



# An adaptation algorithm for an intelligent natural language tutoring system



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## ABSTRACT

The focus of computerised learning has shifted from content delivery towards personalised online learning with Intelligent Tutoring Systems (ITS). Oscar Conversational ITS (CITS) is a sophisticated ITS that uses a natural language interface to enable learners to construct their own knowledge through discussion. Oscar CITS aims to mimic a human tutor by dynamically detecting and adapting to an individual's learning styles whilst directing the conversational tutorial. Oscar CITS is currently live and being successfully used to support learning by university students. The major contribution of this paper is the development of the novel Oscar CITS adaptation algorithm and its application to the Felder–Silverman learning styles model. The generic Oscar CITS adaptation algorithm uniquely combines the strength of an individual's learning style preference with the available adaptive tutoring material for each tutorial question to decide the best fitting adaptation. A case study is described, where Oscar CITS is implemented to deliver an adaptive SQL tutorial. Two experiments are reported which empirically test the Oscar CITS adaptation algorithm with students in a real teaching/learning environment. The results show that learners experiencing a conversational tutorial personalised to their learning styles performed significantly better during the tutorial than those with an unmatched tutorial.

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## 1. Introduction

ITS build on the conventional computerised learning systems' 'one-size-fits-all' approach by capturing and modelling individual characteristics used to personalise the instruction (Stankov, Rosić, Žitko, & Grubišić, 2008). This involves presenting learning material in a style and order to suit the learner (e.g. by presenting learning material matched to poorly understood topics), and also proactively helping learners, e.g. by giving intelligent feedback on incomplete or erroneous solutions and guidance to assist learners in constructing solutions to problems. Most ITS are student-led with menus or hyperlinks to topics, sometimes designed specifically to capture individual traits (Cha, Kim, Park, Yoon, Jung, & Lee, 2006). The increasing complexity of computer systems and their interfaces has stimulated a move towards creating intuitive, human-centred interfaces, such as natural language dialogue via conversational agents (CAs) (O'Shea, Bandar, & Crockett, 2011). Learning is inherently a social process (Jones & Issroff, 2005; Wang & Wu, 2008) and during face-to-face tutorials human tutors automatically pick up behavioural cues from students about their understanding and learning preferences, and adapt their teaching style to aid learning. A few ITS attempt to mimic a human tutor by including CA interfaces that promote the construction of knowledge through discussion (Dzikovska et al., 2010; Graesser, Chipman, Haynes, & Olney, 2005; Rahati & Kabanza, 2010). Such ITS (known as Conversational ITS (CITS)) have now been extended to detect and react to learners' emotions (Lehman, D'Mello, & Graesser, 2012) and learning styles (Latham, Crockett, McLean, & Edmonds, 2012a). Learning styles model the way that groups of people prefer to receive and process information, e.g. by viewing diagrams rather than textual descriptions (Felder & Silverman, 1988; Honey & Mumford, 1992). Research in computer-based education systems has shown that adapting the style of tutoring to match student learning styles can enhance learning (Akbulut & Cardak, 2012; Tsianos, Lekkas, Germanakos, Mourlas, & Samaras, 2008).

Oscar CITS is an innovative Conversational Intelligent Tutoring System that can imitate a human tutor by directing a tutoring conversation and dynamically detecting and adapting to student learning styles during the conversation (Crockett, Latham, McLean, Bandar, &

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O'Shea, 2011; Latham et al., 2012a; Latham, Crockett, McLean, & Edmonds, 2012b). Oscar's tutor-led, conversational approach enables learners to actively discuss problems and collaboratively arrive at solutions, supporting the constructivist style of learning adopted by human tutors. Oscar CITS aims to improve each person's learning experience by using artificial intelligence techniques to adapt its tutoring style to match their existing knowledge and preferred learning style. During the tutorial conversation, Oscar CITS uses prompts and hints to encourage learners to solve problems by themselves and gives instant individual feedback on errors and omissions. Oscar CITS is a live system being successfully used to support learning by students in the School of Computing, Mathematics and Digital Technology at Manchester Metropolitan University.

Oscar CITS is a large and complex system that was designed with a modular architecture to separate the domain and learning styles knowledge from the functionality (see Fig. 1). Oscar CITS' general, modular design facilitates its independence from the tutorial subject domain and learning styles model. A full description of the Oscar CITS architecture and components is given in (Latham et al., 2012b) and summarised here. A central controller module manages the learner interaction and the communication between components. The GUI manages the webpage interaction with the user, displaying responses, images and movies and reacting to user events. The student model manages all information about individual learners, including knowledge, topics visited, test scores and learning styles. The CA accepts a natural language utterance and uses student, learning styles and tutorial knowledge to generate a natural language response. The CA uses a database of scripts containing pattern-based rules that match a stimulus input to a response. Designing the rules is a demanding task: the case study that will be described in Section 4 required 95 scripts containing about 1000 rules, each containing multiple patterns. The tutorial knowledge base manages all course information, such as topic breakdowns, teaching materials and tests and is related but not linked to the CA scripts. The Oscar CITS can be implemented for new subjects by plugging in a different tutorial knowledge base and CA scripts. The learning styles predictor agent uses knowledge of a learning styles model to predict an individual's preferred learning styles from their dialogue and behaviour. The learning styles adapter agent uses knowledge of learning styles, tutorial knowledge and learner preferences to decide the best adaptation to apply for each question. Different learning styles models can be applied to Oscar CITS by replacing the learning styles predictor and adapter agents.

The complex task of the design, development and experimental analysis of Oscar CITS was managed by separating the functionality of learning styles prediction and adaptation. The Oscar CITS predictive subsystem (incorporating the Learning Styles Predictor Agent) was able to implicitly predict an individual's preferred learning styles by capturing aspects of their behaviour and dialogue during the conversation (Crockett et al., 2011; Latham et al., 2012a). The formal methodology for developing the Oscar CITS predictive subsystem to deliver a real time conversational tutorial for SQL is detailed in (Latham et al., 2012a). Several experiments involving real undergraduate and postgraduate students were conducted in a real educational setting to investigate the Oscar CITS predictive subsystem's ability to automatically model learning styles (Latham et al., 2012a). The results show that the Oscar CITS predictive subsystem successfully predicted all eight learning styles in the Felder–Silverman (FS) learning styles model (Felder & Silverman, 1988) with accuracies of 61–100%.

This paper expands on the development methodology for the Oscar CITS adaptive subsystem reported in (Latham et al., 2012b) to describe the design and implementation of the novel Oscar CITS adaptation algorithm. The main contributions of this paper are:

- The design of Oscar CITS innovative approach to adaptation, which selects the best fitting adaptation for each tutorial question, resulting in tutorials containing a variety of teaching styles to promote student engagement. Oscar's generic approach can be applied to individual social factors such as learning style or emotion to provide a personalised conversational tutorial.
- The development of the generic Oscar CITS adaptation algorithm, which uniquely takes into account the availability of adaptive tutoring material for each tutoring question as well as the learner's preferences. The Oscar CITS adaptation algorithm allows several different individual factors to be combined to determine the best fitting adaptation (e.g. several different aspects of learning style).
- The application of the general Oscar CITS adaptation algorithm to the Felder–Silverman learning styles model.
- A case study describing the implementation of Oscar CITS for an SQL tutoring knowledge base, delivering a conversational tutorial which adapts to individual users' learning styles (using the FS model).
- The description of two experiments to empirically test the success of the Oscar CITS adaptation algorithm in a real life teaching/learning environment.

This paper is organised as follows: Section 2 describes the three research areas brought together by this research, namely intelligent tutoring systems, conversational agents and learning styles and reviews relevant related work. Section 3 describes Oscar CITS and the current state of its implementation, a discussion of the Oscar CITS adaptation approach and its generic adaptation algorithm. Section 4

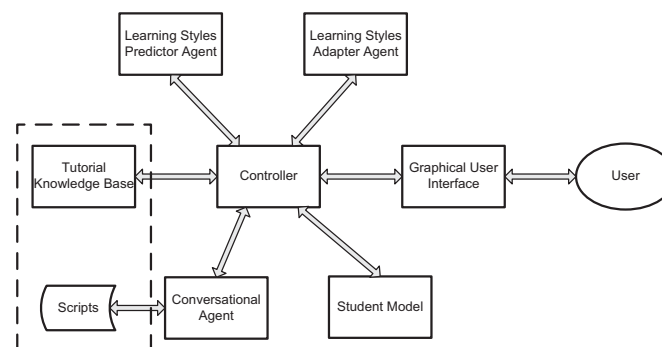


Fig. 1. Generic Oscar CITS architecture.

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