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Back to the Future: Dimensions Revisited

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Abstract. Most recent work on reasoning with cases in law has taken the style of reasoning used in the CATO system as its model, and uses the notion of factors, as found in that system. Fundamental to CATO, a successor the HYPO system, were factors, which are closely related to HYPO-style dimensions. In this paper, we will argue that the simplification involved in using factors, while it has proved pragmatically useful both for clarifying understanding of certain aspects of reasoning with cases and for implementation, causes problems with domain analysis and precludes certain kinds of argument that we would wish to model. We therefore believe that the time is now ripe to go back to the original notion of dimensions, while retaining the insights that have been gained from working with the simpler notion of factors. The paper uses two case studies to argue that this is so.

1 Introduction

[5] gives an account of reasoning with cases as a process involving the construction, evaluation and application of theories. It attempts to articulate the relationship between decided cases, defeasible rules explaining the outcomes of those cases, and societal values promoted by those rules, so as to provide a theory that explains past decisions and that can be applied to as yet unresolved cases. In that paper, cases are taken to be described using *factors*, broadly following work such as that of [7], the CATO project ([1]) and [8]. The set of such factors, and decisions as to whether or not they apply to cases, is taken as being the product of some prior analysis of cases. All of this builds on ideas from the HYPO system (e.g., [2], [3]). In the HYPO system, however, a more sophisticated notion of factor—called a *dimension*—was used. In keeping with the terminology suggested recently by [10], we will refer to the type of factor used by Berman & Hafner, Sartor & Bench-Capon, and others, as CATO-style factors. By comparison, the original conception of dimensions ([13]) was used in other progeny of HYPO, such as CABARET ([11]) and BankXX ([12]).

HYPO-style dimensions allow finer grained comparison of cases than do CATO-style factors. They thus enable closer argumentation about relevant similarities and differences between cases. We believe that it is important that this potential should be available, since otherwise much of the creative reasoning with cases is placed outside the system. From the perspective of theory construction as described in [5], recognition of dimensions allows us

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to make explicit an additional stage in theory construction. Rather than taking factors as simply given in the background, and so not subject to discussion, we can see the move from dimensions to factors as being a topic within the theory construction process. We believe that the time is ripe to return to thinking in terms of dimensions rather than factors, and the primary purpose of this paper is to argue for that belief.

In section 2 we discuss the relationship between factors and dimensions. In section 3 we give two case studies which show the importance of starting from dimensions rather than factors if we are to capture some important aspects of reasoning with cases. In section 4 we draw some conclusions from the case studies and suggest directions for future work.

2 Dimensions and Factors

As used in the work referred to in section 1, a *factor* is:

- some feature of a case which may be present or absent. This is an all or nothing matter; there is no notion of an extent to which the factor is present. We say that a factor that is present is *applicable*;
- if present, a factor always strengthens the case for the same disputant, either the plaintiff or the defendant.

Dimensions are designed to capture the knowledge that a legal problem can be approached in a certain way. They represent a *range* of possible positions that a case can exhibit with regard to the aspect of the problem represented by the dimension. Dimensions have three elements:

- one or more *prerequisites*: some fact or facts of the case that make the dimension applicable to the case;
- one or more *focal slots*: some fact or facts of the case that determine the position in the range applicable to this case;
- a *direction*: one extreme of the range of positions favours the plaintiff, and the other extreme, the defendant. As one moves towards an extreme the appropriate party is increasingly more favoured, *ceteris paribus*.

These three elements are part of the original HYPO definition of a dimension [3]. In addition in HYPO—but not in CABARET or BankXX—factors were grouped into those that generally favoured the plaintiff and those that generally favoured the defendant.

In many of these systems, cases are described in terms of either the collection of factors applicable in them (e.g., in CATO), or the collection of facts (e.g., in HYPO, CABARET), from which it is possible to compute which dimensions are applicable. BankXX represented a case both by its facts and by the set of applicable dimensions and the case's values on them.

Two important contrasts between factors and dimensions emerge from this:

- Whereas the presence of a factor is an all or nothing affair; a case's strength, or value, on the dimension is a matter of more or less. In trade secrets law, the number of outsiders to whom the secret has been divulged is a relevant consideration. The defendant's case is strengthened according to the number of disclosures made. If this dimension were treated as a factor, a decision would need to be made as to precisely how many disclosures were required for the factor to be present, which might mean that a single disclosure had the same effect as ten million;

- Dimensions are *per se* neither pro-plaintiff nor pro-defendant; a dimension can potentially favour either of the parties depending on which position on its range is occupied. No disclosures can be regarded as a strong position for a pro-plaintiff argument, whereas a significant number of disclosures can be a strong position for a pro-defendant argument. One way to represent this with CATO-style factors, would be to have two factors: one, favouring the plaintiff, that applied when there were no disclosures, and another, favouring the defendant, when there were any, even just one, disclosures. Note, however, that CATO did not actually create such a "No-Secrets-Disclosed-Outsiders", because Ashley and Aleven could not find any court cases where a judge had said that an absence of disclosures was a positive strength for the plaintiff. Another way to split this dimension would be to use some intermediate number (N) of disclosures to create two factors, one, favouring the plaintiff, for less than N disclosures and one, favouring the defendant, for greater or equal than N. Again, Ashley and Aleven did not do this because they could not find any court opinion that mandated such a split. Even though CATO might not have used this approach of splitting a (numerical) dimension into two factors, creating CATO-style factors in this way is not precluded. A more typical split occurs when a dimension with only two values is split into two factors; for example, what was done for land in [7], where the land was classified as either "open" or "owned" (by the plaintiff).

In the next section we consider two case studies, both derived from work that uses the notion of factors rather than dimensions. In each case we consider the impact of using dimensions rather than factors, to explore the gains that result in terms of richness of representation and bringing within the system considerations that must otherwise be left to the knowledge engineer.

3 Case Studies

In this section we consider two case studies. The first is from [8] in which they use an artificial example concerning change of domicile. Here we use the simplest form of their example; they also developed a more elaborate example to explore issues relating to a factor hierarchy, which is not relevant to this paper. The second is the set of wild animals cases, used in [7], but since used also by other authors, including Bench-Capon and Sartor ([4],[5]), and Prakken ([9]). Here we extend the example of the wild animal cases by the inclusion of some other related cases not discussed in Berman and Hafner.

3.1 *Prakken and Sartor's Domicile Example*

The aim of the example used in Prakken and Sartor is to show how it is possible to reconstruct a case-based reasoning system, specifically HYPO, in terms of the framework provided by the defeasible logic developed in their earlier work. The issue is whether a stay in another country changes one's fiscal domicile with respect to income tax. They begin by identifying three dimensions:

- whether the applicant gave up his house in his original country of domicile;
- whether the applicant's company is based in the old or the new country;
- whether the applicant's stay in the new country has been long or short.

At this point they explicitly simplify matters by restricting each of these dimensions to two positions, one extreme value favouring the interpretation of change of fiscal domicile and the other extreme value favouring no change of fiscal domicile. They then make the move to factors. They make no use of prerequisites, and so all three dimensions seem to be taken as applicable to all cases, and each case will take one of the two positions. They thus get six factors:

- Pro change is that the old house was given up; con change is that it was kept.
- Pro change is that the taxpayer's company is based in the new country; con change, that it is based in the old country.
- Pro change is that stay is long; con change, that it is short.

In each instance, however, the dimension could have been seen as having a spectrum of values. Certainly the facts of the cases may exhibit variation. For example:

- gave up house: *sold-house, house-kept-occupied-by-family* [this could be made finer grain if we thought the relationship mattered], *rented-out-house, house-kept-unoccupied;*
- foreign company: *foreign-company, multi-national, foreign-subsidiary-of-domestic-company, domestic-company-with-foreign-offices, domestic-company;*
- duration: *number-of-months.*

An immediate problem arises. Once it is recognised that the situation may not fall at either of the two extremes, the knowledge engineer must decide *whether*, in such cases, one of the factors applies, and also *which* factor applies. Suppose the house has been rented out: should this be taken as giving up the house, and so a point *pro change*; as not giving up the house, and so *con change*; or should it be taken as neither, rendering the dimension inapplicable? It is understandable that Prakken and Sartor do not discuss this issue, since their concern is to illustrate a technical point, but were we building a practical system, we would have to answer such questions. In order to represent cases in terms of the dimensions, the knowledge engineer must be in a position to allocate these intermediate positions to one or other of the factors. But

this is precisely the kind of point that might be raised in a case, and which therefore needs to be decided on the basis of authority. This then is the first problem: to use factors, the positions on the range of the dimension must be shoehorned into one of two factors. Once this is done in the representation, it cannot be undone or questioned in the operation of the system. Yet deciding where the line should be drawn seems to be a part of theory construction—certainly, courts are involved in this sort of theory construction—and something we would like to be an explicit subject of debate *within the system.*

The 1998 paper by Prakken and Sartor [8] makes use of factors to construct defeasible rules and to enable cases to establish priorities between rules. Essentially any case will give rise to three rules:

R1 : conjunction of pro-change factors present implies change

R2 : conjunction of con-change factors present implies no change

R3 : if decision was change, R1 > R2, otherwise R2 > R1

This is an appealing and simple way of deriving a set of rules and priorities among them from decided cases. But problems arise if we consider that the intermediate points on a dimension may mean that an outcome is favoured *to a certain extent.*

This presents a second problem. Suppose we draw the line for gave up house at *sold-house*, so that anything else will be a con-change factor. Now suppose we have a case with *house-kept-unoccupied* and *foreign-company*, decided no change. (Ignore for the moment duration: it may be intermediate so that neither duration factor applies). We would conclude that

$$\textit{kept-house-unoccupied} \rightarrow \textit{no change} > \textit{foreign-company} \rightarrow \textit{change}$$

Given a new case where the company was foreign and the house was kept occupied by adult children, we would have to conclude that again there was no change, since the cases cannot be distinguished on their factors. But we might not want to do that. Does this simply mean that we drew the line between *kept house* and *gave up house* in the wrong place, and that *occupied by adult children* should be treated as *gave up house*? We would say not; if we think of *gave up house* as actually selling the house, then

$$\textit{gave-up house} \rightarrow \textit{change} > \textit{short-duration} \rightarrow \textit{no change}$$

looks plausible. But, where *gave-up-house* is only to the extent that it is occupied by adult children, this might not be considered enough to defeat *short-duration.* In other words, in this comparison it seems that we should split the dimension differently, so that occupied by adult children counts as *kept-house-unoccupied.* Ignoring the possibility of several positions within the dimension means that we have to lump together distinguishable situations *in the same way in all comparisons.* But a given position in the range might favour a side sufficiently to defeat some rules but insufficiently to defeat others.

The third problem is factors in combination. If someone has been abroad for only a short time, the fact that the house is rented perhaps should not count against them. It takes time

to sell a house, and it is perhaps sensible to rent it for a short period while arrangements for sale are made. If, however, the person has been abroad for a longer period, holding on to a property useable in the event of return suggests some possibility of return. Thus renting a house should count against change when, *but only when*, the duration exceeds a certain limit. Again there is a need to draw the line once, to cover all situations, whereas it may be appropriate to draw it differently in the context supplied by other factors.

There are therefore three reasons for preferring the analysis to recognise dimensions:

- The split into two positions may be hard to motivate: without an appropriate case we may not be able to justify drawing the line at any particular point;
- By conflating several positions along the dimension together we may get contradictory rule preferences;
- By conflating several positions together we are unable to give the factor a different import in different contexts.

3.2 The Wild Animal Cases

[7] discusses three cases concerning the interrupted pursuit of wild animals. These cases have also been used by Bench-Capon and Sartor (e.g. [4],[5]) and Prakken (e.g. [9]), as well as by [10]. A brief summary of these cases can be given as follows.

In all three cases, the plaintiff (P) was chasing wild animals, and the defendant (D) interrupted the chase, preventing P from capturing those animals. The issue to be decided is whether or not P has a legal remedy (a right to be compensated for the loss of the game) against D. In the first case, *Pierson v Post*, P was hunting a fox on open land in the traditional manner using horse and hound, when D killed and carried off the fox. In this case P was held to have no right to the fox because he had gained no possession of it. In the second case, *Keeble v Hickeringill*, P owned a pond and made his living by luring wild ducks there with decoys, shooting them, and selling them for food. Out of malice, D used guns to scare the ducks away from the pond. Here P won. In the third case, *Young v Hitchens*, both parties were commercial fisherman. While P was closing his nets, D sped into the gap, spread his own net and caught the fish. In this case P won.

Berman and Hafner identify five factors:

1. whether P had not gained possession of the animal (favours D);
2. whether the land was open (favours D);
3. whether the land was owned by P (favours P);
4. whether P was attempting to earn his living (favours P);
5. whether D was in competition with P (favours D).

Note that the second and third factors could be seen as the two extremes of a single dimension, as in Prakken and Sartor. The other three factors seem to come from different dimensions (although the presence of the fourth might be seen as a prerequisite for the fifth).

Using these factors, *Pierson* contains 1 and 2, *Keeble* contains 1, 3 and 4, and *Young* contains 1,2,4 and 5. On this analysis it seems odd that *Pierson* was litigated at all: surely the plaintiff must have thought there was something in his favour? Perhaps we should suspect that the statement in terms of factors has obliterated some important information? Let us look at the cases more closely.

In fact *Keeble* was the first case to be decided (in England, in 1707). Here the ownership of the land was considered crucial. Keeble could be said to own the ducks by "occupancy" even though he could not prevent them from leaving (until he had shot them). As quotations in Berman and Hafner make clear, factor 4 was also considered and used by the judges to support the plaintiff.

Pierson was tried in 1805 in New York. The decisions make it clear that P's claim was that pursuit gave him a right to the fox. Consider first the *Per Curiam* opinion by Tompkins in *Pierson v. Post*, 3 Caines 175 (N.Y.S.Ct. 1805), which was couched in terms of 'occupancy'; it suggests that *Keeble* had been introduced as a precedent. This opinion cites Justinian in saying "pursuit alone vests no property or right for the huntsman," and "even pursuit, accompanied by actual wounding" is not enough, "unless the animal be actually taken." It further cites Pufendorf: "a beast mortally wounded, or greatly maimed, cannot be fairly intercepted by another, whilst the pursuit of the person inflicting the wound continues" and concludes that "The foregoing authorities are decisive to shew, that mere pursuit gave Post no legal right to the fox."

Some contrary authorities are considered. Most past cases "have arisen between the huntsman and the owner of the land upon which beast *ferae naturae* have been apprehended" and are thus not relevant. (But note that this means in effect that the open land is favouring the plaintiff, not the defendant, since it excludes some potentially damaging precedents). It also cites Barbeyrac, who counters Pufendorf with : "actual bodily seizure is not... necessary to constitute possession of wild animals." The opinion agrees with Barbeyrac in so far as "actual bodily seizure is not indispensable" as a condition for possession, speculating that "on the contrary, mortal wounding... by one not abandoning pursuit, may,... be deemed possession..." since the pursuer "manifests an unequivocal intention of appropriating the animal..., has deprived him of his natural liberty, and brought him within his certain control." "So also, encompassing and securing animals with nets and toils, or otherwise intercepting them, in such a manner as to deprive them of their natural liberty, and render escape impossible, may justly be deemed to give possession of them to those persons who, by their industry and labour, have used such means of apprehending them." Finally it distinguishes *Keeble*: "in the report of the same case, 3 Salk. 9. Holt, Chief Justice, states that the ducks were in the plaintiff's decoy pond and *so in his possession*, from which it is obvious the court laid much stress in their opinion upon the plaintiff's possession of the ducks, *ratione soli*."

We should also consider the opinion of Livingston, who favoured the plaintiff. He held that if "on waste and uninhabited ground" then "in full pursuit" would be enough to count as possession, "so as to give greatest encouragement to the destruction of an animal, so cunning and ruthless". Livingston rejects Justinian as simply too old—Justinian was a Byzantine Emperor circa A.D. 550—an authority to carry weight, and acknowledges the difficulty in

deciding where possession should begin: "I... feel great difficulty in determining, whether to acquire dominion over a thing, before in common, it be sufficient that we barely see it, or know where it is,... or whether, in the case of wild beasts, setting a trap, or lying in wait, or starting, or pursuing, be enough; or if actual wounding, or killing, or bodily tact and occupation be necessary." Finally he agrees with Barbeyrac: "[P]roperty in animals *ferae naturae*, may be acquired without bodily touch or manucaption, provided that the pursuer be within reach, or have *a reasonable prospect (which certainly existed here) of taking*" the beast. [our emphasis]

What does this tell us? First that Berman and Hafner were right to identify the failure of Pierson to gain possession as the decisive factor. On the other hand they cannot do justice to the range of positions that were considered; *bodily seizure* (from Barbeyrac), *mortal wounding* or *great maiming* (Pufendorf), *encompassing and securing animals with nets and toils* and *within certain control* (Tompkins), *in full pursuit* (Livingston), *setting a trap*, or *lying in wait*, or *starting* (Livingston). Both Tompkins and Livingston felt the need to draw a line along this range of possibilities. Both felt difficulty; Tompkin is sure that pursuit is not enough, but does not need to pronounce on wounding and maiming, since this did not apply in this case. Livingston, on the other hand will allow full pursuit, but refuses to be drawn on lesser degrees of contact. Where the line was to be drawn between possession and no possession was a central feature of the reasoning of both Tompkins and Livingston, but *they did not draw it*, contenting themselves with a conviction that the particular case was inside it. Confronted with a case featuring great maiming we would need to draw it ourselves. But this is precisely what we cannot do within the five factor framework; the line is drawn when the case is represented and removed from discussion.

A second feature is the question of the open land. First we should note that this was not seen as favouring the defendant. Second, we should see that the possibility of the defendant owning the land was raised by some past cases which were discounted on this ground. Third, in *Keeble*, land ownership was important, not because of the land itself, (since the defendant operated remotely and committed no trespass) but because it conferred possession of the ducks alighting on it. Thus to determine possession, as well as the hunting considerations conferring degrees of possession in *Pierson*, we need to consider also the property considerations that conferred possession in *Keeble*. Following [10], a dimension for possession might then look like:

- Extreme PRO-D = feral & free: under no control by P or anyone else
- animal is seen or started by P
- animal happens to be on P's site (walks through, alights, swims)
- animal is attracted onto P's site (e.g., to visit deerlicks, birdfeeders, food-left-by-P)
- animal is lured onto P's site (e.g., decoys)
- P sets a trap or lies in wait for animal
- animal is hotly pursued by P (e.g., fox/hare/deer hunting)

- animal temporarily confined by P (e.g., in paddock)
- animal wounded by P (e.g., shot, stunned)
- animal is mortally wounded or maimed
- animal caught by P (e.g., in net, trap, toils)
- Extreme PRO-P= animal is killed or totally controlled by P (e.g., in P's gunny bag)

Obviously both the positions and their ordering is something of a matter of conjecture; we would need some more decisions with more definite pronouncements to have any confidence in this ordering. We can, however, say that *Keeble* and *Pierson* together suggest that we have ordered hot pursuit and attracted to the plaintiff's site correctly.

If we still want to include land as a consideration separate from its impact on ownership, we probably need a range of positions here, starting from the extreme pro-d position where the defendant holds the freehold and progressing towards the extreme pro-p position where the plaintiff holds the freehold through a variety of leasehold arrangements and degrees of common and state ownership.

We can also see intermediate positions in the fourth factor. The court was well disposed towards Keeble because he was pursuing his livelihood and the defendant was acting out of malice. But Livingston was disposed towards the fox hunter because he was doing something beneficial to the livelihood of others. Perhaps we need a dimension to capture a range of motives here, ranging from the economic, through the socially beneficial and innocent pleasure, through to malice.

We will not say much about *Young*, except to note that if we use the dimension for possession above, whether factor 1 applies to this case or not seems to depend on whether the fish could have escaped him if not intercepted by Hitchens.

None of this is intended to suggest that Berman and Hafner's analysis was incorrect or superficial. They have chosen their factors and used them to construct a theory, which is both explanatory of the cases and plausibly based on the decisions. This is exactly what we believe reasoning with cases to be about. The point is, however, that other theories can be constructed, but this possibility depends critically on the availability of the dimensions, so that we can describe the cases differently rather than limiting our arguments to what is available from the factors presented in their theory. Thus a good deal of the reasoning has been pre-empted once we have selected the factors and applied them to the cases. We need something like dimensions if this part of the theory construction is to be brought out into the open.

We will conclude this section by mentioning some other cases that have some bearing on the issues involved in this domain.

Consider first *Ghen v Rich* (Mass 1881). Here a finback whale washed ashore at Brewster, Mass. Ellis found it, and sold it by auction to Rich, who stripped off the blubber and tried out the oil. According to local custom, Ellis should have sent word to Provincetown, where Ghen would have identified his bomb-lance, claimed his whale, and paid Ellis a fee. The courts found for the plaintiff here on the basis of established custom in the whaling industry: "[T]he iron holds the whale... a custom which embraced an entire business, and had been

concurred in for a long time by every one engaged in the trade." The result differs from *Young*, where it appears no established custom existed in that trade. Customs are, however, important in other areas. For example, in England all swans and sturgeons are the property of the monarch, and must be offered to the monarch if caught by accident or design. Where customs exist, different considerations relating to the possession dimension clearly apply: this could be reflected through the prerequisite slots in a dimension based system.

Consider next *Conti v ASPCA* (NY 1974). Chester, a parrot used by ASPCA for educational exhibits, flew the coop, was offered food by P and finally entered P's home, where P placed it in a cage. D removed parrot from P's home. Here it was held that Chester was a domesticated animal and thus the rule of ferae naturae did not apply and ASPCA was the true owner with the right to regain possession. This gives us another consideration for our possession dimension: possession through domestication. This suggests a certain pessimism with respect to ever fully articulating the positions on a dimension: the next case may always throw up a new, unanticipated, position.

In our discussion of the wild animals cases we have concentrated on the difficulty in drawing the line through a range of positions, which is necessary if we are to work with factors. As we have seen, drawing this line is regarded by judges as a central part of their responsibility; and also, once drawn, it greatly limits the theories that can be constructed.

4 Discussion

A major difficulty with reasoning with cases is that we need to compare cases so that we can apply conclusions from one case to another case. But the facts of each case are really unique. So we have to find a way of assimilating unlike cases to give a basis of comparison. In the animals cases we have a fox, fowl and fish in disputed possession. When we construct a dimension of possession, we say that any kind of animal may be treated in the same way (even though we may later have to exclude whales and domesticated parrots). But a dimension has a range of positions, and constructing and ordering this range involves classifying different situations into the same position within that range. When we move to factors we map this range of possibilities into an even smaller range, thus grouping several positions on a dimension together. When we use the flexibility of dimensions, we avoid the coalescing and washing out of distinctions that happen with factors. If we go on to allow factors to be mapped into societal values, as in [5], we can, assuming different factors can promote the same societal values, treat cases with different factors promoting the same values as comparable, erasing the differences between cases still further, but again requiring different situations to be treated as if they were alike. Since the smaller the range of the items we map the cases into, the more definite are the comparisons that can be made, the temptation is to aim for the smallest set of items one can get away with in a particular situation. Constructing a theory is in part just making such a set of decisions about what can be compared, and on what basis. But each mapping involves some compression of information, elimination of distinctions, and judgement as to where a line is to be drawn; therefore if we wish to allow a fuller range of alternative theories to be constructed we need to retain the ability to draw the lines differently. Our view is that starting from dimensions rather than factors is essential if we are to retain that ability.

Dimensions, we believe, make possible the following desirable things not possible with

factors:

- The same fact situation can be used by both parties to a dispute. Recall that in *Pierson*, Livingston argued for the plaintiff because he was in pursuit of the fox, whereas Tompkins argued against the plaintiff because he was *only* in pursuit of the fox. If we had a factor to represent the situation, it could favour one side only.
- We can choose whether we think a situation should be treated like another or not: for example whether we believe maiming is enough to count as possession, or whether we think mortal wounding is required. With factors these decisions are made for us.
- We can ascribe different degrees of strength to different positions within the dimension. Earning one's living might overcome lack of possession, whereas altruism might not, even if in other contexts a factor *acting from a socially beneficial motive* might be what was wanted. Once both positions have been classified as making a factor present, the possibly to distinguish these different strengths is lost.

We believe that these are significant benefits, but there is a price to pay. Factors are very much simpler to handle than dimensions, and, when producing an implementation, this is an important consideration. Moreover the investigation of other features, such as the factor hierarchy of CATO and the mapping from cases to rules of [8] is facilitated by working with the simpler notion. Once, however, the insights have been gained from working with the simpler model, we are in position to re-introduce the complications. For example Bench-Capon and Sartor ([6]) provides an extension of the model of [5] that brings dimensions within the theory construction process. This exercise could not have been done without first constructing the simpler model, and it also serves to indicate the considerable complications that using dimensions introduces if an explicit set of defeasible rules is to be derived from precedent cases.

5 Conclusion

In order to understand an area it is often necessary to simplify so that the various difficulties can be attacked one by one. That we learn logic by first understanding propositional calculus, then first order predicate calculus, and only then approach exotic and modal logics, is a good example of this. Only when one stage has been thoroughly understood can we move on to the next. Moreover, each of the simplifications is *useful*: for some purposes propositional calculus suffices, and for many purposes predicate calculus is enough. Only when we need to address particular problems do we need our most elaborate machinery.

Reasoning with cases is a similarly complicated affair, which would inevitably overwhelm us were we to attempt to capture all its richness at once. Over the last decade much progress has been made in modelling reasoning with cases, and the simplification of dimensions into factors has played an important role in moving the area forward. Also, for some purposes, the simplification may be benign; for example factors may be adequate if we wish to build a system that will apply a settled theory. To the extent that we can be confident that the knowledge engineer is in a position to make the right decisions as to the factors to use and the conditions for their presence, to that extent we have no need to require dimensions to be

manipulated. But if we want to capture some aspects of reasoning with cases, factors are, as we hope we have shown, no substitute for dimensions. Just as some kinds of sound logical argument cannot be expressed in propositional calculus, so some kinds of legal argument turn on handling dimensions. It is the very usefulness of factors, in permitting our current level of understanding of the aspects of reasoning with cases that they can capture, that allows for the reintroduction of the associated with dimensions that will allow us to explore these additional aspects of the problem.

As an idea, dimensions have a long history, although they have been little explored in most recent years. They should not be seen as part of the history of the subject—we see the future of modelling reasoning with cases as beginning with their revival.

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