Available online at www.sciencedirect.com
ScienceDirect
Computers in Human Behavior 24 (2008) 1342–1363
Computers in Human Behavior
www.elsevier.com/locate/comphumbeh

"How do you know that I don't understand?" A look at the future of intelligent tutoring systems

Abdolhossein Sarrafzadeh [a,*], Samuel Alexander [a], Farhad Dadgostar [a], Chao Fan [a], Abbas Bigdeli [b]

[a] *Institute of Information and Mathematical Sciences, Massey University, Auckland, New Zealand*
[b] *Safeguarding Australia Program, National ICT Australia (NICTA) Ltd, QLD Lab, Brisbane, Australia*

Available online 14 September 2007

Abstract

Many software systems would significantly improve performance if they could adapt to the emotional state of the user, for example if Intelligent Tutoring Systems (ITSs), ATM's, ticketing machines could recognise when users were confused, frustrated or angry they could guide the user back to remedial help systems so improving the service. Many researchers now feel strongly that ITSs would be significantly enhanced if computers could adapt to the emotions of students. This idea has spawned the developing field of affective tutoring systems (ATSs): ATSs are ITSs that are able to adapt to the affective state of students. The term "affective tutoring system" can be traced back as far as Rosalind Picard's book *Affective Computing* in 1997.

This paper presents research leading to the development of Easy with Eve, an ATS for primary school mathematics. The system utilises a network of computer systems, mainly embedded devices to detect student emotion and other significant bio-signals. It will then adapt to students and displays emotion via a lifelike agent called Eve. Eve's tutoring adaptations are guided by a case-based method for adapting to student states; this method uses data that was generated by an observational study of human tutors. This paper presents the observational study, the case-based method, the ATS itself and its implementation on a distributed computer systems for real-time performance, and finally the implications of the findings for Human Computer Interaction in general

* Corresponding author. Tel.: +64 9 4140800x9549; fax: +64 9 441 8181.
E-mail addresses: H.A.Sarrafzadeh@massey.ac.nz (A. Sarrafzadeh), S.T.Alexander@massey.ac.nz (S. Alexander), F.Dadgostar@massey.ac.nz (F. Dadgostar), C.Fan@massey.ac.nz (C. Fan), Abbas.Bigdeli@nicta.com.au (A. Bigdeli).

0747-5632/$ - see front matter
doi:10.1016/j.chb.2007.07.008

and e-learning in particular. Web-based applications of the technology developed in this research are discussed throughout the paper.

Keywords: Affective tutoring systems; Lifelike agents; Emotion detection; Facial expressions; Human-computer interaction; Affective computing

1. Introduction

Intelligent tutoring systems (ITS) provide individualised instruction, by being able to adapt to the knowledge, learning abilities and needs of each individual student. Existing ITS build a model of the student's current state of knowledge and individualise instruction based on that model (Sarrafzadeh, 2002). Intelligent tutoring systems offer many advantages over the traditional classroom scenario: they are always available, non-judgmental, and provide tailored feedback (Anderson, Corbett, Koedinger, & Pelletier, 1995; Johnson et al., 2003; Self, 1990). They have been proven effective, resulting in increased learning (Aleven & Koedinger, 2000; Aleven, Koedinger, & Cross, 1999; Anderson et al., 1995; Conati & VanLehn, 2001). However, they are still not as effective as one-on-one human tutoring. We believe that an important factor in the success of human one-to-one tutoring is the tutor's ability to identify and respond to affective cues.

Human communication is a combination of both verbal and nonverbal interactions. Human teachers may not know the knowledge state of all the students, however, by looking at the facial expressions, body gesture and other nonverbal cues, a human teacher may change his/her teaching strategy or take some other appropriate measures. Puzzled or bored faces might mean that there is no sense in continuing with the current teaching strategy. When it comes to one to one tutoring these cues may be even more useful.

As teacher shortages loom in both rural and urban schools, especially in mathematics and science, any contribution to alleviate this problem becomes important (The Urban Teacher Collaborative, 2000). We are proposing a new generation of intelligent tutoring systems that model not only the knowledge state of the student but also his/her cognitive and emotional state. Estimating the emotional state of a learner may involve analysing facial expressions, voice tone, heartbeat and other bio-signals.

This paper discusses how intelligent tutoring systems can be enhanced to include learners' affective state in its student model. It gives an overview of a new type of ITS proposed by the authors, *Affective Tutoring Systems (ATS)*, which detect nonverbal behaviour and use this information to individualise interactions with the student. For the ATS systems to be effective the nonverbal behaviour are to be detected in real-time. In order to achieve real-time performance, a network of computer systems mostly embedded is required to pre-process various bio-signals in a distributed fashion. This paper presents an implementation platform compromising low-cost embedded systems utilised to improve the overall system speed and performance. This paper includes a discussion of two primary research foci. First, we introduce a facial expression and gesture analysis system that forms the basis of affective state detection. We then present an affective mathematics tutoring system Easy with Eve which detects affective state detection and a case based reasoning system to react to the emotions of the learner through a lifelike agent called Eve.