Themis, a Legal Agent-based ITS

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Abstract. As an interesting example of ill-defined domain, Law domain has been challenged AI-ED system researchers. In this context, Law students have little chance to deal with realistic situations, requiring to apply real cases, rules, and different viewpoints. To address these issues, we introduce an agent-based Intelligent Tutoring System (ITS) applied to the mentioned domain. Then, we defined an agent-based architecture to support multiple views of domain knowledge, improving the quality of student-ITS interactions and the learning success of the students. Each tutoring agent from the system contains a hybrid knowledge-based system that combines Case-Based Reasoning (CBR) and Rule-Based Reasoning (RBR). In addition, each agent adopts the Reinforcement Learning Algorithm aiming at 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. A case study to demonstrate the feasibility of the system is presented.

Keywords. Artificial intelligence and law, intelligent tutoring systems, case-based reasoning, rule-based systems, reinforcement learning.

Introduction

AIED system researchers have been challenged to approach ill-defined domains, such as example Law domain. Particularly in legal domain, several researches provides evidences that involve Law students with real cases, rules, and different viewpoints of knowledge is often recognized as important to their successful learning, such as [2,11,18,17]. Furthermore, the use of a hybrid solution to the problem solving is also motivated due to the structure of the juridical system [1]. For instance, legislation is the main Legal research, where magistrates make their decision based on the code and laws, originating case solutions. In addition, Legal Intelligent Tutoring Systems (ITS) are a kind of complex, domain-oriented software systems which are frequently pointed out by researchers as suitable applications for the multi-agent approach [8].

To address these issues, we introduce the so-called Themis, an ITS applied to Legal domain, according to the multi-agent architecture derived from Mathema model [7]. The

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

main goal of this model is to increase the opportunities for students to construct their own knowledge through a problem-based learning approach. Moreover, Themis may also solve problems by using CBR or RBR or a combination of them. CBR has been used to check the similarity between old cases to justify new problems and RBR to evaluate the rules of Normative Knowledge. In addition, to improve the pedagogical interaction, the system adopts the Reinforcement Learning Algorithm aiming at identifying the best pedagogical strategy by considering the student profile.

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

Altogether this paper focuses on both architecture and the mentioned Artificial Intelligence techniques into a Legal System. A case study to demonstrate the feasibility of the system is presented.

1. Related Work

Some related works were developed taking into account legal tutoring or hybrid reasoning involving CBR and RBR.

In [1], Aleven proposes an intelligent learning environment designed to help beginning law students learn basic skills making use of arguments with cases.

An ITS for Legal domain, using Rule-Based System and approaching problem-based learning as pedagogical strategy is presented in [21]. This proposal refers to a novel ITS approach applied to Legal domain, using hybrid reasoning (CBR and RBR). It also describes the modeling of multiple views of domain knowledge, providing two-way interaction in a problem-solving process.

[5] combines both the blackboard architecture and distributed AI methods for creating hybrid systems. This means that both RBR and CBR run concurrently giving as output the best result produced by one of the inference mechanisms.

[19] describes a Dutch expert legal system, focused on the domain of landlord-tenant law. It combines knowledge groups like legislation, legal doctrine, expert knowledge and case law.

In [25], the project uses a distributed artificial intelligence approach, operating in the area of credit law that combines CBR and RBR independently. First, the system infers using RBR, thereafter CBR, if RBR does not succeed.

Although [1] and [21] propose an educational system, an intelligent mechanism (Reinforcement Learning) to improve the pedagogical activities were not found. In addition, [25], [19], and [5] do not propose an education system.

This paper proposes a novel ITS approach applied to Legal domain, using hybrid reasoning (CBR, RBR and Q-Learning). Moreover, Themis has an ontology-based approach in order to model domain knowledge, student interaction and pedagogical activities. Equally important, Q-Learning has been used to improve the quality of ITS-Student interaction.

2. Agent Architecture

Figure 1 shows the *Themis* architecture. The system is composed by mediator agent, persistence agent, and an agent society. In the infra-structure layer was used the Jade Framework, because it implements the interoperability standards for agent communication (FIPA [10]).

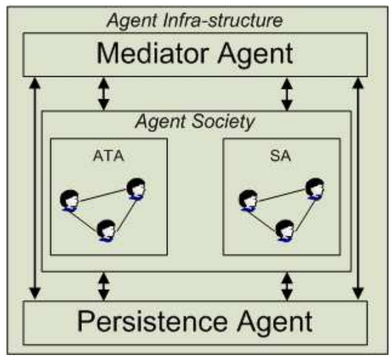

Figure 1. Themis Architecture.

The agent society is composed by artificial tutoring agents (ATA) and support agents (SA). While **ATA** represents an agent-based ITS acting into a specific domain. These agents are responsible for problem solving and providing information to students and each ATA has a domain model ontology (it has the features of a legal domain and subdomains associated), student model ontology (it is composed by interaction information and the knowledge that a student already learned), and pedagogical model ontology (which is divided in i) strategies, which are defined as an elaborated plan of action built by instructors based on the educational theory and ii) tactics, which are atomic actions that can be used into a strategy.). The **SA** provides assistance to ATA agents through inference engines. The support agents are: 1) CBR Agent which is responsible for evaluating the similarity between the jurisprudence and a penal situation, 2) RBR Agent which is responsible to infer by using normative knowledge and 3) Q-Learning Agent: it is used in student-ITS interaction in order to choose the best tactic in a specific situation.

Finally, mediator agent assures the communication between graphical interface and agents, while persistence agents assure the communication with the knowledge bases.

3. Agents Implementation

This section describes Artificial Tutoring Agents and Support Agents.

3.1. Artificial Tutoring Agents

The Autonomous Tutoring Agents were modeled based on the Mathema Model [7] through the reuse [20,6] and development of top ontologies.

3.1.1. *Domain Ontology*

The characteristics of the domain is overcame through a multi-dimensional view of the knowledge (external view), which helps a partitioned view (conducting an internal view) of the domain. The external view represents a domain interpretation of a body of knowledge, while the internal view represents a partition of the domain D. Moreover, each partition of D leads to a sub-domain that are mapped into curriculum structures. The curriculum is composed of pedagogical units (pu), as follows:

$$Curric = \{pu_1, pu_2, \dots, pu_n\}, \tag{1}$$

$Curric$ represents a curriculum and its associated pu_i. Also, each pu_i corresponds to a set of problems and each problem contains concept and results that assist the resolution process. Finally, each problem is associated with conceptual content to support the student, as shown in Figure 2.

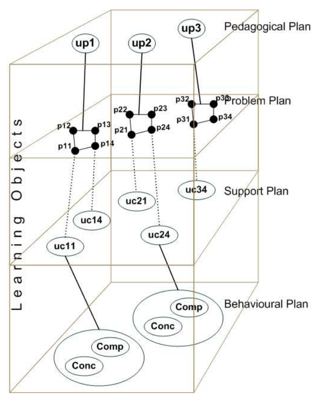

Figure 2. Pedagogical Structure of the Domain Ontology.

3.1.2. *Student Ontology*

The information necessary to this ontology are i) *Static Information*: the student information that do not change during the student-system interaction like name, telephone, address, so on and ii) *Dynamic Information*: the student information that change during the student-system interaction. Figure 3 approaches interaction features between the student and the system. Another important point is that the ontology keeps interaction information such as evaluation of problems, student activities, student knowledge state, learning goals, and so on.

3.1.3. *Pedagogical Ontology*

The pedagogical model construction was based on the works [9,14]. The Strategy used was problem-based learning and the tactics are: increase the problem difficulty degree; decrease the problem difficulty degree; same difficulty degree; change the sub-domain; change the issue and change the problem issue to past issue.

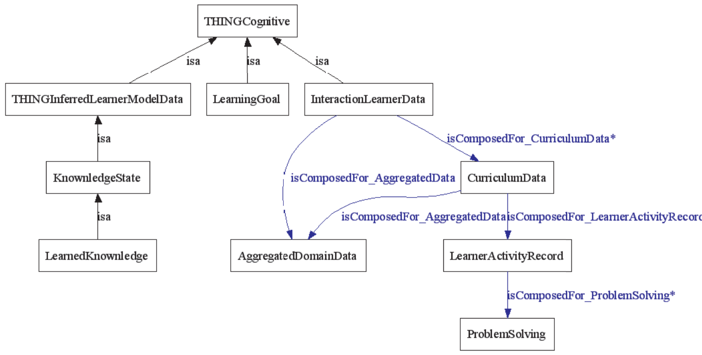

Figure 3. Students Ontology.

3.2. *Support Agents*

3.2.1. *CBR (Case-Based Reasoning) Reasoning*

The knowledge was represented by n attributes $A = \{a_1, a_2, ..., a_n\}$ where each attribute has a weight $W = \{w_1, w_2, ..., w_n\}$, for more details on knowledge representation and similarity functions, see [15]. The similarity function between two cases is defined in Equation 2:

$$SIM(C_1, C_2) = \sum_{i=1}^{n} \left(w_i * sim(a_{i_{C_1}}, a_{i_{C_2}}) \right) \tag{2}$$

While the retrieval process was done in a sequential way, the reuse and revision phases were not used, because jurisprudence can not be adapted.

The case attributes used are: Co-authorship (participation of other person at the crime), crime qualification, kind of action, crime modality, attempt (if have or not the attempt), result (if the result was favorable to the lawyer or to the prosecutor) and CBR is used according to the algorithm below.

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

Algorithm 1: The student solution evaluation algorithm.

3.2.2. *RBR (Rule-Based Reasoning) Agent*

It is responsible for the rules evaluation in the Legal ontology where the rules were modeled considering the Normative Knowledge which enables the whole validation of a penal situation. In addition, were modeled 49 rules to infer about the domain. Follow an example of a rule developed using the Jess [12] environment and integrated within Protege [22]:

```
(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: (i) when the student submits a penal situation to tutoring system; (ii) when the tutoring system submits a penal situation to the student. The hybrid reasoning mechanism, CBR and RBR, can work together with the legal ontology to solve problems submitted by the student or by the tutoring system.

When the *student submits a penal situation to the tutoring system* it tries to solve the penal situation using both CBR and RBR, and the interaction algorithm was implemented as follows:

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

Algorithm 2: The evaluation student problem algorithm.

On the other hand, when the *tutoring system submits a penal situation to the student*, the student describes the solution according to her/his knowledge and only then, the ITS evaluates the student solution according to the algorithm below.

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

Algorithm 3: The student solution evaluation algorithm.

3.2.3. Q-Learning Agent

Some researches pointed out Reinforcement Learning in pedagogical activities approaching the feasibility of the algorithm [3,23,16]. These researches stated that students have different learning style, and these styles can be acquired through the analysis of the interaction. That‘s why a Reinforcement Learning Algorithm was used in order to improve the teaching ITS skills.

This agent aims 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 strategy and MATHEMA Context pairs.
- 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.

• $R : S \times A$: it is described as a utility value, defined for the similarity of the attributes, mapped as a reward function.

It was used in the e-learning environment a proposal approached in [4] that implements an algorithm which is used in the action choice rule which defines what action must be performed when the agent is in state s_t. The heuristic function (Equation 3) included was:

$$\pi(s_t) = \begin{cases} argmax_{at} \left[\hat{Q}(s_t, a_t) + \xi H_t(s_t, a_t)\right] & ifq \leq p, \\ a_{random} & otherwise. \end{cases} \quad (3)$$

• $H : S \times A \rightarrow R$ is the heuristic function.

• ϵ: it is a real variable used to weight the influence of the heuristic function.

• q: it 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 heuristic value $H_t(s_t, a_t)$ can be defined as shown in Equation 4:

$$H(s_t, a_t) = \begin{cases} max_a \ \hat{Q}(s_t, a) - \hat{Q}(s_t, a_t) + \eta & if a_t = \pi^H(s_t), \\ 0 & otherwise. \end{cases} \quad (4)$$

Initialize $Q(s, a)$
Repeat:
  Visit the s state
  Select a strategy using the choice rule
  Receive the reinforcement $r(s, a)$ and observe 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 $s = s_t, s^{'} = s_{t+1}, a = a_t e a^{'} = a_{t+1}$

Algorithm 4: The Heuristics Algorithm.

3.3. Graphical Interface

The Interface is responsible for showing information about the system. Moreover, the Interface Agent works as an assistant, in other words, it is made a step-by-step to the student describes the problem.

• problem specification: the steps for the problem specification are:

1. personages specification (name, age, deficiencies, ...).
2. relation among the personages (father, mother, son, brother, brother in law, friend, ...).
3. fact specification:

(i) Did the murder happen ?

(ii) What are the personages positions (victim, killer, accomplice, witness, ...)?

(iii) Which was the gun (slashing/piercing object, poison, revolver, ...) used ?
(iv) What was the crime reason (revenge, ordered)?
(v) What are the personages conditions (drunken, strong emotion, sleeping, ...)?

- problem solution.

4. An Illustrative Example

This section presents a student-ITS interaction in order to illustrate the functionalities of the system.

Suppose that the student is working for the first time with the ITS, so the student answers a set of question about Legal issues and then, the knowledge level of the student is defined. Below, it is exploited an example where the student submits a problem to the system.

4.1. 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 dies.*

When the student specifies a problem, the system considers the rules and the cases, evaluating the attributes [2]:

- Personages = John, Maria, and Joseph.
- relationship among the personages = Brother(John, Joseph), Married(John, Maria).
- personages positions: Victim(Maria), Accused(John), and Witness(Joseph).
- Personage's deficiency: it specifies if the patient has some physical deficiency that can be considered, for example, a case in which the victim can not protect itself = Maria sleeping in the bed.
- Fact (attempt well successful or not): if the crime was materialized = yes.
- Gun used: the gun is very important, because it can characterize how serious was the crime = gun.
- Reason of the crime: it specifies if the crime was perpetrated for revenge, ordered, among others = adultery.

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

Prosecutor View:

- Normative Knowledge - Qualified Homicide: Art. 121, ï£¡2ï£¡, 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 the victim was sleeping.

- Jurisprudence - Summary: JURI. Qualified Homicide. Research that turn defense of the offended person impossible. Victim Sleeping. [...]

Below follows the rule used to prosecutor view solution.

1. Rule
   If victim = 'impossible defense' or Fact = 'concretized', then Article = 121 and Paragraph = 4 and item = IV

[2]The context of the attributes is considered relevant in Brazilian Code

When the student describes a rule, the system attempts to infer about the characteristics and mapping them in the doctrinaire concepts.

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`;

1. Rule
   If AccusedCondition = 'self-defense', then Article = 23

Lawyer View 2:

• Normative Knowledge - Privileged Homicide: Art. 121, ï£¡1ï£¡;
Doctrine - Privileged Homicide can be used when the author acts through strong emotion.

• Jurisprudence - Summary: JURI. Qualified Homicide. Cohabitation. Condemnation for Privileged Homicide.

1. Rule *If CrimeReason = 'adultery' then AccusedCondition = 'strong emotion' or AccusedCondition = 'depression'*
2. Rule *If AccusedCondition = 'strong emotion' and Fact = 'concretized', then Article = 121 and Paragraph = 1*

In the case, three solutions were returned to the ITS. The ATA Agent 121_2, ATA Agent 121_1 and ATA Agent 23 were used to solve the case, where each solution represents one agent. In addition, Both RBR and CBR agents were used.

5. Final Remarks and Future Work

To sum up, this paper proposed the so-called Themis, a hybrid ITS which provides students with problems and appropriate tutorial feedbacks. The prototype has been used with three types of knowledge domain (Jurisprudence, Normative Knowledge, and doctrines). At the moment, the Case-Based Reasoning model and Rule-Based System that integrate Jurisprudence, Normative Knowledge, doctrines, and the application of the corresponding Legal concepts in the problem solving process were developed. Technologies such as JADE [24], JESS [12], Protégé [22] were used on the development of the prototype.

It is planned a new version of the Themis that includes: (i) to create the strategy structure to the pedagogical model in others parts of the tutor; (ii) to create the student modeling structure to the student model, enabling the holistic view of each individual student to be stored, allowing the tutor to be highly personalized [13]. Finally, it is planned to evaluate the current system with undergraduate students to improve the system's robustness and learning evaluations.

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