Intelligent Tutoring Systems and Planning Techniques: A Systematic Review

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ABSTRACT

Planning is a problem-solving method that generates an action sequence (i.e. plan) to achieve a goal. Instructional Planning is a central issue to develop adaptive educational software and Intelligent Tutoring Systems (ITS). The objective of this paper is to conduct a systematic review about planning techniques used in ITS in the last twenty years. In this review, 969 papers in 6 digital reference libraries extensively used by computer science researchers were identified. After of a selection process using the inclusion and exclusion criteria, 20 relevant papers were choose. The results present the existence of a relevant research gap. Among the retrieved papers, no document which use Goal Reasoning-based planning techniques were found, and more specifically, no system that use process of autonomy based on goals.

Keywords: Intelligent Tutoring Systems, Planning techniques, Instructional Planning

I. INTRODUCTION

In the Education field, the Artificial Intelligence (AI) techniques have been extensively used to get better teaching efficiency and effectiveness, facilitating the creation of smart learning environments and produce tools for teachers that enable knowledge generation in the teaching-learning process [1]. The AI in education enables knowledge generation, dissemination, update, and management [2]. Thus, IA has given way to the improvement and creation of new learning environments. This has allowed switches the traditional teacher-student interaction and learning evaluation methods [3].

AI tries to simulate behaviors of natural intelligence [4]. In the education field, this simulation often is the teacher behavior [5]. ITS is a type of Intelligent System, that integrates AI techniques to know what, who and how to teach individually to each learner [6],[7]. The new mechanisms of IA applied to ITS have allowed his evolution y constant application in many fields [8][9][10]. An ITS is constituted by three main modules: tutor module, student module, expert module, and an interface [11]. The tutor module is also known as "Instructional Planner" [12], [13]. The intelligence of this type of systems consists in the ability to adapt itself to the performance of each learner across its own learning process [14]. Also, is necessary to know the needs and behavior of the student to infer which pedagogical strategy should be applied at a given moment [6]. According to Latham et.al [15], affirm that learner's learning styles should be detected and dynamically adapting the ITS functionality to this style.

Instructional Planning is a central focus to develop adaptive educational software and ITS [16]. This module determines the pedagogical strategies used to adapt and improve the student-based tutorial strategies executed by the system [17]. It must detect the student's performance level, select the next activity to be accomplished by the learner, correct mistakes, present examples, etc. [18].

Planning is a problem-solving method that generates an action sequence (i.e. plan) to achieve a goal [19]. Intelligent tutorial planning (ITP) adapts learning plan for a specific student according to domain knowledge structure, teaching methods, and student's cognitive level of the student [5]. This key module of an ITS allow to the system dynamically combining a set of courseware

and to create learner's individual learning trace [20].

Instructional planning is the process of select a global sequence of instructional goals and to execute actions of a plan that provides consistency, coherence, and continuity to learning lessons and activities throughout an instructional session [16] Planning techniques have been particularly oriented towards domain-independent solutions i.e. algorithms that can work across a variety of knowledge domains provided in ITS Expert Module [21]. This is especially useful in the contexts of ITS which have traditionally been restricted to specific solutions of a class or course [22].

The objective of this paper is to conduct a systematic review about planning techniques used in ITS in the last twenty years. The findings of this review process will allow structuring an overview on ITS Planners, which will constitute the initial phase for building of a Goal Reasoning-based ITS Planner.

This paper is structured as follows: in the second chapter, we explain the research methodology implemented. Then, in the third chapter, the results of the review process are described. Finally, the conclusions of this study are presented.

II. RESEARCH METHODOLOGY

In this paper, a systematic review about scientific literature in Planning Mechanisms used by ITS was carried out, using the following research question as inquiry central guide: What evidence indicates the development of ITS with planning techniques? and What specific knowledge areas have been developed ITS with planning techniques?. The following strings were used for the search: "Intelligent Tutoring Systems" AND ("Planning Techniques" OR "Instructional Planner" OR "Instructional Plan" OR "Planning Model"). The Science Direct, Scopus, IEEE Xplore, ACM and Engineering Village databases were used (See Table 1). The period used to this systematic review was from 2000 to 2020.

Table 1. Studies found in each Database.

Digital Library	Retrieved	Relevant Papers	Papers
Science Direct	385	3	[30], [27], [23],
Scopus	25	3	[34], [38], [28]
Springer Link	377	3	[16], [29], [5]
IEEE Xplore	10	4	[17], [25], [32], [33]
ACM	84	3	[18], [31], [35]
Engineering Village	88	4	[36], [24], [37], [26]
Total	**969**		**20**

Three inclusion criteria and five exclusion criteria in the selection process of relevant papers (19 papers) and they are presented below:

A. Inclusion Criteria

IC-1: Studies about ITS which use planning techniques

IC-2: Researches developed between 2000 and 2020.

IC-3: Primary studies.

B. Exclusion Criteria

EC-1: Papers not written in English.

EC-2: Papers without full-text access.

EC-3. Technical reports, papers that are only available as abstracts or literature reviews.

EC-4. Duplicate papers (the most current was selected).

EC-5. Redundant Papers with the same authors.

III. RESULTS

In the first place, dissemination media of each relavent paper were analyzed. It was found that 50% (10 papers) of the selected papers were published in conferences. 40% (8 papers) were published in journals and 10% (2 papers) were book chapters.

The temporal distribution of the relevant studies was between the years 2000 and 2020. Between the years 2000 and 2004, 7 studies were found. The period between 2005 and 2010, 5 studies were published. In 2011 and 2013 only one paper was found each year. Finally, from 2016 to 2020 were

retrieved 6 papers.

Table 2. Different planning techniques used in ITS.

Paper	Authors	Year	ITS Name	Knowledge area	Planning Techniques
[16]	**Elorriaga and Fernandez Castro**	2000		Hybrid Self-Improving Instructional Planner to ITSs	Case-Based Reasoning technique
[23]	**Reva, Penstein et. al.**	2000	Atlas-Andes	Analysis of a sentence	Semantic mapping rules Reactive planning
[24]	**Cho1, Michael, Rovick et. al.**	2000	CIRCSIM-Tutor	Cardiovascular physiology	Tutoring protocol
[25]	**Nkambou and Kabanza**	2001	Multi-agent ITS architecture	General purpose system	Model checking and Markov decision theoretic techniques
[26]	**Martens and Adelinde M.**	2002	System PLAIT	Health Sciences	HTN planner
[27]	**Quek, Wong And Lool**	2002	TRAINER	Dynamic Physical sistems	Rule-based approach
[28]	**Legaspi, Sison and Numao**	2004	Tutor Agent	Computer Science	Unsupervised machine learning techniques and heuristics for learning from experience.
[29]	**Grundspenkis**	2006			Multiagent and knowledge management techniques
[30]	**Woo, Evens, Freedman, et .al.**	2006	CIRCSIM—Tutor system	Physiology	Adaptive planning techniques and explicit planning rules derived from the analysis of expert human tutoring sessions to build their plans.
[31]	**Duan, Jiang and Cai**	2006			Intelligent tutorial planning algorithms (JUDGE, which judges whether or not the problem has a solution, and output the optimal solution graph if a solution exists. TPLAN, which computes optimal planning according to the optimal solution graph produced by JUDGE)
[32]	**Ramírez, De Antonio**	2007	MAEVIF-(Model for the Application of Intelligent Virtual Environments to Education	Chemistry	Automated planning Planning service of the JSHOP2
[33]	**Rahati and Kabanza**	2010	ITS for medical diagnosis	Medical Sciences and Computer Science	PKS planning algorithm
[18]	**Aguilar R, Muñoz V, González E, et.al.**	2011	-	Number concept and the objectives of sum and subtraction	Fuzzy logic and MultiAgent Systems since
[34]	**Viger, Nkambou, Mephu Nguifo, et.al.**	2013	Canadarm Tutor	Train astronauts how to manipulate the Canadarm2 robot in various situations	Efficient algorithm for robot path planning in constrained-based environments - FADPRM
[35]	**Marinov Valova**	2016	-		Generalized algorithms of Planning and Executive subsystems
[36]	**Garrido, Morales, Serina**	2016	myPTutor	Physics, Bilogy and Chemistry	Case-based planning adaptation process Planning Domain Definition Language (PDDL)
[17]	**Gómez and Caro**	2018	FunPro	Programming	
[37]	**Vannaprathip, Haddawy and Schultheis**	2018	A Planning-Based Approach to Generating Tutorial Dialog	Medical Sciences	Planning Domain PDDL
[38]	**Taub and Azevedo**	2018	MetaTutor	Human circulatory system	Pedagogical agents (subgoals)
[5]	**Gómez, Flórez and Márquez**	2020	Fichas y protocolos en Salud.	Health Care	

Table 2 describes the different planning techniques used in ITS in the last twenty years. The most used techniques are case-based reasoning, rules-based reasoning and others AI mechanisms. These studies do not Goal Reasoning-based planning techniques or processes of autonomy based on goals. Although they use specific languages for IA Planning (i.e PDDL) its Instructional Planning processes do not require autonomy modules.

IV. CONCLUSION

This paper described the findings of a systematic review to answer research questions related to the use of planning techniques in ITS. This study constitutes the first methodological step of a research in progress that aims to build a Goal Reasoning-based ITS Planner. In this review, 969 papers in 6 digital reference libraries extensively used by computer science researchers were identified. After of a selection process using the inclusion and exclusion criteria, 20 relevant papers

were choose.

The results present the existence of a relevant research gap. Among the retrieved papers, no document which use Goal Reasoning-based planning techniques were found, and more specifically, no system that use process of autonomy based on goals. In addition, some the papers retrieved in this review, althought they use specific languages for IA Planning its Instructional Planning processes do not require autonomy modules. Thus, the findings showed open the possibility of a new approach about the modeling and specification of a Goal Reasoning-based ITS.

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