Available online at www.sciencedirect.com
SCIENCE DIRECT®
Information Sciences 170 (2005) 273–307
INFORMATION SCIENCES
AN INTERNATIONAL JOURNAL
www.elsevier.com/locate/ins

Neuro-fuzzy knowledge processing in intelligent learning environments for improved student diagnosis

Regina Stathacopoulou [a,*], George D. Magoulas [b], Maria Grigoriadou [a], Maria Samarakou [c,1]

[a] *Department of Informatics and Telecommunications, University of Athens, Panepistimiopolis, GR-15784 Athens, Greece*
[b] *School of Computer Science and Information Systems, Birkbeck College, University of London, Malet Street, London, WC1E 7HX, UK*
[c] *Department of Energy Technology, Technological Education Institute of Athens, Ag. Spyridonos Str. GR 12210, Egaleo, Athens, Greece*

Received 25 January 2003; received in revised form 23 February 2004; accepted 26 February 2004

Abstract

In this paper, a neural network implementation for a fuzzy logic-based model of the diagnostic process is proposed as a means to achieve accurate student diagnosis and updates of the student model in Intelligent Learning Environments. The neuro-fuzzy synergy allows the diagnostic model to some extent "imitate" teachers in diagnosing students' characteristics, and equips the intelligent learning environment with reasoning capabilities that can be further used to drive pedagogical decisions depending on the student learning style. The neuro-fuzzy implementation helps to encode both structured and non-structured teachers' knowledge: when teachers' reasoning is available and well defined, it can be encoded in the form of fuzzy rules; when teachers' reasoning is not well defined but is available through practical examples illustrating their experience, then the networks can be trained to represent this experience. The proposed approach has been tested in diagnosing aspects of student's learning style in a discovery-learning environment that aims to help students to construct the concepts of vectors in physics and

* Corresponding author. Tel.: +30-210-7275230; fax: +30-210-7275214.
E-mail addresses: sreg@di.uoa.gr (R. Stathacopoulou), gmagoulas@dcs.bbk.ac.uk (G.D. Magoulas), gregor@di.uoa.gr (M. Grigoriadou), marsam@teiath.gr (M. Samarakou).
[1] Tel.: +30-210-5385322; fax: +30-210-5385306.

doi:10.1016/j.ins.2004.02.026

mathematics. The diagnosis outcomes of the model have been compared against the recommendations of a group of five experienced teachers, and the results produced by two alternative soft computing methods. The results of our pilot study show that the neuro-fuzzy model successfully manages the inherent uncertainty of the diagnostic process; especially for marginal cases, i.e. where it is very difficult, even for human tutors, to diagnose and accurately evaluate students by directly synthesizing subjective and, some times, conflicting judgments.

Keywords: Student diagnosis; Uncertainty management; Fuzzy logic; Neural networks; Student modelling; Intelligent learning environments; Intelligent tutoring systems; Discovery learning environments; Learning styles

1. Introduction

User and student modeling is a fundamental mechanism to achieve individualized interaction between computer systems and humans [42]. It is usually concerned with modelling several user related issues, such as goals, plans, preferences, attitudes, knowledge or beliefs. The most difficult task in this context is the process of interpreting the information gathered during interaction in order to generate hypotheses about users and students behaviour [42], and involves managing a good deal of uncertainty. Interactive computer systems deal in general with more meagre and haphazardly collected users' data than it usually happens when humans are engaged in face-to-face interaction [27]. Thus, the gap between the nature of the available evidence and the conclusions that are to be drawn is often much greater [27]. Numerical techniques have been employed in several cases in order to manage uncertainty, [3,13,23–25,27,28,32,43,59], and neural networks have been used in order to add learning and generalization abilities in user models and draw conclusions from existing user profiles [10,22,34,38,39,46,53,61].

According to Self, [50], student modelling is the process of creating and maintaining student models. It is divided into the design of two different but tightly interwoven components [55]: (i) the *student model* which, in its simplest form, is a data structure that stores information about the student; (ii) the *diagnostic module* which performs the diagnostic process that updates the student model. Student models are distinguishing features of Artificial Intelligence, (AI), based computer-based instructional systems.

This work focuses on an application of student modelling in Intelligent Learning Environments (ILE). ILEs are considered as generalization of traditional Intelligent Tutoring Systems (ITSs), which are based on objectivist epistemology, and embrace instructional environments that make use of theories on constructivism and situated cognition [1]. Naturally, a good back-