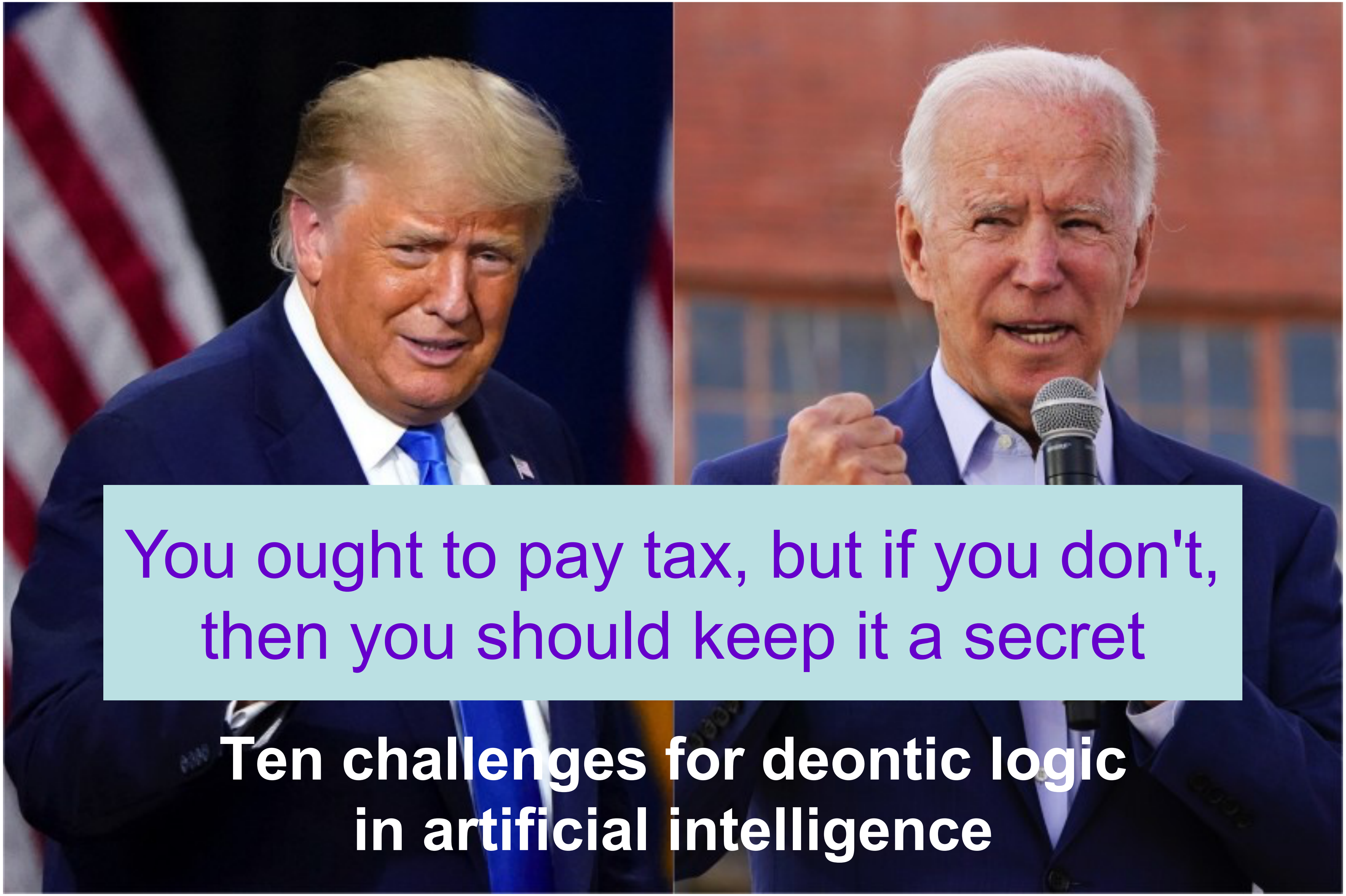

You ought to pay tax, but if you don't, then you should keep it a secret

Ten challenges for deontic logic in artificial intelligence

Leon van der Torre

Layout

1. Introduction: AI, logic and deontics
2. A brief history of deontic logic
3. Ten challenges for deontic logic
    1. Core 3: ought implies can, explosion, ideality
    2. CWA & 3 priorities: specificity, authority, revision
    3. The other 3: defaults, action, practical reasoning
4. Looking forward

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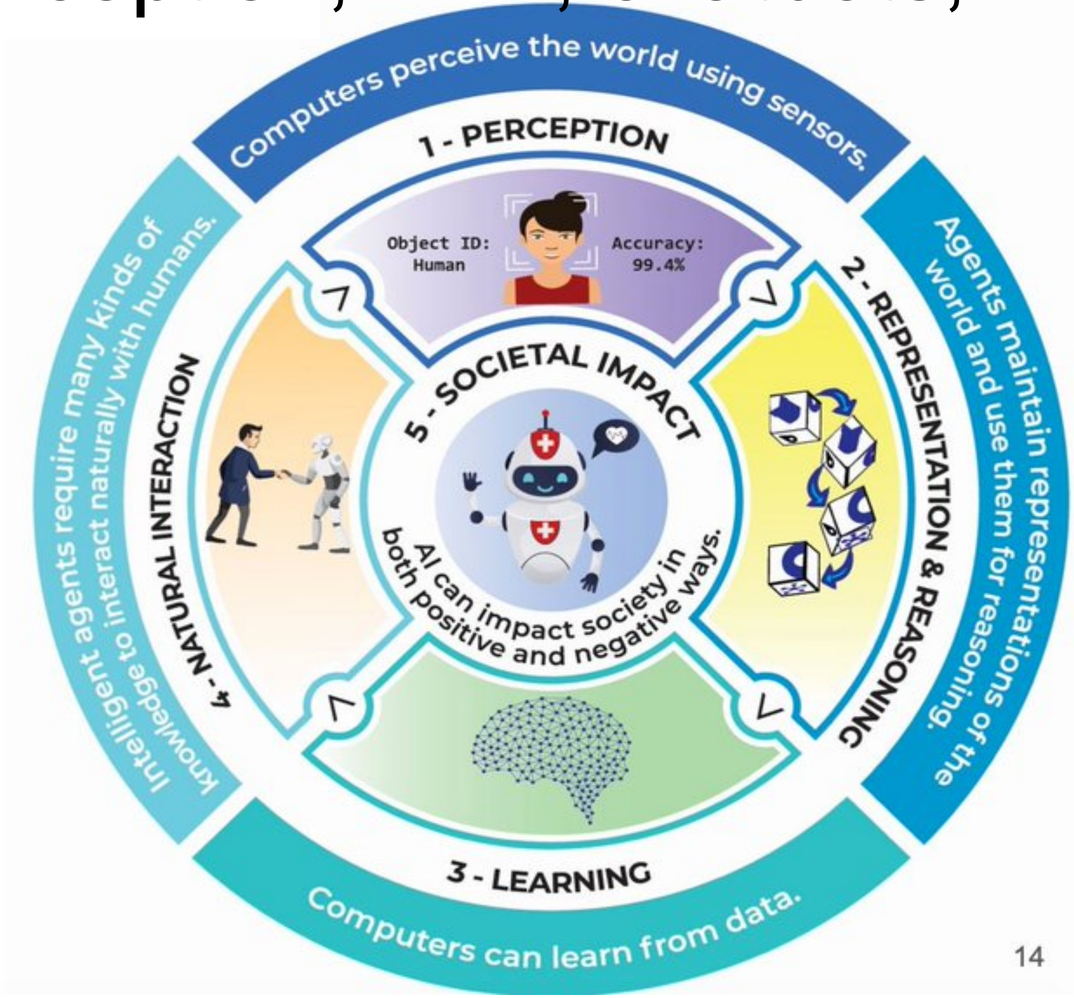
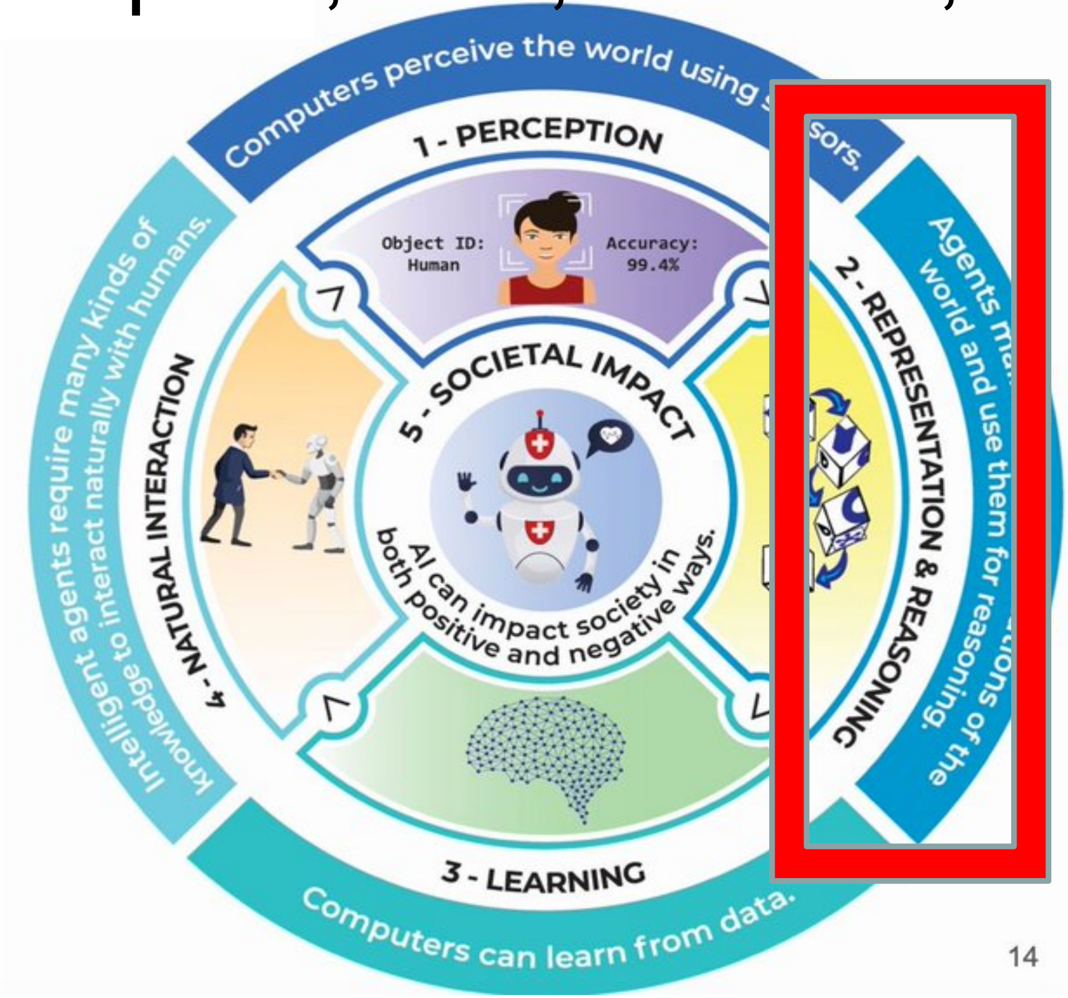
AI & The Other AI

- Machine learning, perception, NLP, chatbots, …



AI & The Other AI

- Machine learning, perception, NLP, chatbots, …
- The other AI: KRR
  - – Classical logic
  - – The other logic



AI & The Other AI

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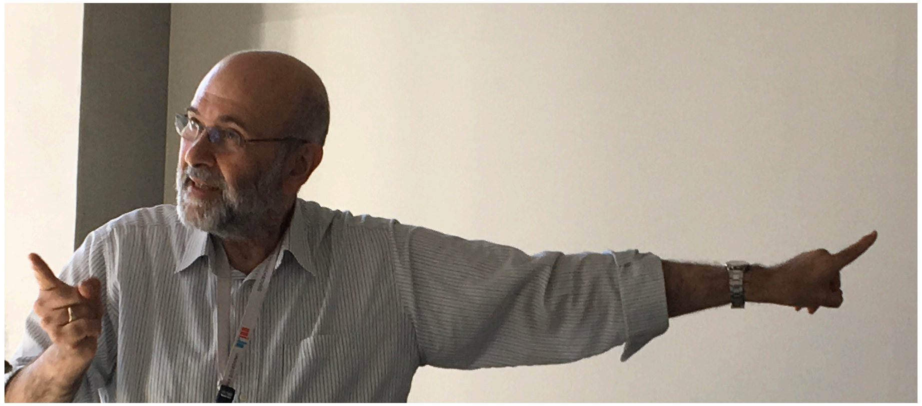
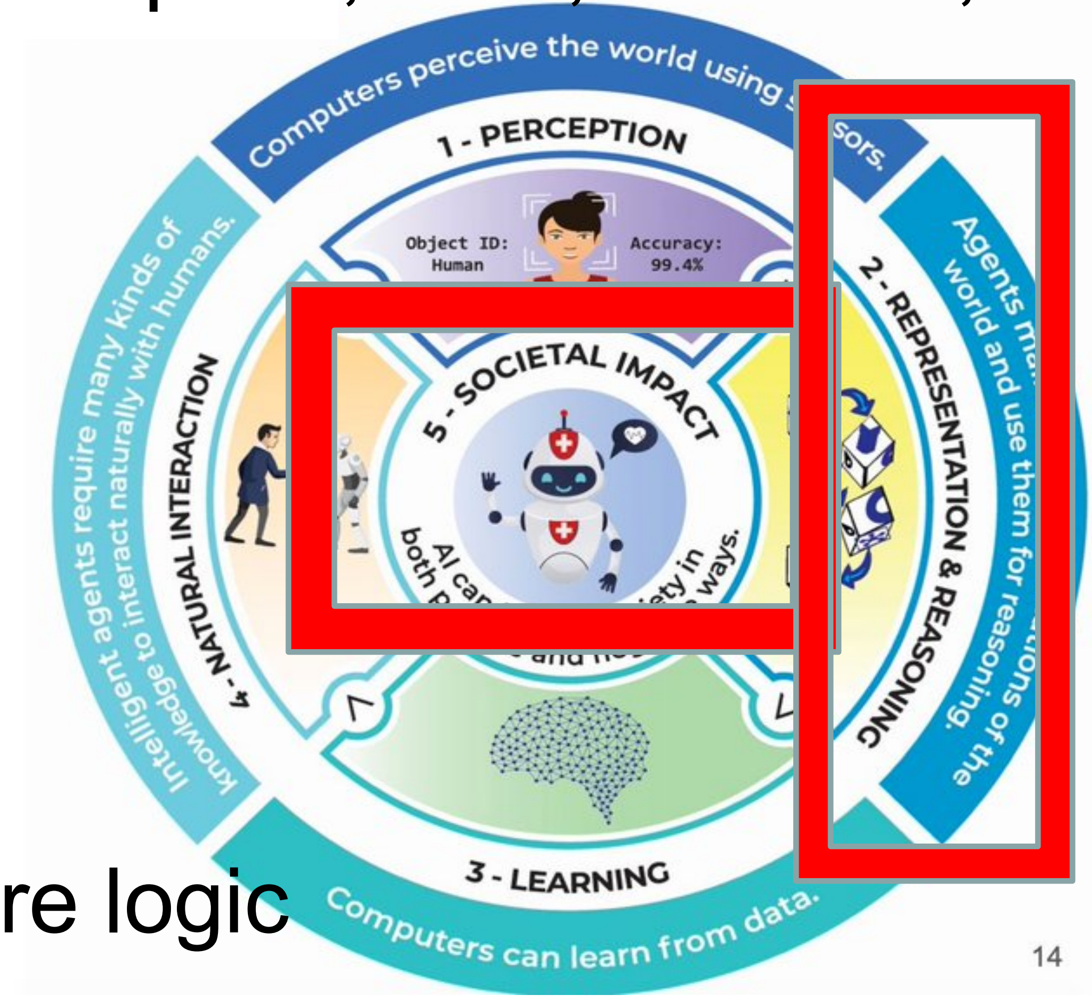


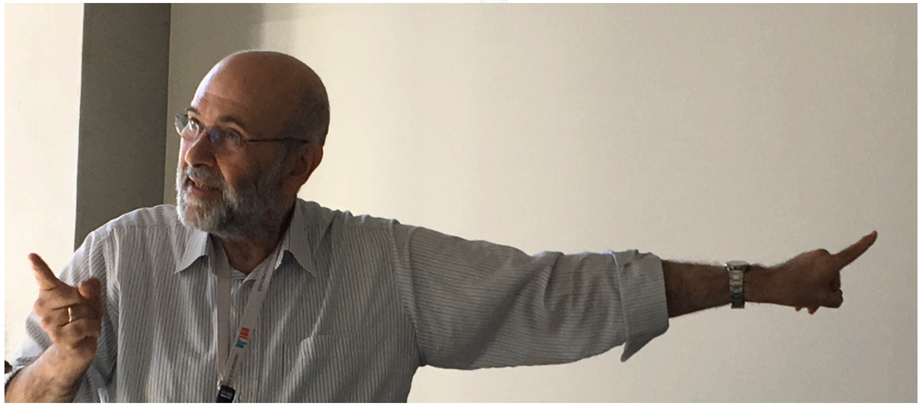


- The world needs more logic

The World Needs More Logic

The World Needs More Logic

Manifesto



- Logic for all
- Logic of the 21st century
- Including fake news, lies, fallacies, …

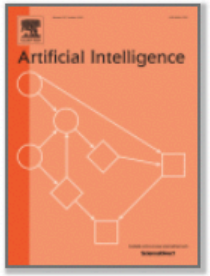
The World Needs More Logic

Deontic Logic

ELSEVIER

Artificial Intelligence

Volume 287, October 2020, 103348



Designing normative theories for ethical and legal reasoning: LogiKEy framework, methodology, and tool support ☆

Christoph Benzmüller [b, a], Xavier Parent [a], Leendert van der Torre [a, c]

Show more

https://doi.org/10.1016/j.artint.2020.103348

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Linguists 50s

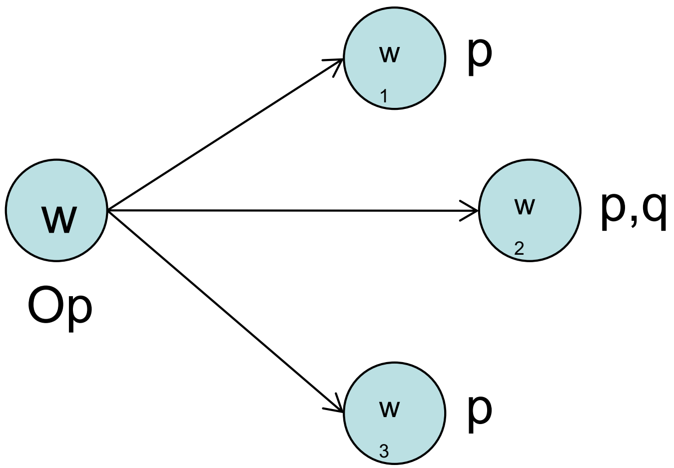
- Formalize the normative use of language

x is obligatory iff in the ideal world, *x* is true

- So-called “deontic paradoxes”
  - If you should mail the letter, then you should mail or burn it
  - If you should help a robbed man, then he should be robbed

Monadic "Standard" Deontic Logic

- Von Wright, Deontic Logic. *Mind*, 1951.
  - possible p = not necessary not p
  - permitted p = not obligatory not p



- Semantics: Op = ideal worlds satisfy p

Varieties of Modal Readings

(1) Jones must be the murderer.

(2) Jones ought to be in his eighties now.

(3) Jones ought to be in jail now (but he enjoys a free life).

(4) (If the rumours are correct,) Jones ought to be in jail now.

(5) He should be in his office by now.

(6) You should be in your office on time!

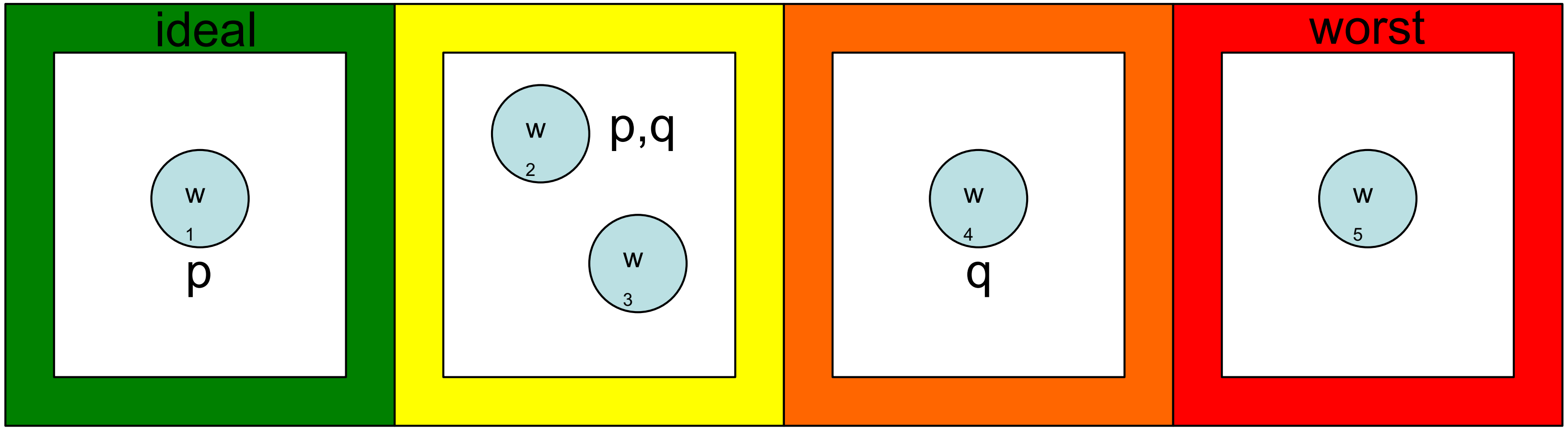
Ethics 60s

- What should I do? A theory of (moral) action
  - When may we shoot down a plane hijacked by terrorists?

x is obligatory iff *x* is better than the absence of *x*

Dyadic “Standard” Deontic Logic

- Hansson, An analysis of some … *Nous*, 1969
  - Bridge to preference logic (without Ceteris Paribus)

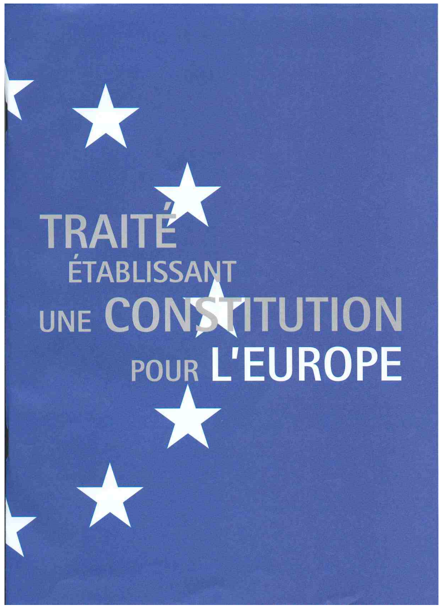


if not mentioned, a propositional atom is false

- Semantics: O(p|q) = preferred q worlds satisfy p

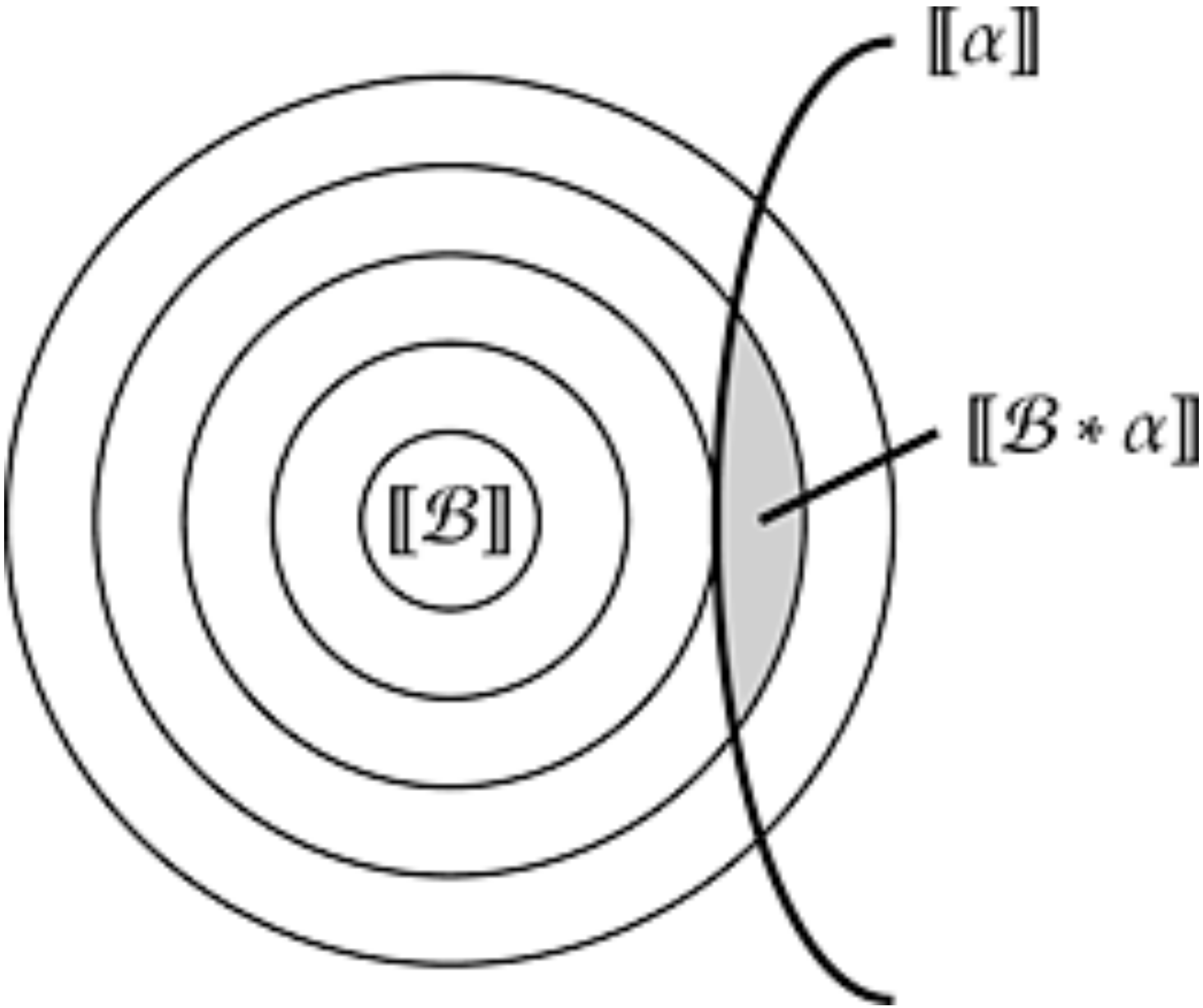
Law 70s

- Whose behavior is not compliant to the norm?
  - And what is the sanction?



- *x* is obligatory iff *x* follows from norms in context

Philosophy of Science 80s



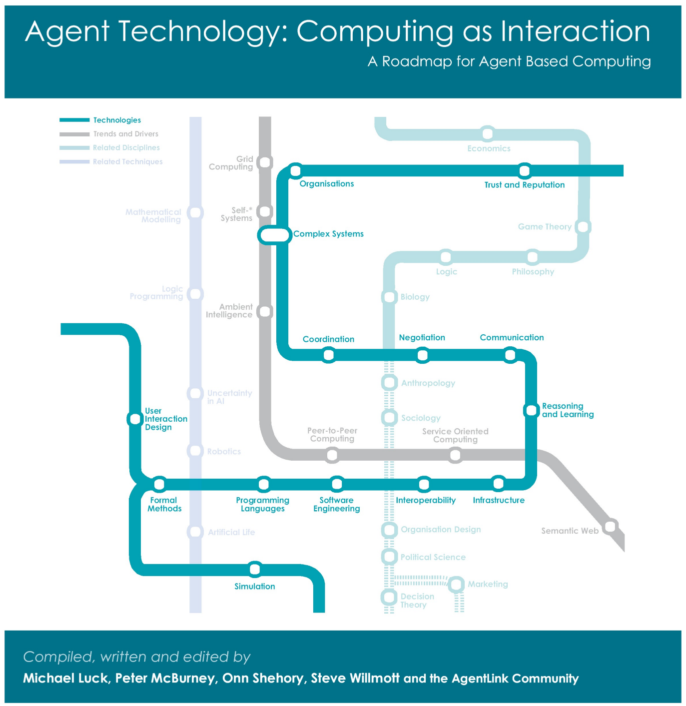
CS and AI 90s

- DEON 1991: Deontic logic in computer science
  - Systems more secure & reliable.

- Defeasible deontic logic, defeasible norms
  - We discuss this more in detail in part 3 on the challenges

Multi-Agent Systems 00s .

- NORMAS 2005: Norms regulate agent behavior



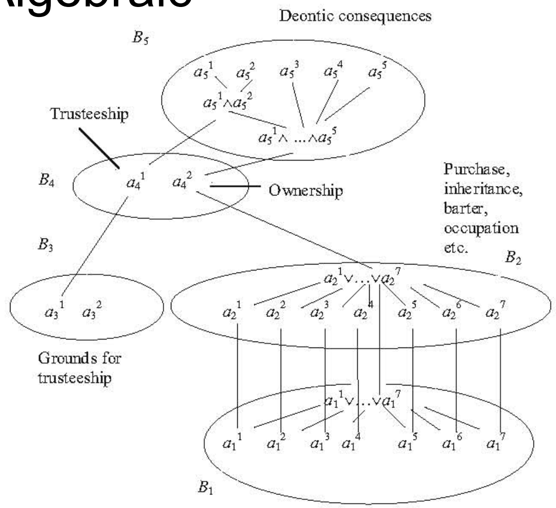
Infrastructure for Open Communities	Web mining Data integration and Semantic Web Metadata	Semantic interaction Agent-enabled semantic web (services) Electronic institutions Dynamic norms, roles, laws, organisations
n Open Environments	Organisational views of agent systems	Enhanced understanding of agent society dynamics Theory and practice of argumentation strategies Norms and social structure Theory and practice of negotiation strategie
earning Technologies	Adaptation Personalisation Hybrid technologies	Evolving Agents Self organisation Distributed learning
Trust and Reputation	Security and verifiability for agents Reliability testing for agents Self-enforcing protocols	Norms and social structures Reputation mechanisms Formal methods for open agent systems Electronic contracts

Figure 7.1: Agent technology comprises areas that will be addressed over different timescales

M. Luck et al, AgentLink Roadmap, 2003.

Handbook of DL & NS, 10s

Algebraic



Non-Monotonic

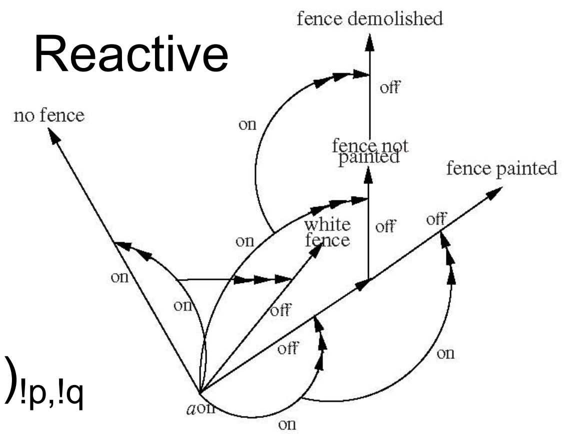
a:b/Oc

Programming

Code fragment 3.1 Conference management system.

```
Roles: chair, author, reviewer
Facts: phase(closed). id(0).
Effects:
 {rea(C,chair), phase(closed)}  open(C) {not phase(closed), phase(abstracts)}
 {rea(A,author), phase(abstracts), id(PId)} uploadAbstract(A) {abstract(A,PId), not id(PId), id(PId+1)}
 ...
Norm-level 0:
 page_size(): <phase(submission) and abstract(A,PId), F(pages(PId) > 15), phase(review), not paper(A,PId)>
 review_due(): <phase(review) and assigned(R,PId), O(review(R,PId)), phase(collect_reviews), blacklist(R)>
 minimum_reviews(PId): <phase(submission) and paper(PId), O( nr_reviews(PId) >= 2 ), phase(collect_reviews), ⊤>
Norm-level 1:
 viol_minimum(): <viol(minimum_reviews(PId)) and rea(C,chair), O(review(C,PId)), phase(notification), blacklist(C)>
```

Reactive



Iterative

a in out(C,b)

Diagnostic

q /\ ¬V(n) → p

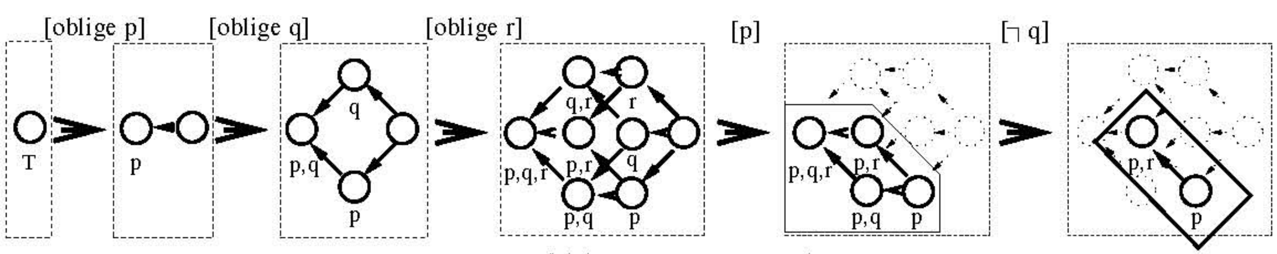
Labeled

$Op_{!p}, Oq_{!q}$ ^{2} $O(p/\backslash q)_{!p,!q}$

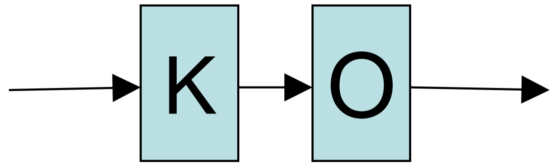
Imperativistic

!p,!q ^{2} O(p/\q)

Dynamic



Input/Output



2010 slide

Deontic Logic in 2020

1. Unification: preference + detachment + action
   - Modal logic of obligations & permissions
     - Obligation & permission in terms of ideality & preference
   - The theory of rules and normative systems
     - Obligation and permission as derivable from a system
   - Norm and action, obligation and agency
     - Obligation as an instrument to achieve a goal
2. Experimentation with normative reasoners
   - Including tools for explaining normative decisions

A Compositional Theory of Conditional Obligation and Permission

Input/output logic + Constraints (preferences)

$\varphi > \bigcirc\psi \in derive_i^O(N^O)$

if and only if

$(\varphi, \psi) \in derive_i^{\mathbf{Fm}(X)}(N^O)$ and

For every preference Boolean algebra $M = \langle \mathcal{B}, \mathcal{V}, \succeq_f \rangle$, for every valuation $V_i \in opt_{\succeq_f}(\varphi)$ we have $V_i(\psi) = 1_{\mathcal{B}}$

$\varphi > P\psi \in derive_i^P(N^P)$

if and only if

$(\varphi, \psi) \in derive_i^{\mathbf{Fm}(X)}(N^P)$ and

For every preference Boolean algebra $M = \langle \mathcal{B}, \mathcal{V}, \succeq_f \rangle$, there is a valuation $V_i \in opt_{\succeq_f}(\varphi)$ such that $V_i(\psi) = 1_{\mathcal{B}}$

- $\mathcal{B}$ is a Boolean algebra,
- $\mathcal{V} = \{V_i\}_{i \in I}$ is the set of valuations from $\mathbf{Fm}(X)$ on $\mathcal{B}$,
- $\succeq_f \subseteq \mathcal{V} \times \mathcal{V}$: $\succeq_f$ is a betterness or comparative goodness relation over valuatio $\mathbf{Fm}(X)$ to $\mathcal{B}$ such that $V_i \succeq_f V_j$ iff $(\{\varphi | V_i(\varphi) = 1_{\mathcal{B}}\}, \{\psi | V_j(\psi) = 1_{\mathcal{B}}\}) \in f$.

Ali 2020 slides

Recap: brief history of deontic logic

- Methodology of the “deontic paradoxes”
  – DP are benchmark scenarios of deontic logic
- Deontic logic is used across many disciplines
  – Each with their own own pecularities and issues
  – We need specific instances for specific applications
  – We need to experiment with these instances
- There is a general theory of deontic modality
  – DL facilitates interdisciplinary collaboration
  – Component of the logic for all !

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Ten challenges in deontic logic

- We discuss some examples from deontic logic
  - From the perspective of nonmonotonic (AI) logic
- There is no “best” logic for every example
  - The examples illustrate the kind of logics we want
- Last part of the talk: bridges to classical logic

A Minimal Deontic Language

- $a, x, \neg a, a \wedge x, a \vee x, a \rightarrow x$, etc: propositional logic
- $a \dashrightarrow x$: if *a* then normally *x*
- O(*x*|*a*): *x* is obligatory in context *a*
- O(*x*): *x* is obligatory
- P(*x*|*a*): *x* is permitted in context *a*
- …
- $S \mid\!\sim x$: *x* is a consequence of *S* Snake!
- $S \not\mid\!\sim x$: *x* is **not** a consequence of *S*

Example (pragmatic oddity)

- O(pay-tax) — You ought to pay tax
- O(keep-secret | ¬ pay-tax) — If you don't, then you should keep it a secret
- ¬pay-tax — You do not pay tax

- $O(p), O(k \mid \neg p), \neg p \mid\sim O(p)$ — R
- $O(p), O(k \mid \neg p), \neg p \mid\sim O(k)$ — FD
- $O(p), O(k \mid \neg p), \neg p \not\mid\sim O(p \wedge k)$ — ? AND

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Challenge 1: Ought Implies Can

- If p is obligatory, then p can be true (or false)

- $O(p) \mid\!\sim O(p)$ R
- $O(p), \neg p \not\mid\!\sim O(p)$? R

- $O(p), O(k \mid \neg p), \neg p \not\mid\!\sim O(p)$ R
- $O(p), O(k \mid \neg p), \neg p \mid\!\sim O(k)$ FD
- $O(p), O(k \mid \neg p), \neg p \not\mid\!\sim O(p \wedge k)$ AND

Challenge 1: Ought Implies Can

- If p is obligatory, then p can be true (or false)

- $O(p) \mid\sim O(p)$
  R
- $O(p), \neg p \mid\not\sim O(p)$ R

- Issue: how to represent violations and CTD ob?
- $O(p) \wedge \neg p \rightarrow O(sanction)$

Challenge 1: Ought Implies Can

- O(¬ fence) There should be no fence
- O(white fence | fence) If there is a fence, then it should be a white one

- $O(\neg f), O(w \wedge f \mid f) \mid\!\sim O(\neg f)$ R
- $O(\neg f), O(w \wedge f \mid f), f \mid\!\sim O(w \wedge f)$ FD
- $O(\neg f), O(w \wedge f \mid f), f \not\mid\!\sim O(\neg f \wedge w \wedge f)$ AND
- $O(\neg f), O(w \wedge f \mid f), f \not\mid\!\sim O(\neg f)$? R

Challenge 2: Deontic Explosion

- Moral dilemmas (e.g. Sartre)
- you should not kill (your conscience tells you),
- you should kill (because you are soldier in war)

- $O(k) \mid\!\sim O(k)$ R
- $O(k), O(\neg k) \not\mid\!\sim O(k)$? R
- $O(k), O(\neg k) \not\mid\!\sim O(k \wedge \neg k)$? AND
- $O(k), O(\neg k) \not\mid\!\sim O(x)$ CC

Challenge 2: Deontic Explosion

- Moral dilemmas (e.g. Sartre)
- you should not kill (your conscience tells you),
- you should kill (because you are soldier in war)

- $O(k), O(a) \mid\!\sim O(k \wedge a)$ AND
- $O(k), O(\neg k), O(a) \mid\!\sim O(k \wedge a) ; O(\neg k \wedge a)$
- $O(k), O(\neg k), O(a) \mid\!\sim_{\cap} O(a)$ Skep
- $O(k), O(\neg k), O(a) \mid\!\sim_{\cup} O(k \wedge a) \wedge O(\neg k \wedge a)$ Cred

Challenge 2: Deontic Explosion

- Travel dilemma.
- O(paris): You must go to Paris
- O(london): You must go to London
- ¬(paris ∧ london): You cannot go to both

- $O(p), O(l) \mid\!\sim O(p \wedge l)$ AND
- $O(p), O(l), \neg(p \wedge l) \not\mid\!\sim O(p \wedge l)$ AND

Challenge 2: Deontic Explosion

- $O(f \vee s)$: You should fight in the army or do alternative service
- $O(\neg f)$: You should not fight in the army

- $O(f \vee s), O(\neg f) \mid\!\sim O(s \wedge \neg f)$ AND
- $O(f \vee s), O(\neg f) \mid\!\sim O(s)$ CC
- $O(f \vee s), O(\neg f), f \not\mid\!\sim O(s)$ CC

Challenge 3: Ideal Obligations

- A man should assist his neighbours
- If he goes, then he should tell that he comes

- $O(a), O(t|a) \mid\!\sim O(t)$ DD
- $O(a), O(t|a), \neg a \not\mid\!\sim O(t)$ DD

- Deontic detachment
- Happy flow

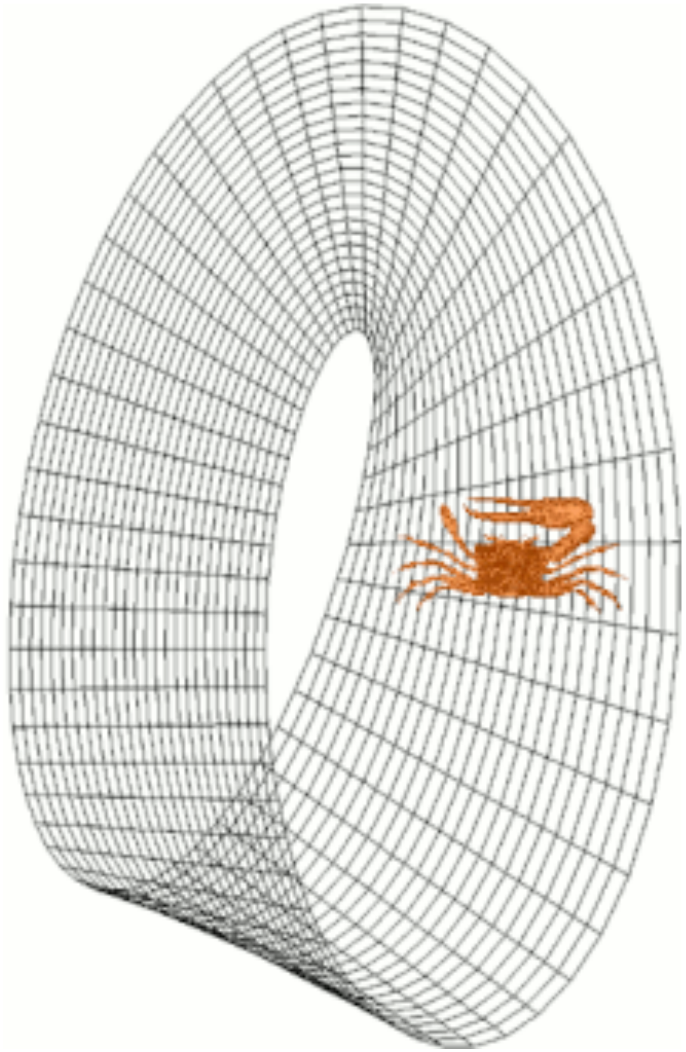
Challenge 3: Ideal Obligations

- A man should assist his neighbours
- If he goes, then he should tell that he comes

- $O(a), O(t|a) \mid\!\sim O(a)$ DD
- $O(a), O(t|a), \neg t \not\mid\!\sim O(a)$? DD

- Happy flow (DD) does not lead to happy ending

2020 Year of Mobiuses



Challenge 3: Ideal Obligations

- Mobius strip: Combining challenge 2 and 3

- $O(a), O(t|a), O(\neg a|t) \mid\sim O(a)$ DD
- $O(a), O(t|a), O(\neg a|t), t \not\mid\sim O(a)$? DD
- or
- $O(a), O(t|a), O(\neg a|t) \mid\sim T; O(a); O(a \wedge t)$
- $O(a), O(t|a), O(\neg a|t), t \mid\sim T; O(a); O(a \wedge t); O(\neg a)$

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Challenge 4: CWA, Strong Permission

- Weak permissions: not forbidden is permitted
- $\mid\!\sim P(a)$ CWA
- $O(\neg a) \mid\!\not\sim P(a)$ CWA

- Strong permissions as exceptions
- $O(a) \mid\!\sim O(a)$ R
- $O(a), P(\neg a) \mid\!\not\sim O(a)$ R

Challenge 5: Priority 1: Specificity

- O(¬ fence) There should be no fence
- O(white fence | fence) If there is a fence, then it should be a white one
- O(white fence | dog) If there is a dog, then it should be a white fence
- $O(\neg f), O(w \wedge f \mid f) \mid\!\sim O(\neg f)$ R
- $O(\neg f), O(w \wedge f \mid f), f \mid\!\sim O(w \wedge f)$ FD
- $O(\neg f), O(w \wedge f \mid f), O(w \wedge f \mid d), d \not\mid\!\sim O(\neg f)$ R

Combining Semantics / Logics

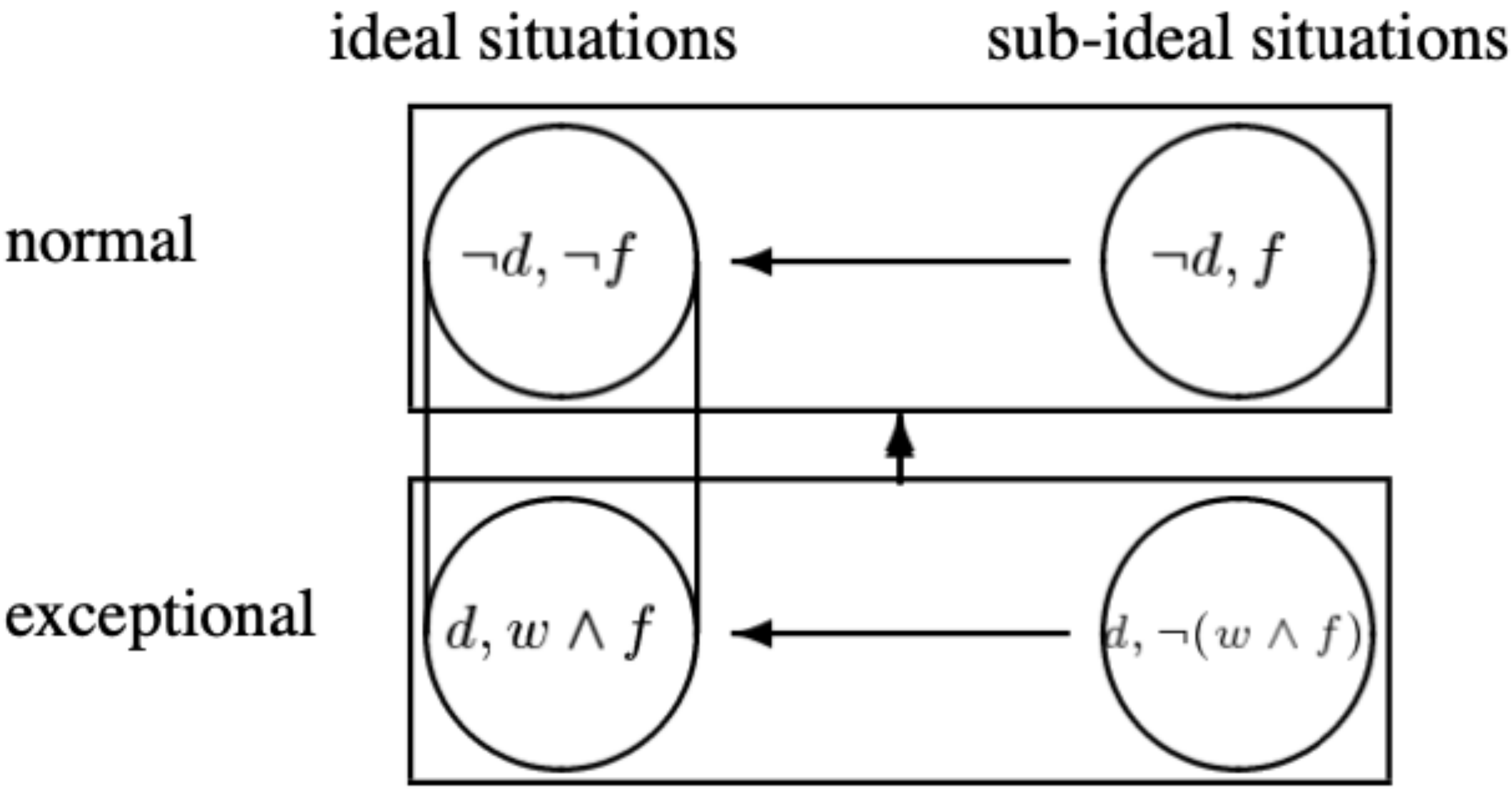

Fig. 14. Multi-preference relation of the Fence example

Challenge 6: Priority 2: Authority

1. O(heat) Ca: The heat should be turned on
2. O(¬open) M: Window should be closed
3. O(open | heat) Co: If the heat is turned on, then it should be a white fence

- $O_1(h), O_2(\neg o)\ O_3(o \mid h) \not\mid\!\sim O(h)$? R
- $O_1(h), O_2(\neg o)\ O_3(o \mid h) \not\mid\!\sim O(\neg o)$? R
- $O_1(h), O_2(\neg o)\ O_3(o \mid h) \not\mid\!\sim O(o)$? DD

Challenge 7: Priority 3: Revision

- The indexes now refer to a moment in time

- $O_t(\neg f) \mid\!\sim O_{t+1}(\neg f)$ Pers
- $O_t(\neg f), O_{t+1}(f) \not\mid\!\sim O_{t+1}(\neg f)$ Pers

- Norm change vs obligations change

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Challenge 8: Facts

- $a \dashrightarrow x$: if *a* then normally *x*
- $b \dashrightarrow f,\ (p \wedge b) \dashrightarrow \neg f$: birds fly, but penguins don't

- $b \dashrightarrow f,\ (p \wedge b) \dashrightarrow \neg f,\ p \wedge b \mid\!\sim \neg f$ Spec
- $b \dashrightarrow f,\ (p \wedge b) \dashrightarrow \neg f,\ p \wedge b,\ O(h|f), O(\neg h|f \wedge b) \mid\!\sim \neg f$ Spec

- No wishful thinking: obligations not affect facts

Challenge 9: Agency and Action

- All examples can be rephrased using action
  - If in the ideal world I win the lottery, then should I buy a lottery ticket?
- New: bounded reasoning & multi-agent systems
  - The indexes now refer to agents

- $O(pay), O(receipt|pay) \mid\sim O(receipt)$ DD
- $O_1(pay), O_2(receipt|pay) \mid\not\sim O_2(receipt)$ DD

Challenge 10: Practical Reasoning

- Means-end reasoning

- $t \dashrightarrow p, O(p) \mid\!\sim O(t)$ Abd
- $t \dashrightarrow p, f \dashrightarrow p, O(p) \not\mid\!\sim O(t)$ Abd

Challenge 10: Practical Reasoning

- My favourite challenge, formalize:

- If you want to smoke, you should go to a cigarette store
- If you want to smoke, you should not go to a cigarette store
- You want to smoke

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Von Wright

Ratio Juris

An International Journal of Jurisprudence and Philosophy of Law

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Deontic Logic: A Personal View

Georg Henrik Von Wright

First published: 17 December 2002 | https://doi.org/10.1111/1467-9337.00106 |

Ratio Juris
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Abstract

This article contains an overview of the author's long-standing involvement with deontic logic, both from a technical and from a wider philosophical point of view. As far as the formal aspects of deontic logic are concerned, the author describes his intellectual development from the original discovery of the analogy between modal (and deontic) notions on the one hand, and quantifiers on the other, through the formulation of a systematic theory of [illegible] foundation for deontic logic. In a more philosophical vein, the author discusses such questions as the very possibility of deontic logic if norms have no truth-value, the relation between the descriptive interpretation of classical deontic logic and the logic of norm-propositions, the correct representation of conditional or hypothetical norms, the distinction between moral obligation and practical necessity, and the interdefinability of permission and obligation.[1]

Deontic Logic in AI: Horty

- John F. Horty: Deontic Logic as Founded on Nonmonotonic Logic. Ann. Math. Artif. Intell. 9(1-2): 69-91 (1993)
- John F. Horty: Agency and Deontic Logic. Oxford University Press (2001)
- John F. Horty: Deontic modals: Why abandon the classical semantics? (2014)

Deontic Logic in 2020

1. Unification: preference + detachment + action
   - Modal logic of obligations & permissions
     - Obligation & permission in terms of ideality & preference
   - The theory of rules and normative systems
     - Obligation and permission as derivable from a system
   - Norm and action, obligation and agency
     - Obligation as an instrument to achieve a goal
2. Experimentation with normative reasoners
   - Including tools for explaining normative decisions

Makinson (1999)

On a Fundamental Problem of Deontic Logic

David Makinson

The usual presentations of deontic logic, whether axiomatic or semantic, treat norms as if they could bear truth-values. A fundamental problem of deontic logic, we believe, is to reconstruct it in accord with the philosophical position that norms direct rather than describe, and are neither true nor false.

(Alchourron and Bulygin 1981) have indeed made such a construction, refining an earlier one of (Stenius 1963), based on the distinction between a norm and a proposition about norms. However it has the limitation that it does not deal with conditional norms. These are covered by an extension of (Alchourrón 1993), but with certain shortcomings. Our purpose is to extend the basic 1981 construction in another manner which, we suggest, provides a more satisfactory and sensitive analysis of conditional norms within the same philosophical perspective.

David Makinson, "On a fundamental problem of deontic logic", Norms, Logics and Information Systems. New Studies in Deontic Logic and Computer Science, edited by Paul McNamara and Henry Prakken (Amsterdam: IOS Press, Series: Frontiers in Artificial Intelligence and Applications, Volume: 49, 1999) pp 29-53.

Makinson (2005)

- Bridges from classical logic to the other logic
  - For the users: Learning curve
  - For logicians: To organize the area

- To reuse existing results like proof theory?

Makinson

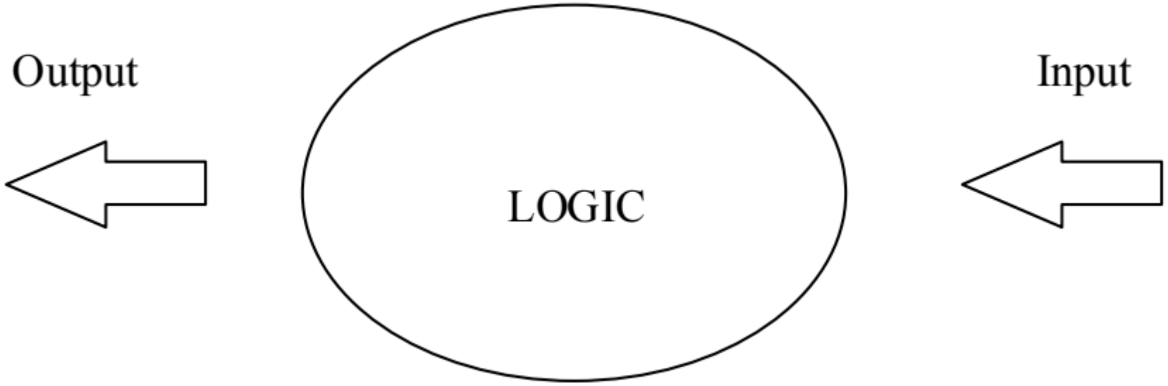

Figure 1

Traditional Picture of Logic as an Inference Motor

Makinson and vdT, Input/Output Logic. JPL 2000.

Makinson

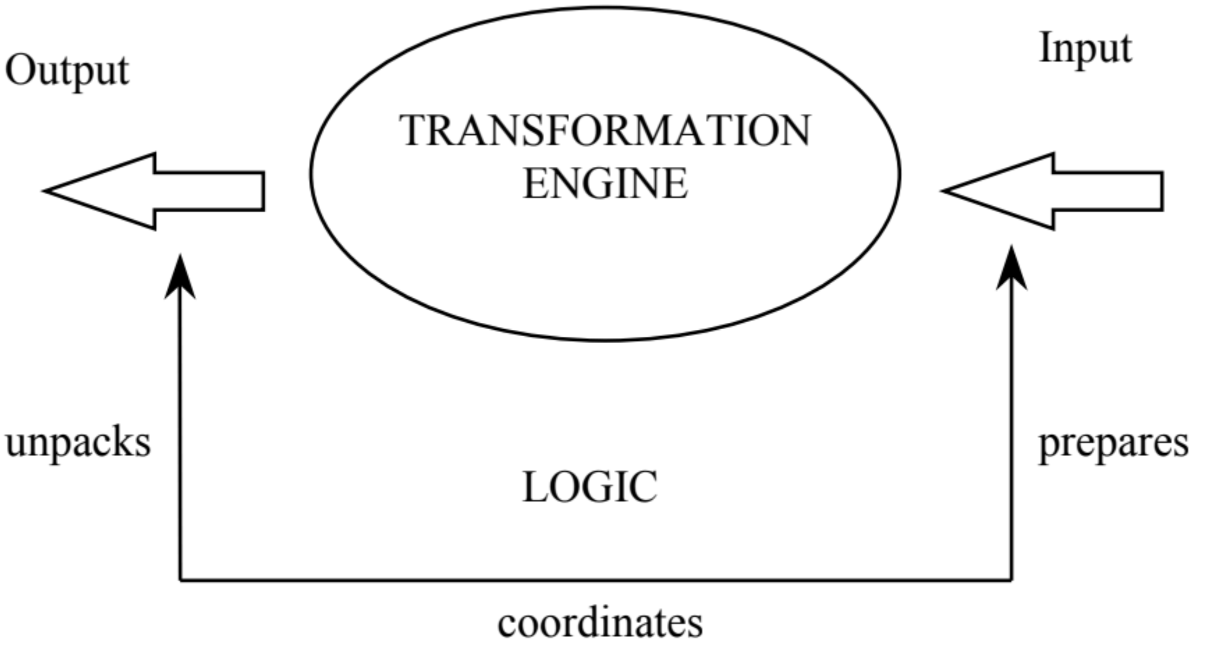

Figure 2
Picture of Logic Assisting a Transformation Engine

Makinson and vdT, Input/Output Logic. JPL 2000.

Makinson

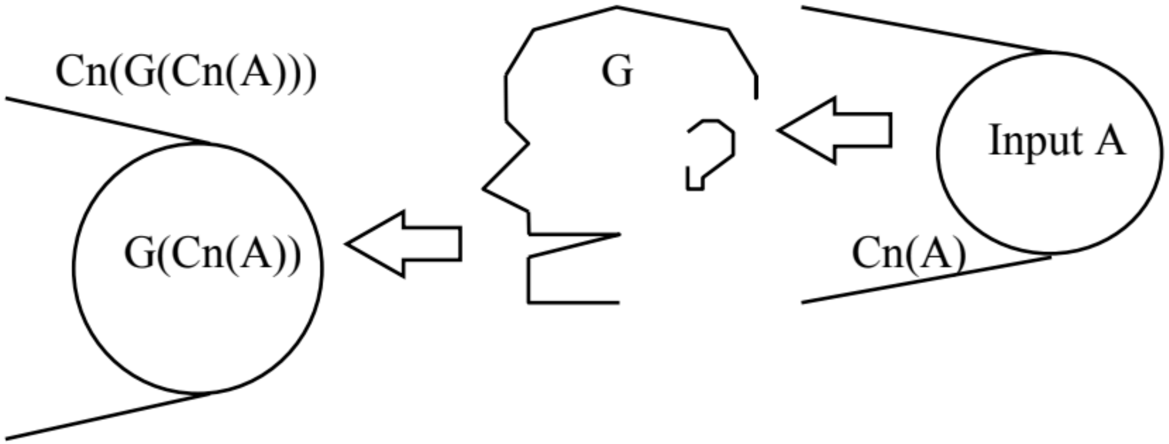

Figure 3
Simple-Minded Output: $out_1(G,A) = Cn(G(Cn(A)))$

Makinson and vdT, Input/Output Logic. JPL 2000.

Challenge 6: Priority 2: Authority

1. O(heat) Ca: The heat should be turned on
2. O(¬open) M: Window should be closed
3. O(open | heat) Co: If the heat is turned on, then it should be a white fence

- $O_1(h), O_2(\neg o)\ O_3(o \mid h) \not\mid\!\sim O(h)$? R
- $O_1(h), O_2(\neg o)\ O_3(o \mid h) \not\mid\!\sim O(\neg o)$? R
- $O_1(h), O_2(\neg o)\ O_3(o \mid h) \not\mid\!\sim O(o)$? DD

Challenge 6: Priority 2: Authority

'Suppose that there is an agent, called Corporal O'Reilly, and that he is subject to the commands of three superior officers: a Captain, a Major, and a Colonel. The Captain, who does not like to be cold, issues a standing order that, during the winter, the heat should be turned on. The Major, who is concerned about energy conservation, issues an order that during the winter, the window should not be opened. And the Colonel, who does not like to be too warm and does not care about energy conservation, issues an order that, whenever the heat is on the window should be opened.'

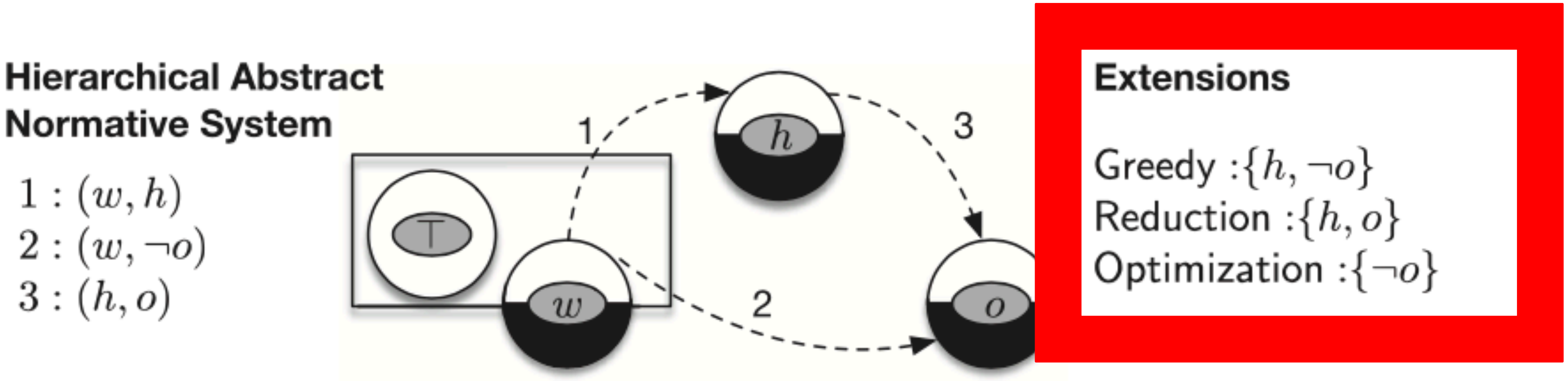

FIGURE 1. The Order puzzle example, represented using the graphical notation of Tosatto *et al.* [29] with edges annotated by norm strength.

Liao et al, Prioritized norms in formal argumentation. JLC 2019.

Kratzer/Hansen vs Makinson

- Kratzer/Hansen: Logic of normative systems
  - The model is a normative system (no more worlds)
  - NS |= O(x) and |- and |~
- Makinson: Logic of a normative system
  - Each normative system has a logic
  - |-$_{NS}$ and |~$_{NS}$
- New: hidden logic of norms
  - NS |- (a,x) and NS |~ (a,x)
  - Minimizing norm/obligation violations

Alternative: Formal Argumentation ?

Abstract

The purpose of this paper is to study the fundamental mechanism, humans use in argumentation, and to explore ways to implement this mechanism on computers.

acceptability of arguments. Then we argue for the "correctness" or "appropriateness" of our theory with two strong arguments. The first one shows that most of the major approaches to nonmonotonic reasoning in AI and logic programming are special forms of our theory of argumentation. The second argument illustrates how our theory can be used

result showing that our theory captures naturally the solutions of the theory of *n*-person games and of the well-known stable marriage problem.

By showing that argumentation can be viewed as a special form of logic programming with negation as failure, we introduce a general logic-programming-based method for generating meta-interpreters for argumentation systems, a method very much similar to the compiler-compiler idea in conventional programming.

Keywords: Argumentation; Nonmonotonic reasoning; Logic programming; *n*-person games; The stable marriage problem

On the acceptability of arguments and its fundamental role role in nonmonotonic Reasoning, logic programming and n-person games.

Dung 1995: A Story of Odd Attack Cycles

Russel's paradox | Stable sets | ♲ Mobius strip ♲

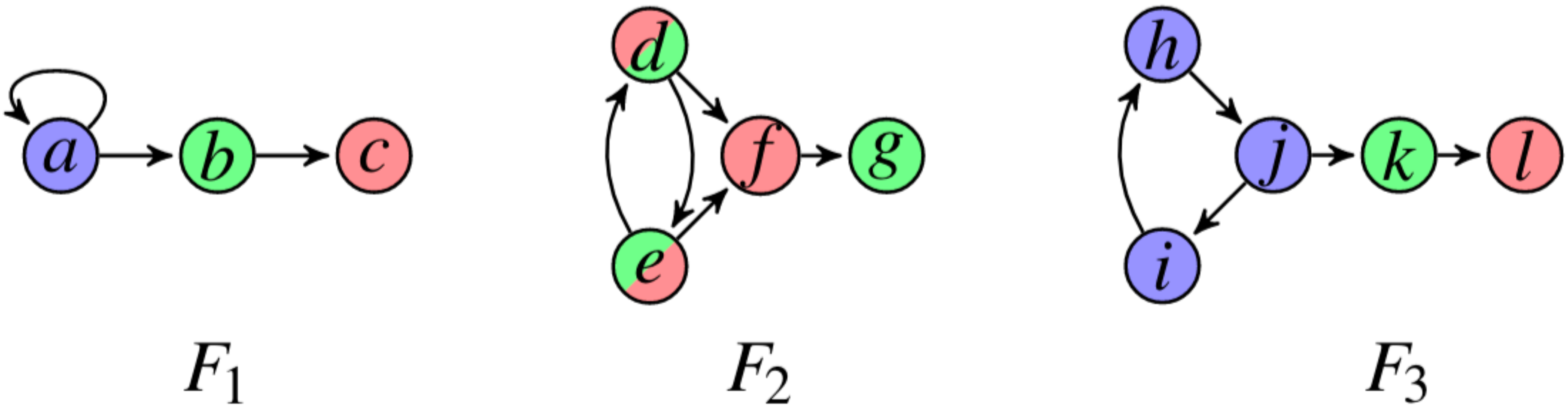

Figure 1. Three argumentation frameworks

Dauphin, Rienstra and vdT: A Principle-Based Analysis of Weakly Admissible Semantics. Proceedings of COMMA2020. (Best paper award)

Alternative: Formal Argumentation ?

Alternative or method for explanation?

Methodology: Experimentation

ELSEVIER

Data in Brief
Volume 33, December 2020, 106409

Journal Data in Brief

Data Article

LogiKEy workbench: Deontic logics, logic combinations and expressive ethical and legal reasoning (Isabelle/HOL dataset)

Christoph Benzmüller [a, b], Ali Farjami [a], David Fuenmayor [b], Paul Meder [a], Xavier Parent [a], Alexander Steen [a], Leendert van der Torre [a, c], Valeria Zahoransky [a, d]

Summary

1. The world needs more (deontic) logic
2. (Deontic) logic bridges disciplines
3. Ten challenges for deontic logic
   – 3 essential deontic phenomena are nonmonotonic
   – 4 more nonmonotonic phenomena in deontic logic
   – 3 other NMR challenges to deontic logic in AI
4. Looking forward: many new logics to study

Questions?

1. The world needs more (deontic) logic
2. (Deontic) logic bridges disciplines
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