Complete List of Research Publications

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18th June 2016

This document contains the complete list of my publication. The publications are presented in reversed chronological order. For each publication the abstract or summary is included.

2016

1 On ASPIC$^+$ and Defeasible Logic

Dung-like argumentation framework ASPIC$^+$ and Defeasible Logic (DL) are both well-studied rule-based formalisms for defeasible reasoning. We compare the two frameworks and establishes a linkage between an instantiation of ASPIC$^+$ and the argumentation semantics of DL, which leads to a better understanding and cross-fertilization – in particular our work sheds light on features such as ambiguity propagating/blocking, team defeat and strict rules for argumentation, while emphasizing the argumentation-theoretic features of DL. [192]

2 On Labelling Statements in Multi-labelling Argumentation

In computational models of argumentation, argument justification has attracted more attention than statement justification, and significant sensitivity losses are identifiable when dealing with the justification of statements by otherwise appealing formalisms. This paper reappraises statement justification as a formalism-independent component in argumentation-based reasoning. We introduce a novel general model of argumentation-based reasoning based on multiple stages of labellings, the last one being devoted to statement justifi- cation and identify two alternative paths from argument acceptance to statement justification, comparing their expressiveness. We then show that this model encompasses several prominent literature proposals as special cases, thereby enabling a systematic comparison of existing approaches to statement justification and of their merits and limits. Finally we illustrate our model with the specifications of a so-called ignorance-aware statement justification, and show how these specifications can be seamlessly integrated in different formalisms. [32]

1

3 Untrusted Business Process Monitoring and Execution Using Blockchain

The integration of business processes across organisations is typically beneficial for all involved parties. The lack of trust in the other parties, however, is in practice among the most important roadblocks for such integration. *Blockchain* is an emerging technology for decentralized and transactional data sharing across a large network of untrusted participants. It can be used to *find agreement* about the shared state of collaborating parties without trusting a central authority or any particular participant. Blockchain network also provides a global computational infrastructure to run autonomous programs called smart contracts. In this paper, we address the fundamental problem of trust in collaborative process execution using blockchain. We develop a technique to integrate blockchain into the choreography of processes in such a way that no central authority is needed, but trust maintained. Our solution comprises the combination of an intricate set of components, which allow utilising the computational infrastructure of blockchain networks to either monitor or coordinate business processes. We implemented our solution and demonstrate its feasibility by applying it to three use case processes. Our evaluation includes the creation of more than 500 smart contracts and the execution over 8,000 blockchain transactions. [255]

4 On Logic-Based Smart Contracts and Blockchain Systems

While procedural languages are commonly used to program smart contracts in blockchain systems, logic programming languages may be interesting alternatives, but such alternatives remain to be investigated. In this paper, we inspect what are the possible legal and technical (dis)advantages of logic smart contracts in light of common activities featuring ordinary contracts, then we provide insights on how to use such logic smart contracts in combination with blockchain systems. These insights lead us to emphasize a fundamental challenge: algorithms for logic approaches have to be efficient, but they also have to be literally cheap [179]

5 Sequence Semantics for Norms and Obligations

This paper presents a new version of the sequence semantics presented at DEON 2014. This new version allows us for a capturing the distinction between logic of obligations and logic of norms. Several axiom schemata are discussed, while soundness and completeness results are proved. [116]

6 Sequence Semantics for Modelling Reason-based Preferences

We study how the non-classical n-ary operator $\otimes$, originally intended to capture the concept of reparative obligation, can be used in the context of social choice theory to model preferences. A novel possible-world model-theoretic semantics, called sequence semantics, was proposed for the operator. In this paper, we propose a sound a complete axiomatisation of a minimal modal logic for the operator, and we extend it with axioms

suitable to model social choice consistency principles such as extension consistency and contraction consistency. We provide completeness results for such extensions. [47]

7 On Learning Attacks in Probabilistic Abstract Argumentation

Probabilistic argumentation combines the quantitative uncertainty accounted by probability theory with the qualitative uncertainty captured by argumentation. In this paper, we investigate the problem of learning the structure of an argumentative graph to account for a distribution of labellings of a set of arguments. We consider a general abstract framework, where the structure of arguments is left unspecified, and we focus on the grounded semantics. We present, with experimental insights, an anytime algorithm evaluating 'on the fly' hypothetical attacks from the examination of an input stream of labellings [227]

8 On the Justification of Statements in Argumentation-based Reasoning

In the study of argumentation-based reasoning, argument justification has received far more attention than statement justification, often treated as a simple byproduct of the former. As a consequence, counterintuitive results and significant losses of sensitivity can be identified in the treatment of statement justification by otherwise appealing formalisms. To overcome this limitation, we propose to reappraise statement justification as a first-class formalism-independent component. To this purpose, we introduce a novel general model of argumentation-based reasoning based on multiple levels of labellings, one of which is devoted to statement justification. [31]

9 A Policy-based B2C e-Contract Management Workflow Methodology Using Semantic Web Agents

Since e-Commerce has become a discipline, e-Contracts are acknowledged as the tools that will assure the safety and robustness of the transactions. A typical e-Contract is a binding agreement between parties that creates relations and obligations. It consists of clauses that address specific tasks of the overall procedure which can be represented as workflows. Similarly to e-Contracts, Intelligent Agents manage a private policy, a set of rules representing requirements, obligations and restrictions, additionally to personal data that meet their user's interests. Hence, this study focuses on e-Contracts executed by Intelligent Agents, proposing a policy-based workflow management methodology using semantic web agents, since agents benefit from Semantic Web technologies for data and policy exchanges, such as RDF and RuleML that maximize interoperability among parties. Yet, in order to deal with issues related to agent use this study presents the integration of the methodology into a multi-agent knowledge- based framework, which ensures that even in the case of rules exchange where no common syntax is used, the exchanged policies will be correctly interpreted through appropriate reasoning services. Finally, a B2C e-Commerce scenario is presented that demonstrates the added value of the approach. [186]

10 The Rational behind the Concept of Goal

The paper proposes a fresh look at the concept of goal and advances that motivational attitudes like desire, goal and intention are just facets of the broader notion of (acceptable) outcome. We propose to encode the preferences of an agent as sequences of "alternative acceptable outcomes". We then study how the agent's beliefs and norms can be used to filter the mental attitudes out of the sequences of alternative acceptable outcomes. Finally, we formalise such intuitions in a novel Modal Defeasible Logic and we prove that the resulting formalisation is computationally feasible. [127]

11 Normative Requirements for Regulatory Compliance: An Abstract Formal Framework

By definition, regulatory rules (in legal context called *norms*) intend to achieve specific behaviour from business processes, and might be relevant to the whole or part of a business process. They can impose conditions on different aspects of process models, e.g., control-flow, data and resources etc. Based on the rules sets, norms can be classified into various classes and sub-classes according to their effects. This paper presents an abstract framework consisting of a list of norms and a generic compliance checking approach on the idea of (possible) execution of processes. The proposed framework is independent of any existing formalism, and provides a conceptually rich and exhaustive ontology and semantics of norms needed for business process compliance checking. Apart from the other uses, the proposed framework can be used to compare different compliance management frameworks. [176]

2015

1 Revision of Defeasible Preferences

There are several contexts of non-monotonic reasoning where a priority between rules is established with the purpose of preventing conflicts. We investigate how to modify such a preference relation in a non-monotonic logic in order to change the conclusions of the theory itself. We shall argue that the approach we adopt has a natural counter part in many real life areas such as legal reasoning, where users cannot typically change the facts or the rules, but can propose their *preferences* about the relative strength of the rules. The main result of the present work is the proof that the problem of revising a non-monotonic theory by changing only the superiority order between conflicting rules is general computationally hard. After such an analysis, we identify three contraction/revision/update operators and study them against the AGM postulates for belief revision, to discover at the end that only a part of these postulates are satisfied in the specific non-monotonic setting. [117]

2 Burden of Compliance and Burden of Violations

It this paper we address the issue of what it means to comply with or violate norms, and we propose a computationally oriented approach to reason about such notions. [79]

3 The Regorous approach to process compliance

In this paper we propose an ITC (Information and Communication Technology) approach to support regulatory compliance for business processes, and we report on the development and evaluation of a business process compliance checker called Regorous, based on the compliance-by-design methodology proposed by Governatori and Sadiq [166]. [92]

4 Compliant business processes with exclusive choices from agent specification

In this paper we analyse the problem of synthesising compliant business processes from rules-based declarative specifications for agents. In particular, we consider the approach by [1,2] and we propose computationally efficient algorithms to combine plans extracted from the deliberation of an agent to generate the corresponding business processes with exclusive choice patterns. [204]

5 Semantics for Modelling Reason-based Preferences

In [10] the authors developed a logical system based on the definition of a new non-classical connective $\otimes$ originally capturing the notion of reparative obligation. The operator $\otimes$ and the system were proved to be appropriate for rather handling well-known contrary-to-duty paradoxes. Later on, a suitable model-theoretic possible-world semantics has been developed [4,5]. In this paper we show how a version of this semantics can be used to develop a sound and complete logic of preference and offer a suitable possible-world semantics. The semantics is a sequence- based non-normal one extending and generalising semantics for classical modal logics. [46]

6 No Time for Compliance

In the past few years several business process compliance framework based on temporal logic have been proposed. In this paper we investigate whether the use of temporal logic is suitable for the task at hand: namely to check whether the specifications of a business process are compatible with the formalisation of the norms regulating the business process. We provide an example inspired by real life norms where the use of linear temporal logic produces a result that is not compatible with the legal understanding of the norms in the example. [96]

7 LegalRuleML: Design Principles and Foundations

This tutorial presents the principles of the OASIS LegalRuleML applied to the legal domain and discusses why, how, and when LegalRuleML is well-suited for modelling norms. To provide a framework of reference, we present a comprehensive list of requirements for devising rule interchange languages that capture the peculiarities of legal rule modelling in support of legal reasoning. The tutorial comprises syntactic, semantic, and pragmatic foundations, a LegalRuleML primer, as well as use case examples from the legal domain. [30]

8 RuleOMS: A Rule-Based Online Management System

In this paper, we propose an architecture for a rule-based online management systems (RuleOMS). Typically, many domain areas face the problem that stakeholders maintain databases of their business core information and they have to take decisions or create reports according to guidelines, policies or regulations. To address this issue we propose the integration of databases, in particular relational databases, with logic reasoner and rule engine. We argue that defeasible logic is an appropriate formalism to model rules, in particular when the rules are meant to model regulations. The resulting RuleOMS provides an efficient and flexible solution to the problem at hand using defeasible inference. A case study of an online child care management system is used to illustrate the proposed architecture. [180]

9 Deontic Defeasible Reasoning in Legal Interpretation

This paper offers a fresh logical machinery for reasoning about interpretive canons. We identify different formal options for modelling reasoning about interpretations and show that interpretative argumentation has a distinctive structure where the claim that a legal text ought or may be interpreted in a certain way can be supported or attacked by arguments, whose conflicts may have to be assessed according to further arguments. [231]

10 Thou Shalt is not You Will

In this paper we discuss some reasons why temporal logic might not be suitable to model real life norms. To show this, we present a novel deontic logic contrary-to-duty/derived permission paradox based on the interaction of obligations, permissions and contrary-to-duty obligations. The paradox is inspired by real life norms. [93]

11 Logics for Legal Dynamics

Legal dynamics is an important aspect of legal reasoning that inspired the area of belief revision. While formal models of belief revision have been thoroughly examined, the formalisation of legal dynamic has been mostly neglected. In this contribution we propose Temporal Defeasible Logic to model legal dynamics. We build such a logic in steps starting from basic defeasible logic, and we show how to use it to model different forms of modifications such as derogations, textual modifications, abrogation and annulment. [153]

12 Managing Regulatory Compliance in Business Processes

The ever-increasing obligations of regulatory compliance are presenting a new breed of challenges for organizations across several industry sectors. Aligning control objectives that stem from regulations and legislation with business objectives devised for improved business performance is a foremost challenge. The organizational as well as IT structures

for the two classes of objectives are often distinct and potentially in conflict. In this chapter, we present an overarching methodology for aligning business and control objectives. The various phases of the methodology are then used as a basis for discussing state-of-the-art in compliance management. Contributions from research and academia as well as industry solutions are discussed. The chapter concludes with a discussion on the role of BPM as a driver for regulatory compliance and a presentation of open questions and challenges. [232]

13 Algorithms for Tractable Compliance Problems

In general the problem of verifying whether a structured business process is compliant with a given set of regulations is **NP**-hard. The present paper focuses on identifying a tractable subset of this problem, namely verifying whether a structured business process is compliant with a single global obligation. Global obligations are those whose validity spans for the entire execution of a business process. We identify two types of obligations: achievement and maintenance. In the present paper we firstly define an abstract framework capable to model the problem and secondly we define procedures and algorithms to deal with the compliance problem of checking the compliance of a structured business process with respect to a single global obligation. We show that the algorithms proposed in the paper run in polynomial time. [54]

14 Business Process Regulatory Compliance is Hard

Verifying whether a business process is compliant with a regulatory framework is a difficult task. In the present paper we prove the hardness of the business process regulatory compliance problem by taking into account a sub-problem of the general problem. This limited problem allows to verify only the compliance of structured processes with respect to a regulatory framework composed of a set of conditional obligations including a deadline. Experimental evidence from existing studies shows that compliance is a difficult task. In this paper, despite considering a sub-problem of the general problem, we provide some theoretical evidence of the difficulty of the task. In particular we show that the source of the complexity lies in the core language of verifying conditional obligations with a deadline. We prove that for this simplified case verifying partial compliance belongs to the class of **NP**-complete problems, and verifying full compliance belongs to the class of co**NP**-complete problems. Thus by proving the difficulty of a simplified compliance problem we prove that the general problem of verifying business process regulatory compliance is hard. [51]

2014

1 Checking Licenses Compatibility between Vocabularies and Data

In the Web of Data, licenses specifying the terms of use and reuse are associated not only to datasets but also to vocabularies. However, even less support is provided for taking

the licenses of vocabularies into account than for datasets, which says it all. In particular, this paper addresses the following issue: checking the compatibility among the set of licenses assigned to the vocabularies used to constitute a dataset, and the license that is intended to be associated to the dataset itself. We provide a framework called LIVE able to support data publishers in such compatibility checking step, taking into consideration both the licenses associated to the vocabularies and those assigned to the data. [105]

2 Strategic Argumentation under Grounded Semantics is NP-Complete

We study the complexity of the Strategic Argumentation Problem for 2-player dialogue games where a player should decide what move to play at each turn in order to prove (disprove) a given claim. We shall prove that this is an NP-complete problem. The result covers one the most popular argumentation semantics proposed by Dung [**Dung:1995**]: the grounded semantics. [111]

3 Legal Interpretations in LegalRuleML

Legislative documents are by their own nature subject to interpretation, and interpretations of one document can diverge. In this paper we discuss the mechanism proposed by LegalRuleML to capture alternative interpretations or renderings of a legal source. LegalRuleML allows for mutually incompatible renderings (or interpretations) of a legal source to coexist in the same LegalRuleML document, and provides facilities to identify the interpretations and to select them. The mechanism is illustrated with an example form Italian Jurisprudence. [29]

4 Social Interaction Based Audience Segregation for Online Social Networks

Online social networking is the latest craze that has captured the attention of masses, people use these sites to communicate with their friends and family. These sites offer attractive means of social interactions and communications, but also raise privacy concerns. This paper examines user's abilities to control access to their personal information posted in online social networks. Online social networks lack common mechanism used by individuals in their real life to manage their privacy. The lack of such mechanism significantly affects the level of user control over their self presentation in online social networks. In this paper, we present social interaction based audience segregation model for online social networks. This model mimics real life interaction patterns and makes online social networks more privacy friendly. Our model uses type, frequency, and initiation factor of social interactions to calculate friendship strength. The main contribution of the model is that it considers set of all possible interactions among friends and assigns a numerical weight to each type of interaction in order to increase or decrease its contribution in calculation of friendship strength based on its importance in the development of relationship ties. [1]

5 On the Equivalence of Defeasible Deontic Logic and Temporal Defeasible Logic

In this paper we formally prove that compliance results derived from temporal defeasible logic are equivalent to the ones obtained in the standard defeasible deontic logic. In order to do so we first introduce an operator allowing us to translate rules from the standard to the temporal framework. Then we consider the sets of obligations used in the compliance checking algorithm from [138] and prove that they are isomorphic to the previously defined operator. Being able to add time to standard deontic logic will allow for a better and more elegant representation of obligations and improvement in computational efficiency. [2]

6 A Preference-Based Semantics for CTD Reasoning

In [152] the authors developed a logical system based on the definition of a new non-classical connective $\otimes$ capturing the notion of reparative obligation. The system proved to be appropriate for handling well-known contrary-to-duty paradoxes but no model-theoretic semantics was presented. In this paper we fill the gap and define a suitable possible-world semantics for the system for which we can prove soundness and completeness. The semantics is a preference-based non-normal one extending and generalizing semantics for classical modal logics. [45]

7 Licentia: a Tool for Supporting Users in Data Licensing on the Web of Data

In the Web of Data, licenses specifying the terms of use and reuse are associated not only to datasets but also to vocabularies. However, even less support is provided for taking the licenses of vocabularies into account than for datasets, which says it all. In particular, this paper addresses the following issue: checking the compatibility among the set of licenses assigned to the vocabularies used to constitute a dataset, and the license that is intended to be associated to the dataset itself. We provide a framework called LIVE able to support data publishers in such compatibility checking step, taking into consideration both the licenses associated to the vocabularies and those assigned to the data. [48]

8 Detecting Deontic Conflicts in Dynamic Settings

Regulations, through the use of obligations and permissions, are widely used in modern society to define acceptable behaviours. Thus it is indeed important that these regulations do not conflict with each other and contain contradicting obligations. In the present paper we focus on identifying conflicts between obligations in dynamic settings. We first show the need of an alternative semantics rather than the more classic modelled by standard deontic logic. Second we introduce a new semantics for the obligations capable of representing and reasoning about them in these dynamic settings, and lastly we use it to identify the necessary and sufficient conditions to identify conflicting obligations. [52]

9 Strategic Argumentation is NP-complete

We study the complexity of the Strategic Argumentation Problem for 2-player dialogue games where a player should decide what move (set of rules) to play at each turn in order to prove (disprove) a given thesis. We show that this is an NP-complete problem. [126]

10 The Hardness of Revising Defeasible Preferences

Non-monotonic reasoning typically deals with three kinds of knowledge. *Facts* are meant to describe immutable statements of the environment. *Rules* define relationships among elements. Lastly, an ordering among the rules, in the form of a *superiority relation*, establishes the relative strength of rules. To revise a non-monotonic theory, we can change either one of these three elements. We prove that the problem of revising a non-monotonic theory by only changing the superiority relation is a NP-complete problem. [125]

11 LIVE: a Tool for Checking Licenses Compatibility between Vocabularies and Data

In the Web of Data, licenses specifying the terms of use and reuse are associated not only to datasets but also to vocabularies. However, even less support is provided for taking the licenses of vocabularies into account than for datasets, which says it all. In this paper, we present a framework called LIVE able to support data publishers in verifying licenses compatibility, taking into account both the licenses associated to the vocabularies and those assigned to the data built using such vocabularies. [103]

12 Two Faces of Strategic Argumentation in Legal Reasoning

In strategic argumentation players exchange arguments to prove or reject a claim. This paper discusses and reports on research about two basic issues regarding the game-theoretic understanding of strategic argumentation games in the law: whether such games can be reasonably modelled as zero-sum games and as games with complete information. [122]

2013

1 OASIS LegalRuleML

In this paper we present the motivation, use cases, design principles, abstract syntax, and initial core of LegalRuleML. The LegalRuleMLcore is sufficiently rich for expressing legal sources, time, defeasibility, and deontic operators. An example is provided. LegalRuleMLis compared to related work. [28]

2 One License to Compose Them All - A Deontic Logic Approach to Data Licensing on the Web of Data

In the domain of Linked Open Data a need is emerging for developing automated frameworks able to generate the licensing terms associated to data coming from heterogeneous distributed sources. This paper proposes and evaluates a deontic logic semantics which allows us to define the deontic components of the licenses, i.e., permissions, obligations, and prohibitions, and generate a composite license compliant with the licensing items of the composed different licenses. Some heuristics are proposed to support the data publisher in choosing the licenses composition strategy which better suits her needs w.r.t. the data she is publishing. [165]

3 Picking Up the Best Goal - An Analytical Study in Defeasible Logic

In this paper we analyse different notions of the concept of goal starting from the idea of sequences of "alternative acceptable outcomes". We study the relationships between goals and concepts like agent's beliefs, norms, and desires, and we propose a formalisation using Defeasible Logic that will be able to provide a computationally feasible approach. The resulting system captures various nuances of the notion of goal against different normative domains, for which the right decision is not only context-dependent, but it must be chosen from a pool of alternatives as wide as possible. [121]

4 Computing Temporal Defeasible Logic

We investigate the complexity of temporal defeasible logic, and propose an efficient algorithm to compute the extension of any theory. The logic and algorithm are discussed in regard to modeling deadlines and normative retroactivity. [146]

5 Regorous: A Business Process Compliance Checker

We report on the development of Regorous, a business process compliance checker, based on the compliance-by-design methodology proposed by Governatori and Sadiq [166]. [168]

6 Legal Contractions: A Logical Analysis

This paper systematically investigates how to model legal contraction in an expressive variant of Defeasible Deontic Logic. We argue that legal contraction is an umbrella concept that includes operations which are conceptually and technically different: removing rules, adding exceptions, and modifying rule priorities. The peculiarities of deleting legal conclusions show that an extension of those operations is sometimes needed, which works on the indirect conclusions from which the target effect of the contraction is obtained. The proposed techniques are discussed in the context of a new version for the logic of AGM postulates of contraction. [159]

7 Heuristics for Licenses Composition

The Web of Data is assisting to a growth of interest with respect to the open challenge of represent and reason in an automated way over licensing and copyright. In this paper, we deal with the problem of checking the compatibility of a set of licenses associated to a single query result returned on the Web of Data, and subsequently compose them into a so called *composite* license. More precisely, we analyze two composition heuristics, *AND-composition* and *OR-composition*, showing how they can be used to combine the deontic components specified by the licenses, i.e., permissions, obligations, and prohibitions, and which are the most suitable combinations depending on the starting licenses. Such heuristics are evaluated using the SPINdle logic reasoner. [104]

8 A Methodological Evaluation of Business Process Compliance Management Frameworks

Existing compliance management frameworks (CMFs) offer a multitude of compliance management functionalities for the modeling of specific norms for specific domain and compliance checking of normative requirements. This makes difficult for enterprises to decide on a framework suitable for their compliance requirements. Making a decision on the suitability requires a deep understanding of the functionalities of a framework. Gaining such an understanding is a difficult task which, in turn, requires specialised tools and methodologies for evaluation. Current compliance research lacks such tools and methodologies for evaluating CMFs. This paper reports a methodological evaluation of existing CMFs based on pre-defined evaluation criteria. Our evaluation highlights what existing CMFs can offer, and what they cannot. Also, it underpins various open questions and discusses the challenges in this direction. [173]

9 Normative Requirements for Business Process Compliance

Norms regulate the behaviour of their subjects and define what is legal and what is illegal. Norms typically describe the conditions under which they are applicable and the normative effects as a result of their applications. On the other hand, process models specify how a business operation or service is to be carried out to achieve a desired outcome. Norms can have a significant impact on how business operations are conducted and they can apply to the whole or a part of a business process. For example, they may impose conditions on the different aspects of a process (e.g., perform tasks in a specific sequence (control-flow), at a specific time or within a certain time frame (temporal aspect), by specific people (resources)). We propose a framework that provides the formal semantics of the normative requirements for determining whether a business process complies with a normative document (where a normative document can be understood in a very broad sense, ranging from internal policies to best practice policies, to statutory acts). We also present a classification of normal requirements based on the notion of different types of obligations and the effects of violating these obligations. [175]

10 Compliant Business Process Design by Declarative Specifications

We propose algorithms to synthesise the specifications modelling the capabilities of an agent, the environment she acts in, and the governing norms, into a process graph. This process graph corresponds to a collection of courses of action and represents all the licit alternatives the agent may choose to meet her outcomes. The starting point is a compliant situation, i.e., a situation where an agent is capable of reaching all her outcomes without violating the norms. In this case, the resulting process will be *compliant by design*. [205]

11 A Methodology for Plan Revision under Norm and Outcome Compliance

Scholars understand an agent as a system acting in an environment. Such an environment is usually governed by norms, and the agent has to obey to such norms when pursuing her objectives. We report a non-monotonic modal logic able to describe the environment, the norms, and the agent's capabilities as well as her mental attitudes (e.g., desires, intentions). First, we show how such a logic is expressive enough to determine when the agent is compliant with respect to norms and objectives by extending it with a formal characterisation of the concepts of norm and outcome compliance. Then, in the case the agent violates some norms or does not achieve all her objectives, we propose a preliminary analysis of methodologies to revise the theory and restore compliance. [234]

12 The Uses of Norms

This chapter presents a variety of applications of norms. These applications include governance in sociotechnical systems, data licensing and data collection, understanding software development teams, requirements engineering, assurance, natural resource allocation, wireless grids, autonomous vehicles, serious games, and virtual worlds. [235]

13 Towards an Abstract Framework for Compliance

The present paper aims at providing an abstract framework to define the regulatory compliance problem. In particular we show how the framework can be used to solve the problem of deciding whether a structured process is compliant with a single regulation, which is composed of a primary obligation and a chain of compensations. [53]

14 Algorithms for Basic Compliance Problems

The present paper focuses on the problems of verifying compliance for global achievement and maintenance obligations. We first introduce the elements needed to identify and study compliance to these two classes of obligations in processes. Additionally, we define procedures and algorithms to efficiently deal with the identified compliance problem. We finally show that both algorithms proposed in the paper belong to the complexity class **P**. [55]

15 A Study on Translating Regulatory Rules from Natural Language to Defeasible Logics

Legally binding regulations are expressed in natural language. Yet, we cannot formally or automatically reason with regulations in that form. Defeasible Logic has been used to formally represent the semantic interpretation of regulations; such representations may provide the abstract specification for a machine-readable and processable representation as in LegalRuleML. However, manual translation is prohibitively costly in terms of time, labour, and knowledge. The paper discusses work in progress using the state-of-the-art in automatic translation of a sample of regulatory clauses to a machine readable formal representation and a comparison to correlated Defeasible Logic representations. It outlines some key problems and proposes tasks to address the problems. [256]

16 Towards a Model of UAVs Navigation in Urban Canyon through Defeasible Logic

This paper shows how a non-monotonic rule based system (defeasible logic) can be integrated with numerical computation engines, and how this can be applied to solve the Vehicle Routing Problem (VRP). To this end, we have simulated a physical system from which we can obtain numerical information. The physical system perceives information from its environment and generates predicates that can be reasoned by a defeasible logic engine. The conclusions/decisions derived will then realized by the physical system as it takes actions based on the conclusion derived. Here we consider a scenario where a "flock" of UAVs have to navigate within an urban canyon environment. The UAVs are self-autonomous without centralized control. The goal of the UAVs is to navigate to their desired destinations without colliding with each other. In case of possible collision, the UAVs concerned will communicate with each other and use their background knowledge or travel guidelines to resolve the conflicts. [190]

17 Computing Strong and Weak Permissions in Defeasible Logic

In this paper we propose an extension of Defeasible Logic to represent and compute different concepts of defeasible permission. In particular, we discuss some types of explicit permissive norms that work as exceptions to opposite obligations or encode permissive rights. Moreover, we show how strong permissions can be represented both with, and without introducing a new consequence relation for inferring conclusions from explicit permissive norms. Finally, we illustrate how a preference operator applicable to contrary-to-duty obligations can be combined with a new operator representing ordered sequences of strong permissions. The logical system is studied from a computational standpoint and is shown to have linear computational complexity. [118]

18 Business Process Compliance: An Abstract Normative Framework

In this paper we propose an abstract framework to model the deontic notions relevant for business process compliance. In particular, we provide a comprehensive classification

of the obligation types relevant for modelling whether a process is compliant, and we describe their semantics in terms of execution traces. [80]

2012

1 Rule Based Business Process Compliance

In this paper we report on the development and evaluation of a business process compliance checker, based on the compliance-by-design methodology proposed by Governatori and Sadiq [166]. [169]

2 A history of AI and Law in 50 papers: 25 years of the international conference on AI and Law

We provide a retrospective of 25 years of the International Conference on AI and Law, which was first held in 1987. Fifty papers have been selected from the thirteen conferences and each of them is described in a short subsection individually written by one of the 24 authors. These subsections attempt to place the paper discussed in the context of the development of AI and Law, while often offering some personal reactions and reflections. As a whole, the subsections build into a history of the last quarter century of the field, and provide some insights into where it has come from, where it is now, and where it might go. [34]

3 Possible World Semantics for Defeasible Deontic Logic

Defeasible Deontic Logic is a simple and computationally efficient approach for the representation of normative reasoning. Traditionally defeasible logics are defined proof theoretically based on the proof conditions for the logic. While several logic programming, operational and argumentation semantics have been provided for defeasible logics, possible world semantics for (modal) defeasible logics remained elusive. In this paper we address this issue. [158]

4 Narrowing Legal Concepts

We propose a framework for reconstructing the arguments supporting the restrictive interpretations of legal provisions. The idea is that the interpretation of legal concepts may require to change the counts-as rules defining them. Some connections with revision theory techniques are considered. [119]

5 Business Process Data Compliance

Most approaches to business process compliance are restricted to the analysis of the structure of processes. It has been argued that full regulatory compliance requires information on not only the structure of processes but also on what the tasks in a process do. To this end Governatori and Sadiq [2007] proposed to extend business processes with semantic annotations. We propose a methodology to automatically extract one kind of such annotations; in particular the annotations related to the data schema and templates linked to the various tasks in a business process. [174]

6 On Compliance Checking for Clausal Constraints in Annotated Process Models

Compliance management is important in several industry sectors where there is a high incidence of regulatory control. It must be ensured that business practices, as reflected in business processes, comply with the rules. Such compliance checks are challenging due to (1) the different life cycles of rules and processes, and (2) their disparate representations. (1) requires retrospective checking of process models. To address (2), we herein devise a framework where processes are annotated to capture the semantics of task execution, and compliance is checked against a set of constraints posing restrictions on the desirable process states. Each constraint is a clause, i.e., a disjunction of literals. If a process can reach a state that falsifies all literals of one of the constraints, then that constraint is violated in that state, and indicates non-compliance. Naively, such compliance can be checked by enumerating all reachable states. Since long waiting times are undesirable, it is important to develop efficient (low-order polynomial time) algorithms that (a) perform exact compliance checking for restricted cases, or (b) perform approximate compliance checking for more general cases. Herein, we observe that methods of both kinds can be defined as a natural extension of our earlier work on semantic business process validation. We devise one method of type (a), and we devise two methods of type (b); both are based on similar restrictions to the processes, where the restrictions made by methods (b) are a subset of those made by method (a). The approximate methods each guarantee either of soundness (finding only non-compliances) or completeness (finding all non-compliances). We describe how one can trace the state evolution back to the process activities which caused the (potential) non-compliance, and hence provide the user with an error diagnosis. [177]

7 Distributed Defeasible Speculative Reasoning in Ambient Environment

Speculative Computation is an effective means for solving problems with incomplete information in an open and distributed environment, such as peer-to-peer environment. It allows such a system to compute tentative (and possibly final) solutions using default knowledge about the current environment, or the agent's perception, even if the communications between peers are delayed or broken. However, previous work in speculative reasoning assumed that agents are hierarchically structured, which may not be the case in reality. We propose a more general multi-agents system with no centralized control.

Agents in the framework have equivalent functionalities and can collaborate with each other to achieve their common goals. We characterize the framework using the argumentation semantics of defeasible logic, which provides support of speculative reasoning in the presence of conflicting information. We provide an operational model for the framework and present a prototype implementation of the model. [193]

8 An Implicit Approach to Deal with Periodically Repeated Medical Data

Context: Temporal information plays a crucial role in medicine, so that in medical informatics there is an increasing awareness that suitable database approaches are needed to store and support it. Specifically, a great amount of clinical data (e.g., therapeutic data) are periodically repeated. Although an explicit treatment is possible in most cases, it causes severe storage and disk I/O problems. *Objective*: In this paper, we propose an innovative approach to cope with periodic relational medical data in an implicit way. *Methods*: We propose a new data model, representing periodic data in a compact (implicit) way, which is a consistent extension of TSQL2 consensus approach. Then, we identify some important types of temporal queries, and present query answering algorithms to answer them. Finally, we also run experiments to evaluate our approach. Results: The experiments show that our approach outperforms current explicit approaches, especially as regard disk I/O. *Conclusion*: We have provided an implicit approach to periodic data with is a consistent extension of TSQL2 (and which is thus grant interoperable with it), and we have experimentally proven that it outperforms current explicit approaches. [246]

9 On Modeling Punishment in Multi-Agent Systems

In this paper we study isolation as a form of punishment. Although the isolated violator is punished as it can not benefit from the interactions with other agents, compliant agents may also suffer from not engaging with the violators. In this paper we analyze such problems. Certain modifications of the multi agent system are needed to solve this problem. These modifications are aimed to make the violator redundant so that it can be ignored and hence isolated. In this paper we show that deciding on these modifications is NP-complete and give approximation algorithms. [252]

2011

1 Levels of modality for BDI Logic

Legal texts are the foundational resource where to discover rules and norms that feed into different concrete (often XML-based) Web applications. Legislative documents provide general norms and specific procedural rules for eGovernment and eCommerce environments, while contracts specify the conditions of services and business rules (e.g. service level agreements for cloud computing), and judgments provide information about the legal argumentation and interpretation of norms to concrete case-law. Such legal knowledge is

an important source that should be detected, properly modeled and expressively represented in order to capture all the domain particularities. This paper provides an extension of RuleML called LegalRuleML for fostering the characteristics of legal knowledge and to permit its full usage in legal reasoning and in the business rule domain. LegalRuleML encourages the effective exchange and sharing of such semantic information between legal documents, business rules, and software applications. [38]

2 Time and Defeasibility in FIPA ACL Semantics

In this paper we propose an extension of Defeasible Logic to represent different concepts of defeasible permission. Special attention is paid in particular to permissive norms that work as exceptions to opposite obligations. [42]

3 Approximate Record Matching Using Hash Grams

Accurately identifying duplicate records between multiple data sources is a persistent problem that continues to plague organizations and researchers alike. Small inconsistencies between records can prevent detection between two otherwise identical records. In this paper, we present a new probabilistic h-gram (hash gram) record matching technique by extending traditional n-grams and utilizing scale based hashing for equality testing. h-gram matching highly reduces the number of comparisons to be performed for duplicate record detection applicable to a variety of data types and data sizes by transforming data into its equivalent numerical realities. One of the key features of h-gram matching is that it is highly extensible providing more intuitive and flexible results. With the sampling technique in place, our method can be applied on variable size databases to perform data linkage and probabilistic results can be quickly obtained. We have extensively evaluated h-gram matching on large samples of real-world data and the results show higher level of accuracy as well as reduction in required time when compared with existing techniques. [74]

4 Ontology Guided Data Linkage Framework for Discovering Meaningful Data Facts

Making sensible queries on databases collected from different organizations presents a challenging task for linking semantic equivalent data facts. Current techniques primarily focused on performing pair-wise attribute matching and paid little attention towards discovering probabilistic structural dependencies by exploiting the ontological domain knowledge of tables, attributes and tuples to construct hierarchical cluster mapping trees. In this paper, we present Ontology Guided Data Linkage (OGDL) framework for self-organizing heterogeneous data sources into homogeneous ontological clusters through multi-faceted classification. Through the evaluation on real-world data, we demonstrate the robustness and accuracy of our system. [75]

5 Designing for Compliance: Norms and Goals

We address the problem of define a modal defeasible theory able to capture intuitions as "being compliant" with a set of *norms* and a set of *goals*. We will treat norms and goals as modalised literals. From the definition of this new kind of logic, two main issues arises whether a theory is compliant or not: (a) how to revise a non compliant theory to obtain a new compliant one; (b) in case the theory is compliant how to create an entirely new process starting from the theory, i.e., from the fully declarative description of the specifications for a process and the norms. [123]

6 Justice Delayed Is Justice Denied: Logics for a Temporal Account of Reparations and Legal Compliance

In this paper we extend the logic of violation proposed by Governatori and Rotolo with time, more precisely, we temporalise that logic. The resulting system allows us to capture many subtleties of the concept of legal compliance. In particular, the formal characterisation of compliance can handle different types of legal obligation and different temporal constraints over them. The logic is also able to represent, and reason about, chains of reparative obligations, since in many cases the fulfillment of these types of obligation still amount to legally acceptable situations. [150]

7 Three Concepts of Defeasible Permission

In this paper we propose an extension of Defeasible Logic to represent different concepts of defeasible permission. Special attention is paid in particular to permissive norms that work as exceptions to opposite obligations. [120]

8 On the Relationship between Carneades and Defeasible Logic

We study the formal relationships between the inferential aspects of Carneades (a general argumentation framework) and Defeasible Logic. The outcome of the investigation is that the current proof standards proposed in the Carneades framework correspond to some variants of Defeasible Logic. [88]

9 A Modal Defeasible Reasoner of Deontic Logic for the Semantic Web

Defeasible logic is a non-monotonic formalism that deals with incomplete and conflicting information, whereas modal logic deals with the concepts of necessity and possibility. These types of logics play a significant role in the emerging Semantic Web, which enriches the available Web information with meaning, leading to better cooperation between end-users and applications. Defeasible and modal logics, in general, and, particularly, deontic logic provide means for modeling agent communities, where each agent is characterized by its cognitive profile and normative system, as well as policies, which define privacy requirements, access permissions, and individual rights. Toward this direction, this article discusses the extension of DR-DEVICE, a Semantic Web-aware defeasible reasoner, with

a mechanism for expressing modal logic operators, while testing the implementation via deontic logic operators, concerned with obligations, permissions, and related concepts. The motivation behind this work is to develop a practical defeasible reasoner for the Semantic Web that takes advantage of the expressive power offered by modal logics, accompanied by the flexibility to define diverse agent behaviours. A further incentive is to study the various motivational notions of deontic logic and discuss the cognitive state of agents, as well as the interactions among them. [185]

10 Fibred BDI Logics: Completeness Preservation in the Presence of Interaction Axioms

In [6,9] the authors have shown how to combine propositional BDI logics using Gabbay's fibring methodology and in [11,10] they outlined a tableaux proof procedure for the fibred BDI logic. In this paper we provide a proof related to completeness preservation of the combined BDI logic in the presence of interaction axioms of the form $\Box_1\varphi \Rightarrow \Box_2\varphi$ in terms of canonical models. To be more precise, let Λ_a, Λ_b, Λ_c, Λ_d be canonical normal modal logics and $\Lambda_{abcd} = \Lambda_a \odot \Lambda_b \odot \Lambda_c \odot \Lambda_d$ be the logics obtained by fibring/dovetailing Λ_a, Λ_b, Λ_c, Λ_d. Then we show that $\Lambda_{abcd} \oplus \Diamond_a\Box_b\varphi \Rightarrow \Box_c\Diamond_d\varphi$ is characterised by the class of fibred models satisfying the condition TBW. [213]

11 Incorporating Temporal Planning Within a BDI Architecture

In this paper we make two important contributions (1) we extend the basic BDI architecture so as to include an *action-base* with temporal durations (2) extend the existing classical planning cycle in BDI with temporal planning using our *GeneratePlan* method. The main motivation is to make BDI-like systems capable of handling plan failures in a much more efficient way by extracting plans when *relevant plans* are not found in the plan library. To show the feasibility of our method we implemented our planning algorithms with respect to a travel planning scenario. [215]

12 Modelling Temporal Legal Rules

Legal reasoning involves multiple temporal dimensions but the existing state of the art of legal representation languages does not allow us to easily combine expressiveness, performance and legal reasoning requirements. Moreover we also aim at the combination of legal temporal reasoning with the defeasible logic approach, maintaining a computable complexity. The contribution of this work is to extend LKIF-rules with temporal dimensions and defeasible tools, extending our previous work [217]. [216]

13 LegalRuleML: XML-Based Rules and Norms

Legal texts are the foundational resource where to discover rules and norms that feed into different concrete (often XML-based) Web applications. Legislative documents provide general norms and specific procedural rules for eGovernment and eCommerce environments, while contracts specify the conditions of services and business rules (e.g. service

level agreements for cloud computing), and judgments provide information about the legal argumentation and interpretation of norms to concrete case-law. Such legal knowledge is an important source that should be detected, properly modeled and expressively represented in order to capture all the domain particularities. This paper provides an extension of RuleML called LegalRuleML for fostering the characteristics of legal knowledge and to permit its full usage in legal reasoning and in the business rule domain. LegalRuleML encourages the effective exchange and sharing of such semantic information between legal documents, business rules, and software applications. [218]

14 A Modelling and Reasoning Framework for Social Networks Policies

Policy languages (such as privacy and rights) have had little impact on the wider community. Now that Social Networks have taken off, the need to revisit Policy languages and realign them towards Social Networks requirements has become more apparent. One such language is explored as to its applicability to the Social Networks masses. We also argue that policy languages alone are not sufficient and thus they should be paired with reasoning mechanisms to provide precise and unambiguous execution models of the policies. To this end we propose a computationally oriented model to represent, reason with and execute policies for Social Networks. [101]

15 What Are the Necessity Rules in Defeasible Reasoning

This paper investigates a new approach for computing the inference of defeasible logic. The algorithm proposed can substantially reduced the theory size increase due to transformations while preserving the representation properties in different variants of DL. Experiments also show that our algorithm outperform traditional approach by several order of amplitudes. [191]

2010

1 A Conceptually Rich Model of Business Process Compliance

In this paper we extend the preliminary work developed elsewhere and investigate how to characterise many aspects of the compliance problem in business process modeling. We first define a formal and conceptually rich language able to represent, and reason about, chains of reparational obligations of various types. Second, we devise a mechanism for normalising a system of legal norms. Third, we specify a suitable language for business process modeling able to automate and optimise business procedures and to embed normative constraints. Fourth, we develop an algorithm for compliance checking and discuss some computational issues regarding the possibility of checking compliance runtime or of enforcing it at design time. [138]

2 Temporal Dimensions in Rules Modelling

Typically legal reasoning involves multiple temporal dimensions. The contribution of this work is to extend LKIF-rules (LKIF is a proposed mark-up language designed for legal documents and legal knowledge in ESTRELLA Project [3]) with temporal dimensions. We propose an XML-schema to model the various aspects of the temporal dimensions in legal domain, and we discuss the design choices. We illustrate the use of the temporal dimensions in rules with the help of real life examples. [217]

3 Changing legal systems: legal abrogations and annulments in Defeasible Logic

In this paper we investigate how to represent and reason about legal abrogations and annulments in Defeasible Logic. We examine some options that embed in this setting, and in similar rule-based systems, ideas from belief and base revision. In both cases, our conclusion is negative, which suggests to adopt a different logical model. This model expresses temporal aspects of legal rules, and distinguishes between two main timelines, one internal to a given temporal version of the legal system, and another relative to how the legal system evolves over time. Accordingly, we propose a temporal extension of Defeasible Logic suitable to express this model and to capture abrogation and annulment. We show that the proposed framework overcomes the difficulties discussed in regard to belief and base revision, and is sufficiently flexible to represent many of the subtleties characterizing legal abrogations and annulments. [145]

4 An Inclusion Theorem for Defeasible Logic

Defeasible reasoning is a computationally simple nonmonotonic reasoning approach that has attracted significant theoretical and practical attention. It comprises a family of logics that capture different intuitions, among them ambiguity propagation versus ambiguity blocking, and the adoption or rejection of team defeat. This paper provides a compact presentation of the defeasible logic variants, and derives an Inclusion Theorem which shows that different notions of provability in defeasible logic form a chain of levels of proof. [35]

5 Implementing Temporal Defeasible Logic for Modeling Legal Reasoning

In this paper we briefly present an efficient implementation of temporal defeasible logic, and we argue that it can be used to efficiently capture the the legal concepts of persistence, retroactivity and periodicity. In particular, we illustrate how the system works with a real life example of a regulation. [162]

6 *Lex minus dixit quam voluit, lex magis dixit quam voluit*: A Formal Study on Legal Compliance and Interpretation

This paper argues in favour of the necessity of dynamically restricting and expanding the applicability of norms regulating computer systems like multiagent systems, in situations where the compliance to the norm does not achieve the purpose of the norm. We propose a logical framework which distinguishes between constitutive and regulative norms and captures the norm change power and at the same time the limitations of the judicial system in dynamically revising the set of constitutive rules defining the concepts on which the applicability of norms is based. In particular, the framework is used to reconstruct some interpretive arguments described in legal theory such as those corresponding to the Roman maxims *lex minus dixit quam voluit* and *lex magis dixit quam voluit*. The logical framework is based on an extension of defeasible logic. [44]

7 A Logical Understanding of Legal Interpretation

If compliance with a norm does not achieve its purpose, then its applicability must dynamically be restricted or expanded. Legal interpretation is a mechanism from law allowing norms to be adapted to unforeseen situations. We model this mechanism for norms regulating computer systems by representing the purpose of norms by social goals and by revising the constitutive rules defining the applicability of norms. We illustrate the interpretation mechanism by examples. [43]

8 Layered Argumentation for Fuzzy Automation Controllers

We develop a layered argumentation system (LAS) for efficient implementation of Fuzzy automation controllers. LAS extends a logic based proposal of argumentation with subsumption concept and varying degree of confidences in beliefs. We show that this argumentation system can be used to model Fuzzy automation controllers. The argumentation system is based on a nonmonotonic logic, the computational complexity of which is known to be linear to the size of the knowledge base. LAS theories can also be mapped into RTL-VHDL (Register Transfer Level-VLSI Hardware Description Language) or RTL Verilog for very efficient hardware implementation of Fuzzy automation controllers. [244]

9 Norm Compliance in Business Process Modeling

We investigate the concept of norm compliance in business process modeling. In particular we propose an extension of Formal Contract Logic (FCL), a combination of defeasible logic and a logic of violation, with a richer deontic language capable of capture many different facets of normative requirements. The resulting logic, called Process Compliance Logic (PCL), is able to capture both semantic compliance and structural compliance. This paper focuses on structural compliance, that is we show how PCL can capture obligations concerning the structure of a business process. [154]

10 A Contract Agreement Policy-based Workflow Methodology for Agents Interacting in the Semantic Web

The Semantic Web aims at automating Web content understanding and user request satisfaction. Intelligent agents assist towards this by performing complex actions on behalf of their users into real-life applications, such as e-Contracts, which make transactions simple by modeling the processes involved. This paper, presents a policy-based workflow methodology for efficient contract agreement among agents interacting in the Semantic Web. In addition, we present the integration of this methodology into a multi-agent knowledge-based framework, providing flexibility, reusability and interoperability of behavior between agents. The main advantage of our approach is that it provides a safe, generic, and reusable framework for modeling and monitoring e-Contract agreements, which could be used for different types of on-line transactions among agents. Furthermore, our framework is based on Semantic Web and FIPA standards, to maximize interoperability and reusability. Finally, an e-Commerce contract negotiation scenario is presented that illustrates the usability of the approach. [187]

11 Superiority Based Revision of Defeasible Theories

We propose a systematic investigation on how to modify a preference relation in a defeasible logic theory to change the conclusions of the theory itself. We argue that the approach we adopt is applicable to legal reasoning, where users, in general, cannot change facts and rules, but can propose their preferences about the relative strength of the rules. We provide a comprehensive study of the possible combinatorial cases and we identify and analyse the cases where the revision process is successful. [124]

12 Transformation of SBVR Compliant Business Rules to Executable FCL Rules

The main source of changing requirements of the dynamic business environment is response to changes in regulations and contracts towards which businesses are obligated to comply. At the same time, many organizations have their business processes specified independently of their business obligations (which include adherence to contracts laws and regulations). Thus, the problem of mapping business changes into computational systems becomes much more complicated. In this paper we address the problem by providing an automated transformation of business rules into a formal language capable of directly mapping onto executable specifications. The model transformation is consistent with MDA/MOF/QVT concepts using ATL to perform the mapping. Business rules are compliant to SBVR metamodel, and are transformed into FCL, a logic based formalism, known to have a direct mapping onto executable specifications. Both, source and target rules are based on principles of deontic logic, the core of which are obligations, permissions and prohibitions. [184]

13 On the problem of computing Ambiguity Propagation and Well-Founded Semantics in Defeasible Logic

In this paper we present the well founded variants of ambiguity blocking and ambiguity propagating defeasible logics. We also show how to extend SPINdle, a state of the art, defeasible logic implementation to handle all such variants of defeasible logic. [188]

14 SBVR based Business Contract and Business Rule IDE

We propose an IDE – Integrated Development Environment to model SBVR (Semantic of Business Vocabulary and Business Rule) compliant business rules [2] extracted from business contract of services and store them in an ontological structure of rules, facts and terms as defined in the SBVR metamodel. Business rules are based on principles of deontic logic for treating expressions in the form of normative policies. Deontic constraints express what parties to the contract are required to perform (obligations), what they are allowed to do (permissions), or what they are not allowed to do (prohibitions). [183]

15 Law, Logic and Business Processes

Since its inception one of the aims of legal informatics has been to provide tools to support and improve the day to day activities of legal and normative practice and a better understanding of legal reasoning. The internet revolutions, where more and more daily activities are routinely performed with the support of ITC tools, offers new opportunities to legal informatics. We argue that the current technology begins to be mature enough to embrace in the challenge to make intelligent ICT support widespread in the legal and normative domain. In this paper we examine a logical model to encode norms and we use the formalisation of relevant law and regulations for regulatory compliance for business processes. [87]

16 Towards an Implicit Treatment of Periodically-Repeated Medical Data

Temporal information plays a crucial role in medicine, so that in Medical Informatics there is an increasing awareness that suitable database approaches are needed to store and support it. Specifically, a great amount of clinical data (e.g., therapeutic data) are periodically repeated. Although an explicit treatment is possible in most cases, it causes severe storage and disk I/O problems. In this paper, we propose an innovative approach to cope with periodic medical data in an implicit way. We propose a new data model, representing periodic data in a compact (implicit) way, which is a consistent extension of TSQL2 consensus approach. Then, we identify some important types of temporal queries, and present query answering algorithms to answer them. We also sketch a temporal relational algebra for our approach. Finally, we show experimentally that our approach outperforms current explicit approaches. [247]

17 Burdens of Proof in Monological Argumentation

We shall argue that burdens of proof are relevant also to monological reasoning, i.e., for deriving the conclusions of a knowledge-base allowing for conflicting arguments. Reasoning with burdens of proof can provide a useful extension of current argument-based non-monotonic logics, at least a different perspective on them. Firstly we shall provide an objective characterisation of burdens of proof, assuming that burdens concerns rule antecedents (literals in the body of rules), rather than agents. Secondly, we shall analyse the conditions for a burden to be satisfied, by considering credulous or skeptical derivability of the concerned antecedent or of its complement. Finally, we shall develop a method for developing inferences out of a knowledge base merging rules and proof burdens in the framework of defeasible logic. [167]

18 A Logic Framework of Normative-based Contract Management

In this paper an extended Defeasible Logic framework is presented to do the representation and reasoning work for the normative-based contract management. A simple case based on FIDIC is followed as the usage example. This paper is based on the idea that normative concepts and normative rules should play the decisive roles in the normative-based contract management. Those normative concepts and rules are based on the normative literals and operators like action, obligation, permission and violation. The normative reduction is based on the normative concepts, normative connections and normative rules, especially on the superiority relation over the defeasible rules. [78]

19 Automatic Synthesis of Reactive Agents

This paper introduces a new approach to designing smart control chips that enables automatic synthesis of real-time control systems from agent specifications. An agent specification is compiled into a hardware description format, such as RTL-VHDL (Register Transfer Level–VLSI Hardware Description Language) or RTL Verilog, which is synthesized using computer-assisted tools to develop ASIC masks or FPGA configurations. A rule-based specification language called Layered Argumentation System (LAS) is defined and a sound and complete mapping to Verilog is developed. LAS combines fuzzy reasoning and non-monotonic reasoning. This enables chip designers to capture common-sense knowledge and concepts having varying degrees of confidence collaboratively and incrementally. [243]

2009

1 The Journey to Business Process Compliance

It is a typical scenario that many organisations have their business processes specified independently of their business obligations (which includes contractual obligations to business partners, as well as obligations a business has to fulfil against regulations and industry standards). This is because of the lack of guidelines and tools that facilitate

derivation of processes from contracts but also because of the traditional mindset of treating contracts separately from business processes. This chapter will provide a solution to one specific problem that arises from this situation, namely the lack of mechanisms to check whether business processes are compliant with business contracts. The chapter begins by defining the space for business process compliance and the eco-system for ensuring that process are compliant. The key point is that compliance is a relationship between two sets of specifications: the specifications for executing a business process and the specifications regulating a business. The central part of the chapter focuses on a logic based formalism for describing both the semantics of normative specifications and the semantics of compliance checking procedures. [166]

2 Modal Tableaux for Verifying Stream Authentication Protocols

To develop theories to specify and reason about various aspects of multi-agent systems, many researchers have proposed the use of modal logics such as belief logics, logics of knowledge, and logics of norms. As multi-agent systems operate in dynamic environments, there is also a need to model the evolution of multi-agent systems through time. In order to introduce a temporal dimension to a belief logic, we combine it with a linear-time temporal logic using a powerful technique called fibring for combining logics. We describe a labelled modal tableaux system for the resulting fibred belief logic (FL) which can be used to automatically verify correctness of inter-agent stream authentication protocols. With the resulting fibred belief logic and its associated modal tableaux, one is able to build theories of trust for the description of, and reasoning about, multi-agent systems operating in dynamic environments. [128]

3 A Modal and Deontic Defeasible Reasoning System for Modelling Policies and Multi-Agent Systems

Defeasible reasoning is a well-established nonmonotonic reasoning approach that has recently been combined with Semantic Web technologies. This paper describes modal and deontic extensions of defeasible logic, motivated by potential applications for modelling multi-agent systems and policies. It describes a logic metaprogram that captures the underlying intuitions, and outlines an implemented system. Finally, it demonstrates its use for modelling policies. [10]

4 On Managing Business Processes Variants

Variance in business process execution can be the result of several situations, such as disconnection between documented models and business operations, workarounds in spite of process execution engines, dynamic change and exception handling, flexible and ad-hoc requirements, and collaborative and/or knowledge intensive work. It is imperative that effective support for managing process variances be extended to organizations mature in their BPM (Business Process Management) uptake so that they can ensure organization wide consistency, promote reuse and capitalize on their BPM investments. This paper presents an approach for managing business processes that is conducive to dynamic

change and the need for flexibility in execution. The approach is based on the notion of process constraints. It further provides a technique for effective utilization of the adaptations manifested in process variants. In particular, we will present a facility for discovery of preferred variants through effective search and retrieval based on the notion of process similarity, where multiple aspects of the process variants are compared according to specific query requirements. The advantage of this approach is the ability to provide a quantitative measure for the similarity between process variants, which further facilitates various BPM activities such as process reuse, analysis and discovery. [198]

5 Defining Adaptation Constraints for Business Process Variants

In current dynamic business environment, it has been argued that certain characteristics of ad-hocism in business processes are desirable. Such business processes typically have a very large number of instances, where design decisions for each process instance may be made at runtime. In these cases, predictability and repetitiveness cannot be counted upon, as the complete process knowledge used to define the process model only becomes available at the time after a specific process instance has been instantiated. The basic premise is that for a class of business processes it is possible to specify a small number of essential constraints at design time, but allow for a large number of execution possibilities at runtime. The objective of this paper is to conceptualise a set of constraints for process adaptation at instance level. Based on a comprehensive modelling framework, business requirements can be transformed to a set of minimal constraints, and the support for specification of process constraints and techniques to ensure constraint quality are developed. [200]

6 A Defeasible Logic for Modelling Policy-based Intentions and Motivational Attitudes

In this paper we show how *defeasible logic* could formally account for the non-monotonic properties involved in motivational attitudes like intention and obligation. Usually, *normal* modal operators are used to represent such attitudes wherein classical logical consequence and the rule of necessitation comes into play i.e., $\vdash A/ \vdash \Box A$, that is from $\vdash A$ derive $\vdash \Box A$. This means that such formalisms are affected by the *Logical Omniscience* problem. We show that policy-based intentions exhibit non-monotonic behaviour which could be captured through a non-monotonic system like defeasible logic. To this end we outline a defeasible logic of intention that specifies how modalities can be introduced and manipulated in a non-monotonic setting without giving rise to the problem of logical omniscience. In a similar way we show how to add deontic modalities defeasibly and how to integrate them with other motivational attitudes like beliefs and goals. Finally we show that the basic aspect of the BOID architecture is captured by this extended framework. [132]

7 DR-CONTRACT: an architecture for e-contracts in defeasible logic

We introduce the DR-CONTRACT architecture to represent and reason on e-Contracts. The architecture extends the DR-device architecture by a deontic defeasible logic of violation. We motivate the choice for the logic and we show how to extend RuleML to capture the notions relevant to describe e-contracts for a monitoring perspective in Defeasible Logic. [135]

8 Rules and Norms: Requirements for Rule Interchange Languages in the Legal Domain

In this survey paper we summarize the requirements for rule interchange languages for applications in the legal domain and use these requirements to evaluate RuleML, SBVR, SWRL and RIF. We also present the Legal Knowledge Interchange Format (LKIF), a new rule interchange format developed specifically for applications in the legal domain. [76]

9 The Making of SPINdle

We present the design and implementation of SPINdle – an open source Java based defeasible logic reasoner capable to perform efficient and scalable reasoning on defeasible logic theories (including theories with over 1 million rules). The implementation covers both the standard and modal extensions to It allows users or agents to issues queries, on a given knowledge base or a theory generated on the fly by other applications, and automatically produces the conclusions of its consequences. The theory can also be represented using XML. [189]

10 Modelling and Reasoning Languages for Social Networks Policies

Policy languages (such as privacy and rights) have had little impact on the wider community. Now that Social Networks have taken off, the need to revisit Policy languages and realign them towards Social Networks requirements has become more apparent. One such language is explored as to its applicability to the Social Networks masses. We also argue that policy languages alone are not sufficient and thus they should be paired with reasoning mechanisms to provide precise and unambiguous execution models of the policies. To this end we propose a computationally oriented model to represent, reason with and execute policies for Social Networks. [102]

11 How Do Agents Comply with Norms?

The import of the notion of institution in the design of MASs requires to develop formal and efficient methods for modeling the interaction between agents' behaviour and normative systems. This paper discusses how to check whether agents' behaviour complies with the rules regulating them. The key point of our approach is that compliance is a relationship between two sets of specifications: the specifications for executing a

process and the specifications regulating it. We propose a formalism for describing both the semantics of normative specifications and the semantics of compliance checking procedures. [149]

12 A Model to Coordinate UAVs in Urban Environments Using Defeasible Logic

In this paper we show how a non-monotonic rule based system (defeasible logic) can be integrated with numerical computation engines. To this end we simulate a physical system from which we obtain numerical information. The physical system perceives information from its environment and it sends some predicates which are used by the defeasible logic reasoning engine to make decisions and then these decisions are realized by the physical system as it takes action based on the decision made by the reasoning engine. We consider a scenario where UAVs have to navigate through an urban environment. The UAVs are autonomous and there is no centralized control. The goal of the UAVs is to navigate without any collisions with each other or with any building. In case of a possible collision, the concerned UAVs communicate with each other and use background knowledge or some travel guidelines to resolve the conflicts. [194]

13 How Do Agents Comply with Norms?

The import of the notion of institution in the design of MASs requires to develop formal and efficient methods for modeling the interaction between agents' behaviour and normative systems. This paper discusses how to check whether agents' behaviour is compliant with the rules regulating them. The key point of our approach is that compliance is a relationship between two sets of specifications: the specifications for executing a process and the specifications regulating it. We propose a logic-based formalism for describing both the semantics of normative specifications and the semantics of compliance checking procedures. [148]

14 Extended Defeasible Reasoning for Common Goals in n-Person Argumentation Games

Argumentation games have been proved to be a robust and flexible tool to resolve conflicts among agents. An agent can propose its explanation and its goal known as a claim, which can be refuted by other agents. The situation is more complicated when there are more than two agents playing the game. We propose a weighting mechanism for competing premises to tackle with conflicts from multiple agents in an n-person game. An agent can defend its proposal by giving a counter-argument to change the "opinion" of the majority of opposing agents. Furthermore, using the extended defeasible reasoning an agent can exploit the knowledge that other agents expose in order to promote and defend its main claim. [221]

2008

1 A Computational Framework for Institutional Agency

This paper provides a computational framework, based on Defeasible Logic, to capture some aspects of institutional agency. Our background is Kanger-Lindahl-Pörn account of organised interaction, which describes this interaction within a multi-modal logical setting. This work focuses in particular on the notions of counts-as link and on those of attempt and of personal and direct action to realise states of affairs. We show how standard Defeasible Logic can be extended to represent these concepts: the resulting system preserves some basic properties commonly attributed to them. In addition, the framework enjoys nice computational properties, as it turns out that the extension of any theory can be computed in time linear to the size of the theory itself. [136]

2 BIO Logical Agents: Norms, Beliefs, Intentions in Defeasible Logic

In this paper we follow the BOID (Belief, Obligation, Intention, Desire) architecture to describe agents and agent types in Defeasible Logic. We argue, in particular, that the introduction of obligations can provide a new reading of the concepts of intention and intentionality. Then we examine the notion of social agent (i.e., an agent where obligations prevail over intentions) and discuss some computational and philosophical issues related to it. We show that the notion of social agent either requires more complex computations or has some philosophical drawbacks. [142]

3 Changing Legal Systems: Abrogation and Annulment. Part I: Revision of Defeasible Theories

In this paper we investigate how to model legal abrogation and annulment in Defeasible Logic. We examine some options that embed in this setting, and similar rule-based systems, ideas from belief and base revision. In both cases, our conclusion is negative, which suggests to adopt a different logical model. [143]

4 An Asymmetric Protocol for Argumentation Games in Defeasible Logic

Agent interactions where the agents hold conflicting goals could be modelled as adversarial argumentation games. In many real-life situations (e.g., criminal litigation, consumer legislation), due to ethical, moral or other principles governing interaction, the burden of proof, i.e., which party is to lose if the evidence is balanced [**4**], is *a priori* fixed to one of the parties. Analogously, when resolving disputes in a heterogeneous agent-system the unequal importance of different agents for carrying out the overall system goal need to be accounted for. In this paper we present an asymmetric protocol for an adversarial argumentation game in Defeasible Logic, suggesting Defeasible Logic as a general representation formalism for argumentation games modelling agent interactions. [68]

5 Contextual Agent Deliberation in Defeasible Logic

This article extends Defeasible Logic to deal with the contextual deliberation process of cognitive agents. First, we introduce meta-rules to reason with rules. Meta-rules are rules that have as a consequent rules for motivational components, such as obligations, intentions and desires. In other words, they include nested rules. Second, we introduce explicit preferences among rules. They deal with complex structures where nested rules can be involved. [56]

6 Changing Legal Systems: Abrogation and Annulment. Part II: Temporalised Defeasible Logic

In this paper we propose a temporal extension of Defeasible Logic to model legal modifications, such as abrogation and annulment. Hence, this framework overcomes the difficulty, discussed elsewhere [143], of capturing these modification types using belief and base revision. [144]

7 Approximate Compliance Checking for Annotated Process Models

We describe a method for validating whether the states reached by a process are compliant with a set of constraints. This serves to (i) check the compliance of a new or altered process against the constraints base, and (ii) check the whole process repository against a changed constraints base, e.g., when new regulations come into being. For these purposes we formalize a particular class of compliance rules as well as annotated process models, the latter by combining a notion from the workflow literature with a notion from the AI actions and change literature. The compliance rules in turn pose restrictions on the desirable states. Each rule takes the form of a clausal constraint, i.e., a disjunction of literals. If for a given state there is a grounded clause none of whose literals are true, then the constraint is violated and indicates non-compliance. Checking whether a process is compliant with the rules involves enumerating all reachable states and is in general a hard search problem. Since long waiting times undesirable, it is important to explore restricted classes and approximate methods. We present a polynomial-time algorithm that, for a particular class of processes, computes the sets of literals that are necessarily true at particular points during process execution. Based on this information, we devise two approximate compliance checking methods. One of these is sound but not complete (it guarantees to find only non-compliance instances, but not to find all non-compliance instances); the other method is complete but not sound. We sketch how one can trace the state evolution back to the process activities which caused the (potential) non-compliance, and hence provide the user with some error diagnosis. [254]

8 Agents Adapt to Majority Behaviours

Agents within a group can have different perceptions of their working environment and autonomously fulfil their goals. However, they can be aware of beliefs and goals of the group as well as other members so that they can adjust their behaviours accordingly. To

model these agents, we explicitly include knowledge commonly shared by the group and that obtained from other agents. By avoiding actions which violate "mental attitudes" shared by the majority of the group, agents demonstrate their social commitment to the group. Defeasible logic is chosen as our representation formalism for its computational efficiency, and for its ability to handle incomplete and conflicting information. Hence, our agents can enjoy the low computational cost while performing "reasoning about others". Finally, we present the implementation of our multi-agent system. [219]

9 Labelled Modal Tableaux

Labelled tableaux are extensions of semantic tableaux with annotations (labels, indices) whose main function is to enrich the modal object language with semantic elements. This paper consists of three parts. In the first part we consider some options for labels: simple constant labels vs labels with free variables, logic depended inference rules vs labels manipulation based on a label algebra. In the second and third part we concentrate on a particular labelled tableaux system called KEM using free variable and a specialised label algebra. Specifically in the second part we show how labelled tableaux (KEM) can account for different types of logics (e.g., non-normal modal logics and conditional logics). In the third and final part we investigate the relative complexity of labelled tableaux systems and we show that the uses of KEM's label algebra can lead to speed up on proofs. [84]

10 Defeasible Logic to Model n-person Argumentation Game

In multi-agent systems, an individual agent can pursue its own goals, which may conflict with those hold by other agents. To settle on a common goal for the group of agents, the argumentation/dialogue game provides a robust and flexible tool where an agent can send its explanation for its goal in order to convince other agents. In the setting that the number of agents is greater than two and they are equally trustful, it is not clear how to extend existing argumentation/dialogue frameworks to tackle conflicts from many agents. We propose to use the defeasible logic to model the n-person argumentation game and to use the majority rule as an additional preference mechanism to tackle conflicts between arguments from individual agents. [222]

11 On Extending RuleML for Modal Defeasible Logic

In this paper we present a general methodology to extend Defeasible Logic with modal operators. We motivate the reasons for this type of extension and we argue that the extension will allow for a robust knowledge framework in different application areas. The paper presents an extension of RuleML to capture Modal Defeasible Logic. [220]

12 Settling on the Group's Goals: An n-Person Argumentation Game Approach

Argumentation games have been proved to be a robust and flexible tool to resolve conflicts among agents. An agent can propose its explanation and its goal known as a claim, which can be refuted by other agents. The situation is more complicated when there are more than two agents playing the game. We propose a weighting mechanism for competing premises to tackle with conflicts from multiple agents in an n-person game. An agent can defend its proposal by giving a counter-argument to change the "opinion" of the majority of opposing agents. During the game, an agent can exploit the knowledge that other agents expose in order to promote and defend its main claim. [223]

13 Knowledge Assessment: A Modal Logic Approach

The *possible worlds semantics* is a fruitful approach used in Artificial Intelligence (AI) for both *modelling* as well as *reasoning* about knowledge in agent systems via modal logics. In this work our main idea is not to model/reason about knowledge but to provide a theoretical framework for *knowledge assessment* (KA) with the help of *Monatague-Scott* (MS) semantics of modal logic. In KA questions *asked* and answers *collected* are the central elements and knowledge notions will be defined from these (i.e., possible states of knowledge of subjects in a population with respect to a field of information). [214]

14 Measurement of Compliance Distance in Business Processes

Ensuring that work practice is compliant to regulations and industrial standards is an increasingly important issue in business systems. Whereas as an understanding of control objectives that stem from various legislative, standard and contractual sources may be found at strategic or tactical levels, an assessment of their effective adoption in operational practices is extremely hard. In this paper, we propose a method for assessing the level of compliance in business work practice. The method builds upon business process management platforms, and provides the ability to objectively measure the compliance distance of existing processes within the organization. This in turn empowers process designers and business analysts to quantify the effort required to achieve a compliant process. [197]

15 A Compliance Model of Trust

We present a model of past interaction trust model based on compliance of expected behaviours. [172]

16 An Algorithm for Business Process Compliance

This paper provides a novel mechanism to check whether business processes are compliant with business rules regulating them. The key point is that compliance is a relationship between two sets of specifications: the specifications for executing a business process and the specifications regulating it. [141]

17 A system for modal and deontic defeasible reasoning

Defeasible reasoning is a well-established nonmonotonic reasoning approach that has recently been combined with semantic web technologies. This paper describes modal and deontic extensions of defeasible logic, and shows how these extensions can be used for modelling multi-agent systems and policies. [12]

18 Proof Explanation for a Nonmonotonic Semantic Web Rules Language

In this work, we present the design and implementation of a system for proof explanation in the Semantic Web, based on defeasible reasoning. Trust is a vital feature for Semantic Web. If users (humans and agents) are to use and integrate system answers, they must trust them. Thus, systems should be able to explain their actions, sources, and beliefs. Our system produces automatically proof explanations using a popular logic programming system (XSB), by interpreting the out- put from the proof's trace and converting it into a meaningful representation. It also supports an XML representation for agent communication, which is a common scenario in the Semantic Web. In this paper, we present the design and implementation of the system, a RuleML language extension for the representation of a proof explanation, and we give some examples of the system. The system in essence implements a proof layer for nonmonotonic rules on the Semantic Web. [3]

19 Levels of Modalities for BDI Logic

Defeasible logic is a non-monotonic formalism that deals with incomplete and conflicting information. Modal logic deals with necessity and possibility, exhibiting defeasibility; thus, it is possible to combine defeasible logic with modal operators. This paper reports on the extension of the DR-DEVICE defeasible reasoner with modal and deontic logic operators. The aim is a practical defeasible reasoner that will take advantage of the expressiveness of modal logics and the flexibility to define diverse agent types and behaviors. [37]

20 Time and Defeasibility in FIPA ACL Semantics

Inferences about communicative actions are often conditional, non-monotonic, and involve the issue of time. Most agent communication languages, however, ignore these issues, due to the difficulty to combine them in a single formalism. This paper addresses such issues in defeasible logic, and illustrates how to express a semantics for ACLs in order to make non-monotonic inferences on the basis of communicative actions. [41]

2007

1 FIPA Communicative Acts in Defeasible Logic

In agent communication languages, the inferences that can be made on the basis of a communicative action are inherently conditional, and non-monotonic. For example, a

proposal only leads to a commitment, on the condition that it is accepted. And in a persuasion dialogue, assertions may later be retracted. In this paper we therefore present a defeasible logic that can be used to express a semantics for agent communication languages, and to efficiently make inferences on the basis of communicative actions. The logic is non-monotonic, allows nested rules and mental attitudes as the content of communicative actions, and has an explicit way of expressing persistence over time. Moreover, it expresses that mental attitudes are publicly attributed to agents playing roles in the dialogue. To illustrate the usefulness of the logic, we reformalize the meta-theory underlying the FIPA semantics for agent communication, focusing on inform and propose. We show how composed speech acts can be formalized, and extend the semantics with an account of persuasion. [40]

2 Interaction between Normative Systems and Cognitive agents in Temporal Modal Defeasible Logic

While some recent frameworks on cognitive agents addressed the combination of mental attitudes with deontic concepts, they commonly ignore the representation of time. We propose in this paper a variant of Temporal Modal Defeasible Logic to deal in particular with temporal intervals. [229]

3 DR-NEGOTIATE— A System for Automated Agent Negotiation with Defeasible Logic-Based Strategies

This paper reports on a system for automated agent negotiation, based on a formal and executable approach to capture the behavior of parties involved in a negotiation. It uses the JADE agent framework, and its major distinctive feature is the use of declarative negotiation strategies. The negotiation strategies are expressed in a declarative rules language, defeasible logic, and are applied using the implemented system DR-DEVICE. The key ideas and the overall system architecture are described, and a particular negotiation case is presented in detail. [236]

4 Variants of Temporal Defeasible Logic for Modelling Norm Modifications

This paper proposes some variants of Temporal Defeasible Logic (TDL) to reason about normative modifications. These variants make it possible to differentiate cases in which, for example, modifications at some time change legal rules but their conclusions persist afterwards from cases where also their conclusions are blocked. [161]

5 Strategic Argumentation: A Game Theoretical Investigation

Argumentation is modelled as a game where the payoffs are measured in terms of the probability that the claimed conclusion is, or is not, defeasibly provable, given a history of arguments that have actually been exchanged, and given the probability of the factual premises. The probability of a conclusion is calculated using a standard variant of Defeasible Logic, in combination with standard probability calculus. It is a new element

of the present approach that the exchange of arguments is analysed with game theoretical tools, yielding a prescriptive and to some extent even predictive account of the actual course of play. A brief comparison with existing argument-based dialogue approaches confirms that such a prescriptive account of the actual argumentation has been almost lacking in the approaches proposed so far. [230]

6 Proof Explanation in the DR-DEVICE System

Trust is a vital feature for the Semantic Web: If users (humans and agents) are to use and integrate system answers, they must trust them. Thus, systems should be able to explain their actions, sources, and beliefs, and this issue is the topic of the proof layer in the design of the Semantic Web. This paper presents the design of a system for proof explanation on the Semantic Web, based on defeasible reasoning. The basis of this work is the DR-DEVICE system that is extended to handle proofs. A critical aspect is the representation of proofs in an XML language, which is achieved by a RuleML language extension. [33]

7 A Framework for Utilizing Preferred Work Practice for Business Process Evolution

Many Business Process Management (BPM) systems provide best practice process models, both generic as well as for specific industry sectors. However, it is often the variance from template solutions that provide organizations with intellectual capital and competitive differentiation. Although variance must comply with various contractual, regulatory and operational constraints, it is still an important information resource, representing preferred work practices. In this paper, we present a framework that utilizes desired work practice to support business process evolution. The framework on one hand provides the ability to use domain expert knowledge and experience to tailor individual process instances according to case specific requirements; and on the other, provides a means of using this knowledge through learning techniques to guide subsequent process refinements. [195]

8 Contextual Deliberation of Cognitive Agents in Defeasible Logic

This article extends Defeasible Logic to deal with the contextual deliberation process of cognitive agents. First, we introduce meta-rules to reason with rules. Meta-rules are rules that have as a consequent rules for motivational components, such as obligations, intentions and desires. In other words, they include nested rules. Second, we introduce explicit preferences among rules. They deal with complex structures where nested rules can be involved. [57]

9 A Framework of Normative-based Contract Management

We explore of the feasibility of the computationally oriented institutional agency framework proposed by Governatori and Rotolo testing it against an industrial strength scenario. In particular we show how to encode in defeasible logic the dispute resolution policy described in Article 67 of FIDIC. [253]

10 Modelling of Control Objectives for Business Process Compliance

Business process design is primarily driven by process improvement objectives. However, the role of control objectives stemming from regulations and standards is becoming increasingly important for businesses in light of recent events that led to some of the largest scandals in corporate history. As organizations strive to meet compliance agendas, there is an evident need to provide systematic approaches that assist in the understanding of the interplay between (often conflicting) business and control objectives during business process design. In this paper, our objective is twofold. We will firstly present a research agenda in the space of business process compliance, identifying major technical and organizational challenges. We then tackle a part of the overall problem space, which deals with the effective modeling of control objectives and subsequently their propagation onto business process models. Control objective modeling is proposed through a specialized modal logic based on normative systems theory, and the visualization of control objectives on business process models is achieved procedurally. The proposed approach is demonstrated in the context of a purchase-to-pay scenario. [233]

11 Compliance Aware Business Process Design

Historically, business process design has been driven by business objectives, specifically process improvement. However this cannot come at the price of control objectives which stem from various legislative, standard and business partnership sources. Ensuring the compliance to regulations and industrial standards is an increasingly important issue in the design of business processes. In this paper, we advocate that control objectives should be addressed at an early stage, i.e., design time, so as to minimize the problems of runtime compliance checking and consequent violations and penalties. To this aim, we propose supporting mechanisms for business process designers. This paper specifically presents a support method which allows the process designer to quantitatively measure the compliance degree of a given process model against a set of control objectives. This will allow process designers to comparatively assess the compliance degree of their design as well as be better informed on the cost of non-compliance. [196]

12 Characterising Deadlines in Temporal Modal Defeasible Logic

We provide a conceptual analysis of several kinds of deadlines, represented in Temporal Modal Defeasible Logic. The paper presents a typology of deadlines, based on the following parameters: deontic operator, maintenance or achievement, presence or absence

of sanctions, and persistence after the deadline. The deadline types are illustrated by a set of examples. [99]

13 Dialogue Games in Defeasible Logic

In this paper we show how to capture dialogue games in Defeasible Logic. We argue that Defeasible Logic is a natural candidate and general representation formalism to capture dialogue games even with requirements more complex than existing formalisms for this kind of games. We parse the dialogue into defeasible rules with time of the dialogue as time of the rule. As the dialogue evolves we allow an agent to upgrade the strength of unchallenged rules. The proof procedures of [8] are used to determine the winner of a dialogue game. [251]

14 Temporal Extensions to Defeasible Logic

In this paper, we extend Defeasible Logic (a computationally-oriented non-monotonic logic) in order to deal with temporalised rules. In particular, we extend the logic to cope with durative facts, as well as with delays between the antecedent and the consequent of rules. We showed that the extended temporalised framework is suitable to model different types of causal relations which have been identified by the specialised literature. We also prove that the computational properties of the original logic are still retained by the extended approach. [171]

15 A System for Modal and Deontic Defeasible Reasoning

Defeasible reasoning is a well-established nonmonotonic reasoning approach that has recently been combined with semantic web technologies. This paper describes modal and deontic extensions of defeasible logic, motivated by potential applications for modelling multi-agent systems and policies. It describes a logic metaprogram that captures the underlying intuitions, and outlines an implemented system. [11]

16 On the Representation of Deadlines in a Rental Agreement

The paper provides a conceptual analysis of deadlines, represented in Temporal Modal Defeasible Logic. The typology is based on the following parameters: kind of deontic operator, maintenance or achievement, presence of explicit sanctions, and persistence after the deadline. The adequacy of the typology is validated against a case study of a rental agreement. [100]

17 Proof Explanation for the Semantic Web Using Defeasible Logic

In this work we present the design and implementation of a system for proof explanation in the Semantic Web, based on defeasible reasoning. Trust is a vital feature for Semantic Web. If users (humans and agents) are to use and integrate system answers, they must trust them. Thus, systems should be able to explain their actions, sources, and beliefs. Our system produces automatically proof explanations using a popular logic programming system (XSB), by interpreting the output from the proof's trace and converting it into a meaningful representation. It also supports an XML representation (a RuleML language extension) for agent communication, which is a common scenario in the Semantic Web. The system in essence implements a proof layer for nonmonotonic rules on the Semantic Web. [4]

2006

1 Logic of Violations: A Gentzen System for Reasoning with Contrary-To-Duty Obligations

In this paper we present a Gentzen system for reasoning with contrary-to-duty obligations. The intuition behind the system is that a contrary-to-duty is a special kind of normative exception. The logical machinery to formalise this idea is taken from substructural logics and it is based on the definition of a new non-classical connective capturing the notion of reparational obligation. Then the system is tested against well-known contrary-to-duty paradoxes. [152]

2 Embedding Defeasible Logic into Logic Programming

Defeasible reasoning is a simple but efficient approach to nonmonotonic reasoning that has recently attracted considerable interest and that has found various applications. Defeasible logic and its variants are an important family of defeasible reasoning methods. So far no relationship has been established between defeasible logic and mainstream nonmonotonic reasoning approaches. In this paper we establish close links to known semantics of logic programs. In particular, we give a translation of a defeasible theory D into a meta-program $P(D)$. We show that under a condition of decisiveness, the defeasible consequences of D correspond exactly to the sceptical conclusions of $P(D)$ under the stable model semantics. Without decisiveness, the result holds only in one direction (all defeasible consequences of D are included in all stable models of $P(D)$). If we wish a complete embedding for the general case, we need to use the Kunen semantics of $P(D)$, instead. [6]

3 Using a Temporal Constraint Network for Business Process Execution

Business process management (BPM) has emerged as a dominant technology in current enterprise systems and business solutions. However, the technology continues to face challenges in coping with dynamic business environments where requirements and goals

are constantly changing. In this paper, we present a modelling framework for business processes that is conducive to dynamic change and the need for flexibility in execution. This framework is based on the notion of process constraints. Process constraints may be specified for any aspect of the process, such as task selection, control flow, resource allocation, etc. Our focus in this paper is on a set of scheduling constraints that are specified through a temporal constraint network. We will demonstrate how this specification can lead to increased flexibility in process execution, while maintaining a desired level of control. A key feature and strength of the approach is to use the power of constraints, while still preserving the intuition and visual appeal of graphical languages for process modelling. [201]

4 An Optimization for Query Answering on ALC Database

Query answering over OWLs and RDFs on the Semantic Web is, in general, a deductive process. To this end, OWL, a family of web ontology languages based on description logic, has been proposed as the language for the Semantic Web. However, reasoning even on $\mathcal{ALC}$, a description logic weaker than OWL, faces efficiency problem. To obviate this problem, at least for $\mathcal{ALC}$, we propose a partition approach that improves the efficiency by splitting the search space into independent Aboxes. Each partition class, i.e., an Abox, can be queried independently. The answer to a query is the simple combination of the answers from each Abox. We prove the correctness of this approach and we outline how to represent compactly the content of each independent Abox. This work can be seen as an optimization for querying a deductive semi-structured database. [226]

5 Handling of Current Time in Native XML Databases

The introduction of Native XML databases opens many research questions related to the data models used to represent and manipulate data, including temporal data in XML. Increasing use of XML for Valid Web pages warrants an adequate treatment of *now* in Native XML databases. In this study, we examined how to represent and manipulate *now-relative* temporal data. We identify different approaches being used to represent current time in XML temporal databases, and introduce the notion of storing variables such as 'now' or 'UC' as strings in XML native databases. All approaches are empirically evaluated on a query that time-slices the timeline at the current time. The experimental results indicate that the proposed extension offers several advantages over other approaches: better semantics, less storage space and better response time. [245]

6 Process Modelling: The Deontic Way

Current enterprise systems rely heavily on the modelling and enactment of business processes. One of the key criteria for a business process is to represent not just the behaviours of the participants but also how the contractual relationships among them evolve over the course of an interaction. In this paper we provide a framework in which one can define policies/ business rules using deontic assignments to represent the contractual relationships. To achieve this end we use a combination of deontic/normative concepts

like *proclamation*, *directed obligation* and *direct action* to account for a deontic theory of commitment which in turn can be used to model business processes in their organisational settings. In this way we view a business process as a *social interaction process* for the purpose of doing business. Further, we show how to extend the i^* framework, a well known organisational modelling technique, so as to accommodate our notion of deontic dependency. [212]

7 The Cost of Social Agents

In this paper we follow the BOID (Belief, Obligation, Intention, Desire) architecture to describe agents and agent types in Defeasible Logic. We argue that the introduction of obligations can provide a new reading of the concepts of intention and intentionality. Then we examine the notion of social agent (i.e., an agent where obligations prevail over intentions) and discuss some computational and philosophical issues related to it. We show that the notion of social agent either requires more complex computations or has some philosophical drawbacks. [160]

8 Designing Agent Chips

We outline meta-encoding schemas for compiling nonmonotonic logic theories into Verilog HDL (Hardware Description Language) descriptions. These descriptions can be synthesized into gate level specifications for direct fabrication of silicon chips. The method is applied for designing agent chips incorporating similar features found in the BDI (Belief, Desire, and Intention) and Brooks' subsumption architectures. [239]

9 Utilizing Successful Work Practice for Business Process Evolution

Business process management (BPM) has emerged as a dominant technology in current enterprise systems and business solutions. However, business processes are always evolving in current dynamic business environments where requirements and goals are constantly changing. Whereas literature reports on the importance of domain experts in process modelling and adaptations, current solutions have not addressed this issue effectively. In this paper, we present a framework that utilizes successful work practice to support business process evolution. The framework on one hand provides the ability to use domain expert knowledge and experience to tailor individual process instances according to case specific requirements; and on the other, provides a means of using this knowledge through learning techniques to guide subsequent process changes. [199]

10 A Formal Analysis of a Business Contract Language

This paper presents a formal system for reasoning about violations of obligations in contracts. The system is based on the formalism for the representation of contrary-to-duty obligations. These are the obligations that take place when other obligations are violated as typically applied to penalties in contracts. The paper shows how this formalism can be mapped onto the key policy concepts of a contract specification language, called Business

Contract Language (BCL), previously developed to express contract conditions for run time contract monitoring. The aim of this mapping is to establish a formal underpinning for this key subset of BCL. [112]

11 Affective Web Service Design

In this paper, we propose that, in order to improve customer satisfaction, we need to incorporate communication modes (e.g., speech act) in the current standards of web services specifications. We show that with the communication modes, we can estimate various affects on service consumers during their interactions with web services. With this information, a web-service management system can automatically prevent and compensate potential negative affects, and even take advantage of positive affect [238]

12 On Constructing Fibred Tableaux for BDI Logics

In [**vineetphd**, 130] we showed how to combine propositional BDI logics using Gabbay's *fibring* methodology. In this paper we extend the above mentioned works by providing a tableau-based decision procedure for the combined/fibred logics. We show how to uniformly construct a tableau calculus for the combined logic using Governatori's labelled tableau system KEM [211]

13 Rule-Based Agents in Temporalised Defeasible Logic

This paper provides a framework based on temporal defeasible logic to reason about deliberative rule-based cognitive agents. Compared to previous works in this area our framework has the advantage that it can reason about temporal rules. We show that for rule-based cognitive agents deliberation is more than just deriving conclusions in terms of their mental components. Our paper is an extension of [58, 59] in the area of cognitive agent programming [131]

14 Argumentation Semantics for Temporal Defeasible Logic

We present an extension of the argumentation semantics for defeasible logic to cover the temporalisation of defeasible logic with permanent and immanent temporal literals [228]

15 A Compact Argumentation System for Agent System Specification

We present a non-monotonic logic tailored for specifying compact autonomous agent systems. The language is a consistent instantiation of a logic based argumentation system extended with Brooks' subsumption concept and varying degree of belief. Particularly, we present a practical implementation of the language by developing a meta-encoding method that translates logical specifications into compact general logic programs. The language allows n-ary predicate literals with the usual first-order term definitions. We show that the space complexity of the resulting general logic program is linear to the size of the original theory [237]

16 Analysing Stream Authentication Protocols in Autonomous Agent-Based Systems

In stream authentication protocols used for large-scale data dissemination in autonomuous systems, authentication is based on the timing of the publication of keys, and depends on trust of the receiver in the sender and belief on whether an intruder can have prior knowledge of a key before it is published by a protocol. Many existing logics and approaches have successfully been applied to specify other types of authentication protocols, but most of them are not appropriate for analysing stream authentication protocols. We therefore consider a fibred modal logic that combines a belief logic with a linear-time temporal logic which can be used to analyse time-varying aspects of certain problems. With this logical system one is able to build theories of trust for analysing stream authentication protocols, which can deal with not only agent beliefs but also the timing properties of an autonomous agent-based system. [208]

17 Modal Tableaux for Verifying Security Protocols

To develop theories to specify and reason about various aspects of multi-agent systems, many researchers have proposed the use of modal logics such as belief logics, logics of knowledge, and logics of norms. As multi-agent systems operate in dynamic environments, there is also a need to model the evolution of multi-agent systems through time. In order to introduce a temporal dimension to a belief logic, we combine it with a linear-time temporal logic using a powerful technique called fibring for combining logics. We describe a labelled modal tableaux system for a fibred belief logic (FL) which can be used to automatically verify correctness of inter-agent stream authentication protocols. With the resulting fibred belief logic and its associated modal tableaux, one is able to build theories of trust for the description of, and reasoning about, multi-agent systems operating in dynamic environments. [207]

18 Compliance Checking between Business Processes and Business Contracts

It is a typical scenario that many organisations have their business processes specified independently of their business contracts. This is because of the lack of guidelines and tools that facilitate derivation of processes from contracts but also because of the traditional mindset of treating contracts separately from business processes. This paper provides a solution to one specific problem that arises from this situation, namely the lack of mechanisms to check whether business processes are compliant with business contracts. The central part of the paper are logic based formalism for describing both the semantics of contract and the semantics of compliance checking procedures. [115]

19 Popper on Necessity and Natural Laws

During his philosophical career Popper sought to characterize natural laws alternately as strictly universal and as 'naturally' or 'physically' necessary statements. In this paper we

argue that neither characterization does what Popper claimed and sketch a reconstruction of his views that avoids some of their major drawbacks. [23]

20 $\mathcal{ALE}$ Defeasible Description Logic

One of Semantic Web strengths is the ability to address incomplete knowledge. However, at present, it cannot handle incomplete knowledge directly. Also, it cannot handle non-monotonic reasoning. In this paper, we extend $\mathcal{ALC}^-$ Defeasible Description Logic with existential quantifier, i.e., $\mathcal{ALE}$ Defeasible Description Logic. Also, we modify some parts of the logic, resulting in an increasing efficiency in its reasoning. [225]

21 Hardware Implementation of Temporal Nonmonotonic Logics

In order to apply nonmonotonic logics for specifying industrial automation controllers, we define (1) a method to extend atemporal nonmonotonic logics with temporal operators and (2) a mapping of these new temporal nonmonotonic logics into a Metric Temporal Logic. This mapping provides a formal specification method for real-time temporal reasoning digital circuits for the temporal nonmonotonic logics. We present our method in the context of synthesizing custom digital hardware (called *agent chip*) automatically from high level agent specifications. [240]

22 A Fibred Tableau Calculus for Modal Logics of Agents

In [15,19] we showed how to combine propositional multimodal logics using Gabbay's fibring methodology. In this paper we extend the above mentioned works by providing a tableau-based proof technique for the combined/ fibred logics. To achieve this end we first make a comparison between two types of tableau proof systems, (graph & path), with the help of a scenario (The Friend's Puzzle). Having done that we show how to uniformly construct a tableau calculus for the combined logic using Governatori's labelled tableau system KEM. We conclude with a discussion on KEM's features. [210]

2005

1 Preferences of Agents in Defeasible Logic

We are interested in programming languages for cognitive agents with preferences. We define rule-based agent theories and inference procedures in defeasible logic, and in this setting we discuss patterns of agent behavior called agent types. [58]

2 Programming Cognitive Agents in Defeasible Logic

Defeasible Logic is extended to programming languages for cognitive agents with preferences and actions for planning. We define rule-based agent theories that contain preferences and actions, together with inference procedures. We discuss patterns of agent types in this setting. Finally, we illustrate the language by an example of an agent reasoning about web-services. [59]

3 Probabilistic Automated Bidding in Multiple Auctions

This paper presents an approach to develop bidding agents that participate in multiple alternative auctions, with the goal of obtaining an item with a given probability. The approach consists of a prediction method and a planning algorithm. The prediction method exploits the history of past auctions in order to build probability functions capturing the belief that a bid of a given price may win a given auction. The planning algorithm computes a price, such that by sequentially bidding in a subset of the relevant auctions, the agent can obtain the item at that price with the desired probability. The approach addresses the case where the auctions are for substitutive items with different values. Experimental results show that the approach increases the payoff of their users and the welfare of the market. [64]

4 On the Axiomatization of Elgesem's Logic of Agency and Ability

In this paper we show that the Hilbert system of agency and ability presented by Dag Elgesem is incomplete with respect to the intended semantics. We argue that completeness result may be easily regained. Finally, we shortly discuss some issues related to the philosophical intuition behind his approach. This is done by examining Elgesem's modal logic of agency and ability using semantics with different flavours. [156]

5 Representing Business Contracts in RuleML

This paper presents an approach for the specification and implementation of translating contracts from a human-oriented form into an executable representation for monitoring. This will be done in the setting of RuleML. The task of monitoring contract execution and performance requires a logical account of deontic and defeasible aspects of legal language; currently such aspects are not covered by RuleML; accordingly we show how to extend it to cover such notions. From its logical form, the contract will be thus transformed into a machine readable rule notation and eventually implemented as executable semantics via any mark-up languages depending on the client's preference, for contract monitoring purposes. [91]

6 Temporalised Normative Positions in Defeasible Logic

We propose a computationally oriented non-monotonic multi-modal logic arising from the combination of temporalised agency and temporalised normative positions. We argue about the defeasible nature of these notions and then we show how to represent and reason with them in the setting of Defeasible Logic. [164]

7 Dealing with Contract Violations: Formalism and Domain Specific Language

This paper presents a formal system for reasoning about violations of obligations in contracts. The system is based on the formalism for the representation of contrary-to-duty obligations. These are the obligations that take place when other obligations are violated as typically applied to penalties in contracts. The paper shows how this formalism can be mapped onto the key policy concepts of a contract specification language. This language, called Business Contract Language (BCL) was previously developed to express contract conditions of relevance for run time contract monitoring. The aim of this mapping is to establish a formal underpinning for this key subset of BCL. [114]

8 An Approach for Validating BCL Contract Specifications

We continue the study, started in [5], on the formal relationships between a domain specific contract language (BCL) and the logic of violation (FCL) proposed in [6,7]. We discuss the use of logical methods for the representation and analysis of business contracts. The proposed analysis is based on the notions of normal and canonical forms of contracts expressed in FCL. Finally we present a mapping from FCL to BCL that can be used to provide an executable model of a formal representation of a contract. [113]

9 Observation-based Model for BDI-Agents

We present a new computational model of BDI-agents, called the observation-based BDI-model. The key point of this BDI-model is to express agents' beliefs, desires and intentions as a set of runs (computing paths), which is exactly a *system* in the interpreted system model, a well-known agent model due to Halpern and his colleagues. Our BDI-model is *computationally grounded* in that we are able to associate the BDI-agent model with a computer program, and formulas, involving agents' beliefs, desires (goals) and intentions, can be understood as properties of program computations. We present a sound and complete proof system with respect to our BDI-model and explore how symbolic model checking techniques can be applied to model checking BDI-agents. In order to make our BDI-model more flexible and practically realistic, we generalize it so that agents can have multiple sources of beliefs, goals and intentions. [250]

10 A Computationally Grounded Logic of Knowledge, Belief and Certainty.

This paper presents a logic of knowledge, belief and certainty, which allows us to explicitly express the knowledge, belief and certainty of an agent. A computationally grounded model, called interpreted KBC systems, is given for interpreting this logic. The relationships between knowledge, belief and certainty are explored. In particular, certainty entails belief; and to the agent what it is certain of appears to be the knowledge. To formalize those agents that are able to introspect their own belief and certainty, we identify a subclass of interpreted KBC systems, called *introspective KBC systems*. We provide sound and complete axiomatizations for the logics. We show that the validity problem for the interpreted KBC systems is PSPACE-complete, and the same problem for introspective KBC systems is co-NP complete, thus no harder than that of the propositional logic. [248]

11 A Semantic Web Based Architecture for e-Contracts in Defeasible Logic

We introduce the DR-CONTRACT architecture to represent and reason on e-Contracts. The architecture extends the DR-device architecture by a deontic defeasible logic of violation. We motivate the choice for the logic and we show how to extend RuleML to capture the notions relevant to describe e-contracts for a monitoring perspective in Defeasible Logic. [134]

12 Nested Rules in Defeasible Logic

Defeasible Logic is a rule-based non-monotonic logic with tractable reasoning services. In this paper we extend Defeasible Logic with nested rules. We consider a new Defeasible Logic, called DL^{ns}, where we allow one level of nested rules. A nested rule is a rule where the antecedent or the consequent of the rule are rules themselves. The inference conditions for DL^{ns} are based on reflection on the inference structures (rules) of the particular theory at hand. Accordingly DL^{ns} can be considered an amalgamated reflective system with implicit reflection mechanism. Finally we outline some possible applications of the logic. [241]

13 A Formal Ontology Reasoning with Individual Optimization: A Realization of the Semantic Web

Answering a query over a group of RDF data pages is a trivial process. However, in the Semantic Web, there is a need for ontology technology. Consequently, OWL, a family of web ontology languages based on description logic, has been proposed for the Semantic Web. Answering a query over the SemanticWeb is thus not trivial, but a deductive process. However, the reasoning on OWL with data has an efficiency problem. Thus, we introduce optimization techniques for the inference algorithm. This work demonstrates the techniques for instance checking and instance retrieval problems with respect to $\mathcal{ALC}$ description logic which covers certain parts of OWL. [224]

14 Norm Modifications in Defeasible Logic

This paper proposes a framework based on Defeasible Logic (DL) to reason about normative modifications. We show how to express them in DL and how the logic deals with conflicts between temporalised normative modifications. Some comments will be given with regard to the phenomenon of retroactivity. [133]

15 Computationally Grounded Model of BDI-Agents

We introduce a multimodal logic of belief, desire and intention, called OBDI logic, where the changes and computation of agents' beliefs, desires, and desires are based on agents' observations (i.e. local states), and we propose a model checking techniques for the logic based on interpreted systems. [249]

2004

1 Argumentation Semantics for Defeasible Logics

Defeasible reasoning is a simple but efficient rule-based approach to nonmonotonic reasoning. It has powerful implementations and shows promise to be applied in the areas of legal reasoning and the modeling of business rules. This paper establishes significant links between defeasible reasoning and argumentation. In particular, Dung-like argumentation semantics is provided for two key defeasible logics, of which one is ambiguity propagating and the other ambiguity blocking. There are several reasons for the significance of this work: (a) establishing links between formal systems leads to a better understanding and cross-fertilization, in particular our work sheds light on the argumentation-theoretic features of defeasible logic; (b) we provide the first ambiguity blocking Dung-like argumentation system; (c) defeasible reasoning may provide an efficient implementation platform for systems of argumentation; and (d) argumentation-based semantics support a deeper understanding of defeasible reasoning, especially in the context of the intended applications. [110]

2 Representing and Reasoning on XForms Document

Forms are the most common way to interface users and Web-based applications. Traditional forms cannot provide the functionality needed to fulfil the requirements of complex applications. As such, there is a need for a more advanced format of forms to support Web-based application. We argued that XForms easily fit into this criterion of forms. In addition, we observed that there is a need for a tool to reason about the forms with respect to user needs and application requirements. We propose to use Description Logic $\mathcal{ALCQI}$ to reason about forms generated by XForms. [50]

3 A Model of Dynamic Resource Allocation in Workflow Systems

Current collaborative work environments are characterized by dynamically changing organizational structures. Although there have been several efforts to refine work distribution, especially in workflow management, most literature assumes a static database approach which captures organizational roles, groups and hierarchies and implements a dynamic roles based agent assignment protocol. However, in practice only partial information may be available for organizational models, and in turn a large number of exceptions may emerge at the time of work assignment. In this paper we present an organizational model based on a policy based normative system. The model is based on a combination of an intensional logic of agency and a flexible, but computationally feasible, non-monotonic formalism (Defeasible Logic). Although this paper focuses on the model specification, the proposed approach to modelling agent societies provides a means of reasoning with partial and unpredictable information as is typical of organizational agents in workflow systems. [163]

4 Defeasible Logic: Agency, Intention and Obligation

We propose a computationally oriented non-monotonic multi-modal logic arising from the combination of agency, intention and obligation. We argue about the defeasible nature of these notions and then we show how to represent and reason with them in the setting of defeasible logic. [147]

5 Normative Autonomy and Normative Co-ordination: Declarative Power, Representation, and Mandate

In this paper we provide a formal analysis of the idea of normative co-ordination. We argue that this idea is based on the assumption that agents can achieve flexible co-ordination by conferring normative positions to other agents. These positions include duties, permissions, and powers. In particular, we explain the idea of declarative power, which consists in the capacity of the power-holder of creating normative positions, involving other agents, simply by "proclaiming" such positions. In addition, we account also for the concepts of representation, namely the representative's capacity of acting in the name of his principal, and of mandate, which is the mandatee's duty to act as the mandator has requested. Finally, we show how the framework can be applied to represent the contract-net protocol. Some brief remarks on future research and applications conclude this contribution. [73]

6 On the Axiomatization of Elgesem's Logic of Agency

In this paper we show that the Hilbert system of agency and ability presented by Dag Elgesem is incomplete with respect to the intended semantics. We argue that completeness result may be easily regained. Finally, we shortly discuss some issues related to the philosophical intuition behind his approach. This is done by examining Elgesem's modal logic of agency and ability using semantics with different flavours. [155]

7 An Interaction Model for Affect Monitoring

This paper investigates how we can precisely define what process designers are ought achieve for what they have promised and more importantly in a way that satisfies human users. Toward these goals, an interaction model for processes and an Affect Monitoring Framework (AMF) are proposed based on our analysis on speech act theory and cognitive-based emotion models. The Affect Monitoring Framework is to detect and predict negative affects on users and to resolve caused or predicted causes of negative affects automatically. [242]

8 Defeasible Description Logic

We propose to extend description logic with defeasible rules, and to use the inferential mechanism of defeasible logic to reason with description logic constructors. [81]

9 Representing Contracts Using RuleML

This paper presents an approach for the specification and implementation of e-contracts for Web monitoring. This is done in the setting of *RuleML*. We argue that monitoring contract execution requires also a logical account of deontic concepts and of violations. Accordingly, *RuleML* is extended to cover these aspects. [157]

2003

1 An algorithm for the induction of defeasible logic theories from databases

Defeasible logic is a non-monotonic logic with applications in rule-based domains such as law. To ease the development and improve the accuracy of expert systems based on defeasible logic, it is desirable to automatically induce a theory of the logic from a training set of precedent data. Empirical evidence suggests that minimal theories that describe the training set tend to be more faithful representations of reality. We show via transformation from the hitting set problem that this global minimization problem is intractable, belonging to the class of NP optimisation problems. Given the inherent difficulty of finding the optimal solution, we instead use heuristics and demonstrate that a best-first, greedy, branch and bound algorithm can be used to find good theories in short time. This approach displays significant improvements in both accuracy and theory size as compared to recent work in the area that post-processed the output of an Aprori association rule-mining algorithm, with comparable execution times. [181]

2 On the Relative Complexity of Modal Tableaux

We investigate the relative complexity of two free-variable labelled modal tableaux (KEM and Single Step Tableaux, SST). We discuss the reasons why p-simulation is not a proper measure of the relative complexity of tableaux-like proof systems, and we propose an improved comparison scale (p-search-simulation). Finally we show that KEM p-search-simulates SST while SST cannot p-search-simulate KEM. [90]

3 Induction of Defeasible Logic Theories in the Legal Domain

The market for intelligent legal information systems remains relatively untapped and while this might be interpreted as an indication that it is simply impossible to produce a system that satisfies the needs of the legal community, an analysis of previous attempts at producing such systems reveals a common set of deficiencies that in-part explain why there have been no overwhelming successes to date. Defeasible logic, a logic with proven successes at representing legal knowledge, seems to overcome many of these deficiencies and is a promising approach to representing legal knowledge. Unfortunately, an immediate application of technology to the challenges in this domain is an expensive and computationally intractable problem. So, in light of the benefits, we seek to find a practical algorithm that uses heuristics to discover an approximate solution. As an outcome of this work, we have developed an algorithm that integrates defeasible logic into a decision support system by automatically deriving its knowledge from databases of precedents. Experiments with the new algorithm are very promising – delivering results comparable to and exceeding other approaches. [182]

4 A Defeasible Logic of Institutional Agency

A non-monotonic logic of institutional agency is defined combining a computationally oriented non-monotonic system (Defeasible Logic) and intensional notions of agency. [139]

5 A Defeasible Logic of Policy-based Intention

Most of the theories on formalising intention interpret it as a unary modal operator in Kripkean semantics, which gives it a monotonic look. We argue that policy-based intentions [**bratman1**] exhibit non-monotonic behaviour which could be captured through a non-monotonic system like defeasible logic. To this end we outline a defeasible logic of intention. The proposed technique alleviates most of the problems related to logical omniscience. The proof theory given shows how our approach helps in the maintenance of intention-consistency in agent systems like BDI. [129]

6 A Tableaux System for Deontic Interpreted Systems

We develop a labelled tableaux system for the modal logic $KD45_n^{i-j}$ extended with epistemic notions. This logic characterises a particular type of interpreted systems used to represent and reason about states of correct and incorrect functioning behaviour of the agents in a system, and of the system as a whole. The resulting tableaux system provides a simple decision procedure for the logic. We discuss these issues and we illustrate them with the help of simple examples [106]

7 A Computational Framework for Non-Monotonic Agency, Institutionalised Power and Multi-Agent Systems

This work provides a first computational framework to capture some of the theoretical intuitions developed by the present authors and other colleagues. More precisely, in this paper we propose a computationally oriented model of institutional agency based on Defeasible Logic. The focus here is on the notions of counts-as link and on those of attempt and of personal and direct action to realise states of affairs. [137]

2002

1 On Fibring Semantics for BDI Logics

This study examines BDI logics in the context of Gabbay's *fibring* semantics. We show that *dovetailing* (a special form of fibring) can be adopted as a semantic methodology to combine BDI logics. We develop a set of interaction axioms that can capture static as well as dynamic aspects of the mental states in BDI systems, using Catach's *incestual* schema $G^{a,b,c,d}$. Further we exemplify the constraints required on fibring function to capture the semantics of interactions among modalities. The advantages of having a fibred approach is discussed in the final section. [130]

2 Labelled Tableaux for Non-monotonic Reasoning: Cumulative Consequence Relations

In this paper we present a labelled proof method for computing nonmonotonic consequence relations in a conditional logic setting. The method exploits the strong connection between these deductive relations and conditional logics, and it is based on the usual possible world semantics devised for the latter. The label formalism KEM, introduced to account for the semantics of normal modal logics, is easily adapted to the semantics of conditional logic by simply indexing labels with formulas. The basic inference rules are provided by the propositional system KE$^+$ —a tableau-like analytic proof system devised to be used both as a refutation method and a direct method of proof— that is the classical core of KEM which is thus enlarged with suitable elimination rules for the conditional connective. The resulting algorithmic framework is able to compute cumulative consequence relations in so far as they can be expressed as conditional implications. [25]

3 An Architecture for Assembling Agents that Participate in Alternative Heterogeneous Auctions

This paper addresses the issue of developing agents capable of participating in several potentially simultaneous auctions of different kinds (English, First-Price, Vickrey), with the goal of finding the best price for an item on behalf of their users. Specifically, a multi-agent architecture is proposed, in which a manager agent cooperates with several expert agents, each specialised in a specific kind of auction. The expert agents communicate their knowledge to the manager agent in the form of probability functions, capturing the likelihood that a bid of a given price may win an auction. Given a set of such functions, the manager agent builds a bidding plan that it executes in concert with the expert agents. [67]

4 A Gentzen System for Reasoning with Contrary-To-Duty Obligations. A preliminary Study

In this paper we present a Gentzen system for reasoning with contrary-to-duty obligations. The intuition behind the system is that a contrary-to-duty is a special kind of normative exception. The logical machinery to formalize this idea is taken from substructural logics and it is based on the definition of a new non-classical connective capturing the notion of reparational obligation. Then the system is tested against well-known contrary-to-duty paradoxes. [140]

5 A Probabilistic Approach to Automated Bidding in Alternative Auctions

This paper presents an approach to develop bidding agents that participate in multiple alternative auctions, with the goal of obtaining an item at the lowest price. The approach consists of a prediction method and a planning algorithm. The prediction method exploits the history of past auctions in order to build probability functions capturing the belief that a bid of a given price may win a given auction. The planning algorithm computes the lowest price, such that by sequentially bidding in a subset of the relevant auctions, the agent can obtain the item at that price with an acceptable probability. The approach addresses the case where the auctions are for substitutable items with different values. Experimental results are reported, showing that the approach increases the payoff of their users and the welfare of the market [65]

6 Actions, Institutions, Powers. Preliminary Notes

In this paper we analyse some logical notions relevant for representing the dynamics of institutionalised organisations. In particular, some well-known action concepts introduced in the Kanger-Lindahl-Pörn logical theory of agency are discussed and integrated. Secondly, moving from the work of Jones and Sergot, a logical characterisation is provided of the ideas of institutional links, "counts-as" connections, and institutional facts. This approach is then enriched by a new modal operator *proc*, intended to account for the autonomous

and decentralised creation of new institutional facts and normative positions within institutions. [95]

7 A Formal Approach to Negotiating Agents Development

This paper presents a formal and executable approach to capture the behaviour of parties involved in a negotiation. A party is modeled as a negotiating agent composed of a communication module, a control module, a reasoning module, and a knowledge base. The control module is expressed as a *statechart*, and the reasoning module as a *defeasible logic* program. A strategy specification therefore consists of a statechart, a set of defeasible rules, and a set of initial facts. Such a specification can be dynamically plugged into an agent shell incorporating a statechart interpreter and a defeasible logic inference engine, in order to yield an agent capable of participating in a given type of negotiations. The choice of statecharts and defeasible logic with respect to other formalisms is justified against a set of desirable criteria, and their suitability is illustrated through concrete examples of bidding and multi-lateral bargaining scenarios. [66]

8 Declarative Power, Representation, and Mandate: A Formal Anaysis

In this paper we provide a formal framework for developing the idea of normative co-ordination. We argue that this idea is based on the assumption that agents can achieve flexible co-ordination by conferring normative positions to other agents. These positions include duties, permissions, and powers. In particular, we introduce the idea of declarative power, which consists in the capacity of the power-holder of creating normative positions, involving other agents, simply by "proclaiming" such positions. In addition, we account also for the concepts of representation, consisting in the representative's capacity of acting in the name of his principal, and of mandate, which corresponds the mandatee's duty to act as the mandator has requested. Finally, we show how the above framework can be applied to the contract-net protocol. [72]

2001

1 Representation Results for Defeasible Logic

The importance of transformations and normal forms in logic programming, and generally in computer science, is well documented. This paper investigates transformations and normal forms in the context of Defeasible Logic, a simple but efficient formalism for nonmonotonic reasoning based on rules and priorities. The transformations described in this paper have two main benefits: on one hand they can be used as a theoretical tool that leads to a deeper understanding of the formalism, and on the other hand they have been used in the development of an efficient implementation of defeasible logic. [8]

2 Is Defeasible Logic Applicable?

In this paper the application of defeasible logic for automated negotiation is investigated. Defeasible logic is flexible enough to be adapted to several possible negotiation strategies, has efficient implementations, and provides a formal basis for analysis (e.g. to explain why a negotiation was not successful). Two case studies, one small and one more comprehensive, will be described and the feasibility of approaches based on defeasible logic will be discussed. [98]

3 A Formal Approach to Protocols and Strategies for (Legal) Negotiation

We propose a formal and executable framework for expressing protocols and strategies for automated (legal) negotiation. In this framework a party involved in a negotiation is represented through a software agent composed of four modules: (i) a communication module which manages the interaction with the other agents; (ii) a control module; (iii) a reasoning module specified as a defeasible theory; and (iv) a knowledge base which bridges the control and the reasoning modules, while keeping track of past decisions and interactions. The choice of defeasible logic is justified against a set of desirable criteria for negotiation automation languages. Moreover, the suitability of the framework is illustrated through two case studies. [94]

4 On the Relative Complexity of Labelled Modal Tableaux

The relative computational complexity of two free-variable labelled modal tableaux (KEM and Single Step Tableaux, SST) is investigated. We discuss the reasons why p-simulation is not a proper measure to compare tableaux-like proof systems, and we propose an improved comparison scale (p-search-simulation). It shown that KEM p-search-simulates SST while SST cannot p-search-simulate KEM. [89]

5 Towards the Application of Association Rules for Defeasible Rules Discovery

In this paper we investigate the feasibility of Knowledge Discovery from Database (KDD) in order to facilitate the discovery of defeasible rules that represent the ratio decidendi underpinning legal decision making. Moreover we will argue in favour of Defeasible Logic as the appropriate formal system in which the extracted principles should be encoded. [170]

6 Actions Made Explicit in BDI

The Belief, Desire, Intention (BDI) architecture is increasingly being used in a wide range of complex applications for agents. Many theories and models exists which support this architecture and the recent version is that of Capability being added as an additional construct. In all these models the concept of action is seen in an endogenous manner. We argue that the Result of an action performed by an agent is extremely important

when dealing with composite actions and hence the need for an explicit representation of them. The Capability factor is supported using a RES construct and it is shown how the components of a composite action is supported using these two. Further, we introduce an OPP (opportunity) operator which in alliance with Result and Capability provides a better semantics for practical reasoning in BDI. [209]

2000

1 A Flexible Framework for Defeasible Logics

Logics for knowledge representation suffer from over-specialization: while each logic may provide an ideal representation formalism for some problems, it is less than optimal for others. A solution to this problem is to choose from several logics and, when necessary, combine the representations. In general, such an approach results in a very difficult problem of combination. However, if we can choose the logics from a uniform framework then the problem of combining them is greatly simplified. In this paper, we develop such a framework for defeasible logics. It supports all defeasible logics that satisfy a strong negation principle. We use logic meta-programs as the basis for the framework. [5]

2 Defeasible Logic for Automated Negotiation

Negotiation plays a fundamental role in e-commerce. In this paper, the application of defeasible logic for automated negotiation is investigated. Defeasible logic is flexible enough to be adapted to several possible negotiation strategies, has efficient implementations, and provides a formal basis for analysis (e.g. to explain why a negotiation was not successful). Two case studies, one small and one more comprehensive, will be described and the feasibility of approaches based on defeasible logic will be discussed. [97]

3 An Argumentation-Theoretic Characterization of Defeasible Logic

Defeasible logic is an efficient non-monotonic logic that is defined only proof-theoretically. It has potential application in some legal domains. We present here an argumentation semantics for defeasible logic that will be useful in these applications. Our development differs at several points from existing argumentation frameworks since there are several features of defeasible logic that have not been addressed in the literature. [108]

4 A Family of Defeasible Reasoning Logics and its Implementation

Defeasible reasoning is a direction in nonmonotonic reasoning that is based on the use of rules that may be defeated by other rules. It is a simple, but often more efficient approach than other nonmonotonic reasoning systems. This paper presents a family of defeasible reasoning formalisms built around Nute's defeasible logic. We describe the motivations of these formalisms and derive some basic properties and interrelationships. We also describe a query answering system that supports these formalisms and is available on the World Wide Web. [9]

5 Fibred Modal Tableaux

We describe a general and uniform tableau methodology for multi-modal logics arising from Gabbay's methodology of fibring and Governatori's labelled tableau system KEM. [71]

6 Labelled Modal Sequents

In this paper we present a new labelled sequent calculus for modal logic. The proof method works with a more "liberal" modal language which allows inferential steps where different formulas refer to different labels without moving to a particular world and there computing if the consequence holds. World-paths can be composed, decomposed and manipulated through unification algorithms and formulas in different worlds can be compared even if they are sub-formulas which do not depend directly on the main connective. Accordingly, such a sequent system can provide a general definition of modal consequence relation. Finally, we briefly sketch a proof of the soundness and completeness results. [151]

7 Labelled Tableaux for Non-Normal Modal Logics

In this paper we show how to extend KEM, a tableau-like proof system for normal modal logic, in order to deal with classes of non-normal modal logics, such as monotonic and regular, in a uniform and modular way. [107]

8 Argumentation Semantics for Defeasible Logics

Defeasible logic is an efficient non-monotonic logic that is defined only proof-theoretically. It has potential application in some legal domains. We present here argumentation semantics for variants of defeasible logic that will be useful in these applications. [109]

9 A Labelled Tableau Calculus for Nonmonotonic (Cumulative) Consequence Relations

In this paper we present a labelled proof method for computing nonmonotonic consequence relations in a conditional logic setting. The method is based on the usual possible world semantics for conditional logic. The label formalism KEM, introduced to account for the semantics of normal modal logics, is easily adapted to the semantics of conditional logic by simply indexing labels with formulas. The inference rules are provided by the propositional system KE^+ —a tableau-like analytic proof system devised to be used both as a refutation and a direct method of proof— enlarged with suitable elimination rules for the conditional connective. The resulting algorithmic framework is able to compute cumulative consequence relations in so far as they can be expressed as conditional implications. [24]

1999

1 A Semantic Decomposition of Defeasible Logic

We investigate defeasible logics using a technique which decomposes the semantics of such logics into two parts: a specification of the structure of defeasible reasoning and a semantics for the meta-language in which the specification is written. We show that Nute's Defeasible Logic corresponds to Kunen's semantics, and develop a defeasible logic from the well-founded semantics of Van Gelder, Ross and Schlipf. We also obtain a new defeasible logic which extends an existing language by modifying the specification of Defeasible Logic. Thus our approach is productive in analysing, comparing and designing defeasible logics. [202]

2 On the Modeling and Analysis of Regulations

Regulations are a wide-spread and important part of government and business. They codify how products must be made and processes should be performed. Such regulations can be difficult to understand and apply. In an environment of growing complexity of, and change in, regulation, automated support for reasoning with regulations is becoming increasingly necessary. In this paper we report on ongoing work which aims at providing automated support for the drafting and use of regulations using logic modelling techniques. We highlight the support that can be provided by logic modelling, describe the technical foundation of our project, and report on the status of the project and the next steps. [7]

3 A New Approach to Base Revision

We present three approaches to revision of belief bases, which are also examined in the case in which the sentences in the base are partitioned between those which can and those which cannot be changed; the approaches are shown to be semantically equivalent. A new approach is then presented, based on the modification of individual rules, instead of deletion. The resulting base is semantically equivalent to that generated by the other approaches, in the sense that it has the same models, but the rule part alone has fewer models, that is, is subjected to a smaller change. [61]

4 Analytic modal revision for multi-agent systems

We present two models of hierarchical structured multi-agents, and we describe how to obtain a modal knowledge base from distributed sources. We then propose a computationally oriented revision procedure for modal knowledge bases. This procedure is based on a labelled tableaux calculi supplemented with a formalism to record the dependencies of the formulae. The dependencies are then used to reconstruct the minimal inconsistent sets, and the sub-formulae responsible for the inconsistencies are revised according to well-defined chains of modal functions. [62]

5 Revising Nonmonotonic Belief Sets: The Case of Defeasible Logic

The revision and transformation of knowledge is widely recognized as a key issue in knowledge representation and reasoning. Reasons for the importance of this topic are the fact that intelligent systems are gradually developed and refined, and that often the environment of an intelligent system is not static but changes over time. Traditionally belief revision has been concerned with revising first order theories. Nonmonotonic reasoning provides rigorous techniques for reasoning with incomplete information. Until recently the dynamics of nonmonotonic reasoning approaches has attracted little attention. This paper studies the dynamics of defeasible logic, a simple and efficient form of nonmonotonic reasoning based on defeasible rules and priorities. We define revision and contraction operators, propose postulates motivated by the form or the intuition of the AGM postulates for classical belief revision, and verify that the operators satisfy the postulates. [36]

6 Comparison of Sceptical NAF-Free Logic Programming Approaches

Recently there has been increased interest in logic programming-based default reasoning approaches which are not using negation-as-failure in their object language. Instead, default reasoning is modelled by rules and a priority relation among them. Historically the first logic in this class was Defeasible Logic. In this paper we will study its relationship to other approaches which also rely on the idea of using logic rules and priorities. In particular we will study sceptical LPwNF, courteous logic programs, and priority logic. [13]

7 Modifying Is Better Than Deleting: A New Approach To Base Revision

We present three approaches to belief base revision, which are examined also in the case in which the sentences in the base are partitioned between those which can and those which cannot be changed; the approaches are shown to be semantically equivalent. A new approach is then presented, based on the modification of individual rules, instead of deletion. The resulting base is semantically equivalent to that generated by the other approaches, in the sense that it has the same models, but the rule part alone has less models, that is, is subjected to a smaller change. [63]

1998

1 Shakespearian modal logic: A Labelled Treatment of Modal Identity

In this paper we describe a modal proof system arising from the combination of a tableau-like classical system, which incorporates a restricted ("analytical") version of the cut rule, with a label formalism which allows for a specialised, logic dependant unification algorithm. The system provides a uniform proof-theoretical treatment of first-order (normal) modal logics with identity, with and without Barcan formula and/or its converse [15]

2 A Tableaux Methodology for Deontic Conditional Logics

In this paper we present a theorem proving methodology for a restricted but significant fragment of the conditional language made up of (boolean combinations of) conditional statements with unnested antecedents. The method is based on the possible world semantics for conditional logics. The label formalism introduced in [21, 14] to account for the semantics of normal modal logics is easily adapted to the semantics of conditional logics by simply indexing labels with formulas. The inference rules are provided by the propositional system KE^+ — a tableau-like analytic proof system devised to be used both as a refutation and a direct method of proof — enlarged with suitable elimination rules for the conditional connective. The theorem proving methodology we are going to present can be viewed as a first step towards developing an appropriate algorithmic framework for several conditional logics for (defeasible) conditional obligation. [20]

3 Dealing with Label Dependent Deontic Modalities

In this paper, following Scott's advice, we argue that normative reasoning can be represented in a multi-setting framework; in particular in a multi-modal one, where modalities are indexed. Indexed modalities can model several aspects involved in normative reasoning. Systems are combined using Gabbay's fibring methodology which provides complete semantics that can be used to model a labelled tableau-like proofs system. [70]

4 Ideality and Subideality from a Computational Point of View

Why should Law need automated proof systems? The answer to this question implies an answer to the following question: Is logic needed in Law? In fact it has been argued that logics are useless for Law (see, for example, Kelsen 1989). We believe that logic, and deontic logics in particular – but also modal logics – have a role to play in Law. In this paper we propose an automated proof system for the logic of ideality and subideality developed by Jones and Porn, and it verifies in the above mentioned logical framework whether a given conclusion follows from given premises. Moreover, due to its basic control structure it can also be used as an analytic direct proof system. [82]

5 Modal Tableaux for Nonmonotonic Reasoning

The tableau-like proof system KEM has been proven to be able to cope with a wide variety of (normal) modal logics. KEM is based on D'Agostino and Mondadori's (1994) classical proof system KE, a combination of tableau and natural deduction inference rules which allows for a restricted ("analytic") Use of the cut rule. The key feature of KEM, besides its being based neither on resolution nor on standard sequent/tableau inference techniques, is that it generates models and checks them using a label scheme to bookkeep "world" paths. This formalism can be extended to handle various system of multimodal logic devised for dealing with nonmonotonic reasoning, by relying in particular on Meyer and van der Hoek's (1992) logic for actuality and preference. In this paper we shall be concerned with developing a similar extension this time by relying on Schwind and Siegel's

(1993,1994) system H, another multimodal logic devised for dealing with nonmonotonic inference. [22]

1997

1 A Modal Computational Framework for Default Reasoning

Usually a default rule A : B/C is intended to mean that if A holds in a state of affairs a B is consistent, then C follows by default. However, C is not a necessary conclusion: different states of affairs are possible (conceivable). According to this view, Meyer and van der Hoek developed a multimodal logic, called S5P(n), for treating non-monotonic reasoning in a monotonic setting. In this paper we shall describe a proof search algorithm for S5P(n) which has been implemented as a Prolog Interpreter. [16]

1996

1 Labelled proofs for quantified modal logic

In this paper we describe a modal proof system arising from the combination of a tableau-like classical system, which incorporates a restricted ("analytic") version of the cut rule, with a label formalism which allows for a specialised, logic-dependent unification algorithm. The system provides a uniform proof-theoretical treatment of first-order (normal) modal logics with and without the Barcan Formula and/or its converse. [14]

2 Towards a Computational Treatment of Deontic Defeasibility

In this paper we describe an algorithmic framework for a multi-modal logic arising from the combination of the system of modal (epistemic) logic devised by Meyer and van der Hoek for dealing with nonmonotonic reasoning with a deontic logic of the Jones and Pörn-type. The idea behind this (somewhat eclectic) formal set-up is to have a modal framework expressive enough to model certain kinds of deontic defeasibility, in particular by taking into account preferences on norms. The appropriate inference mechanism is provided by a tableau-like modal theorem proving system which supports a proof method closely related to the semantics of modal operators. We argue that this system is particularly well-suited for mechanizing nonmonotonic forms of inference in a monotonic multi-modal setting. [26]

3 Labelling Ideality and Subideality

In this paper we suggest ways in which logic and law may usefully relate; and we present an analytic proof system dealing with the Jones Pörn's deontic logic of Ideality and Subideality, which offers some suggestions about how to embed legal systems in label formalism. [86]

4 A Duplication and Loop Checking Free System for S4

Most of the sequent/tableau based proof systems for the modal logic S4 need to duplicate formulas and thus are required to adopt some method of loop checking. In what follows we present a tableau-like proof system for S4, based on D'Agostino and Mondadori's classical KE, which is free of duplication and loop checking. The key feature of this system (let us call it KES4) consists in its use of (i) a label formalism which models the semantics of the modal operators according to the usual conditions for S4; and (ii) a label unification scheme which tells us when two labels "denote" the same world in the S4-model(s) generated in the course of proof search. Moreover, it uses special closure conditions to check models for putative contradictions. [77]

1995

1 A Prolog Implementation of KEM

In this paper, we describe a Prolog implementation of a new theorem prover for (normal propositional) modal and multi–modal logics. The theorem prover, which is called KEM, arises from the combination of a classical refutation system which incorporates a restricted ("analytic") version of the cut rule with a label formalism which allows for a specialised logic–dependent unification algorithm. An essential feature of KEM is that it yields a rather simple and efficient proof search procedure which offers many computational advantages over the usual tableau-based proof search methods. This is due partly to the use of linear 2–premise β rules in place of the branching β rules of the standard tableau method, and partly to the crucial role played by the analytic cut (the only branching rule) in eliminating redundancy from the search space. It turns out that KEM method of proof search is not only computationally more efficient but also intuitively more natural than other (e.g. resolution-based) methods leading to simple and easy implementable procedures (two KEM Theorem Prover-like systems have been implemented: an LPA interpreter on Macintosh, and a Quintus compiler on Sun-Sparcstation) which make it well suited for efficient automated proof search in modal logic. [17]

2 KE+: Beyond Refutation

The system KE+, a tableau-like proof system based on D'Agostino-Mondadori KE, is presented in this paper. This system avoids some of the drawbacks of other proof methods. In fact it is completely analytical, it is able to detect whether a formula is either a tautology or a contradiction or only a satisfiable one; in the course of a proof it can detect whether a subformula is a tautology and it uses this fact in the proof of the main formula [83]

3 Labelled Tableaux for Multi-Modal Logics

In this paper we present a tableau-like proof system for multi-modal logics based on D'Agostino and Mondadori's classical refutation system KE. The proposed system, that we call KEM, works for the logics $S5A$ and $S5P_{(n)}$ which have been devised by Mayer and van der Hoek for formalizing the notions of actuality and preference. We shall also show how KEM works with the normal modal logics $K45, D45$, and $S5$ which are frequently used as bases for epistemic operators – knowledge, belief, and we shall briefly sketch how to combine knowledge and belief in a multi-agent setting through KEM modularity. [85]

1994

1 KED: A Deontic Theorem Prover

Deontic logic (DL) is increasingly recognized as an indispensable tool in such application areas as formal representation of legal knowledge and reasoning, formal specification of computer systems and formal analysis of database integrity constraints. Despite this acknowledgement, there have been few attempts to provide computationally tractable inference mechanisms for DL. In this paper we shall be concerned with providing a computationally oriented proof method for standard DL (SDL), i.e., normal systems of modal logic with the usual possible-worlds semantics. Because of the natural and easily implementable style of proof construction it uses, this method seems particularly well-suited for applications in the AI and Law field, and though in the present version it works for SDL only, it forms an appropriate basis for developing efficient proof methods for more expressive and sophisticated extensions of SDL. [19]

2 An Automated Approach to Normative Reasoning

It is by now generally accepted in the Artificial Intelligence and Law field that many aspects of normative language and reasoning can be modelled in deontic logics based on modal logic. This obviously implies the need for computationally tractable inference mechanisms for Deontic Logic. In this paper we shall be concerned with developing a computationally oriented proof method for several normal (in Åqvist classification normal and strongly normal) deontic logics. Since this method is arguably more natural and intuitive than other (e.g. resolution or translation based) proof methods, and it leads to simple and easy implementable procedures, it seems particularly well-suited for applications in the newly developed area of "artificial normative reasoning". Moreover, though in the present version it works for deontic logics of the simplest kind, it is sufficiently generic and flexible to provide an appropriate algorithmic proof framework for deontic logics of greater richness and complexity. [18]

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