Deontic Logic Without Possible Worlds

Leon van der Torre, University of Luxembourg & CSLI

O = Obligation

L’Histoire d’ 

1969
Hansson
1975
Spohn

1968
Danielsson
1973
Lewis
1981
Kratzer
1987/2002
Aqvist
1998
Hansen
2008
Parent

L'Histoire d' 

Paradox

1

H

1 5

S hn

1968

Danielsson

1973

Lewis

1981

Kratzer

1987/2002

Aqvist

1998

Hansen

2008

Parent

L'Histoire d' 

Paradox Failure

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1968
Danielsson
1973
Lewis
1981
Kratzer
1987/2002
Aqvist
1998
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2 8
Parent

L'Histoire d' 

Paradox

Legal systems

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Failure

1968
Danielsson
1973
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Kratzer
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Aqvist
1998
H ns
2 8
Parent

L'Histoire d' 

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Paradox

Legal systems

Ethics advisory

Failure

1968
Danielsson
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H… s
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L'Histoire d' 

Paradox

Legal systems

Ethics advisory

Deontic logic in computer science

Failure

1968
Danielsson
1973
Lewis
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Kratzer
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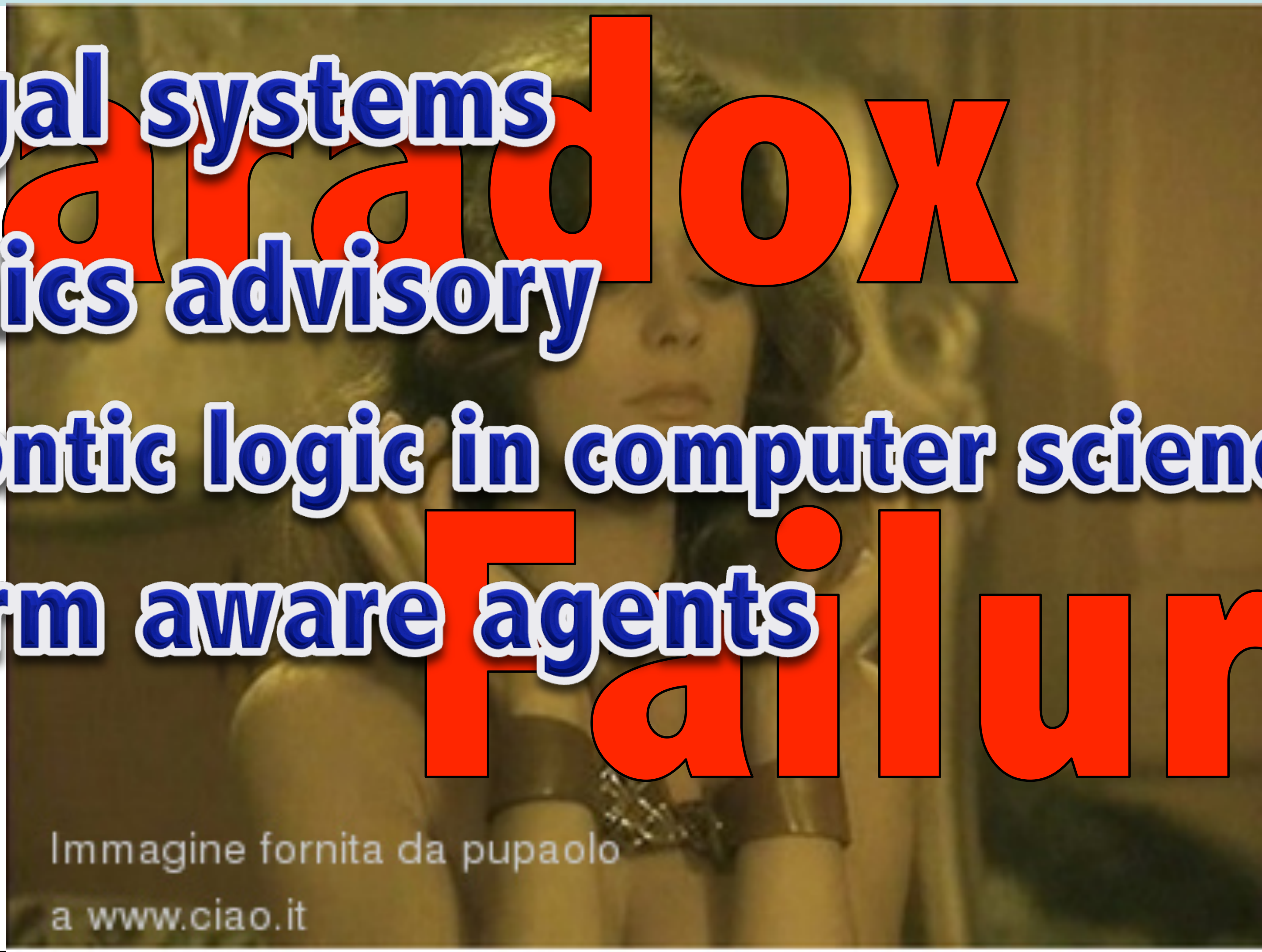
L'Histoire d' 



Paradox

Legal systems

Ethics advisory

Deontic logic in computer science

Norm aware agents

Failure

1968
Danielsson
1973
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Living Without Possible Worlds

- New research agenda for deontic logic:

Beyond manipulating (social) preferences

- Extrinsic (social or collective) preferences
- Intrinsic (individual) preferences

Kai von Fintel

"The opponents of the classic semantics either overlook or too eagerly dismiss ways in which the classic semantics can account for the allegedly recalcitrant data. Further, in several areas, the proposed alternative semantics actually fail to do justice to the data."

Kai von Fintel, The best we can (expect to) get? Challenges to the classic semantics for deontic modals, 2012

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   – Input/output logic, Out1-8, Outfamily
4. Beyond input/output logic (2007-)
   – Reasoning for normative multiagent systems
5. Concluding remarks

Focus on concepts: Technical details in the logic seminar and the course

Introduction

1968

1981

2013

2045

Introduction

1968 

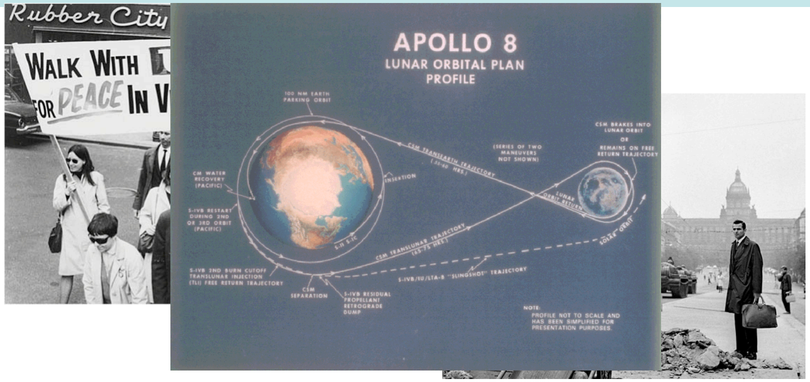
1981

2013

2045

Introduction

1968



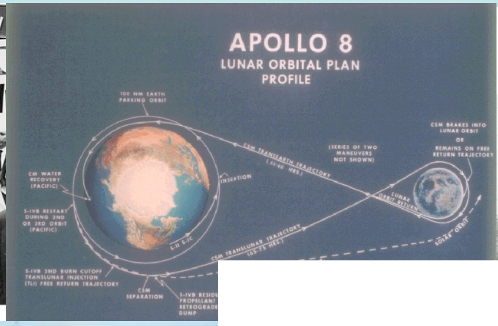
1981

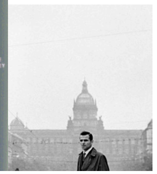
2013

2045

Introduction

1968





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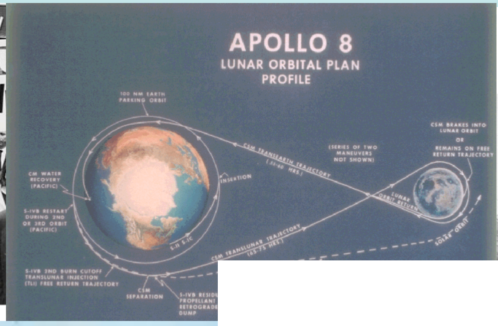

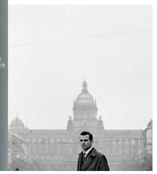

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Introduction

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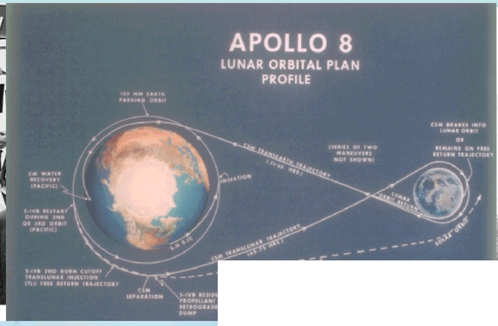

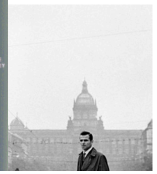

Danielsson

1981

2013

2045

Introduction

1968 Danielsson

1981 Van Eck, Kratzer

2013

2045

Introduction

1968 Danielsson

1981 Van Eck, Kratzer

2013 Handbook DL

2045

Introduction

1968 Danielsson

1981 Van Eck, Kratzer

2013 Handbook DL

2045 NORMAS

Introduction

1968 Danielsson

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Assembler : computers = possible worlds : deontic logic

My Story of O

1986-1992: Erasmus University Rotterdam

Computer science, econometrics, philosophy

My Story of O

1986-1992: Erasmus University Rotterdam

Computer science, econometrics, philosophy

PhD topic: Electronic Commerce

PhD method: Deontic Logic in Computer Science

Biannual DEON conferences since 1991

My Story of O

1986-1992: Erasmus University Rotterdam

Computer science, econometrics, philosophy

1996: DEON96: … ordering and minimizing …

Yao-Hua Tan, L. van der Torre: How to Combine Ordering and Minimizing in a Deontic Logic Based on Preferences. DEON 1996: 216-232

My Story of O

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1997: PhD thesis: Reasoning about obligations:

Defeasibility in preference based deontic logic

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End of preference based deontic logic

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2007: University of Luxembourg

Inaugural speech: Violation games

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End of preference based deontic logic

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Inaugural speech: Violation games

2013: Deontic logic handbook: a new beginning?

ΔEON98: Von Wright

Fourth International Workshop on Deontic Logic in Computer Science

(DEON '98)

Bologna, Italy, 8-10 January, 1998

Armi, Faculty of Law, Palazzo Malvezzi, via Zamboni 22

Thursday, January 8

09.20 - 09.30: Opening

09.30 - 10.30: Invited Speaker 1: Von Wright (University of Helsinki) Deontic Logic --- as I see it.

ΔEON98: Makinson

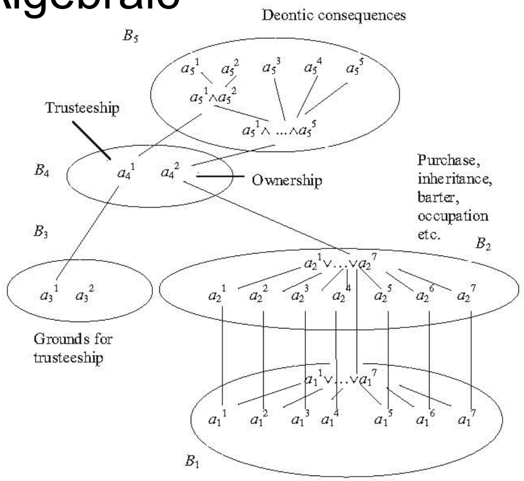
- Jorgensen’s dilemma (1931)
  - ``A fundamental problem of deontic logic, we believe, is to reconstruct it in accord with the philosophical position that norms direct rather than describe, and are neither true nor false.’’
- “No logic of norms without attention to a system of which they form part.” (iterative approach)

Friday, January 9

09.30 - 10.30: Invited Speaker 3: David Makinson (UNESCO, France), On the fundamental problem of deontic logic. (Abstract)

Alternatives to Possible Worlds ?

Algebraic



Non-Monotonic

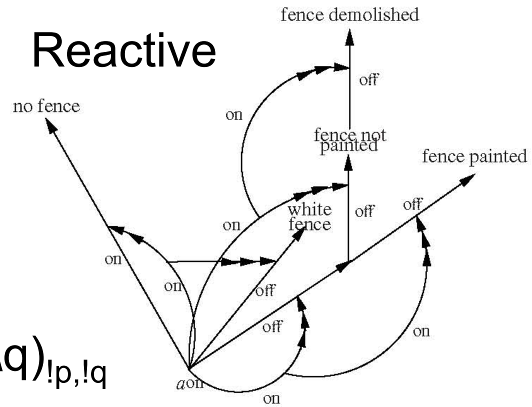
a:b/Oc

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

$q \wedge \neg V(n) \rightarrow p$

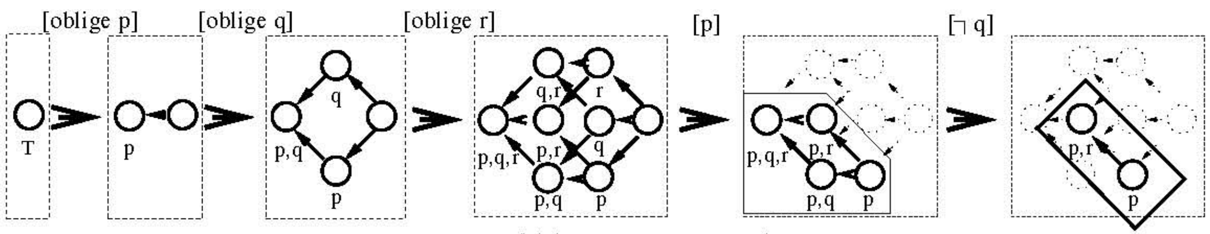
Labeled

$Op_{!p}, Oq_{!q} \rightarrow O(p \wedge q)_{!p,!q}$

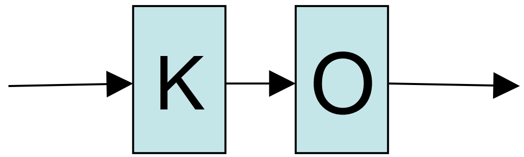
Imperativistic

$!p, !q \rightarrow O(p \wedge q)$

Dynamic



Input/Output



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DSDL family

Slides Xavier

DSDL family

- Trend towards less properties
- Difficult to get axiomatizations
  - Need a simpler approach?

DSDL family

- Trend towards less properties
- Difficult to get axiomatizations
  - Need a simpler approach?

… too eagerly dismiss …

Generalization 5: proof theory

- Boutilier, Lamarre 1991: simulation
- Let ■ be a normal S4.3 modal logic

$$O(A|B)=\Diamond(B \wedge \blacksquare (B \rightarrow A))$$

- Powerful framework for non-monotonic logic
  – And belief revision, and deontic logic

C. Boutilier, Conditional logics of normality: a modal approach, Artificial Intelligence 68 (1994) 87–154.

Generalization 6: PDL

- Von Wright: strengthening of the antecedent
- Hansson 69: there are two kinds of dyadic logic

- J.W. Forrester, Gentle murder, or the adverbial Samaritan, Journal of Philosophy 81 (1984) 193–197.
- L. Goble, A logic of good, would and should, part 1, Journal of Philosophical Logic 19 (1990) 169–199.
- S.O. Hansson, Preference-based deontic logic (PDL), Journal of Philosophical Logic 19 (1990) 75–93.

- Logics without weakening of the consequent

L. van der Torre, Yao-Hua Tan: Contrary-to-duty reasoning with preference-based dyadic obligations. Ann. Math. Artif. Intell. 27(1-4): 49-78 (1999)

Generalisation 6: PDL

- Von Wright: strengthening of the antecedent
- Hansson: there are two kinds of dyadic logic

- In modal preference logic (partial orders):

$$O(A|B)=(A\wedge B)>(\neg A\wedge B)$$

$$\blacksquare((A\wedge B)\rightarrow\blacksquare(B\rightarrow A))$$

- All A worlds are preferred over all $\neg$A worlds
  - No $\neg$A world is preferred to an A world

L. van der Torre, Yao-Hua Tan: Contrary-to-duty reasoning with preference-based dyadic obligations. Ann. Math. Artif. Intell. 27(1-4): 49-78 (1999)

Generalization 7: 2DL

- Combine DSDL and PDL

$$O_{pdl}(A \mid B)$$

$$O_{dsdl}(A \vee C \mid B \wedge D)$$

- Ordering and minimizing is “natural” process
- “Elegant” two phase proof theory

L. Van der Torre, Y.H. Tan. Two-phase deontic logic. Logique et Analyse, volume 43, 2000.

Generalization 8: CoDL

- Combine DSDL and PDL in one formula
  - $O(A \mid B \setminus C)$: A is obligatory if B unless C

$$O(A \mid B \setminus C) = (A \wedge B \wedge C) > (\neg A \wedge B)$$

$$O(A \mid B \setminus T)$$

$$O(A \vee C \mid B \wedge D \setminus A \vee \neg C)$$

- As a Reiter default, or Toulmin scheme

L. van der Torre: Contextual Deontic Logic: Normative Agents, Violations and Independence. Ann. Math. Artif. Intell. 37(1-2): 33-63 (2003)

Generalization 8: MPS

- Maybe we need more preference orders?
  - Multi preference (decision–theoretic) semantics

- Boutilier, N for normality and I for ideality:

$$G(A \mid B) = I(A \mid N(B))$$

- Alternatively:

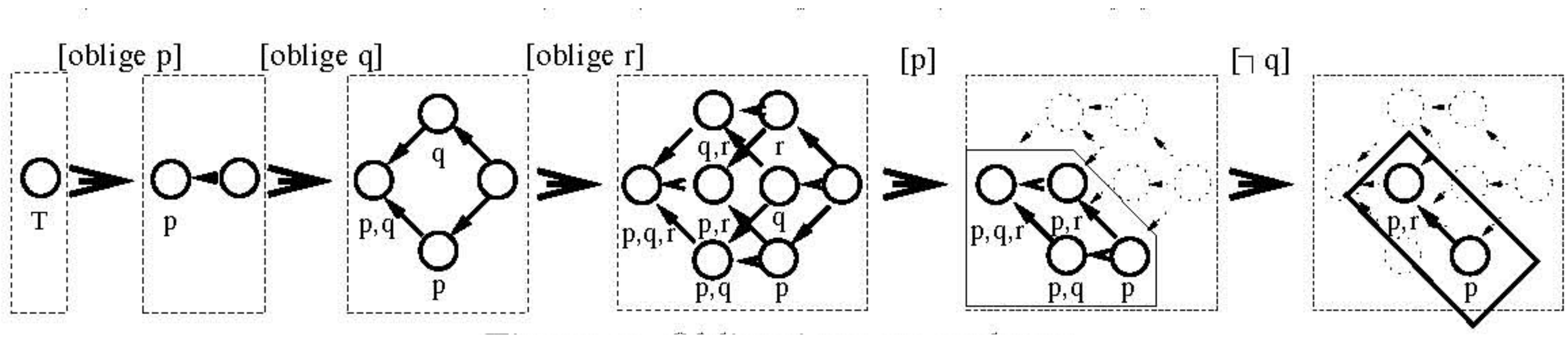
$$O(A \mid B) = N(A \land B) > N(\neg A \land B)$$

- Further studied in qualitative decision theory

Yao-Hua Tan, L. van der Torre: Why Defeasible Deontic Logic needs a Multi Preference Semantics. ECSQARU 1995: 412-419

Generalisation 9: DUS

- Jorgensen's dilemma: no truth values
  - Use Veltman's update semantics



L. van der Torre, Y. Tan. An update semantics for deontic reasoning. In Proceedings of Deon'98, 1998.

Advantages DSDL family?

Advantages DSDL family?

- Representation of violations
  - Theory of diagnosis, in propositional logic?
- Intuitive representation of the CTD paradoxes
  - Combining preference orders?
- Modal logic: combining reasoning
  - Combining preference orders?
  - BDI_{CTL}, agreement technologies?

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Deontic Logic Founded on NML

- Horty formalizes van Fraassen's 1973 account
  - Reasoning about dilemmas
  - Concerned with consistent aggregation
    - Classical problem from paraconsistent logic
- Reiter's default logic instead of preferences
  - Rules generate extensions
  - $O(A|B), O(\neg A|B), B$
  - Extensions $Cn(A), Cn(\neg A)$

John F. Horty: Deontic Logic as Founded on Nonmonotonic Logic. Ann. Math. Artif. Intell. 9(1-2): 69-91 (1993)

Causal Deontic Logic

- Dynamic interventions and static observations
  - explained and unexplained abnormalities

- Declarations and assertions
- Creating an obligation for another agent and evaluating whether such deontic states hold
- Power and permission to create obligations and permissions

L. van der Torre, Causal deontic logic. In Proceedings of the Fifth Workshop on Deontic Logic in Computer Science (Deon'2000), Toulouse, 2000.

diOde and diO(de)2

- Reiter's theory of diagnosis
  - Principle of parsimony: minimize abnormalities
- Use it for deontic reasoning?
  - diOde: The agent has to minimize norm violations
  - diO(de)2: Extension with norm fulfillments

n:O(A|B) $B \wedge \neg V(n) \rightarrow A$

L. van der Torre, Yao-Hua Tan: Diagnosis and Decision Making in Normative Reasoning. Artif. Intell. Law 7(1): 51-67 (1999)

Labeled Deontic Logic

- Inspired by Gabbay labeled deductive systems
  - Index each obligation by the norms from which it is derived, and use these labels in derivations

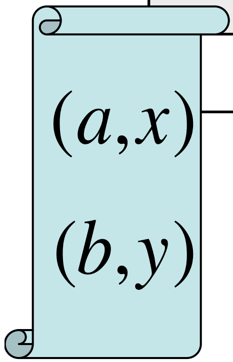
$$O(A,B)_{O(A|B)}$$

$$O(A \vee C | B \wedge D)_{O(A|B)}$$

- 3 pages in my PhD thesis, basis of Makinson98

ΔEON00: Input/Output Logic

- Makinson & vdTorre: proof system for iterative



Norms (& Imperatives)	Obligations
Rule	Application
Law	Case
$(a,x) \in N$	$x \in out(N,a)$

$x \in out(N,a)$

- Numerous IO logics (seven studied in JPL00)
  - Iterative and other kinds of detachment

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

IOL Semantics: Detachment

	Input	T	a	¬a	b	a∧b	a∧¬b	a∧b∧c	…
N=(a,x),(b,y)	out_1(N,Input)	T	x	T	y	x∧y	x	x∧y	…

- Example: out_1 = simple-minded output

1. (a,x): If input implies a, then output implies x
2. Each out_1(N,Input) is closed under "Cn"

$$N(A) = \{x \mid (a,x) \in N, a \in A\}$$

$$Out_1(N,a) = Cn(N(Cn(a)))$$

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

IOL Derivibility

- Let N be set of pairs of formulas (rules)
- $Deriv_i(N)$ is closure under set of rules (+RLE)
  - $Deriv_1$:SI,WO,AND
  - $Deriv_2$:SI,WO,AND,OR
  - $Deriv_3$:SI,WO,AND,CT
  - $Deriv_4$:SI,WO,AND,OR,CT

$$\frac{(a,x)}{(a\wedge b,x)}\text{SI} \quad \frac{(a,x\wedge y)}{(a,x)}\text{WO} \quad \frac{(a,x)\quad(a,y)}{(a,x\wedge y)}\text{AND} \quad \frac{(a\wedge b,x)\quad(a\wedge\neg b,x)}{(a,x)}\text{OR} \quad \frac{(a,b)\quad(a\wedge b,x)}{(a,x)}\text{CT}$$

- $Deriv_i^+$: $Deriv_i$ and ID

$$\frac{}{(a,a)}\text{ID}$$

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

Example IOL Derivibility

- $N=\{(a\wedge b,x),(a\wedge\neg b,x),(x,y)\}$ $A=\{a\wedge c\}$
- Query: Is y obligatory in out_4?

- I.e.: y in $out_4(\{(a\wedge b,x),(a\wedge\neg b,x),(x,y)\},a\wedge c)$?
  - $deriv_4$: SI, WO, AND, OR, CT

$$\cfrac{\cfrac{\cfrac{(a\wedge b,x)\quad(a\wedge\neg b,x)}{(a,x)}\,\text{OR}\qquad\cfrac{(x,y)}{(a\wedge x,y)}\,\text{SI}}{(a,y)}\,\text{CT}}{(a\wedge c,y)}\,\text{SI}$$

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

Soundness & Completeness

- Soundness $(a,x) \in deriv_1(N) \Rightarrow x \in out_1(N,a)$
  - E.g., SI $Cn(N(Cn(a))) \subseteq Cn(N(Cn(a \wedge b)))$

- Completeness $(a,x) \in deriv_1(N) \Leftarrow x \in out_1(N,a)$
  - Assume

    $x \in Cn(N(Cn(a)))$
  - Then

    $(a_1,x_1),(a_2,x_2),\ldots(a_n,x_n) \in N$

$$\dfrac{\dfrac{\dfrac{(a_1,x_1)}{(a,x_1)}\,\text{SI} \quad \dfrac{(a_2,x_2)}{(a,x_2)}\,\text{SI} \quad \cdots \quad \dfrac{(a_n,x_n)}{(a,x_n)}\,\text{SI}}{(a,\ x_1 \wedge x_2 \wedge \ldots \wedge x_n)}\,\text{AND}}{(a,\ x)}\,\text{WO}$$

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

Out_1 Tarskian Consequence

$$(a,x) \in out'(N) \Leftrightarrow x \in out(N,a)$$

- Reflexivity (Law2Case principle)

$$N \subseteq out'(N) \qquad (a,x) \in N \Rightarrow x \in out(N,a)$$

- Monotony

$$out'(N_1) \subseteq out'(N_1 \cup N_2)$$

- Idempotence (strong Case2Law principle)

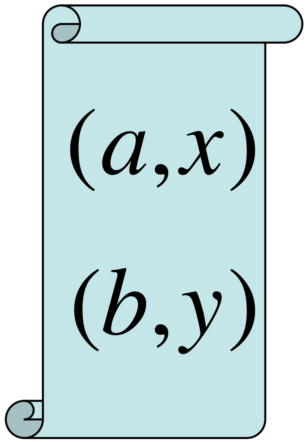
$$out'(N) = out'(out'(N))$$

- In general, this does not have to be the case!

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

Law2Case Bridge Principle

If



then

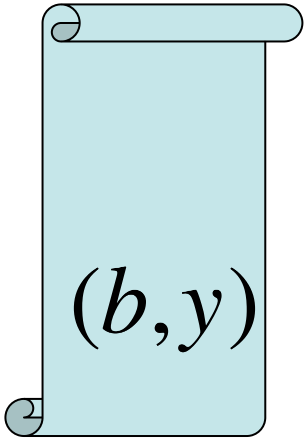
$$(a,x) \in N \qquad\qquad x \in out(N,a)$$

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

Strong Case2Law Bridge Principle

If

then



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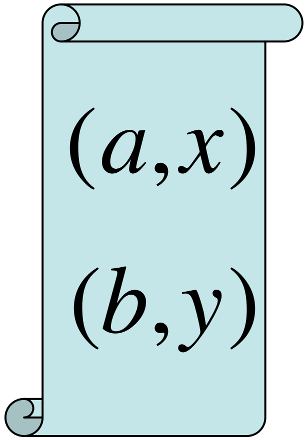


$$x \in out(N,a)$$

$$\forall A : out(N,A) = out(N \cup (a,x),A)$$

D. Makinson and L. van der Torre, Input/output logic. Journal of Philosophical Logic, 29: 383-408, 2000.

IOL Semantics: Constraints

- Needed for dealing with violations (CTD)

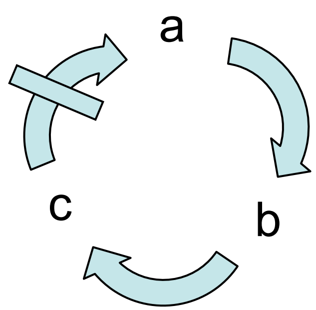
- A and C are sets of formulas
- Maxfamily(N,A.C) = maximal subsets of N
  - such that Out(N,A) is consistent with C

- Outfamily(N,A,C) = out restricted to maxfamily

D. Makinson and L. van der Torre, Constraints for input/output logics. Journal of Philosophical Logic, 30(2): 155-185, 2001.

Example: Rule Maximality

- Outfamily({(a,b),(b,c),(c,¬a)},{a},{a})=…



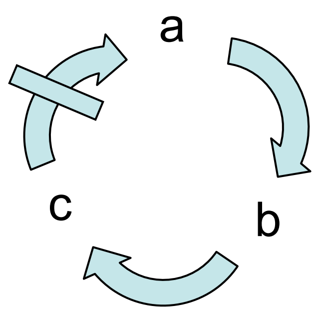
D. Makinson and L. van der Torre, Constraints for input/output logics. Journal of Philosophical Logic, 30(2): 155-185, 2001.

Example: Rule Maximality

- Outfamily({(a,b),(b,c),(c,¬a)},{a},{a})=…

- Maxfamily({(a,b),(b,c),(c,¬a)},{a},{a})=…

- {(a,b),(b,c)}
- {(a,b),(c,¬a)}
- {(b,c),(c,¬a)}



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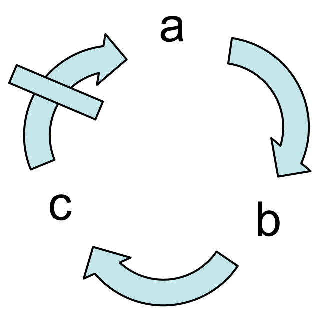
Example: Rule Maximality

- Outfamily({(a,b),(b,c),(c,¬a)},{a},{a})=…

- Maxfamily({(a,b),(b,c),(c,¬a)},{a},{a})=…

- {(a,b),(b,c)} Cn({b,c})
- {(a,b),(c,¬a)} Cn({b})
- {(b,c),(c,¬a)} Cn({})



D. Makinson and L. van der Torre, Constraints for input/output logics. Journal of Philosophical Logic, 30(2): 155-185, 2001.

Proof System Constrained Output?

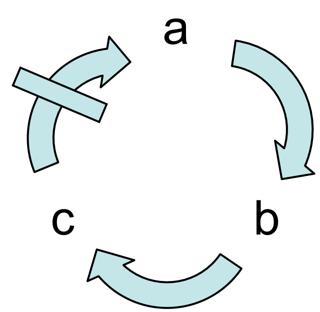
- We have proof system for input/output logic
  - Goes beyond iterative
- How about constrained output?
  - JPL01: constraints on derivations, globally or locally
- How to define a closure operation for outfamily?

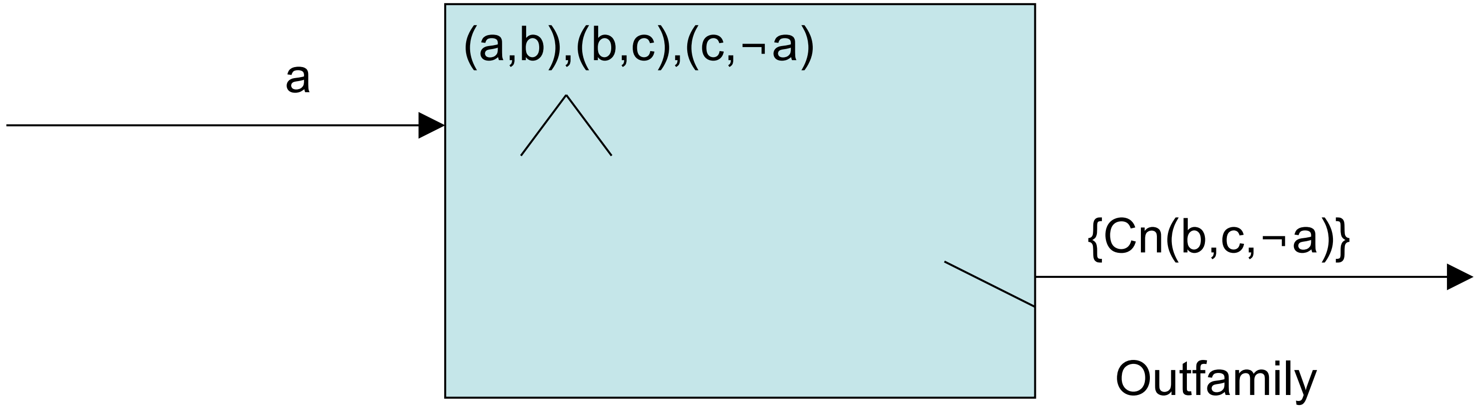
$$(a,x) \in outfamily(N)$$

$$\exists E \in outfamily(N,a,C) : x \in E$$

D. Makinson and L. van der Torre, Constraints for input/output logics. Journal of Philosophical Logic, 30(2): 155-185, 2001.

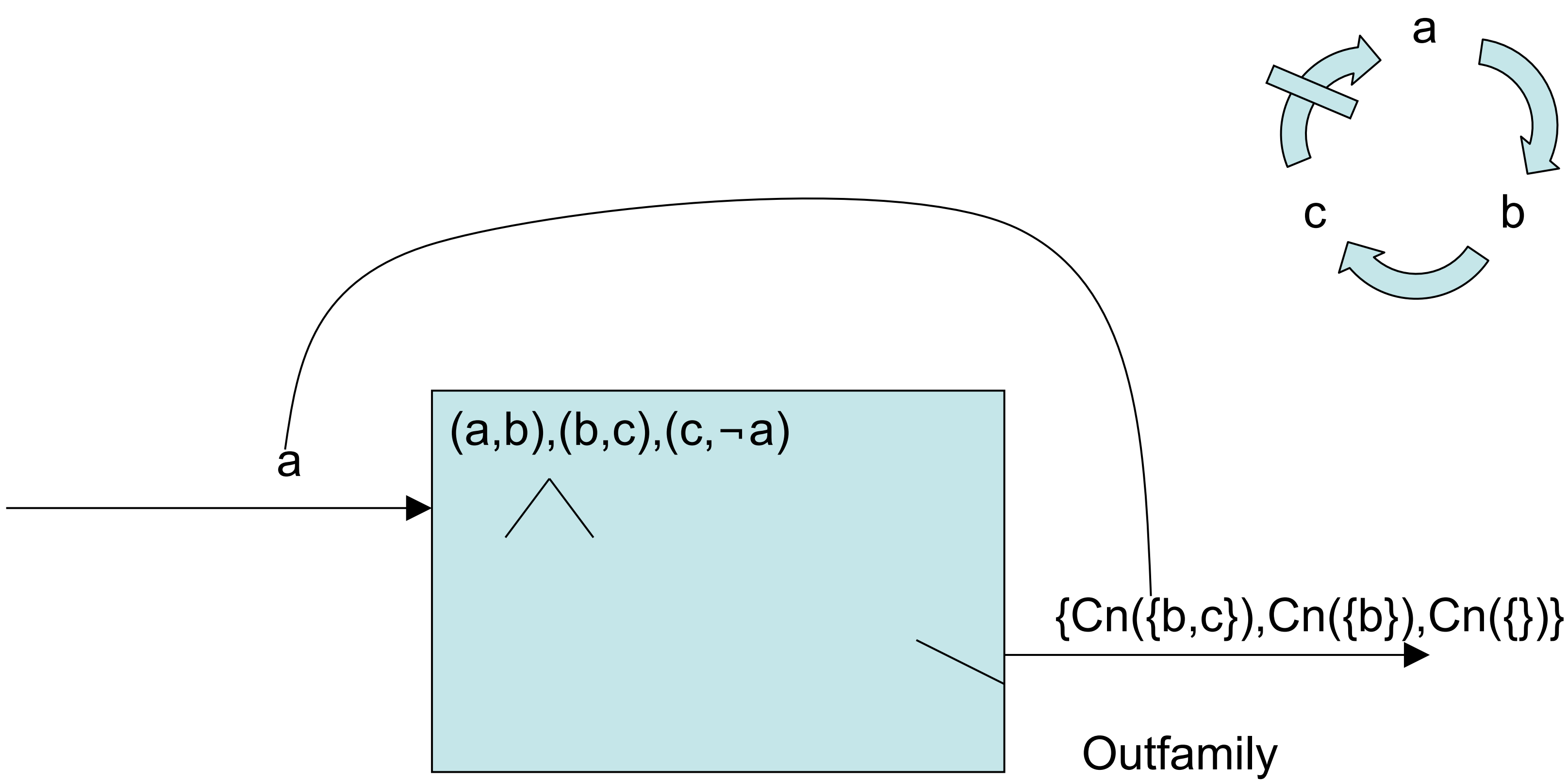
Output Constraint





D. Makinson and L. van der Torre, Constraints for input/output logics. Journal of Philosophical Logic, 30(2): 155-185, 2001.

Input/Output Constraint



D. Makinson and L. van der Torre, Constraints for input/output logics. Journal of Philosophical Logic, 30(2): 155-185, 2001.

Constraints

- Maxfamily(N,A) = maximal subsets of N
  1. such that Out(N,A) consistent, or
  2. such that Out(N,A) consistent with A
- Outfamily = out restricted to maxfamily

- For each member of outfamily, there is a unique member of maxfamily generating it
- Proof (e.g. out_1): if N1 generates E, and N2 generates E, then N1+N2 generates E

D. Makinson and L. van der Torre, Constraints for input/output logics. Journal of Philosophical Logic, 30(2): 155-185, 2001.

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   – DSDL3, G, CO, PDL, 2DL, CoDL, MPS, DUS
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   – Input/output logic, Out1-8, Outfamily
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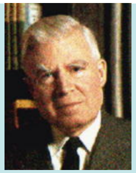
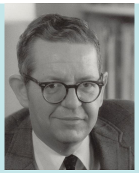
   – Reasoning for normative multiagent systems
5. Concluding remarks

NORMAS

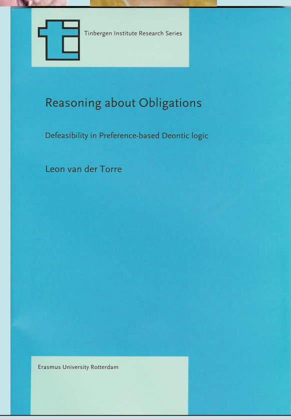
Histoire d' O

O	V	CTD	>	*Extensions*	DEON	*Applications*	Violation Games
1951	1958	1963	1969		1990	1997	2007

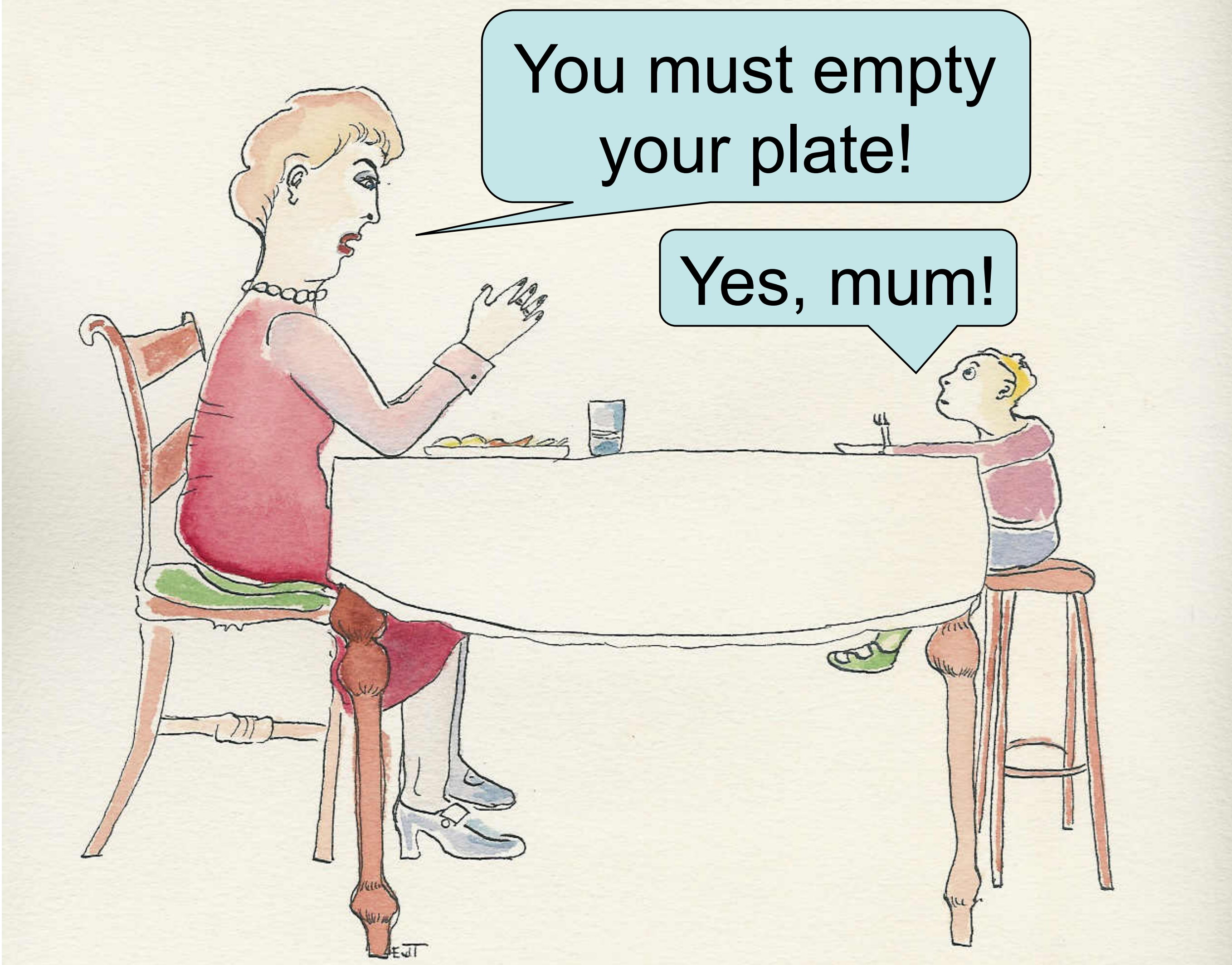





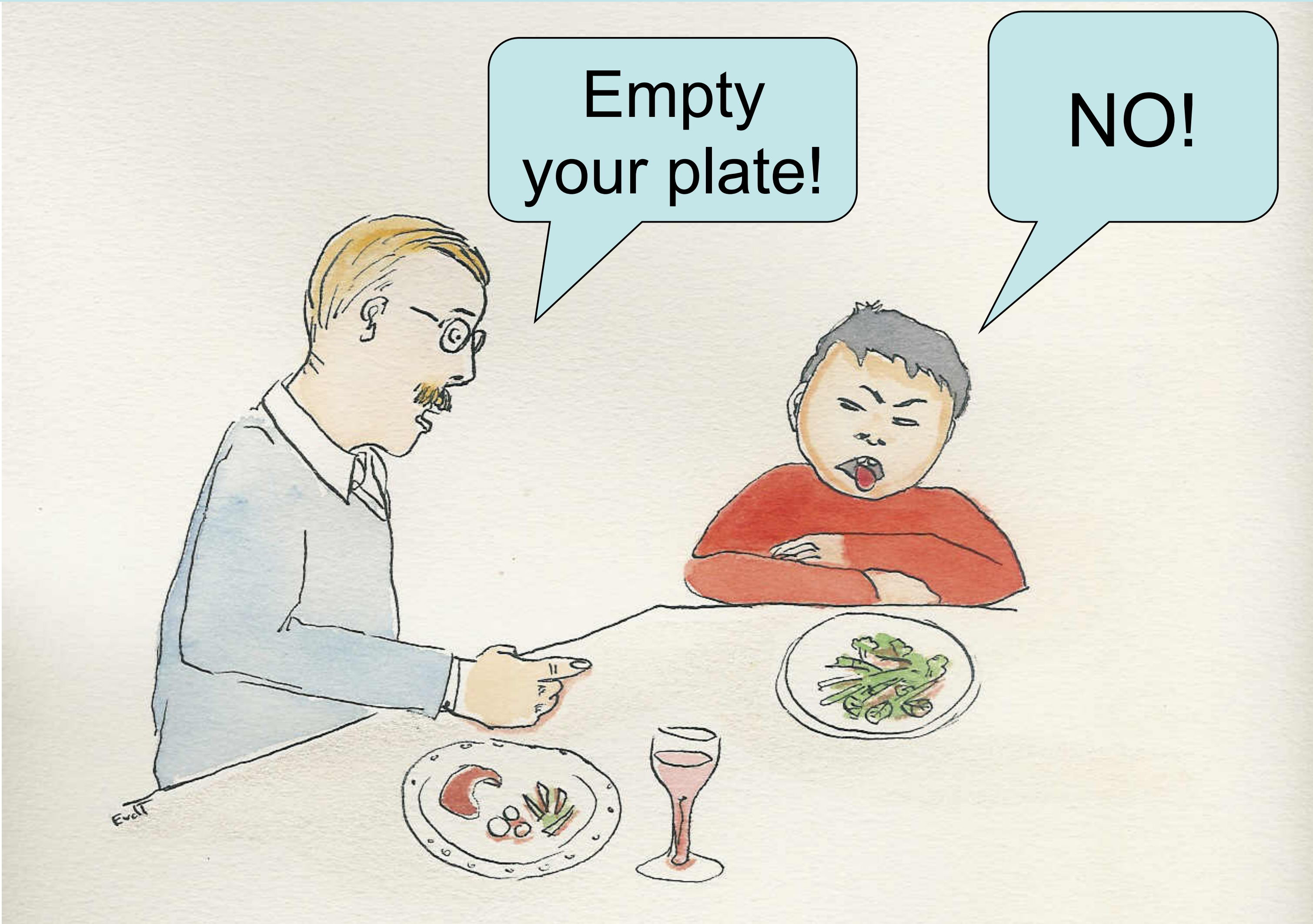




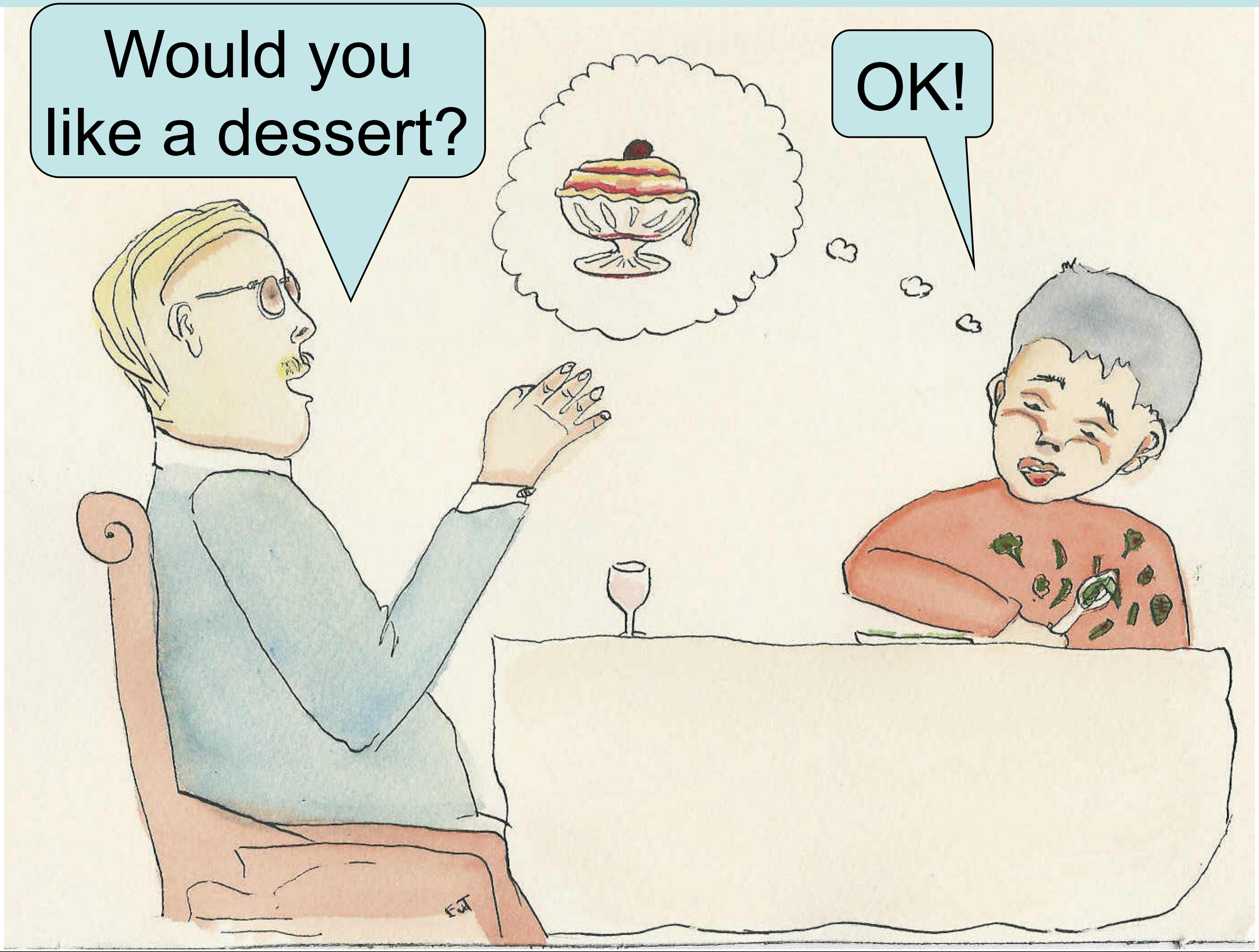
Violation Game 1: Conformance



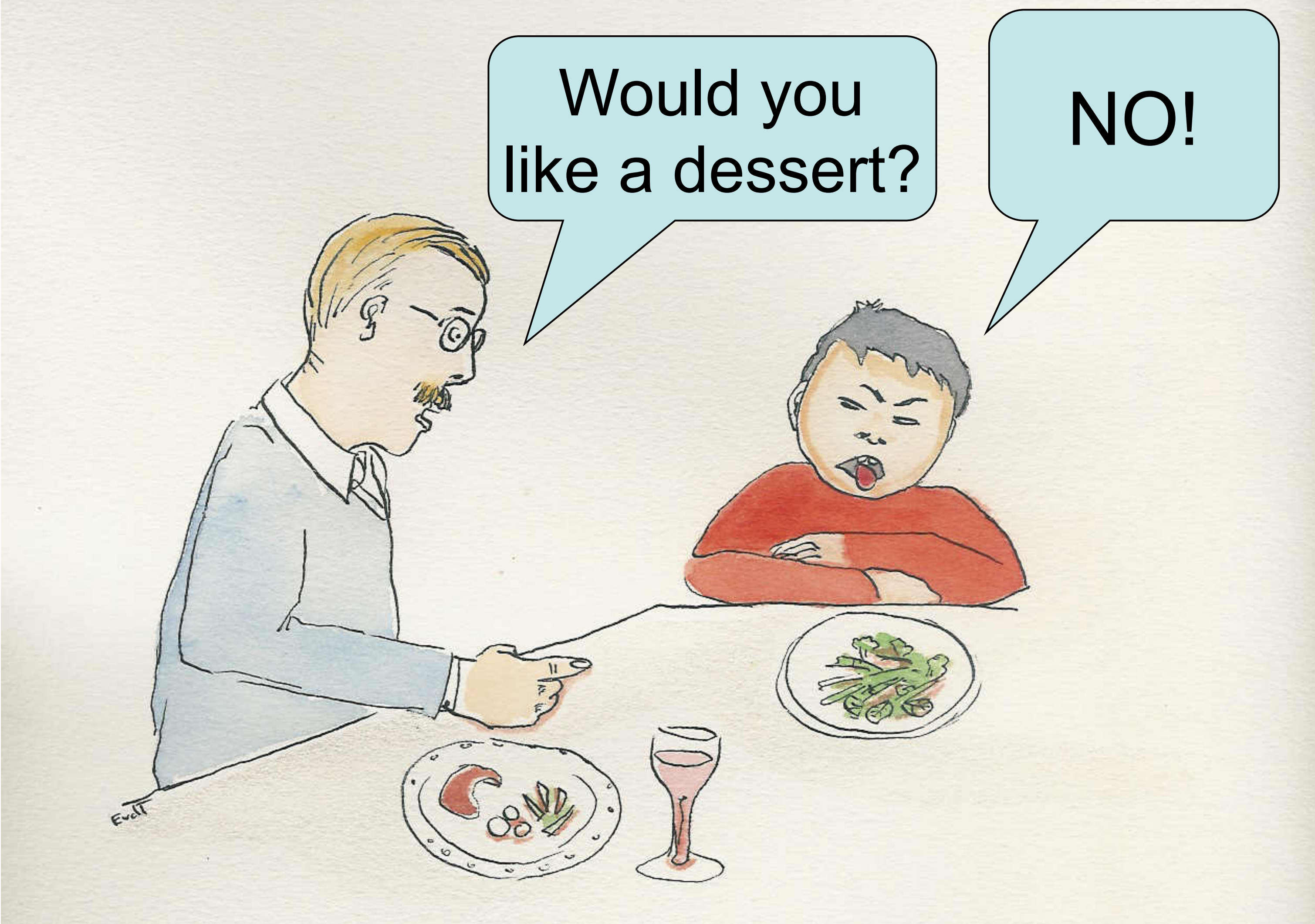
Violation Games: Problem



Violation Game 2: Incentives

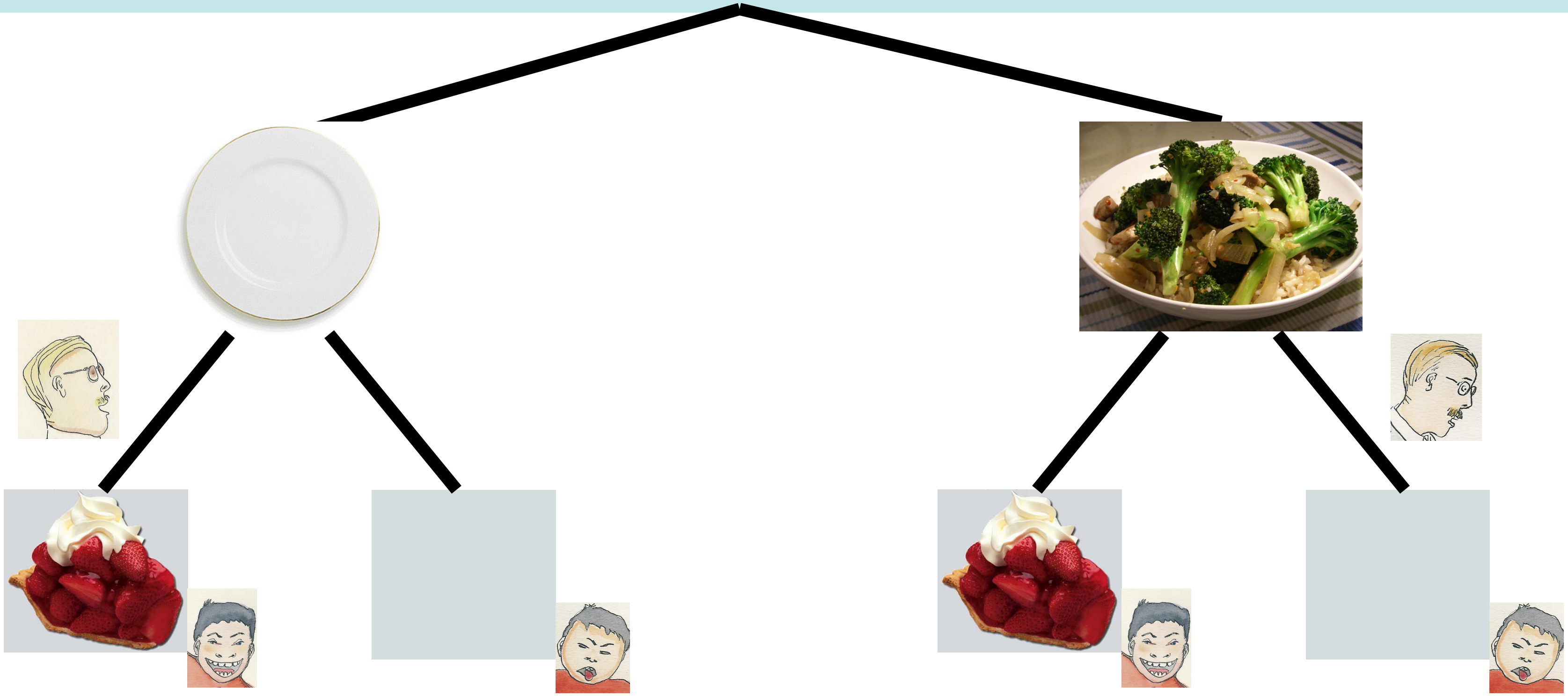


Violation Games: Problem



Violation Game 3: Negotiation

Logic of Violation Games

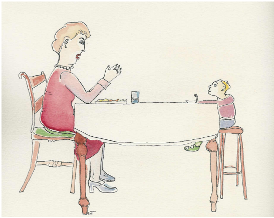


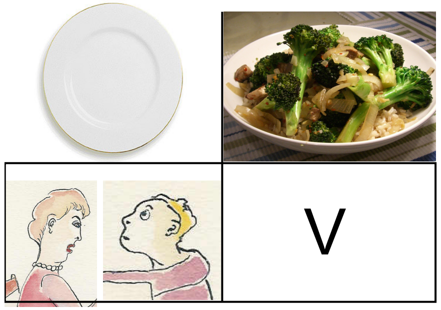
O() = if , then is expected

$$Ox = E(\neg x \rightarrow V)$$

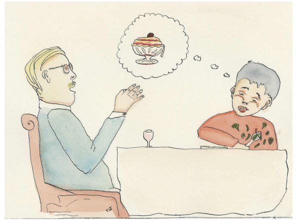
Logic of Violation Games

1. Conformance

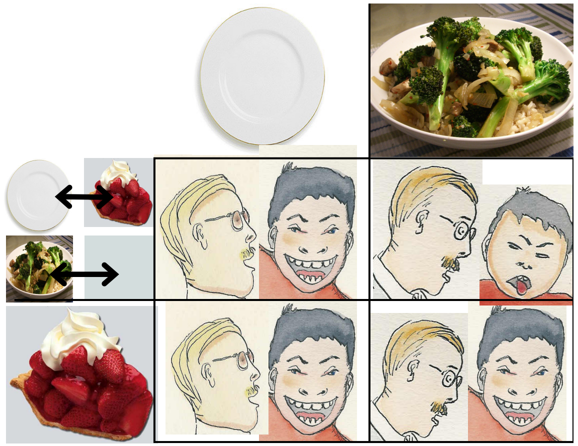




2. Incentives

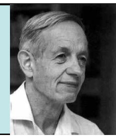


3. Negotiation



O() =  with is equilibrium

Ox = stable (¬x : V)



Normative Automata

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DSDL Generalizations

1. Nested conditionals (G)
2. Dilemmas (DSDL2)
3. Preference
4. Simulation in modal logic (CO)
5. Truth conditions (PDL)
6. Two phase (2DL)
7. Three place conditionals (CoDL)
8. Decision theoretic (MPS)
9. Jorgensen's dilemma (DUS)

Norm / Rule Based Semantics

- Norm / Rule Based systems
  - Deontic logic founded on nonmonotonic logic
  - Causal deontic logic
  - Labeled deontic logic
  - Input/output logic
- New challenges
  - Normative multiagent systems, games
  - Normative automata

Preference

Lesson 1: Economics

Pr

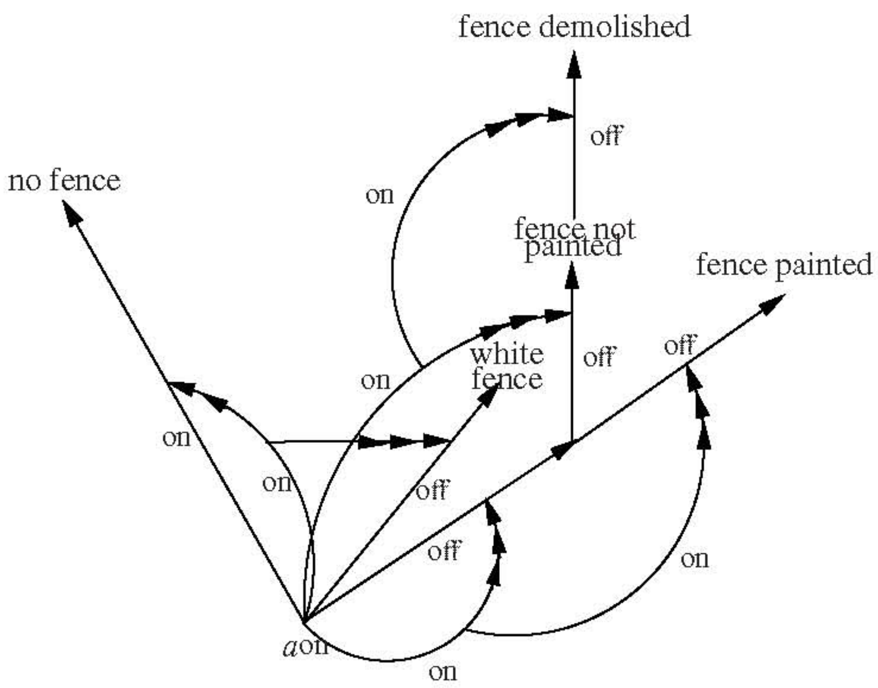
Problems

Problems

Arrow's theorem

Lesson 2: Modal Logic

Modal logic is a fragment of first order logic



Gabbay's reactive deontic logic

Modal Logic

- 7 input/output logic conditionals in modal logic:
  - Unnatural and complicated
- Non-monotonic modal logic:
  - NML1 in 1980, auto-epistemic logic
  - Project “abandoned”
- Modal preference logic:
  - Boutilier left the topic and went to economic quantitative theory
- It can be done…

Modal Logic

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Lesson 3: Handbook

Methodology

What is a good deontic logic?

Methodology

What is a good deontic logic?

- There are five clusters of challenges:
- (i) problems having to do with right upward monotonicity (Ross' Paradox, Professor Procrastinate),
- (ii) moral dilemmas,
- (iii) information sensitivity (Miners Paradox),
- (iv) the interpretation of certain deontic conditionals (such as *if p, ought p*),
- (v) issues surrounding the (non-)gradability of deontic modal expressions.

Methodology

What is a good deontic logic?

1. O(A|A)
2. Strong permissions
3. Mobius strip

Methodology

What is a good deontic logic?

Expressive power? Complexity?

Methodology

What is a good deontic logic?

Expressive power? Complexity?

= Turing machine

Methodology

What is a good deontic logic?

Formalizing the Talmud

- It has to be natural
- It has to be useful

My Applications

- Violation vs exception (1997 PhD thesis)
- Compliance checking
- Agent architecture
- Norm change
- Mechanism design NORMAS
- Agreement technologies

Norm Change

Out(N)

out1((a,x))

In	T	a	¬a	avb	a∧b	a∧¬b	a∧b∧c	…
out1(N,In)	T	x	T	T	x	x	x	…

$\div(a \wedge b, x)$

-x (a) -x (a∧b) -x (a∧b∧c)

Out(N')

out1((a∧¬b,x))

In	T	a	¬a	avb	a∧b	a∧¬b	a∧b∧c	…
out1(N,In)	T	T	T	T	T	x	T	…

$\oplus(a \wedge b, x)$

+x (a∧b) +x (a∧b∧c)

out1((a∧¬b,x),(a∧b,x))

In	T	a	¬a	avb	a∧b	a∧¬b	a∧b∧c	…
out1(N,In)	T	T	T	T	x	x	x	…

G. Boella, G. Pigozzi and L. van der Torre, A normative framework for norm change. *Proceedings of International Conference on Autonomous Agents and MultiAgent Systems (AAMAS)*, 2009.

http:\\deonticlogic.org