Reasoning with Portions of Precedents[1]

L. Karl Branting
Department of Computer Science
University of Wyoming
Laramie, Wyoming 82071-3682
karl@eolus.uwyo.edu

Abstract

This paper argues that the task of matching in case-based reasoning can often be improved by comparing new cases to portions of precedents. An example is presented that illustrates how combining portions of multiple precedents can permit new cases to be resolved that would be indeterminate if new cases could only be compared to entire precedents. A system that uses of portions of precedents for legal analysis in the domain of Texas worker's compensation law, GREBE, is described, and examples of GREBE's analysis that combine reasoning steps from multiple precedents are presented.

1 Introduction

A central problem in automated legal reasoning is that many legal predicates lack definitions that provide necessary and sufficient conditions for their satisfaction (McCarty, 1990; Gardner, 1984). Such legal predicates are said to be "open-textured." Open texture in legal predicates is an instance of the broader phenomenon of *category polymorphy* (Rosch and Mervis, 1975), the absence of precise conditions for category membership.

Open-textured legal predicates are typically highly abstract terms occurring in the antecedents of legal rules. For example, antecedents of legal rules for liability or guilt include abstract, general predicates like "reasonable care," "malice," or "activity in furtherance of employment." The gap in generality between abstract predicates occurring in rule antecedents and the concrete facts of particular cases leads to uncertainty about whether the predicates are satisfied in any given new case.

One of the most important techniques for reasoning about open-textured legal predicates is case-based reasoning (Ashley, 1988; Rissland, 1990). Under this approach, the applicability of an open-textured predicate to a new case is determined by comparing the facts of the case to those of precedent cases in which the truth value of the predicate was determined by a previous court or to uncontroversial hypothetical cases (Burton, 1985; Christie, 1969; Feinman, 1989). Case-based reasoning addresses the gap in generality between abstract rule antecedents and the concrete facts of particular cases because the facts of precedents and those of new cases are expressed at the same low level of abstraction.

However, case-based reasoning is itself subject to a different form of uncertainty. A new case invariably differs in some respects from any given precedent. The process of case-based evaluation of predicates therefore consists of two distinct steps: (1) determining the relevant similarities and differences between a new case and each applicable precedent, and (2) using knowledge of the similarities and differences to determine the controlling precedent (or constructing conflicting arguments, if no unique controlling precedent can be determined).

Various approaches to the second part of case-based evaluation of predicates—determining the controlling precedent given the similarities and differences—have been investigated. The simplest approach, *weighted feature matching*, depends upon an *a priori* assignment of *salience*, or weights, to case features. The overall similarity between cases is then calculated as a function of the weights of the shared features. The classification of the precedent with the highest overall

[1]Support for this research was provided by grants from the Army Research Office (ARO-DAAG29-84-K-0060) and the National Science Foundation (IRI-8620052), and by contributions from Apple Corporation, Texas Instruments, the Cray Foundation, and Hughes Research Laboratories.

match strength is then applied to the new case (Stanfill and Waltz, 1986; Salzberg, 1988; Bradshaw, 1987). A second approach is the "prototype-plus-deformation" model described in (McCarty and Sridharan, 1982). In this approach, a predicate is satisfied by a new case if the set of transformations that includes both the exemplars of the predicate and the new case is more coherent than the set of transformations that excludes the new case. A third approach, *dimensional analysis* (Ashley, 1988), uses knowledge of the factors that tend to establish or negate a predicate and the magnitude of these factors in precedents and new cases. These factors, or *dimensions*, provide criteria for determining the "most on point" precedents and a mechanism for generating arguments based on a comparison between a new case and precedents.

The focus of this paper, however, is on the first part of the task of case-based evaluation of predicates: determining the relevant similarities and differences between cases. Inference can frequently reduce the degree of difference between a new case and relevant precedents. Minimizing the degree of unexplained difference between cases can lead to greater overall match accuracy.

Two distinct forms of case-matching inference can be distinguished: case elaboration and term reformulation. *Case elaboration* consists of inferring facts that are not explicitly stated in cases in order to improve their match. For example, a new case can match a precedent even if it lacks some of the precedent's attributes, provided that the missing attributes can be inferred. Similarly, differing case features can be matched if both are manifestations of the same abstract feature, *e.g.,* if both are symptoms caused by the same underlying physiological state or both have the same generalization.[2] Protos (Porter et al., 1990) and Casey (Koton, 1988) used case elaboration to improve match accuracy.

A second form of case-matching inference is *term reformulation,* the process of replacing an

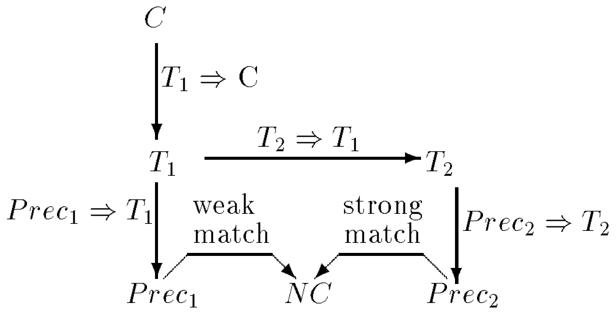

Figure 1: The rule $T_2 \Rightarrow T_1$ permits a reformulation step between T_1 and T_2. This leads to a stronger explanation of C because NC matches $Prec_2$ more strongly than $Prec_1$.

open-textured predicate with one or more predicates for which there are precedents that match the case more closely than do precedents of the original predicate. Suppose, for example, that a domain theory consists of the rule $T_1 \Rightarrow C$, precedent $Prec_1$ of T_1, and precedent $Prec_2$ of T_2. Suppose that new case NC matches $Prec_1$ weakly but matches $Prec_2$ strongly. The only explanation for classifying NC into the category C involves a weak match between NC and $Prec_1$. However, adding the rule $T_2 \Rightarrow T_1$ to the domain theory permits the term T_1 to be reformulated as T_2. This leads to a stronger alternative explanation involving a strong match between NC and $Prec_2$.

A particularly important use of term reformulation is in permitting new cases to be compared to portions of several precedents. The price of using precedents to bridge the gap in generality between abstract legal predicates and case descriptions is the necessity of matching the multiplicity of specific facts that a precedent typically comprises. If the facts of a precedent can be partitioned into smaller meaningful collections, these collections can more easily be matched. This can lead to stronger explanations because a new case may match portions of the facts of several precedents more strongly than it matches the entire set of facts of any single precedent.

Section two of this paper illustrates with an extended example the manner in which reasoning with portions of precedents, or *precedent constituents,* can improve case matching. Section three describes how precedent constituents are used in GREBE, a system for legal analysis in the domain of Texas worker's compensation law. Sec-

[2] Case elaboration was termed *knowledge-based pattern matching* in (Porter et al., 1990). In the context of analogical reasoning, the process of determining "implicit shared properties" of cases from differing explicit representations has been termed *reformulation* (Russell, 1986). A related notion in machine learning is *constructive induction,* which has been defined as "any form of induction that generates new descriptors not present in the input data" (Dietterich and Michalski, 1983).

tion four considers some of the jurisprudential issues raised by the model of precedent constituents advocated here.

2 Precedent Constituents Can Improve Matching

Explanations of precedents often contain inferences that connect portions of case facts to intermediate conclusions justified by those facts. These inferences are like precedents in that they connect specific case facts to abstract predicates, but they differ from precedents in that their antecedents contain only a portion of the facts of a case. Warrants that connect meaningful collections of case facts to abstract predicates are termed *precedent constituents* in this paper.[3]

The constituents of legal precedents can be determined by analyzing the reasoning of published judicial opinions. Any reasoning step in a judicial opinion in which the court found that a given set of specific facts was sufficient to justify a legal predicate can be represented as a precedent constituent. For example, the case of *Janak v. Texas Employer's Ins. Co.,* 381 S.W.2d 176 (1964), involved an accident that occurred during a deviation from the direct route to the drill site where Draplia, the driver, and Janak, the passenger, worked on an oil drilling crew. The purpose of the deviation was to get ice to cool the crew's drinking water. In holding that the traveling was "in furtherance of employment," the Texas Supreme Court reasoned in part that the ice was "reasonably essential" for the drilling activities. The court did not enunciate a rule or definition for "reasonably essential thing," but merely affirmed that the relevant facts of the case constituted an instance of this abstract predicate. This reasoning step is therefore best represented as a precedent constituent, since it connects a collection of specific case facts to an abstract predicate.

[3]Under this definition, an entire precedent is itself a precedent constituent, since a precedent represents an inference from the facts of a case to an abstract predicate. In the ensuing discussion, the term "precedent" refers specifically to precedent constituents whose facts are not a subset of the facts of any other precedent constituent. Precedent constituents are a particular form of case "snippets" (Redmond, 1990; Kolodner, 1988), individual inferences appearing in a precedent. Precedent constituents were termed *exemplar-based explanations* in (Branting, 1989).

Prec.	Class.	Material facts
$Prec_1$	$\neg B$	F_1 = hitting hockey stick $\wedge$ F_2 = hockey game
$Prec_2$	B	F_3 = punching chin $\wedge$ F_4 = family argument

Table 1: A coarse-granularity view of $Prec_1$ and $Prec_2$.

New Case	Facts
NC_1	F_3' = punching nose $\wedge$ F_2' = boxing match
NC_2	F_1' = shoving umbrella $\wedge$ F_4' = argument at store

Table 2: Two new cases to be classified.

The utility of precedent constituents can be illustrated with a simplified example. Suppose that a domain theory for the legal category *battery* consists of two precedents:

- Precedent 1. During a hockey game, John intentionally hit a hockey stick held by Bill. John was not liable to Bill for battery.
- Precedent 2. Sam intentionally hit Jim in the chin during a heated family argument. Sam was liable to Jim for battery.

The precedents are summarized in Table 1.

Consider the task of determining whether the following two new cases are instances of battery:

- New case 1. Fred punched Roger in the nose during a boxing match.
- New case Arthur shoved an umbrella held by Mary during an argument over some items on sale at a department store.

The new cases are summarized in Table 2.

Directly comparing the facts of NC_1 and NC_2 with those of the precedents is insufficient to determine whether the new cases are instances of battery because each case partially matches both $Prec_1$ and $Prec_2$. NC_1 matches $Prec_1$ in that boxing and hockey are both types of games. However, NC_1 matches $Prec_2$ in that a punch to the nose and a punch to the chin are both involve direct contact with the body. Similarly, NC_2 matches $Prec_1$ in that a hockey stick and an umbrella are both objects in contact with the body.

However, NC_2 matches $Prec_2$ in that a family argument and an argument at a store are both types of arguments. Thus, there are conflicting weak arguments for both classifications for each case.

This indeterminacy can be resolved by using the explanations of the precedents to refine their granularity. Suppose that the domain theory includes the rule that battery (B) is satisfied if and only if there is an intentional touching (T) and no consent ($\neg C$), *i.e.,* $T \wedge \neg C \Leftrightarrow B$, where intentional touching and consent are abstract features. Suppose further that $Prec_1$ and $Prec_2$ have the following explanations (illustrated in figure 2): Battery is not satisfied in $Prec_1$ because a participant in hockey has implicitly consented to the physical contacts that are part of the game (*i.e.,* $F_2 \Rightarrow C$). Thus, even though intentionally hitting a player's hockey stick is sufficient to satisfy the requirement of intentional touching (*i.e.,* $F_1 \Rightarrow T$), the requirements for battery are not met. On the other hand, battery is satisfied in $Prec_2$ because a blow to the chin satisfies the touching requirement (*i.e.,* $F_3 \Rightarrow T$) and there is no consent to being hit in a family argument (*i.e.,* $F_4 \Rightarrow \neg C$). The inferences connecting the specific facts of the precedents to the abstract predicates are precedent constituents. Table 2 summarizes the precedent constituents in the explanations of $Prec_1$ and $Prec_2$.

NC_1 and NC_2 match individual precedent constituents more strongly than they match the entire facts of either $Prec_1$ or $Prec_2$. The rule relating abstract predicates T and C to the category B permits matches to individual precedent constituents to be combined to create strong explanations of the classifications of both new cases. These explanations, illustrated in figure 3, are as follows:

- NC_1. An intentional touching does not constitute battery if there is consent to the touching. Part of the explanation of $Prec_1$ is that a participant in hockey has implicitly consented to the physical contacts that are part of the game (*i.e.,* $F_2 \Rightarrow C$). Boxing is similar to hockey in that both involve physical contact (*i.e.,* F_2' matches F_2).[4] Thus, there is implicit consent to being punched in the nose during boxing, and such punches therefore do not constitute battery.

- NC_2. Battery requires intentional touching and no consent. A second part of the explanation of $Prec_1$ is that intentionally hitting a player's hockey stick is sufficient to satisfy the requirement of intentional touching (*i.e.,* $F_1 \Rightarrow T$). Intentionally shoving someone's umbrella is similar to intentionally hitting their hockey stick in that both involve contact with something that is contact with the person (*i.e.,* F_1' matches F_1). Thus, the element of intentional touching, (*i.e.,* T), was satisfied by Arthur shoving Mary's umbrella. Part of the explanation of $Prec_2$ is that there is no consent to being hit in a family argument (*i.e.,* $F_4 \Rightarrow \neg C$). An argument over sale items is similar to a family argument (*i.e.,* F_4' matches F_4). Accordingly, there was no consent to the intentional touching (*i.e.,* $\neg C$). Since the elements of battery—intentional touching and no consent—are satisfied, NC_2 is an instance of battery.

[4]Note that this and the other matching steps in the explanations of NC_1 and NC_2 require case elaboration or one of the techniques for determining the controlling precedent discussed above, such as dimensional analysis, since they involve matching nonidentical case facts. For simplicity of presentation, these matching inferences are omitted.

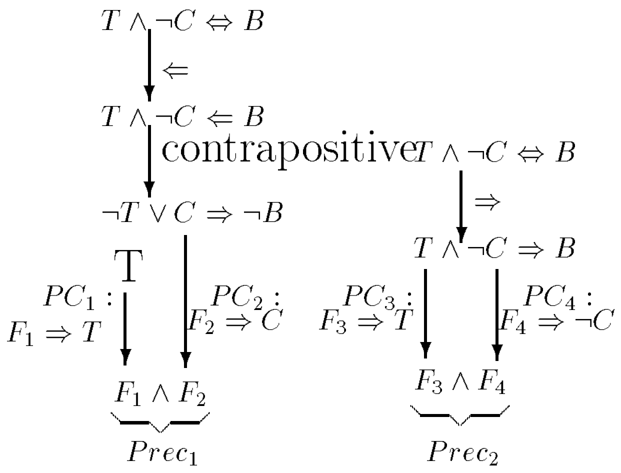

Figure 2: Explanations of precedents $Prec_1$ and $Prec_2$.

The explanations of the classifications of NC_1 and NC_2 illustrate how refining the granularity of precedents by identifying precedent constituents permits multiple partial matches to be leveraged into strong explanations. Precedent-granularity refinement requires two types of knowledge. The

Precedent constituent	Class.	Material facts
PC_1	T	F_1
PC_2	C	F_2
PC_3	T	F_3
PC_4	$\neg C$	F_4

Table 3: A fine-granularity view of the precedent constituents of $Prec_1$ and $Prec_2$ revealed by their explanations.

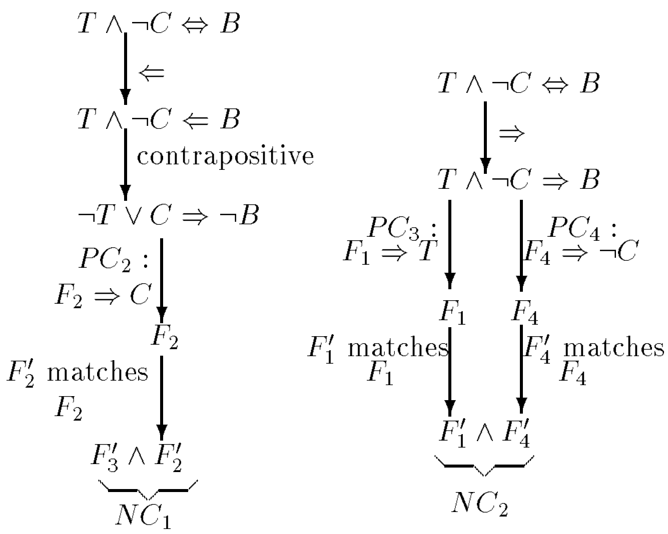

Figure 3: Explanations of two new cases, NC_1 and NC_2, using precedent constituents from $Prec_1$ and $Prec_2$ together with the rule that $T \wedge \neg C \Leftrightarrow B$.

first is knowledge of precedent constituents, that is, the collections of specific case facts that warranted conclusions about abstract case features. The second is knowledge of general domain rules relating abstract predicates to classifications. Knowledge of precedent constituents derives from the explanations of precedents. Rules relating abstract predicates may come either from precedent explanations or from *a priori* domain theory (such as the rule that battery requires an intentional touching and no consent).

3 Precedent Constituents in GREBE

GREBE (GeneratoR of Exemplar-Based Explanations) is a system for legal analysis in the domain of Texas worker's compensation law that is able to reason with precedent constituents (Branting, 1991). The top-level components of GREBE consist of an explanation generator, a memorandum generator, and a knowledge base of rules and cases. When the explanation generator receives a new case and a proposition about that case, it attempts to construct an explanation for the proposition by back-chaining, using any combination of rules and precedent constituents. If successful, the explanation generator outputs one or more explanations of the proposition. The memorandum generator orders these explanations by a heuristic estimate of their strengths. It then generates a natural-language equivalent of the explanations using a library of templates.

GREBE's explanation generator is similar to horn-clause resolution theorem-provers like Prolog. It differs primarily in that it returns an explanation structure as well as a binding list and in that it can use case-based reasoning as an alternative method of explaining goals. The explanation structure that it produces sets forth, for each inference step, the warrant (*i.e.,* rule or precedent constituent) that justifies that inference step.

GREBE's case-based reasoning component consists of three modules: a precedent retriever, a structure mapper, and a match improver. The precedent retriever attempts to find precedent constituents of the current goal's category (and contrast set) that most closely match the new case. The facts of the retrieved precedent constituents then are compared with those of the new case using the mechanism of structure matching (Gentner, 1989; Holyoak and Thagard, 1989). Structure matching (as opposed to simple feature matching) is necessitated by GREBE's semantic network representation of case facts. If there are mismatches between a precedent constituent and a new case, the match improver attempts case elaboration to infer conclusions about the new case that would improve the match.

GREBE's case library contains 16 published legal precedents concerning the compensability under Texas worker's compensation law of injuries sustained while a worker is traveling. In addition, the knowledge base includes four *paradigm cases* representing stereotypical situations. Each precedent can be viewed as a warrant connecting a particular case description to the legal predicate "worker's compensation liability" (or its negation). However, to facilitate term reformulation, these 20 precedents are represented as 35 distinct precedent constituents. Each precedent constituent acts as a warrant connecting some subset of the facts of a precedent to one of eight distinct legal predicates.[5]

In addition to precedent constituents, the worker's compensation knowledge base includes both legal and common-sense rules. Legal rules include statutory rules and common-law rules. An example of the former is the basic rule for worker's compensation liability in Texas, Tex.Civ.St. Art. 8309 §1, which provides that an employer is liable to his employee for worker's compensation if the injury is "sustained in the course of employment." An example of the latter is a rule enunciated in *Janak* that a passenger in a business carpool is in the course of employment whenever the driver is in the course of his employment, provided that they have the same employer.

There are two types of common-sense rules in the worker's compensation knowledge base. Rules of the first type, which are derived from judicial opinions, represent reasoning in opinions that is implicit because it is too obvious (to humans) to need pointing out. An example is the inference that if an activity is a duty of employment, then each necessary step of that activity is a duty of employment as well. The second type of common-sense rules are *semantic rules*, taxonomic relations among individual predicates (*e.g.,* a passenger is a kind of traveler, and a traveler is a kind of agent). There are approximately 57 legal and nonsemantic common-sense rules and 132 semantic rules in the worker's compensation knowledge base.

[5] Legal predicates having precedent constituents as warrants include **in-furtherance-of-employment** (*e.g.,* an employee's working on an assembly line is ordinarily an activity in furtherance of his employment), **reasonably-essential-for** (*e.g.,* having adequate air and light at a job site is reasonably essential for performing employment duties), and **passenger-in-business-carpool** (*e.g.,* being a passenger in a car pursuant to a reciprocal agreement to provide transportation to a common work-site).

4 Using Precedent Constituents in Legal Analysis

This section illustrates how GREBE's use of precedent constituents enables it to combine the reasoning of several precedents in a single analysis. Consider the following hypothetical case:

> Joan and Donald were employed by the school district as teachers at a middle school and carpooled together. Each workday, the driver of the carpool was responsible for picking up some sandwiches on the way to work for both teachers to eat because there was no cafeteria at the school. On the day of the accident, Donald picked up Joan at her house and drove toward the school. Donald then deviated from the direct route to the school on his way to the sandwich shop. Before reaching the sandwich shop, Donald had an automobile accident in which Joan was injured. Does Joan have a claim for worker's compensation against the school district?

GREBE begins its analysis by back-chaining through the statutory rules for worker's compensation liability. When it reaches the goal of showing that the traveling was within the scope of Joan's employment, however, it finds two distinct alternative analyses. The first uses a case-based explanation in which Joan's traveling is compared to the traveling of Draplia in the case of *Janak*. The analogy to Draplia is weak, however, because, unlike Draplia, Joan was not the driver, nor was she responsible for picking up the sandwiches.

The alternative analysis involves term reformulation using the rule from *Janak* that a passenger in a business carpool is in the course of employment whenever the driver is in the course of employment. This rule is used to replace the goal of showing that Joan was within the scope of her employment with a new goal of showing that Donald was within the scope of his employment at the time of the accident. Donald's traveling is much more closely analogous to Draplia's traveling, so a strong argument can be made that Donald, and therefore Joan, was acting in furtherance of employment.

The stronger analysis identifies the business-carpool passenger rule from *Janak* and shows how its antecedents are satisfied:[6]

> ...
> The trip to the sandwich shop was an activity in furtherance of Joan's employment.
>
> This conclusion follows from the rule of Janak v. Texas Employer's Ins. Co., 381 S.W.2d 176 (1964) that a passenger in a business carpool is in the course of employment whenever the driver is in the course of employment if:
>
> ...
>
> iv. Joan was a passenger in the trip to the sandwich shop pursuant to a business carpool.
> This conclusion follows from the very strong analogy between the given case and the facts of Janak v. Texas Employer's Ins. Co., 381 S.W.2d 176 (1964) that were relevant to the conclusion that the Janak crew was a passenger in the deviation to Runge pursuant to a business carpool.
>
> v. The trip to the sandwich shop was an activity in furtherance of Donald's employment.

Having shown that Joan's status depends on whether Donald's traveling was in furtherance of his employment, the analysis turns to the latter question. Donald's traveling matches both Draplia's driving in *Janak* and ordinary commuting.

> Two conflicting arguments can be made concerning whether the trip to the sandwich shop was an activity in furtherance of Donald's employment.
>
> The stronger argument is that:
>
> The trip to the sandwich shop was an activity in furtherance of Donald's employment.
>
> This conclusion follows from the very strong analogy between the given case and the facts of Janak v. Texas Employer's Ins. Co., 381 S.W.2d 176 (1964) that were relevant to the conclusion that the deviation to Runge was an activity in furtherance of Draplia's employment.

An important intermediate conclusion in the reasoning of *Janak* was that the object of Draplia's deviation, ice water, was *reasonably essential* for oil drilling. However, the facts of the hypothetical don't state that sandwiches were "reasonably essential" for teaching. GREBE therefore attempts case elaboration, *i.e,* attempts to improve the match by inferring this fact. GREBE's knowledge base contains two precedent constituents for "reasonably essential:" ice water was found to be reasonably essential under the facts of *Janak*, and food was found to be reasonably essential under the facts of *Vaughn v. Highlands Underwriters Ins. Co.,* 445 S.W.2d 234 (1969). However, the facts of *Vaughn* relevant to the predicate "reasonably essential" are closer to the facts of the hypothetical than are the facts of *Janak* relevant to the same predicate, so GREBE uses a precedent constituent from *Vaughn* to support the conclusion that sandwiches were reasonably essential for teaching.

> This analogy is supported by the following inference:
>
> Sandwiches being at the middle school was reasonably essential for teaching children.
>
> This conclusion follows from the very strong analogy between the given case and the facts of Vaughn v. Highlands Underwriters Ins. Co., 445 S.W.2d 234 (1969) that were relevant to the conclusion that Vaughn's having food was reasonably essential for Vaughn transporting sulfur.

[6]Text printed in typewriter font is excerpted verbatim from the output of GREBE's memorandum generator.

A relevant difference between *Janak* and the hypothetical is identified: the crew's need to keep cool in *Janak* was a function of the temperature of the place where they worked, whereas the teachers' need for food was not influenced by the conditions of the workplace.

> Relevant differences between the given case and Janak v. Texas Employer's Ins. Co., 381 S.W.2d 176 (1964) with respect to the issue whether the trip to the sandwich shop was an activity in furtherance of Donald's employment are that:
>
> - It was not the case that the intensity of Teachers food need depended on the temperature of the middle school.
>
> Whereas in the Janak case:
>
> - The intensity of Janak crew cooling need depended on the temperature of Ecleto.
>
> ...

Consider the effect of altering the hypothetical so that the accident occurs after Donald purchased the sandwiches and was back on a direct route to the middle school. As in the previous case, both the business-carpool passenger rule and case-based reasoning are applicable to the goal of showing that Joan's traveling was in furtherance of her employment. Unlike the previous case, however, the business-carpool passenger rule does not lead to the stronger analysis. This is because the accident occurred after the deviation from the direct route to the school in second hypothetical, whereas in *Janak* and in the previous hypothetical, it occurred during the deviation. As a result, the match between Donald's traveling and Draplia's traveling in *Janak* is weaker than in the previous cases. The strongest analysis involves instead, a direct match of Joan's traveling to ordinary commuting.

> The stronger argument in Carpool Case number 2 is that the school district is not liable under worker compensation to Joan for Joan's injury.
>
> ...
>
> The stronger argument is that:
>
> The trip to the Middle School was not an activity in furtherance of Joan's employment.
>
> This conclusion follows from the very strong analogy between the given case and the facts that are relevant to the conclusion that ordinary commuting to work is not an activity in furtherance of a typical employee's employment as held in American General Ins. v. Coleman, 157 Tx. 377, 303 S.W.2d 370.
>
> ...

American General Ins. v. Coleman, 157 Tx. 377, 303 S.W.2d 370, is not itself a typical commuting case, but is a frequently cited authority for the proposition that ordinary commuting is not an activity in furtherance of employment.

This example illustrates how a small change in facts—in this case modifying the accident to occur after, rather than during, the deviation—can alter the particular sequence of rules and precedent constituents that leads to the strongest argument.

5 A Jurisprudential Critique of Precedent Constituents

The use of portions of the reasoning of precedents is a commonplace in legal analysis. Published case reports are typically accompanied by several distinct headnotes precisely because most precedents comprise a number of distinct reasoning steps, any one of which may be applicable to some future case. References to *Janak* in subsequent cases illustrate the use of portions of precedents. The court in *Liberty Mutual Ins. Co. v. Chesnut*, 539 S.W.2d 924 (Tx.Civ.App. 1976), cited *Janak* only for its analysis of the status of a passenger in a business carpool with respect to course of employment. By contrast, *Vaughn v. Highlands Underwriters Ins. Co.,* 445 S.W.2d 234 (Tx.Civ.App 1969), cited *Janak* only for its discussion of the effects of deviations for business purposes. There was no deviation in *Chesnut* and no carpool in *Vaughn*. Thus, only a part of the reasoning of *Janak* was relevant to each of these subsequent cases.

The model implemented in GREBE of precedents as warrants connecting the material facts of the case to an abstract predicate is consistent with the theory of *ratio decidendi* advocated by Arthur Goodhart (Goodhart, 1930). Goodhart argued that the authoritative portions of a precedent consist of "the material facts as seen by the judge and his conclusion based on them ..." (Goodhart, 1959). Goodhart's theory has been criticized on the grounds that judges often fail to make explicit the facts that they consider to be material to their decisions (Bodenheimer, 1974). Goodhart advocated looking to "the reasons given by the judge in his opinion, or his statement of the rule of law he is following ..." as a guide to determining the material facts. However, even with the assistance of the reasoning set forth in an opinion and the analyses of subsequent commentators and courts, determining the facts that were material to a given conclusion in a case may constitute a difficult exercise in judgment.

GREBE's model of precedent constituents currently fails to distinguish between reasoning steps in which a court determines that there is sufficient evidence to support a given conclusion (*e.g.*, as in reversing a judgment *n.o.v.* or in affirming a finding of fact below) from those in which a court determines that a conclusion follows from the facts as a matter of law (*e.g.,* as in affirming a judgment *n.o.v.* or in reversing a finding of fact below). While the standards for making these two types of determinations are very different, the disparity in precedential weight between the two is often less clear. For example, the Texas Supreme Court in *Janak* merely reinstated the factual finding at the trial level that Janak's traveling was within the scope of employment. However, 5 years later the same court stated that *Janak* "held ...that the transporting of ice to a drilling rig is in furtherance of the employer's business." *Johnson v. Pac. Employers Indem. Co.*, 439 S.W.2d 824, 829 (1969). Conflating these two types of determinations is thus not entirely inconsistent with actual legal practice, even if it involves a significant simplification of jurisprudential theory.

6 Conclusion

This paper has argued that the task of matching in case-based reasoning can often be improved by comparing new cases to portions of precedents. The explanations of legal precedents frequently contain reasoning steps that connect meaningful portions of the facts of the precedent to intermediate conclusions. Such a reasoning step, called a *precedent constituent,* can act as a warrant for the same conclusion in any new case that matches the same portions of the precedent's facts. Systems capable of term reformulation—the process of replacing an open-textured predicate with one or more predicates for which there are precedents that more closely match the new case—can combine precedent constituents from multiple cases. A example was presented that illustrated how combining precedent constituents from multiple cases can permit new cases to be resolved that would be indeterminate if the new cases could only be compared to entire precedents.

Use of precedent constituents in an implemented system was illustrated by GREBE, a system for legal analysis in the domain of Texas worker's compensation law. The 20 precedents in GREBE's case library are represented as 35 precedent constituents. Excerpts from GREBE's analyses of two cases showed how the strength of explanations is improved by (1) permitting precedent constituents from different cases to be combined in a single explanation, and (2) having the flexibility either to apply case-based reasoning to evaluate a predicate or instead reformulating the predicate, depending on which leads to a better match.

References

Ashley, K. (1988). *Modelling Legal Argument: Reasoning with Cases and Hypotheticals.* PhD thesis, The University of Massachusetts.

Bodenheimer, E. (1974). *Jurisprudence.* Harvard University Press, Cambridge, MA.

Bradshaw, G. (1987). Learning to recognize speech sounds: The nexus project. In *Proceedings of the Fourth International Workshop on Machine Learning*, pages 1–11.

Branting, L. K. (1989). Integrating generalizations with exemplar-based reasoning. In *Proceedings of the Eleventh Annual Conference of the Cognitive Science Society*, Ann Arbor, Michigan.

Branting, L. K. (1991). *Integrating Rules and Precedents for Classification and Explanation: Automating Legal Analysis.* PhD thesis, University of Texas at Austin.

Burton, S. J. (1985). *An Introduction to Law and Legal Reasoning*. Little, Brown and Company.

Christie, G. C. (1969). Objectivity in law. *Yale Law Journal*, 78:1311–1350.

Dietterich, T. G. and Michalski, R. S. (1983). A comparative review of selected methods for learning from examples. In Carbonell, J. G., Michalski, R. S., and Mitchell, T. M., editors, *Machine Learning*, volume 1, pages 41–81, 46. Tioga, Palo Alto, CA.

Feinman, J. M. (1989). The jurisprudence of classification. *Stanford Law Review*, 41:661–717.

Gardner, A. (1984). *An Artificial Intelligence Approach to Legal Reasoning*. PhD thesis, Stanford University.

Gentner, D. (1989). The mechanisms of analogical learning. In Vosniadu, S. and Ortony, A., editors, *Similarity and Analogical Reasoning*. Cambridge University Press, London.

Goodhart, A. (1930). Determining the *ratio decidendi* of a case. *Yale Law Review*, 40:161.

Goodhart, A. (1959). The *ratio decidendi* of a case. *Modern Law Review*, 22:117.

Holyoak, K. and Thagard, P. (1989). Analogical mapping by constraint satisfaction. *Cognitive Science*, 13(3).

Kolodner, J. (1988). Retrieving events from a case memory: A parallel implementation. In *Proceedings of the DARPA Workshop on Case-based Reasoning*, Clearwater, Florida. Morgan Kaufmann.

Koton, P. (1988). *Using Experience in Learning and Problem Solving*. PhD thesis, Massachusetts Institute of Technology. Department of Electrical Engineering and Computer Science.

McCarty, L. T. (1990). Artificial intelligence and law: How to get there from here. In *Ratio Juris*, volume 3, pages 189–200. Also in *Workshop Notes from the Eighth National Conference on Artificial Intelligence: Adversarial Reasoning and Artificial Intelligence and Legal Reasoning*, Boston, American Association for Artificial Intelligence.

McCarty, L. T. and Sridharan, N. S. (1982). A computational theory of legal argument. Technical Report LRP-TR-13, Laboratory for Computer Science Research, Rutgers University.

Porter, B. W., Bareiss, E. R., and Holte, R. C. (1990). Concept learning and heuristic classification in weak-theory domains. *Artificial Intelligence*, 45(1–2).

Redmond, M. (1990). Distributed cases for case-based reasoning; facilitating use of multiple cases. In *Proceedings of AAAI-90*, Boston. American Association for Artificial Intelligence.

Rissland, E. L. (1990). Artificial intelligence and law: Stepping stones to a model of legal reasoning. *Yale Law Review*, 99:1957–1981.

Rosch, E. and Mervis, C. B. (1975). Family resemblance: Studies in the internal structure of categories. *Cognitive Psychology*, 7:573–605.

Russell, S. J. (1986). *Analogical and Inductive Reasoning*. PhD thesis, Stanford University.

Salzberg, S. (1988). Exemplar-based learning: theory and implementation. Technical Report TR-10-88, Center for Research in Computing Technology, Harvard University.

Stanfill, C. and Waltz, D. (1986). Toward memory-based reasoning. *Communications of the ACM*, 29(12).