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Towards Generic Visualisation Tools and Techniques for Adaptive E-Learning

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Abstract: In this paper, we describe the work on the visualisation tools and techniques currently developed in the GRAPPLE research project. Since the GRAPPLE project aims at developing a generic solution for adaptive e-learning, also the visualisation tools need to be as generic as the GRAPPLE approach and its data models are. This paper also discusses related work in this field and outlines differences and advantages of the newly developed visualisation tools and techniques. Especially comparisons are made with a tool which relies on visualizing competence-based knowledge structures.

Keywords: adaptive e-learning, open learner model approach, visualisation technique, meta-cognitive support

Introduction

Visualisation has often been used in e-learning to stimulate meta-cognition by providing feedback to the learners about their learning process. In order to provide visual information to learners, learner models are needed which can be used as basis for this information. This approach is well known as Open Learner Model (OLM) approach and has been often described in literature (for example in [4] and [8]). In adaptive e-learning systems user and adaptation models are used to achieve adaptation of learning resources to the learners' characteristics. Traditionally, these models are not revealed to the learners, but used for adaptation algorithms only. Especially adaptive systems make use of user models which often are available at a detailed level. Therefore, opening up these models can provide rich information which can support the learner in his or her self-reflection activities.

Obviously, presenting user model data to the learner highly depends on the available information of a learning system and how this information is organised and structured. Based on that data visualisation techniques are be employed to make accessible the user models for the learner. Making understandable the presented data is a key factor for achieving reflective and meta-cognitive activities of learners.

This paper presents a new visualisation approach which aims at being more generic than existing visualisation strategies in adaptive e-learning systems. This approach is currently developed in the context of the GRAPPLE (Generic Responsive Adaptive Personalized Learning Environment) research project [6] which aims at delivering generic adaptation functionality for various Learning Management Systems. To this end, flexible learner models are used for adaptation functionality. Therefore, also the visualisation technique has to cover the same flexibility, which brings new possibilities to the learner regarding the visually accessible information.

1. Visualisation in Adaptive E-Learning

In order to outline some of the key features of visualisation approaches in adaptive e-learning systems, an example from previous work in this field is introduced in this section. The visualisation tools for making visible and accessible learner models based on Competence-based Knowledge Space Theory (CbKST Tools) [3][9] has been developed in the research project iClass [7]. Instead of providing a general overview of visualisation in adaptive e-learning and OLM, the newly developed approach is compared with the CbKST Tools, which reveals the advantages, but also limitations of the GRAPPLE visualisation approach.

The CbKST Tools are based on a domain and user model which both follow the mathematical-psychological approach of Competence-based Knowledge Space Theory [2]. The central element is the set of skills and prerequisite structure on skills which arise due to psychological dependences (see Figure 1). In order to model a domain, the skills necessary to cover this domain are modelled and the structure of these skills is identified. Learning resources are associated with skills, whereas learning objects can convey skills and assessment items can test skills.

The user model relies on the domain model and can express different user characteristics. Goals can be defined as a set of skills which should be attained. The skill or knowledge state of a learner can also be defined as a set of skills which the learner already has available. This is outlined in Figure 1 with red circles in the skill structure. The learning history can be shown either as sequence of learning resources or as sequence of the skills associated with the performed learning resources.

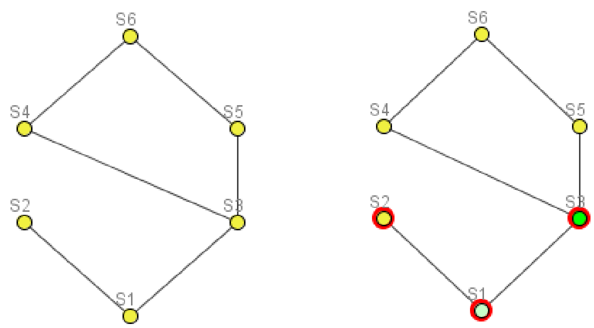

Figure 1: Prerequisite structure on skills (a) and possible competence state of a learner (b).

The logical structure of the prerequisite relations of the skills can be depicted as acyclic directed graph with the special property that transitive relations are not drawn. In the example in Figure 1 the skills below other skills connected with a line are prerequisite for those skills. For example, skills S1 is prerequisite for skills S3, but also for skills S4, S5, and S6. This structure can be visually displayed to the learner as it is shown in Figure 1. In this way the conceptual part (skills, but not associated learning resources) are visualised and opened up to the learner.

The user model consisting of goals, skill state, and learning history is directly depicted on the skill structure. Since all of these elements are related to skills, the respective skills can be marked and highlighted (Figure 1b). In this way the learner is always presented with the same structure (for a specific domain), but the user model values are changing on this visual structure.

In addition to use these visualisations as display for domain and user model values, the same visualisation can be used to guide the learner though the learning process. Since it is meaningful to sequence the skills to be attained according to the prerequisite structure, a learning path reveals as learners should start with easier skills at the bottom of the structure and continuing with higher levelled skills. Learners see their skills state easily, so they can choose skills one level higher as their available skills. The visualisations have been made interactive, so that by clicking on a skill, the associated learning resources are offered to the learner. Hence, the learner gets interactive navigational support by using this visualisation.

Using that visualisation technique learners are supported to perform meta-cognitive aspects on their own learning process. They can set goals by picking skills, they can make plans by choosing learning resources associated with the goal, and they get feedback and orientation about their current learning state and progress.

Other approaches also take into account group work and collaboration and reflect them in visualisations. For example the technique presented in [8] aims at mirroring the activity of small teams engaged in a task. Each individual is contributing to the group and the ways that team members interact with each other are displayed in a so-called Wattle Tree visualisation.

2. Domain and Learner Model in GRAPPLE

The models in GRAPPLE follow a different approach than described in Section 1, except that there are also domain and user models (see Figure 2). The domain model [5] basically consists of a concept map of the learning domain. The relations between concepts can express semantic relations between concepts (as usually done in concept maps), but also hierarchical relations between concepts can be expressed. In addition to the domain model, the Conceptual Adaptation Model (CAM) is the basic model where adaptive lessons are defined by using concepts of the concept map and connecting them with pedagogical relations. Pedagogical relations can freely be defined and used in adaptive lessons to indicate the sequence of concepts for the adaptive engine.

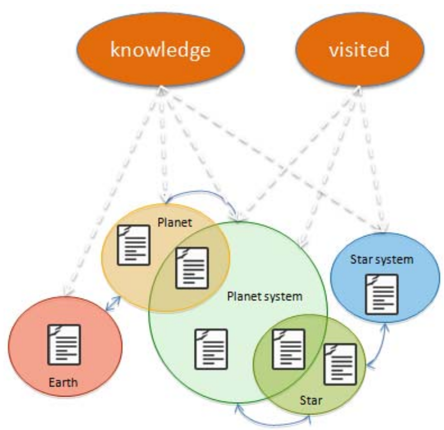

Figure 2: GRAPPLE domain model (concepts with related learning resources) with user model variables defined on these concepts.

The user model [1] is totally flexible, since every kind of user model variable can be defined upon a domain model. A user model variable is a variable of any data type and is associated with all concepts of an adaptive lesson. For example the variable *knowledge* can be defined as integer with a range from 0 to 100, so that the user model can express the knowledge level for all concepts. Another example is the variable *visited* defined as boolean, which is used to express all concepts a user has visited with associated learning resources.

The user model of the CbKST tool has a simpler structure, since the skills can be seen as the knowledge dimension of concepts. Hence, in the notation of GRAPPLE there is only one predefined user model variable knowledge, which cannot be altered. Also the relation between concepts of the CbKST Tool can be seen as a special case of the GRAPPLE approach, since in GRAPPLE every kind of relationship can be defined. However, defining such relations in GRAPPLE is rather a pedagogical design than psychologically proven dependences between skills.

3. Visualisation Tools and Techniques

Following the flexible user and domain model approach described in Section 2, also the visualisation techniques have to be flexible in order to capture the information provided in these models. According to the domain and especially user model, there are several dimensions which can be displayed to the learner:

- a distinction between a single and a multiple learner view
- different user model variables defined on concepts
- performed activities in terms of learning resources
- goals in terms of concepts and user model variable values on concepts

In order to achieve flexibility also for the visualisation technique, standard visualisation techniques have been developed which can capture all or most of the information dimensions described above. For example, Figure 3 shows two of the developed visualisation techniques. Figure 3a depicts the knowledge user model variable for the concepts of a lesson for one learner (purple bars). Furthermore the average values of the other learners are shown (red bars) and the expected level (goal) is also shown for each concept (top black line). Figure 3b outlines which learner has performed which activity (purple circle on crossings in matrix). Furthermore, the average values for learners and activities are expressed with the small bar diagrams. Both representations can be employed for other representations, whereas the information to be represented can freely be chosen.

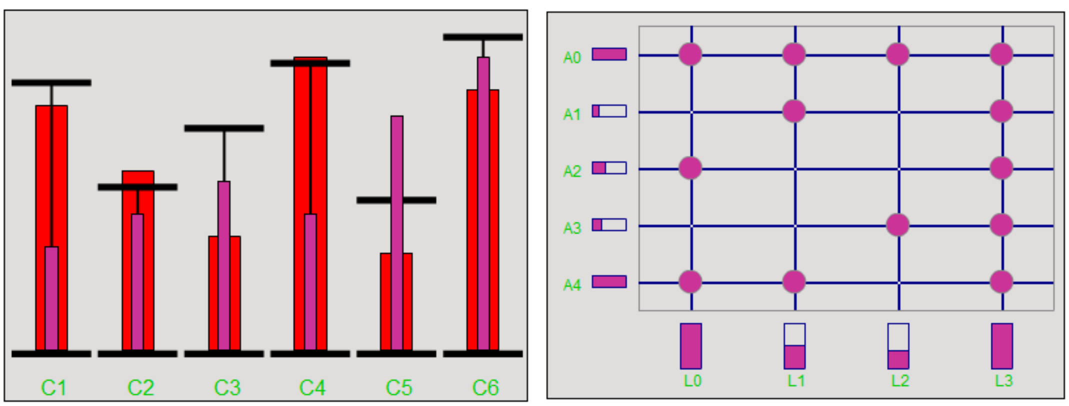

Figure 3: Two different visualisations: (a) knowledge level of the concepts of a lesson for a single learner, and (b) activities performed for a class.

A set of visualisation widgets has been implemented where each widget uses a specific visualisation technique or user model representation respectively. Some of them are simpler in terms of the presented information and others are rather complex connected information is displayed in one widget. Furthermore, some of the widgets are intended to be used by learners and others are rather suitable for teachers or tutors.

A data format has been defined (in JSON format) which can contain all the information and each visualisation tool gets the same data for a lesson. Depending on the visualisation technique and the chosen information dimensions to be visualised, the tool selects the respective parts and renders them. These tools have been implemented as Flash objects (using Macromedia Flex), which get the data over HTTP from a Web application having access to the user and domain model data. The visualisation tools can be included in Web pages of Learning Management Systems connected to GRAPPLE. According to the configuration settings different information dimension can be displayed.

4. Conclusion and Outlook

In this paper visualisation techniques and according tools have been presented which are capable of rendering flexible user model data. These tools visually open up the data used for adaptation of learning resources, which should help learners to get an overview on their current learning progress. Furthermore, they can compare themselves with other learners, which should have positive effect on their motivation. A limitation can be identified, that no meaningful guidance can be provided with these tools as it easily could be done with the CbKST Tools.

An initial evaluation has been conducted with 43 students and 32 university lectures. The overall result of the student and teacher visualisations indicated a medium to good quality in all aspects (suitability for the task, self-descriptiveness, usability, meta-cognition, cognitive load, benefits for instructors, and acceptance). This result suggests that these visualisations are suitable for their intended purpose and also largely self-descriptive and understandable. Learners think that this visualizations are suitable for getting an overview of the current status in learning process. The result of the more complex visualisation (Figure 3b) is significantly inferior to those of the simpler visualisations (e.g. Figure 3a). The reason might be that it is more difficult for students to understand the complex information.

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References

[1] Abel, F., Heckmann, D., Herder, E., Hidders, J., Houben, G.-J., Krause, D., Leonardi, L., & Sluijs, K. van der (2009). A Framework for Flexible User Profile Mashups. Paper at the International Workshop on Adaptation and Personalization for Web 2.0 (APWEB 2.0 2009).

[2] Albert, D., & Lukas, J. (Eds.) (1999). Knowledge Spaces: Theories, Empirical Research, and Applications. Mahwah, NJ: Lawrence Erlbaum Associates.

[3] Albert, D., Nussbaumer, A., & Steiner, C. (2008). Using Visual Guidance and Feedback Based on Competence Structures for Personalising E-Learning Experience. Proceedings of the 16th International Conference on Computers in Education (ICCE 2008), 27-31 October 2008, Taipei, Taiwan.

[4] Bull, S., & Kay, J. (2008). Metacognition and Open Learner Models. In: The 3rd Workshop on Meta-Cognition and Self-Regulated Learning in Educational Technologies, at ITS2008.

[5] De Bra, P., Smits, D., Sluijs, K. van der, Cristea, A., & Hendrix, M. (2010). GRAPPLE: Personalization and Adaptation in Learning Management Systems. To appear in: Proceedings of the 22nd World Conference on Educational Multimedia, Hypermedia & Telecommunications (ED-MEDIA 2010)

[6] GRAPPLE (2010). Generic Responsive Adaptive Personalized Learning Environment. EC-funded FP7 research project, http://www.grapple-project.org/

[7] iClass (2010). Intelligent Distributed Cognitive-based Open Learning System for Schools. EC-funded FP6 research project, http://www.iclass.info/

[8] Kay, J., Kalina, Y., & Reinmann,.P. (2007). Visualisations for Team Learning: Small Teams Working on Long-term Projects. Proceedings of the Conference on Computer-supported Collaborative Learning (CSCL 2007), International Society of the Learning Sciences.

[9] Steiner, C., Nussbaumer, A., & Albert, D. (2009). Supporting Self-Regulated Personalised Learning through Competence-Based Knowledge Space Theory. In Policy Futures in Education, Vol 2009/7/6.