

Chapter 7.8

A Cognitive Computational Knowledge Representation Theory

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ABSTRACT

Encouraging results of last years in the field of knowledge representation within virtual learning environments confirms that artificial intelligence research in this topic find it very beneficial to integrate the knowledge psychological research have accumulated on understanding the cognitive mechanism of human learning and all the positive results obtained in computational modelling theories. This chapter introduces a novel cognitive and computational knowledge representation approach inspired by cognitive theories which explain the human cognitive activity in terms of memory subsystems and their processes, and whose aim is to suggest formal computational models of knowledge that offer efficient and expressive representation structures for virtual learning. Prac-

tical studies both contribute to validate the novel approach and permit to draw general conclusions.

INTRODUCTION

Almost since the advent of the computer age, researchers have recognised the computer's enormous potential as an educational aid, and although the idea of using software resources for teaching and learning purpose dates back more than three decades, having recourse to virtual learning environments (VLE) in teaching and training constitute an axis of interest which has not stopped growing. Indeed, this important technological concept is being more and more considered by an increasing number of universities and colleges. Various attempts (Wells & Travis, 1996; Rzepa & Tonge, 1998; Lintermann & Deussen, 1999; Heermann & Fuhrmann, 2000) to create strongly interac-

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tive VLE were made, generating a remarkable enthusiasm within the educational community. However, if one has the ambition to build such environments that provide specific teaching material and exploit technology-based features and which are equipped with tutorial strategies able to interact with learners that have various levels of intelligence and different capacities of knowledge acquisition—especially, to adapt contents to each student profile and its needs (Brusilovsky & Peylo, 2003) and to provide tailored aid to learners according to their cognitive states (de Rosis, 2001), then understanding the human learning processes and the manners of structuring and handling knowledge during those processes is a fundamental task.

Recent multidisciplinary researches on cognitive informatics (Wang, 2003; Wang et al., 2003; Wang & Wang, 2006; Wang & Kinsner, 2006) that study internal information processing mechanisms and processes of the brain (and that investigate how human beings acquire, interpret and express knowledge by using the memory and the mind) lead to seriously consider the idea to adopt a memory-based approach which perceives the memory as the foundation for any kind of intelligence. Incontestably, representing the acquired/handled knowledge of students during learning constitutes a real challenge. One solution to the outcome issues expressed above could be offered thanks to the adoption of a cognitive, computational and memory-based knowledge representation approach that formalise the structuring of the domain knowledge which is handled and/or acquired by learners during training activities via VLE.

In this chapter, we introduce AURELLIO¹, a cognitive and computational knowledge representation approach inspired by cognitive theories which explain the human cognitive activity in terms of memory subsystems and their processes, and whose aim is to suggest formal computational models of knowledge representation. The proposed models are innovative in many respects. These models (1) use parsimoniously

cognitive structures suggested by psychology to dynamically encode the knowledge, (2) take into account an episodic knowledge—defined within a novel context—whose analysis serves for a better understanding of the learner behaviour (Najjar et al., 2006), and (3) treat explicitly the student's goals for reasoning purpose. The rest of the article is organised as follows. First, we present the AURELLIO knowledge representation theoretical approach. Second, we describe an AURELLIO-based authoring tool whose purpose is to facilitate modelling the domain knowledge via a user-centered graphical interface which is ergonomic and easy to use by non-experts in informatics. The objective (through this section) is to point out in detail the various knowledge representation structures proposed by AURELLIO. Third, we report on two practical studies that try to validate AURELLIO-based models of knowledge representation in the scope of the expressivity and efficiency contexts. In the first study, the objective was to conceive an AURELLIO model that represents the domain knowledge of a technical and rigorous discipline—the usage of reduction rules of algebraic Boolean expressions. In the second study, the focus was on the cognitive aspects of the AURELLIO knowledge representation and reasoning in comparison with ACT-R (Anderson, 1993), a famous and widely acknowledged cognitive architecture. Here, the interest was on modelling interrupted activities and the interruptions' consequence on the task achievement. Fourth, we underline some originalities of AURELLIO and we discuss relations between our approach and the ACT-R knowledge representation theory. In the last section, by way of conclusion, we mention our current work.

THE AURELLIO KNOWLEDGE REPRESENTATION APPROACH

If we are interested in education and teaching, and have the ambition to endow an artificial system

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