A new methodology for teaching default reasoning

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Abstract

Default reasoning is a method of knowledge representation and reasoning which allows one to deal adequately with incomplete information. Applications of such methods can be found in software engineering, artificial intelligence, law, marketing, business etc. In this paper we describe why default reasoning is difficult, and describe a new methodology for teaching default reasoning, which has been applied with significant success over the past couple of years. It is based on the idea of operationalizing the basic concepts of the logic.

1 Motivation

The *representation of information* has been at the heart of computer science for a long time. For example, it is a central issue in requirements engineering, software specification and derivation, databases, knowledge-based systems etc. Apart from representing information it is necessary to *reason* with the available information in order to draw additional information that is inherently present. The most common representation and reasoning method in computer science is predicate logic in its various manifestations.

Information systems are often faced with the problem of *reasoning with incomplete information*. That means, the information actually needed to make a decision is unavailable (or there is not enough time or resources to collect the necessary information), yet the system needs to perform in an adequate way. What it needs to do is make plausible assumptions about the missing pieces of information. Depending on how these assumptions are made and justified, we get different approaches to reasoning with incomplete information. In *default reasoning*, assumptions are based on default rules. The most prominent approach to default reasoning is default logic [5], which will be the focus of this paper. In computer science curricula, default reasoning would be taught in 3rd year undergraduate subjects and/or at the postgraduate level.

A simple example of default reasoning is the closed world assumption known in the database area for a long time: If a fact is not found in the database then it is wrong. For example, if we look up a database of flights and don't find a direct flight from Osnabrueck to Albany, then we assume that there is no such flight. Of course, this is only an assumption, since there might be an extra flight in case a special event took place.

Default rules prevail in many domains, including requirements engineering, marketing, business processes, legal information etc. Indeed the idea of a default rule is easily explained to novices. Nevertheless, there is a broad perception that default reasoning, as other forms of nonmonotonic reasoning, is inherently difficult, mysterious, understandable only by mathematically sophisticated people.

This paper will argue that this perception is wrong, and that it is due to the way default logic has been taught so far. Then we will briefly describe a new teaching methodology which can be used to introduce default logic smoothly, and which has been tested successfully at Universities and tutorials.

2 The problem

In default logic there are two kinds of information: *facts* which represent certain information, expressed in classical logic, and *default rules* which represent plausible assumptions. Default rules have the form $\frac{A:B}{C}$ with logical formulas A, B, C. The intuitive meaning is: If A is known and *not* B is not known, then conclude C. For example the default rule

$$\frac{AAAmember : likesCars}{likesCars}$$

expresses the fact that typically AAA members like cars. So if we know that a particular person X is a AAA member, we can conclude that he likes cars. But later on we may receive specific information that actually X doesn't like cars, in which case we have to take back our previous assumption.

The meaning of a specification in default logic is given in terms of so-called *extensions*. They are alternative world views that are based on the given facts and default rules. In general, there may be more than one extensions, since default rules may lead to conflicting assumptions.

Extensions are the central concept of default logic, since they describe the meaning (semantics) of the given information. We argue that the way extensions have been introduced to students lies at the heart of the problems that the students experience. To illustrate the point we need a little bit of formality.

In the conventional approach, when we seek to apply a default $\frac{A:B}{C}$ we have to establish that A is currently known (this causes no problem), but also that *not* B is not included in E, the extension yet to be constructed! Stated another way, extensions E are defined as the solutions of the equation

$$\Lambda_T(E) = E,$$

where E has to be *guessed* beforehand. We claim that this is an almost impossible way of presenting a theory, since students are asked to guess before they were able to develop an intuitive understanding of the concept.

Of course, fixed-points are a useful and elegant mathematical tool. But the average computer science student does not possess the mathematical insight and sophistication to deal with such equations easily. Thus the impression that default reasoning, as other forms of nonmonotonic reasoning, is something mysterious and is only accessible to persons with thorough mathematical training.

Apart from having to guess, there is a second problem with the presentation outlined above: even if one guesses correctly and establishes that some E is an extension, how can one be sure that they have found *all* extensions of the given information?

In the following section we will describe a solution to these difficulties. In particular we will present a constructive way of determining extensions, which proceeds in a step-by-step manner and does not require guessing.

3 The solution

Instead of requiring the user to first make a guess on what an extension might be and then to verify that guess, the method introduced in [1] allows a step-by-step approach in which the user can rely on available, local information only. In particular, when one tests a default $\frac{A:B}{C}$ for applicability, it is required that A be currently known, and that *not* B be not included *in the current state of the knowledge base*. In other words, we refer strictly to available, local information only. In particular, we are not required to check that *not B* is not included in the illusive extension E yet to be constructed.

The process involves a systematic search of all possible reasoning chains, with some branches leading to failure (a sort of dead end). But when we establish that a reasoning chain is *closed*, meaning that no further default rules can be applied, and *successful*, meaning that we haven't made an assumption that turned out to be wrong, then we have indeed constructed an extension. Both tests for closure and success refer to local information only.

This methodology allows one to compute extensions without guessing. We will illustrate the approach using the following very simple example. Suppose that we are given the following information:

$$AAAmember$$

$$green$$

$$\frac{AAAmember : likesCars}{likesCars}$$

$$\frac{green : not\ likesCars}{not\ likesCars}.$$

In the beginning we may decide to apply the first default rule: the information $AAAmember$ is already known, and *not* $likesCars$ is not known. Thus we apply the default rules and conclude $likesCars$. Can we *subsequently* apply the second default? Well, no, because we have already conclude $likesCars$, therefore we cannot assume *not* $likesCars$, as required by the second default rule. In this sense we have a reasoning chain that is closed (no further default rule can be applied) and successful (there is no contradiction between the assumptions we made along the way and the current information we have). Thus we have reached an extension; it is the deductive closure of

$$AAAmember, green, likesCars.$$

Alternatively, in the first step we could have applied the second default rule *instead* of the first one. Then we would conclude *not* $likesCars$. Now it is the first default rule that cannot be applied (now we do know *not* $likesCars$, so we cannot assume that the person likes cars), and reach a second extension, the deductive closure of

$$AAAmember, green, not\ likesCars.$$

Obviously there is no other possible reasoning chain. So we can be sure that the extensions we found are all the extensions of the given information (recall that we couldn't be sure simply by guessing).

4 Current and future work: towards a computational teaching tool

The method outlined in the previous section has been successfully used in classes at Universities in Germany and Australia, and has formed the basis for a series of tutorials presented by the author at some of the most important conferences on artificial intelligence, including the National Conference on Artificial Intelligence (AAAI), and the International Joint Conference on Artificial Intelligence (IJCAI). It is also the basis for a big part of a textbook published by The MIT Press in 1997 [2]. This already illustrates the acceptance and success of our presentation method of default logic.

The next step in our work to support teaching of default reasoning and other methods for intelligent information management will be to develop a computer-based educational tool. There is consensus today that certain kinds of mechanical support are essential if logic is to be used effectively [4]. This has led to the development of several programs for teaching classical logic, one of the best-known and successful such systems being *Tarski's World* [3]. No such tool currently exists for default reasoning (the existing systems are research prototypes, typically concerned with machine power rather than education).

Our development of the instructional tool is guided by a number of educational principles. It will allow students to focus on conceptual issues rather than computational ones. The importance of reducing the conceptual load associated with any learning task is well understood, and is illustrated through the use of the common calculator as part of mathematics instruction.

The system will provide scope for active student experimentation, thus supporting *experiential learning.* It will provide explanation facilities for conclusions, which we expect to be of great help to the student learning. Finally the system will have an extensive library of examples, which will again support student experimentation in the sense of *situated cognition* [6], meaning that the problems and examples will be relevant to the students' own background and interests, rather than being artificial.

References

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[4] D. Goldson, S. Reeves and R. Bornat. A Review of Several Programs for the Teaching of Logic. *The Computer Journal* 36,4 (1993): 373-386.

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Witten, I. and Bell, T. (1993) "Getting research students started—a tale of two courses", *Proceedings of SIGCSE 1993*, pp. 165-169.

APPENDIX: CHECKLISTS OF EVALUATION CRITERIA

Alexander, A. and Tate, M. Criteria for evaluating advocacy, business/marketing, informational pages, news, and personal home pages http://www.science.widener.edu/~withers/webeval.htm

Scholz, A. "Evaluating World Wide Web Information", a set of general criteria. <http://thorplus.lib.purdue.edu/research/classes/gs175/3gs175/evaluation.html>

Schrock, K. "Kathy Schrock's Guide for Educators: Critical Evaluations Surveys", criteria for material used in primary and secondary schools <http://www.capecod.net/Wixon/eval.htm>

[i] http://liinwww.ira.uka.de/bibliography
[ii] http://www.carl.org/uncover/brochure.html