Knowledge Representation in an Adaptive Pedagogical Module.

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This paper is framed within the area of representing knowledge in the context of Web-based intelligent systems in education (AIED). The development of specifications and tools related to the Semantic Web is producing that ontologies are created in different domains with the aim of interconnecting knowledge at a global level. The use of this knowledge in an educational context requires process technologies able to search, filter and reorganize that knowledge automatically in order to generate an appropriate answer to an educational target. Currently, existing systems cannot perform these functions automatically and therefore it is adopted a medium granularity level of knowledge representation oriented to the instructional process in the way of content object like SCORM proposes.

This work is part of the research carried out for the development of a Educational Web Server named Adaptive Pedagogical Module (MAP) that aims to improve the tutoring abilities in the teaching process over the Web. It clearly keeps the difference between the explaining-oriented knowledge (instructive) and the thinking-oriented one using a semantic representation for processing and tracking.

Keywords Knowledge Representation,; Intelligent Tutoring Systems; Instructional Knowledge; Educational Servers.

1. Introduction

From mid Twentieth Century the *ITS* (Intelligent Tutoring System) paradigm has evolved and contributed with new models and system theories. These advances were based on different ways of adapting the content sequencing that was applied in some experimental environments. The development and diffusion of the Internet, especially Web technologies, has changed traditional education through the introduction of new possibilities in the learning process globally known as e-learning. This new stage is being used by researchers and educational organizations to extend and enlarge their experiences out of laboratories. To this end, large efforts are being dedicated to the creation of specifications and standards that can simplify the automation of the teaching process by creating a more intelligent Web [2] with semantic codification [3], the development of ontologies [4] and its computational integration [5].

The teaching-learning process is a complete, non-divisible entity where numerous real and abstract elements take part. These elements artificially group in functions within different domains: Emotional, Cognitive, Instructional, Behavioural and Interactive. Cognitive domain is responsible for tracking and estimating the student knowledge while instruccional domain controls the inputs received by the student in order to change his cognitive state. This paper focuses in the interconnection between both domains and the need for a knowledge codification with common elements that simplify interaction and automation.

Instructional domain handles transmitter-knowledge used by a teacher in his teaching activity whereas the cognitive domain tries to represent transferred-knowledge. Usually, many ways exist to explain the same thing; therefore the instructional knowledge is an explicit temporal representation of the content created by a teacher to deliver a piece of knowledge in cognitive level. It could be said that cognitive domain deals with thinking-oriented knowledge (*ToK*) while instructional domain works with explaining-oriented knowledge (*EoK*) as Fig. 1 shows.

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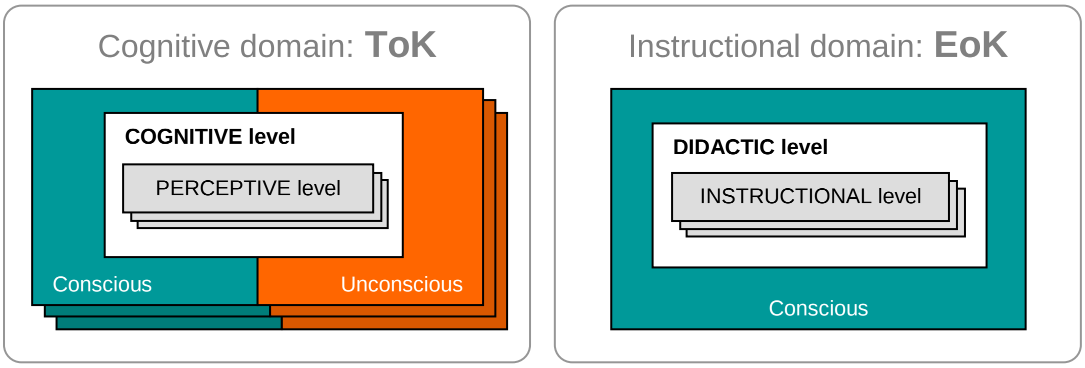

Fig. 1 *ToK-EoK*. Comparison between characteristics of both types of knowledge.

Knowledge in cognitive domain depends on the features of the internal processors in the human's mind, it works in parallel, its type is associative-implicit and it is codified in symbolic elements based in perceptive parameters. Instructional knowledge depends on the characteristics of the teaching media, it works sequentially, it is explicit type, and it is codified in didactic elements that contain instructional actions. Thin granulometric in the representation of cognitive knowledge facilitates the reasoning at all levels, whereas instructional knowledge is codified at large scale to make it easier to handle in the teaching-process.

The e-learning standards have focused in the representation of *EoK* whose best example is *CAM* (Content Aggregation Model) of SCORM [6]. As for the learning tracking, standardization works are centered on the creation of *Competency Models* in different disciplines with the objective to certify and compare knowledge, abilities and behaviours between curricula. Competency specification is simpler when it is considered at a large scale (degrees, subjects, topics) being its greater difficulty the creation of GUID (Globally Unique IDentifier). Nevertheless, the education systems require a representation of greater detail than allows decision making. In this case, the representation becomes more complex including descriptions, structures, groups and dependency relations that reflect the reality of knowledge.

2. Adaptive Pedagogical Module

In the area of *Education Technologies* at the *Institute of Education Sciences* of the *Polytechnic University of Madrid* we develop projects for the improvement of the pedagogical capacities of the *Distance Education Systems*. Currently two lines of work exist based on Internet technologies: a hypermedia adaptive system *TIX* (*eXtensible Intelligent Tutor*) [7] and an educative server [8] named *MAP* (*Adaptive Pedagogical Module*).

Project *MAP*'s aim is to extend the capabilities of pedagogical answer in the direct interaction with a student like an *ISS* (*Interactive Storytelling System*). In order to achieve this, it uses a signal codification of internal processing that combines the symbolic-perceptual knowledge with parameters of emotional and behavioural characterization.

The system has two components shown in Figure 2: a slave Web client that makes the interface function like a *RIA* (*Rich Internet Application*) and a master server in charge of all the processing of the interaction and the student tracking.

Currently, system *MAP* is in experimental phase and it has been tested in two training courses for teachers about *Web Design*. The analysis of the results shows similar performance to that obtained in the adaptive hypermedia system and also very dependent on the initial level of the student. At present, we are analysing the student's degree of learning and his level of acquisition and integration.

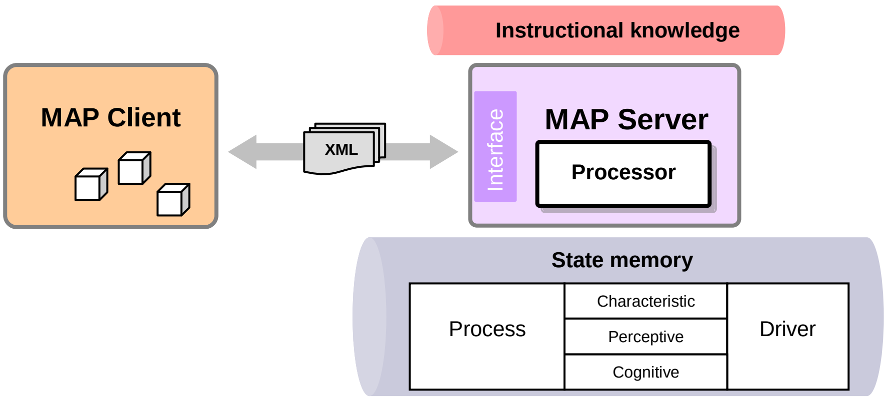

Fig. 2 *MAP Architecture.*

3. Knowledge Representation

Every computer-aided education system includes an instruccional domain that defines its possibilities and that directly affects the effectiveness of the process. *Instruccional knowledge* is the perceptual artifice that a teacher uses to influence the student cognitive domain. For that reason, it will always be a structure of perceptual resources somehow linked with the reality of knowledge at cognitive level.

In order for the system to have the versatility that the teaching-learning process requires, the representation of the instruccional knowledge should follow some guidelines:

Structured. The fundamental factor of an intelligent system is its knowledge structure. The codification must be such that it allows to increase or to decrease the structuring degree according to the author and the needs of the system. This is normally done through entity-relation hierarchies.
Characterized. The relationships that define the internal structure must contain parameters that facilitate the adaptability of the process. Since the objective is to transfer a piece of knowledge, the internal description will be centered in pedagogical aspects like *Depth Level* (Memory / Understanding / Application), *Type of Transference* (Generalization / Explanation, Classification, Assessment), etc.
Categorized. Instruccional knowledge must follow a hierarchy of categories or classes that define their structural logic (Fact / Concept / Procedure, Subject/Section, etc.).
Coherent. Each element of the structure must be independent and complete, so that the system may be able to explain a complete course or to respond to smaller queries.
Continuous. Entities that form the knowledge must be joined by means of some type of *glue knowledge* [9] that facilitates a continuous instruction.
Regulated. Instruccional knowledge must incorporate the experience that facilitates its sequencing. Normally, different ways of presentation are included, such as tracking elements (queries and tests) and even *erroneous knowledge* [10], with the aim to guide the student and to avoid the most common errors.

The *MAP* model of instruccional knowledge (Fig. 3) is based on a network of different container-elements nested by reference: *Instructional Components* (*IC*) and *Instructional Resources* (*IR*). The former define the didactic, symbolic and conscious structure of the knowledge whereas the latter represent the subsymbolic-perceptual side. The complexity and granulometric level is adaptable and it depends on the inclusion structure of some elements within others.

All the elements of the network are defined by an *Identifier*, a *Type* and a description set of *Metadata*. The references between elements can be absolute: *ID*, or relative: *Selector* (group of descriptive values of the element). In addition, the reference can introduce a *Filter* that allows selecting part of the element's content.

IC are characterized by their *Type* (Concept / Fact / Test / …), *Title*, *Abstraction Degree*, *Depth* and *Link Type* with previous knowledge. Their structure can include three types of elements and relations:

Didactic (dR). Inclusion relation between components characterized by its *Function* (Motivation / Content / Guide / Bibliography / …).
Instruccionales (iR). They represent different ways to instantiate the component in form of instructional resource.
Presentation (pR). Inclusion of generic resources like images, backgrounds and melodies associated to the component. They allow its presentation in diverse environments.

Instruccional process is finally translated into the presentation of sensorial stimuli to the student. These stimuli group in *Instructional Resources* (*IR*) that depend directly on the *VLE* (*Virtual Learning Environment*). A *IR* represents a specific form to explain a *IC* and is characterized by its *Type* (Denotative / Interrogative / Expositive / …), *Teaching Strategy* and *Audience Description* (Sex, Age, Education Degree, etc.). The *IR* group a set of *Content Elements* (*C*) structured by means of *Action Relations* (aR) that establish the sequence and the conditions for the presentation in the *VLE*. A content element (C) is a sequence of resources (Text, Image, Sound) that uses certain communication channels and learning processes. When designing contents (C) it is a must to always bear in mind the *Perception Laws* to avoid ambiguities and noise in the process.

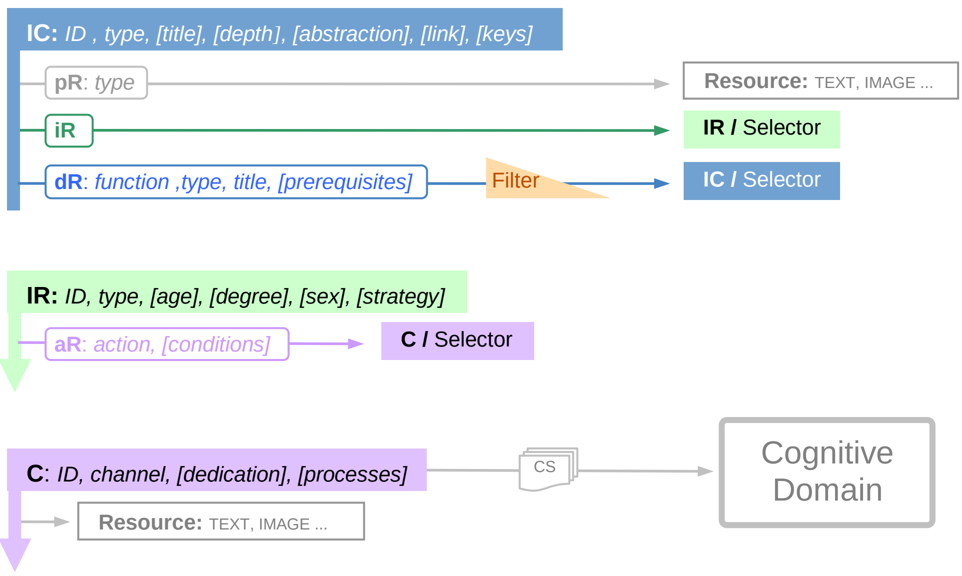

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Fig. 3 *Instructional knowledge model.*

In this model the union between instruccional and cognitive domains is established through *Cognitive Sentences* (*CS*) associated to *Content Elements* (*C*). When the system estimates that the student has perceived or assimilated a content element, it sends sentences to the cognitive domain with the purpose of maintaining an estimation of the student's knowledge.

Cognitive Sentences are a form of implementation of significant structures, *Insights* [11] or *Propositions* [12] with semantic content. The activation of a sentence increases or decreases the certainty of the associated cognitive elements. The certainty is defined by two dimensions: first, *Perception Certainty*, that depends directly on the spent time; second, *Assimilation Certainty*, that is updated in the evaluation processes. In some cases the contents do not have any associated sentence, in which case these are didactic type elements without any cognitive referent.

4. Conclusion

The proposed model of instruccional knowledge in *MAP* is similar to the one proposed in the current e-learning standards in which a structure of resources with metadata is defined. The basic difference is that *MAP* codification, based in component relationships, allows to represent the contents with greater semantic weight, and this facilitates the operation of the system. We could say that current standards as *SCORM* define instructional contents whereas MAP model defines instructional knowledge.

The more the representation of the instructional contents has in common with the cognitive representation of the knowledge that it tries to transmit the greater capacity of intelligent answer of the system. In the near future knowledge representation in the distance education systems will be unique. Thus the knowledge will contain a high semantic weight with ontological criteria that will facilitate the reasoning of the system and, nevertheless, it will not mean a difficulty to be transferred to a student.

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