Combining AI Techniques into a Legal Agent-based Intelligent Tutoring System

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Abstract

Computer based learning gets more and more important in higher education. Particularly, in Legal domain, students have little chance to deal with realistic situations. One way to alleviate this problem is to provide Law students with real cases, rules and different viewpoints of which a given body of knowledge is often recognized as important to their successful learning. We propose a novel approach to ITS applied to Legal domain in order to address each of the above concerns. Then, we define an agent-based architecture to support multiple views of domain knowledge, aiming to improve the quality of student-ITS interactions and the learning success of the students. Each tutoring agent from the system contains a knowledge-based system that combines case-based reasoning and rule-based system. In addition, each agent adopts the reinforcement learning Algorithm aiming to identifying the best pedagogical strategy by considering the student profile. This paper focuses on both architecture and the mentioned Artificial Intelligence techniques into a Legal System. Finally, an example scenario is shown to demonstrate the feasibility of our approach.

1 Introduction

Providing Law students with real cases, rules and different viewpoints of a given body of knowledge is often recognized as important to their successful learning. In fact, these requirements are hot topics and seem to be more realistic to be explored in the context of Legal Intelligent Tutoring System research. However, little research has been done on these aspects.

We propose a novel approach to ITS applied to Legal domain in order to address each of the above concerns. Then, we define an agent-based architecture to support multiple views of domain knowledge, aiming to improve the quality of student-ITS interactions and the learning success of the students. Here, learning is considered as problem-solving, where students solve problems and are individually assisted and guided by the system during the solution process. The system may also solve problems. CBR has been used for checking the similarity with old cases to justify new problems and RBS for evaluating the rules of Normative Knowledge. In addition, each agent adopts the reinforcement learning Algorithm aiming to identifying the best pedagogical strategy by considering the student profile.

The use of a hybrid solution to the problem solving has been motivated due the structure of the juridical system [1]. Legislation is the main Legal research, where magistrates making their decision based on the code and laws, originating case solutions. One of the best ways to solve Legal problems based on legislation is using rules, due this, rules is approached in the ITS. For this reason, Case Based Reasoning and Rule Based System make necessary to the ITS.

Some related works were developed taking into consideration legal tutoring or hybrid reasoning. In [1], is approached an intelligent learning environment designed to help beginning law students learn basic skills of making arguments with cases. In [11] was found an ITS for Legal domain, using rule-based system and approach problem-based learning as pedagogical strategy. Our proposal refers to a novel ITS approach applied to Legal domain, using hybrid reasoning (CBR and RBS), besides the modeling of multiple views of domain knowledge, providing two-way interaction in the problem solving. Others Legal approaches were found, however, were not focused as comparative works. These works have total relevance and some of them that can be cited are [10, 5].

In our approach, the idea is to engage Law students into interactions with ITS based on the resolution of Legal problems and their consequences on other tutorial activities, concerning the Civil Law. The starting point of these interactions occurs when ITS submits a penal situ-

[1] Civil Law, also known as Continental Law or Roman Law has been used in the system

ation to Law students. Then, they will learn two fundamental but different skills of Legal problems. First, know how to identify relevant cases and Legal concepts (normative knowledge, for instance) of the cases. Second, know how to use them effectively as examples justifying position in a Legal argument. When using an automated information retrieval system, one needs to use a query or a set of queries that captures the issues and the intended use of the cases in an argument[2]. Therefore, Case-based reasoning has been used to know what kind of cases can result better solutions and rule-based system to find better concepts, and consequently giving support for better explanations of the problem.

2 System Architecture and Implementation

Basic components in the architecture represents the classical ITS approach, however, details about specific agents in these components are explained in the next subsections.

The **Interface Agent** is responsible for communicating the student, providing access to Legal information such as jurisprudence and normative knowledge. The kinds of screens displayed are about student credentials, student information, problem, solution, solution evaluation and argumentation. In addition, a **Broker Agent** was inserted for mapping the information between the agents.

We adopt an ontology that represents the base of the Legal knowledge to be used within Intelligent Tutoring System.

2.1 Expert Module

The Expert Module was modeled as shown in Figure 1. In this subsection, details of the Domain Architecture are presented.

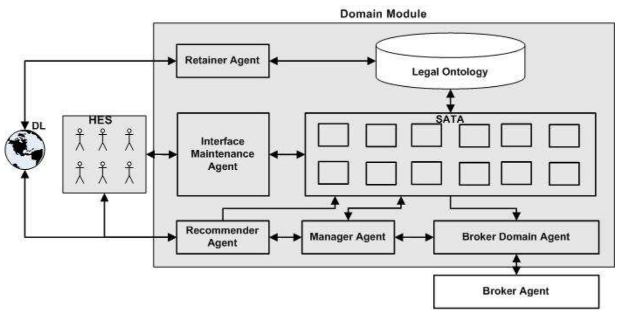

Figure 1: Expert Module Architecture

The ontology approached in our ITS was developed by using Protégé [12] tool, providing flexibility and a lot of plug-ins.

Figure 2 shows a relevant part of the legal ontology. In this figure, it is possible to see some concepts and their relationships. Ontology has been developed take into consideration MATHEMA Model, described into 2.1.1.

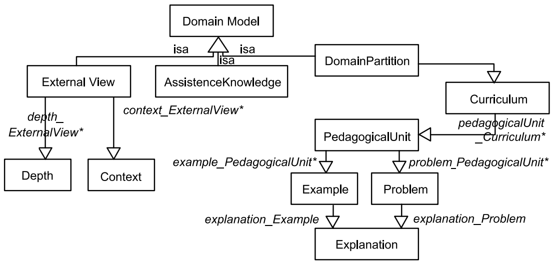

Figure 2: Ontology Description

Based on the Legal ontology developed to the ITS, a problem is defined as a 3-Tuple $\langle P, I, F \rangle$, where:

- P: represents the real penal situation;
- I: represents a set of interpretations (solutions) to the problem P. The related interpretations are based on:
  - Prosecutor view;
  - Lawyer view.
- F: P x I: represents the theoretical fundamentation in the relation P x I, that can be a Doctrine, Jurisprudence or web site.

2.1.1 Agents

- **SATA** is a society of artificial tutoring agents that represents an agent-based ITS acting in a specific domain. Each agent in SATA play pedagogical roles. These agents are responsible for problem solving and providing information of the student profile and pedagogical strategies. In the problem resolution, cooperation is one of the features of the SATA. Cooperation is approached by considering a multidimensional view, where the expert knowledge is distributed in each agent from SATA. The idea is the division of the domain knowledge into many sub domains, represented by agents. This division tries to orient a search in the expert knowledge distributed. In addition, each agent has a curriculum manager that chooses problems for the student, but it is optional.

  SATA Reasoning: This subsection approaches the reasoning presents in SATA structure. Rule-based system and case-based reasoning are two known approaches adopted in the Expert Module Agents in the Intelligent Tutoring Systems (ITS). They are natural alternatives in knowledge representation. Rules usually represent general knowledge, whereas cases encompass knowledge accumulated from specific (specialized) situations. Each approach has advantages and disadvantages. Due to their interchangeable nature, rules and cases can be integrated and thus produce effective ITS. Below characteristics of CBR and RBS reasoning are described.

CBR (Case-Based Reasoning) Reasoning

The CBR Reasoning is responsible for evaluating the similarity between the jurisprudence (inserted in the case base) and the penal situation sent by Law student.

The knowledge representation was done as a relational representation, with n attributes $A = \{a_1, a_2, ..., a_n\}$ where each attribute has a weight $W = \{w_1, w_2, ..., w_n\}$, for details of the knowledge representation and similarity functions, see [8]. The similarity function between two cases is defined as:

$$SIM(C_1, C_2) = \sum_{i=1}^{n} \left(w_i * sim(a_{i_{C_1}}, a_{i_{C_2}}) \right)$$

In both cases, the case retrieval was divided into two levels. First, it is used the similarity function for simple attributes (numeric and boolean, for instance) and more important index. Second, it is compared the complex attributes such as strings. This division turns the case retrieval faster than the sequential retrieval method. Adaptation and retention are not necessary because the jurisprudence can not be changed.

RBS (Rule-Based System) Reasoning

RBS (Rule-based System) Reasoning is responsible for the rules evaluation in the Legal ontology. The rules were modeled by considering the normative knowledge, which enables the whole validation of a penal situation. When the Law Student describes a problem, the system tries to infer about the features and map them in doctrine concepts defined in the ontology. In addition, were modeled 49 rules to infer of the domain. Follow an examples of rules developed in the Jess [6] environment and integrated within protégé[12].

```
(bind ?article new Article) (defrule concept
    ("corporalLesion")
    ?article getInstance() )
```

The interactions between the Law students and the ITS in the problem solving can happen in two ways: a) when the student submits a penal situation to tutoring system and b) when the tutoring system submits a penal situation to the student.

In both cases, can be use a hybrid mechanism of reasoning, CBR (Case-Based Reasoning) and RBS (Rule-Based System) working together with the legal ontology to solve problems submitted by the student or by the tutoring system. The interactions between the techniques can be structured as follows:

– CBR reasoning and RBS reasoning return the solution, exploiting the jurisprudence and normative knowledge researches;
– CBR reasoning returns the solution. This situation happens when the RBS reasoning is unable to infer from the given problem;
– RBS reasoning returns the solution. This situation happens when the CBR reasoning is unable to infer from the given problem;
– none of them. If this situation occurs, the system will send a message to the student, requesting better description from the given problem.

When the *student submits the tutoring system to a penal situation*, ITS tries to solve the penal situation integrating CBR and RBR. This interaction algorithm was implemented as follows

Algorithm 1 The EvaluationStudentProblem Algorithm

Initialize $Evaluate(studentProblem)$;
Initialize $RBSInfer()$;
$rbsSolution \leftarrow$ try infer from NormativeKnowledge;
Initialize $CBRCycle()$;
$casesBase \leftarrow$ select jurisprudence from Ontology;
Execute Retrieve from CBRCycle;
Select similarCase;
Select similarityValue;
$MountSolution(rbsSolution, similarCase)$;

Second, when the *tutoring system submits a penal situation to the student*, the student describes the solution as far as her/his concerning. After that, ITS evaluates the student solution according to the algorithm below.

Algorithm 2 The StudentSolutionEvaluation Algorithm

Initialize $Evaluate(studentSolution)$;
Initialize $CBRCycle()$;
$casesBase \leftarrow$ select casesSolution from Ontology;
Execute Retrieve from CBRCycle;
Select similarCase;
Select similarityValue;

- **HES (Human Expert Society)**: represents an external knowledge source integrated in SATA, which provides a kind of maintenance necessaries in the SATA, such as inclusion and exclusion of agents, besides give support to Law students. The support to the Law student is possible through the recommender agent.

- **Interface Maintenance Agent**: represents the communication between HES and SATA.
- **Manager Agent**: Responsible for all the flow interaction ITS-student. The tutoring process can happen as: a) guided, where the ITS gives assistance to the student about the curriculum or b) free, where the student choose the curriculum he/she intends to study or search about Legal Concepts as jurisprudence, Doctrine and Legislation. The characteristics of this agent are:
  - choose which SATA Agent will tutoring the student or give assistance;
  - manage kinds of pedagogical strategy are given to the student, like hints, warnings and others;
  - choose which SATA Agent(s) will solve a problem sent by the student.
- **Broker Domain Agent**: responsible for delegating actions to the Recommender Agent, Explainer Agent and SATA, besides send information to the Broker agent.
- **Recommender Agent**: responsible for providing supports to the Law student, providing additional researches aiming the improvement of learning process. The following are the kind of supports provided for the Recommender Agent:
  - HES (Human Expert Society) can be recommended to give support to the Law student;
  - information in a Digital Library can be sent to support the learning process;
  - an agent in SATA to supervise the student is recommended to provide better resolution about the problems and to help him/her with doubts concerning the domain knowledge.
- **Retainer Agent**: one of the biggest problems found in Case-Based Reasoning systems for the Legal domain refers to the jurisprudence that updates everyday. To solve this problem, a Retainer Agent in the intelligent tutoring system for evaluating of new jurisprudence in virtual libraries was added.

2.2 Pedagogical Module

Some researches have been doing into intelligent tutoring system, exploring Reinforcement Learning in pedagogical activities [3, 13, 9]. The Pedagogical Module was modeled as shown in Figure 3.

In order to improve the quality of the solutions and student learning, a Reinforcement Learning Algorithm was used concerning the strategies above.

- Increase the Problem Difficulty Degree;

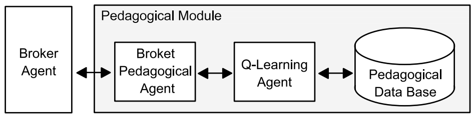

Figure 3: Pedagogical Module Architecture

- Decrease the Problem Difficulty Degree;
- Same Difficulty Degree;
- Change the Level;
- Change the issue;
- Change the Problem Issue to past issue.

Q-Learning algorithm is used after the definition of the student profile (features of the student profile was not focused), due this, in student-ITS interaction, the algorithm, through rewards, define and select the best strategy to use in a specific situation. The selection of strategy takes into consideration groups of profiles as shown in Figure 4.

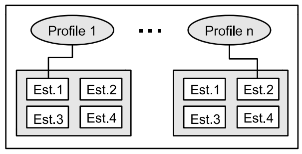

Figure 4: Q−Learning Strategy

2.2.1 Q-Learning Structure

The goal of the agent in a Reinforcement Learning Problem is to learn an action policy that maximizes the expected long term sum of values of the reinforcement signal, from any starting state [4]. In the present work, the problem is defined as a Markov Decision Process (MDP) solution.

The chosen of better strategies has been modeled as a 4-tuple (S, A, T, R), where:

- S: set of pair of strategy and MATHEMA Context;
- A: finite set of strategies;
- $T : S \times A \rightarrow \Pi(s)$: state transition function represented for the probability value, signalizing the betters strategy to be chosen;
- $R : S \times A$: is described as a utility value, defined for the similarity of the attributes, mapped as a reward function.

We use in the e-learning environment a proposal approached in [4], that implements an algorithm which is used in the action choice rule, which defines which action must be performed when the agent is in state s_t. The heuristic function included

$$\pi(s_t) = \begin{cases} argmax_{at} & \left[\hat{Q}(s_t, a_t) + \xi H_t(s_t, a_t)\right] & ifq \leq p, \\ a_{random} & & otherwise. \end{cases}$$

- $H : S \times A \rightarrow R$ is the heuristic function;
- ϵ: is a real variable used to weight the influence of the heuristic function;
- q: is a random uniform probability density mapped in [0, 1] and $p(0 \leq p \leq 1)$ is the parameter which defines the exploration divided for exploitation balance;
- a_{random} is a random action selected among the possible actions in state s_t;

Then, the value heuristic $H_t(s_t, a_t)$ that can be defined as:

$$H(s_t, a_t) = \begin{cases} max_a & \hat{Q}(s_t, a) - \hat{Q}(s_t, a_t) + \eta & ifa_t = \pi^H(s_t), \\ 0 & & otherwise. \end{cases}$$

Algorithm 3 The Heuristics Algorithm

Initialize $Q(s, a)$
Repeat:
 Visit the s state
 Select a strategy using the choice rule
 Receive the reinforcement $r(s, a)$ and observe the next state $s^{'}$.
 Update the values of $H_t(s, a)$.
 Update the values of $Q_t(s, a)$ according to:
 $\hat{Q}(s, a) = \hat{Q}(s, a) + \alpha \left[r + \gamma max \hat{Q}(s^{'}, a^{'}) - \hat{Q}(s, a)\right]$
 Update the $s \leftarrow s^{'}$ state
Until some stop criteria is reached,
where $s = s_t, s^{'} = s_{t+1}, a = a_t e a^{'} = a_{t+1}$

3 An Illustrative Example

To illustrate the functionality of the system we show a learner working with problem-solving of a penal situation approaching multiple views of the knowledge.

Imagine that the student works the first time in the ITS. The student answers a set of question about Legal issue and then, the level knowledge of the student is defined. Below, we exploit an example where the student submits a problem to the system.

3.1 Case

Problem: *John arrives in his home and see Maria and Joseph (John´s brother), sleeping in the bed, naked. Then John overdrew his gun and shot against Maria, which died.*

Solution: The solution is divided into two views: The Prosecutor view, where tries to increase the punishment and the Lawyer view that tries to decrease the punishment.

Prosecutor View:

- Normative Knowledge - Qualified Homicide: Art. 121, §2º, IV;
  Doctrine - Qualified Homicide can be used when happens a crime through research that makes difficult or impossible the defense or the offended person, by the fact of the victim been sleeping.
- Jurisprudence - Summary: JURI. Qualified Homicide. Research that turn defense of the offended person impossible. Victim Sleeping. [...]

Lawyer View 1:

- Normative Knowledge - Self-Defense: Art. 23;
  Doctrine - Self-Defense can be used when the author has his honor stained for the victim;
- Jurisprudence - Summary: Homicide - Self-Defense of the honor - Accused that, [...].
- Site: `http://jus2.uol.com.br/doutrina/texto.asp?id=980`;

Lawyer View 2:

- Normative Knowledge - Privileged Homicide: Art. 121, §1º;
  Doctrine - Privileged Homicide can be used when the author act through strong emotion;
- Jurisprudence - Summary: JURI. Qualified Homicide. Cohabitation. Condemnation for Privileged Homicide.

In the case, three solutions were returned to the ITS. Three SATA Agents were used to solve the case, where each solution represented one agent. The table 1 with the agents characteristics follows below.

Table 1: Agents characteristics

Agent	Context
SATA Agent 121_2	Crime versus live
SATA Agent 121_1	Crime versus live
SATA Agent 23	About the Crime

Other characteristic present in the example is that all SATA Agents knew solve the case using the hybrid reasoning. On the other hand, only the SATA Agent 23 found a site to guide the student with others knowledge of the solution.

The Figure 5 shows the solution retrieve of the system.

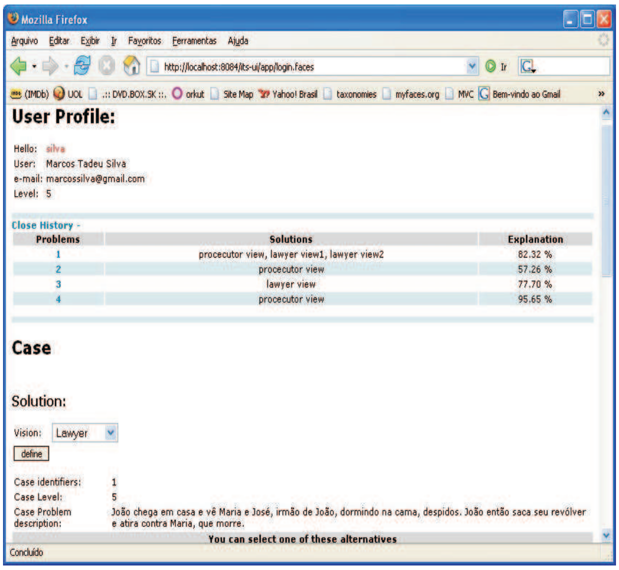

Figure 5: Prototype Resolution

4 Final Remarks and Future Work

This paper describes a hybrid ITS which provides human learning by problem posing to Law students and giving those appropriate tutorial feedbacks. The prototype has been used with three types of knowledge domain (Jurisprudence, Normative knowledge and doctrines). At the moment, we described the Case-Based Reasoning model and Rule-Based System that integrates Jurisprudence, Normative knowledge and doctrines and the application of the corresponding Legal concepts in the problem solving process. Technologies such as JADE[14], JESS [6], Protégé[12] were used on the development of the prototype. Each one of these tools can be considered as the state of art in its application domain.

Now, It has been developed the version 2.0 of the ITS. We have planned to this new version: a) create the strategy structure to the pedagogical model in others parts of the tutor; b) create the student modeling structure to the student model, providing a holistic view of each individual student is stored, allowing the tutor to be highly personalized [7]. Finally, we are planning to evaluate the current system with undergraduate students to improve the system's robustness.

5 Additional Authors

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References

[1] Vincent Aleven. Using background knowledge in case-based legal reasoning: a computational model and an intelligent learning environment. *Artif. Intell.*, 150(1-2):183–237, 2003.

[2] Vincent Aleven and Kevin D. Ashley. What law students need to know to win. In R. P. Jones and K. V. Russell, editors, *Proceedings of the Fourth International Conference on Artificial Intelligence and Law*, pages 115–129, Abingdon, UK: Carfax Publishing Co, 1993. University of Melbourne.

[3] Amy L. Baylor and Yanghee Kim. Simulating instructional roles through pedagogical agents. *International Journal of Artificial Intelligence in Education*, 15, 2005.

[4] Reinaldo A. Cosda BIANCHI. *Uso de heurísticas para a aceleração do aprendizado por reforço*. Tese de doutorado, Escola Politécnica, Universidade de São Paulo, 2004.

[5] Tharam Dillon Vivian Vossos George Vossos, John Zeleznikow. An example of integrating legal case based reasoning with object-oriented rule-based systems: Ikbals ii. In *ICAIL '91: Third International Conference on Artificial Intelligence and Law*, New York, NY, USA, 1991. ACM Press.

[6] Jess the rule engine for the java platforme, 2003.

[7] Vive Kumar and D. Brokenshire. An ontological framework to collect and disseminate user model data. In *I2LOR: ELearning for the Future: from Content to Services, 2nd Annual Scientific Conference of LORNET research network, Vancouver, Canada, accepted for publication*, 2005.

[8] Rosina Lee. *Pesquisa Jurisprudencial Inteligente*. Tese de doutorado, Programa de Pós-Graduação em Engenharia de Produção, Universidade Federal de Santa Catarina, 1998.

[9] Kimberly N. Martim and Ivon Arroyo. Agentx: Using reinforcement to improving the effectiveness of intelligent tutoring system. In *Intelligent Tutoring System, Maceió, Alagoas, Brazil*, pages 564–572, 2004.

[10] A. Oskamp, R. F. Walker, J. A. Schrickx, and P. H. van den Berg. Prolexs divide and rule: a legal application. In *ICAIL '89: Proceedings of the 2nd international conference on Artificial intelligence and law*, pages 54–62, New York, NY, USA, 1989. ACM Press.

[11] Georges Span. Lites, an intelligent tutoring system for legal problem solving in the domain of dutch civil law. In *ICAIL '93: Proceedings of the 4th international conference on Artificial intelligence and law*, pages 76–81, New York, NY, USA, 1993. ACM Press.

[12] Stanford. Protégé ontology editor and knowledge acquisition system, 2000.

[13] Joel Tetreault and Diane Litman. Using reinforcement learning to build a better model of dialogue state. In *11th Conference of the European Chapter of the Association for Computational Linguistics (EACL), Trento, Italy (to appear in April)*, 2006.

[14] Tilab. Java agent development framework, 2005.