

# The Legal Applications of Logic Programming Workshop at the ICLP 94 Conference<sup>1</sup>

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## 1 Introduction

The representation of parts of legislation in logic, successively implemented in the language of *logic programming* and managed by Prolog interpreters, has by now existed for more than ten years. The first and most well-known projects were those by the *Logic Programming Group* of Imperial College of London which, in 1985, formalized the *British Nationality Act* (Sergot et al., 1986; Sergot, 1990). Other projects followed, for the most part European, including the Italian project, *Esplex*, developed in Florence (Biagioli et al., 1987), the Dutch project, *Prolex*, (Walker et al., 1990), the German project born of the collaboration between IBM and the University of Tübingen (Alschwee, Grundmann, 1986), and the Japanese project, *Les-2* (Yoshino, 1986). There are precise reasons to explain why a particular preference took shape for logic programming in European countries, most of which have *civil law* legal systems (as in Japan), which is to say legal systems strongly based on written norms: codifications, laws, regulations. The rule-based formalization was unanimously considered to be suited to dealing with knowledge models as closely isomorphic to the text as possible (Bench-Capon & Coenen, 1991). On the other hand, *common law* countries (principally the United States), where to a small extent, the normative base consists of written norms and for the most part of preceding legal decisions (*case-law*), which are binding on the *stare decisis* principal, have adopted descriptive formalisms of factual situations such as *frames*, *script*, etc. (Ashley, 1990, 1993; Skalak & Rissland, 1992).

Robert Kowalski, too, has for a long time been interested in the legal domain as (the) field of application for logic programming, as it is considered to be rich in features that can provide interesting points in developing extensions of logic programming techniques which are also valid in other domains (Kowalski, 1990, 1991).

To make this brief exposition clearer, I shall focus the themes which today constitute the points of greatest interest both in general for the sector of AI and Law, and in particular for *logic programming*, conducting a synthetic survey on the results obtained, along with a specific reference to the contributions presented at the *ICLP 94 Workshop on Legal Applications of Logic Programming*, held in Santa Margherita Ligure, Italy.

To complete the information, let me add that there is an A.I. and Law International Association that directs an international review, joined by an Australian and an English review; the A.I. and Law international congress (ICAIL) takes place every two years.<sup>2</sup> Other conferences on the theme are held in Great Britain (Exeter University), Holland (*Jurix*), Italy, in Florence, and at the Istituto per la Documentazione Giuridica of the National Research Council (*Logica, Informatica e Diritto*<sup>3</sup>). Sessions devoted to legal applications are hosted by the annual Italian congress on logic

<sup>1</sup>A preliminary version of the proceedings of the workshop (Biagioli et al., eds.) is available from I.D.G., Via Panciatichi, 56/16, Florence, Italy.

<sup>2</sup>The fifth event will be held at the University of Maryland, USA, in 1995; previous conferences were held in Boston (1987), Vancouver (1989), Oxford (1991) and Amsterdam (1993). The proceedings are published by the ACM Press.

<sup>3</sup>Four editions (1981, 1985, 1989, 1993).

programming (*Gulp*), by the annual *Dexa Conference* and, as of this year, also by the *ECAI* (European Conference on Artificial Intelligence) in Amsterdam, as well as by the *ICLP* (International Conference on Logic Programming).

## 2 The argument paradigm

As already said above, in the tradition of continental countries, the building of decision support systems has been commonly based on deductive logic models and on the use of *logic programming* languages. But, after more than ten years experience, the inadequacy of the deductive model, largely revealed by legal theory, is also found in its computational transpositions: to think that a decision logically (and mechanically) follows from premises made up of facts, norms and definitions of concepts is only valid with regard to *clear cases* (Hart, 1961). Widening the model must, therefore, enable the interpretation phase of *hard cases* to be reproduced (the generation of *multiple interpretation models*) and, furthermore, must enable inferences to be drawn from them, providing *criteria of choice*.

On a computational level, the problem of overcoming the limitations of the deductive paradigm is grounded on theoretical research in artificial intelligence in different domains: epistemic, nonmonotonic and conditional logic approaches to *commonsense reasoning*. In the monotonic inference of classical logic, the addition of new premises to a logic theory does not invalidate the previously inferred theorems; in nonmonotonic logic the addition of new premises (for example, of new knowledge inconsistent with some of the already existing knowledge) may defeat what has been previously inferred. (Kowalski, 1988; Kowalski & Sadri, 1990; Poole, 1988; Brewka, 1991; Pollock, 1987; Prakken, 1992; Sartor, 1991).

In this way, we would have a theory from which theorems that are inconsistent among themselves become derivable; only *provable* formulae are derivable theorems. A formula is *provable* if a consistent argument can be built based on the most reliable hypotheses (Rescher, 1964), nonmonotonic inference is used in practice for selecting, from within a set of inconsistent norms (theory), a consistent subset on which to base the decision. This means that several consistent subsets can be selected that justify conclusions which are contradictory (*conflicting defaults*).

Formally, by *argument construction*, we mean “the inference of propositions justified by consistent premises” (Prakken, 1992). Applying such an approach to the legal domain is particularly effective, because it constitutes an operation that is very close to the arguments a lawyer makes in support of his thesis (legally founded motivations), or the attorney when he wishes to convince the judge to make a favourable decision for his clients, and the legal scholar when he wishes to sustain a specific theoretical position or dogmatic construction, as well, in part, as the judge also, when he reaches a decision by evaluating, in substance, the plausibility of the opposing theses put before him by the parties and, therefore, by choosing the one that is most founded.

The formal (artificial intelligence) approach has advantages compared with the approach to argumentation in legal theory (Perelman & Olbrechts-Tyteca, 1956; Toulmin, 1958) and in the theory of discourse (Alexy, 1978), where, in the absence of a complete theory, a criterion for evaluating the arguments is also lacking. The analysis is on a pragmatic (the description of legal arguments as they occur in reality) or analytical level (the classification of types of arguments), but it does not give suggestions about whether an interpretation is correct or whether there are grounds for the decision (Alexy, 1992).

One of the most interesting aspects of research in this sector is indeed that, within these logics, it is possible to define *syntactic criteria of preference*, that enable the ordering of subsets on the basis of the best grounds. Criteria of *hierarchy*, *temporality* and *speciality* for solving normative conflicts can be introduced, as well as *multiple interpretative choices* (Sartor, 1991, 1993; Gordon, 1989; Guidotti et al., 1992; Prakken, 1993).

The concept of *logical consequence*, substituted with that of *defeasible consequence*, enables additional types of knowledge and different kind of *decisions* (*grounded*, *plausible*, *justified*

*consequences*: Sartor, 1993; Loui, 1993; Prakken, 1993) to be defined according to whether there is a counter-argument capable of invalidating the argument that is placed, and that this counter-argument is of the same or higher hierarchical level ("strength") as the adopted argument. This leads to a weakening of the causal link between the antecedent of a norm (the facts of the case or their generalization in the normative fact situation) and the legal consequence. The concept of consequence in nonmonotonic logic is defined in different ways according to the adopted models: either as an abductive hypothesis in logic programming (Kakas et al., 1992), rule of inference (Reiter, 1987), or as a relation of conditional implication in Gordon (1993), who adopts Pearl's conditional logic, as a relation of causality; *reason* in Hage (1993); *warrant* in Branting (1991, 1993), etc. As far as the nature of the interrelation between conditions is concerned, they are *necessary* in norms (and not merely sufficient, if not in a nonmonotonic sense), for establishing whether the consequent can be derived. In decisions, the elements of the case are *factors*, each one relevant *per se* for the purposes of the decision.

The use of an argumentative tree of a rule of statutory law requires the conditions of *applicability* to be met. Strictly speaking, this means that the conditions of the formal (or substantive) validity of the norm, as well as the correctness of the path taken from the normative sentence to the rule are satisfied (as the *baking* predicate in Gordon, 1993); broadly speaking, that any conflicts between norms which can both be applied to the same case are solved (Sartor, 1993). The conditions of applicability work on a *metaknowledge level*, although they may constitute the content of argumentation (and, above all, of counter argumentation) and, therefore, provide argumentative strategies.

That the logic programming paradigm supports nonmonotonic inferences has been claimed for many years, and much comparison between traditional AI and Lp approaches has been outlined: the invited speech of Kowalski at the workshop ("*An abstract argumentation-theoretic framework for non-monotonic reasoning*") addressed this topic, aiming to define an abductive and argumentative interpretation of negation as failure. The framework is general enough to include logic programming, epistemic, nonmonotonic default logic: the semantics are based on the concept of "acceptability" for abductive assertions.

### 3 Metaprogramming

From the above it is clear that not only complex reasoning schemata, but also *different types of knowledge* can be used in the legal reasoning processes. For example, additional knowledge is constituted by the theories formulated from dogmatics (Nitta et al., 1993), from generalizations of principles induced from decisions (Loui, 1993), from general principles (the *ratio decidendi* in Bernam & Hafner, 1993), or from taxonomies of always true definitional knowledge (Yoshino, 1993).

From what has been said so far, the distinction between object-knowledge and meta-knowledge, or rules for processing this knowledge, or strategies for evaluating which rule of reasoning to apply or heuristic principles for guiding these strategies, has implicitly emerged. Various kinds of terminology are used, because it is difficult to identify unambiguous terms for indicating concepts or ideas that are not, in fact, unambiguous, nor whose boundaries or lines of demarcation are easy to establish. The common feature of this kind of integrative knowledge is the *metalevel* dimension and the twofold scope of it: the reasoning processes, as well as the legal content of this reasoning. To give an example, in strictly logic-based models (e.g. Prakken, 1992) the introduction of syntactic criteria for evaluating the strength of the arguments is a form of heuristic criterium. However, the content of such criteria (hierarchy, types of interpretation, similarity) fall under metaknowledge more than under control strategies. In other projects (Loui, 1993), a kind of heuristics is introduced from the reasoning process followed in similar earlier cases; in Gordon (1993) the rules that guide the reasoning strategies are extracted from the theory of the discourse (Alexy, 1978, 1992) and the theory of argumentation (Perelman & Olbrechts-Tyteca, 1956; Toulmin, 1958).

Another approach is the possibility of using precedents not as interpreted models of individual pieces of the process, but as global models of all legal reasoning, that is, of how the judge is faced with the problem and how he solves it (Groendigk & Oskamp, 1993). In this case, as in the *rationales* introduced by Loui (1993), it is the *way the knowledge was treated* that becomes the *new knowledge*. On the other hand, cognitive science highlights how a determining phase in the problem solving process is constituted by the representation of the problem. Mapping partially similar problems, therefore, for transferring from one to the other the entire strategy to be used, and controlling the knowledge seems appropriate, even though it is, nevertheless, difficult to express what, in effect, these strategies are.

The logic programming approach makes it possible to confront different levels of knowledge in a logically sound and descriptively clear manner. The use of meta-programming techniques to deal with analogical reasoning (Davies & Russel, 1987; Hamfelt & Barklund, 1989, 1992; Costantini & Lanzarone, 1989), conflict resolution (Guidotti et al., 1992), nonmonotonic inferences (Nute, 1988; Sartor, 1991) is widely adopted; at the ICLP workshops, a proposal was presented (Bertarello et al., "*Explanation-based learning of open textured predicates in logic programming models of law*") to utilize Reflective Prolog (a Prolog version that contains reflexivity rules between levels) to define vague legal concepts (*open textured*).

The problem of dealing with legal knowledge, which is to say, to introduce conceptual elements along with syntactical criteria, remains an open question, as with the entire sector of knowledge engineering. The importance of representation languages also emerged from the workshop's accomplishments (Tojo & Nitta, "*Automatic generation of temporal relations in a legal Case*"; Nitta et al., "*Knowledge representation of new HELIC II*"; Yoshino, "*Representation of legal knowledge by compound predicate formula*"; Valente & Breuker, "*A common-sense formalisation of normative systems*"; Weusten, "*The use of different representation techniques in validation and verification of legal KB-systems*"), as well as from Marek Sergot's paper ("*Quasi-legal application of logic programming*"), aimed at investigating the possible fields of application of methodologies developed within logic programming and legal knowledge representation, with particular attention to the role of deontic logic.

#### 4 Deontic logic

Theorists and philosophers of law have always debated on the descriptive or prescriptive nature of norms, as they have on the possibility of building logically valid normative systems, the deductive or inductive character of legal reasoning, true/false values attributable to norms, relations between normative cases in point and individual facts.

The fact that norms (intended as a product of the interpretation, meaning of normative statements) have a function different from the descriptive/informative function of everyday language is obvious. What is much less obvious, however, is how to adapt the formal tools of classic logic to deal with this characteristic. Moving onto the domain of AI, for a long time it was denied (Breuker & den Haan, 1991) that there was a need to enhance the FOL representation of legal knowledge with operators of prescriptivity, introducing *ad hoc* modal operators (McCarthy, 1986, 1989).

As the ties between computer science and philosophical, epistemological and cognitive sciences prove to be increasingly close (which is even truer for AI), the answer is to be found principally on the level of theory. In the first approaches to formalizing legislation as logic programs, it was felt that the defining nature of laws was well-expressed in the Horn clause form, also considering that disjuncted conclusions are rarely reached in law. The procedural interpretation of clauses made it possible to "apply" the norm, verifying the facts interactively (query to the user: Sergot et al., 1986). Systems containing simple deontic operators (Biagioli et al., 1987) did not provide in-depth justification as to why they were necessary for representation.

Due to limited space, the approaches and the problems relating to modal and deontic logic will not be discussed in detail here (see, for instance, the *Proceedings of the Deon 91 Conferences*;

Amsterdam, 1991; Oslo, 1993). We shall only note one of the most significant aspects from the viewpoint of knowledge representation: Andrew Jones' (1990) claim whereby classical logic does not support the representation of a very frequent situation in law, the *violation of an obligation*. The problem, known to deontic logicians by the name of the *Chisholm paradox*, is generated by the fact that the existence of a norm that makes an action obligatory and, in case of violation, makes it's contrary obligatory, produces a conflict between two obligations.<sup>4</sup> Jones demonstrates how, by utilizing the deontic logic system DL,<sup>5</sup> extended to deal with nonmonotonic inferences (based on Delgrande conditional logic), it is possible to solve the conflict between obligations, distinguishing between *prima facie* and *actual obligations*.

It should be noted how the interest for deontic logic in the field of computer technology may present a different, original feature: an interpretation of deontic operators *within programs*, as tools for controlling and managing the knowledge itself is added to the traditional view of deontic logic as a tool for analysing and representing the prescriptive aspects of normative knowledge (Wieringa & Meyer, 1993).

Another interesting logic programming application is the automatic generation, through a Prolog programme, of the *normative positions*. In legal philosophy, the *theory of normative positions*, anticipated by Bentham and J. Austin, was developed by the American philosopher Hohfeld (1913) with the name of "Fundamental Legal Conceptions", reduced to a formal system by the Scandinavian philosophers Kanger (1966) and Lindhal (1977), and finally translated into computable models by Allen and Saxon (1986, 1987, 1991), Morris and MacDermitt (1991) and Jones and Sergot (1992).

It allows the definition, in terms of first order logical expressions extended with action (*Do*) and deontic operators (starting from the obligation *O*), of the legal relations (*power, duty, right, claim, freedom . . .*) existing between a subject and a position or between several subjects, and offers many possibilities for extending models of interpretation, sustained by the introduction of computational techniques on two levels: instrumental and substantive.

Regarding the former, it means activating relatively simple programmes able to generate all the possible normative positions, to eliminate inconsistencies and redundancies; for example, the computational reformulation of the Hohfeldian theory in Allen and Saxon (1991) altogether enables 36 combinations of fundamental legal concepts to be generated.<sup>6</sup>

On the substantive level, let us briefly mention here a particular view of the outlined methodology as a tool, that allows the program to "understand" the normative positions of the party-user and to behave as a result of this. The consequences that derive from this could lead to an overturning of the relationship between the legal domain and computational models: that is, by moving to a still greater degree of abstraction, to build a logic system (theory) with its own axioms and inference rules in which legal reality is seen as a model in the logic sense. That is, an aspect of

<sup>4</sup>*Contrary to duty obligation*: "Roughly, the paradox is that a reasonable formalization of these sentences implies that there is simultaneously an obligation to take disciplinary action against *p* and an obligation not to take disciplinary action against *p*" (Wieringa & Meyer, 1993).

<sup>5</sup>The DL deontic system (Jones & Port, 1985) contains, among other things, a fascinating semantic interpretation that distinguishes between ideal worlds in which the obligations are fulfilled and sub-ideal worlds in which they can be violated.

<sup>6</sup>Jones and Sergot define *fact position*, that is, positions with respect to a fact *A*; given: *a* (subject), a function *f(a)*(object relative to *a*), and a relation *H* that represents a state of fact relative to *a* in relation to the object *f(a)*,  $A = aHf(a)$ .

From the fact positions: (*A* and *notA*), to which the operator or obligation (*O*) is added the possible normative fact positions are generated:

*OA*

*O notA*

*notOa & not O notA*

to which the operator of action *E* (*Exp = x* brings it about that *p*) is added;

(with the negation) 12 expressions are obtained. From the conjunction of these (64), having eliminated those that are inconsistent and redundant, 7 *normative one-agent act-positions* are obtained that correspond to Lindal's 7 *basic-types of one-agent legal positions*.

reality that makes everything either a part of the axioms or of the theorems of the theory true. Thus, the theoretical elaboration of legal concepts, not so much that of Hofheld, which begins with an analysis of jurisprudence, as that of Lindhal, which by starting off from a language and the atomic elements of it, identifies all the possible combinations guaranteeing their consistency and completeness by leaving it to the lawyer to establish the links with reality. The application of such theories to relatively simple domains could be interpreted as attributing normative powers to the program, which, by being able to classify behaviour (its own and that of the user) in regard to all the possible legal implications, is capable of regulating them automatically.<sup>7</sup>

In the ICLP workshop, two aspects were further developed. On the one hand, the difficulties of developing computable deontic formal systems; McCarthy (*“Modalities over actions. I Model Theory”*), presented an action-language able to represent concurrent and repetitive events in which a deontic language is embedded that allows “free choice permissions” to be dealt with. Both the semantic (model theoretic) interpretation and the proof procedure (in logic programming style in order to adopt *negation as failure* for dealing with nonmonotonic inferences) were presented. A Prolog interpreter able to deal with deontic inferences (Artosi et al., *“KED: a deontic theorem prover”*) was also presented.

On the other hand, a new proposal to deal with a “diagnostic” deontic logic system, which is to say, able to support defeasible inferences, as in the Chisholm Paradox and Forrester Paradox; the framework is based on the Reiter (1987) analysis of diagnostic reasoning, extended to deal with deontic reasoning. The semantic interpretation follows the distinction between ideal and sub-ideal words (Yao-Hua Tan, & van der Torre, *“DIADE: deontic logic founded on a theory of diagnosis from first principles”*).

## References

- Alexy, R, 1978. “Theorie der juristischen Argumentation,” Suhrkamp, Frankfurt.
- Alexy, R, 1992. *Legal Argumentation as Rational Discourse*.
- Allen, LE and Saxon, CS, 1986. “Analysis of the logical structure of legal rules by a modernized and formalized version of Hofheld’s fundamental legal conceptions” In: AA Martino and F Soccie (eds.), *Automated Analysis of Legal Texts*, North-Holland.
- Allen, LE and Saxon CS, 1987. “Some problems in designing expert systems to aid legal reasoning” In: *First International Conference on Artificial Intelligence and Law*, ACM Press, pp 94–103.
- Allen, LE and Saxon, CS, 1991. “A-Hofheld: A language for robust structural representation of knowledge in the legal domain” In: *Proceedings of the First International Workshop on Deontic Logic in Computer Science (DEON ’91)*, Amsterdam, The Netherlands.
- Alschwee, B and Grundmann, S, 1986. “System design for computer-aided juridical expert systems” In: AA Martino and F Soccie (eds.), *Automated Analysis of Legal Texts*, North-Holland, pp 567–579.
- Artosi, A, Cattabriga, P and Governatori, G, 1994. “KED: a deontic theorem prover” *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze, pp 60–76.
- Ashley, K, 1990. *Modelling Legal Argument: Reasoning with Cases and Hypotheticals*, MIT Press.
- Ashley, K, 1993. “Case-based reasoning and its implications for legal expert systems” *Artificial Intelligence and Law 2*.
- Bench Capon, T and Coenen, F. 1991. “Exploiting isomorphism: Development of a KBS to support British Coal insurance claims” In: *Proceedings of the Third International Conference on Artificial Intelligence and Law*, ACM, NY, pp 62–68.
- Routen, T and Bench Capon, T, 1991. “Hierarchical formalisations” *International Journal of Man-Machine Studies 35*.

<sup>7</sup>(Jones & Sergot, 1992, pp 50–52): “Let us suppose that the Chief Librarian wants us to introduce a system of computers and other administrative procedures so designed and constructed as to guarantee that the library functions in the way that it should. The Chief Librarian wants us to view the Library Regulations as a specification of how the system should operate . . . At the appropriate level of abstraction, law and computer systems, and many other kinds of organisation, can be viewed as normative systems.” And further: (Kowalski & Sergot, 1991, p 109): “Such uses of logical models of the law resemble uses of executable specifications in software engineering. A specification in software engineering is a precise description of what it is that a computer system is supposed to do.”

- Bernam, D and Hafner, C, 1993. "Representing teleological structure in case-based reasoning: the missing link" In: *Proceedings of the Fourth ICAIL*, Amsterdam, pp 50–59.
- Bertarello, S, Costantini, S and Lanzarone, G, 1994. "Explanation-based learning of open textured predicates in logic programming models of law" In: *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze, pp 13–32.
- Biagioli, C, Mariani, P and Tiscornia, D, 1987. "EXPLEX: A rule and conceptual based model for representing statutes" In: *Proceedings of the First International Conference on Artificial Intelligence and Law*. ACM, pp 240–251.
- Branting, KL, 1991. "Reasoning with portion of precedents" In: *Proceedings of the Third International Conference on Artificial Intelligence and Law*, ACM Press, pp 145–154.
- Branting, KL, 1993. "A reduction-graph model for ratio decidendi" In: *Proceedings of the Fourth International Conference on Artificial Intelligence and Law*, ACM Press, pp 40–49.
- Breuker, J and den Hann, N, 1991. "Separating world and regulation knowledge: where is the logic?" In: *Proceedings of the Third International Conference on Artificial Intelligence and Law*, ACM.
- Costantini, S and Lanzarone, G, 1989. "Analogical reasoning in Reflective Prolog" In: *Preproceedings of the Third International Conference Logica, Informatica, Diritto*, Florence, pp 117–136.
- Davies, TR and Russel, SJ, 1987. "A logical approach to reasoning by analogy" In *Proceedings of the 3rd IJCAI*, Morgan Kaufmann.
- Gordon, T, 1993. "The pleadings game—formalizing procedural justice" In: *Proceedings of the Fourth ICAIL*, Amsterdam, pp 10–19.
- Hage, J, 1993. "Monological reason-based logic" In: *Proceedings of the Fourth ICAIL*, Amsterdam, pp 30–39.
- Guidotti, P, Mariani, P, Sardu, G and Tiscornia, D, 1992. "Metalevel reasoning. The design of a system to handle legal knowledge bases" In: *Proceedings of the 7th Italian Conference on Logic Programming (GULP 92)*, Milan.
- Groendigk, C and Oskamp, A, 1993. "Case recognition and strategy classification" In: *Proceedings of the Fourth ICAIL*, Amsterdam, pp 125–134.
- Hanfelt, A and Barklund, J, 1989. "Metalevels in legal knowledge and their runnable representation in logic" In: *Preproceedings of the Third International Conference Logica, Informatica Diritto*, Florence, pp 557–576.
- Hanfelt, A and Barklund, J, 1992. "Hierarchical representation of legal knowledge with metaprogramming in logic" In: *Proceedings of First Compulog-Net Workshop*, London.
- Hart, HL, 1961. *The Concept of Law*, Clarendon Press.
- Hofheld, WN, 1913. "Fundamental legal conceptions as applied in judicial reasoning" *Yale Law Journal* (23).
- Kakas, AC, Kowalski, R and Toni, F, 1992. "Abductive logic programming" *Journal of Logic in Computation* 2 (6) 719–770.
- Kanger, S and Kanger, H, 1966. "Rights and parliamentarianism" *Theoria* (32).
- Kowalski, R and Sergot, M, 1989. "The use of logical models in legal problem solving" In: Narayan and Bennum (eds.), *Law, Computer Science and Artificial Intelligence*, Ablex.
- Kowalski, R, 1989. "The treatment of negation in logic programs for representing legislation" In: *Proceedings of the Second International Conference on Artificial Intelligence and Law*, ACM, pp 11–15.
- Kowalski, R, 1990. "Problem and promises of computational logic" In: *Proceedings of the Symposium on Computational Logic*, Springer-Verlag.
- Kowalski, R and Sadri, F, 1990. "Logic programs with exceptions" In: *Proceedings of the Seventh International Conference on Logic Programming*, MIT Press, pp 598–613.
- Kowalski, R, 1991. "Legislation as logic programs." Research Report, ESPRIT Basic Research Working Group 3152 on Foundations of Legal Reasoning.
- Kowalski, R, 1994. "An abstract argumentation-theoretic framework for non-monotonic reasoning" *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze.
- Jones, A and Porn, I, 1985. "Ideality, sub-ideality and deontic logic" *Syntheses* 65 275–290.
- Jones, A, 1990. "Deontic logic and legal knowledge representation" *Ratio Juris*, (2).
- Jones, A and Sergot, M, 1992. "Deontic logic in the representation of law: towards a methodology" *Artificial Intelligence and the Law*, 1 45–64.
- Lindhal, L, 1977. *Position and Change*, Reidel.
- Loui, R, Norman, J, Olson, J and Merrill, A, 1993. "A design for reasoning with policies, precedents, and rationales" In: *Proceedings of the Fourth ICAIL*, Amsterdam, pp 202–211.
- Morris, P and McDermid, J, 1991. "The structure of permission: A normative framework for access right" In: *Proceedings of the First International Workshop on Deontic Logic in Computer Science (DEON '91)*, Amsterdam.
- McCarthy, LT, 1986. "Permissions and Obligations: An informal introduction" In: AA Martino and F Socci Natali (eds.), *Automated Analysis of Legal Texts: Logic, Informatics, Law*, North-Holland, pp 307–337.

- McCarthy, LT, 1989. "A Language for legal discourse, 1. Basic features" In: *Proceedings of the Second International Conference on AI and Law*, Vancouver, pp 202–211.
- McCarthy, LT, 1994. "Modalities over actions. I Model Theory" In: *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze, pp 2–13.
- Nitta, K, Young, S and Yoshihisa Ohtake, 1993. "A computational model for trial reasoning" In: *Proceedings of the Fourth International Conference on AI and Law*, Amsterdam, pp 20–29.
- Nitta, K, Shibasaki, M, Sakata, T, Yamaji, T, Ohsaki, H, Tojo, S, Kobubo, I and Suzuki, T, 1994. "Knowledge representation of new HELIC II" In: *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze.
- Nute, D, 1988. "Defeasible reasoning: a philosophical analysis in Prolog" *Aspects of Artificial Intelligence*.
- Perelman, CH and Olbrechts-Tyeca, L, 1958. "Traiti de l'argumentation. La nouvelle rhetorique." Paris, PUF. (It. Trans.: Trattato dell'argomentazione. La nuova retorica. Torino, Einaudi, 1956.)
- Poole, DL, 1988. "A logical framework for default reasoning" *Artificial Intelligence* 36 (1) 27–47.
- Pollock, JL, 1987. "Defeasible reasoning" *Cognitive Science* 11 481–518.
- Prakken, H, 1992. *Logical Tools for Modelling Legal Argument*, Free Universitat, Amsterdam.
- Prakken, H, 1993. In: *Proceedings of the IV ICAIL*, Amsterdam.
- Sartor, G, 1991. "The structure of norm conditions and nonmonotonic reasoning in law" In: *Proceedings of the 3rd International Conference on Artificial Intelligence and Law*, ACM Press, pp 155–164.
- Sartor, G, 1993. "A simple computational model for nonmonotonic and adversarial legal reasoning" In: *Proceedings of the IV ICAIL*, Amsterdam.
- Sergot, M, Sadri, F, Kowalski, R, Kriwaczek, R, Hammond, P and Cory, HT, 1986. "The British Nationality Act as a logic program" *Communications of the ACM* 29 370–386.
- Sergot, M, 1990. "The representation of law in computer programs: A survey and comparison" In: T Bench Capon (ed.), *Knowledge Based Systems in the Law*, Academic Press.
- Sergot, M, 1991. "The representation of law in computer programs" In: T Bench Capon (ed.), *Knowledge Based Systems and Legal Applications*, Academic Press, pp 3–68.
- Skalak, DB and Rissland, E. 1992. "Arguments and cases: An inevitable intertwining" *Artificial Intelligence and Law* 1.
- Toulmin, S, 1958. *The uses of Argument*, Cambridge University Press.
- Tojo, S and Nitta, K. 1994. "Automatic generation of temporal relations in a legal case" *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze.
- Valente, A and Breuker, J, 1994. "A commonsense formalization of normative systems" In: *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze.
- Walker, RF, Oskamp, A, Schrickx, JA, Odporp, G and van der Bergh, G, 1990. "Prolexs: creating law and order in Heterogeneous domain" *International Journal of Man-Machine Studies* 35 35–67.
- Wieringa, RJ and Meyer, J, 1993. "Applications of deontic logic in computer science: A concise overview" In: *Deontic Logic in Computer Science*, Wiley.
- Yao-Hua Tan, L and van der Torre, 1994. "DIADE: deontic logic founded on a theory of diagnosis from first principles" In: *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze, pp 138–151.
- Yoshino, H, Kagayama, S, Otha, S, Kithara, M, Kondoh, H, Nakakawaji, M, Ishimaru, K and Takao, S, 1986. "Legal expert systems les-2" In: G Goos and J Harmanis (eds.), *Lecture Notes in Computer Science*, Springer-Verlag, pp 34–35.
- Yoshino, H, Haraguchi, M, Sakurai, S and Kagayama, S, 1993. "Towards a legal analogical system: Knowledge representation and reasoning methods" In: *Proceedings of IV ICAIL*, Amsterdam.
- Yoshino, H, 1994. "Representation of legal knowledge by compound predicate formula" In: *Preproceedings of the Workshop on Legal Applications of Logic Programming (ICLP 94)*, IDG, Firenze.