fills the gaps in the proof plan. (3) They can check the correctness of the user's calculation or derivation. (4) The system can help with feedback of different sorts, e.g. on where it is promising to explore and where dead ends are reached.

References

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