A POSSIBILISTIC MODEL FOR THE INTERPRETATION OF TRAINS OF ARGUMENTS

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Abstract

The analysis of events and general world knowledge for the generation of predictions or diagnoses presupposes that there are (i) rules for evaluating the argumentative importance of single propositions (ii) regular forms for the combination of propositions (trains of arguments) and (iii) rules for assessing the credibility or plausibility of the given trains of arguments. A possibilistic model is suggested that specifies how arguments can be related (chains, trees, and nets) and how the type of the train of arguments determines the interpretation of quantifiers in propositions.

Keywords: linguistic variables, fuzzy quantifiers, computational approach to reasoning, computer-aided decision making

1. THE GENERAL STRUCTURE OF ARGUMENTS

In normal discourse and especially in scientific discourse the rational combination of factual evidence and general world knowledge is undoubtedly of utmost importance. However, the classical approaches to this problem fail because in these frameworks only parts of the available arguments can be evaluated.

For instance, syllogistic logic discards any kind of expression that is not formed by means of the standard binary relations and of standard quantifiers. Furthermore, the expressions have to be true or false and they are to be arranged in a linear fashion (e.g. major premise, minor premise, conclusion). On the other hand, Bayesian, belief-function or information-theoretic approaches for the evaluation of evidence rely on the completeness and precision of their parameters, that usually excludes qualitative (vague or fuzzy) judgments like, for instance, "normally x is y" (for an exception, see Zimmer 1986a).

In order to arrive at a more naturalistic approach to rational discourse, it seems fruitful to look at the structure of arguments in more detail. According to Toulmin, Rieke & Janik (1979) an argument consists of claims, grounds, warrants, a backing, and finally rebuttals. These constituents of an argument can be defined in our context as follows:

(i) claims or assertions about actual purported states of the world or states which are presupposed to happen

(ii) grounds or reasons for believing the claims to be valid

(iii) warrants, that is, statements about the relations between grounds and claims (e.g. causality, necessity, sufficiency, contingency)

(iv) backing, that is commonly shared knowledge (Smith 1982) which provides the rules for a combination of grounds and warrants in order to justify the claims (e.g. rules of syllogistic reasoning, or statistical inference)

(v) rebuttals, that is, alternative claims which can also be inferred from the grounds, warrants, and the backing. Rebuttals can be overcome by either showing that they imply a smaller set of consistent propositions than the claim or by comparing the overall modal qualification of the rebuttals with the evaluation of the claims.

This list has to be completed by the introduction of

(vi) modal qualifications (e.g. "possibly", "usually", "necessarily") which apply to the propositions and to the inferential process (e.g. rules of fuzzy reasoning). The modal quantification of the ground together with the fuzzy truth values resulting from the inferential process determine the modal quantification of the claim.

In Zimmer (1986b) it has been demonstrated how these constituents of arguments can be elicited from experts and how the meaning of the modal qualifications can be interactively determined. One result of this study was that arguments in isolation are rare exceptions, the normal case being trains of arguments, that is, (i) linear chains (as described in Zimmer 1985), (ii) hierarchical trees and lattices (Sandewall 1985), or (iii) evidential nets (Zimmer & Körndle, 1987). While Zimmer (1986b) was mainly concerned with the techniques to elicit the context of expertise in order to develop knowledge bases for expert systems, the model described here concentrates on the structural properties of the trains of arguments. Of special interest in this context are the following questions:

(i) What are the rules for the interpretation of qualitative modifiers in single propositions?

(ii) What kinds of structural organization can be found in trains of arguments and to what extent do they influence the meaning of the constituents?

(iii) And finally, how can rules devised for the aggregation of evidence in trains of arguments independently from the form of their constituents?

2. THE INTERPRETATION OF QUANTIFIERS AND UNCERTAINTY EXPRESSIONS

In normal discourse, quantifying modifiers are ubiquitious:

most, many and few (for people, animals or objects), likely, possible and uncertain (for events), little and much (for quantities) etc.. These expressions are used in making absolute judgments with or without the further explication of a point or frame of reference, e.g. "there is little water in the jar" or "there are many cars in the parking lot" (the parts of the sentences specifying the reference point or context are underlined). Concerning these expressions, we have the paradoxical situation that on the one hand they are vague or fuzzy (Zadeh, 1975, on linguistic variables and Lakoff, 1975, on hedges and fuzzy concepts) and furthermore context dependent (see, for instance, the difference in the meaning of "few" in "few cars" and "few small cars" (Hörmann, 1983)). On the other hand, people do not only predominantly use absolute judgments in normal discourse (Ulshöfer-Heinloth 1964) but seem to be at ease and effective in communicating by means of these expressions (Zimmer 1980). This paradox of semantics and discourse could be easily discarded if the ease and effectiveness were merely an illusion. However, a host of experimented results indicate that this is not the case: people are very adaptive to the implied or explicitly stated contexts as speakers as well as listeners (Wever & Zener 1928, Witte 1960, Helson 1964, Hörmann 1983).

The seminal papers by Zadeh (1975) on linguistic variables have provided an integration of empirical and formal approaches to the problem of absolute judgments. Of special interest is Zadeh's (1983) approach for the analysis of the colloquial usage of standard (all, some, none, not all) and non-standard (few, many, most) quantifiers. Goguen (1969) had suggested that the colloquial usage of standard quantifiers is a fuzzified version of their application in logic. Zadeh's (1983) "computational approach" to this problem consists in regarding fuzzy quantifiers as elements of a linguistic variable and furthermore as fuzzy numbers (Dubois & Prade 1980) in the unit interval. This interpretation of quantifiers results in an unified framework of standard and non-standard quantifiers preserving the meaning of quantifiers in standard predicate calculus as limiting cases. The empirical results of Zimmer (1982) on the colloquial meaning of quantifiers in everyday situations, social sciences, and natural sciences fit well into Zadeh's (1983) computational approach. The modification of their meaning by the contexts of colloquial usage, however, indicates that for an integrated approach towards a formalization of mundane reasoning it is necessary to model the pragmatics of colloquial quantifiers by combining the context-independent meaning of quantifiers with the fuzzy constraints exerted by the context.

There are two contrasting approaches to the assessment of subjective judgments of uncertainty:

(i) to ask for numerical values and to calibrate and/or transform these values in such a way that additivity and multiplicativity are given, or

(ii) to ask for qualitative judgment of uncertainty and to calibrate them as fuzzy numbers and to test if fuzzy addition and fuzzy multiplication for disjoint events is given.

Both approaches can be integrated by interpreting the results as fuzzy numbers in the unit interval. However, Wallsten & Budescu

(1983) and especially Zimmer (1983) have shown that qualitative judgments of uncertainty seem to be closer to the intuitions of the analyzed subjects. Furthermore, if these judgments are analyzed subject for subject, biasing effects on these judgments as, for instance, conservatism vanish.

3. DIFFERENT STRUCTURES FOR TRAINS OF ARGUMENTS

The qualitative modifiers interpreted as fuzzy numbers imply the application of a fuzzy calculus for the evaluation of the prototypical form of arguments, namely, syllogisms where the quantifiers of the major and the minor premise are combined by a fuzzy operator in order to determine the quantifier of the conclusion. The structure of the standard syllogism can be represented by the graph in Figure 1.

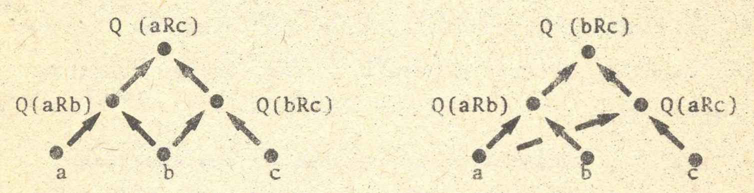

Figure 1: Graphical representations of the standard syllogism

If the Q are fuzzy quantifiers and the R represent the relation "is a", the evaluation of the conclusion simply consists of multiplying the quantifiers of the premises.

This, however, is not the most simple structure of arguments. Much simpler and at least as important are linear chains of arguments of the form: a implies b to the degree Q_1, b implies c to the degree Q_c, ... and y implies z to the degree Q_{z-1}, therefore a implies z to the degree of $f[Q_1 \ldots Q_{z-1}]$. The major problem with this structure of arguments, namely, that the longer the chain is the less information the conclusion tends to be, has been analyzed in Zimmer (1985). From a logical point of view this result is straightforward but it does not fit the empirical results on human reasoning. Apparently humans tend to compromise between the sticking to already held opinions (the confirmation principle) and the taking into account sufficiently surprising new information (the novelty principle). If the confirmation principle prevails, only supportive information is processed and upsetting new information is discarded. The resulting information processing behavior exhibits the bias of extreme conservatism. If, however, merely the novel and surprising information is used for the updating, an erratic behavior of blind trial-and-error results. The empirically observed behavior lies in between these two extremes. It can be modelled as in Formula 1 where Q_i is the quantification at time i, b_i is the corroboration parameter $(0 \leq b_i \leq 1)$ for the quantified proposition until time i, I_{i+1} is the novel information obtained at time i+1, and the parameter $\alpha_{crit} (0 \leq \alpha \leq 1)$ determines whether the information processing is primarily conservative or governed by the novelty principle.

$$(1) \qquad Q_i = \underset{x}{\mathrm{MAX}} \left[\frac{\underset{x}{\mathrm{MIN}} \left[b_i Q_{i(x)};\ (1-b_i) I_{i+1}(x) \right]}{\left[\underset{x}{\mathrm{MAX}}\ Q_i;\ I_{i+1}(x) \right]} ; \left\{ \begin{array}{ll} & \text{iff } \alpha > \alpha_{crit} \\ \left[\underset{x}{\mathrm{MAX}}\ Q_i;\ I_{i+1}(x) \right] & \text{otherwise} \end{array} \right. \right]$$

where

$$(2) \qquad \alpha = \sup \left[\underset{x}{\mathrm{MIN}}\ Q_i(x);\ I_{i+1}(x) \right]$$

If α_{crit} approaches 0, a compromise between Q_i and I_{i+1} is achieved even if I_{i+1} contradicts Q_i. The higher the value for

α_{crit} is, the more probable is a bifurcation between the "old" and the "new" claim. It can be seen without formal proof that Bayesian information updating is a special case of this model of linear chains of arguments.

In section 2 it has been mentioned that the empirical results of Pepper (1981), Zimmer (1982), and Hörmann (1983) show contextual influences on the meaning of frequency expressions and colloquial quantifiers. Linear chains of arguments cannot handle this problem because in this case there is not only a bottom-up or temporal integration of propositions but there are also top-down constraints on the meaning of the quantifiers in these propositions. This can be modelled in an interactive heterarchy for propositions (Figure 2).

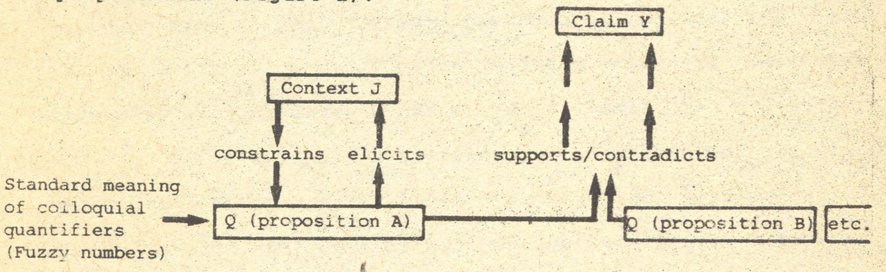

Figure 2: Information processing with context-dependent quantifiers

Even more complex trains of arguments can be found in the literature on Bayesian and non-Bayesian updating of evidence (Shafer 1976, Shafer & Tversky 1985, Kyburg 1987). However, in order to handle these nets of evidence, they have to be reorganized according to the assumed syntax of the evidential scheme in question. This virtually results in a linearization or hierarchization as in Figure 1.

4. AGGREGATING EVIDENCE FOR ARGUMENTS

In the proceeding section it has been shown how syllogistic arguments can be computationally evaluated if the quantifiers are interpreted as fuzzy numbers. Furthermore, we had postulated that evidential nets can be reorganized as hierarchies of arguments which in turn can be analyzed computationally.

Shafer & Tversky (1985) have discussed a Baysian partitioning design which has proved to be quite generally applicable in the case of evidence nets (Zimmer & Körndle 1987). The example of a murder case analyzed by Shafer & Tversky reveals one major weakness of such designs if the processed evidence is weighed with numerical probability estimates: they tend to depend not so much on the strength of the evidence but more on its consistency. Even if only very weak but consistent circumstantial evidence has been gathered and analyzed, the outcome indicates a very strong corroboration of the claim (in this example a probability of .98 for the guilt of the accused). In Zimmer & Körndle (1987) verbal uncertainty expressions for the weighing of the evidence have been elicited and transformed into empirically determined fuzzy numbers. The result is shown in Figure 3.

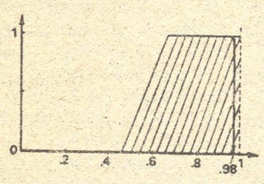

Figure 3: Evaluation of evidence for the Shafer & Tversky (1985) example. The shaded area indicates the resulting fuzzy number if verbal uncertainy expressions are analyzed; the arrow indicates the result of Shafer & Tversky with numerical estimates.

Figure 3 indicates that the result of Shafer & Tversky with numerical estimates is subsumed by the fuzzy number which results from the evaluation of the verbal uncertainty expressions if these are interpreted as values of a linguistic variable. Of further interest is the comparison of the resulting corroboration of the claim (in this case: x is the murderer) if (i) the normative Bayesian partitioning design is applied or (ii) subjects are asked to estimate the overall evidence for the claim. It turns out that subjects apparently process only very small parts of the body of evidence in their overall evaluation of the claim, they seem to be especially insensitive to complex dependencies. Therefore, it is advisable for the design of decision support systems to restrict the propositions to be evaluated by experts to simple conditional statements. The overall evaluation, however, should be done by a computer according to the structure of the applicable evidential design.

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