A semantic system to support teachers to create differentiated digital learning resources

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Abstract. This paper presents the design of a semantic system to index digital learning resources according to the metadata describing their cognitive features. By ñcognitive featureò we mean the cognitive activities (e.g., reading, listening, body interactions, etc.) associated with the form of presentation (e.g., text, audio, image, etc.). The semantic system includes a parser, which detects the semiotic components of a resource, and two ontologies that formally describe the cognitive styles and the semiotic descriptors, as well their association.

Keywords. Differentiated instruction, Cognitive styles, Semantic indexation, Digital learning resources.

1 Introduction

Information and Communication Technologies for Education enable teachers to carry out different types of Digital Learning Resources (DLR). A DLR could be a text explaining a concept, a practical work to train students, an interactive simulation, an exercise to evaluate their level of knowledge, etc., available on websites and on repositories of learning objects[1]. Each DLR is the creative outcome of a teacher, who acts a pedagogical designer. In fact, even if a teacher does not create learning resources from scratch, (sh)he can reuse and adapt preexisting DLR in order to fit learnersô pedagogical goals, cognitive abilities and learning preferences.

In regard to this personalized learning issue, a teacher runs into difficulties because of the little availability of details about the cognitive features of a DLR. By ñcognitive featureò we mean the cognitive activities (e.g., reading, listening, body interactions, etc.) associated with the specific forms of presentation (e.g., audio, image, text, etc.) of a DLR. So, for example, a learner who is asked to read a text uses different cognitive abilities and skills than when (s)he observes a diagram illustrating the same content, and maybe (s)he better understands through the former cognitive activity than by the latter.

[1] For instance, AMSER https://amser.org/, MERLOT http://www.merlot.org/merlot/index.htm

The main goal of our research question is to help teachers to create differentiated DLR fitting studentôs learning abilities. To tackle this problem, we propose an automatic semantic system to index the cognitive features of a DLR.
This paper is built as follows. In the first section we explain the scientific problem and we suggest our approach to index the cognitive features of a DLR. In the second section, we define our set of descriptors concerning the cognitive features inserted in a DLR. In the third section, we present the architecture of our system we plan to develop.

2 Design differentiated digital learning resources: a creativity problem

Personalized learning means to adapt the pedagogical contents and activities to the learnerôs cognitive styles [1] [2], as well as to design differentiated forms of a same pedagogical content [3]. Thus, when a teacher is in charge of the design of a DLR, (s)he also has to reason on which structure and form of presentation could be in adequacy with (her)his learnersô specific cognitive styles [4] and, therefore, the most efficient for their learning. For example, a philosophy teacher must prepare a lesson on modal logic intended for students in visual arts: (her)his first intention could only be to present logic symbols and formalisms, whereas those students would be more effective when they processed images and narrative forms, as if they owned a particular way of information processing. This research tackles the issue of design differentiated DLR: how could we help teachers to create differentiates DLR that would enable students to be more effective in their learning process?

Amongst works on cognitive and learning styles [5] [6], and the complex links between these two constructs [7], we suggest a different theoretical approach, the Multiple Intelligence Theory [4]. According to the MI theory, the intelligence of a person is a set of abilities and skills (s)he develops to solve problems and process information. In MI theory, there are between seven and nine sets of abilities and skills (intelligences), seldom applied separately, especially when a human being achieves a complex task in a precise context. These sets would be relatively autonomous to one another: intrapersonal, interpersonal, kinaesthetic, linguistic, logical-mathematical, musical, visuo-spatial. For example, a person who has a visuo-spatial intelligence is able to better think through visual elements (e.g., images, graphs, cards, colors, etc.) and structures (e.g., patterns, diagrams, etc.) rather than speeches (linguistic intelligence), symbols (logical-mathematical), etc. Two main reasons trigger our theoretical choice. First, previous works have successfully applied the MI theory in the design of Technology Enhanced Learning environments [8]. Secondly, as we found in our previous works [9], the modularity of the MI theory let us formalize the association between a form of presentation (textual, audio, etc.), its semiotic components (words, sentence, images, etc.) and the cognitive activities required (reading, manipulating, etc). In fact, we built a grid of analysis linking the semiotic components of a DLR (sentences, keywords, etc) to the multiple intelligences (table 1). For instance, a DLR whose contents are presented by keywords, short sentences and diagrams, generally expresses the logical-mathematical intelligence, whereas a DLR containing images (fixed or animated) and videos requires a visuo-spatial intelligence.

Semiotics components	**Gardnerôs intelligences**
Sentences describing and explaining a concept	Linguistic
Keywords, short sentences, diagrams	Logical-Mathematical
Sounds, music	Musical
Fixed images, animated images, videos	Visuo-Spatial
Interactive animations in which the learner must perform some gestures (e.g. click and drop)	Kinaesthetic
Linguistic expressions showing the personal feeling of the author of the learning resource	Interpersonal
Linguistic expressions engaging the learner to think	Intrapersonal

Table 1. - Grid analysis linking Gardner's theory to the semiotic components of a DLR

3 A Semantic System to Index the Digital Learning Resources

Our SEmantic System to Index Digital learning resources (SESID) analyzes the semiotic components of a DLR and produces the metadata describing cognitive features of a DLR. The SESID want to produce an automatic indexation of DLR, because teachers usually do not fill several and high complex descriptors, such as Learning Object Metadata (LOM). The SESID is build on three components.

i) *Morphological analyzer*. A parser detects the semiotic components of each DLR by means of the grid analysis we presented above, and calculates their number. Its output is recorded in a database and also in an external spreadsheet file. We developed the parser under Java (1.7.0_11), and we used the Apache POI library (http://poi.apache.org/) to retrieve the semiotic components inside the *.ppt*, *.pptx*, *.doc* and *.docx* files, as well the itext library (http://itextpdf.com/) for the *.pdf* files. For example, for each slide of a .ppt file, the Apache POI creates a set of shapes. Then, by means of a set of algorithms we developed, the parser distinguishes between animated and static images (an icon, a draw or a scheme).

ii) *Domain Ontologies*. Considering the connections between semantic web and ontologies [10] [11], we created two domain ontologies [25]. First, in the *Semiotic Descriptors* ontology (SD) we formally specified the semiotic components of a DLR and their relations. The SD ontology (fig. 1) formally describes that, for instance, an icon is a fixed image.

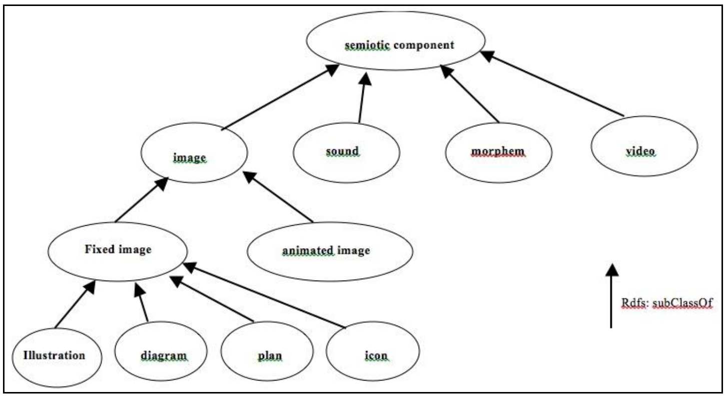

Figure 1 - Domain ontology of semiotic descriptors

Second, in the *Cognitive Style* ontology (CS) we formally described the Gardnerôs Multiple Intelligence theory [4] and we described the seven ways of presenting the learning contents of a DLRs (fig. 2).

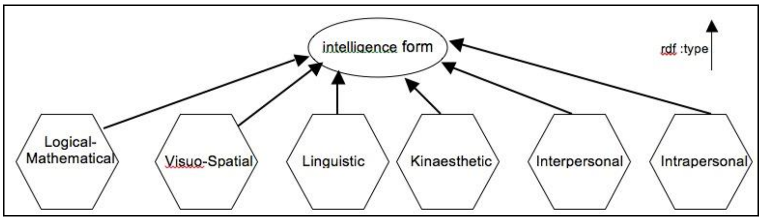

Figure 2 - Ontology of Multiple Intelligence

iii). *Application Ontology*. We designed two application ontologies, to construct ontological classes and relationships between classes. First, the *Linking Ontology* (LO), in which we formally described the association between semiotic components and forms of intelligence in the Gardnerôs approach (see Table 1). For instance, when the parser detects and counts the semiotic descriptors ñmorphemesò, the Linking Ontology enables to associate the morpheme to the Linguistic form of intelligence. ontologies. Second, we build the *Counting Ontology* (CO) to classify each form of intelligence associated to a DLR according to the number of semiotic descriptors that compose each DLR.

3.1 Justification of our choice

The function of a parser is necessary. In fact, in spite of some ontology-based image system [28] and some metadata granularity broad (e.g., the standard LOM allows the description of « image, fixed image and animated image »), we observed that the DLRs are seldom indexed in general, and in particular in the learning repositories we have worked on for this research[2]. The parser uses some API (Java) such as itext or doc.office, which includes some *getters* (ex: getTitle, getSlidesé). The ñfile headerò of each file gives us also useful information to distinguish a fixed from an animated image.

First, an ontology allows to describe complex interrelationships between the concepts [12] [13] and remains independent by the processing of the inference engine [14]. So, for instance, the Cognitive Style ontology could be reusable in other software, like an application monitoring when the user (teacher or student) tries to select the DLRs in adequacy with (his)her cognitive style [15] [16]. Our purpose is to establish the inter-ontology relations between the SID metadata and other existing ontologies and standards [17], as the Dublin Core [18] [19], the Learning Object Metadata (LOM) [20], the Standard Content Sharable Object Model Reference (SCORM). So, we aim to establish the links between our CS ontology and the Dublin Core metadata, which index digital resources from the title, the author, the date of edition, etc. Concerning the LOM [21] and MLR (Metadata for Learning Resources) [22] [23], we are going to study how integrating the metadata of the SESIID in LOM number of category 5 and 8 [24]. Category 5, entitled ñEducationalò, includes the pedagogical characteristics of a resource (type of resource, role of the user, context of useé), whereas category 8, called ñannotationò, allows to add annotations on the pedagogical use of the DLR. About SCORM, in the fourth release we estimate to ingrate the metadata of SID with the section ñsystem of content descriptionò. We now introduce the two ontologies.

4 Conclusions

In this paper, we presented an original proposal to index DLRs according to their cognitive style. We choose to formally define Multiple Intelligences theory as ontology. We described the architecture of a system called SESID to index DLR, consisting of two ontologies and a parser. The SESID detects the cognitive style conveyed by a DLR, letting teacher select some parts of a DLR, combine them with others and create differentiated learning resources in order to fit learnersô multiple intelligences.

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