

Design and Development of Topic-based Students' Knowledge Modelling System using Fuzzy Set Theory and Visual Analytics

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Abstract

To the field of education, advances in technologies raise opportunities and challenges in delivering personalised learning to heterogeneous group of learners while monitoring and analysing their learning progress and learning outcomes. This paper addresses the challenges of gaining a big picture about learners' knowledge that is essential for providing personalised learning. Next, a system that models students' knowledge is proposed in which topic-based approach, fuzzy set theory, and visual analytics were applied to design and develop the proposed system. The proposed system was designed with the capabilities to model, analyse and report individual learner's knowledge, whereas its applicability was presented and discussed based on a real-world case study.

Keywords: Fuzzy set theory; Knowledge modelling system; Topic-based student modelling system; Visual analytics.

1. Introduction

Throughout the past decades, the technologies of supporting learning and instructions are changing and evolving. Among the emerging technologies, recent research shows that personalised learning has great potential in transforming learning and instruction [1]. In this paper, personalised learning is referred to any approach that can be used to guide individual learners to the most appropriate educational contents in accounts of any relevant learning characteristics of the learners [2]. The learning characteristics of the learners may vary in terms of their knowledge level, abilities and disabilities, learning needs, learning goals, preferences, and so forth [3], [4].

Compared to the traditional one-method-fits-all approach, personalised learning takes the diverse needs of learners into consideration in order to guide the learners to the most appropriate educational contents [5], resulting in better learning performance for group of heterogeneous learners [6], [7]. In other words, knowing whom to adapt [8] and which decisions have to be made to guide the learners to the most appropriate educational contents [2] are the important aspects in providing personalised learning.

This study employs the student modelling techniques to gain the big picture of learners' knowledge. Such techniques were introduced in the field of Intelligent Tutoring Systems (ITS) for collecting, analysing and maintaining the learning characteristics of learners to form student models [9]. Although student modelling techniques were proposed in the field of ITS, such techniques were applied in different educational applications that adopt personalised learning [10]–[12]. Hence, in this paper, a topic-based, structural student modelling system that is capable of collecting, reasoning, and keeping track of learners' knowledge is proposed.

The fuzzy sets theory [13] was also utilised for reasoning the knowledge of the learners. Often, to assess the knowledge of the learners, a set of assessments is generated by instructors and to be solved by the learners [11]. However, the learners' knowledge may not be reflected accurately based on the assessments results

as the reasoning of the knowledge can be influenced by other factors, such as the difficulty level of an assessment, time spent to solve the assessment and so forth. [11]. Indeed, these factors as well as learners' knowledge are ambiguous and vague in nature. The process of determining the knowledge level tends to be uncertain [11]. Therefore, this study employed the fuzzy set theory, which is capable of handling such vagueness and uncertainties mathematically, for reasoning learners' knowledge by taking into consideration the various imprecise factors.

A visual analytics component was also incorporated into the proposed system to provide detailed insight into learners' knowledge. With the aid of this visual analytics component, the burden of analysing whom to adapt and what learners have learned can also be reduced. As the result, the feasibility of adopting personalised learning among the heterogeneous group of learners is enhanced [14].

The subsequent sections of this paper are organized as follows: Section 2 presents the background and relevant works; Section 3 and 4 elaborate on the design and development of the students' knowledge modelling system, which employed the topic-based approach, fuzzy set theory and visual analytics; Section 5 discusses the implementation of the proposed system; and Section 6 provides the conclusion and recommendations of future work.

2. Background and Related Works

This section focuses on the background and related past studies on student modelling system, fuzzy set theory and visual analytics.

2.1. Student Modelling System

Student modelling system was originally proposed in the field of Intelligent Tutoring Systems (ITS) [9]. It is referred as a system that is capable to collect and infer the particular learning characteristics of a learner and maintain these characteristics in the form of student models [9], [15]. A student model can represent the