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CABARET: rule interpretation in a hybrid architecture

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Rules often contain terms that are ambiguous, poorly defined or not defined at all. In order to interpret and apply rules containing such terms, appeal must be made to their previous constructions, as in the interpretation of legal statutes through relevant legal cases. We describe a system CABARET (CAse-BAsed REasoning Tool) that provides a domain-independent shell that integrates reasoning with rules and reasoning with previous cases in order to apply rules containing ill-defined terms. The integration of these two reasoning paradigms is performed via a collection of control heuristics, which suggest how to interleave case-based methods and rule-based methods to construct an argument to support a particular interpretation. CABARET is currently instantiated with cases and rules from an area of income tax law, the so-called "home office deduction". An example of CABARET's processing of an actual tax case is provided in some detail. The advantages of CABARET's hybrid approach to interpretation stem from the synergy derived from interleaving case-based and rule-based tasks.

1. Introduction

This paper discusses the integration of case-based reasoning with rule-based reasoning to perform interpretation tasks. We focus on realistic, complex domains where the concepts, terms and predicates used by domain rules or by rule-based models are not well-defined. Often, in such inherently ill-defined domains the rules do not encompass all the situations they are asked or assumed to cover, admit tacit exceptions, or can be contradicted and annulled by other rules. Interpretation is therefore required of the terms and predicates used. The law is a prototypical example of such an area, where terms used in legal statutes are not completely defined by legal regulations.

The use of case-based reasoning (CBR) to complement and supplement other types of reasoning involves many computational questions of system architecture and control. The key focus of this work is how and when to interleave CBR with other modes of reasoning in the context of applying a rule or model to a new set of facts in light of a corpus of cases of past application. The goal is to generate an explanation or argument as to how the new fact situation might be interpreted.

In particular, we report on a system called CABARET (CAse-BAsed REasoning Tool), a hybrid architecture we have built to study and experiment with these issues. CABARET integrates rule-based reasoning (RBR) and case-based reasoning. In this paper, we discuss CABARET in the application area of income tax law concerning the deduction for expenses relating to an office maintained in one's home.

One may fairly ask whether interleaving distinct reasoning techniques is required

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to perform interpretation tasks. Why not simply run the knowledge sources serially: run one, and then the other? Four reasons are immediate. First, opportunism can be exploited through interleaving processes. Subgoals established using one paradigm may be inserted in arguments supported by another paradigm. Second, deficiencies in a reasoner may be overcome using another knowledge source, enabling the deficient knowledge source to continue reasoning. Serial invocation of these knowledge sources would make it impossible for arguments using either paradigm to dynamically support processing using the other. Third, each reasoning paradigm may decrease the search space to be considered by the other. This decrease may be cumulative as reasoning switches back and forth between two distinct paradigms. Fourth, each reasoner helps to provide a focus of attention for the other. Case-based reasoning, for example, can suggest that the focus of attention for a rule-based component be on a particular statutory term.

We have several reasons for investigating mixed paradigm CBR/RBR reasoning. From the general point of view of Artificial Intelligence (AI), such study deepens our understanding of CBR, allows us to explore key issues in the architecture and control of systems that must use a variety of techniques to solve problems, and suggests approaches to mitigate certain limitations or difficulties with particular reasoning methods, such as brittleness and concept drift (Brachman, 1990).

From the particular point of view of AI and Law (Rissland, 1990), we believe that the ability to combine reasoning with cases and reasoning with rules and models is necessary for a complete model of legal reasoning. Without question, this capability is required in statutory domains, but it may also be required in common law domains where there are nonetheless rule-like elements: expert heuristic rules of thumb, "blackletter" rules summarizing the law induced from a body of cases, and for each case, a "rule of the case" expressing what the case stands for. In situations requiring reasoning with a "deep" domain model, knowing how to combine reasoning with cases and reasoning with the model will also be necessary. From the point of view of our own research program, this work continues our research group's interest in precedent-based CBR and example-based reasoning (Rissland, Valcarce & Ashley, 1984; Rissland & Ashley, 1986; Ashley & Rissland, 1987; Ashley & Rissland, 1988*a*; Ashley & Rissland, 1988*b*; Ashley, 1988; Skalak, 1988; Rissland & Skalak, 1989).

To date, research on case-based reasoning and research using other reasoning techniques have largely been carried out in isolation of each other except in a handful of exceptional instances (Sycara, 1987; Koton 1988*a*; Koton, 1988*b*; Goel & Chandrasekaran, 1988; Marques, Latto & McDermott, 1988). A unique approach to integrating reasoning modes is taken by Stanfill and Waltz's (1988) MBRTalk system, which performs rule-like and case-like processing within a single paradigm—memory-based reasoning. There have been very few examples of mixed paradigm reasoning involving traditional CBR methods, although certain CBR systems, such as CHEF and MEDIATOR contained rule-based submodules used to support CBR (Hammond, 1986; Kolodner, 1987).† Koton's CASEY and Gardner's legal reasoning system used cases to supplement rule-based mechanisms (Gardner, 1987;

† CHEF contained a rule-based simulation model to test a proposed solution and perform a diagnosis of failures. MEDIATOR contained a classic rule-based goal-driven planner.

Koton, 1988*b*). A number of systems, particularly those in planning-oriented CBR (see Section 3), have relied on simulation models to test derived plans (Hammond, 1986; Koton, 1988*b*; Kopeikina, Brandau & Lemmon 1988). However, in none of these systems did the CBR and RBR components really have equal responsibility for problem solving. None of these systems made a dynamic decision to call on one or the other knowledge source.† More recently, there has been some interest in using more truly hybrid approaches incorporating a CBR module (Bonissone, Blau & Ayub, 1990; Branting, 1990). See also Branting's article in this issue. The work of the PROLEXS group at the Vrije Universiteit of Amsterdam is another significant example of a hybrid approach (Oskamp, Walker, Schrickx & van den Berg, 1989; Walker, Zeinstra & van den Berg, 1988).

From the viewpoint of AI, many of the issues addressed in this paper center on questions of *control*: how to coordinate the reasoning of co-reasoners (as one might call the individual CBR and RBR reasoners) and what information to allow them to share. Control issues for hybrid CBR architectures include:

(1) What architecture and control options can be used in such a hybrid so that the reasoning activities can be dynamically interleaved?
(2) What special requirements must be taken into account for reasoning modules whose processing context is a mixed paradigm environment? Is the internal processing of each co-reasoner in such an environment different from when each is used "standalone"?
(3) How and what information and results should be shared between the co-reasoners? How should one deal with redundancy of knowledge between the reasoners and the multiple views of the same domain knowledge that redundancy permits?
(4) How can co-reasoners be used to supplement and complement each other, especially when one is deficient in some way?
(5) How can results from the co-reasoners be integrated into arguments, explanations and advice using both cases and rules or models?

Clearly, these issues are not independent of one another. Nor can they be divorced from the internals of the co-reasoners, such as which cases count as relevant or what results qualify as success or failure. Even more fundamentally, some of the answers depend on the overall purpose for which the system is being used, such as argumentation, explanation or advice-giving.

From the legal viewpoint, this work touches on issues central to *statutory interpretation*: the process of determining the meaning of a legal rule and applying it to a particular set of facts. Specific questions of legal rule interpretation include:

(1) How can cases be used to compensate for the absence of well-defined concepts or predicates and precise rules?
(2) How can cases be used to accommodate drift in the meaning of concepts and rules and the emergence of new requirements and exceptions?

† For instance, in CHEF and MEDIATOR, the RBR was always in support of the CBR and occurred at exactly the same point in the overall reasoning. In Gardner's system, the CBR was only called in support of the RBR to check its conclusions or step in when it became stymied.

(3) How can regularities in the case base be used? Can such regularities be represented redundantly with rules?
(4) How should conflicts between case-based and rule-based treatments of a problem be handled and presented?
(5) How can cases be used to support a user's argumentative preference that a statutory rule be applicable or inapplicable?

In this paper we address mixed paradigm reasoning from the two points of view: (1) artificial intelligence, particularly, case-based reasoning; and (2) artificial intelligence and law, specifically a version of the general problem of statutory interpretation. We address a reduced version of the problem of statutory interpretation in that we do not explicitly consider the policies or principles underlying a statute. The rest of the paper is organized as follows. In section 2 we discuss the general problem of statutory interpretation, provide examples both from everyday experience and statutory law, and discuss combining CBR with other reasoning paradigms in other disciplines. In section 3 we briefly provide some general background on CBR, including the major subtypes of CBR and CBR's fundamental reasoning steps, and summarize our group's past work on precedent-based CBR. In section 4 we present CABARET, our mixed paradigm CBR/RBR architecture, and concentrate in section 5 on the control heuristics used by the system to direct its reasoning and accomplish various *Argument Stances* through *Argument Moves*. In sections 6 and 7, after providing an overview of CABARET's domain from tax law and its representation in the CBR and RBR paradigms within CABARET, we present excerpts of CABARET's problem solving on a tax example. In sections 8 and 9, we discuss the strengths and weaknesses of CABARET; these suggest several future research directions. The Appendix contains a listing of CABARET's current set of heuristics for controlling the system, a full trace of the tax example, and various details of CABARET's knowledge base.

2. The problem of statutory interpretation

In law, "statutory interpretation" refers to the process of determining the meaning of a legal rule, including determining the meaning of its constituent terms, and then applying it to a particular set of facts (Levi, 1949). The difficulty presented by this task to adjudicators, advocates and administrators is that critical statutory terms typically are not sufficiently well defined by statute or regulations to enable straightforward application. Rules often have unspoken qualifications and exceptions. Furthermore, one might need to go beyond the statute itself to other sources of knowledge, particularly cases, and even to historical background about the statute's promulgation, for clues to its meaning and the meaning of its constituent elements.

While rules are the primary method of specifying legal requirements in statutory domains (e.g. the rules in the Internal Revenue Code specifying the obligations of taxpayers, the rules of Section 2 of Uniform Commercial Code as to the purchase and sale of goods, the rules in National Labor Relations Act delineating the rights and responsibilities of employers and employees), invariably those rules use vague, under-defined terms. This deficiency forces one to reason with case law relevant to the statute and its terms in order to resolve interpretation problems. One compares

and contrasts precedents with the instant case, reason about the similarities and differences with past cases, and ultimately argues or explains why a previous interpretation can (or cannot) be applied. In essence, one uses cases in order to determine whether the new case is "in" or "out" of the category of the rule or predicate (Skalak, 1989). Since the desired interpretation usually depends on one's point of view, statutory interpretation, like common law reasoning, is an adversarial exercise in what might be called "competitive theory formation", with each side trying to construct a theory justifying its own desired interpretation.

In the fullest sense, statutory interpretation might also require consideration of how a term or rule "ought" to be applied and of the intent of those who wrote the rule (e.g. Congress). Although these normative aspects are important in the law—and perhaps, critically so—in this discussion we leave aside those considerations which involve reasoning about legislative intent, policy and ethics (Levi, 1949; Fuller, 1958; Hart, 1958; Llewellyn, 1960; Twining & Miers, 1982). We address what we call the "restricted" interpretation problem, where these normative aspects are ignored and the focus is on the use of cases for interpreting individual statutory terms and phrases. Our goal is to explore mixed paradigm methods involving cases and rules and the strategies useful for handling rule interpretation problems by appeal to cases (Rissland & Skalak, 1989*a*).

2.1. SOME EXAMPLES OF INTERPRETATION

The problem of interpretation arises almost any time one confronts application of a rule. The problem is most acute in adversarial settings where two parties argue for competing constructions. Typical situations for the average citizen occur in the context of difficulties with governmental regulations, such as those concerning taxes and motor vehicles, or with institutional regulations in the home or at work. The following two examples illustrate everyday interpretation problems.

The first example concerns a recent controversy about "mopeds" ("motorized bicycles") on the Island of Martha's Vineyard:

> During the summer of 1988, island moped rental businesses and law enforcement officers clashed over the definitions of "motorcycle" and "motorized bicycle". Appealing to Chapter 90 of the Massachusetts General Laws, which states that mopeds must be capable of no more than 25 miles per hour, Oak Bluffs police seized certain two-wheeled vehicles that they clocked in radar tests at speeds from 31 to 35 miles per hour and thus judged to be motorcycles. The police found the moped drivers to be in violation of state motor vehicle law, because the operators did not have a license to operate a motorcycle, which of course would be required if the vehicle were considered a motorcycle. A spokesperson for the State Registry of Motor Vehicles told the local newspaper that the agency "knows of no case law which clarifies the definitions of mopeds in Chapter 90" and "[T]o the best of our knowledge no element of the definition of mopeds has ever been defined beyond what is written in the law" and added that the Registry does not have a formal position on *the meaning of the phrase* "maximum design speed", which is critical to an application of the law (Adapted from *Vineyard Gazette, 143,* 14, August 5, 1988).

The relevant portion of Chapter 90† defines:

> "Motorcycle", any motor vehicle having a seat or saddle for the use of the rider and designed to travel on not more than three wheels in contact with the ground, including

† Mass. Gen. Laws Annot. Ch. 90 Section 1 (1990), italics added for emphasis.

> any bicycle with a motor or driving wheel attached, except a tractor or a motor vehicle designed for the carrying of golf clubs and not more than four persons, an industrial three-wheel truck, a motor vehicle on which the operator and passenger ride within an enclosed cab, or a motorized bicycle.
>
> "Motorized bicycle", a pedal bicycle which has a helper motor rated no more than 1.5 brake horsepower, a cylinder capacity not exceeding fifty cubic centimeters, an automatic transmission, and which is capable of a *maximum design speed* of no more than twenty-five miles per hour.

For the purposes of applying the definitions in Chapter 90 in the Martha's Vineyard situation, interpretation of the legal terms *motorcycle, motorized bicycle* and especially *maximum design speed* are critical. Since the statute does not offer tight definitions (although the wording of the statute can be used to infer that motor-assisted bicycles capable of speeds greater than 25 mph fall into the category of *motorcycles*), developing an interpretation would of necessity involve reasoning with any available precedential cases as well as the statutory definition. One might even appeal to the legislative purposes of the statute (e.g. the desire to insure safety on public roads, regulate the usage of motorized bikes, or even produce revenue through registration fees), especially if very few cases speak directly to the meanings of the terms at issue. Furthermore, the cases must be reasoned with in ways that serve interpretation of the statute, it would not do to reason with moped cases without tying them to the statute, and particularly the issue of maximum design speed.

A second example of common rule construction is that of the "legalistic child" (Rissland & Skalak, 1986*b*) from a book on rules and rule interpretation by Twining and Miers:

> Johnny, aged 7, is an only child. In recent months his mother has been mildly worried because he has developed a craving for sweet things and this has affected his appetite at meal times . . . Then one afternoon she finds that Johnny has gone into the larder and helped himself to half a pot of strawberry jam . . . [S]he does not punish Johnny on this occasion. Instead she says, 'That's naughty. In future you are never to enter the larder without my permission.' 'What does enter mean, Mummy?' asks Johnny. 'To go into,' says his mother. 'O.K.', says Johnny, relieved that he has got off so lightly.
>
> [Two] incidents then follow in quick succession.
>
> First, Johnny gets a broom and hooks out the pot of jam from the larder and helps himself. 'I didn't *enter* the larder', he says.
>
> Next, the cat enters the larder and attacks the salmon which mother has bought for a special meal to celebrate father's birthday. Mother, upstairs, hears Johnny hooting with laughter. She comes down to see him standing outside the larder door watching the cat eating the fish. 'I may not go into the larder', he says (Twining & Miers, 1982, p. 7).

Clearly Johnny and his mother are at odds about the meaning of *enter* in the first "case" of hooking the jam pot. In the 'salmon' case disagreement is over implied exceptions to the rule (or alternatively over the meaning of *never*). In the long run, what the words and the rule mean will be defined through cases involving Johnny and others. If Johnny's mother persists in her legislative approach to dealing with Johnny's behaviour—which might not be the wisest course given what we know about such situations—she might also need to revise the rule to better suit situations she wants the rule to address. For instance, she might create exceptions to the "permission" requirement in certain "reasonable" situations (e.g. when Johnny is home alone, dinner is going to be very late). Of course, such expression would raise new problems regarding the scope and meaning of the exceptions (e.g. how late is

"very late"?). In fact, there will be a dialectic between reasoning with the cases and the rule and, in the long run, a need to deal with concept and rule evolution (Rissland, 1984; Rissland & Collins, 1986). This need to deal with evolving rules incidentally underscores the need for including methods from machine learning in a mixed paradigm system (Skalak & Rissland, 1990).

In summary, statutory interpretation is a task where there are both explicit rules and explicit cases, where the rules and cases both require interpretation, where neither rule-based nor case-based reasoning alone is sufficient, and where one must interleave reasoning with rules and reasoning with the cases to develop interpretations in new cases.

2.2. INTERPRETATION IN LAW

As can be seen in our two examples, much of the need for interpretation stems from imprecise or "open-textured" rule terms (e.g. *maximum design speed, enter*). Another major source is shortcomings in the rule itself, for instance, unstated prerequisite conditions and exceptions, or circularities in definition (e.g. exigent situations, as in the salmon case) (Berman, 1989). Unstated prerequisites call into question the sufficiency of the rule's antecedents and unstated exceptions, their necessity. These sources of interpretive difficulties are often the focus of case-based reasoning. We discuss these difficulties, and a bit of their jurisprudential background, in this section.

By an "open-textured" concept we mean one that cannot be defined by necessary and sufficient conditions (Hart, 1961). Figuratively, the boundary of an open-textured concept is not sharp: in the gray area near the boundary one will have difficulty classifying cases. The notion of open set from mathematics provides a useful metaphor for "open-textured" concepts since in them one can always sneak in a "neighborhood of radius ϵ" around a point near the boundary that still remains within the concept definition.

Many concepts in domains like the law are open-textured, including some very familiar (and perhaps unexpected) ones, such as "contract". Even technical terms specific to a statute, such as "gross income" from the Internal Revenue Code, Section 61, may reveal a surprisingly open-textured lining, despite statutory attempts at definition.† Concepts, such as "due care" or "reasonable notice", used to indicate a variable standard, are clearly polymorphic. The terms "regular use", "principal place of business" and "meeting or dealing" are examples of technical yet open-textured terms from CABARET's home office deduction rule domain. The question of whether the facts in a particular situation count as a "contract", as "gross income", or as "meeting or dealing" is settled by appeal to past determinations of similar issues.‡§

† The Code says "Except as otherwise provided in this statute, gross income means all income from whatever source derived, including (but not restricted to) the following items: (1) Compensation for service, including fees, commissions, and similar items; (2) Gross income (*sic*) derived from business; . . ." Internal Revenue Code Section 61(a).

‡ For example, *Eisner v. Macomber,* 252 U.S. 189 (1920) interpreted stock dividends as income; *Benaglia* 36 B.T.A. 838 (1937), acq. 1940–1 C.B. 1, construed meals and lodging provided to a hotel manager as income.

§ For instance, the Tax Court in a case involving Max Frankel, *The New York Times* Managing Editor, *Max and Tobia Frankel v. Commissioner,* 82 T.C. 318 (1984), construed the *meeting or dealing* predicate of the home office deduction statute to require physical contact.

Open-textured concepts have been much discussed in jurisprudence (Hart, 1961; Hart, 1983; Dworkin, 1977; Dworkin, 1985). They often arise in discussions about the "core of settled meaning" and the "penumbra" of a concept (Hart, 1961) and in conjunction with the distinction between "hard" and "easy" cases in law (Hart, 1961; Dworkin, 1985). The idea also arises in philosophy, particularly regarding "natural kind" classes (Putnam, 1975) and "family resemblances" (Wittgenstein, 1958). The central role of open-textured concepts in legal reasoning was addressed in Gardner's work (1987), where for example, she discussed how open-textured legal concepts give rise to hard cases, that is cases over whose resolution experts (judges, scholars, etc.) disagree.

One classic discussion of the problem of statutory interpretation was the "Hart-Fuller debate", between H. L. A. Hart (1958) and Lon Fuller (1958). In a pair of well-known *Harvard Law Review* articles they discussed the nature and status of rules and the role of normative aspects in statutory interpretation. A large part of their discussion concerned the quandaries involved in applying such rules to "penumbral" or "hard" cases. Hart and Fuller at least agree that legal rules can never be purged of definitional ambiguities and shortcomings. The topic of hard and easy cases is still the subject of lively jurisprudential discussion (Moore, 1981). Another classic treatment of statutory interpretation is an article by Karl Llewellyn (1950) that lists 28 maxims and what might be called "anti-maxims", stating guidelines to statutory interpretation and countervailing principles.† In *The Common Law Tradition,* Llewellyn (1960) lists 64 heuristics for reasoning with precedents and rules‡ which he extracted from actual legal opinions, for example:

(1) The constellation of prior decisions has frozen the meaning of the rule;
(2) The prior rule is consciously applied or extended to a new fact-situation;
(3) The prior rule or distinction is kept from application because its reason does not fit.

It is interesting to note how similar these legal maxims collected by Llewellyn are to Polya's heuristics for problem-solving in mathematics (Polya, 1957). (Compare also the principles of interpretation collected by Sunstein, 1989.) Each is a heuristic rule that a working mathematician or a practising lawyer might use. Both Polya and Llewellyn took a realistic approach to their respective disciplines, by describing how work is actually done, rather than emphasizing the textbook "Sunday School" version of law or mathematics, where the product of the analysis is presented formally, without regard to the process that gave rise to the result.

Note that the need to do statutory interpretation is not necessarily the result of inept legal drafting. Rather it is an endemic feature of rule-creation that resists a legislature's best good-faith drafting efforts. Most generally, the persistence is due to the nature of the law and its relation to society; more particularly, to factual circumstances unanticipated at the time of drafting and a changing societal context (Levi, 1949; Hart, 1958; Fuller, 1958; Sunstein, 1989).

† "A statute cannot go beyond its text" *vs* "To effect its purpose a statute may be implemented beyond its text", and "If language is plain and unambiguous it must be given effect" *vs* "Not when literal interpretation would lead to absurd or mischievous consequences or thwart manifest purpose".

‡ The word *rule* here often means the rule derived from the common law or a "rule of the case", a short statement of what the case stands for.

2.3. MIXED PARADIGM REASONING IN OTHER FIELDS

Although law is the focus of this discussion of mixed CBR/RBR paradigm reasoning, lawyers are by no means the only ones to combine these two different modes of reasoning. For instance, mathematicians, policy makers, meteorologists and designers use hybrid approaches.

Mathematics bears pointed comparison to the law (Polya, 1965; Lakatos, 1976; Rissland, 1978). Both have rules (in mathematics, theorems, lemmas) and cases (examples) but the characterization of what counts as an answer (in mathematics, something proved) and how the answer changes over time (in mathematics, almost never) are very different (Rissland, 1984). Nonetheless, problem solving in each requires combining case-based and other sorts of reasoning.

Mathematicians routinely combine reasoning deductively and reasoning with examples. Even though mathematics is an extreme example of an area with a "strong" domain theory—in the sense that the definitions, axioms and theorems formally, completely and unambiguously define the domain—examples constitute a powerful aspect of expertise (Rissland, 1978), which is, unfortunately, usually overshadowed by the more formal aspects. The "dialectical" process discussed by Lakatos (1976) depends critically on use of exemplar cases as much as it does on proof analysis. This point was also borne out in Lenat's mathematical discovery system AM, which used examples as a powerful source of control and focus of attention (Lenat, 1977).

Traditionally in mathematics one does not try to "prove" by example that which can be deductively established. On the other hand, in the absence of useful theorems or successful deduction, the best one can do is to reason with examples and counter-examples. The "control" of these two styles of reasoning can be complex and opportunistic, as described in Polya's "alternating process":

> A problem to prove is concerned with a clearly stated assertion A of which we do not know whether it is true or false: we are in a state of doubt. The aim of the problem is to remove this doubt, to prove A or to disprove it . . . To prove A we should look for some propositions from which, or for some strategy by which, we could derive A. To disprove A we should look for a counterexample.
>
> A good scheme is to work alternatively, now in one direction, then in the other. When the hope to attain the end in one direction fades, or we get tired of working in that direction, we turn to the other direction, prepared to come back if need be, and see, by learning from our work in both directions, we may eventually succeed (Polya 1965, p. 50).

Thus one reason to switch to case-based reasoning arises when deductive, theorem-proving reasoning stalls; when the cases examined stand as counter-examples, one abandons or otherwise modifies one's deductive goals. In the opposite direction, when one has a hunch or is ready to make an inductive leap based on success with cases, one switches to deductive reasoning to prove the conjecture.

Legal reasoning also suggests a sense of alternating between two modes of reasoning:

> So in the lawyer's working day he is constantly involved in an interplay between emerging facts and constructed theories. The facts which are recited initially suggest theories, which when amplified and modified by thought and work suggest further inquiries concerning facts, which again suggest amplification and modification of theories.

> The alternating process continues until a solution is recognized and acted on. In the interplay, acceptable descriptions of significant facts and acceptable statements of relevant theories are hoarded: facts without significance and theories without relevance are discarded, until the solution (sometimes, of course, false) emerges. No fact is significant without theory: no theory is relevant without facts (Morris 1937, p. 35).

Thus, in mathematics and law there is a need for combining different modes of reasoning. While case-based inferences have more of an exalted status in the law, especially common law, than in mathematics, both case-based and rule-based inferences are needed in both disciplines. Furthermore, expert behavior in each discipline can be viewed as an exercise in theory formation. In both there is a sense in which one "defaults" to CBR when deductive reasoning fails and uses CBR as a "sanity check" when deductive reasoning succeeds. Such uses of CBR were investigated by Gardner (1987) in her landmark research on open-textured concepts and their relation to the paradigm of hard/easy questions.

Many domains which have become classic application domains for expert systems, such as medicine, geology or financial planning, are in fact mixed paradigm domains. Cases exist and there are many questions having competing or contradictory answers, which are often a matter of degree and depend on point of view. For instance, in medicine even though heuristic, diagnostic rules have formed the core of medical expert systems, there is a rich body of specific cases which ought not to be ignored (Koton, 1988*b*). As in law, every expert has a great deal of case-based knowledge (e.g. specific cases from personal practice, such as "Mrs. Jones, the woman whose unexpected diagnosis turned out to be borderline hypertension", paradigm text book cases, unusual cases within a physician's personal experience) which can be brought to bear, especially in cases where application of the rules are unclear or require judgement. Equally important, even though expert systems traditionally treat concepts like "hypertension" as well-defined, such terms really are not so clear-cut: part of their meaning lies in how they were used in past cases by the community of medical practitioners. In "softer" domains like foreign policy, cases can play an even larger role since the domain theory is often extremely weak in the sense that there may not even be express rules or concepts and, if there are, they suffer from all manner of definitional flaws. In such domains, the only thing one knows for sure are past cases and that these cannot be ignored (Neustadt & May, 1986).

Many of the rule-based approaches in what are truly mixed paradigm domains are attempts to express a classification taxonomy based on cases in rule form. For the most part, there is nothing wrong with this aside from the fact it ignores a large part of expert knowledge, or at the least, forces it into another form. However, where it is impossible to induce general rules from a corpus of cases—for instance, because similar cases have different categorizations—reasoning with the cases themselves provides a method that avoids risky generalizations and construction of *ad hoc* conceptual classifications (Skalak & Rissland, 1989).

3. Background: case-based reasoning

In this section, we review some general background on case-based reasoning and summarize the work of our research group on a type of CBR called "precedent-based" CBR.

3.1. CBR IN GENERAL

Case-based reasoning is the process of using the results of past problem-solving episodes (cases) to analyse or solve a new problem, explaining why the past analysis or solution is, or is not, similar and therefore whether it can justifiably be followed, and/or adapting the past analysis or solution to meet any different requirements of the new situation. Central to CBR are such notions as "similarity", "difference", "relevance", "analogy" and "on-pointness".

There are two basic kinds of CBR: (1) "precedent-based" or "interpretive" CBR, in which past cases, "precedents", are used not only to find a new solution (typically an analysis of interpretation together with its pros, cons and sensitivity to various factors), but also to justify it and explain its rationale; and (2) "problem-solving" or "planning-oriented" CBR, in which past cases are used to find a new solution, typically a plan, detailed problem solution or course of action, and where the new solution is typically generated by adaptation of a past one. Major differences between these two varieties of CBR are the indispensability of interpretation and justification in precedent-based CBR and the central role of plans and adaptation in problem-solving CBR.

Anglo-American common law with its doctrine of *stare decisis,* or reasoning by precedent, is a paradigm of a domain where precedent-based CBR techniques are used for analysis and interpretation of a new case in terms of old cases and where decisions are mandated to be justified by cases (Levi, 1949; Llewellyn, 1989). In precedent-based CBR, the relevant precedents, or citations to them, are woven into the solution (an argument or explanation) and a significant part of the reasoning deals with assessing the similarities and differences between the past and present situations. In an adversarial setting, if one wants to emphasize the appropriateness or relevancy of a past case to a new one, one concentrates on their similarities; if one wants to block such a view, one concentrates on differences. The HYPO system is a paradigm example of a precedent-based CBR system, which computationally defines notions such as "relevant case" and "best case" in order to generate a skeletal precedent-citing argument (Ashley, 1990). In certain precedent-based CBR, the emphasis is on reasoning with prototypical cases and a gradient of prototypicality (e.g. based on how much an explanation of a prototypical case is strained to cover another case) to classify a new case (Bareiss, 1989).

Design and planning tasks provide excellent examples of problem-solving CBR since new solutions are found through transformations of past ones. In current approaches to problem-solving CBR, problem solutions and patches to them are remembered and dynamically indexed (Kolodner, 1987, 1988*a,* 1988*b*; Hammond, 1988, 1989). In this type of CBR, one delves into the detailed plan steps of the cases in order to adapt them (Hammond, 1989). Some programs, such as Hammond's CHEF, actually get better at their problem-solving since they have the ability to learn fixes to enable the system to anticipate and compensate for past failures, such as undesirable side-effects of an adaptation. Some older work on example-based reasoning, such as "constrained example generation" (Rissland, 1981; Suthers & Rissland, 1988), followed a problem-solving CBR approach; however, it was less sophisticated in the management of memory and reasoning about adaptations. In certain systems, fragments of cases can brought together to construct a new solution (Kolodner, 1988*a*). In Branting's recent work (see Branting's article in this issue), a

more problem-solving CBR approach is taken to the generation of precedent-based arguments.

When presented with a problem situation, a CBR system proceeds as follows:

(1) *Find relevant cases from case memory.* The goal of the first step of CBR is to cast a broad net to retrieve enough "good" cases to support the rest of the reasoning. Techniques in this critical, initial step depend on the structure of case memory, what information is actually stored in a case, indices into the case base, notions of similarity and relevance, and what the case is to be used for and what general knowledge about the domain is available.

(2) *From the collection of cases retrieved in Step 1, select the most promising case or cases to reason with.* The set of relevant cases retrieved in Step 1 is winnowed to a few candidates worthy of intensive consideration as the foundations for the interpretation or solution to be generated in the next step. In problem-solving CBR, the approach typically is to choose one best case to reason with and this case will be adapted to solve the current problem.† In precedent-based CBR, there is usually a select handful of best or most-on-point cases, each representing a different line of attack on the analysis. In an adversarial setting presenting competing interpretations or conflicting goals, each side typically has its own set of best cases.

(3) *Construct a solution or interpretation for the new case.* In problem-solving CBR, one constructs a solution to the new case by adapting solutions from old ones, usually one particularly apt case selected in Step 2, although some systems attempt to merge relevant fragments from several cases. In precedent-based CBR, the cases selected in Step 2 are used to construct arguments and an interpretation. This involves drawing analogies by focusing on shared, relevant similarities with "positive" supporting cases, that is, cases speaking for a proposed interpretation, as well as distinguishing cases and thwarting analogies with "negative", oppositely pointing cases. The result of Step 3 is a solution with supporting implementation details or an interpretation or argument with supporting discussion.

(4) *Test and criticize the output from Step 3.* In this step, one evaluates the results of Step 3. In precedent-based systems, this can done by taking the opposing stance (as a devil's advocate) and/or posing hypotheticals to test the robustness of an interpretation. For instance, one might construct a slippery slope argument to show that the dividing line between the interpretations is more chimerical than real and that while interpretations in the extremes may be clear, those in the middle ground are not. In planning-oriented CBR systems, this step is sometimes performed with a simulation model of the domain. This phase is very helpful in giving the consumer of the result, such as a judge or tactical decision maker, a feeling for a solution's utility, robustness or weak points.

(5) *Update case memory/adjust indexing mechanisms.* The solution or interpretation plus underlying facts and supporting reasoning is stored for future use. Indices for case retrieval may need to be adjusted.

† This absence of reasoning with several best cases is more of an historical accident than a theoretical limitation; in fact, one could use precedent-based techniques to aid in the selection of a few well-chosen best cases to be used as the basis of the solution in problem-solving CBR. Similarly, the absence of the use of adaptation in precedent-based CBR, for instance, to adapt past arguments to suit a new case, is also a coincidence of the research history of the field. We expect to see a greater synthesis of the two CBR approaches (for instance, see Branting's article in this issue).

In summary, there are certain canonical sources of knowledge in any CBR system: a case base, indices into the case base, metrics for assessing similarity or relevancy of cases, and procedures for creating the actual solution or interpretation. Case-based reasoning is a multi-step process involving several sources of knowledge: (1) accepting a new problem case and analysing it (e.g. by computing features, relations and indices) to retrieve relevant cases from case memory; (2) selecting a set of best cases from which to craft a solution or interpretation for the problem case; (3) deriving a solution or interpretation; (4) testing the solution (e.g. with simulations) or the interpretation (e.g. with hypotheticals); and (5) storing the newly solved or interpreted case into case memory and appropriately adjusting indices into memory.

3.2. PRECEDENT-BASED CBR

In precedent-based CBR, as exemplified by Ashley and Rissland's HYPO (Rissland & Ashley, 1987, 1988; Ashley & Rissland, 1988*a*; Ashley, 1988, 1990) and the derivative TAX-HYPO† Rissland and Skalak (1989*a*) system, the key idea is to reason from cases similar to the current case in order to argue for a particular interpretation in the current case and to justify the reasoning in terms of the past cases. A large part of the effort is on selecting and arguing about the relevancy of cases: showing similarity with supporting cases and distinguishing contrary cases. The result is an argument or explanation complete with citations to relevant precedents.

Cases in HYPO-style systems are represented at two levels: (1) *factual features,* which represent the input description of a case; and (2) *factual predicates,* which are computed from the factual features (Rissland *et al.*, 1984; Ashley, 1990). At the first level, a case is represented as a structured, hierarchical set of frames, with the slots containing the values of the factual features (e.g. the EMPLOYEE is Max Frankel, the EMPLOYER is *The New York Times,* the LOCATION of the office is in Frankel's home), with frame units addressing related sets of facts (e.g. the physical layout of the home and home office). At the second level (the "interpretation frame" level, Ashley, 1990), a case is represented slightly more abstractly in terms of features, computed from the concrete factual features input to the system (e.g., INTERP-FRAME-CONDITION-OF-EMPLOYMENT, INTERP-FRAME-NECESSARY-TO-PERFORM-DUTIES). The cases are stored at the level of factual features, and are contained in a case knowledge base (CKB), which is an unstructured, "flat" memory. Although we have included inter-case links of various kinds in some of our cases bases (e.g. case-1 overrules/affirms/cites case-2), we have not yet made any significant use of them to date.

Indices into the CKB in HYPO-style systems are called *Dimensions* (Rissland *et al.*, 1984; Ashley, 1990). Dimensions encode domain knowledge that certain groups of operative facts and features derived from them enable one to make certain

† The TAX-HYPO project involved the excision of (a small amount of) domain-dependent knowledge from the HYPO program in order to create a domain independent HYPO shell. The resulting shell was then re-instantiated with knowledge relevant to an area of income tax law. The goal of the TAX-HYPO project was to determine how well the mechanisms of HYPO would work in an area governed by a legal statute. HYPO's original domain was trade secrets misappropriation, an area governed substantially by case law.

arguments or address a case in a certain way. In effect, Dimensions summarize lines of cases that have addressed a point of law in a particular way. Dimensions are engineered with dimensional prerequisites that specify what data must be available in order for it to make sense to address the problem situation in terms of that dimension. If all of a dimension's prerequisites are present, the dimension is considered *applicable.* A dimension speaks not only to whether a particular approach applies to a case but also how strong or weak the case is according to that approach. For instance, in a case brought for the misappropriation of trade secrets (HYPO's domain), the fewer people told of a secret, the stronger the argument that the secret has been adequately protected. In a case dealing with the income tax deduction for a home office, the domain discussed below, the more one uses a home office to discharge primary responsibilities, the stronger the argument that it is a bona fide office that should receive the deduction. Dimensions are diagnostic knowledge sources that include a rule-like statement joining the dimension's factual prerequisites to the line of argument it enables. Furthermore, of all the dimension's prerequisites one or two are designated as being indicative of a case's strength along the Dimension; these prerequisites are called *focal slots.* For example, in the trade secrets domain, *number-of-disclosures* is focal to the *voluntary-disclosure* Dimension; *percentage-of-time-spent-in-home-office* is the focal slot for the *home-work-relative-time* Dimension in the home office deduction domain (see section 6.). Focal slots typically take their values from totally or partially ordered sets and a case's position on that order relative to other cases of known strength is used to assess its relative strength.

Metrics for assessing relevancy or "on-pointness" in HYPO-style systems are based on the intersection between the sets of Dimensions applicable to the instant case and cases from the CKB. In HYPO, for instance, the greater the overlap, the more on-point the precedent is (Ashley, 1990). However, HYPO does not rely merely on the number of dimensions appearing in the intersection. Cases from the CKB are partially ordered according to the precise subset of Dimensions that appear in common with the problem case. The partial order is captured in a lattice referred to as a "claim lattice" (Ashley & Rissland, 1988*a*; Ashley, 1990). Construction of this partial ordering allows HYPO-style systems to deal with various lines of cases with bearing on a specific subset of relevant Dimensions; such lines of cases are linear suborderings within the claim lattice. For an in-depth exposition of HYPO's mechanisms for indexing, retrieval and sorting of relevant cases, as well as of HYPO's case and index knowledge representation scheme, see Ashley (1990) and Ashley's article in this issue. CABARET can also apply a metric based on the symmetric difference of the applicable dimensions in two cases. Both systems reason about the relative strength/weakness along the dimensions in assessing on-pointness.

4. CABARET: an overview

CABARET is a system that interleaves reasoning with cases and reasoning with rules. To get an idea of how CABARET performs mixed paradigm reasoning, consider the following scenario.

Suppose one has begun reasoning using rule-based reasoning and has reached an impasse in backward chaining because a particular statutory predicate cannot be

resolved (said to be true or false) on the basis of the rule set and the facts known. For example, suppose the "regular use" requirement of the statutory rule governing the home office deduction is unresolved.† Suppose further that this creates a "near miss" situation: the unresolved statutory predicate ("regular-use") is the only unmet antecedent of a rule. One can then switch to CBR and focus CBR on generating arguments *pro* and *con* particular interpretations for the predicate in question, "regular use".

In particular, if one wants to obtain the rule consequent (say, to receive a home office deduction) one might try to establish the interpretation that the missing predicate is indeed met in the situation. If the case-based reasoner produces results favoring this interpretation (e.g. because all the most on point cases support this), one can then resume RBR with the unresolved predicate assumed to be resolved. If the cases do not point to such a clear result, one could select the one that looks "best" (on the basis of some assessment, such as the strength of an argument) and resume RBR with that result. Thus, a conclusion supported by CBR can be "inserted" into a rule-based justification.

Alternatively, one could use CBR to establish that the missing predicate isn't really needed to establish the consequent of the rule. This tack may be made by finding case support where the consequent was deemed to hold even though the predicate did not. For instance, one might search for cases where a taxpayer received a home office deduction but failed to establish the "regular use" predicate. On the basis of such a case, one could argue that one ought to receive the deduction even though a stated precondition is not met.

With either approach, one should additionally post tasks to remedy any deficiencies in the support for the desired interpretation, or at least inform the user of potential weak links in the supporting argument. Furthermore, if one is working in a situation where there are several predicates that the CBR-side needs to deal with and there is a variety of ways to approach them (e.g. because there are many lines of cases addressing the issue), then CBR might be further constrained by the requirements of RBR (e.g. focus the CBR on lines of cases which can be used for resolving other unresolved predicates).

4.1. A MIXED PARADIGM ARCHITECTURE

CABARET is an agenda-based architecture for integrating CBR and RBR. It provides a domain-independent shell with the following basic features:

(1) There are two primary knowledge sources (**co-reasoners**): a HYPO-style case-based reasoner and a traditional rule-based reasoner. Each co-reasoner is capable of running in a stand-alone manner.
(2) Each co-reasoner has a dedicated **monitor** that makes observations on its co-reasoner's progress toward a solution, including goal satisfaction and certain intermediate problem-solving states, and describes them in a language (the "Control Description Language", CDL) understandable to the controller.
(3) Observations are reported to a **controller** process that uses the monitors' observations to decide how the system as a whole and the individual processes are to

† Regular use—as opposed to occasional use—of a home office is required to receive a deduction under Section 280A. See section 6 for a discussion of that and other statutory requirements.

proceed. This decision is based on the controller's set of *control heuristics*, which are also encoded in the control description language.

The primary tasks for the monitors are harvesting observations and translating them into the CDL. The primary task for the controller is to take those observations and generate tasks for the individual CBR and RBR processes to perform. Figure 1 is a sketch of CABARET's architecture.

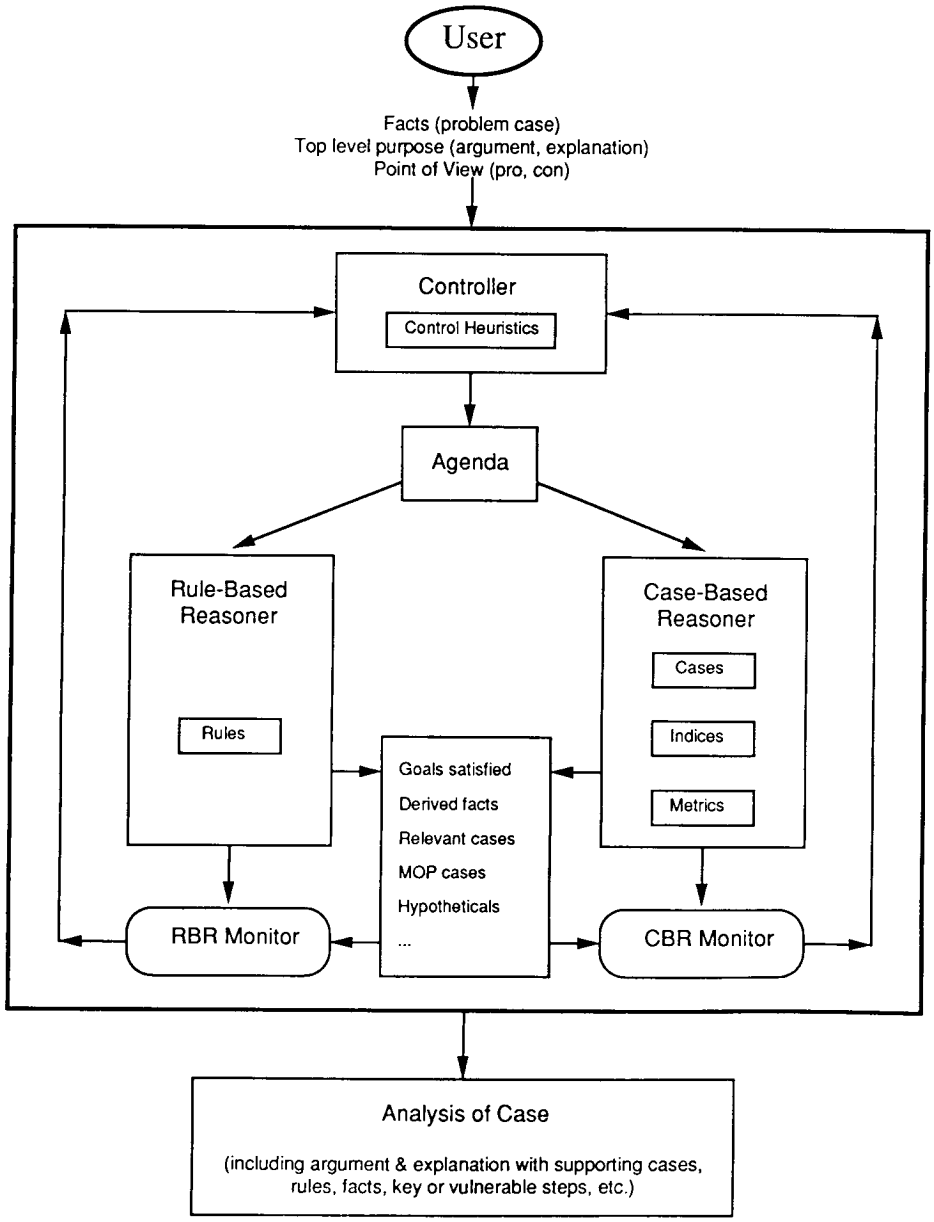

FIGURE 1. Dataflow diagram for the CABARET architecture.

The primary static† sources of knowledge in CABARET are:

(1) Case knowledge base (CKB), encoded in a case representation language, and index knowledge base (IKB), encoded in part in terms of factual predicates, used by the CBR co-reasoner.
(2) Rule-base, encoded in terms of factual predicates, used by the RBR co-reasoner.
(3) Domain knowledge, encoded as domain hierarchies ("half-order theories"), accessible to all modules.
(4) Heuristic control rules, encoded in the Control Description Language, used by the controller.

The primary dynamic repositories of knowledge are:

(1) CBR Reports (a data structure containing descriptions of the intermediate and the final results of analysis by the CBR knowledge source).
(2) RBR Reports (analogous to the CBR Report, for the RBR knowledge source).
(3) Control facts (the context for the heuristic control rules).

The overall behavior of CABARET is as follows:

(1) The user inputs a case (a "fact situation"), a point of view regarding it (e.g. that it is desired to establish or defeat an interpretation of it), and an overall goal for the system (e.g. produce an argument, an explanation for the interpretation).
(2) The system analyses the fact situation by using rules and cases, opportunistically reasons and creates a trace of reasoning tasks concerning the applicability and relevancy of known rules and cases.
(3) Generates an argument or explanation from the desired point of view as to why a certain interpretation should or should not hold, complete with case-based and rule-based support both pro and con.

CABARET dynamically interleaves CBR and RBR by spawning specific CBR and RBR tasks on the fly. The information that is observable at the CBR/RBR processor level influences what processing is to be done next.

4.2. A SYSTEM DEVELOPMENT TOOL

CABARET serves two purposes: (1) to experiment with hybrid, agenda-driven architectures; and (2) to support our efforts to build precedent-based CBR systems. As a CBR tool, CABARET provides an environment for building, modifying and maintaining the basic components of a CBR system, such as CKB's, libraries of indices, various metrics of similarity, etc. In CABARET we attempted to reduce the burden on the system builder for such tasks as building and maintaining pointers between cases and indices and for performing the bookkeeping associated with adding and deleting cases from case memory. Some specific features of CABARET

† These do not change during a CABARET run; changes must be made by the user or system maintainer.

are the following:

- Object types for cases, indices, metrics, factual predicates, etc.
- A three-tiered set of basic functions for cases and indices of: *definitions, prototypes* and *instances*. The definitional level is used for defining objects, their components (e.g. slots) and their relations; this level is particularly useful when knowledge engineering a new application domain. The prototype level is reserved for creating prototypical subclasses and instances of objects and relations (currently not implemented). The instance level is used for building concrete instances of defined objects, especially during knowledge acquisition.
- Basic functions for operating on cases and indices, such as *create, modify, rename, delete, copy, revise* and functions to *browse* individual objects, their components and groups of them (e.g. all the cases indexed by a set of indices). Each toolkit function has a version tuned to meet the requirements of each level and each type of object. CABARET's basic functions "know" how to tailor themselves based on object type and tier without specification by the user.
- CABARET allows experimentation with CBR internals such as similarity metrics and methods for computing most-on-point cases and neighborhoods of cases (e.g. HYPO's on-point metric and the symmetric difference metric).
- Facilities to use or load different CKB's (e.g. only Federal cases, only cases recently entered), index libraries, rule-bases and control heuristics.
- Explicit mechanisms to handle half-order domain knowledge (e.g. knowledge about slot filler values, ranges, hierarchies, etc.). Explicit mechanisms for capturing domain knowledge are particularly important in mixed paradigm systems where co-reasoners use the same domain knowledge.

As an experimental environment, CABARET was designed to facilitate experimentation with its various pieces without undue work. A knowledge engineer who is instantiating the shell in a new domain may want to experiment with the collection of facts used by the rule-based component, the collection of rules, the factors used as case indices, the cases in the case base, and so forth. To do this CABARET provides a "Control Panel" interface, which is principally mouse-driven and which allows a user developing an application to switch in and out these various components of the system. In particular, the precise subcollection of the universe of control rules to be in force can be set by the user. A user may "turn off" the sanity checks (if time is critical), or may run CABARET as a stand-alone HYPO-style case-based reasoning system or as an independent production system that does not rely on support from cases to aid rule chaining. Of course, the selection of a smaller subset of control rules for activation may not result in as studied an analysis of a problem situation. However for real-time, satisficing (read "quick and dirty") analyses, a limited collection may be desirable.

5. Control in CABARET

CABARET uses a classic agenda-based controller, which applies heuristic control rules to observations about the state of problem-solving in order to propose tasks and rank order the agenda. In effect in this approach, proposed tasks constitute the righthand sides of the heuristic control rules and the observations, passed "upwards" by the monitors and couched in the Control Description Language, constitute the lefthand sides.

In CABARET, the tasks are posted to an agenda using approximately 36 heuristics. The following are examples of heuristics currently used:†

- Fail ⇒ Switch: if one mode of reasoning fails, then switch to the other.
- Sanity Check: once a conclusion is reached, switch the form of reasoning to determine if the same conclusion is derived.
- RBR Near-Miss: if all but one antecedent to a rule can be established, then use CBR to broaden the application of the rule with respect to the missed antecedent.
- Broaden Missing Antecedent: to broaden a near-miss rule, use CBR on the missing antecedent to show the antecedent can be established with supporting cases.
- Broaden-01: to broaden a near-miss rule, use CBR to show the missed antecedent is not necessary (i.e. there are cases where the consequent is true but the antecedent is unestablished, unknown or false).
- Deliberate Open Texture: on deliberate open-textured predicates use CBR.
- Broaden Open Texture: appeal to any available domain knowledge to find supporting cases that deal with similar circumstances. For example, find cases that deal with elementary or secondary school teachers as an analogy to a problem situation that involves a university professor.
- Match Statutory Predicates: find a case that has failed and succeeded on exactly the same statutory predicates.

These rules are encoded in the Control Description Language. The CDL contains approximately 15 terms, such as: *near miss, missing antecedent, all but one, obtains, necessary, deliberate open texture, most on point case, point of view.* CABARET's monitor processes contain the knowledge required to translate their observations of the co-reasoners into the CDL. For instance, the RBR Monitor can inspect the RBR module's processing to determine if a rule that would establish a statutory predicate has failed to fire because a single antecedent has not been established. This capacity requires that the CBR and RBR processors be designed as "glass boxes", transparent to some inspection by the monitors.

5.1. POINT OF VIEW AND ARGUMENT STANCES

How one reasons in a statutory domain depends on one's point of view. For instance, a taxpayer's point of view typically is to argue in favor of establishing the home office deduction, whereas the Internal Revenue Service typically argues against the deduction. In CABARET, the user can specify a *point-of-view*, which is a descriptor in CABARET's Control Description Language. The *point-of-view* is associated with the top-level goal, such as to establish an argument for a home office deduction, and is also associated with certain immediate subgoals of the top-level goal, such as to establish a particular statutory predicate, for example, "regular-use". In the current implementation, CABARET supports *pro* and *con* points of view.

The *point-of-view* descriptor enables CABARET to use the cases and rules to support a particular position. For instance, the RBR Near Miss heuristic given above really was stated from the *pro* point of view, that of wanting a rule to succeed; there are dual heuristics for defeating a rule. Thus, the control rules really

† See the Appendix for a list of heuristic control rules.

contain the pair of control heuristics dealing with rule-based near misses:†

[PRO&RBR-NEAR-MISS⇒BROADEN:] If a rule is a *near miss* and one *wants the rule to succeed,* then *broaden* the interpretation of the rule.

(A particular broadening heuristic, in turn, might suggest using CBR to argue that the missing antecedent has been established in analogous situations.)

[CON&RBR-NEAR-miss⇒CONFIRM-MISS:] If a rule is a *near miss* and one *wants the rule to fail,* then use CBR to *confirm the miss.*

(A heuristic to confirm the miss might suggest using CBR to argue that the missing antecedent is not present in the current problem situation but is necessary.)

The choice of point of view, in combination with the possibility that a rule may fire or fail to fire, leads to four strategies, called **argument stances** here, that CABARET may follow in using cases to support rule-based reasoning:

(1) confirming that a rule should succeed (confirming a "hit");
(2) confirming that a rule should not succeed (confirming a "miss");
(3) enabling a rule to succeed ("broadening" the scope of a rule); and
(4) disabling a rule from succeeding (limiting the scope of a rule, "discrediting" a rule).

These circumstances under which the Argument Stances are applied are summarized in the matrix in Figure 2. For instance, if Rule 1 has fired, but the user doesn't like some consequence of Rule 1 (the point of view is "con"), CABARET may take the argument stance of "discrediting the rule" and look for ways to do just that. Or if Rule 1 has failed to fire, but the user really wants to make it applicable, CABARET may look for ways to "broaden" a rule, that is, make it cover more factual situations (in particular, the user's) than indicated on its face.

Broadening is the stance that uses cases to argue that a rule or predicate applies to a situation where the rules hold it does not apply. In discrediting, one uses cases to argue that the rule or predicate does not apply to a situation even though it appears it does. Confirming a hit or a miss simply uses cases to support the interpretation indicated by the rule. How an Argument Stance is effected depends on the body of on-point cases that are found. This is discussed in the next section.

5.2. CASE-BASED ARGUMENT MOVES: WAYS TO ACCOMPLISH ARGUMENT STANCES

Each of the four Argument Stances can be carried out in different ways, depending on the nature of the cases available to provide support and the result of the attempted rule application. CABARET has methods, which we call Argument

Rule conditions/ Point of view	**Rule conditions met**	**Rule conditions not met**
Point of view: *Pro*	*Confirm the Hit*	*Broaden the Rule*
Point of view: *Con*	*Discredit the Rule*	*Confirm the Miss*

FIGURE 2. Table of the four Argument Stances and the conditions under which they are assumed.

† It is interesting to note the similarity of these heuristics to those used by mathematicians regarding the necessity and sufficiency of conditions. See the discussion in section 2.3.

Moves, that carry out the Argument Stance in a particular circumstance. Argument Moves depend on the point of view, the interpretation indicated by the rule, and the relevant cases that can be found. One can think of the Argument Stances as general strategies and the Argument Moves as tactics implementing them. In CABARET, both stances and moves are represented in the heuristic control rules. Figure 3 indicates the relationship between argument stances and argument moves.

For instance, broadening, which is used to make a rule or a rule-predicate apply to a wider range of situations than it appears it does, can be accomplished by using CBR in a variety of ways. CBR can be used to find cases where the rule's conclusion was held to apply, point out the similarities between those cases and the present case, and thus effectively show that the conditions you have are sufficient to obtain the consequent of the rule. Alternatively, cases could be used to show support for the interpretation that the facts actually satisfy the missing conjunct, and consequently, the firing of the rule. Yet another way to accomplish broadening is to use CBR to find cases where the rule did not fire, but the consequent of the rule still held, thereby showing that the missing conjunct is not necessary to obtain the result of the rule.

In general there are four different sorts of case-based Argument Moves that can

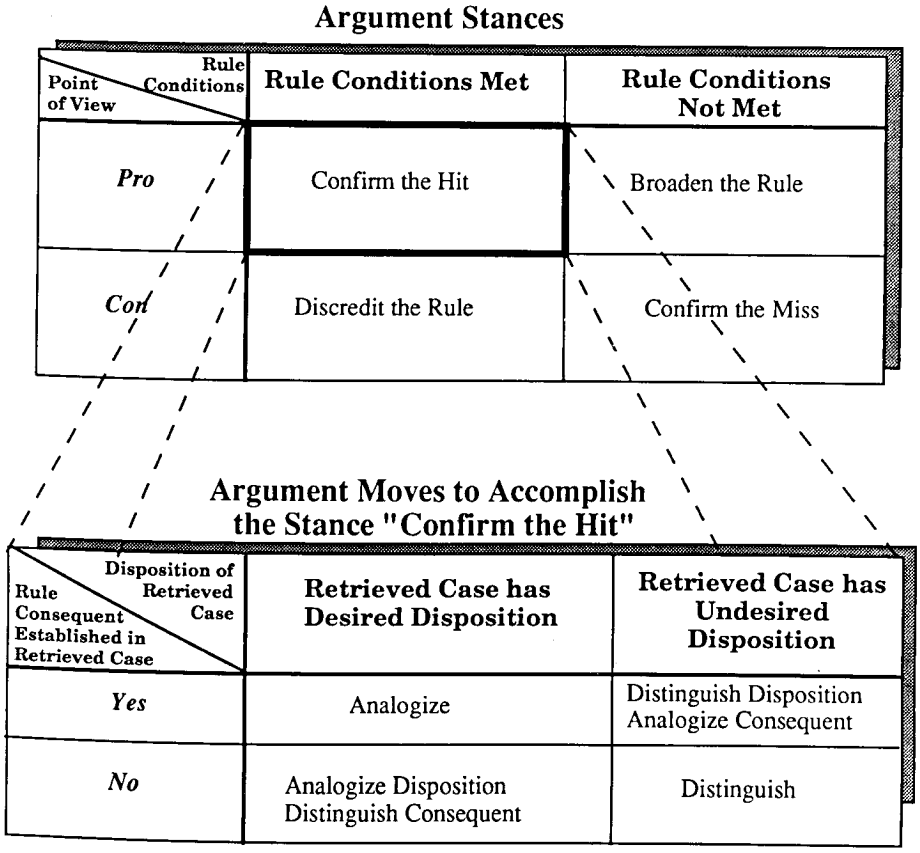

FIGURE 3. The relationship between Argument Stances and Argument Moves.

Rule consequent established in retrieved case	Retrieved case has desired disposition	Retrieved case has undesired disposition
Yes	Analogize	Distinguish disposition Analogize consequent
No	Analogize disposition Distinguish consequent	Distinguish

FIGURE 4. Table of Argument Moves to accomplish the stances *Broaden* and *Confirm a Hit.*

be used to effectuate each of the four stances. Figure 4 summarizes for the stance "confirming a hit" when these moves may be invoked, according to the disposition of a retrieved case and whether a particular rule consequent was established in the retrieved case. Thus, the move to confirm a hit using a case where the rule consequent was established will come from the top row; the choice of move depends on whether the relevant case has the same, "pro", disposition or not. It is possible that a case in which a desired rule consequent was established to have been decided "the wrong way" from the arguer's point of view. For instance, one could have "regular use" established as the consequent of a rule but the case as a whole denying the desired deduction, with a denial on some other basis. Thus, one would use a combination of analogizing the consequent (regular use) and distinguishing the ultimate outcome of the case.

The two stances with the "*pro*" point of view (confirm a hit and broaden) and the two stances with the "*con*" point of view (confirm a miss and discredit) share the same tables of argument moves. The table for the Argument Stances Broaden and Confirm a Hit is given in Figure 4. Figure 5 gives the table for the stances discredit and confirm a miss. For instance, suppose a taxpayer fails to satisfy the requirements of a rule that would establish regular use of a home office. The taxpayer's stance then would be to broaden that rule. The specific argument move to be made by the taxpayer will depend on each case retrieved from the case base. In this setting, if a case is retrieved (or presented by the IRS) that was decided for the IRS where regular use was not established by that rule, the taxpayer will distinguish that IRS case (lower right-hand pane of Figure 4). On the other hand, suppose the taxpayer's stance was to confirm a hit by assuming that the regular-use rule *did* establish regular use by the taxpayer. With this Stance, the taxpayer's Argument Move, in response to the case cited by the IRS, will remain the same: to distinguish that case from her own situation. Thus, the stances *Broaden and Confirm a Hit* are advanced by the same Argument Move.

Disposition of retrieved case/ Rule consequent is established in retrieved case	Retrieved case has desired disposition	Retrieved case has undesired disposition
Yes	Analogize disposition Distinguish consequent	Distinguish
No	Analogize	Distinguish disposition Analogize consequent

FIGURE 5. Table of Argument Moves to accomplish the stances *Discredit a Rule* and *Confirm a Miss.*

Despite this sharing of Argument Moves between stances with similar perspectives, different stances entail distinctions in the way the moves are implemented and in the degree of argumentative force that an Argument Move has within the context of a particular stance.† Many of the less forceful Argument Moves have not been implemented in CABARET. Internally, an Argument Move is implemented in two stages: (1) retrieval of relevant cases; (2) analogizing or distinguishing those retrieved cases and the current problem case.

The retrieval is done by "filtering" cases that meet two requirements: (a) they have a specified disposition (*pro* or *con*); and (b) a specified statutory predicate is established or not in the retrieved case. For example, a move may filter the case base and return cases that were (a) decided for the pro-taxpayer point of view; and (b) where the "regular-use" requirement was satisfied. To enable this filtering, cases are indexed by outcome and by whether the statutory predicates were established by rule in the case's last (saved) analysis by CABARET. Since a case may be decided either for the one side or the other (the "disposition" is "*pro*" or "*con*") and the consequent of the rule that is in question may have been established or not established in the retrieved case ("rule consequent established" is "yes" or "no"), there are in combination four filters that each argumentative move may perform.

Once a screened set of cases is retrieved, an appropriate rhetorical task—analogize or distinguish—must be performed to complete the argument move. The task depends on the filter used to screen the cases and on the overall argument stance. The task may be to analogize each retrieved case, distinguish it with respect to a particular statutory predicate, perform a combination of those, and similar procedures.

Thus, for example, if the rule to establish the "convenience of employer" predicate has fired and we want it to fire, CABARET will confirm the hit by first retrieving and then examining relevant cases where the disposition is for the taxpayer and in which convenience of employer was established. Then CABARET could analogize those cases by considering all the dimensions, or using those dimensions that speak to the term convenience of employer (for example, whether the office was required by the employer, and whether the office was necessary in order for the employee to perform his or her duties).

5.3. SOME GENERIC ARGUMENT MOVES

To recapitulate, there are four argument stances, each of which depends on the point of view (*pro* or *con*) and status of the rule or predicate (is established or not) in the *current* case. For each of the four instances, there are four Argument Moves, each of which depends on the disposition (*pro* or *con*) and the status of the rule or predicate at issue in a *retrieved* case. Thus, each of the stances has a

† By way of illustration, when the stance is to broaden a rule, it may be more advisable to analogize retrieved cases of *undesired* disposition where the rule consequent is nonetheless established (the top right-hand pane of Figure 4) than when the stance is merely to confirm a hit. In broadening a rule, one attempts to stretch received doctrine, which may require appeal to cases of any ultimate disposition as long as they reflect the desired treatment of the rule consequent at issue. In *Confirming a Hit,* often only a "make-weight" argument is required. One need only supply analogies to cases with the desired disposition where the rule consequent also has been established (the top left-hand pane of Figure 4) and may not have to resort to the rhetorically riskier and more delicate arguments required for broadening. See section 5.3.

four-pane tableau of moves. Furthermore, each tableau contains the same set of moves; the difference between tableaux is in the circumstances under which a move is applied and the details of how it is carried out. In this way, the four moves of (1) *Analogize,* (2) *Distinguish,* (3) *Analogize Consequent/Distinguish Disposition,* and (4) *Distinguish Consequent/Analogize Disposition* can be said to be generic.

Each of these argument moves can bear a little explication.

Analogize: through analogizing, one makes a desired result from a retrieved case applicable to the current, problem case. This move is used when a retrieved case reflects the user's point of view both as to ultimate disposition and as to the establishment of a rule consequent. For instance, if the user's point of view is "*con*", and the stance is to "*Confirm a Miss*", CABARET will analogize a retrieved case that has the desired overall disposition and where the rule consequent is not established. There two ways to carry out the analogizing:

(1) analogizing can be done with respect to Dimensions that speak only to the rule consequent in issue ("*Analogizing by Consequent*"); or
(2) by considering any of the available Dimensions ("*Analogizing by Disposition*").

Either move will help to advance the argument stance to confirm the failure of a rule to fire: analogize cases with a favorable outcome in which that rule consequent is not established. This move is perhaps the most obvious and useful.

Distinguish Disposition and Analogize Consequent: This move is used when a retrieved case reflects the user's point of view as to rule consequent establishment, but not as to ultimate disposition. It involves two subtasks: (1) analogize the retrieved case with respect to the consequent that has been established; but at the same time (2) distinguish it with respect to other factors. It is best that both these tasks are performed, so that analogizing a favorable part of a case does not extend to analogizing the entire case, whose outcome is unfavorable. This move requires a somewhat steadier rhetorical hand than the previous move.

Distinguish: Through distinguishing, one attempts to prevent an undesired result from a retrieved case from being applied by analogy to the current case. This move is applied when a retrieved case does not reflect the user's point of view with respect to both the disposition and the rule consequent. Suppose the user's point of view is "*pro*" the firing of a rule, and CABARET is attempting to effect the stance "*Broaden the Rule*". To argue that the rule should apply to the current situation, CABARET distinguishes cases that are of the opposite outcome, and where the consequent was not established. The argument boils down to establishing that the rule *should* apply in this case because it's *unlike* those cases where the rule didn't apply. In this instance, this move has the flavor of a "double negative".

Analogize Disposition and Distinguish Consequent: This move is used when the retrieved case has the desired disposition but the rule consequent establishment is counter to the user's point of view. For example, if the point of view is "*con*" and the user is trying to discredit a rule, CABARET may retrieve a case where that rule actually fired, but the case did have the ultimate disposition wanted. In this situation, CABARET attempts to argue that a retrieved case is overall similar to the current one and therefore the same general result should apply. At the same time, this move distinguishes the retrieved case as to a particular rule consequent—that it's unlike the current case in regard to a particular predicate. This move requires

the delicate distinguishing of an unfavorable piece of a case that is favorable overall to one's viewpoint. It would only be used to respond to a case cited by an opponent, or if no better cases could be found to support one's point of view. In practice, this move can be difficult to apply effectively.

6. The home office deduction domain

One of the domains in which CABARET is currently instantiated is an area of U.S. Federal income tax law regarding the "home office deduction". The home office deduction domain is governed primarily by Section 280A of the Internal Revenue Code, and we have focused on Section 280A(c)(1), which contains the heart of the statute:

> [A deduction may be taken for] any item to the extent such item is allocable to a portion of the dwelling unit which is EXCLUSIVELY USED on a REGULAR basis—
>
> (A) [as] the PRINCIPAL PLACE OF BUSINESS for any trade or business of the taxpayer,
>
> (B) as a place of business which is used by patients, clients, or customers in MEETING OR DEALING with the taxpayer in the normal course of his trade or business, or
>
> (C) in the case of a SEPARATE STRUCTURE which is not attached to the dwelling unit, in connection with the taxpayer's trade or business.
>
> In the case of an employee, the preceding sentence shall apply only if the exclusive use referred to in the preceding sentence is for the CONVENIENCE OF HIS EMPLOYER [I.R.C. Section 280A(c)(1), capitalization supplied].

The home office deduction deals with the circumstances under which a taxpayer may legitimately deduct on a Federal income tax return expenses relating to an office maintained at the taxpayer's residence. We have supplied capitalization to certain terms to emphasize their role as *statutory predicates*, important words or phrases on which the meaning of the statute turns. In tax litigation over home office deductions, taxpayers and the IRS have argued—and presumably will continue to disagree—about the meaning of these terms. While the meaning of such phrases is sometimes partially clarified by Treasury regulations, statutory predicates are inherently open-textured: their meanings are fundamentally unclear, vary greatly according to the factual context in which they are used, and defeat precise definition by rules. For clues to interpretation and scope, practitioners rely on previously litigated cases that have construed these terms.

In this domain, CABARET's Case Knowledge Base consists of 29 actual and hypothetical cases dealing with the home office deduction and related aspects of U.S. Federal income taxation. The Index Knowledge Base consists of 14 dimensions. The Rule Base contains 10 home office deduction rules, which consist of a representation of Section 280A(c)(1) and related, typically knowledge-engineered condition-action rules, which have been abstracted from tax cases by members of our group and from tax service treatises.

6.1. THE CASE KNOWLEDGE BASE

CABARET's case base in the home office deduction domain currently contains representations of 23 actually litigated tax cases. In addition, there are six

hypothetical cases in the CKB. A complete listing of actual cases is contained in the Appendix. Several examples of litigated cases follow.

- The case of the Ernest Drucker, *Drucker v. Commissioner,* 715 F.2d 67 (2d Cir. 1983), who was a violinist with the Metropolitan Opera Orchestra concerns the CONVENIENCE OF EMPLOYER requirement for employees (among other requirements of Section 280A). Drucker was not provided with any sort of practice room at Lincoln Center or elsewhere, for that matter. Drucker and others in the orchestra thus maintained home practice studios. Practice, of course, was absolutely necessary to the fulfillment of the musicians' responsibilities. The U.S. Court of Appeals for the Second Circuit held that the home practice areas were for the convenience of the Met, since it relieved the Met from providing practice space.
- The case of Lars Honan, an Eastern Airlines pilot, *Honan v. Commissioner,* 48 T.C.M. 79 (1984), addresses disjunct (A) of Section 280A(c)(1): PRINCIPAL PLACE OF BUSINESS. Honan spent an average of three days a week flying and four days on the ground. He usually spent his days off at his home in Virginia. There in his home office, he claimed he studied 25–30 hours to fulfill his obligation under FAA regulations to be familiar with the latest changes to flight manuals, aircraft technical manuals, charts, maps, etc. The Tax Court denied that his home office was his principal place of business, implying that the cockpit was.
- The case of Sally Meiers, a laundromat manager, *Meiers v. Commissioner,* 782 F.2d 75 (7th Cir. 1986), also addressed disjunct (A): PRINCIPAL PLACE OF BUSINESS. Mrs. Meiers, who managed a laundromat, spent an hour a day there, assisting customers, washing customers' clothes and cleaning. Two hours a day she spent in a home office where she drafted work schedules for her employees and did the laundromat's bookkeeping. In rejecting the rigid application of the "focal point test", a legal test used to determine a taxpayer's principal place of business, the court said that, at least where the taxpayer's job involves distinct activities, the principal place of business is where the dominant portion of her work is accomplished. Applying this approach, the court found the home office to be the principal place of Mrs. Meier's business and granted the home office deduction.
- The case of Yolanda Baie, *Baie v. Commissioner,* 74 T.C. 105 (1980), a woman who operated a foodstand near her residence in Los Angeles also addresses PRINCIPAL PLACE OF BUSINESS. Appearing for herself in front of the Tax Court (and apparently doing an excellent job), Ms. Baie argued that—since she used her kitchen for preparing food, particularly hot dogs for her stand the "Gay Dog"—her kitchen (and not the stand) was her principal place of business. In denying the deduction, the court used the "focal point test", which looked to the "focal point" of the taxpayer's activities, which was the Gay Dog itself.
- The case of Max Frankel, Editor of *The New York Times, Max and Tobia Frankel v. Commissioner,* 82 T.C. 318 (1984) addresses disjunct (B): MEETING OR DEALING. Mr. Frankel maintained an office at his home in the Bronx, which he used for reading the morning papers, writing memoranda, clipping materials, and speaking by telephone to his employees, to community leaders and to prominent politicians. Although the Tax Court granted a home office deduction on grounds relating to a consulting position Mrs. Frankel had, it denied that Mr. Frankel met any of the three disjunctive requirements of the statute, (A), (B) or (C) above. In particular, it held that the use of the telephone to conduct business does not satisfy the MEETING OR DEALING predicate, which was construed to require the physical presence of the business contacts.

The hypothetical cases included in the CKB are an assortment of cases which are either skeletal, clear cases or factually rich cases, which cause CABARET to exhibit its "bells and whistles" (captured, for instances, in the hypothetical *Bells* case). The clear cases provide test cases for CABARET from the legal point of view; the factually rich, from an AI point of view.

6.2. THE DIMENSIONS

CABARET's index knowledge base in the home office deduction domain currently contains 14 Dimensions based on factors taken from legal cases, law journal analyses and commercial tax materials. Example Dimensions are:

- *specific-frequency-of-use* (how many hours per week the home office is used);
- *relative-home-work-time* (the relative amount of working time spent at a home office and at other locations);
- *personal-use* (the extent of personal activities conducted in the home office);
- *primary-responsibility-location* (whether the home office was where the primary responsibilities of the taxpayer were carried out);
- *income-from-home-office* (the income derived from activities conducted in the home office).

The Dimensions can be grouped according to the statutory predicate they address. A complete listing of the dimensions, grouped according to the statutory predicate addressed, are given in the Appendix. CABARET's CBR module tracks HYPO's knowledge representation scheme for dimensions, except that several slots used by HYPO are not used in CABARET. For a complete exposition of HYPO's dimensions and their representation, see Ashley (1990). Figure 6 sets out CABARET's representation for the relative-home-work-time Dimension.

6.3. THE RULES

CABARET has a small collection of heuristic rules (10 rules) regarding the home office deduction, in addition to a representation of Section 280A(c)(1) as a CABARET rule. There are no helpful regulations currently in effect that explicate the meaning of the predicates in Section 280A(c)(1), so most of CABARET's rules have been culled from legal opinions and proposed regulations, or have been constructed by us as reasonable "bright-line" rules that one working in this domain might use.

An example rule of thumb is the exclusive-use rule, which says that the home

```
(dimension
 rel-home-work-time
   :name rel-home-work-time
   :short-title "Rel home work time"
   :prerequisites (taxpayer
                   home-office
                   exists-other-office
                   taxpayer-works-for-employer
                   percent-time-in-home-office)
   :near-miss-prerequisites (percent-time-in-home-office)
   :focal-slots ((home-office percent-time-in-home-office))
   :ranges '(((:type interval)
              (:values (0·0 100·0))
              (:units "percent total work time")))
   :pro-p-directions '((greater))
)
```

FIGURE 6. The relative-home-work-time dimension.

```
(rule exclusive-use-rule
      :antecedent
       (:and (:seq (?:x interp-frame-use-for-any-personal-purposes ?:w)
                          (:lisp (member ?:w (negatory))))
             (?:x interp-frame-physical-separation-within-unit t)
             (:seq (?:x interp-frame-presence-of-personal-furnishings ?:z)
                          (:lisp (member ?:z (negatory)))))
      :consequent (?:x exclusive-use t)
      :directions :both
      :interned-in (:home-office-rules)
      :info ((statutory-predicate . t))
      :comments "Exclusive use")
```

FIGURE 7. The exclusive use rule.

office may be considered as satisfying the "exclusive-use" predicate if the home office is not used for any personal activities, it is physically separated from the rest of the dwelling, and there are no personal furnishings present.

Figure 7 shows the Exclusive Use rule as encoded by CABARET. Note that the rule is encoded at the factual predicate level (the second level of representation), it can be run either backward or forward, and is tagged as dealing with the statutory predicate "exclusive use".

7. An example: the *Weissman* case

To illustrate the workings of CABARET, particularly the dynamic interleaving of CBR and RBR, we discuss how CABARET processes an actual litigated case, the *Weissman* case. The *Weissman*† case is a recent home office deduction case that incorporates a somewhat more flexible view of some of the requirements for a home office deduction than in most previous home office cases. This problem situation therefore serves as a pointed example of CABARET's approach. The facts of *Weissman* are as follows:

> David Weissman was a professor of philosophy at City College in New York City. Although he was provided with a shared office at City College, it was not "a safe place to leave teaching, writing, or research materials and equipment". [Court of Appeals Opinion, p. 513, quoting the lower Tax Court opinion.] So, in his 10-room apartment, Professor Weissman maintained a home office, consisting of two rooms and adjoining bathroom. He estimated working between 64 and 75 hours each week, but spent only 20% of that time in his City College office. The Internal Revenue Service challenged Professor Weissman's 1976 tax return deduction of $1540 of rent and other expenses relating to his home office. The IRS claimed that Weissman's home office did not satisfy the requirements of the statute, particularly that it was not his principal place of business and that it was not for the convenience of his employer, City College.

One of the major issues that CABARET (or an attorney analysing this situation) has to consider is the issue of whether Weissman has established one of the disjunctive requirements of the statute. Since the facts of the case indicate that the home office is not in a separate structure (Section 280A(c)(1)(C)) and is not used for

† *Weissman v. Comm.*, 751 F.2d 512 (2d Cir. 1984).

meeting or dealing with clients of any sort (Section 280A(c)(1)(B)), Weissman's only option is to show that his home office is his principal place of business.

Principal place of business turns out to be an issue that is of particular importance in occupations where there is a strong intuitive connection between that job and its usual *situs,* such as between a teacher and a classroom or between an airline pilot and a cockpit. This intuitive association has been memorialized in the "focal point test" that courts have applied to determine a taxpayer's principal place of business.†

We concentrate on CABARET's treatment of the principal place of business issue in discussion of the *Weissman* trace in the next section.

7.1. EXTRACTS FROM CABARET's PROCESSING OF WEISSMAN

In this section, we discuss major points in the trace of CABARET on the *Weissman* case. For this run, we used the complete set of control heuristics. As can be seen, this results in multiple attacks on the same problem and a large amount of checking.

A full trace of the CABARET run is given in the Appendix, where the heuristic control rule applied to yield each task is given. The numbers in the discussion refer to the task numbers in that trace. CABARET's treatment of the principal place of business issue, beginning at Task 27, exemplifies the style of processing done in CABARET. Although we won't discuss the tasks preceding this section of the trace in any detail, the session began with the user-supplied goal of working on the "occupation" of the taxpayer to determine whether the taxpayer was in an occupation favorably viewed for home office claims, but immediately switched to consideration of "regular use" and "convenience of the employer". Concerning "regular use", CABARET establishes that Weissman meets this requirement (Tasks 2–6) and confirms it (Tasks 11, 12). Convenience of employer is taken up in Task 7 on the CBR side and confirmed on the RBR side in Task 13, and reconfirmed on the CBR side in Tasks 14, 15. See the Appendix for a full trace.

The question of Weissman's occupation is taken up again in Task 16 and forms the focus of attention in tasks up to Task 25. After ensuring that dimensional analysis has been done using all Dimensions—and not merely those corresponding to a particular statutory predicate—CABARET begins addressing the "principal place of business" term. We shall come back to the question of occupation, after discussing CABARET's treatment of principal place of business.

Task 27: In the configuration used in this run, the system has a preference for case-based reasoning, so it starts by doing dimensional analysis on the principal place of business predicate. Three of the four Dimensions for principal place of business are applicable: *income-from-home-office, relative-home-work-time* and

† The focal point rule applied by the Tax Court sought to determine the "focal point" of a taxpayer's activities, which was often the most visible situs of a taxpayer's job. The test was susceptible to mechanical application, whereby a taxpayer's occupational category, rather than his or her particular duties, was considered. For example, a rigid application of the test would place a judge's principal place of business in the courtroom, regardless of the amount of work actually done outside the court. More recently in applying the focal point rule, some courts have considered the circumstances and location of each individual taxpayer's responsibilities. The Second and Seventh Circuits have spearheaded movement towards a more flexible determination of a taxpayer's principal place of business, although it is unclear whether these courts reject the focal point test or merely require its more flexible application. See, for example, the *Meiers* and *Drucker* cases outlined in section 6.1. The *Weissman* case was an early case that applied an extended examination of the location of a taxpayer's employment.

relative-time-in-home-office, a variant of the second Dimension. The fourth Dimension indexed under principal place of business, *primary-responsibility-location,* is not applicable because the location of Weissman's primary responsibility is not immediate from the facts of the case, but is rather an issue in dispute. The Dimension *income-from-home-office* is triggered because its dimensional prerequisites were satisfied; in particular, Weissman received income due in part to the work he performed at home. *Relative-home-work-time* is triggered because the case contained sufficient information to address the relative amount of time that Weissman spent working at home and in the office.

Task 28: Since the heuristic "sanity-check-by-rbr-predicate" is applicable (as are all sanity checks in this run), CABARET attempts to confirm the reasonableness of the CBR analysis by backward chaining on the goal principal-place-of-business. The only rule with principal place of business as its consequent does not fire, but only one antecedent is missing: the rule is a near miss. The missing antecedent is whether the primary responsibilities were discharged in the home office. The underlying case representation does not contain enough information to make this determination and that antecedent remains unsatisfied.

Task 29: With further rule-based progress blocked, CABARET now resumes its focus on case-based reasoning methods. Building on the dimensional analysis performed in Task 27, CABARET now constructs and displays a claim lattice for the statutory predicate principal-place-of-business by considering only those Dimensions that have a bearing on it (Figure 8). The default metric, the one originally used by HYPO, is applied, in which similarity is determined by the degree of intersection of applicable dimensions for the problem case and for each retrieved case. The *Meiers* case, together with two hypothetical cases, show up as most on point cases in the claim lattice. The *Drucker* and *Baie* cases are in the first level of the lattice and are nearly most on point, although *Baie* (decided for the IRS) is trumped by *Meiers* (decided for the taxpayer). That is, *Meiers* is more on-point than *Baie* and was decidedly oppositely.

In fact this analysis reflects the course of the law. In *Meiers,* which historically came after *Drucker, Weissman* and *Baie,* the Seventh Circuit Court of Appeals said,

> Since *Baie,* the Tax Court has consistently applied the focal point test in evaluating the deductibility of home office expenses. [At 78]. . . .
>
> Yet we do not believe that this approach is fair to taxpayers or carries out in the most appropriate way the apparent intent of Congress."
>
> In determining the taxpayer's principal place of business we think a major consideration ought to be the length of time the taxpayer spends in the home office as opposed to other locations [At 79].

Task 30: CABARET checks the constructed claim lattice for "deficiencies". The only deficiencies that CABARET currently looks for are (1) a surfeit of most on point cases, and (2) whether the root node of the lattice is a "conflict node". A conflict node is a node that contains cases of different dispositions (Ashley & Rissland, 1988*b*). However, CABARET finds neither a root conflict node nor too many most on point cases in the present lattice.

Thus at the conclusion of Task 30, CABARET has completed a case-based analysis of *Weissman* and has determined that *Meiers* is a case on which Weissman can rely regarding the principal place of business and that can be used to trump the

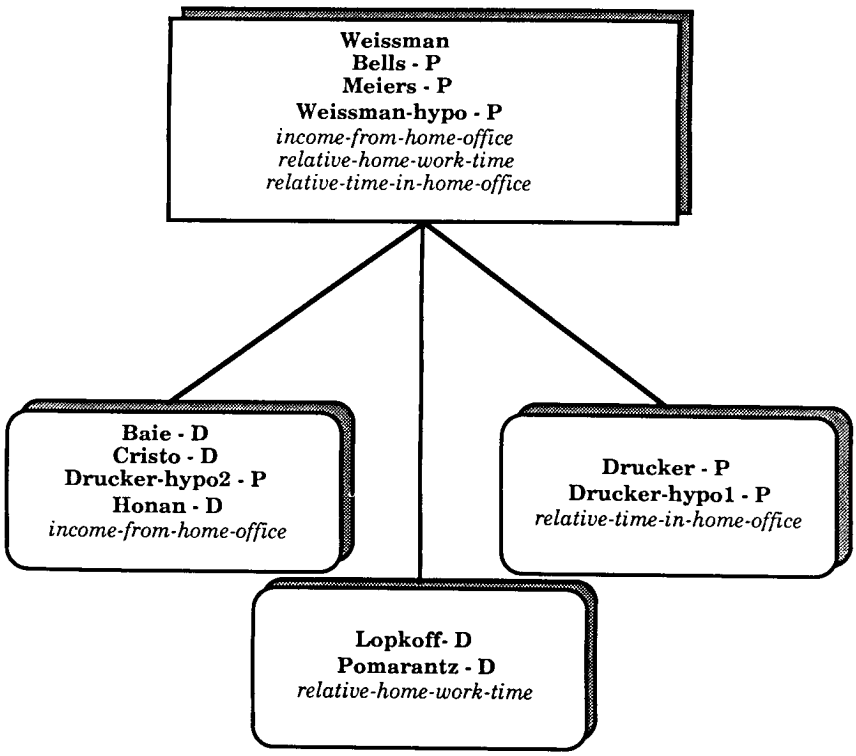

FIGURE 8. The claim lattice for the statutory predicate "Principal Place of Business".

IRS's possible reliance on *Baie* as a countervailing case. CABARET has found the *Drucker* case, which can be used as support. On the other hand, CABARET has not been able to clinch the principal place of business with rules. The situation is hopeful, however, since all but one antecedent of the rule establishing the principal place of business requirement has been satisfied. Attempts to make good on this near miss are the subject of the next three tasks.

Task 31: Since the principal-place-of-business rule experienced a near miss in Task 28, CABARET makes several attempts to broaden the scope of the principal-place-of-business-rule. One technique to broaden a near miss is to attempt to establish a missing antecedent. One way to establish a missing antecedent is to find, if possible, cases in which that antecedent was satisfied. This is the approach taken in CABARET's first attempts at broadening. Again, *Drucker* is found, along with a hypothetical test case from a partition of the case base in which certain hypotheticals reside. An argument that Weissman's primary responsibility location is his home office can be built upon an analogy to the *Drucker* case.

As a matter of fact, an argument of this sort was made in *Weissman,* in speaking about the predicate convenience of employer, which is closely bound up with the principal place of business term:

> The Commissioner attempts to distinguish *Drucker* on the ground that the employer there provided *no* space for practice, while here the employer provided some space, *i.e.*,

> a shared office and the library. *Drucker* is not so easily distinguished, however, for there, as here, the relevant fact is that the employer provided no *suitable* space for engaging in necessary employment-related activities. [*Weissman,* at 516-7.]

Task 32: In a second broadening attempt, CABARET tries to find cases where the principal place of business requirement was also not satisfied by rule, but the case still was decided for the taxpayer. This task was an attempt to show that this predicate was not necessary for the ultimate result the taxpayer wants. Eight such cases are found, including *Drucker* and *Meiers,* which were also found before through direct case-based analysis of principal place of business. All eight cases are analogized and shared dimensions are noted. *Drucker* and *Meiers* share a number of similarities with *Weissman.*

Task 33: A third way to broaden that same rule is to find and distinguish cases where the rule also did not fire, but the decision was for the IRS. This heuristic tries to minimize the damage done by the failure of the rule to fire, by giving a basis to argue that this case is unlike the cases that have been decided the "wrong way", in spite of the rule's failure to fire. Ten cases are retrieved; a variety of Dimensions that are present in each retrieved case but not in the problem case and *vice versa* are returned.

Thus, *Drucker* and *Meiers* are emerging as excellent cases for Weissman to use: they can be used to support his case and to show that Weissman meets the requirements of the tax code. These two cases can be used by analogy as cases that were decided for the taxpayer and are quite similar to *Weissman.* In addition, they serve as examples of other cases that were decided for the taxpayer, but failed to satisfy the principal place of business rule contained in the CABARET rule base. At this point the CBR report contains sufficient information to make a solely case-based argument in support of Weissman's deduction. The RBR and CBR reports together contain the backbone of a composite argument that Weissman meets the principal place of business requirement because he almost satisfies that rule, and case support exists to argue for the broadening of that rule.

CABARET can also take advantage of domain knowledge that is not available in the forms of rules or cases. While a knowledge engineer building a mixed paradigm system must decide on appropriate representations for his knowledge—rules or cases—there is some knowledge that might be better expressed using yet another representation such as a semantic net. CABARET stores such information in global data structures so as to provide access to it from either the CBR or the RBR side of the system. In a current instantiation of CABARET in the home office domain, a separate domain "is-a" hierarchy is provided for the occupation of the taxpayer. While there are no legal rules that refer explicitly to the occupation of the taxpayer, it does constitute a relevant additional consideration. In Knobbe (1986), for example, the stereotypical merits of the claims of each of half a dozen occupational categories is presented. As a matter of informal practice, teachers may have a more difficult time receiving a home office deduction, since they have to overcome the presumption that their principal place of business is the classroom. Doctors, on the other hand, who commonly work out of an office attached to their dwelling, may not have such a presumption working against them. Occupation becomes a pragmatic consideration, and a tree of occupational categories and specific occupations is

useful additional information for a hybrid reasoner, as shown in the following passage from a CABARET run.

Task 16: At this point in CABARET's analysis, the predicates regular use and conveinence of employer have been analysed, and the focus of attention is returned to the taxpayer's occupation. Recall that Task 1 was a user-supplied task to backward chain on that predicate. The result of Task 1 was that since Weissman is a professor, he's not in a list of traditionally "favored" occupations. The heuristic "occupation test" rule requires in essence a history of successful home office claims by taxpayers with the same occupation as the current taxpayer. That single antecedent is unsatisfied in Weissman's case, and a near miss occurs with respect to the occupation test rule. CABARET looks for ways to broaden that rule. In Task 16, the system looks for cases to establish the missing antecedent. None are found.

Task 17: CABARET tries to find and analogize cases dealing with a related occupation, (high school and elementary) teachers. It finds the *Cousino*† case, which dealt with a junior high school teacher, but only finds a couple of dimensions in common with *Weissman.*

Task 18: CABARET tries to find and analogize cases dealing with a more expansive occupational category, "educators". It finds no cases, however.

Task 19: As a final attempt to broaden the heuristic rule relating to the occupation of the taxpayer, CABARET analogizes other cases which were decided for the taxpayer, but did not involve favorable occupations. Nine cases are found; the Dimensions they have in common are noted.

Task 20: Since we are dealing with a small case base, we have maintained a crude, shotgun heuristic rule, which, as a last resort, retrieves all the cases that have been decided for the point of view of the user, in this case the taxpayer's point of view.

Task 21: The lattice-creating module of CABARET attempts to create a claim lattice of cases with respect to occupation. But since no dimensions are implemented that inform the occupation, a trivial lattice consisting of a single node results.

Task 22: The lattice created in Task 21 is checked. The trivial lattice triggers the "too many most-on-point cases" deficiency; with no implemented dimensions, all cases are most-on-point.

Task 23: Cases are distinguished that were decided for the IRS and where the occupation test rule also did not fire. The implicit argument is that, despite this rule's failure to fire, the current fact situation is nonetheless unlike cases that were decided for the opposing side.

Task 24: The CBR module tries to do dimensional analysis to establish whether the occupation is one traditionally favored for home office deduction claims. But no implemented dimensions speak to this predicate.

Task 25: Another attempt to create a claim lattice is made in view of the defects uncovered in Task 22, this time using the minimum difference metric.

These many attempts by CABARET to expand the occupation test rule result in failure, and this negative result suggest that Weissman may still have an uphill battle in attempting to overcome the apparent historical difficulty of professors to establish the home office deduction. One case has been found that can be relied upon

† *Cousino v. Comm.*, 679 F.2d 604 (6th Cir. 1982).

(*Cousino*). But the trace demonstrates a variety of techniques that CABARET can apply to try to overcome a block in processing.

In particular, CABARET examines the claim lattices that it creates in the course of executing CBR tasks. If a claim lattice computed using one similarity metric turns out to be deficient for any of a variety of reasons, the claim lattice is recomputed using another metric. Two possible metrics are the default metric first applied by HYPO, "maximum overlap", and the "minimum difference" metric. "Maximum overlap" holds that two cases are similar if they have many similarities; "minimum difference" construes two cases are similar if they have few differences. If a claim lattice computed using the default metric has "too many" most on point cases, then a new claim lattice is computed, using a different metric. If a large percentage of cases in the case base are considered most on point cases, then the discriminatory power usually inherent in the concept of "most similar" is lacking. Or, if the root node of the claim lattice (the node that contains the problem case) is a conflict node, containing many cases of equal similarity but opposite result, then the metric is toggled. An advocate would then argue similarities or differences as being paramount according to the metric that produced the lattice that works to his benefit. All the most on point cases, for instance, may be for the user's point of view in one lattice, but not in another. In the *Weissman* case, for example, during the processing of CABARET, a regular claim lattice for the predicate "exclusive use" is generated using the usual maximum overlap metric (Task 36). The root node of the lattice contains a number of cases and is in fact a conflict node. The change-similarity-metric control heuristic then generates a claim lattice for the minimum difference metric (Task 40). In this metric, the most on point cases are *Bells* and *Pomarantz*. Now, the task of the arguer is much easier, since only the *Pomarantz*† case needs to be "distinguished away". The other cases that previously were decided for the defendant (*Cally, Cally-hypo, Honan*)‡ now are no longer most on point cases. These cases are now in nodes one level below the most on point cases, since these cases possess extraneous Dimensions *personal-use* and *personal-furnishings*. These cases can now be distinguished as having those two Dimensions, which are not applicable to *Weissman*.

In the balance of the trace, CABARET deals with the other statutory predicates for the home office deduction. It establishes "exclusive use" and checks that it holds in Tasks 34–40. It then deals with "in separate structure", which fails to hold, in Tasks 41–46, and "meeting or dealing" in Tasks 47–50.

Thus, at the conclusion of this run, CABARET has established that Weissman does satisfy the "convenience of employer", "regular use" and "exclusive use" predicates; fails the "in separate structure" and "meeting or dealing" predicates. Concerning the "principal place of business" predicate, CABARET finds that this result cannot be established with RBR, but does find a number of good cases supporting the interpretation that Weissman should receive the home office deduction. *Drucker* and *Meiers* are on-point for this critical predicate. The results for the analysis of the entire case are summarized in the RBR and CBR Reports, given in Figures 9 and 10. The CBR Report reflects a case-based analysis that takes

† In *Pomarantz*, a hospital physician used a home office for medical journal reading.

‡ *Cally* involved a hospital physician in the Catskills who occasionally used a home office to see patients.

```
Top level goal:
    GOAL            : (WEISSMAN HOME-OFFICE-DEDUCTION T)
    SUCCESS         : NIL


Statutory predicates:
    (SEPARATE-STRUCTURE NIL)
    (REGULAR-USE T)
    (PRINCIPAL-PLACE-OF-BUSINESS NIL)
    (OCCUPATION-TEST NIL)
    (MEETING-OR-DEALING NIL)
    (EXCLUSIVE-USE T)
    (CONVENIENCE-OF-EMPLOYER T)


Fired rules:
    (OCCUPATION-TEST-RULE NIL)
    (REGULAR-USE-RULE T)
    (EMPLOYER-CONVENIENCE-RULE T)
    (PRINCIPAL-PLACE-OF-BUSINESS-RULE NIL)
    (EXCLUSIVE-USE-RULE T)


Near misses:
    RULE:                   OCCUPATION-TEST-RULE
    MISSED ANTECEDENT :
    ((SEQ (WEISSMAN OCCUPATION NAME 'PROFESSOR)
          (LISP (MEMBER 'PROFESSOR (GOOD-OCCUPATIONS-LIST)))))
    CONSEQUENT:         ((WEISSMAN OCCUPATION-TEST T))


    RULE:                   PRINCIPAL-PLACE-OF-BUSINESS-RULE
    MISSED ANTECEDENT:
    ((WEISSMAN PRIMARY-RESPONSIBILITY-IN-HOME-OFFICE T))
    CONSEQUENT          ((WEISSMAN PRINCIPAL-PLACE-OF-BUSINESS T))


Goals set:
    ((WEISSMAN OCCUPATION NAME 'PROFESSOR) T)
    ((WEISSMAN OCCUPATION-TEST T) NIL)
    ((WEISSMAN REGULAR-USE T) T)
    ((WEISSMAN EXISTS-FREQUENCY-OF-USE-INFO T) T)
    ((WEISSMAN SPECIFIC-FREQUENCY-OF-USE-INFO (55·6)) T)
...
```

FIGURE 9. A summary of the RBR report for the *Weissman* case.

into account all of cases in the CKB, both real and hypothetical. Occasionally, hypothetical cases are most on-point, effectively demoting actual cases that would be most on-point in the absence of the hypotheticals. In this CBR Report, the *Bells* and *Weissman-hypo* cases are hypothetical; *Weissman-hypo* is a variant of *Weissman*, which was stored in the CKB before this run on the actual *Weissman* case. Through its Control Panel interface, CABARET's case base can be restricted to litigated

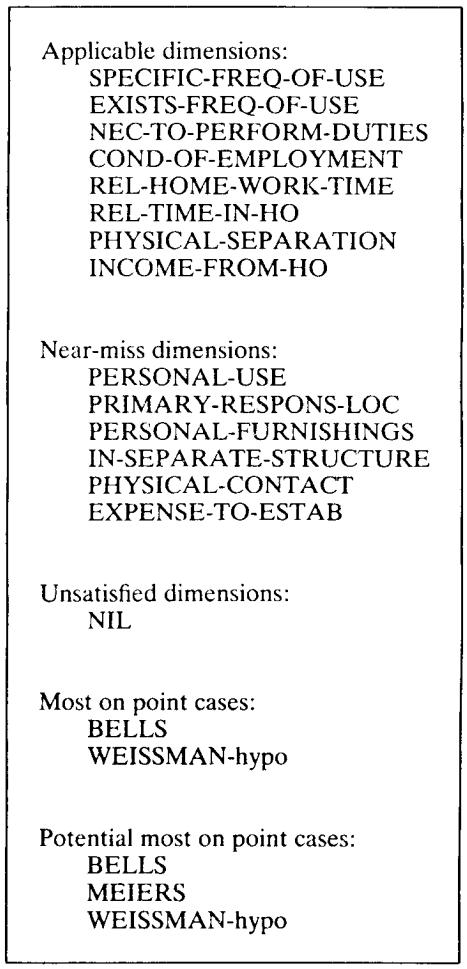

FIGURE 10. A summary of the CBR report for the *Weissman* case. All cases in the Case Knowledge Base, both real and hypothetical, have been taken into account. (With hypothetical cases considered, the CBR module of CABARET regards the *Drucker* case as nearly most on-point although *Drucker* does not appear in this particular Summary. See the discussion on pp. 872–873.)

cases only. In that event, the most on-point cases are *Drucker, Meiers* and *Honan* (described above); they would then appear in the summary of the CBR Report output by CABARET.

Currently, CABARET reports a summary of its processing only through its side-by-side display of the CBR and RBR Reports and various claim lattices. We are currently adding to CABARET a module to produce a template-driven argument similar to that provided by HYPO. A task or series of tasks are associated with a template containing canned text describing the system's argument stance. A template is then instantiated with the combined results of the case-based and rule-based knowledge sources. Figures 11 and 12 include a sample of CABARET's current argument output.

```
;;;  ==========================================
;;;  ARGUMENT for the WEISSMAN case with respect to
;;;  the predicate PRINCIPAL-PLACE-OF-BUSINESS:
;;;  ==========================================

While the rule PRINCIPAL-PLACE-OF-BUSINESS-RULE
 did not fire and the consequent of the rule,
 PRINCIPAL-PLACE-OF-BUSINESS, WAS NOT established,
 we may appeal to the following arguments
 to support a claim for the predicate PRINCIPAL-PLACE-OF-BUSINESS:

[1.] Note that only one conjunct of that rule,
((WEISSMAN PRIMARY-RESPONSIBILITY-IN-HOME-OFFICE T)), was missing.

  For cases where that domain rule did fire and the result of the case was favorable,
  consider the following cases as analogies:
    ADAMS, DRUCKER, FRANKEL, JUNIOR CHAMBER, MEIERS,
      SCOTT, . . . .

    . . .
    To analogize DRUCKER and WEISSMAN, consider the following factors
      possessed by them in common:

          there was evidence as to the frequency of usage of the
                home office by the taxpayer,
          the home office was necessary to perform the taxpayer's
                duties . . . .

[2.] Looking at case-based analysis, . . .
 dimensional analysis on the WEISSMAN case yields
 for the predicate PRINCIPAL-PLACE-OF-BUSINESS:
 The APPLICABLE factors are:
          income was derived from activities in the home office;
          there was evidence as to the relative use of the home
              office and other work places;
          . . .
 The NEAR MISS factors are:
       the home office was the location where the primary
            responsibilities were discharged.
 The UNSATISFIED factors are:
            NONE.
```

FIGURE 11. Excerpts from CABARET argument for the *Principal Place of Business* predicate.

For a pure COMMON LAW argument, the best cases
to cite with respect to the
predicate PRINCIPAL-PLACE-OF-BUSINESS are:
BELLS MEIERS WEISSMAN-hypo

To analogize BELLS and WEISSMAN, consider the following factors
in common: . . . .

[3.] The best cases for the OPPOSING side with respect to
the predicate PRINCIPAL-PLACE-OF-BUSINESS are:
BAIE CRISTO HONAN LOPKOFF POMARANTZ.

To distinguish BAIE from WEISSMAN,
consider the following factors that were present
in WEISSMAN but not in BAIE:

there was evidence as to the frequency of
usage of the home office by the taxpayer;
there was evidence as to the relative use
of the home office and other work places;
the home office was physically separated from the living area
. . .

On the other hand, also consider the following factors
that were present in BAIE but not in WEISSMAN:
. . .

FIGURE 12. Excerpts from CABARET argument for the *Principal Place of Business* predicate, continued.

8. Critique of CABARET

8.1. STRENGTHS

CABARET provides an architecture for integrating CBR and RBR in an opportunistic manner that allows one reasoning paradigm to compensate for deficiencies in the other and for each to supplement the other. In particular:

(1) CABARET provides CBR approaches to handling problems with open-textured predicates and ill-defined rules.
(2) The control heuristics used by CABARET provide a codification of reasoning strategies in mixed paradigm reasoning and statutory interpretation.
(3) CABARET, through its control rules, especially those that define and implement argument stances and argument moves, provides a computational approach to a theory of argumentation, which enriches previous work of our group on this topic.
(4) CABARET provides an environment for developing mixed paradigm CBR/RBR systems.

(5) In CABARET, the CBR and RBR paradigms have equal status. Each reasoner can call or be called by the other.
(6) Methods to analogize and distinguish cases have been extended by exploiting the presence of the rule-based module in CABARET's architecture. In a system that interleaves CBR and RBR, cases can be compared on the basis of how they perform under a rule set, as well as on the basis of purely case-based dimensional analysis.

In summary, the insights from CABARET's approach and implementation are three-fold: (1) they are useful from the computer science viewpoint as a hybrid architecture for mixed paradigm reasoning; (2) they are useful from the cognitive modeling perspective in that they provide a detailed account of such reasoning, which is consonant with the performance of a human legal reasoner; and (3) they provide descriptions and mechanisms that can be used for pedagogical purposes, such as teaching students (both law students and others) how to go about reasoning and coping with difficulties in such mixed paradigm domains.

8.2. WEAKNESSES

While CABARET offers some initial steps toward the integration of diverse reasoning paradigms, it exhibits a variety of shortcomings in its design and implementation. A few are noted here; some may provide fertile ground for research.

(1) CABARET demonstrates only local intelligence in the choice of tasks for interpretation; it lacks any overall control plan.
(2) The system has no ability to investigate alternative worlds representing different interpretations of the facts. Truth maintenance facilities are not present in CABARET.
(3) The hypothetical-creation capabilities of HYPO have not been implemented yet in CABARET, with more work to be done on the creation of hypotheticals in a mixed paradigm environment.
(4) The argument generation module of CABARET does not adequately integrate the processing of the CBR and RBR components. For example, if a case were good for one point of view to cite on one statutory predicate in a rule, but very bad for that point of view with respect to another statutory term, CABARET would blindly plow ahead and cite that case.
(5) While CABARET's CKB Browser expands the knowledge acquisition bottleneck, case input remains a somewhat laborious process.
(6) CABARET is uninterruptible and synchronous, so that asynchronous changes to working memory or asynchronous procedural call-outs are not permitted. (cf. Bonissone *et al.*, 1990, which describes a design for a mixed paradigm reasoner that allows asynchronous call-out.)

9. Possible future research directions

Two possible approaches to controlling a mixed paradigm system may provide fruitful research. The first direction is a response to what we perceive as an irony in CABARET. While traditional rule-based processing alone is unsuitable for a variety

of problem-solving tasks, we have nonetheless implemented CABARET's control module as a forward-chaining production system. To eradicate this irony, we have considered giving CABARET a case-based controller. In this CBR approach to control, past statutory interpretation episodes would be used to derive a plan for creating an interpretation of a new case. On the basis of these past examples of performing statutory interpretation, a CBR-control module would determine what tasks must be performed by the CBR and RBR knowledge sources. This would import problem-solving CBR into our largely precedent-based approach: the problem is to generate a plan for interpreting a statute with respect to a new problem situation. To do this would require control cases (past cases of interpretation), control similarity metrics (as to similarity of interpretation problems), and control dimensions (to retrieve past interpretation episodes). This research direction would entail a recapitulation of our CBR module at a control level. However, just as CABARET currently uses the same underlying mechanism to do rule-based processing on the domain and control levels, so will it be able to use the same case-based shell for both the domain and control tasks.

A second research direction, and another approach to control, is one that we considered when we originally conceived the CABARET shell. AI software designers will immediately notice that CABARET may be reimplemented as a blackboard system (cf. Walker *et al.*, 1988). Our efforts in developing the current version of CABARET were to use the simplest techniques necessary to research the control heuristics for interleaving the knowledge sources. The interpretation problem did not appear to require the hierarchy of solution space abstract levels or present the complexity of classical blackboard applications (Erman *et al.*, 1980; Nii *et al.*, 1982). Appearances were deceiving. We are now considering the Generic Blackboard Development System (Blackboard Technology Group 1990) to support a CABARET-like hybrid architecture. Preliminary efforts to express CABARET's control rules as GBB knowledge sources, responsive to changes to a control blackboard, have already resulted in a running re-implementation of CABARET.

A third research direction would consist of the addition of yet another knowledge source to CABARET: an inductive learning component. The system is ripe for the addition of some learning algorithm in that CABARET already possesses both the input and a means to handle the output of some inductive algorithms: in cases it has ready training examples, and has a rule-based component to use induced generalizations. We have performed some minor experiments using ID5 (Utgoff, 1988; Quinlan, 1986) and briefly considered this research possibility in Skalak and Rissland (1990).

10. Summary

Our investigations with CABARET shed light not only on questions of architecture and control but also on the workings of the individual reasoning paradigms. It elucidates the process of interpreting ill-defined concepts with knowledge of their use in rules and models and their use in past cases. Ultimately, work on mixed paradigm CBR should help advance other approaches that require reasoning with cases to be successful or efficient, like theorem proving or learning and knowledge acquisition.

Case-based interpretation is necessary in all but the most tightly defined domains. In particular, even though many domains have been treated as if their terms were well-defined in current AI techniques (like expert systems), they often are not and a better approach would be to recognize this and handle them accordingly. The work reported on here is a strong step in that direction. It also provides a bridge between CBR and traditional AI methods such as expert systems (Skalak & Rissland, 1989).

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Appendix: details of CABARET's implementation

CONTROL HEURISTICS

Listed below is the current, and still evolving set of control heuristics applied by CABARET. Each heuristic is followed by an informal description of its function.

- BROADEN-0
  To BROADEN a rule, use CBR to find cases whose *disposition* was consistent with the overall *point of view* provided by the user.
  (This rule suggests a crude, shotgun approach, sometimes useful to unveil a skewed case base.)
- BROADEN-01
  To BROADEN a rule, use CBR to find cases such that the rule did not fire, but the case had a *disposition* consistent with the user's *point of view*. *Analogize* those cases.
  (This rule suggests that one does not need the consequent in order to get a favorable overall decision.)
- BROADEN-1
  To BROADEN a rule, use CBR to find cases such that the rule did not fire, and the consequent of the rule still holds.
  (This heuristic requires a sense of what it means to establish the consequent of a rule (say, a statutory predicate) in the absence of that rule's firing.)
- BROADEN-2A
  To BROADEN a rule, use CBR to *distinguish* cases whose disposition was inconsistent with the user's *point of view* and where the rule did not fire. (The argument that this heuristic uses is slightly attenuated: that the rule should fire in this situation because it's unlike those situations where the rule didn't fire (and the other side lost.))
- BROADEN-3
  To BROADEN a rule, broaden an *open-textured predicate* in the rule.
- BROADEN-4
  To BROADEN a rule, where there is a *near miss* on the rule, run a demon procedure that may provide the missing antecedent.
- BROADEN-MISSING-ANTECEDENT
  To BROADEN a rule, where there is a *near miss* on the rule, try to find cases that establish that missing antecedent.
- BROADEN-OT1-PARENTS
  To BROADEN a rule, expand the *open-textured* predicates in the rule: look for terms that appear in a term hierarchy that are referenced in the rule; look for cases that correspond to terms that are parents of that term in the hierarchy; *analogize* the current case to the close cases where the rule fired.
- BROADEN-OT2-SIBLINGS
  To BROADEN a rule, expand the *open-textured* predicates in the rule: look for terms that appear in a term hierarchy that are referenced in the rule; look for cases that correspond to terms that are siblings to that term in the hierarchy; *analogize* the current case to the close cases where the rule fired.
- CHANGE-SIMILARITY-METRIC
  If a claim lattice has been generated for a predicate, and that lattice is deficient in some way, then change the similarity metric and create a new lattice.

(A claim lattice is deficient if it has a conflict node at its root or yields a surfeit of most on point cases.)

- CON&RBR-HIT ⇒ DISCREDIT
  If a rule has fired and the user's *point of view* is *con* (against) the rule's firing, DISCREDIT the rule.
- CON&RBR-NEAR-MISS ⇒ CONFIRM-MISS
  If a rule has a *near miss,* and the user's *point of view* is that the rule should not fire, CONFIRM-the-MISS on the rule.
- CONFIRM-HIT-01
  To support a rule's firing, find cases with a *disposition* consistent with the user's *point of view* where the rule consequent was established; *analogize* those cases by *disposition.*
- CONFIRM-HIT-1
  To support a rule's firing, find cases with a *disposition* consistent with the user's *point of view* where the rule consequent was established; *analogize* those cases by consequent (a statutory predicate).
- CONFIRM-HIT-2
  To support a rule's firing, use CBR to find no (or a minimum of) cases such that the rule fired and the consequent of the rule doesn't hold.
  (Requires implementation of a sense that a consequent of a rule has failed to have been established in the presence of a rule's firing.)
- CONFIRM-MISS-2A
  To support a rule's NOT firing, use CBR to find cases with the rule didn't fire a *disposition* consistent with the user's *point of view*; *analogize* those cases, by considering all dimensions.
- CONFIRM-MISS-2B
  To support a rule's NOT firing, use CBR to find cases with the rule didn't fire a *disposition* consistent with the user's *point of view*; *analogize* those cases, by considering dimensions relevant to the consequent of the rule.
- DISCREDIT-1
  To DISCREDIT a rule, use CBR to find cases with a *disposition* consistent with the *point of view* given the rule by the user, where the rule does fire, BUT the consequent of the rule was not established *analogize* those cases. (The idea of this heuristic is that even though a rule may fire, that may not be enough to establish its consequent, as demonstrated by analogous cases. This rule requires that the cases have recorded whether certain consequents were obtained, independent of applicable rules.)
- DISCREDIT-2
  To DISCREDIT a rule, use CBR to find cases such that the consequent of a rule is not established and the case went for the opposite side. *Analogize* those cases with respect to that predicate. (The idea is that one may walk a narrow line by finding and analogizing cases decided for the opposite side but which still bear the similarity that the rule consequent was not established. Requires the possibility that a rule may fire, but its consequent may not be established according to an opinion or other authoritative domain judgement.)
- DISCREDIT-2A
  To DISCREDIT a rule, use CBR to find cases with a *disposition* opposite to the user's *point of view,* and where the rule did fire; *distinguish* those cases, taking into account all dimensions.
- DISCREDIT-2B
  To DISCREDIT a rule, use CBR to find cases with a disposition opposite to the user's *point of view,* and where the rule did fire; *distinguish* those cases, taking into account dimensions relevant to the consequent.
- DISCREDIT-3
  To DISCREDIT a rule, NARROW the *open-textured* predicates in the rule.
- DRIVE-WITH-RBR
  To begin analysis, do RBR, backward-chaining on the *top-level goal.*
- MANY-FACTS-DRIVE-WITH-RBR
  To begin analysis where *many facts* are in issue, do RBR, forward-chaining.

- MATCH-STAT-PREDS
  To establish the *top-level goal,* find cases that were decided with the *point of view* of the current case and that failed on exactly the same *statutory predicates.*
- NARROW-MISSING-ANTECEDENT
  To NARROW a rule that's suffered a *near miss,* try to find cases that failed to establish that missing antecedent.
- OPEN-TEXTURE ⇒ CBR
  If there is an *open-textured* predicate that has been satisfied, do CBR on the missed predicate.
- PRO&RBR-HIT ⇒ CONFIRM-HIT
  If a rule has fired, and the user's *point of view* is *pro* the rule's firing, CONFIRM the firing of the rule.
- PRO&RBR-NEAR-MISS ⇒ BROADEN
  If there is *near miss* on a rule, and the user's *point of view* is *pro* the rule's firing, BROADEN the rule.
- RBR-NEAR-MISS ⇒ CBR
  If there is a *near miss* on a rule, use CBR on that predicate.
- SANITY-CHECK-BY-CBR
  If the *top-level goal* has been established by RBR, do CBR to confirm the result of RBR processing on the *top-level goal.*
- SANITY-CHECK-BY-CBR-PREDICATE
  If the *statutory-predicate* goal has been established by RBR, do CBR to confirm the result of RBR processing of a *statutory-predicate* goal.
- SANITY-CHECK-BY-RBR-PREDICATE
  If dimensional analysis has been done on a statutory predicate for the current case, run the RBR backward on that predicate to confirm.
- START-WITH-CBR
  As an initial mode of analysis on the *top-level goal,* do CBR on the current case.
  (This heuristic is implemented so that it also will fire in the event RBR processing fails to establish the top-level goal.)
- START-WITH-CBR-PREDICATE
  As an initial attempt to establish a *statutory predicate,* do dimensional analysis on that predicate.
  (This heuristic is implemented so that it also will fire in the event RBR processing fails to establish the statutory-predicate goal.)
- START-WITH-RBR
  As an initial attempt to establish a top-level goal, do backward-chaining RBR on the *top-level goal.*
- START-WITH-RBR-PREDICATE
  As an initial attempt to establish a *statutory predicate* goal, do backward-chaining RBR to establish that goal.

DIMENSIONS IN CABARET

Listed below are brief descriptions of the implemented dimensions in CABARET, indexed according to the statutory predicate addressed.

(1) Regular-use:

- *exists-frequency-of-use* (whether there is sufficient information in the case to address the issue of how often the home office is used)
- *specific-frequency-of-use* (number of hours per week the home office is used)

(2) Exclusive-use:

- *personal-use* (whether the home office is used for personal activities)
- *physical-separation* (whether the home office is separated from the rest of the living space)
- *personal-furnishings* (extent to which non-business furniture is present)

(3) Convenience-of-employer:

- *condition-of-employment* (whether the employer requires that employee maintain a home office as a condition of her employment)
- *necessary-to-perform duties* (whether the home office is necessary as a practical matter to perform an employee's assigned duties)

(4) Principal-place-of-business:

- *income-from-home-office* (extent to which income is derived from the home office)
- *primary-responsibility-location* (whether the home office is the location where the most important responsibilities of the taxpayer are discharged)
- *relative-home-work-time* (percentage of total work time represented by time spent in home office)
- *relative-time-in-home-office* (percentage of total work time represented by time spent in home office, variant of *relative-home-work-time*)

(5) Meeting-or-dealing:

- *expense-to-establish* (amount of money used initially to establish home office)
- *physical-contact* (extent to which clients visit home office)

(6) Separate-structure:

- *in-separate-structure* (whether the home office is located in a building entirely separate from the rest of a dwelling)

CASES IN CABARET

Listed below are the *bona fide* tax cases currently represented in CABARET's Case Knowledge Base. The CKB also contains six hypothetical tax cases and two separate representations of the Drucker and Weissman cases.

(1) Adams *v.* U.S., 585 F.2d 1060 (Ct.Cl. 1978)
(2) Baie *v.* Comm., 74 T.C.105, (1980)
(3) Cally *v.* Comm., 45 T.C.M. 1312 (1983)
(4) Chauls *v.* Comm., 41 T.C.M. 234 (1980)
(5) Cousino *v.* Comm., 679 F.2d 604 (6th Cir. 1982)
(6) Cristo *v.* Comm., 44 T.C.M. 1057 (1982)
(7) Drucker *v.* Comm., 715 F.2d 67 (2d Cir. 1983)
(8) Frankel *v.* Comm., 82 T.C. 318 (1984)
(9) Gomez *v.* Comm., 41 T.C.M. 585 (1980)
(10) Green *v.* Comm., 707 F.2d 404 (9th Cir. 1983)
(11) Honan *v.* Comm., 48 T.C.M. 79 (1984)
(12) U.S. Junior Chamber of Commerce *v.* U.S., 334 F.2d 660 (Ct.Cl. 1964)
(13) Lopkoff *v.* Comm., 45 T.C.M. 256 (1982)
(14) Meiers *v.* Comm., 782 F.2d 75 (7th Cir. 1986)
(15) Naggar *v.* Comm., 46 T.C.M. 1362 (1983)
(16) Pomarantz *v.* Comm., 52 T.C.M. 599 (1986)
(17) Scott *v.* Comm., 84 T.C. 683 (1985)
(18) Sharon *v.* Comm., 66 T.C. 515 (1976)
(19) Smith *v.* Comm., 44 T.C.M. 1180 (1982)
(20) Thalacker *v.* Comm., 48 T.C.M. 1104 (1984)
(21) Tyson *v.* Comm., 38 T.C.M. 557 (1979)

(22) Weightman *v.* Comm., 42 T.C.M. 105 (1981)
(23) Weissman *v.* Comm., 751 F.2d 512 (2d Cir. 1984)

WEISSMAN TRACE

Below is a listing of a trace of agenda tasks performed during a recent CABARET run, using the Weissman case as the problem situation presented *de novo* to the system. The facts of *Weissman* were summarized and the case discussed in Section 7. Each task is summarized; the control heuristic(s) that placed the task on the agenda are bracketed.

(1) Do backward-chaining on the goal of testing the occupation of the taxpayer. [User-supplied].
(2) Do dimensional analysis on the predicate regular-use. [Start-with-cbr-predicate, open-texture ⇒ cbr].
(3) Make-lattice on regular-use. [Create-predicate-claim-lattice].
(4) Check the claim lattice for deficiencies. [Check-predicate-claim-lattice].
(5) Create a lattice using the minimum difference metric. [Change-similarity-metric].
(6) Backward chain on the goal regular-use. [Sanity-check-by-rbr-predicate].
(7) Do dimensional analysis on convenience of employer. [Start-with-cbr-predicate].
(8) Make-lattice on convenience of employer. [Create-predicate-claim-lattice].
(9) Check the claim lattice. [Check-predicate-claim-lattice].
(10) Create a lattice using the minimum difference metric. [Change-similarity-metric].
(11) Analogize a likely list of cases dealing with regular-use. [Confirm-hit-01].
(12) Analogize the same list of cases, using only those dimensions that speak to regular-use. [Confirm-hit-1].
(13) Backward-chain on convenience of employer. [Sanity-check-by-rbr-predicate].
(14) Analogize case list. [Confirm-hit-01].
(15) Analogize case list. [Confirm-hit-1].
(16) Broaden missing antecedent in rule for occupation. [Broaden-missing-antecedent].
(17) Find cases that deal with occupations that are siblings of professor in a domain hierarchy tree. [Broaden-ot2-siblings].
(18) Find cases that deal with parent nodes of professor in a domain hierarchy tree. [Broaden-ot1-parents].
(19) Analogize cases where occupation-test-rule has fired. [Broaden-1].
(20) Retrieve the cases won by plaintiff. [Broaden-0].
(21) Create a lattice of cases using any dimensions that speak to occupation. [Create-predicate-claim-lattice].
(22) Check claim lattice for conflict nodes or a surfeit of most on point cases. [Check-predicate-claim-lattice].
(23) Distinguish a group of cases that could be cited by opponent. [Broaden-2A].
(24) Do dimensional-analysis on "occupation". [Rbr-near-miss ⇒ cbr, start-with-cbr].
(25) Create another lattice for the predicate occupation-test, using the minimum difference metric. [Change-similarity-metric].

(26) Do dimensional analysis, taking all dimensions into account. [Start-with-cbr].
(27) Do dimensional analysis on principal-place-of-business. [Start-with-cbr-predicate].
(28) Backward-chain on principal-place-of-business. [Sanity-check-by-rbr-predicate].
(29) Make lattice on principal-place-of-business. [Create-predicate-claim-lattice].
(30) Check claim lattice. [Check-predicate-claim-lattice].
(31) Broaden-missing-antecedent primary-responsibility-in-home-office. [Broaden-missing-antecedent].
(32) Analogize case-list. [Broaden-01].
(33) Distinguish case-list. [Broaden-2A].
(34) Do dimensional analysis on exclusive-use. [Start-with-cbr-predicate].
(35) Backward-chain on exclusive use. [Sanity-check-by-rbr-predicate].
(36) Make lattice for exclusive-use. [Check-predicate-claim lattice].
(37) Check claim lattice. [Check-predicate-claim-lattice].
(38) Analogize case-list. [Confirm-hit-01].
(39) Analogize case-list. [Confirm-hit-1].
(40) Make lattice for exclusive-use using different metric. [Change-similarity-metric].
(41) Do dimensional analysis on separate-structure. [Start-with-cbr-predicate].
(42) Make-lattice for separate-structure. [Create-predicate-claim-lattice].
(43) Backward-chain on separate-structure. [Sanity-check-by-rbr-predicate].
(44) Make lattice. [Create-predicate-claim-lattice].
(45) Check claim lattice. [Check-predicate-claim-lattice].
(46) Make lattice using different metric. [Change-similarity-metric].
(47) Do dimensional analysis on meeting-or-dealing. [Start-with-cbr-predicate].
(48) Backward-chain on meeting-or-dealing. [Sanity-check-by-rbr-predicate].
(49) Make lattice for meeting-or-dealing. [Create-predicate-claim-lattice].
(50) Check lattice for meeting-or-dealing. [Check-predicate-claim-lattice].