Tutorial Normative Reasoning and Decision Making

Guido Boella & Gabriella Pigozzi & Leon van der Torre

Agreement Technologies

- WG1: “Semantics”
- WG2: “**Norms**”
- WG3: “Organizations”
- WG4: “Argumentation and Negotiation”
- WG5: “Trust”

Some Norms

- You are obliged to return the book in 2 weeks
- Role X is permitted to access resource Y
- Actions of agent X count as actions of agent Y
- Advocates should act in the interest of their clients
- Violations should be sanctioned
- Don’t do to them what you don’t want them to do to you
- People should know the law
- Every adult has the right to vote
- Make your homework!
- We start at 09:00

Merriam-Webster Online Dictionary

- ‘normative’: ‘conforming to or based on norms’,
  - as in normative behavior, normative judgments
  - not: ‘of, relating to, or determining norms or standards’, as in normative tests, or ‘prescribing norms’, as in normative rules of ethics or normative grammar.
- ‘norm’: ‘a principle of right action binding upon the members of a group and serving to guide, control, or regulate proper and acceptable behavior’.
  - Not: ‘an authoritative standard or model’, ‘an average like a standard, typical pattern, widespread practice or rule in a group’, and various definitions used in mathematics.

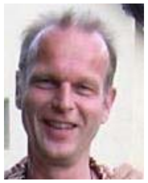
Normative Systems (1971)

“When a deductive correlation is such that the first sentence of the ordered pair is a case and the second is a solution, it will be called normative. If among the deductive correlations of the set there is at least one normative correlation, we shall say that the set has normative consequences. A system of sentences which has some normative consequences will be called a normative system.”

C. Alchourron and E. Bulygin. Normative Systems. Springer, 1971.

Normative Systems (1993)

- Normative systems are "systems in the behavior of which norms play a role and which need normative concepts in order to be described or specified"



J.-J. Meyer and R. Wieringa. Deontic Logic in Computer Science: Normative System Specification. John Wiley & Sons, 1993.

- Many distinct notions of "normative systems"
  – Social expectation, legal law, linguistic imperative…
- Role of norms in computer science is changing
  – Solutions based on multiagent systems increasing

Layout

- Challenges due to uncertainty and imprecision in normative reasoning and decision making

1. Normative reasoning in computer science
2. Imprecision & uncertainty normative systems
3. Decision making in normative systems
4. Norm change

AgentLink RoadMap (2003)

	Short Term	Medium Term	Long Term
oftware	Peer to peer Better development tools Agent UML Service oriented computing	Generic designs for coordination Libraries for agent-oriented development	Best practice in agent systems design
Agreed Standards	FIPA ACL Peer to peer Better development tools Service oriented computing Semantic description	Flexible business/trading languages Libraries of interaction protocols	Tools for evolutions of communications languages and protocols
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	Shared, improved ontologies
Reasoning in 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 strategies	Automated eScience systems and other application domains
Learning Technologies	Adaptation Personalisation Hybrid technologies	Evolving Agents Self organisation Distributed learning	Run-time reconfiguration and re-design
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	Trust techniques for coping with malicious agents

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

2005: Normative MultiAgent Systems

- are multiagent systems with normative systems
- in which agents can decide whether to follow the explicitly represented norms, and
- the normative systems specify how and in which extent the agents can modify the norms.''

G. Boella, L. van der Torre, H. Verhagen, Introduction to normative multiagent systems. *Computational and Mathematical Organization Theory, double special issue on normative multiagent systems,* 2006.

"The normchange definition"

2007: Normative MultiAgent System

- is a multiagent system organized by means of
- mechanisms to represent, communicate, distribute, detect, create, modify, and enforce norms, and
- mechanisms to deliberate about norms and detect norm violation and fulfillment."

G. Boella, L. van der Torre, and H. Verhagen, Introduction to the special issue on normative multiagent systems. *Autonomous Agents and MultiAgent Systems,* Aug. 2008.

"The mechanism design definition"

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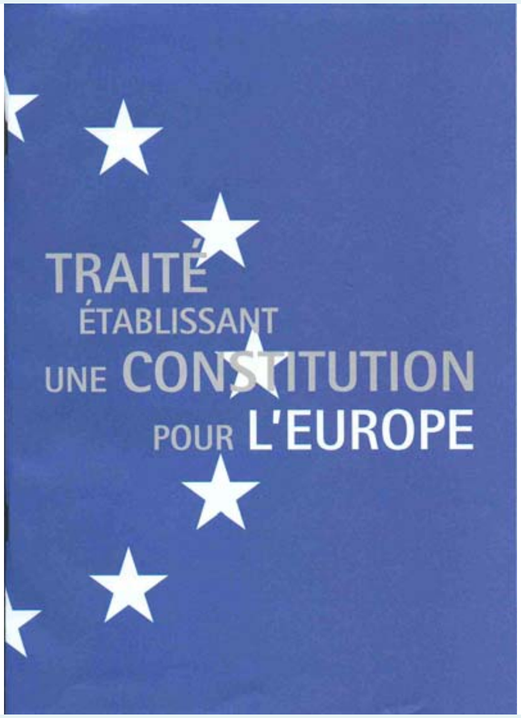
Norms: Certain and Precise?

- Norms are rules to distinguish right from wrong.

- Dilemmas: when may we shoot down a hijacked plane?

Violations: Certain and Imprecise?

- Norms describe what counts as a violation.



- Budget deficit > 3 % of GDP is a violation?

Design: Uncertain and Imprecise

- Norms are rules to guide, control or regulate behavior.

- What are the effects of new norms on behavior?

Guide, Control, Regulate Behavior

What's new with respect to constraints?

Guide, Control, Regulate Behavior

Ways to deal with violations, representation of permissive norms, the evolution of norms over time (in deontic logic), the relation between the cognitive abilities of agents and the global properties of norms, how agents can acquire norms, how agents can violate norms, how an agent can be autonomous (in normative agent architectures and decision making), how norms are created by legislator, emerge spontaneously or are negotiated among agents, how norms are enforced, how constitutive or counts-as norms are used to describe institutions, how norms are related to social and legal concepts, how norms structure organizations, how norms coordinate groups and societies, how contracts are related to contract frames & contract law, how legal courts are related, how normative systems interact, …

Normative Reasoning

Norms are rules to guide, control or regulate behavior.

Infrastructure for open communities.
Reasoning in open environments.
Trust and reputation.

More than distinguishing right from wrong.
More than describing what counts as a violation.
More than constraints.
Uncertain and imprecise.

Security and Reliability

- Norms make systems more secure & reliable.

- How to prevent over-regulation?

Trust

- Norms build up trust in international trade.

- Which mechanisms for electronic commerce?

Example: ESCROW

- Norms describing coordination
  - Agent communication: sales agreement
  - Agent transaction: payment for shipment
- Norms describing fees and compensation
  - ESCROW gets percentage (from seller or buyer)
  - Return merchandize within 5 days
- Norms ensure fulfillment of some obligations
  - Seller is paid for goods, or goods will be returned
  - (under assumption of trustworthiness of ESCROW)
- Some obligations can still be violated:
  - Seller does not ship goods, shipper unreliable, …



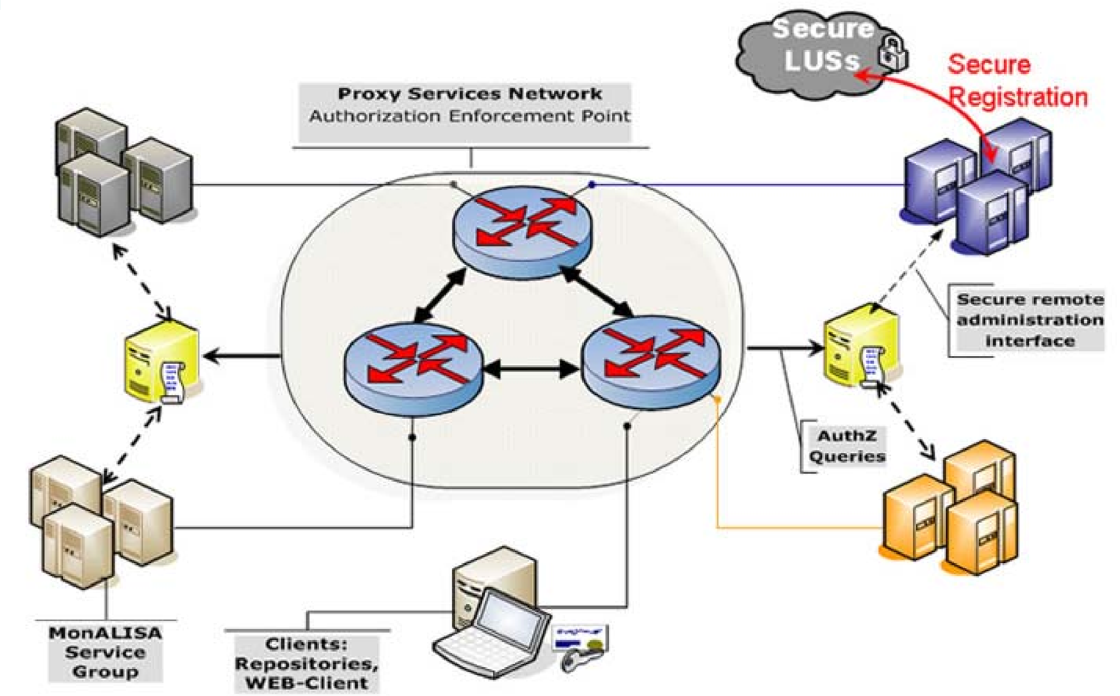
Virtual Communities

- Social norms are emerging in Second Life.

- How to prevent exclusion from communities?

Autonomous Systems

- *aut-* + *nomos*: making ones own norms.



- How to define global policies about local ones?

Applications Normative Reasoning

Norms are rules used to control or regulate behavior.

Risk management for computer security.
Designing trust mechanisms for electronic commerce.
Recognition of emerging social norms in Second Life.
Local and global policies for autonomous systems.

Layout

- Challenges due to uncertainty and imprecision in normative reasoning and decision making

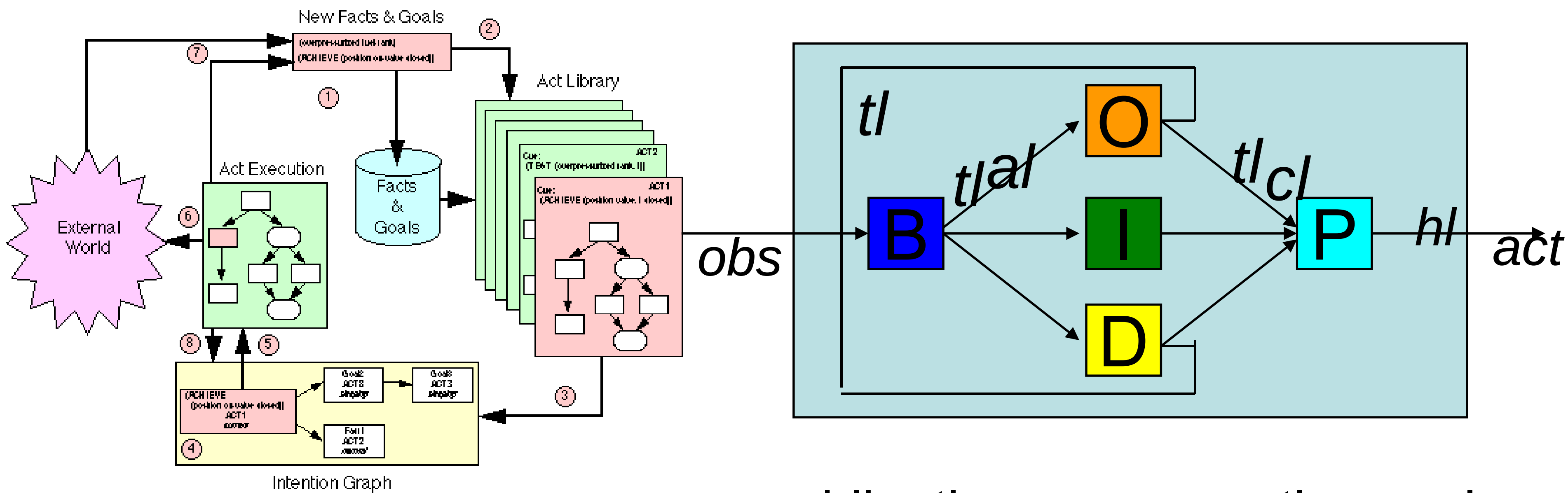
1. Normative reasoning in computer science
2. Imprecision & uncertainty normative systems
3. Decision making in normative systems
4. Norm change

Examples: How to decide …

- … whether to fulfill or violate a norm?
- … whether behavior counts as a violation?
- … whether an excuse for a violation is acceptable?
- … whether a violation should be sanctioned?
- … whether to accept a norm / contract / … ?
- ... whether to accept sanctions of a norm?
- … which contract to propose / norm to create?
- … whether an agent conforms to the norm?
- … whether a procedure is compliant to the norm?
- … on a constitution for Europe?

Basis: Decision Making With Norms

- Introducing obligations in agent architectures



obligations as normative goals

- Introducing obligations in agent programming

Exercise: When Violate a Norm?

- When you are not able to fulfill it
- When the sanction is too low
- When the probability to be caught is too low
- …

Exercise: When Violate a Norm?

- When you are not able to fulfill it
- When the sanction is too low
- When the probability to be caught is too low
- When you don’t know the norm
- When there is another more important desire
- When there is another more important obligation
- When you have a good excuse
- When you like to take risks
- When other agents violate the norm
- When the norm does not make sense

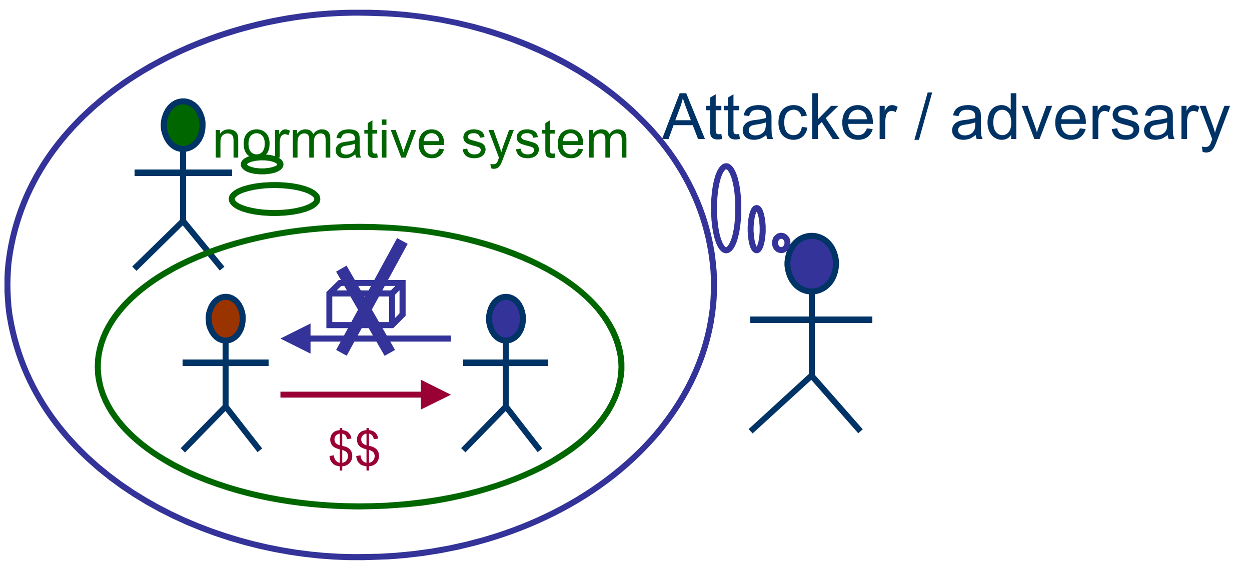
When to Violate/Fulfill: Challenge

- Multiagent structure of a normative system
  - Many agents involved in agent interaction
  - Interaction is highly structured

- Normative system regulates their roles
  - Powers of roles described by counts-as norms, and
  - Their behavior is regulated by procedural norms.

Norm Compliance

- Attacker = agent trying to profit from violation
  - Violation undetected, no sanction, or less than profit



- Anticipate rather than regiment (mechanism design)

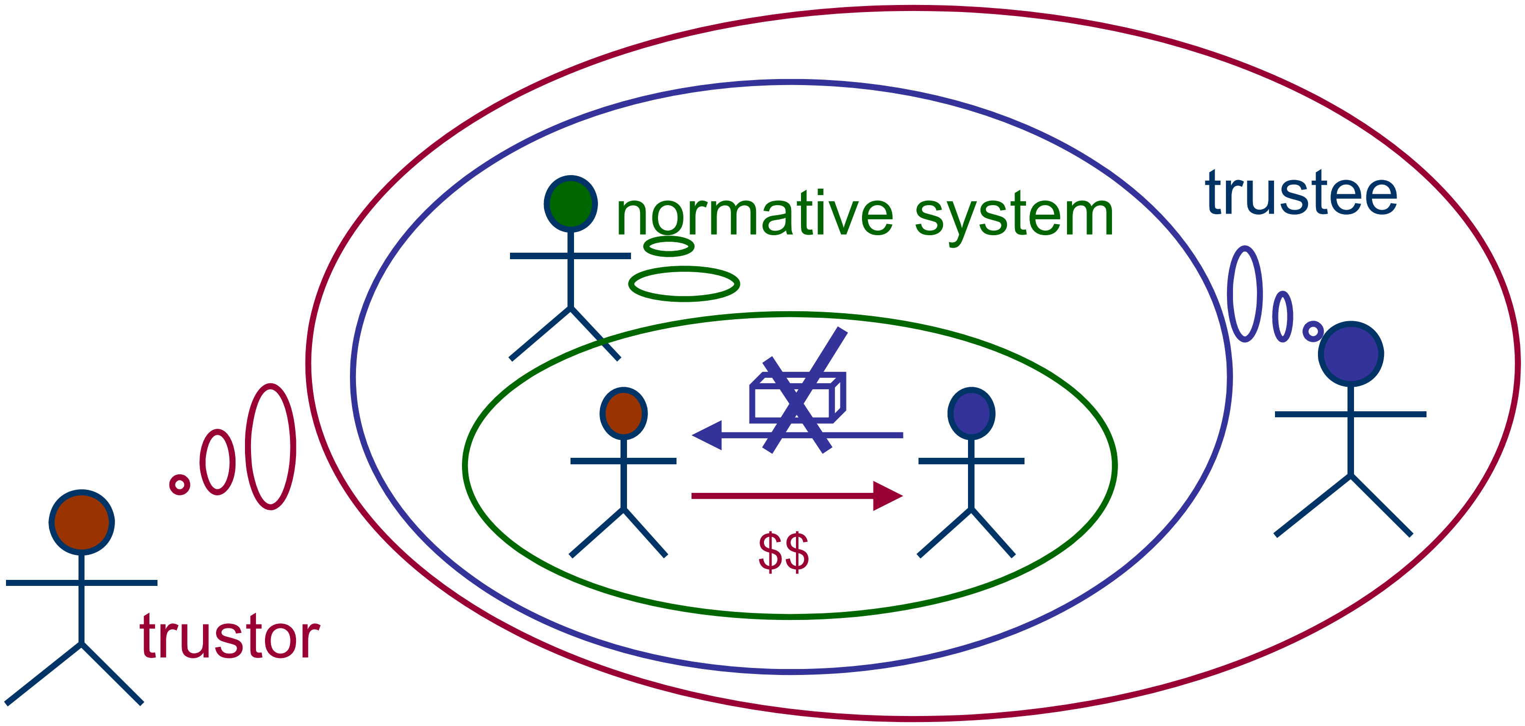
Profile *NS* of Attacker *A* (for *Op*)

1. *NS* desires *p* (“your wish is my command”).
2. Absence of *p* is considered as violation of *A.*
   - Anderson’s reduction of deontic logic to modal logic.
3. *NS* desires that there are no violations.
4. If violation, then *NS* is motivated to sanction.
5. *NS* does not like to sanction.
6. *A* does not like being sanctioned.
7. *NS* has the power to count absence of *p* as violation.
8. *NS* has the power to enforce sanction.

Example: You are obliged to return the book in 2 weeks

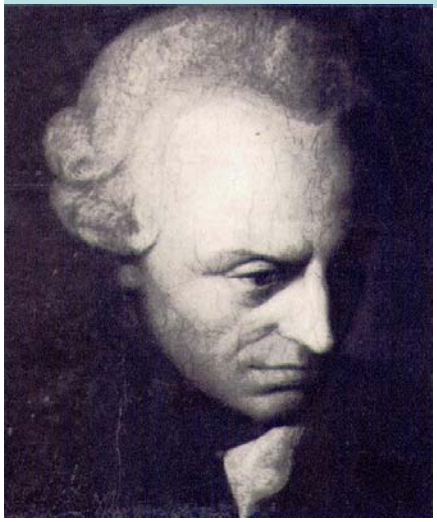
Question: Why do we need all of them? Is it complete?

When to Accept a Contract?

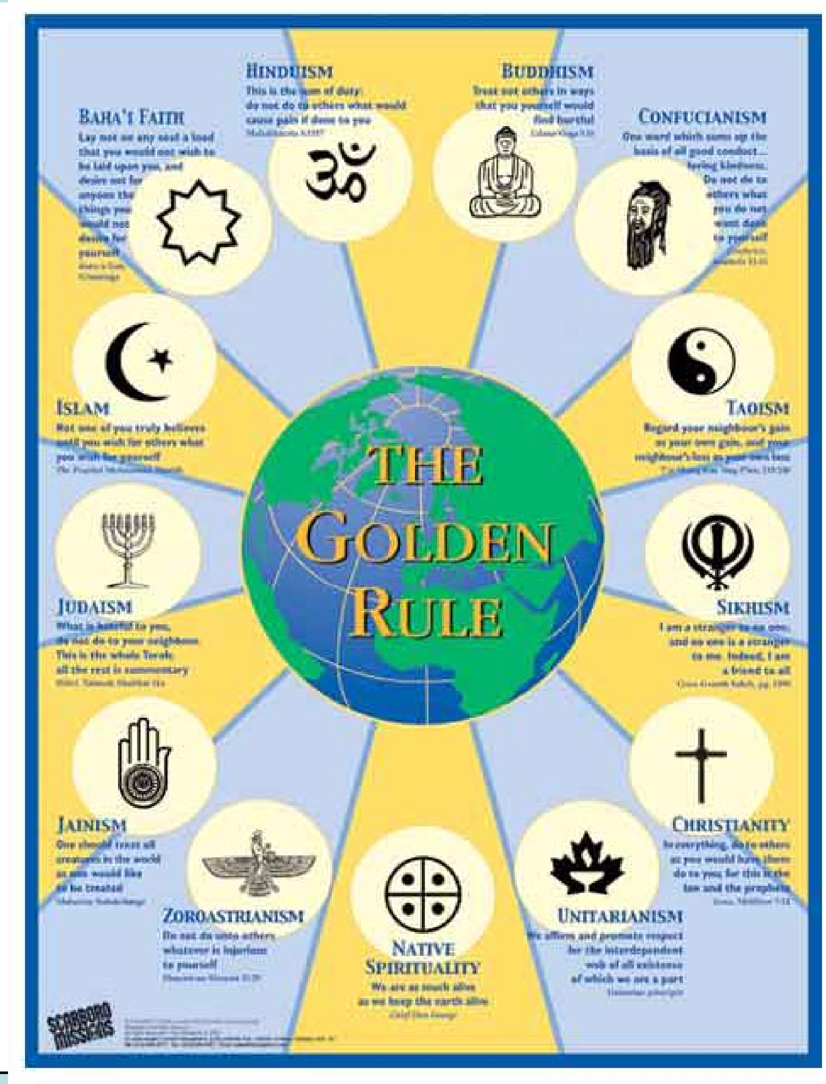


- Decision making of trustor taking profiles of trustee and normative system into account

Challenge: When to Accept a Norm

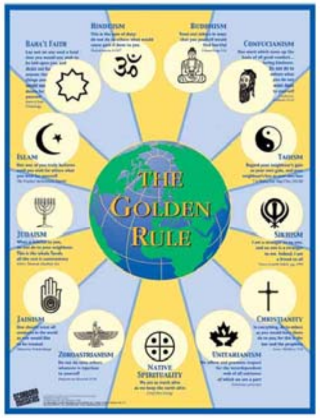


- Immanuel Kant, Metaphysics of Morals, 1785

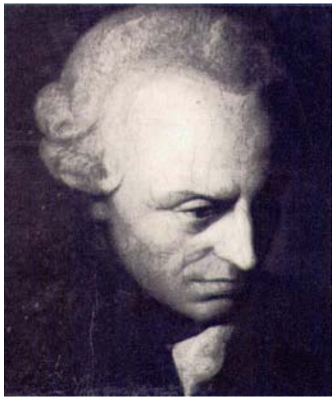


- "Act only according to that maxim whereby you can at the same time will that it should become a universal law."

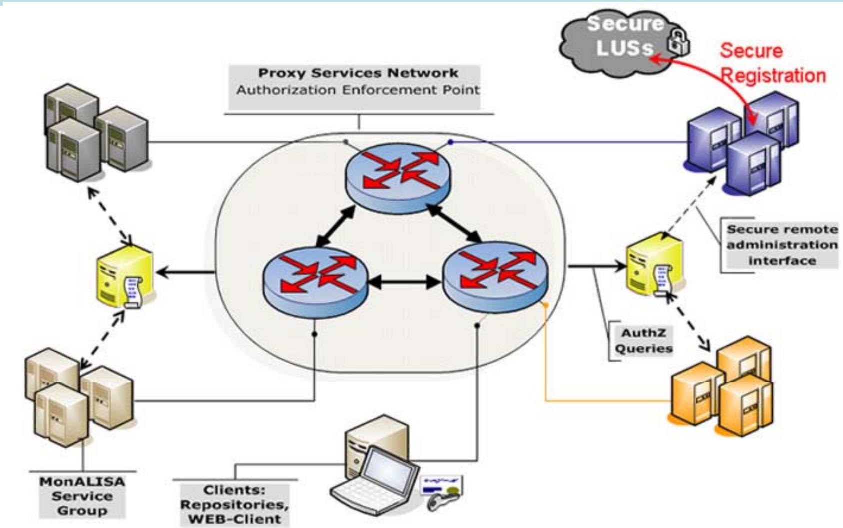
Emergence of Norms



- Don't do to them, what you don't want them to do to you
- Social delegation cycle
  - Agent desires
  - Merging: Social goal
  - Planning: Norm
  - Acceptance: Agent desires
- I accept if you fulfill the norm on the assumption that all others fulfill it

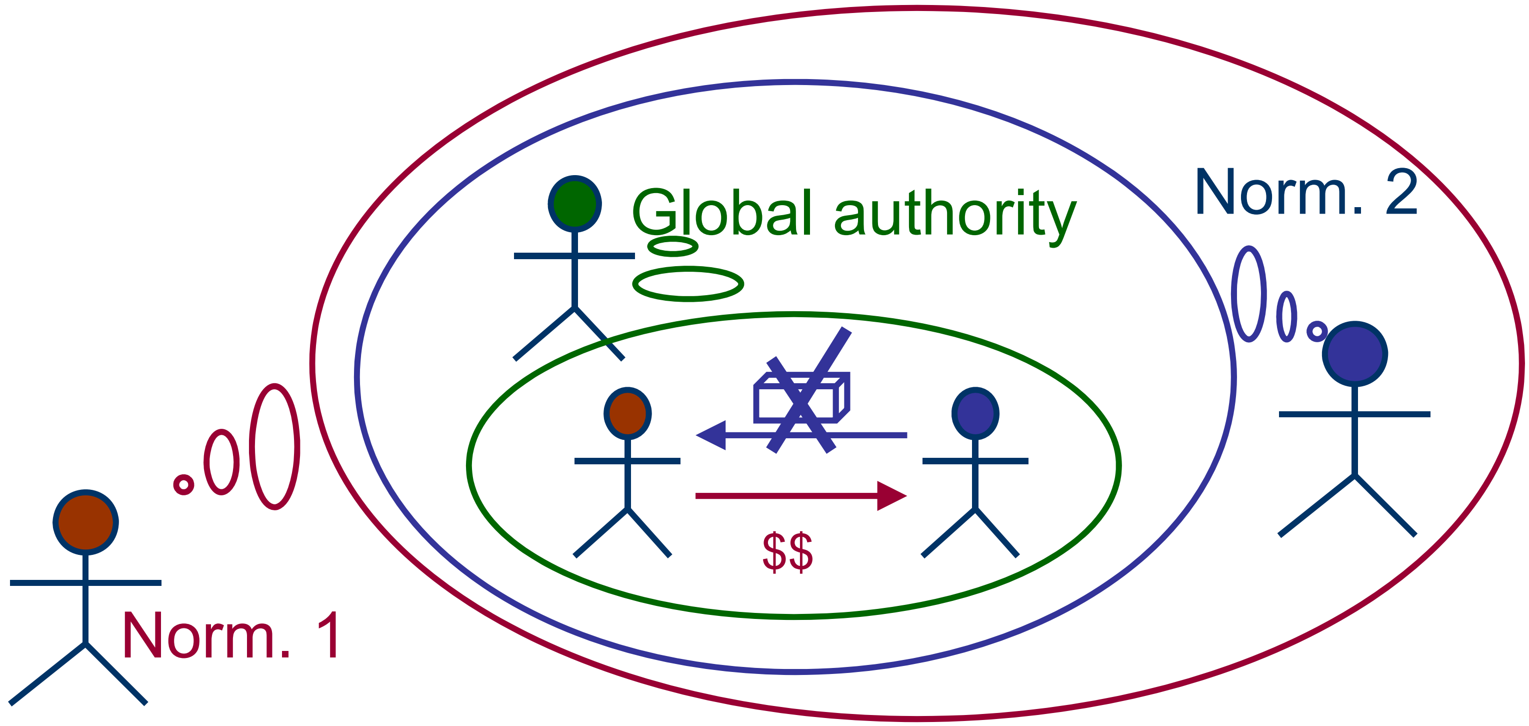


Autonomous Systems



- Legal institutions in context of legal institutions
  - Norm dynamics described by counts-as norms
- Strong permissions in norm creation (Bulygin)
- Global policies about local policies
  - Von Wright: transmission of will by nested norms

Hierarchical Normative Systems



- Decision making of norm. system 1 taking profiles of norm. system 2 and global authority into account

Decision Making in NMAS

Norms are rules used to control or regulate behavior.

Norm conformance and compliance.
Multiagent structure of normative systems.
Norm acceptance for emergence of norms.
Hierarchical normative systems for autonomy.

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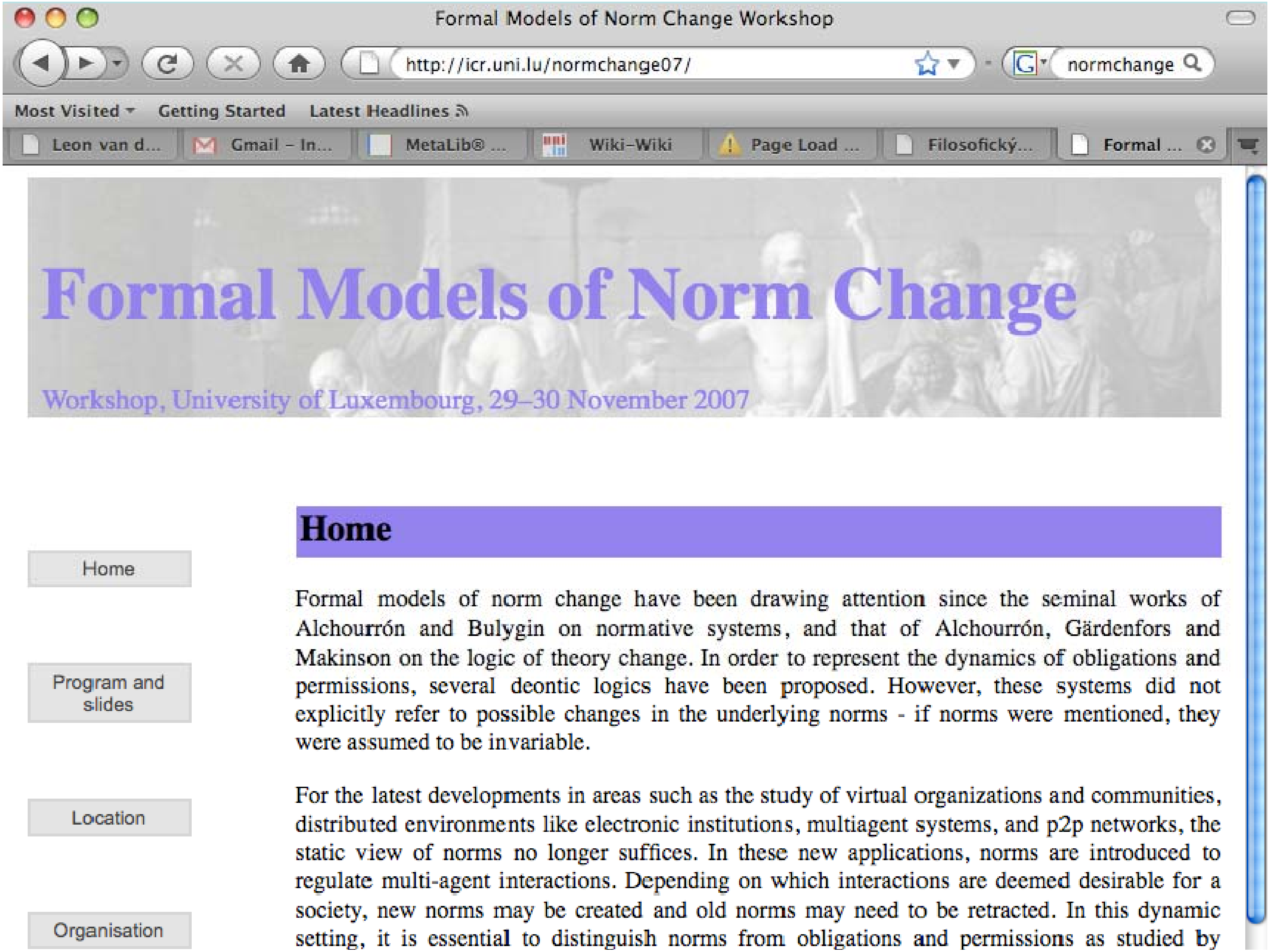


Formal Models of Norm Change

Workshop, University of Luxembourg, 29–30 November 2007

Home

Program and slides

Location

Organisation

Home

Formal models of norm change have been drawing attention since the seminal works of Alchourrón and Bulygin on normative systems, and that of Alchourrón, Gärdenfors and Makinson on the logic of theory change. In order to represent the dynamics of obligations and permissions, several deontic logics have been proposed. However, these systems did not explicitly refer to possible changes in the underlying norms - if norms were mentioned, they were assumed to be invariable.

For the latest developments in areas such as the study of virtual organizations and communities, distributed environments like electronic institutions, multiagent systems, and p2p networks, the static view of norms no longer suffices. In these new applications, norms are introduced to regulate multi-agent interactions. Depending on which interactions are deemed desirable for a society, new norms may be created and old norms may need to be retracted. In this dynamic setting, it is essential to distinguish norms from obligations and permissions as studied by

Norm Change

4.1. Abstract model for norm change

4.2. Norm contraction

4.3. Norm revision

- Conceptual framework based on Makinson and van der Torre's input/output logic (JPL00, 01, 03)

G. Boella, G. Pigozzi and L. van der Torre, A normative framework for normative change, Proceedings of AAMAS09.

Philosophical Foundations

period	tradition	main issue
50s	monadic modal logic	relation O and P
60s	dyadic modal logic	relation O and facts, violations, sub-ideality and optimality, CTD
70s	temporal deontic logic	relation O and time
80s	action deontic logic	relation O and actions
90s	defeasible deontic logic	dilemmas, CTD
00s	imperatives, normative systems	Jorgensen's dilemma

Table 4. A schematic reconstruction of deontic logic

Modern deontic logic started in 1969:

don't refer to the prehistory of deontic logic

Input/Output Logic Principles

1. Norms are represented by pairs of formulas
2. Meaning of norms is derivation of obligations
3. Implicit implication among norms
4. Tarskian closure properties norm implication

- MvdT give seven examples of IO logics
  - and sketch a number of directions for further study

IOL-1: Norms are Pairs of Formulas

$$N = \{(a_1, x_1), (a_2, x_2), \ldots, (a_n, x_n)\}$$

– "if a_1, then it is obligatory that x_1", … (thus: rules)

- $a_1, x_1, a_2, x_2, \ldots, a_n, x_n$ propositional formulas

- Others: first-order, temporal, deadlines, primary & secondary, permissive, constitutive, etc.

Exercise

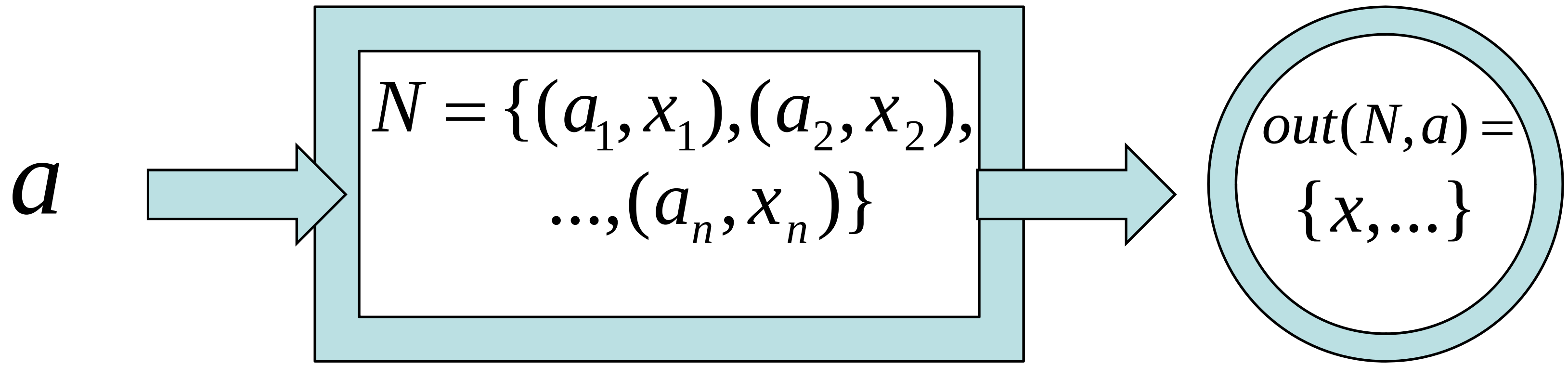
- Give the normative system consisting of two norms stating that the community has to give a house with low rent (house) to low income agents (poor), and to provide free health insurance (healthins) to elderly agents (old).

Solution

- Give the normative system consisting of two norms stating that the community has to give a house with low rent (house) to low income agents (poor), and to provide free health insurance (healthins) to elderly agents (old).

- N = {(poor, house), (old, healthins)}.

IOL-2: Norms Derive Obligations



- $x \in out(N,a)$ ("operational semantics")
- Calculate whether according to normative system N and in context a, a formula x is obligatory
- Others: multiple output sets, structured, etc.
- Other possible uses: determine whether norms are in force, adopted, achieved, violated, etc.

Exercise

- N = {(poor, house), (old, healthins)}

- Represent that the community has to provide a house to someone with no income if no-income implies poor

Solution

- $N = \{(poor, house), (old, healthins)\}$

- Represent that the community has to provide a house to someone with no income if no-income implies poor.

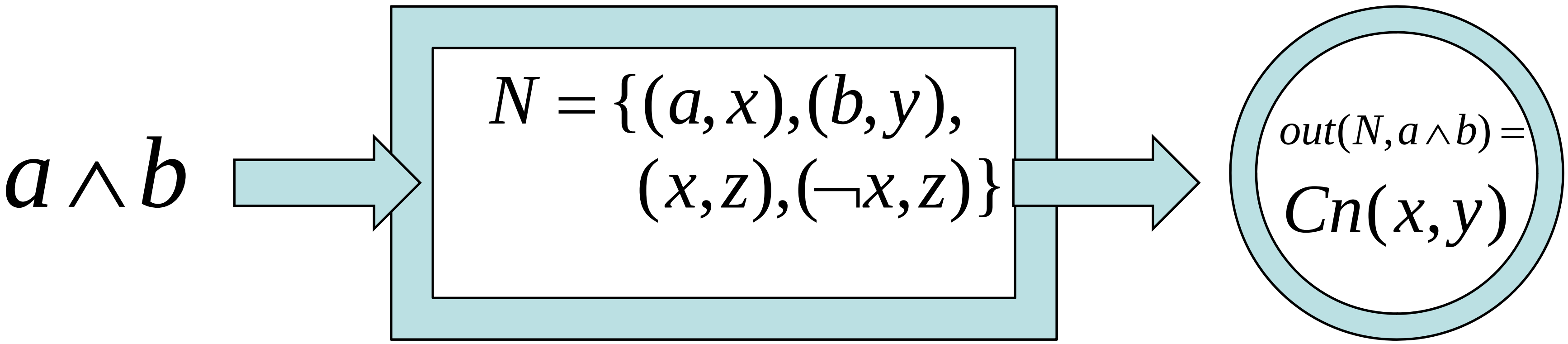
- $house \in out(N, (no\text{-}income \rightarrow poor) \wedge no\text{-}income)$

Irrelevance of Syntax

1. If $x \in out(N,a)$, a is equivalent to b, and x is equivalent to y, then $y \in out(N,b)$

2. If $x \in out(N \cup \{(b,y)\},a)$, b is equivalent to c, y is equivalent to z, then $x \in out(N \cup \{(c,z)\},a)$

Example: out1 = simple-minded output



$$N(S) = \{o \mid i \in S, (i,o) \in N\}$$

$$out_1(N,a) = Cn(N(Cn(a)))$$

Exercise: Why is irrelevance of syntax satisfied?

Exercise

- $N = \{(poor, house), (old, healthins)\}$

- Show that the following holds:
- $house \in out1(N, (no\text{-}income \rightarrow poor) \wedge no\text{-}income)$

Solution

- $N = \{(poor, house), (old, healthins)\}$

- Show that the following holds:
- $house \in out1(N, (no\text{-}income \rightarrow poor) \wedge no\text{-}income)$

- $poor \in Cn((no\text{-}income \rightarrow poor) \wedge no\text{-}income)$
- $(poor, house) \in N$
- $house \in Cn(house)$.

Exercise

- N = {(poor, house), (old, healthins)}
- house $\in$ out1(N, (no-income $\rightarrow$ poor) $\wedge$ no-income)

- What are all the obligations of the community for low income elderly agents?

Solution

- $N = \{(poor, house), (old, healthins)\}$
- $house \in out1(N, (no\text{-}income \rightarrow poor) \wedge no\text{-}income)$

- What are all the obligations of the community for low income elderly agents?

- All logical consequences of giving a house with low rent and providing a free health insurance
- $out1(N, poor \wedge old) = Cn(house \wedge healthins)$

Equivalence

- N and M are equivalent iff for all a

$$out(N,a) = out(M,a)$$

- (a,x) is redundant in N iff
  N is equivalent to $N \setminus \{(a,x)\}$

- This is central and commonly used notion
- But: stronger notions of equivalence studied too

IOL-3: Implication Among Norms

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

- Compare: $a \models x \Leftrightarrow x \in Cn(a)$

- Nota bene:
  - $(a,x) \in out(N)$ is the easy and short notation
  - $x \in out(N,a)$ says what it really means

Example

Out(N)

out1((a,x∧y))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

- Out(N,In) is single output
- Out(N) is set of outputs (for all possible inputs)

- In Out(N,In) we leave out "Cn" for readability

Example: Irrelevance of syntax

$$\frac{x \in out(N,a)}{y \in out(N,b)} \; a \leftrightarrow b, x \leftrightarrow y$$

Example: Irrelevance of syntax

$$\frac{x \in out(N,a)}{y \in out(N,b)} \; a \leftrightarrow b, x \leftrightarrow y$$

- In the alternative representation:

$$\frac{(a,x) \in out(N)}{(b,y) \in out(N)} \; a \leftrightarrow b, x \leftrightarrow y$$

Example: Irrelevance of syntax

$$\frac{x \in out(N,a)}{y \in out(N,b)} \; a \leftrightarrow b, x \leftrightarrow y$$

- When normative system is unambiguous, also:

$$\frac{(a,x)}{(b,y)} \; a \leftrightarrow b, x \leftrightarrow y$$

Exercise

- What does strengthening of the input mean?

$$\frac{(a,x)}{(a \wedge b,x)} \qquad \frac{(a,x) \in out(N)}{(a \wedge b,x) \in out(N)}$$

Solution

- What does strengthening of the input mean?

$$\frac{(a,x)}{(a \wedge b, x)} \qquad \frac{(a,x) \in out(N)}{(a \wedge b, x) \in out(N)} \qquad \frac{x \in out(N,a)}{x \in out(N, a \wedge b)}$$

Exercise

- Strengthening of the input

$$\frac{(a,x)}{(a\wedge b,x)} \qquad \frac{(a,x)\in out(N)}{(a\wedge b,x)\in out(N)} \qquad \frac{x\in out(N,a)}{x\in out(N,a\wedge b)}$$

- What is corresponding rule for weak permission for $\neg x$

$$\langle a,x\rangle \in out(N) \Leftrightarrow x\notin out(N,a)$$

Solution

- Strengthening of the input

$$\frac{(a,x)}{(a\wedge b,x)} \qquad \frac{(a,x)\in out(N)}{(a\wedge b,x)\in out(N)} \qquad \frac{x\in out(N,a)}{x\in out(N,a\wedge b)}$$

- What is corresponding rule for weak permission for $\neg x$

$$\langle a,x\rangle \in out(N) \Leftrightarrow x \notin out(N,a)$$

- Weakening of the input

$$\frac{\langle a\wedge b,x\rangle}{\langle a,x\rangle} \qquad \frac{\langle a\wedge b,x\rangle\in out(N)}{\langle a,x\rangle\in out(N)} \qquad \frac{x\notin out(N,a\wedge b)}{x\notin out(N,a)}$$

IOL-4: Tarskian Consequence

- Reflexivity

$$N \subseteq out(N)$$

- Monotony

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

- Idempotence

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

- What do these properties mean for norms?

IOL-4: Tarskian Consequence

- Reflexivity

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

- Monotony

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

- Idempotence

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

IOL-4: Tarskian Consequence

- Reflexivity

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

- Monotony

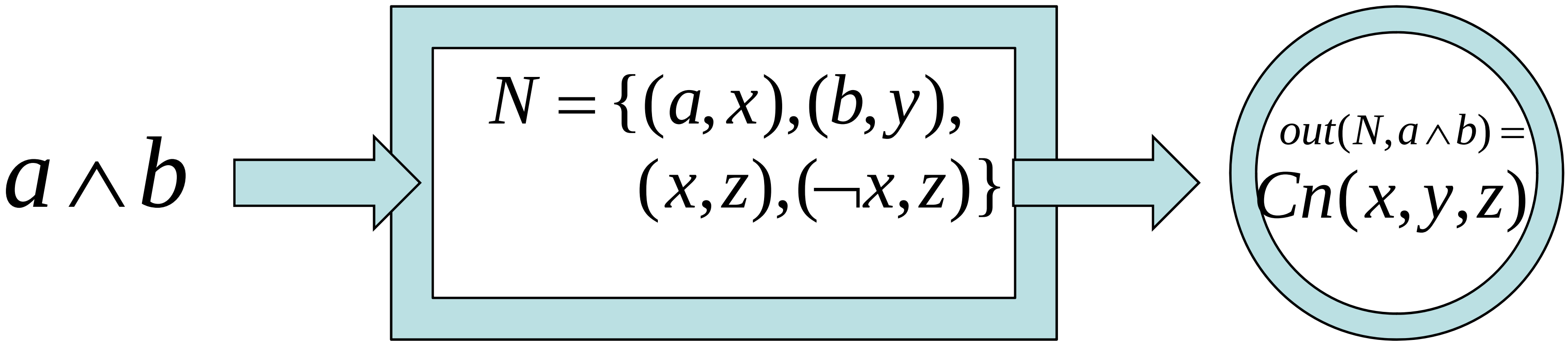
$$out(N_1) \subseteq out(N_1 \cup N_2)$$

- Idempotence

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

- $out(N)$ are "implicit" rules in normative system

Example: out2 = basic output



- V is a conjunction of complete set of literals

$$out_2(N,a) = \cap\{out_1(V) \mid a \in Cn(V), V complete\}$$

Example

Out(N)

out1((a,x∧y))

out2((a,x∧y))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…
Out2(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

Out(N)

out1((a,x),(b,y),(x,z))

out2((a,x),(b,y),(x,z))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x	T	T	x∧y	x	x∧y	…
Out2(N,In)	T	x	T	x\/y	x∧y	x	x∧y	…

Example: out3 = reusable output

$$a \wedge b$$

$$N = \{(a,x),(b,y),(x,z),(\neg x,z)\}$$

$$out(N, a \wedge b) = Cn(x,y,z)$$

$$out_3(N,a) = \cap\{out_1(N,V) \mid a \in Cn(V), out_1(N,V) \subseteq Cn(V)\}$$

Example

Out(N)

out1((a,x∧y))

out2((a,x∧y))

out3((a,x∧y))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…
Out2(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…
Out3(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

Out(N)

out1((a,x),(b,y),(x,z))

out2((a,x),(b,y),(x,z))

out3((a,x),(b,y),(x,z))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x	T	T	x∧y	x	x∧y	…
Out2(N,In)	T	x	T	x∨y	x∧y	x	x∧y	…
Out3(N,In)	T	x∧z	T	T	x∧y∧z	x∧z	x∧y∧z	…

2. Uncertainty and imprecision in normative reasoning
3. Decision making in normative systems
4. Norm change

Input/output Logic Examples

- Output closed under propositional consequence

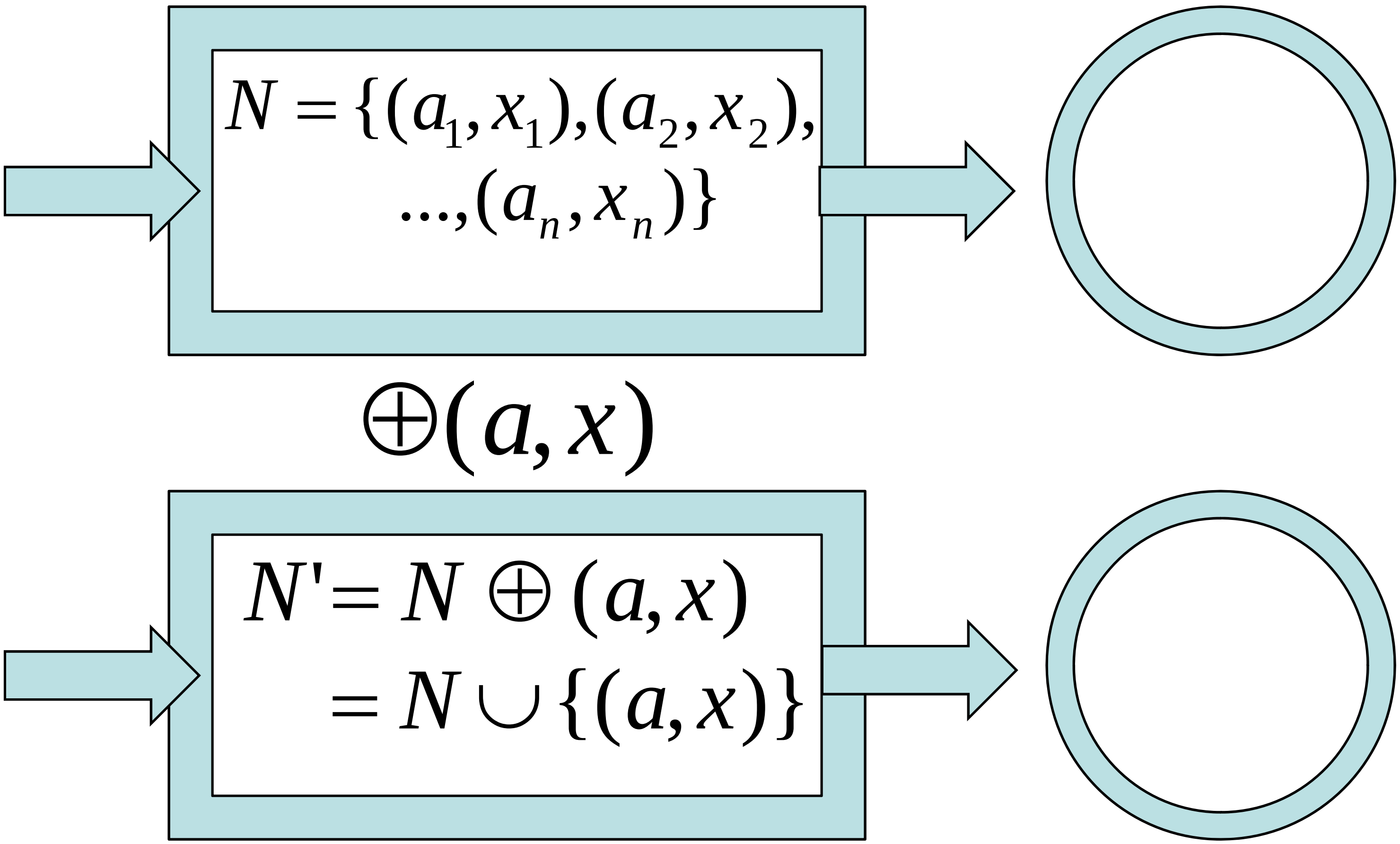
- Out_1: if more input, then more output (SI)
- Out_2: out_1 + reasoning by cases (OR)
- Out_3: out_1 + iterative application of rules (CT)
- Out_4: All of the above
- Out_i^+: Out_i together with reflexivity

Norm Change

- Inspired by belief change:
  - Expansion: $N' = N \oplus (a, x)$
  - Contraction $N' = N \div (a, x)$
  - Revision $N' = N \otimes (a, x)$

(one norm at a time)

Expansion of Norms



$$N = \{(a_1, x_1), (a_2, x_2), \ldots, (a_n, x_n)\}$$

$$\oplus (a, x)$$

$$N' = N \oplus (a, x) = N \cup \{(a, x)\}$$

- Straightforward

Example

Out(N)

out((a,x∧y)) =

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

$\oplus (b, z)$

+z

+z

Out(N‘)

out((a,x∧y),(b,z)) =

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out(N’,In)	T	x∧y	T	T	x∧y∧z	x∧y	x∧y∧z	…

2. Uncertainty and imprecision in normative reasoning
3. Decision making in normative systems
4. Norm change

Example

Out(N)

out1((a,x∧y))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

$$\oplus (b, z)$$

Out(N')

out1 ((a,x∧y),(b,z))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x∧y	T	T	x∧y∧z	x∧y	x∧y∧z	…

Example

Out1(N)

out1((a,x∧y))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

$$\oplus (b, z)$$

+z

+z

Out1(N')

out1 ((a,x∧y),(b,z))

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out1(N,In)	T	x∧y	T	T	x∧y∧z	x∧y	x∧y∧z	…

2. Uncertainty and imprecision in normative reasoning
3. Decision making in normative systems
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Norm Change

4.1. Abstract model for norm change

4.2. Norm contraction

4.3. Norm revision

- Conceptual framework based on Makinson and van der Torre's input/output logic (JPL00,01,03)

G. Boella, G. Pigozzi and L. van der Torre, A normative framework for normative change, Proceedings of AAMAS09.

AGM Contraction Postulates

No norm equivalent for K-7 and K-8

K-1: $K - x$ is a theory — closure (or type)

K-2: $K - x \subseteq K$ — inclusion (contraction)

K-3: If $x \notin K$ then $K = K - x$ — vacuity (min. action)

K-4: If 0 x then $x \notin K - x$ — success

K-5: If $x \in K$ then $K \subseteq (K - x) + x$ — recovery

K-6: If \`$x \leftrightarrow y$ then $K - x = K - y$ — extensionality

K-7: $((K - x) \cap (K - y)) \subseteq K - (x \wedge y)$ — min-conjunction

K-8: If $x \notin K - (x \wedge y)$ then $K - (x \wedge y) \subseteq K - x$ — max-conjunction

Norm Contraction Postulates

Let *N* set of norms closed under input/output logic *out.*

N-1: $N \div (a,x)$ is closed under *out* closure (or type)

N-2: $N \div (a,x) \subseteq N$ inclusion (contraction)

N-3: If $(a,x) \notin N$ then $N = N \div (a,x)$ vacuity (min. action)

N-4: If $(a,x) \notin out(\emptyset)$ then $(a,x) \notin N \div (a,x)$ success

N-5: If $(a,x) \in N$ then $N \subseteq (N \div (a,x)) \oplus (a,x)$ recovery

N-6: If $out((a,x)) = out((b,y))$ then $N \div (a,x) = N \div (b,y)$ extensionality

N-1: closure (or type)

K-1: $K - x$ is a theory

N-1: $N \div (a, x)$ is closed under *out*

N-2: Inclusion (contraction)

K-2: $K - x \subseteq K$

N-2: $N \div (a, x) \subseteq N$

N-3: Vacuity (min. action)

K-3: If $x \notin K$ then $K = K - x$

N-3: If $(a,x) \notin N$ then $N = N \div (a,x)$

N-4: Success

K-4: If 0 x then $x \notin K - x$

N-4: If $(a,x) \notin out(\emptyset)$ then $(a,x) \notin N \div (a,x)$

N-4: If $x \notin out(\emptyset, a)$ then $x \notin out(N \div (a,x), a)$

Example

N

out((a,x∧y))

$=$

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

…

…

Example

N

out(($a,x\wedge y$))

=

In	$\top$	a	$\neg a$	$a\vee b$	$a\wedge b$	$a\wedge\neg b$	$a\wedge b\wedge c$	…
Out(N,In)	$\top$	$x\wedge y$	$\top$	$\top$	$x\wedge y$	$x\wedge y$	$x\wedge y$	…

$\downarrow \ominus(a\wedge b,x)$

N'

=

In	$\top$	a	$\neg a$	$a\vee b$	$a\wedge b$	$a\wedge\neg b$	$a\wedge b\wedge c$	…
Out(N',In)					y			…

Example

N

out((a,$x \wedge y$))

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

In	$\top$	a	$\neg a$	$a \vee b$	$a \wedge b$	$a \wedge \neg b$	$a \wedge b \wedge c$	…
Out(N,In)	$\top$	$x \wedge y$	$\top$	$\top$	$x \wedge y$	$x \wedge y$	$x \wedge y$	…

N'

out((a,y))

In	$\top$	a	$\neg a$	$a \vee b$	$a \wedge b$	$a \wedge \neg b$	$a \wedge b \wedge c$	…
Out(N',In)	$\top$	y	$\top$	$\top$	y	y	y	…

Example

N

out((a,x∧y)) =

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out(N,In)	T	x∧y	T	T	x∧y	x∧y	x∧y	…

$\downarrow \ominus(a \wedge b, x)$

	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c
	↓	↓ -x	↓	↓	↓ -x	↓ -x	↓ -x

N'

out((a,y)) =

In	T	a	¬a	a∨b	a∧b	a∧¬b	a∧b∧c	…
Out(N',In)	T	y	T	T	y	y	y	…

Example

N

out((a, x∧y))

$\downarrow \ominus(a \wedge b, x)$

N'

out((a,y), (a∧¬b, x∧y))

In	T	a	a∧b	a∧¬b	…
Out(N,In)	T	x∧y	x∧y	x∧y	…

	↓	↓ -x	↓ -x	↓	

In	T	a	a∧b	a∧¬b	…
Out(N’,In)	T	y	y	x∧y	…

2. Uncertainty and imprecision in normative reasoning
3. Decision making in normative systems
4. Norm change

Example

N

$out((a, x \wedge y))$ =

In	$\top$	a	$a \wedge \neg b$	$a \wedge b \wedge c$	…
Out(N,In)	$\top$	$x \wedge y$	$x \wedge y$	$x \wedge y$	…

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

-x

N'

$out((a,y), (a \wedge \neg b, x \wedge y), (a \wedge b \wedge c, x \wedge y))$ =

In	$\top$	a	$a \wedge \neg b$	$a \wedge b \wedge c$	…
Out(N',In)	$\top$	y	$x \wedge y$	$x \wedge y$	…

Another Example

N

out((a,x),(b,y)) $=$

In	$\top$	a	$\neg$a	b	a$\wedge$b	a$\wedge\neg$b	a$\wedge$b$\wedge$c	…
Out(N,In)	$\top$	x	$\top$	y	x$\wedge$y	x	x$\wedge$y	…

$\ominus$(a$\wedge$b,x$\wedge$y)

$\downarrow$	$\downarrow$	$\downarrow$	$\downarrow$ -y	$\downarrow$ -x$\wedge$y	$\downarrow$	$\downarrow$ -x$\wedge$y	

N'

out((a,x)) $=$

In	$\top$	a	$\neg$a	b	a$\wedge$b	a$\wedge\neg$b	a$\wedge$b$\wedge$c	…
Out(N',In)	$\top$	x	$\top$	$\top$	x	x	x	…

Example for Out3

N

$out((a,x),(a \wedge x,y))$

In	$\top$	a	$\neg a$	x	$a \wedge x$	$a \wedge \neg x$	$a \wedge x \wedge b$	…
Out(N,In)	$\top$	$x \wedge y$	$\top$	$\top$	$x \wedge y$	$x \wedge y$	$x \wedge y$	…

$\ominus(a,y)$

N'

$Out((a \wedge x,y))$

In	$\top$	a	$\neg a$	x	$a \wedge x$	$a \wedge \neg x$	$a \wedge x \wedge b$	…
Out(N',In)	$\top$	$\top$	$\top$	$\top$	y	$\top$	y	…

2. Uncertainty and imprecision in normative reasoning
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N-5: recovery

K-5: If $x \in K$ then $K \subseteq (K - x) + x$

N-5: If $(a,x) \in N$ then $N \subseteq (N \div (a,x)) \oplus (a,x)$

Theorem

- Out_1 cannot satisfy N-1 – N-5
  - Example: $(a,x) \notin (\{(a,x)\} \div (a \wedge b, x)) \oplus (a \wedge b, x)$
- Out_2 can satisfy N-1 – N-5
  - There exists a complete V implying a such that $out(N \div (a,x), V) = out(N,V) - x$
- Out_3 cannot satisfy N-1 – N-5
  - Same counterexample as out_1

Example

N

out((a,x)) =

$\top$	a	$\neg a$	$a\vee b$	$a\wedge b$	$a\wedge\neg b$	$a\wedge b\wedge c$	…
$\top$	x	$\top$	$\top$	x	x	x	…

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

-x -x -x -x

N'

out(($a\wedge\neg b$,x)) =

$\top$	a	$\neg a$	$a\vee b$	$a\wedge b$	$a\wedge\neg b$	$a\wedge b\wedge c$	…
$\top$	$\top$	$\top$	$\top$	$\top$	x	$\top$	…

$+(a\wedge b,x)$

+x +x +x

out(($a\wedge\neg b$,x),($a\wedge b$,x)) =

$\top$	a	$\neg a$	$a\vee b$	$a\wedge b$	$a\wedge\neg b$	$a\wedge b\wedge c$	…
$\top$	$\top$	$\top$	$\top$	x	x	x	…

Theorem

- Logical consequences of success criterion for out1, out2 and out3 are inverses of proof rules
- Proof. Follows from obs. 3 of MvdT:JPL3
- The non-repetition property holds for:
  - Out_1 with TAUT, SI, WO, AND
  - Out_2 with TAUT, SI, WO, AND, OR
  - Out_3 with TAUT, SI, WO, CTA

$$\frac{\langle a \wedge b, x\rangle}{\langle a, x\rangle} \qquad \frac{\langle a \wedge b, x\rangle \in out(N)}{\langle a, x\rangle \in out(N)} \qquad \frac{x \notin out(N, a \wedge b)}{x \notin out(N, a)}$$

N-6: Extensionality

K-6: If ` $x \leftrightarrow y$ then $K - x = K - y$

N-6: If $out((a,x)) = out((b,y))$ then $N \div (a,x) = N \div (b,y)$

Norm Change

4.1. Abstract model for norm change

4.2. Norm contraction

4.3. Norm revision

- Conceptual framework based on Makinson and van der Torre's input/output logic (JPL00,01,03)

G. Boella, G. Pigozzi and L. van der Torre, A normative framework for normative change, Proceedings of AAMAS09.

Revision of Norms

$$N = \{(a_1, x_1), (a_2, x_2), \ldots, (a_n, x_n)\}$$

$$\otimes (a, x)$$

$$N' = N \otimes (a, x) = ???$$

- When is expansion of a norm “too much”?

Revision of Norms

$$N' = N \otimes (a, x)$$

- When is a normative system coherent?
  - For all contexts, output is consistent
  - For all contexts, output + context is consistent
  - For all consistent inputs, output is consistent
  - For all $(a, x) \in N$, context a, output consistent
  - …

J. Hansen, G. Pigozzi and L. van der Torre, Ten philosophical problems in deontic logic, Dagstuhl DROPS proceedings 07122, 2007.

AGM Revision Postulates

K*1: $K * x$ is a belief set	closure (or type)
K*2: $x \in (K * x)$	success
K*3: $K * x \subseteq K + x$	inclusion (contraction)
K*4: If $\neg x \notin K$ then $K + x = K * x$	vacuity
K*5: $K * x = KF$ iff $\vdash \neg x$	triviality
K*6: If $\vdash x \leftrightarrow y$ then $K * x = K * y$	extensionality

Norm Revision Postulates

Let *N* set of norms closed under input/output logic *out.*

N*1: $N \otimes (a,x)$ is closed under *out* — closure (or type)

N*2: $(a,x) \in (N \otimes (a,x))$ — success

N*3: $N \otimes (a,x) \subseteq N \oplus (a,x)$ — inclusion

N*4: If $\neg(a,x) \notin N$ then $N \otimes (a,x) = N \oplus (a,x)$ — vacuity

N*5: $N \otimes (a,x) = NF$ iff $\neg(a,x) \in out(\varnothing)$ — triviality

N*6: If $out((a,x)) = out((b,y))$ then $N*(a,x) = N*(b,y)$ — extensionality

Summary Norm Change

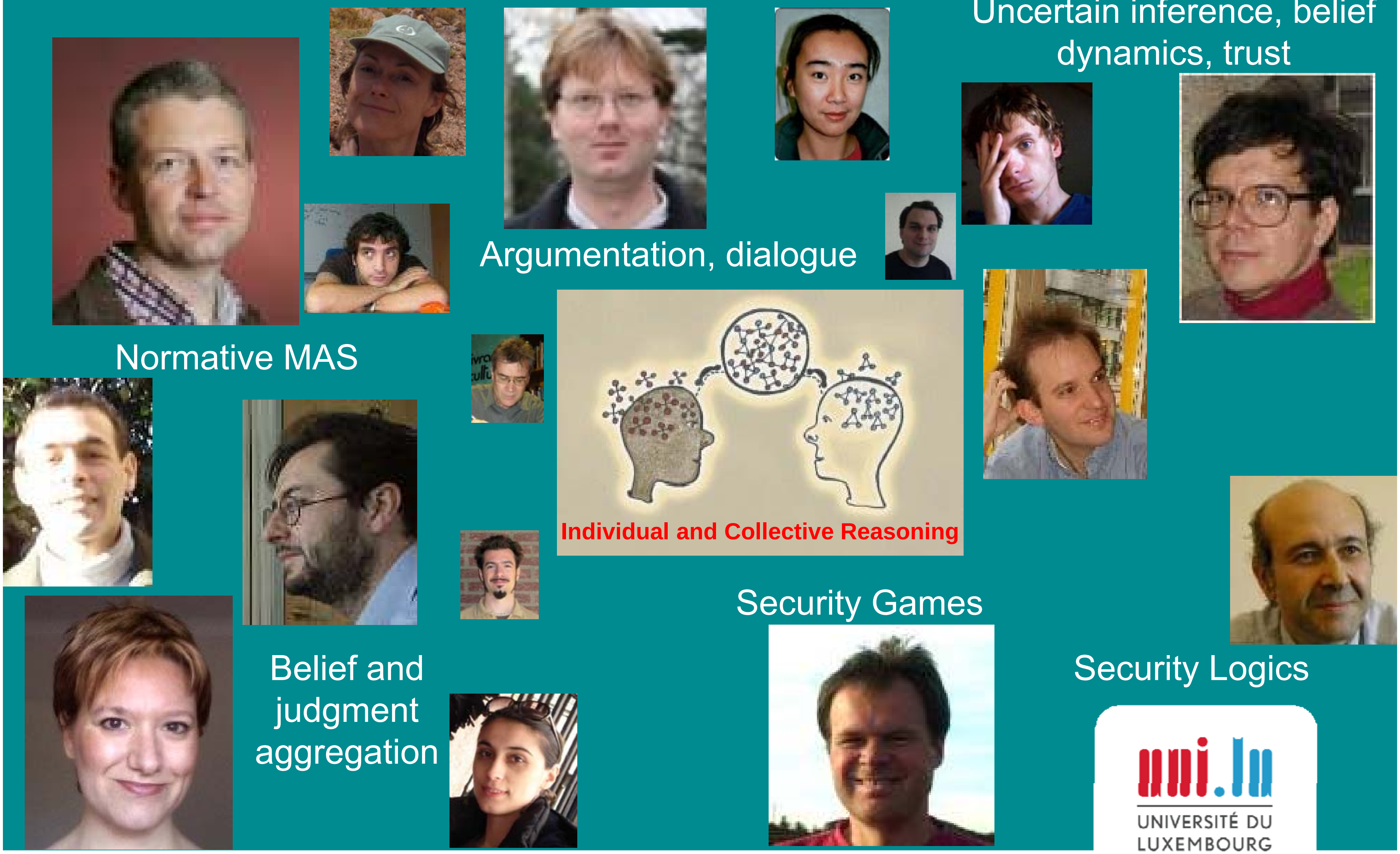
- Norm change is a problem in NorMAS
  - But the scope of possible solutions seems huge
- Norm change reusing results of theory change
  - Input/output framework, $out(N,a)$ and $out(N)$
- First results on contraction
  - E.g., consistent only for out_2, not for out_1 and out_3

Concluding Remarks

- Challenges due to uncertainty and imprecision in normative reasoning and decision making

1. Normative reasoning in computer science
2. Imprecision & uncertainty normative systems
3. Decision making in normative systems
4. Norm change

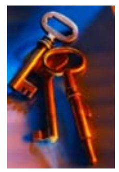
Normative Reasoning in Luxembourg



1 Prof, 2 Invited prof, 6 Postdocs, 5 PhD Students http://icr.uni.lu

Applications Norms in Luxembourg

- Interdisciplinary Laboratory of Intelligent and Adaptive Systems
  – Four labs in computer science and communication research unit
  – Strategic priorities uni.lu: Security and Trust research, Bioinformatics

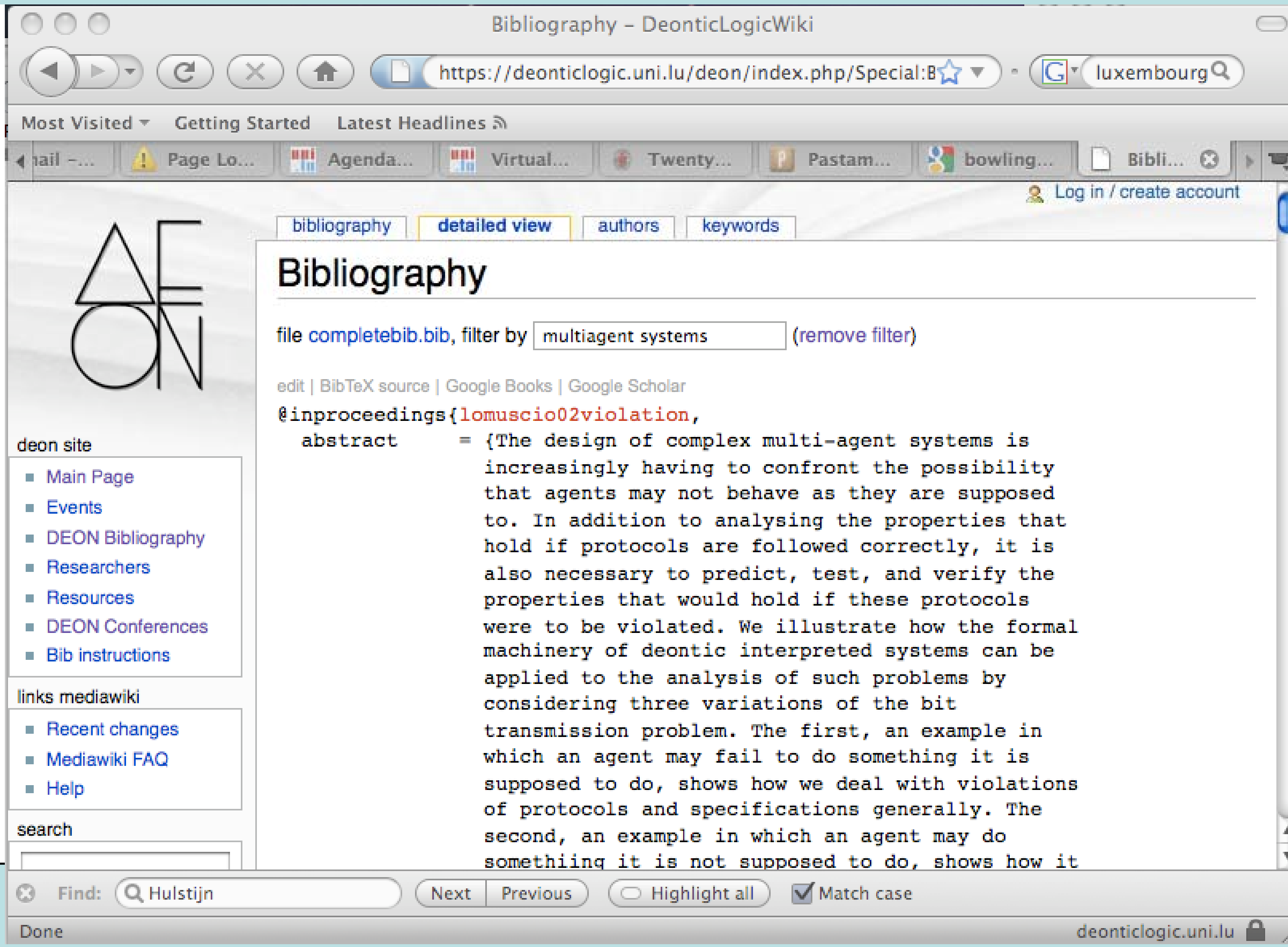





1. Individual and Collective Reasoning ICR
   – Leon van der Torre
2. Optimization and Parallel Computing
   – Pascal Bouvry
3. Information Management and Knowledge Discovery
   – Christoph Schommer
4. Information Theory and Stochastic Inference
   – Ulrich Sorger
5. Decision Systems
   – Raymond Bisdorff

NORMAS 2005, 2007, 2008, 2009

http:\\deonticlogic.org



Further Reading

- Normative multiagent systems proceedings:
  - *Computational and Mathematical Organization Theory, double special issue on normative multiagent systems,* 2006.
  - *Normative Multiagent Systems, 18.03. - 23.03.2007, Schloss Dagstuhl, Germany, 2007.*
  - *Autonomous Agents and Multiagent Systems Journal, special issue on normative multiagent systems, August* 2008.
  - 4rd International Workshop on Normative Multiagent Systems (NORMAS2009), Dagstuhl, March 2009
- Introductions to the area and its challenges
  - Ten philosophical problems in deontic logic
  - Ten challenges for normative multiagent systems
  - Ten guidelines for norms in computer science

Ten Philosophical Problems

1. How can deontic logic be reconstructed in accord with the philosophical position that norms are neither true nor false?
2. When is a set of norms to be termed `coherent'?
3. How can deontic logic accommodate possible conflicts of norms? How can the resolution of apparent conflicts be semantically modeled?
4. How do we reason with contrary-to-duty obligations which are in force only in case of norm violations?
5. How to define dyadic deontic operators with regard to given sets of norms and facts?
6. How to distinguish various kinds of permissions and relate them to obligations?
7. How can meaning postulates and intermediate terms be modeled in semantics for deontic logic reasoning?
8. How to define counts-as conditionals and relate them to obligations and permissions?
9. How to revise a set of regulations or obligations? Does belief revision offer a satisfactory framework for norm revision?
10. Can the belief merging framework deal with the problem of merging sets of norms?

J. Hansen, G. Pigozzi and L. van der Torre, Ten philosophical problems in deontic logic, Dagstuhl DROPS proceedings 07122, 2007.

Ten Challenges for NorMAS

1. Tools for agents supporting communities in their task of recognizing, creating, and communicating norms to agents.
2. Tools for agents to simplify normative systems, recognize when norms have become redundant, and to remove norms.
3. Tools for agents to enforce norms. In a distributed approach, roles should be defined for agents in charge of monitoring and sanctioning.
4. Tools for agents to preserve their autonomy.
5. Tools for agents to construct organizations.
6. Tools for agents to create intermediate concepts and normative ontology, for example to decide about normative gaps.
7. Tools for agents to decide about norm conflicts.
8. Tools for agents to voluntarily give up some norm autonomy by allowing automated norm processing in agent acting and decision making
9. Tools for conviviality.
10. Tools for legal responsibility of the agents and their principals.

G. Boella, L. van der Torre, H. Verhagen, Introduction to the special issue on normative multiagent systems. *Autonomous Agents and MultiAgent Systems,* Aug 2008.

Ten Guidelines

1. Motivate which definition of normative multiagent system is used.
2. Make explicit why norms are a kind of (soft) constraints deserving special analysis.
3. Explain why and how norms can be changed at runtime.
4. Discuss the use and role of norms as a mechanism in a game-theoretic setting.
5. Clarify the role of norms in the multiagent system.
6. Relate the notion of "norm" to the legal, social, or moral literature.
7. Use norms not only to distinguish right from wrong, but also to resolve dilemmas, and use norms not only describe violations, but in general to coordinate, organize, guide, regulate or control interaction among agents.
8. Distinguish norms from obligations, prohibitions and permissions.
9. Use the deontic paradoxes only to illustrate the normative multiagent system.
10. Consider regulative norms in relation to other kinds of norms and concepts.

Table 6. Ten guidelines for the development of normative multiagent systems

Guideline 1

1. Motivate which definition of normative multiagent system is used.

- Norms explicitly represented in system
  - (the ‘strong’ interpretation: too strict?)
- Norms explicitly represented in specification
  - (the ‘weak’ interpretation: too general?)
  - Norm compliance, norm implementation, ...
- Something else

Guideline 2

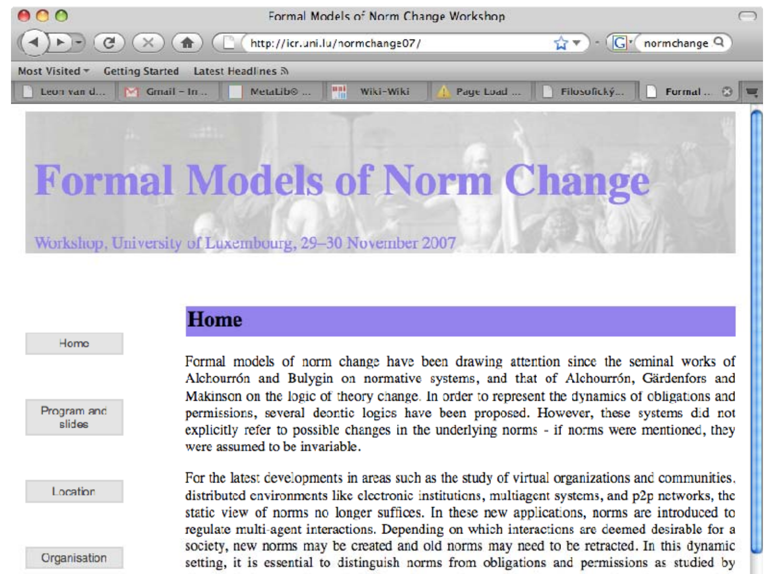
2. Make explicit why norms are a kind of (soft) constraints deserving special analysis.

- Ways to deal with violations, representation of permissive norms, the evolution of norms over time (in deontic logic), the relation between the cognitive abilities of agents and the global properties of norms, how agents can acquire norms, how agents can violate norms, how an agent can be autonomous (in normative agent architectures and decision making), how norms are created by legislator, emerge spontaneously or are negotiated among agents, how norms are enforced, how constitutive or counts-as norms are used to describe institutions, how norms are related to social and legal concepts, how norms structure organizations, how norms coordinate groups and societies, how contracts are related to contract frames & contract law, how legal courts are related, how normative systems interact?

Guideline 3

3. Explain why and how norms can be changed at runtime.

Figure 1.2



- E.g., legislators and voting on acceptance, observe behavior and violations to modify…

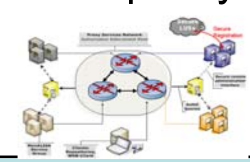
Guideline 4

4. Discuss the use and role of norms as a mechanism in a game-theoretic setting.

- D. Lewis “master and slave” game
- E. Bulygin “rex, minister and subject” game
- G. Boella c.s.: violation games, institutionalized games, negotiation games, norm creation games, control games

Norms are rules specifying violation games.




Guideline 5

5. Clarify role of norms in the multiagent system.

- Norms guide (…) desired system behavior

- Norms are incentives to motivate agents
  - Gneezy and Rustichini's daycare example
- Norms organize systems
  - Modularity, abstractions

Guideline 6

6. Relate the notion of “norm” to the legal, social, or moral literature.

Five phases in normas design:

1. off-line norm design
2. norm representation
3. norm manipulation
4. social reality
5. moral reality

Guideline 7

7. Use norms not only to distinguish right from wrong, but also to resolve dilemmas, and use norms not only describe violations, but in general to coordinate, organize, guide, regulate or control interaction among agents.

Guideline 8

8. Distinguish norms from obligations, prohibitions and permissions.

- Deontic logic: logical relations obligations, etc
  - normative system is typically left implicit
- Two distinct philosophical traditions
  - Von Wright: norms and normative propositions
  - Alchourron: prescriptive and descriptive obligations

J. Hansen. Imperatives and Deontic Logic. PhD thesis, University of Leipzig, 2008.

Guideline 9

9. Use the deontic paradoxes only to illustrate the normative multiagent system.

1. A certain man should go to the assistance of his neighbors,
2. If he goes, he should tell them he is coming
3. If he does not go, he should not tell them that he is coming
4. He does not go.

$\{Oa, O(a \,!\, t), \neg a \,!\, O(\neg t), \neg a\}$ $\{Oa, a \,!\, O(t), \neg a \,!\, O(\neg t), \neg a\}$

Guideline 10

10. Consider regulative norms in relation to other kinds of norms and concepts.

- in relation to permissive norms, constitutive norms, procedural norms, agents, roles, groups, societies, rights, duties, obligations, time, beliefs, desires, intentions, goals, roles, and other kinds of norms and other social-cognitive computer science concepts.

The Question

- Could (or should) “norms” play a similar role in computer science like “service”, “contract” or “trust”?
  - Since the use of norms is a key element of human social intelligence, norms may be essential too for artificial agents that collaborate with humans, or that are to display behavior comparable to human intelligent behavior.
  - Norms are thought to ensure efficiency at the level of the multiagent system whilst respecting individual autonomy.
- We have to build more flexible normative multiagent systems, and test them in practice, before we know where they can be used best.