

Using Visual Guidance and Feedback Based on Competence Structures for Personalising E-Learning Experience

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Abstract: In this paper a novel approach is presented how visualisation of knowledge and competence structures can be employed in order to support personalisation in e-learning systems. Information visualisation strategies are used to present ontology-based domain knowledge and related competence structures to the learner. In contrast to adaptive e-learning systems which employ domain and user models for the adaptation and personalisation strategies, the learner uses these visual knowledge maps to decide on the own learning process. Furthermore, visual knowledge maps are used to give feedback to the learner about learning progress and assessment result. Methods and techniques are presented how these maps can be used for visual guidance and feedback. A set of learning tools have been developed which implement and demonstrate the proposed approach.

Keywords: Adaptive system, adaptivity, self-regulated learning, skill, competence, Knowledge Space Theory, information visualisation, open learner model

Introduction

Adaptivity and personalisation provided by adaptive systems capable of tailoring content and behaviour to characteristics and needs of learners has been an important research strand in e-learning for a long time. This research field has its origin in technological developments (computer systems, Internet, hypermedia) and is characterised by research how technology can support and guide the learning process. However, this approach to e-learning holds the risk of having the learning process to a large extent controlled by the system. Furthermore, if the models or structures underlying system behaviour are invalid, then guidance provided by the system is actually worse than no guidance (De Bra, 2000).

The approach presented in this paper makes use of competence-based models and structures in a different way than adaptive systems employ them for determining system behaviour. In contrast to traditional adaptive systems, these models are not hidden from the user and only used by the adaptation algorithms, but - and this is seen as the major innovation of this paper - these models are presented to the learner directly in a visual and interactive way. In contrast to some experiences with open learner models in the last years (Bull & Kay, 2008), our approach focuses on visualising skill-based models. With the help of these models the learner gets both more control over the own learning process and specific information about the own learning progress. Instead of traditional system guidance the learner gets visual guidance and feedback which does not limit the learner to automated decisions of the adaptive systems.

A set of learning tools has been developed which follow and demonstrate this approach. Research and development of these tools are part of the iClass research project

(iClass, 2008). The aim was to support a self-regulative learning cycle, which according to (Zimmerman, 2002) consists of forethought (planning), performance (monitoring) and reflection. The developed tools support the planning and reflection processes, performance (viewing learning objects) is done by the use of other iClass components.

The next section gives an overview on the research fields which are basis for our approach. Section 2 gives a more detailed description of the knowledge representation model which is used for our approach. Section 3 explains principles how guidance and feedback can be realised in a visual way and Section 4 presents some developed learning tools which implement those principles. Future work and conclusion can be found in Section 5.

1. Theoretical Foundation and Background

1.1 Competence-based Knowledge Space Theory

Knowledge Space Theory (KST) and its competence-based extensions (CbKST) are prominent examples how an adaptation strategy can be grounded on a theoretical framework (Hockemeyer, 2003). KST constitutes a sound psychological mathematical framework for both structuring knowledge domains and for representing the knowledge of learners (Albert et al., 1999). Due to (psychological) dependencies between problems prerequisite relations can be established. The knowledge state of a learner is identified with the subset of all problems this learner is capable of solving. By associating assessment problems with learning objects, a structure on learning objects can be established, which constitutes the basis for meaningful learning paths adapted to the learners knowledge state.

Competence-based Knowledge Space Theory (CbKST) incorporates psychological assumptions on underlying skills and competencies that are required for solving the problems under consideration (Korossy, 1996 and Heller et al. 2006). This approach assigns to each problem a collection of skills which are needed to solve this problem and to each learning objects those skills which are taught. Similar to the knowledge state a competence state can be defined which consists of a set of skills which the learner has available. Furthermore, there may also be prerequisite relationships between skills.

CbKST provides algorithms for efficient adaptive assessment to determine the learner's current knowledge and competence state, which builds the basis for personalization purposes. Based on this learner information, personalised learning paths can be created. Goal setting can be done by defining skills to be achieved (competence goal) or problems to be capable of solving. The competence gap to be closed during learning is represented by the skills which are part of the goal but not part of the competence state of a learner.

1.2 Adaptive Systems and Guidance

The concept of adaptivity has a long tradition in technology-enhanced learning, for example it has been applied in Intelligent Tutoring Systems (ITS), user-model-based Adaptive Systems (AS), and Adaptive Hypermedia Systems (AHS) (Brusilovsky, 2000). Following the discussion in (Brusilovsky, 1996 and De Bra et al., 2004), users (learners) differ in terms of (learning) goals, pre-knowledge, individual traits and needs, as well as pedagogical parameters. Based on these characteristics adaptive presentation (adaptation on the content level) and adaptive navigation support (direct guidance, adaptive ordering, hiding, and annotation of links) are the most important features which can be provided by an adaptive

system. Domain models and user models are defined in order to specify relationships between users and content, which forms the basis for the adaptation functionality. In educational applications these relationships typically represent the knowledge about learners and content. Furthermore, adaptive systems usually contain adaptation models which determine the adaptation strategy of those systems. In this way an adaptive system can help the learner to navigate through a course by providing user-specific paths.

1.3 Information and Knowledge Visualisation

The abilities of humans to recognise visual information are highly developed. Patterns, colours, shapes and textures can rapidly and without any difficulty be detected. On the other hand, the perception of text-based content is much more effort than the perception of visual information (Shneiderman, 1996). Information visualisation is the transformation of abstract data and information into a form that can be recognised and understood by humans. In this sense, information visualisation can be seen as an interface to abstract information spaces. So exploring large volumes of data can be done effectively by humans.

Information visualisation techniques are widely used in Web-based social software (e.g. graph visualisation is used to outline online community networks and tag clouds are often used to provide overview on collaboratively tagged Web content) and especially in knowledge management (e.g. visualisation of large knowledge structures for providing overview and interface to it). In (Herman et. al, 2000) an overview and survey on graph visualisation techniques is provided. In contrast to these application areas, information visualisation is barely used in e-learning applications. For example, in (Kay et al., 2007) visualisation techniques are described how visual feedback and mirroring can be provided to group and collaborative learning.

2. Knowledge Representation Model

The knowledge representation model elaborated in the context of the iClass project is based on two pillars: The first pillar is the domain model which represents the knowledge of the domain and the second pillar is the user model which represents the knowledge of the learner. The knowledge representation model for a single domain is depicted in Figure 1.

The domain model is based on CbKST and comprises the structure how the domain is represented regarding learning objects, problems (assessment items), skills, concepts, and action verbs. The central elements are skills which are assigned to both learning objects and assessment items. A skill is defined by a set of domain concepts and an action verb which specifies the level of expertise regarding the respective concepts (e.g. apply the Pythagorean Theorem). The prerequisite relations between skills build the competence structure. The domain model is based on the model described in (Görgün et al., 2005), and has been slightly simplified in order to allow teachers to easily create their own models of the domains they teach.

A domain map represents a knowledge domain and consists of domain information populated in line with the structure of the domain model. This can be done by content authors as well as by teachers. Domain maps can be differentiated between subjective and objective maps to indicate their state of validation. Objective maps are empirically validated (ideal case) and subjective maps are not validated, even if they have been created by domain experts.

The learner model characterises knowledge, competences and learning goal of a learner. It refers to elements of the domain model, since the learner's knowledge is defined

through references to domain knowledge. The knowledge state is a set of problems which the learner is capable of solving, the competence state is a set of skills which the learner has available, and the competence goal is a set of skills which the learner should acquire.

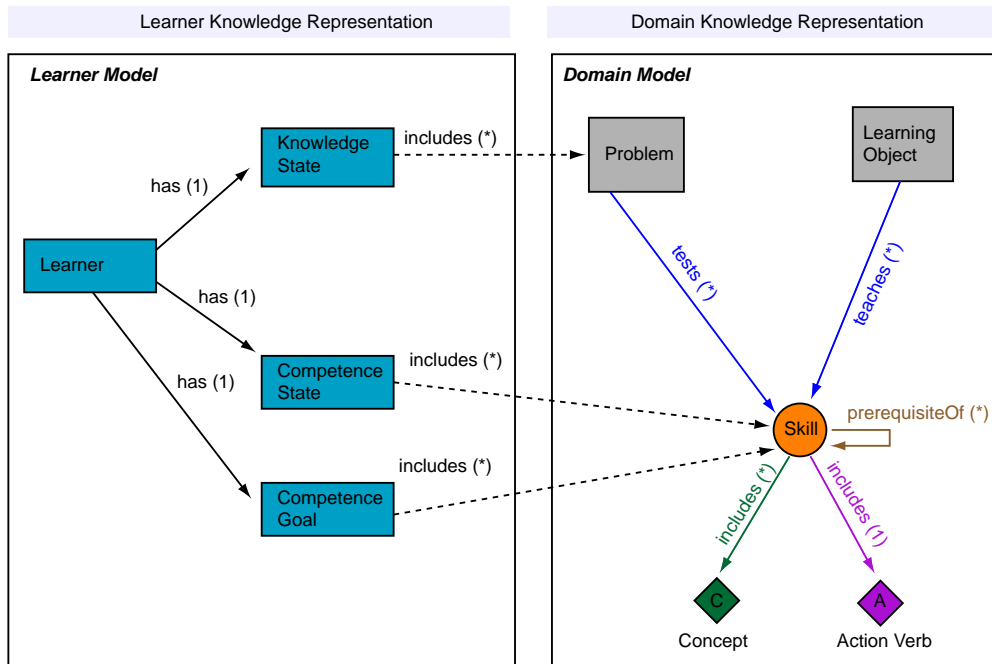


Figure 1: Knowledge Representation Model consisting of domain model and learner model.

3. Visual Guidance and Feedback

The basic idea how to provide learner and teacher support through visual guidance and feedback is to visualise the elements and relations of the knowledge representation model which are typically used by adaptive systems for the personalisation process. An interactive learning tool which renders the models enables the learner to visually interact with visualised information for several purposes. For example, plans and sequences of learning objects and their related skills can be created, learning progress and assessment result can be reported, and a history of the learning experience can be displayed. The learner gets an overview on both the domain and the own learning progress.

For example, a visual representation of the structure (prerequisite relation) on skills can be used for both guidance and feedback. In Figure 2 such a structure is depicted as Hasse diagram for six skills, with ascending sequences of line segments representing prerequisite relationships. On this structure a learner can see what should be learned, i.e. the six skills making up the competence goal. Due to the prerequisite relation, it also can be seen, that there is an order how the skills should be acquired. Before addressing higher-ordered skills, the relevant prerequisite skills should be learned. Since skills are assigned to learning objects, learning objects can be searched which teach the respective skills. In this way, a plan consisting of a meaningful sequence of learning objects can be created. After the learning process, an assessment can be conducted which detects the acquired skills of a learner and the result can again be displayed in the visualisation of the competence structure. In this way, the learner can e.g. reflect on his current competence in relation to the competence goal (see Figure 2). To complete the learning cycle the missing (not acquired) skills can immediately be recognised and a new plan of learning objects can be composed which teach those skills.

As outlined in this example, using these structures the number of reasonable choices can be significantly reduced. Information on the learner's current competence state can be utilised for recommending learning options from which to choose that correspond to possible next steps of learning. In a similar way, the other elements of the knowledge representation model can be utilised. Concepts and action verbs can visually be related to skills which supports the understanding of skills.

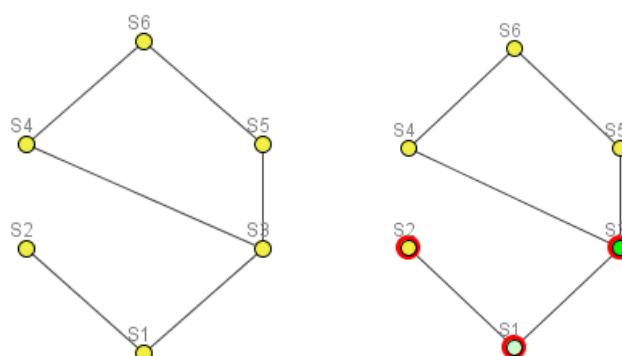


Figure 2: Structure on skills illustrated as Hasse diagram. In the right figure available skills of a learner are displayed.

4. Implemented Learning Tools

The principles of visual guidance and feedback described above have been implemented in the iClass system in various tools to support the learning and teaching process.

4.1 Skill-based Planning Tool

The Planning Tool (Figure 3) supports the learning processes of goal setting and use of task strategies. This tool visualises the domain skills and their prerequisite relation as Hasse diagram. On this graph, skills can be chosen to define the competence goal and subsequently sequenced on the visual plan component. Prerequisite skills of the chosen skills are also added to the plan. If the created sequence of the skills is not in line with the prerequisite structure, this tool gives visual feedback about this situation (in terms of coloured skills). It also provides the functionality of automatically sequencing the chosen skills corresponding to the prerequisite relations. Furthermore, for each skill learning objects can be searched and chosen which teach the respective skill. As soon as for all skills of the competence goal learning objects have been added to the plan, visual feedback is provided that the plan is complete. Further guidance is granted, as the tool also can propose meaningful sequences of learning objects by using the relations between learning object and skill.

4.2 Adaptive Assessment Tool

An adaptive assessment based on KST (Doignon and Falmagne, 1999) is conducted to determine which skills a learner has available. Questions are posed to the learner taking into account previous answers and exploiting prerequisite relationships among problems. The traditional algorithm calculates the sequence of questions and is capable of posing a minimal number of questions to determine the learner's knowledge. The result of the

assessment is a (verified) set of skills (competence state) which the learner has available, which is subsequently visualised and reported to the learner.

4.3 Self-Evaluation Tool

A learner may reflect on what has been learned by defining skills which consist of concepts and action verbs. This is done in three steps: (1) The learner is provided with a list of concepts and chooses those concepts that has been covered in the learning process so far. (2) Then for each concept the level of 'expertise' is to be indicated which have been acquired so far according to the learner's estimation – these levels are indicated by the Bloom taxonomy levels, i.e. the action verbs remember, understand, and apply. (3) The combination of concepts and Bloom level action verbs results in skills – defined by the learner.

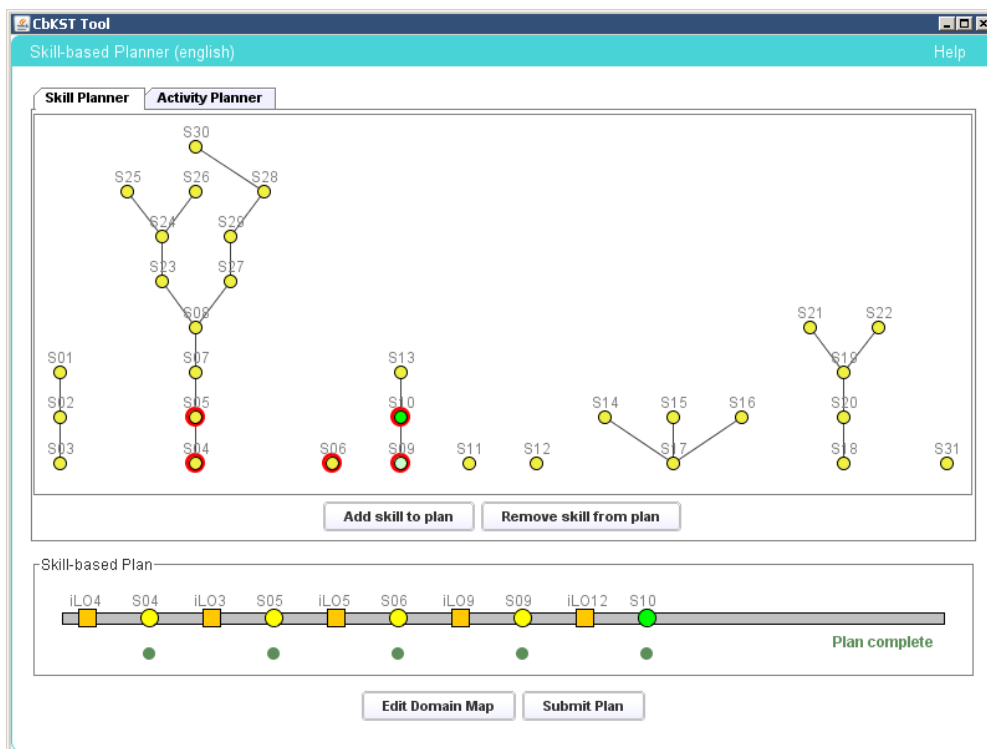


Figure 3: Skill-based Planning Tool visualises the competence structure where the learner can interactively create the own learning plan.

4.4 Knowledge Representation Tool

This tool presents the skills learned during the learning process. Three sources for this information are used: (1) The skills which have been taught by learning objects are visualised in a chronological order together with the learning objects, (2) the acquired (verified) skills resulted from the adaptive assessment and (3) the skills (non-verified) resulted from the Self-evaluation Tool. The presentation of skills is done in a visual way, learned and acquired skills (verified and non-verified) are rendered in different colours. Furthermore, the competence goal (also set of skills) is rendered in a way that missing skills can be seen immediately. In this way the learner directly monitors his learning progress and skill gap (compared to the competence goal).

4.5 Domain Map Editor

All presented tools rely on the knowledge representation model consisting of skills, learning objects, assessment question, concepts, and action verbs. Creating the domain map for a certain knowledge domain is usually the task of teachers and domain authors. A tool has been developed which allows for easily creating domain maps by again employing visualisation techniques. For example, defined prerequisite relations between skills can be immediately visualised, and the assignment of skills to learning objects is depicted in a fish-eye visualisation where all learning objects including the assigned skills are shown and the selected learning object is magnified (Figure 4).

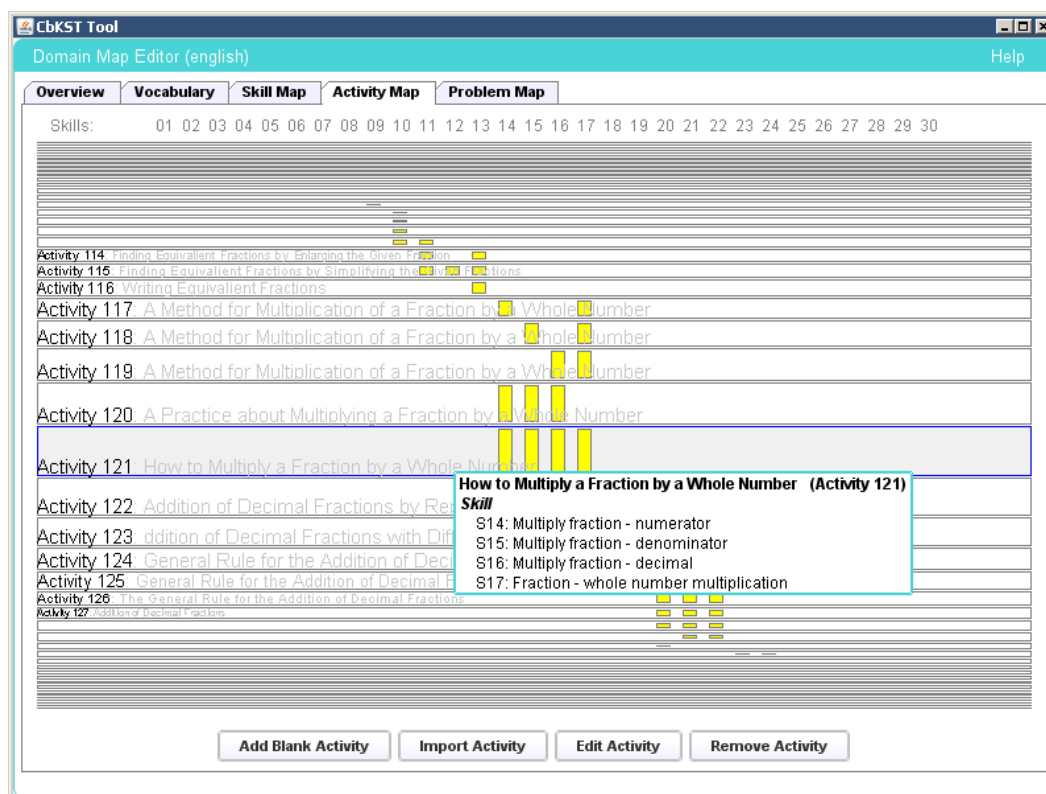


Figure 4: Domain Map Editor. All learning objects (activities) of a domain are displayed together with the assigned skills. A fish-eye distortion magnifies the selected learning object.

5. Conclusion and Outlook

In this paper a novel approach has been presented how learning can be supported and stimulated by using visualisation techniques. This approach makes use of concepts of adaptive systems and related research in order to integrate guidance in learning processes. A knowledge representation model (domain and user model) is used as a basis for the guidance. In contrast to adaptive systems, these models are not hidden from the user and only used by the adaptation algorithms, but - and this is seen as the major innovation of this paper - these models are visualised by the learning tools. Through these visualisations the learner can get both guidance and responsibility for his learning process at the same time. Several tools have been developed which exploit this novel approach in order to support particular self-regulated learning processes.

The presented approach is supposed to have great potential for further work and can enrich the lively research field of information visualisation by new possibilities of visual

guidance and feedback. More relations between elements of the knowledge representation model can be visualised and used for the further learning tools. Furthermore, the presented approach is also supposed to have great influence to the field of self-regulated learning. Visual guidance can stimulate the self-regulated planning process of a learner, and visual feedback can support self-monitoring and reflection on learning

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