CONCEPTUALLY MODELING THE DOMAIN KNOWLEDGE FOR ASSISTED LEARNING IN AN IT DISCIPLINE

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Abstract
This paper presents a solution for conceptually modeling the training domain knowledge of computer-assisted instructional environments. Conceptual organization of the training domain knowledge, with learning stages phasing, can constitute a solution to the problem of adapting the instructional system interaction to users with different cognitive style and needs.

LEARNING AND INDIVIDUAL COGNITIVE STYLES

Correlating the assistance capability of instructional systems with different cognitive styles of potential users has lately become an important study and research subject in the area of computer–assisted instruction. The possibility of personalizing the educational process is the main demand in building computer-assisted learning systems for any form of education, continuous education and professional re-conversion included. In the case of these education forms, the subject of study frequently consists of groups of users; between these users there can be significant differences concerning the training level, age or internal goals pursued through study. Consequently, the way the educational process is approached – the cognitive style – can be extremely different among the users who form the study groups (Nicola 1992, Larmat 1997).

When computer-assisted learning systems are used for any of these forms of education, they have to be able to dynamically adapt to the various cognitive necessities and demands of the users, in order to ensure the efficiency of the educational act.

Considerable research effort has gone into implementing adaptive (depending on the cognitive style) training systems. A direction pursued by many systems designers is to dynamically build a behavioral–cognitive profile of each user. Another trend in implementing adaptive web-based training systems consists of a specific structuring of the content elements included in the Domain Model. This structuring is achieved either from the training phases of the instructional process, or from a hierarchy of clearly stated instructional goals and sub-goals. In both cases, knowledge space browsing is monitored in order to dynamically adjust it whenever the user correctly performs certain acts, or reaches certain stages (La Passardiere and Dufresne, 1992, ). The organization model of the training material, which is tightly connected to the representation of the training domain knowledge, has to allow multiple views (presentations) of the concepts in the training domain (Messing, 1990).

Studies of computer-based training systems have shown that if they contain a structural model, they facilitate learning. A network-like model with interconnected knowledge nodes would best reflect the structure-based learning paradigm. Network nodes should contain the description of concepts or of their instances, and the links should contain logical relations between these concepts.
A THEORETICAL MODEL FOR REPRESENTING THE DOMAIN KNOWLEDGE

The model described herein is destined to represent the domain knowledge of an instructional system. The model was called COUL-M (Conceptual Units’ Lattice Model). The mathematical formalization of the COUL-M model has been developed in (Pecheanu, 2003a), and has been derived mainly from two mathematical theories: the Formal Concepts Analysis, (Ganter and Wille, 1999) and the Logical Concept Analysis, (Perre, 1999).

In the COUL-M approach, the key elements in modeling the domain knowledge of a CAI system are the followings: the Conceptual Unit, the Conceptual Structure, and the Conceptual Transition Path. These three elements will be defined below.

Definition 1: A Conceptual Unit $C_i$ is a group of related concepts belonging to the domain knowledge of an instructional system. Conceptual Units are obtained by applying a relation (or a set of relations) over a set of concepts belonging to that domain knowledge.

Definition 2: A Conceptual Structure $S$ is a tuple $(N, R_N, C_S, L_S)$, where $N$ is a set of concepts belonging to the domain knowledge of course or discipline, $R_N$ is an order relation over $N$, $C_S$ is the set of Conceptual Units obtained by applying the relation $R_N$ over the set $N$, and $L_S$ is the set of traversal paths of the structure $S$.

Definition 3: A Conceptual Transition Path $T_s \in L_S$ is a set of conceptual units $(C_{1s}, C_{2s}, \ldots, C_{Ns})$ interconnected within a Conceptual Structure $S$. A Conceptual Transition Path $T_s$ has as origin a Conceptual Unit $C_{1s}$, considered initial, and as destination a Conceptual Unit $C_{Ns}$, which encapsulates a set of concepts comprising a study goal within an interactive course.

A Conceptual Structure is a model meant to represent the domain knowledge of an interactive course. A Conceptual Structure should map the cognitive structure of the domain knowledge, and should also reflect the pedagogical vision of the teacher/author of that course. The model has to allow for flexibility, i.e., to provide as many as possible transition paths for learning the domain’s main concepts. The COUL-M model (Pecheanu, 2003b) is a solution for building the Conceptual Structure covering the domain knowledge of a CAI system. The starting point in developing the COUL-M model (and thus, the Conceptual Structure) for a certain domain is the analysis of the pedagogical relations between that domain’s concepts. From a logical point of view, several types of relations can exist among the concepts within a domain knowledge: hierarchical order, implication, equivalence, influence etc. From a pedagogical point of view, two such relations might be of interest:

1. The Precedence Relation between concepts, which refers to the order of presenting the concepts within an interactive course;
2. The Contribution Relation between concepts, which refers to the explicit contribution (participation) of a concept in the presentation of another concept.

The mathematical formalization of the relations above (the Precedence Relation and the Contribution Relation), combined with their transformation into incidence relations (Pecheanu, 2003a), allows for building a formal context and then, the concept lattice for this context. The terms of formal context, formal concept and concept lattice are considered in the sense of the Formal Concept Analysis approach. (Ganter and Wille, 1999). The resulting model, a complete lattice of formal concepts, expresses the relations among the course concepts, as described by the teacher/author. The lattice-like model implicitly includes the generalization-specialization relation (a complete lattice is a hierarchical generalization-specialization mathematical structure).
The formal concept lattice is isomorphic to a complete lattice of Conceptual Units (Pecheanu, 2003a), which is the structure (the model) aggregating the related concepts within the domain knowledge. This aggregation model, lattice-like, can constitutes a Conceptual Structure for the domain knowledge (Pecheanu, 2003a).

**Example 1:** We will consider the domain knowledge of a training system which is meant for assisted instruction in an IT discipline: Operating Systems. Furthermore, we will consider a set of concepts belonging to a specific chapter of this discipline (domain), the “Processes’ Mutual Exclusion” chapter. The most important concepts of the “Mutual Exclusion” chapter are considered to be (in the author’s pedagogical vision) the following ones: MEP, CR, CS, WA, Sem, SA, PC, where these abbreviations stand for:

- A = MEP = Mutual Exclusion;
- B = CR = Critical Resource;
- C = CS = Critical Section;
- D = WA = Wait-Activation Method;
- E = Sem = Semaphore;
- F = SA = Strict-Alternation Method;
- G = PC = Producer-Consumer.

It is assumed that the professor who authored the interactive course has specified the pedagogical precedence between these concepts (according to their signification within the subject of study and according to the professor’s pedagogical vision) as an ordered list: CR, MEP, CS, Sem, SA, WA, PC. The representation of these Mutual Exclusion chapter’s concepts using the COUL-M model is shown in Figure 1.

![Figure 1. The COUL-M model, for the Precedence Relation within a domain knowledge.](image)

The list of formal concepts:

- \( C_1 = 1234567 : \Phi \)
- \( C_2 = 134567 : B \)
- \( C_3 = 34567 : AB \)
- \( C_4 = 4567 : ABC \)
- \( C_5 = 567 : ABCD \)
- \( C_6 = 67 : ABCDE \)
- \( C_7 = 7 : ABCDEF \)
- \( C_8 = \Phi : ABCDEFG \)

The list of Conceptual Units:

- \( C_1 = \Phi \)
- \( C_2 = B \)
- \( C_3 = AB \)
- \( C_4 = ABC \)
- \( C_5 = ABCD \)
- \( C_6 = ABCDE \)
- \( C_7 = ABCDEF \)
- \( C_8 = ABCDEFG \)

Figure 1 shows, intuitively, that the COUL-M model (the lattice of Conceptual Units), preserves the significations of the Precedence Relation that has been established initially:

- the formal concepts \( C_2, C_3, C_4, C_5, C_6, C_7, C_8 \) correspond, respectively, with the course concepts identified as: B, A, C, D, E, F, G (CR, MEP, CS, Sem, SA, WA, PC); the \( C_2 \) formal concept is a formal representation for the course concept called CR (Critical Resources), the formal concept \( C_3 \) is a formal representation for the course concept called MEP (Mutual Exclusion of Processes), and so on.
- a Conceptual Unit includes all the concepts belonging to the other “smaller” Conceptual Units, which is an adequate expression of the pedagogical rule: a concept (notion) of a course should be presented (in order to be ‘learnt’) to students only after all the preceding concepts have been presented (understood, assimilated);
- the complete lattice making up the COUL-M model has the shape of a simple chain, which corresponds to the precedence in any training activity: learning content’s pieces in succession, similarly to the linear reading of printed text.

These observations lead to the idea of adequacy of the complete lattice model for representing instructional content of an interactive course.
The Contribution Relation between a domain’s concepts might be modeled in a very similar way: by applying a sequence of mathematical operations (decomposition and aggregation) this relation can be transformed in an incidence relation (Pecheanu, 2003a). Then, the formal concept and concept lattice can be built and the lattice of Conceptual Units, standing as the Conceptual Structure of the domain, can be finally derived (Pecheanu, 2003a).

Figure 2.a. shows the COUL-M Model of representation for the domain knowledge, based upon the Precedence Relation. Figure 2.b. shows the COUL-M model for the Contribution Relation within the domain knowledge. Finally, the Figure 2.c. is showing the COUL-M model of representation in case of combining the Precedence Relation and the Contribution Relation in the same structure (formal context subposition, Ganter and Wille, 1999).

A further development can be realized if the course concepts are considered to be teach by using several pedagogical methods, and if we consider a pedagogical method as a set of related pedagogical resources. As a result, a new, more detailed model of knowledge representation can be built: the COUL-FM, Conceptual Units Lattice – Formal Model.
The table from Figure 3, listing a set of pedagogical methods, viewed as collections of resources with a well-stated pedagogical role, and the diagram is showing the mapping of this instructional elements over the lattice-like model of the domain knowledge.

In COUL-FM model, the Conceptual Units become logical formulae expressing the aggregation between the conceptual model of the domain knowledge, instructional methods and pedagogical resources. Consequently, a knowledge base and an inference engine for an intelligent instructional system can be developed upon the basis of the COUL-FM model.
The COUL-FM model has been implemented by means of a software tool: a knowledge compiler named COUL-COMP (COnceptual Units’ Lattice – knowledge COMPiler). COUL-COMP stands for an authoring system, able to realize the representation of the domain knowledge for a computer assisted instructional system. A easy to use specification language, COUL-SL (Conceptual Units’ Lattice - Specification Language) has been also developed, in order to allow teacher to perform the description of the domain’s knowledge structure, i.e., the specification of the relations between the domain’s concepts. The COUL-SL language allows descriptions for the instructional methods and the pedagogical resources (in terms of specifications) as well as for the role a pedagogical resource can play in a an instructional method deployment.

The compiler COUL-COMP is able to lexically and syntactically check the correctitude a “program”, i.e., a set of specifications written in COUL-SL language. If the program is syntactically correct, the compiler will produce a set of pedagogical prescriptions. These prescriptions are derived from the COUL-FM model implemented by the compiler and are strongly depending of the specification of the relations between concepts belonging to a subjects matter and the specification of the intended pedagogical methods and of the existing pedagogical resources for teaching one subjects matter.

CONCLUSIONS AND FURTHER DEVELOPMENTS

The lattice-like COUL-M model is able to represent, in a comprehensible way, the relations between the concepts of the training domain of a CAI system. Furthermore, the COUL-FM model is including knowledge about the targeted instructional methods and the existing instructional resources. The compiler COUL-COMP is a computational representation of the COUL-FM model, able to extract pedagogical prescriptions from the model.

The COUL model can constitute a low level layer for various types of training systems. The model is providing some essential elements for developing adaptive training systems: a mapping of instructional methods and pedagogical resources over a conceptual structure of the domain knowledge. The COUL-M model can be integrated in any instructional environment including a Pool of Pedagogical resources (like the Ariadne system).

REFERENCES

MESSING, J. (1990). The Use of Teaching Strategy Control Features in Computer Assisted Learning Courseware, Charles Sturt University