An assistant for learning logic deduction

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Abstract. Education is profiting from the use of new technologies and computers. The future measurement to keep track of students’ effort will take into account out-of-class work, which means that generating new tools for giving students the chance to learn autonomously will be convenient. We still can go a step forward and use artificial intelligence techniques and Cognitive Science improvements in matter of teach. Within this framework, Intelligent Agents Model lets us designing and developing assistants which will be suitable to guide students throughout specific subjects. Here we present the Natural Deduction Assistant (ADN – Asistente para la Deducción Natural), an agent which helps us making logic deductions using the natural deduction technique and which is ran through the Internet.

Keywords: Artificial Intelligence, Intelligent Agents, Education, Intelligent Tutors, Assistants.

1. Applying Artificial Intelligence techniques to Education

Nowadays, there are a great number of essays and researches about Artificial Intelligence (AI) in all of its many subfields (reasoning, problem solving, perception, machine learning…), featuring several applications (planning, robotics, natural language processing, computer vision…). In the last years, we are moving from toy problems to real world applications. We are now in artificial intelligent component stage [1], where concrete solutions to specific problems are constantly emerging for our daily life devices, and having intelligent electrical appliances is more frequent: washing machines saving soap and energy, cameras which focus automatically…

Artificial Intelligence techniques have been applied to several fields but we are now interested in Education. Terms like multimedia, simulations, computer aided learning, computer networks, the Internet, e-learning and teaching at a distance, are already part from teachers vocabulary. New technologies have fully entered into the world of education, but real consequences of its use have just started. Hence, the next improvement for the present moment will come from the application of AI techniques to teaching. Breakthroughs in Cognitive Sciences [2] have let us better know how we think, solve problems and learn, whereas improvements in Artificial Intelligence have
aided us to better understand how to represent knowledge, reason about it and get new knowledge automatically. Putting both together will let us develop applications which could help students learn better with an interface more human and friendlier at the same time [3].

Intelligent tutor systems are widespread among classrooms. These tutors are omniscient (they know all things concerning his knowledge domain). They do not let us make mistake and we can always ask them for help. We simply have to follow their steps. We all know the benefits of their use (personal learning, less dedication time, out of class use…), although they can be a little bit irritating sometimes. On the other hand, stupid apprentices are those systems which we are trying to teach something to and, if we do not explain things correctly to them, they will make mistakes (we learn from the errors too). Really, we know and master a subject when we are able to teach it to another person (we all have suffered it at our first stages as teachers).

At this point of meeting between Artificial Intelligence and Education, we find us at a privileged position, because of our double side being Artificial Intelligence researchers and university teachers, which is the reason by which we have been developing tools in order to help us in our labour as teachers, where we have applied our Artificial Intelligence concepts and techniques.

2. Logic deduction

Lógica Computacional (Computational Logic) is one of the subjects shaping the scheme of the computer science career at University of Alicante. Among its goals we find the knowledge of logic inference and the handling of some of its techniques. Specifically, students learn Natural Deduction. The application which has been developed for this article is for learning this technique.

Logic brings us calculus methods which let us infer new formulas from known ones through easy syntactic handling. One of these methods is Natural Deduction, whose mechanism resembles human intuitive reasoning. So, simply done, we get fixed conclusions starting from given formulas which are known as premises, just by using some basic rules. Main idea is breaking the knowledge jump between premises and conclusions into little steps which are considered to be correct. By doing this, if we assume the premises to be true and each single step is justified by a basic rule, we will be getting new logic formulas which can be considered conclusions derived from premises.

In order to set the basic rules of Natural Deduction, we will base on the idea of mounting and dismantling logic formulas. Hence we will have two rules: one for introduction and other one for elimination. These two basic rules are applied to each logic symbol, this is, the four connectives (negation, conjunction, disjunction and implication) and the two quantifiers (universal and existential). If one basic rule inserts into the conclusion one connective or quantifier which was not present in its premises, we will be talking about an introduction rule. Instead, if this basic rule eliminates from its conclusion one connective or quantifier which was present in its premises, this rule will be an elimination one. A deduction will be considered correct
when we will get a finite sequence of formulas, where each of them had been got by
the use of some inference rule. The initial formulas of the sequence will be the
premises and the last one will be the conclusion.

Presently, there are several tools which can help learning logic [4, 5, 6]. We have
developed one for the specific task of teaching Natural Deduction, ADN (*Asistente
para la Deducción Natural*), which is ran remotely throughout the Internet and is
designed and developed using Intelligent Agents paradigm.

### 3. Intelligent Agents Model and the Internet

Intelligent or Rational Agents can be seen as a unifying conception of AI which let us
integrate several distinct techniques inside a common model, interrelating gotten
results from each one of these techniques. In fact, text books treatment of AI is more
and more frequent done from Agents point of view [7, 8]. Following this way we can
work with intelligent systems (agents) of growing complexity, from fundamental
reactive agents to agents which make the most of its environment. We can work with
environments within multiple agents coexist, cooperating or competing, but always
interrelating ones with others, constituting a Multiagent System (MAS) [9, 10, 11].

One of the most important media for the Intelligent Agents is the Internet, which
makes the use of the model common for developing applications for the web.

One of the biggest fields of application of agents is in interfaces between users and
computers. Moreover, these agents can make use of artificial intelligence techniques
which let them deal with some kinds of problems. This way do not just make kinder
relations between humans and computers but, furthermore, we can have agents which
take the initiative and suggest us changes, cooperating with people at fixed tasks.
Among this kind of agents we find ones called assistants. Our purpose goes this way
and we have developed an assistant to help us in the task of realizing a natural
deduction.

### 4. ADN: An assistant for learning Natural Deduction.

We are presenting a didactic tool designed to help learning of the Natural Deduction
technique. This tool has been conceived and developed in the department of *Ciencia
de la Computación e Inteligencia Artificial* (Computer Science and Artificial
Intelligence) at the University of Alicante. The tool tries to be a didactic instrument in
order to help students to write well-formed logic formulas (wffs) and to make
deductions correctly. It is not a system which constructs demonstrations automatically; it is just an assistant which will oversee and guide students during the
process, helping to elaborate their own deductions. It checks if new formulas are
syntactically correct (if they are wffs) and if they are derived in an adequate fashion
(by the application of basic rules). Furthermore, it possesses some support tools, like

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1 Natural Deduction Assistant
the syntactic-tree viewer for formulas, the basic rules viewer, the adviser, detailed error informs and the online help.

ADN incorporates an interface agent operating at the top level of the application. This agent checks the state of each system component as well as the user actions and receives event notifications every time something important happens. Mixing all these pieces of information, the agent guesses what the user needs are at the present moment and tries to satisfy them. All the interactions with the user are done through this agent.

ADN can be run using a common navigator, because it is implemented as a Java Applet. It is available at the website: http://www.dccia.ua.es/logica/ADN

So, we need a computer connected to the Internet, because the application is run online. Moreover, it has a version which can be installed and run locally, without the need to be connected to the Internet. Whichever the method we choose for running the application, a window like the one shown at Fig. 1 is opened. From this window we can have access to the two parts of the tool: the Natural Deduction tutorial and the application which lets carrying out deductions.

In the main window of ADN (Fig. 2) we can see these parts:

1. Goal formula editor: Lets us edit the formula which will be the goal of our deduction.
2. Deduction body (*blackboard*): The deduction steps will be shown here. We can see three different parts (column aligned):
   a. Line numbers, used to reference the lines.
   b. Logic formulas which are obtained so far. Indentation is used to clarify assumptions, forming groups called subdeductions.
   c. Justification of the new formula gotten from the use of some basic rule involving one or more previous formulas.
3. Formula editor: used to insert new formulas inside the line of deduction telling from which formulas are derived the new ones.
4. Options area: here we have buttons to access different functions of ADN like new deduction, tree, delete, about and tutorial.
5. Assistant: Agent for helping the user which lets asking for advises or notes, seeing the rules or opening an exercise.

![Fig. 2. ADN Main Window](image)

ADN only lets us using basic rules. At the basic rules window we see rules for introduction and elimination corresponding to the logic operator related which is selected in the upper combobox. As an example (Fig.3) we can see what the implication connector rules look like.
ADN has an agent which assists us in the task of constructing the deduction. One of its responsibilities is giving us advises to guide us towards our goal, telling us which rules can we apply at every moment. The assistant could take us to no solution; it is just a support, because first-order natural deduction is not a decidable problem. We can run the assistant at every moment by clicking over its avatar (Fig.4).

Once we have requested an advice, a suggestion telling us what we can do is shown in the upper part of the window, with a graphic tip of the formulas of our deduction. It also shows us how many advices have been generated and which one are we seeing presently, letting us navigate throughout these advices by using Previous.
and Next buttons. ADN shows us generated advices from top to bottom (based on premises and previous formulas gotten) as well as advices generated form bottom to top (based on the goal to achieve).

![ADN generated advices](image)

**Fig. 5. ADN generated advices**

To end with this ADN description, the next figure shows a natural deduction done with this tool:

\[
\exists x \ (P(x) \land \forall y \ (Q(y) \rightarrow R(x,y))) \Rightarrow \forall y \ (Q(y) \rightarrow \exists x \ (P(x) \land R(x,y)))
\]

![Natural deduction example](image)

**Fig. 6. Example of a natural deduction done with ADN**

5. Conclusions

A didactic tool designed ad-hoc using the Intelligent Agents model and conceived for teaching the natural deduction technique which is run through the Internet, has been presented. Its design has been based on watching and analysing the difficulties which
students have to deal with in order to learn and be able to apply this technique, as well as from the most usual mistakes. This tool has been developed profiting from new technologies of information and communication as well as the steps through in Artificial Intelligence (multimedia effects, net-through running, Java technology, Intelligent Agents and strong algorithms) and their use for Education. Special care has been taken with aesthetic appearance and ease of use (user-ADN interaction).

References