SYNTHESIS OF PEDAGOGICAL ANNOTATIONS

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Abstract

For the creation of learning session in an ITS pedagogical knowledge is needed. This is created by teachers. An ITS (Intelligent Tutoring System) should have some abilities of teachers, e.g. for learning content creation. It is the future of ITSs to be more independent from human pre-defined content. This would allow an ITS to reduce the workload of teachers in adapting content to a student through automatic creation of learning content. This paper introduces a concept of different layers of information to be used with a rule system with which annotations in an educational context for expert knowledge can be created. The level of automation is one step beyond the classical ITS concept.

Keywords: ITS, Intelligent Tutoring, Pedagogical knowledge, Adaptation, Automation.

1 INTRODUCTION

An Intelligent Tutoring System (ITS) is an educational teaching and training software, which has the task to – abstractly speaking – transfer knowledge from a database to a human learner. For this purpose, it needs to copy some of the behavior of the teacher such as to filter the knowledge so that it matches the student's needs and to explain it in a way that is easy to understand. If we focus on the knowledge an ITS adapts to a student, we have the expert knowledge (also called domain model), as the knowledge that we want to transfer [8], and the pedagogical knowledge, which explains how to teach it. The pedagogical knowledge (also called tutorial model) is a component of ITSs that is equally important as the expert knowledge [9], even though it is often only partly integrated into the expert knowledge or even ignored in implementations. Shown in figure 1 is a common ITS architecture where the pedagogical module is named "Tutoring module". There the basic problem is visible, the pedagogical knowledge is too much integrated into other parts. Whereas the expert knowledge is an – usually fact and rule based – amount of knowledge, the pedagogical knowledge can be seen as the semantic annotation of the expert knowledge, for example adding context, additional rules and rationale to the facts and rules. With this additional knowledge, an ITS can "work" with the expert knowledge: it can structure the content according to case-based training, to diagnostic reasoning, but also for example to develop a logical coherent lecture. The latter is an example, where the ITS uses a pedagogically founded sequentialization of the expert knowledge to create lecture material. The problem is that the pedagogical knowledge is bound to the representation of expert knowledge and therefore, usually the reuse of the pedagogical knowledge is not allowed. Knowledge engineers have to work with teachers to add these annotations to existing expert knowledge databases without merging them to one. That means many hours of manual labour to create this bound pedagogical knowledge. This knowledge engineering is the classical bottleneck in all ITS – and the main reason, why the pedagogical knowledge is missing in quite a lot modern ITSs.

Our approach tries to fill the gap between and to overcome the bounded restrictions of a combined expert- and pedagogical knowledge model. In the following section 2 we analyze the pedagogical knowledge component in existing ITS. In section 3 we describe our approach to enhance the ITS with a more abstract and general understanding of pedagogical knowledge. Based on this approach, section 3 introduces a new way to endorse an autonomous process of creating educational meta data. In section 4, we claim, pedagogical knowledge can be constructed by developing rules which can create educational meta data.

2 STATE OF THE ART IN CONTENT DEVELOPMENT

The problem of current ITS is that the expert knowledge often also contains pedagogical knowledge, even if it has a pedagogical component [11]. Only the part of the pedagogical knowledge is extracted from the expert knowledge which is important for the adaptation of the learning content to the student. Then the expert knowledge is not really only expert knowledge, but includes a sequencing of learning content. The sequence is not complete but separated into smaller chunks to reorder the learning material for the student or skip some parts.
Figure 1: Common ITS architecture [1]. Pedagogical Knowledge is included in the Tutoring Module and not explicitly shown. The knowledge is not reusable because it is heavily bound to Expert knowledge.

Figure 2: Learning content creation gap.

The ITS can come from two directions to create a learning session: from the user side or from the expert knowledge side, see figure 2.

We start with the perspective to create a learning session from the learner side (figure 2, left side). The student knows about thematic areas and their names. He wants to learn one session of this area matched to him. A learning session includes the passive and active learning part as described in. Each of them needs some expert knowledge matched to the student, the area and the type of learning to generate content. Then what is required is an amount of computationally available big chunks of learning content which is sequenced in a way so that it „somehow“ matches the student’s interest.

The second approach to create a learning session is from the expert knowledge side (figure 2, right side). We have expert knowledge representations easily readable for the ITS. However, the ITS can open and scan the content, but does not „understand“ it. This approach is usually done by humans, but some metrics can be reliably gathered with a system from the representation (character count, sentence length, pixel count, colors used), other information is easily understood by humans (knowledge type) and can be manually added. These basic metrics are not specialized for the educational context. With annotations in that context learning content creation would be improved.

The gap between the two approaches is typically bridged by human teacher with knowledge about appropriate elements of the expert knowledge fitting for the student, and the appropriate order and level of detail needed to teach efficiently. A human teacher has high effort to create learning content which can be reused in many learning sessions with many different types of students. We aim to create a concept to make this gap as small a possible with a system being a part of an ITS.

In [4] a general ITS process is derived from [8], in it you need the expert knowledge, a student profile and pedagogical knowledge. This pedagogical knowledge is typically bound to the expert knowledge. The pedagogical knowledge occurs in form of annotations of the expert knowledge to assist the creation of learning content. The student profile provides information about preferences and
capabilities of the student. When all three are available, it allows the system to create a learning session which is adapted to the student. One of the main advantages of an ITS is the cost effective adaptivity to the student, and 1:1 teaching [3].

3 OUR APPROACH TO FILL THE GAP

The first goal is to make a clear separation between expert knowledge and pedagogical knowledge as information sources for the ITS. In current ITSs, the student model tends to be clearly separated from the knowledge bases (figure 1) and is used to save relevant student information during the process of teaching. The separation can be achieved by removing the pedagogical knowledge from the expert system on a structural basis. For this purpose, we looked at the underlying knowledge types (see next subsection) and representation types. Based on this, we developed the insight that the solution can be achieved by piecing the expert knowledge to very small parts. This has the effect that the system can adapt knowledge transfer more flexible to student’s needs.

3.1 Knowledge types

Knowledge types should be the smallest knowledge common dominator with no educational intent but just only writing up knowledge from a given domain. They are the form of the idea to be saved and then submitted. This basic type is very relevant for creating learning content, because you can implicitly derive more educational information in combination with other metrics.

We found different types of them listed here:

- Technical term
- Structure model
- Evaluation rule
- Process
- Example
- Further explanation of a detail

Other types for small expert knowledge parts we found could be classified into one of those types.

3.2 Expert knowledge piece

We call the small parts from the expert knowledge "expert knowledge pieces". The expert knowledge piece is an instance of a knowledge type in one representation form. It is beneficial to be redundant in a way to include different representations of the same expert knowledge and knowledge type, to give access to the knowledge from different angles. The preference of the student should be detected or manually entered and allows the ITS to select the correct expert knowledge piece for the student that explains it for this student best. They are the representations of knowledge types and their collection is the given expert knowledge. These pieces are just small bits of information explaining one thing in one way. The benefit of small expert knowledge pieces is that in a created learning session for the student the content can be more adaptive.

The expert knowledge piece is the representation of the knowledge types. We found different representation types:

- Text
- Graphic
- Domain specific language
- Formula
- Table or enumeration
- Audio
- Video
- Interactive
One knowledge type can be represented in different ways. A model can be represented as a text, a formula, a graphic and many other. For every knowledge type there are more than one way to express them in a representation. Each representation does have its own set of advantages, disadvantages and basic meta data. Some meta data are specific to the representation and some are shared among multiple or all of the representations. The representation text do have a number of characters, referencing technical terms, length of the sentences and other basic meta data which can be automatically or manually derived.

3.3 Basic meta data of expert knowledge pieces

There are several approaches to present meta data in ITS, for example LOM [6] or SCORM [7]. These approaches focus on content as a whole structural unit, and do not focus on adaptation of small content entities. Thus, they are not usable for our approach. The meta data we use for our purpose helps us give the ITS the information about an expert knowledge.

Basic meta data of expert knowledge pieces as the enrichment of the given expert knowledge with meta data. The meta data can be either automatically generate or be provided by a human.

On the first hand, meta data can be automatically generated. This information is added as meta data of an expert knowledge piece. These are mostly metrics about the expert knowledge piece. This can also include complex metrics such as semantic clustering of natural texts, as recent attempts show in [2] using "Latent Dirichlet Allocation".

On the second hand, meta data, such as simple classifications, can be manually added. Below we show three important meta data approaches, which are potentially more easy defined by humans then by computer systems.

One example is the classification of the expert knowledge to the knowledge types, this is one of the most relevant classifications. But it is only the representation of the expert knowledge pieces available, since it is mostly easy to classify the knowledge type for an expert knowledge piece for a human and can get very hard for the system.

Another example are the dependencies from different expert knowledge pieces to each other, it can be very hard for machines if it is not a text. In a text one example algorithm to determine the dependency is that every appearance of a word which is a definition in another piece of expert knowledge.

The third example is the thematic clustering of the different expert knowledge pieces to one thematic area. The expert system pieces do belong to at least one thematic area. Knowing that two pieces belong to the same area is useful for the generation of pedagogical knowledge.

3.4 Educational enrichment rules

The educational enrichment rules comes from didactics or instructional sciences, which should be knowledge a teacher has to have to be able to generate new learning content from not yet known expert knowledge. It represents the rules how to annotate existing expert knowledge with meta data important for learning session generation, then there is not need to annotate the expert knowledge through manual labor. It is not bound to a specific expert knowledge, but can however be bound to a certain field. Since the ITS is partly modeled after a teacher, the creation of teaching content and a matching teaching strategy for knowledge should also be a feature that should be copied. With educational enrichment rules it is not needed to create educational meta data for every new expert knowledge which is added, because the educational enrichment rules is reusable, at least in one field of study. Even if the expected result is not as good as the human created educational meta data, the adaptivity, speed and cost efficiency should make enough benefits to use it, besides the necessity for an ITS when human teachers are not available.

The educational enrichment rules is build from rules, which can be evaluated on the available expert knowledge pieces and their basic meta data. The rules evaluate through already defined conditions if knowledge pieces and then can add their result as additional educational meta data. So it is an analysis of the knowledge pieces with their meta data to enrich them with information that is useful for learning content creation: Educational classification, suitable for the different learning types and annotation of educational dependencies.

The rules have a scope, which limits them to a domain or subdomain, but they are not fixed to a certain expert knowledge database. To use such rules in an automated way to create bound
pedagogical knowledge and be exchangeable they have to be formally defined. We have investigated our approach in some examples and have been able to show, that the general model is working. In the paper, the model, a software prototype and first insights in applying the method to examples where shown. On example is shortly sketched here: language learning. A educational enrichment rules rule could be that definitions, which reference others are more complex or that two similar words should be learned together. A general pedagogical rule that is specific to the domain could be that longer words are harder to learn. The general rules can be applied to technical terms in different domains, while the domain specific rule are often wrong where the complexity of the meaning of words do not correspond with their length. While these rules are not correct in every case, the automation reduces the abstracts many details about the expert knowledge and the implementation and allows (especially with an authoring system) an easier access for didactic / instructional design experts.

3.5 Educational meta data
The information which is bound to expert knowledge and is suitable to relate it to the educational context without understanding the knowledge itself is educational meta data. It is some additional meta data only in the educational context for humans.

With the expert knowledge pieces, the generated educational meta data and the student model the ITS has everything needed to create a learning session adapted to the student.

3.6 Examples
Here we show some examples what the different layers, seen in figure 3, could mean.

![Figure 3: Layers of the ITS knowledge for learning content creation.](image)

Example for student logs: Student has mastered knowledge piece with success rate of a specific percent, Student needed help on a specific question

Example for student profile: Student does know a specific math thematic area very well, student is weak on Mondays, student has a preference for visual explanations, student does not understand one specific concept

Example for expert knowledge piece: Instances of knowledge types representations, like a graphic displaying a process of some sort or an audio file with the definition of natural numbers

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Example for basic meta data of expert knowledge piece: Knowledge type, Is dependent from other definition

Example for educational enrichment rules: If the length of the text is short and it is not referencing other expert knowledge pieces and its knowledge type is definition and it is a thematic cluster with not many references to knowledge pieces outside of the knowledge piece the educational complexity is seen as low

Example for educational meta data: Educational complexity of an expert knowledge piece, Dependency from one expert knowledge piece to another only relevant in an educational context, Fitting to a learning type.

Example for learning content: A path through different expert knowledge pieces to explain a thematic cluster matching the student profile with filling content to bond the pieces together, a simple collection of the most important rules and definitions for the thematic cluster.

Example for learning session: A full fledged learning unit for a thematic area (precise naming and definition of the area, hopefully matching a thematic cluster) including a passive and active learning part visible for the student to learn a thematic area he is interested in following the ITS process.

4 CONCLUSIONS

An incorporated module for automatic creation of educational meta data is useful in cases where manual labor from teachers is not possible, because there are no teachers available. The benefits of a system is, that it can adapt the lecture to single students in a very short time and even if the results from the automation are not as good, if it is acceptable, this could be a good alternative. Because the cost and speed of an ITS for learning content generation would be better. The educational meta data would not be created multiple times, it could be reused for new adapted learning content generation matching the student profile.

One problem that occurs for the system is the naming of the thematic clusters and relating them to existing thematic area names. Thematic clusters are automatically gathered through the similarity of expert knowledge pieces to one another. They are not named and if we want to rebuild the thematic areas which are already named and defined this mapping has to be done by hand.

It is the first step to build a system with the knowledge how to construct lecture material in a more general and independent way. That more of the labor a teacher has to do can also be done by a system for specific use cases, for example mobile self teaching between real lectures [10].

REFERENCES


