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Workshop 4 - Computational Dialectics:
Models of Argumentation, Negotiation and Decision Making

Mediating Systems for Group Decision Making: the Zeno System

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Abstract

This paper is a contribution to the recently introduced field of Computational Dialectics, which investigates computer models of norms for real-life discource. Computer Science has yet to provide adequate tools for supporting rational, effective and fair decision-making, when resources, such as information, time and memory are limited, and conflicts of claims and arguments are common. Zeno is a mediating system for group decision-making built on a normative model of limited rationality. Its architecture is presented here, the focus of attention being the Argumentation Framework Layer. The relevant concepts are introduced, and the arising matters of priority relationships and decision making are discussed. Finally, a quite extensive, but not exhaustive, presentation of related research is cited and criticized, aiming at instilling sound properties for the implementation of such a system.

1 Introduction

Computational Dialectics[1] (CD) is a recently introduced area of AI, exploring computational models of the processes by which groups of natural or artificial agents construct judgement, agreement, or other forms of social choice during any kind of debate. Special emphasis is given on methods for recognizing or achieving an outcome in a fair and effective way. CD investigates formal models of defeasible argumentation and negotiation as well as approaches that model group decision making processes. In each case, one has to weigh reasons for and against a certain option. Among relevant topics we mention mediating systems, qualitative and quantitative models of decision making, negotiation protocols, standards of correctness, effectiveness, and fairness of protocols, handling of uncertain and incomplete information, and decision making in the legal domain. The area of Computational Dialectics receives currently the interest of researchers from various well-established areas, such as nonmonotonic reasoning, distributed AI, decision theory, legal reasoning, philosophy, psychology and cognitive science.

The ubiquitous task in practical problem solving is that of identifying and choosing among alternative courses of action. Computer science has yet to provide adequate tools for supporting rational, effective and fair decision-making, when time, information and other resources are limited, and conflicts of interest and opinion are common. Models of rational

[1] the term was launched by T. Gordon [Gordon, 94a], [Gordon, 94b].

decision-making in groups are needed which take these considerations into account. The goal of the *Zeno* project is to design and implement a *mediating system* for supporting decision-making in groups founded on a normative model of limited rationality. The thesis adopted is that rationality can best be understood as theory construction regulated by discourse norms.

The rest of this paper is organized as follows: Section 2 sketches the proposed architecture for a mediating system, presenting informally aims and tasks at each level. Section 3 discusses extensively concepts of the second level, the Argumentation Framework Layer, introduces our approach for defeasible qualitative decision making, and highlights some difficulties arising in real world cases, due to incomplete information. Finally, current work concerning Zeno and GEOMED projects and the idea of a WWW-based implementation, related work as well as future research issues and targets are presented in Section 4.

2 An abstract model of mediating systems for group decision making

Conceptually, a mediating system for group decision making consists of the following four levels:

(i) the *Logic Layer*, where the notions of necessary *consequence* and *contradiction* are defined. This layer specifies formally the notions of theory that will be used and provides the appropriate derivability relation specifying whether or not some position is in this theory. Formal models of argumentation have been built on various logics (see for example [Brewka, 94b] reconstructing Rescher's [Rescher, 77] theory of formal disputation, [Prakken, 93] based on Reiter's [Reiter, 80] default logic, and [Gordon, 93b], [Gordon, 94b] using Geffner and Pearl's [Geffner and Pearl, 92] nonmonotonic logic, conditional entailment). Whether it makes sense to use nonmonotonic, inductive or analogical logics at the bottom layer is extensively discussed in [Prakken, 95]. In this paper, we will not strictly specify the logic we intend to be used in the system. The formalization of the next (higher) layers does not assume any particular choice of logic. Related systems of defeasible argumentation have also left unspecified the underlying logic (see for example [Vreeswijk, 93]).

(ii) the *Argumentation Framework Layer*[2], where the concepts of positions, supporting arguments, counterarguments and issues as well as linguistic constructs for arguing about priority relationships among competing arguments are defined. The argumentation concepts at this level result in a kind of nonmonotonic formalism, founded on argumentation principles. Both declarative and procedural models of argumentation, emerging from AI and Law, should be considered in the definition of this layer (see also [Prakken, 95]). The current state of any argumentation or negotiation procedure, taking place in a dispute, should be represented in this layer. Section 3 illustrates extensively the specification of this layer in Zeno system.

[2] the term *Argumentation Framework* was coined by H. Prakken [Prakken, 95].

(iii) the *Speech Act Layer*[3], where the space of possible kinds of actions a participant may "perform" during a discussion is defined. Participants may alter the structure of the Argumentation Framework at the second level by, for example, adding and deleting either claims or arguments.

(iv) the *Protocol Layer*, where norms and rules about duties and rights of the agents to perform actions (defined at the previous layer) are specified. The need for norms or *protocols* arises mainly from the conflicts of interest and goals each participant has during a debate. Protocols provide a means for structuring in advance our demands for possible communication actions. They should promote *fairness*, *rationality* and *efficiency*. Ideas from similar structures in formalised public activities should be exploited together with methods from AI and Law, such as Deontic Logic and Argumentation Theory, as well as from Distributed AI. Protocols could also aid to the limitation of redundant communication [Campbell and D'Inverno, 90]. Following the above interpretation, any participant in a discussion should be "protocol-oriented", in the sense that he/she is familiar with the existing protocol in order to make his/her contribution. Multiple protocols may also be defined, depending on the type of the debate. Protocols should take into account the roles of participants and/or the evolution of the decision making procedure. Finally, they should be "open", extensible, debatable, and not automatic or self-applying.

3 The Zeno Argumentation Framework

In this section we introduce the concepts behind the Argumentation Framework Layer of Zeno, and we sketch the methods for approaching the arising matters of priority relationships, decision making and dependency propagation.

3.1 Specification of concepts

Propositions are the lowest level of granularity in our framework. Any kind of data an agent wants to assert during a dialectical process can be used to represent a proposition. A proposition may be represented by a text, spreadsheet, graphic, part of a database, map etc. The proposition used can be true or false, important or irrelevant for the corresponding problem, and may become acceptable or non-acceptable.

Each proposition has a *label* indicating its status, derived from decisions about priority relationships, taken either automatically (that is, recommended by the system) or decided by the system user(s). In the current approach we allow for the following labels:

- SRA: system recommended accept
- SRR: system recommended reject
- NSR: no system recommendation

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[3] the term *Speech Act* was introduced rather by the English linguistic philosopher J.L. Austin [Austin, 62], as an act carrying some propositional content plus "illocutionary force".

Issues comprise two parts: a set of alternative propositions and a set of related *constraints*. The propositions represent the positions (or claims[4]) asserted so far. The issue is which alternative position to prefer, if any. Following [Brewka and Gordon, 94], it is not possible to select more than one alternative position of an issue. In addition, an issue includes a "dummy" position, named `nil`, denoting the "selection of none of the current positions". `nil` provides a means of handling our aims, i.e., a possible system indication than none of the alternative propositions in this issue is recommended[5]. It should also be mentioned here, that the `nil` proposition is not unique for all issues; each issue has its own.

Constraints provide a qualitative way to argue about preferences and value judgements in order to weigh reasons for and against a certain option. In other words, they give to the users the ability of ranking the quality of alternative positions. Constraints are interpreted as *meta-issues*, including a `nil` position as well as possible constraints on them. This provides a means for expressing agents' belief for the constraint, that is either acceptance or rejection of it, or "no decision about its validity".

Finally, *arguments* are assertions about the positions regarding their properties or attributes, which speak for or against them. We allow for two kinds of them, *supporting arguments* (pro) and *counterarguments* (con). An argument links together two propositions of different issues. Following [Brewka, 89] and [Brewka, 94a], we consider that there are not unrefutable arguments. Two conflicting arguments can simultaneously be applied. The multiple meanings of the term "argument" are discussed in [Prakken, 95].

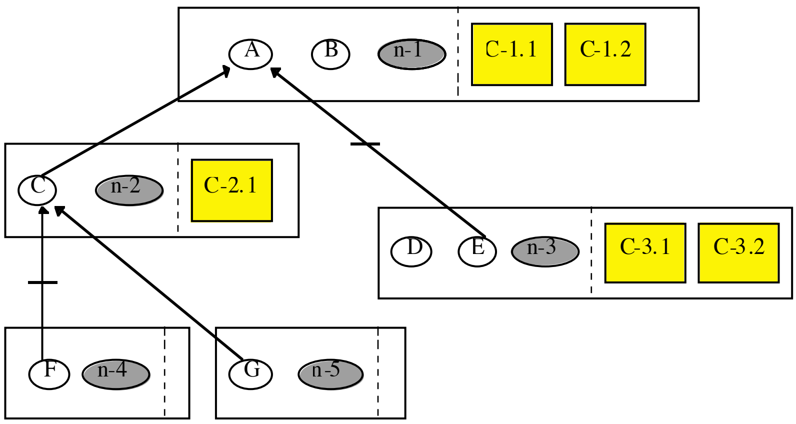

Figure 1: *An instance of the system structure.*

[4] we use the terms *position* and *claim* interchangeably throughout this paper.

[5] for example, in an issue consisting of only one position *A*, the "recommendation" of `nil` indicates that the system accepts neither *A* nor its negation, ¬*A*.

The above concepts are illustrated in Figure 1. Positions are denoted with ellipses (the dummy `nil` propositions are coloured gray), issues with rectangles, supporting arguments with plain arrows, and counterarguments with arrows crossed by a simple line. Constraints may appear in the second part of each issue. Due to space limitations, they are simply shown here with shadowed rectangles, although they retain the structure of issues.

3.2 Decision Making

Factors to be considered in real world instances of decision making have been illustrated in [Gordon, 94a] and [Brewka and Gordon, 94]. The Argumentation Framework Layer has to address the subjects of default reasoning and priority relationships for resolving conflicts in order to provide the appropriate assessment of positions and, consequently, the decision making procedure.

We draw on concepts first introduced in [Brewka and Gordon, 94] about a Qualitative Value Logic (QVL), a logic for defeasible qualitative decision making[6]. According to it, decision making is governed by preferences among arguments for and against some position. QVL's major advantage is that it allows for overcoming problems arising when one uses in the underlying Logic Layer a single preference relation. Legal reasoning, for example, often makes use of "Lex Superior" and "Lex Posterior", while a lot of AI approaches support only the "specificity principle" (see for example [Geffner and Pearl, 92] on conditional entailment). In the proposed formalism, aiming at the independence of the Argumentation Framework Layer from the Logic one, knowledge about preferences is encoded as part of the domain theory. In other words, the model of conflict resolution and decision-making in the Argumentation Framework Layer is independent of the method used to encode preferences in the domain theory of the underlying Logic Layer. In this model, supporting and counter arguments can be weighed against each other. The constraints of an issue allow for the combination of weak arguments to defeat a strong argument.

The subject of priority relationships and preference orders has been mostly handled through quantitative approaches (see for example [Pinkas, 91] and [Sian, 91], using the concepts of "cost of not taking a premise into account" and "confidence factors", respectively). Well defined utility and probability functions regarding properties or attributes of alternative positions, used for example in traditional OR approaches, as well as complete ordering of these properties are usually absent.

Dealing with real world problem instances the following subjects have been revealed: (i) A complete preference ordering among arguments is not always attainable. There may be some formal properties such as transitivity and noncircularity (see also [Prakken, 95]), but still a partial ordering is what we are able to achieve. (ii) There is not always complete information for each alternative proposition of an issue regarding the attributes asserted by the arguments. For instance, in order to conclude an issue with two alternative propositions A

[6] in fact QVL allows reasoning about preferences via either quantitative or qualitative values.

and B, it is possible to know that "A has the attributes a, b and g", while "B has the attributes a, d, e and z" (consider the case where no information regardingthe ordering of b, g, d, e and z has been given). All the above advocate in preferringQVL-like approaches in Zeno system.

Trying to solving an issue, the system considers the related supporting and counter arguments as well as the asserted constraints[7]. Depending on the information has been provided, the system can (i) recommend the acceptance of a *single* proposition (SRA), and, consequently, the rejection of the rest of them (SRR), (ii) recommend the rejection of some positions (for example, in cases resulting only to partial preferences among the positions, the SRR label may appear $m \leq n-2$ times, where n is the number of the alternatives), or (iii) make no recommendation at all.

Let I be the set of issues in a debate, $I = \{I_1, I_2, ..., I_n\}$, C_i the set of constraints of an issue i, $C_i = \{C_{i,1}, C_{i,2}, ..., C_{i,k}\}$, P_i the set of propositions of an issue i, $P_i = \{P_{i,1}, P_{i,2}, ..., P_{i,p}\} \cup \mathtt{nil}_i$, n, k, $p \in N^+$, and $P_i' = \{P_{i,1}, P_{i,2}, ..., P_{i,p}\}$. Let also the functions *label*(x), $x \in P_i$, and *con*(y), $y \in I$, for the labelling of propositions and conclusion of issues, respectively. As it has been stated above, arguments link together propositions of different issues. In the proposed system, we don't allow for cycles. Consequently, the structure of the system is tree-like. The decision-making procedure follows a *bottom-up* approach, starting from the "leaves" issues and heading for more "coarse" ones. A first sketch of the decision making procedure taking place in each issue is given below:

in an issue i:

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    conclude the constraints C_i,1, C_i,2, ..., C_i,k   ;; find the accepted, rejected and undecided ones
    if the accepted constraints are inconsistent
        then   con(i) = undecided
        else   label(x)=NSR, ∀ x ∈ P_i'             ;; initially we assume that every position
                                                     ;; is not recommended
               solve the issue                       ;; try to find total or partial preferences
               labelling and conclusion of the issue
               propagation of decision
    endif
end
```

The *labelling* procedure for the propositions of issue i is as follows:

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(cond  (optimal solution := P_i,x)      (and  (label(P_i,x)=SRA)
                                              (label(P_i,y)=SRR, ∀ P_i,y ∈ P_i' ,y≠x)
                                              (label(nil_i)=SRR)    )
       (P_i,k better than P_i,m)[8]     (and  (label(P_i,m)=SRR)
                                              (label(nil_i)=SRA)    )
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[7] the conclusion of an issue implies usually the solution of a constraint optimization problem; exploiting abilities of constraint programming languages can guarantee consistency checking for the constraints.

[8] in this case we have only partial ordering of the alternative positions.

else[9] (*and* ($label(P_{i,v})$=SRR, $\forall P_{i,v} \in P_i'$)
($label$(`nil`$_i$)=SRA)))

Finally, the *conclusion* procedure is:

(if ($\exists P_{i,j} \in P_i' \ni label(P_{i,j})$=SRA)
(con(i) = decided) ;; *then* part
(con(i) = undecided)) ;; *else* part[10]

Initially, any issue of a debate is considered undecided. After the labelling and conclusion procedures, *propagation* of the eventual decision has to take place. As it is obvious, this has to be done only when an optimal solution has been found for an issue i, in a way that its *parent-issue* k has to be concluded taking that into account. In other words, if issue i is remained undecided, then issue k will be concluded with no additional information from this "branch" of it. Not giving the complete formalization of the system in this paper, we just argue that propagation of the optimal solution found in issue i has to be embedded in the constraints part of the parent-issue k.

4 Discussion

Work being done in the context of Zeno project has both theoretical and practical goals. The theoretical goal is to improve formal models of rationality given restricted resources. This will be a contribution to the field of Computational Dialectics. Rationality in Zeno has been understood as a theory construction language game regulated by procedural discourse norms. The practical goal is to design and implement a mediating system for the World Wide Web. This will be a new kind of conferencing and group decision-support system. The services to be provided include managing the dependencies between arguments, claims, positions and issues, helping users to be aware of their rights and obligations in a proceeding, and providing access to procedures for negotiation and conflict resolution. As it has been made previously clear, it is not the role of the system to enforce the rules of the proceeding. Its task is to assist and advise the participants, not to be a cop or judge.

The Zeno interpreter is being implemented as a World Wide Web Common Gateway Interface (CGI) script, using the Scheme Shell. Any WWW browser, such as Mosaic or Netscape, will be sufficient to take part in a Zeno mediated discussion. The intended prototype application for Zeno is to assist government and businesses with the retrieval, use and reuse of information, practices and knowledge in cooperative, distributed planning procedures requiring access to geographical information. Application scenarios include that of a company or government trying to decide where to locate a new factory or agency, a community deciding how to partition the lots of a new housing district, or neighbouring countries planning the

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[9] in this case every alternative position has been rejected.

[10] in this case some or all of the positions in P_i' have been labelled as SRR.

path of a highway between two cities. Zeno is participating in the Geographical Mediation Systems (GEOMED-F) feasibility project sponsored by the European Union[11].

In the rest of the section research work related to Zeno´s goals is presented. The list is not exhaustive, but focused on previous, well-tried concepts and theories, which we intend to further explore and adapt in our formalism:

- Toulmin´s (second) theory of argumentation [Toulmin, 58]: Toulmin´s main thesis is that logic is generalized jurisprudence. He argues that the mathematical orientation of "logics" is overemphasized and, although necessary, not of greatest practical significance. For him, "logic" is a set of norms regulating practical discourse. The legitimate aspect of logic encompasses all norms required for regulating such discourses, and not just the subset concerning logical necessity and contradiction. Toulmin´s theory most interesting aspect is undoubtfully its structure of arguments. , Briefly, a *claim* is a statement asserted by the proponent, who has to support it with a *datum*, if the opponent challenges it. If the opponent doubts that the datum supports the conclusion, the proponent is called upon to present a *warrant*, which is also defeasible and, in case of opponent´s challenging, has to be supported by *backing*. Toulmin also distinguishes between "substantial" and "analytic" arguments, after examining their structure in various fields, such as physics, ethics and law. Weaknesses of Toulmin´s theory are highlighted in [Gordon, 93a] (pp. 54-59). These are: (i) The cooperative only aspect of Toulmin´s argumentation; agreement is only possible if there is a certain willingness by both parties to agree. Instead, Zeno is intended to be "open" and applicable to any kind of adversarial, cooperative, or group decision making process; (ii) The lack of the appropriate formalism for ordering competing arguments. This is addressed in Zeno exploiting abilities of QVL; (iii) Its failure to fairly balance the interests of the proponent and the opponent; the proponent is obliged to face the opponent´s right for limitless objection. The definition of efficient protocols in Zeno´s Protocol Layer, taking into account resource limitations, will relieve argumentation of such an "inadequacy"; (iv) Toulmin´s "premature" rejection of mathematics, arguing that an argumentation theory can profit from insights from both jurisprudence and mathematics.

- Pollock's OSCAR model of defeasible reasoning [Pollock, 88]: Pollock´s approach was one of the first attempts to base defeasible reasoning on arguments, influencing later work (see for example [Simari and Loui, 92] and [Geffner and Pearl, 92]). His model does not deal with resolving disputes, but with prescribing the set of beliefs a single rational agent should hold, under certain simplifying assumptions. Following to it, the initial *epistemic basis* of an agent comprise a set of positions, called *foundational states*, either supported by perception or recalled from memory, that are not necessarily believed, a set of *defeasible inference rules* and a set of *nondefeasible inference rules*. Belief on positions stands until defeated by new reasons, disregarding the original ones. OSCAR distinguishes between *warranted* and *justified belief*, taking seriously computational limitations, such as memory and time, into account. Such limitations should be considered in the definition

[11] DG XIII, Telematics, Information Engineering Project No. 174. Other members of the GEOMED consortium include: Université Joseph Fourier LIFIA - IMAG (France), TNO Building and Construction Research (The Netherlands) and the Artificial Intelligence Laboratory, Vrije Universiteit Brussel (Belgium).

of Zeno´s Protocol Layer. Pollock also discusses three kinds of *belief formation* (moves), namely *adoption*, *defeat* and *reinstatement rules*. Finally, OSCAR does not distinguish between roles of players, and there are no reasoning schemata provided for the validity of inference rules, or their relative weight and priority. Quoting [Gordon, 93a][12], both Toulmin and Pollock "are interested in the problems of practical, substantial reasoning, and both attempt to account for how humans combine deductive, defeasible, inductive and probabilistic reasoning".

- The work of Rescher [Rescher, 77] on a theory of formal disputation: Rescher considers disputation to be a three-party game, taking place with a *proponent* (asserting a certain position), an *opponent* (able to challenge proponent´s position, i.e., through counterarguments) and a *determiner* (which decides whether the proponent´s position was defended successfully or not). Rescher also identified three fundamental legal moves, namely, the *categorical*, *cautious* and *provisoed assertions*. A more formal reconstruction of Rescher´s theory is presented in [Brewka, 94b], based on Reiter´s Default Logic and, more especially, on its SDL variant[13]. Brewka´s work clarifies Rescher´s concepts and goes ahead defining *elementary* and *legal moves* during a dispute, as well as *winning situations*. Nevertheless, both approaches are limited in that "the players have no chance to disagree about defaults"[14]. Regarding the Zeno model, the abovementioned approaches provide a number of stimulating instances for the formal specification of its levels.

- The *IBIS* (Issue-Based Information System) *rhetorical method* developed at MCC: Concepts addressed in this approach are *issues* (questions or problems), *positions* (possible resolutions of an issue), and *arguments* (the pros and cons of the alternative positions) [Conklin, 92]. Also interesting for Zeno´s goals is its "groupware version" (called *gIBIS* - Graphical Issue-Based Information System), an application specific hypertext system originally used for the software development process, aiding the structuring and the documentation of the decision steps [Yakemovic and Conklin, 90].

5 Conclusion

Various concepts of Computational Dialectics and mediating systems were discussed in this paper. Presenting work being performed in Zeno project, the paper focused on the presentation of an abstract model of mediating systems for group decision making. We suggest a four layer structure, introducing the corresponding concepts should be defined in each one of them. The second layer, namely Argumentation Framework Layer, is extensively addressed. The notions of propositions, issues and arguments (pro and con) are given, and a semi-formal approach for

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12 [Gordon, 93a] provides an extensive evaluation of Pollock´s OSCAR model (pp. 77-81).

13 SDL has also been developed by Brewka, and it is a variant of classical DL, allowing for inclusion of the "specificity principle".

14 [Brewka, 94b], page 25.

the conclusion of an issue is attempted. Finally, promising indications and results from related work are discussed and evaluated from Zeno´s point of view.

We argued that a mediating system for group decision making should be efficient, fair and rational. Thus, it should exploit "logic" concepts revealing both from jurisprudence and mathematics, consider both claims and arguments as defeasible, be "open" and applicable to any kind of debate, provide the appropriate formalism for ordering competing arguments (both qualitatively and quantitatively), and take into account resource limitations, such as memory and time.

References

[Austin, 62] J.L. Austin, "How to do things with words", Oxford University Press, 1962.

[Brewka, 89] G. Brewka, "Preferred Subtheories - An Extended Logical Framework for Default Reasoning", Proceedings of IJCAI-89, Detroit, 1989, pp. 1043-1048.

[Brewka, 94a] G. Brewka, "Reasoning about Priorities in Default Logic", Proceedings of AAAI-94, Seattle, 1994, pp. 940-945.

[Brewka, 94b] G. Brewka, "A Reconstruction of Rescher's Theory of Formal Disputation Based on Default Logic", Working Notes of AAAI-94 Workshop on Computational Dialectics, Seattle, 1994, pp. 15-27.

[Brewka and Gordon, 94] G. Brewka and T. Gordon, "How to Buy a Porsche: An Approach to Defeasible Decision Making", Working Notes of AAAI-94 Workshop on Computational Dialectics, Seattle, 1994, pp. 28-38; available in `http://nathan.gmd.de/projects/zeno/zeno2.html`.

[Campbell and D'Inverno, 90] J.A. Campbell and M.P. D'Inverno, "Knowledge Interchange Protocols", in Y. Demazeau and J.P. Müller (eds.) Decentralized AI, Elsevier Science Publishers, 1990.

[Conklin, 92] E.J. Conklin, "Capturing Organizational Memory", in D. Coleman (ed.) Groupware '92, Morgan Kaufmann Publishers, pp. 133-137.

[Geffner and Pearl, 92] H. Geffner and J. Pearl, "Conditional Entailment: Bridging two Approaches to Default Reasoning", Artificial Intelligence, 53 (2-3), 1992, pp. 209-244.

[Gordon, 93a] T. Gordon, "The Pleadings Game: An Artificial Intelligence Model of Procedural Justice", Ph.D. Dissertation, Fachbereich Informatik, Technische Hochschule Darmstadt, 1993.

[Gordon, 93b] T. Gordon, "The Pleadings Game: Formalizing Procedural Justice", Proceedings of the Fourth International Conference on Artificial Intelligence and Law, ACM Press, 1993, pp. 10-19.

[Gordon, 94a] T. Gordon, "Computational Dialectics", Proceedings of Workshop Kooperative Juristische Informationssysteme, Wien, Austria, GMD Studien Nr. 241, 1994, pp. 25-36; available in `http://nathan.gmd.de/projects/zeno/zeno2.html`.

[Gordon, 94b] T. Gordon, "The Pleadings Game: An Exercise in Computational Dialectics", Artificial Intelligence and Law, 2(4), 1994, pp. 239-292.

[Pinkas, 91] G. Pinkas, "Propositional Non-Monotonic Reasoning and Inconsistency in Symmetric Neural Networks", Proceedings of IJCAI-91, Sydney, 1991.

[Pollock, 88] J. Pollock, "Defeasible Reasoning", Cognitive Science, 11, 1988, pp. 481-518.

[Prakken, 93] H. Prakken, "Logical tools for modelling legal argument", Ph.D. Dissertation, Free University of Amsterdam, 1993.

[Prakken, 95] H. Prakken, "From Logic to Dialectics in Legal Argument", to appear in Proceedings of International Conference of AI and Law, 1995.

[Reiter, 80] R. Reiter, "A Logic for Default Reasoning", Artificial Intelligence 13, 1980, pp. 81-132.

[Rescher, 77] N. Rescher, "Dialectics: A Controversy-Oriented Approach to the Theory of Knowledge", State University of New York Press, Albany, 1977.

[Sian, 91] S.S. Sian, "Adaptation based on cooperative learning in multi-agent systems", in Y. Demazeau and J.P. Müller (eds.) Decentralized AI 2, Elsevier Science Publishers, 1992.

[Simari and Loui, 92] G.R. Simari and R.P. Loui, "A Mathematical Treatment of Defeasible Reasoning and its Implementation", Artificial Intelligence 53 (2-3), 1992, pp. 125-157.

[Toulmin, 58] S.E. Toulmin, "The Uses of Argument", Cambridge University Press, 1958.

[Vreeswijk, 93] G. Vreeswijk, "Studies in Defeasible Argumentation", Ph.D. Dissertation, Free University of Amsterdam, 1993.

[Yakemovic and Conklin, 90] K.C.B. Yakemovic and E.J. Conklin, "Report on a Development Project Use of an Issue-Based Information System", in F. Halasz (ed.) Proceedings of CSCW 90, LA, October 1990, pp. 105-118.