Institut de Recherche en Informatique de Toulouse
CNRS - Toulouse INP - UT - UT Capitole - UT2

ADRIA
Argumentation Décision Raisonnement Incertitude Apprentissage

Formalization of belief change and stories in AI

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Knowledge, Reasoning and Decision-Making
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Introduction

Reasoning formalization: a field of AI

- What for?
  - Produce an ideal reasoning (rational)
  - Simulate human reasoning:
    - in order to understand it (make its mechanism explicit)
    - to predict a conclusion that a human will reach
  - To repair (complete/correct) or guide (with guarantees)

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    - implicit knowledge: knowing how to do (technical skills), knowing how to be (interpersonal skills), ability to recognize
  - Represent Knowledge
  - Define inference rules adapted to the chosen representation
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Belief change formalization: in which domain?

AI
- "data AI" (statistics):
  - machine learning (pattern recognition, alphaGo)
  - automatic prediction/generation (LLM (chatGPT))
- "knowledge AI" ("symbolic[1] AI" or "KR" (Knowledge representation and reasoning))
  - Causal/temporal/spatial Reasoning
  - Non-monotonic Reasoning
  - Ontological Reasoning
  - Reasoning on imperfect knowledge (uncertainty, incompleteness, fuzzyness)

[1] Knowledge is the symbolic possession of things"[Godin, 2018]

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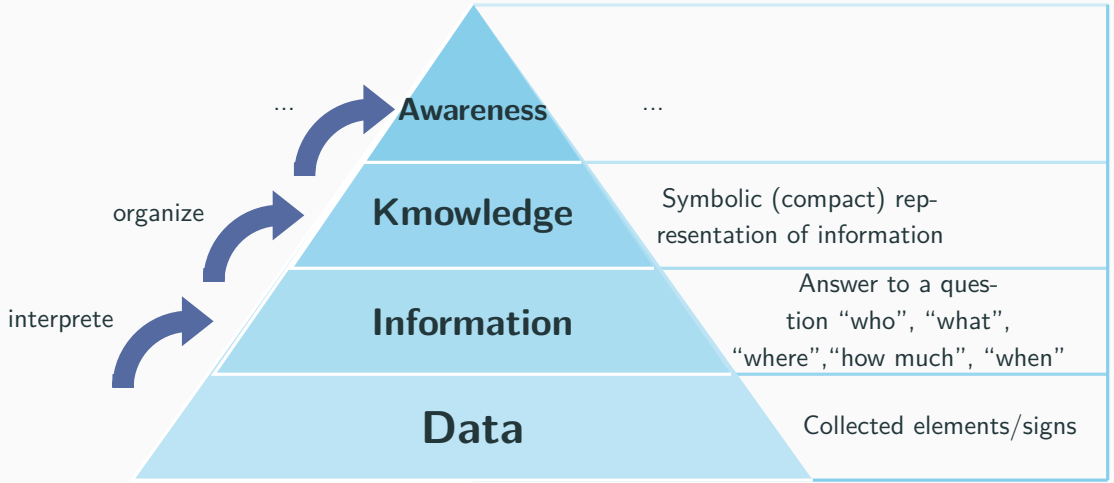
From data to knowledge (and beyond)

The DIKW pyramid :



Belief change

Belief change

"Only fools never change their minds."

Belief change

"Only fools never change their minds.
That's my opinion, and I don't see why I should change it."

Philippe Geluck

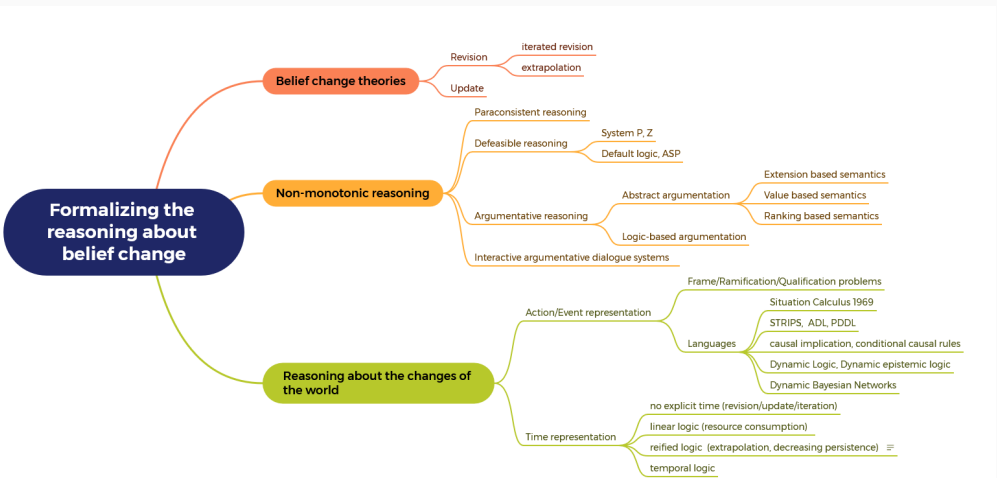
Evolving Beliefs: what's the point?

- Homo Sapiens = individual beliefs
  - For what purpose?
    - to predict, to plan
    - to explain : causal attribution
  - How ? Formation/adaptation of beliefs (intuition, reasoning)
    - causal laws (causal generalization)
    - facts
- But above all : common beliefs and social norms
  - What for?
    - to cooperate
    - to compete
    - to get organized (assign responsibilities, etc.)
  - How ?
    - Communication (sending, receiving) : persuasion

Formalizing reasoning about belief change: how to do it? The challenges

- Taking into account human traits that are more or less desirable
  - Bounded rationality:
    - available brain time [Bisquert et al., 2017],
    - limited memory capacity [Bisquert and Dupin de Saint-Cyr, 2021],
    - fallacious reasoning [Bisquert et al., 2019],
    - sensitivity to form [Dupin de Saint-Cyr and Bisquert, 2024]
  - Humor [Dupin de Saint-Cyr and Prade, 2023],
  - Candid commitment [Dupin de Saint-Cyr et al., 2024]
  - Prejudices [Dupin de Saint-Cyr and Faux, 2023]
- Taking into account the characteristics of representations that are more or less *desirable*
  - Dealing with uncertainty
  - Dealing with incompleteness
  - Managing inconsistency (minimizing beliefs to be discarded, ...)
  - Adapting material implication

Formalizing reasoning about belief change: how to do it?
The approaches



Stories: an important thing = the narrative tension

[2]

- "Understand" a story ...
- Implies a candid engagement

[2] Heliotrope, tome 3 - "Le prix de mes larmes", Joann Sfar et Benjamin Chaud, 2024, Dupuis

Stories: What's the point ?

- Need to find a connection between things/events
- A simple way to communicate ideas/beliefs
  - Compact: easier to remember and pass on
  - With images: emotions
  - Deliberately incomplete: leaves room for the imagination
- Engaging: narrative tension creates a commitment to listen [Baroni, 2007]
- The listener's engagement enables persuasion [Green and Brock, 2000]
  (convincing (rational) $\neq$ persuading (emotional))

Need for tools to:

- Analyze discourse:
  - Explain the mechanisms of persuasion and communication objectives
  - Stimulate critical thinking
- (Help) Generate discourse

Stories: How to Do It? Speech vs. Narration

- Rhetoric: the art of public speaking (speech)
  - inventio ("inventing"): figuring out what to say.
  - dispositio ("arrange"): knowing how to organize what you are going to say.
  - elocutio ("elocution"): choosing how to say it.
  - actio ("action"): knowing how to combine speech and gesture.
  - memoria ("memory"): remembering what one must say

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- Narratology: the science studying narrative techniques and structures
  - ▶ AI approach: computational narration (linear logic, planning, games, serious games...)

Narratology: the three levels

$$\text{Story telling} = \begin{cases} 1. \quad \text{choose the events/facts} \\ 2. \quad \text{choose when and how to tell them} \\ \text{with a communication goal in mind} \end{cases}$$

Level 1: Speech "*Cecilia enters her office. She sees a closed box lying on her desk that was not there when she last left the room.*"

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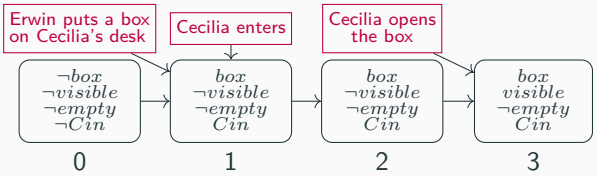
Level 3: Scenario



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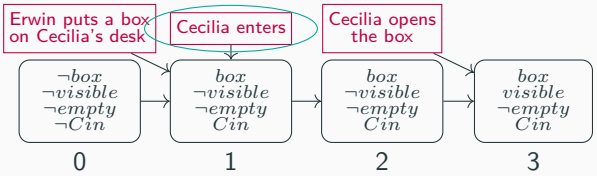

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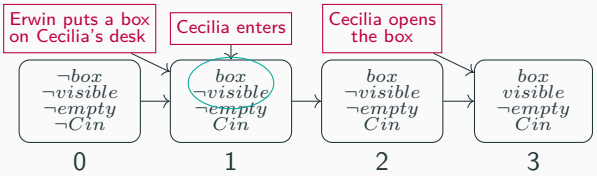

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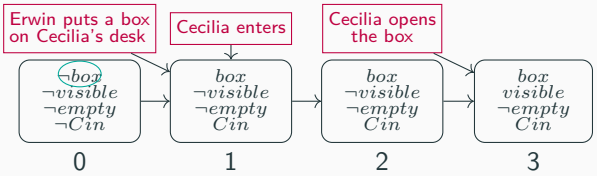

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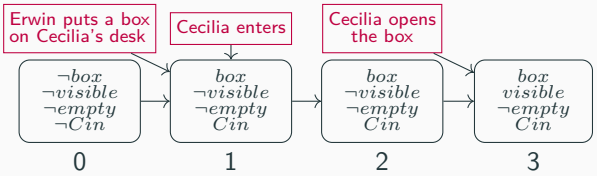

How do speeches differ from stories?

Speech	Story
commitment on: ideas being defended	commitment to: listening until the end immersion in a fictional world
empathy toward the speaker	forgetting the speaker empathy toward character(s)
sensitivity to form	sensitivity to the world
communicative objective +/- known	+/- implicit
1 level of knowledge about the discourse: what the speaker says	2 levels: what the speaker says + what the character knows

What won't we be discussing?

- Data-driven AI
  - Reinforcement learning
  - Deep learning
  - "Generative AI" (LLM)
- Decision support: utilities (preferences)
- Multi-agent systems

What won't we be discussing?

- Data-driven AI
  - Reinforcement learning
  - Deep learning
  - "Generative AI" (LLM) although I might mention it anyway
- Decision support: utilities (preferences) although ...
- Multi-agent systems although ...

Table of contents

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3. Narrative tension

Belief change theories

Belief base and change

Belief base

$lime(a)$
$yellow(b)$
$q(nixon) \wedge r(nixon)$
$p(tweety)$
$b(tweety)$
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$lime(X) \rightarrow green(X)$
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- incompleteness
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Several problems :

- incompleteness :
  several possible interpretations/worlds

  $lime(a), \overline{lime(b)}$, $\overline{f(a)}, yelow(b)$, ...

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  $\cdots$

  $lime(a), \overline{lime(b)}$, $f(a), yelow(b)$, ...
- inconsistency
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- incompleteness
- inconsistency : contradiction
  no interpretation
  $\emptyset$
- change

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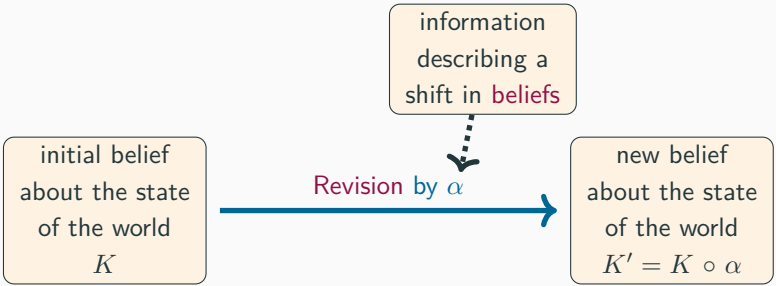
Several problems :

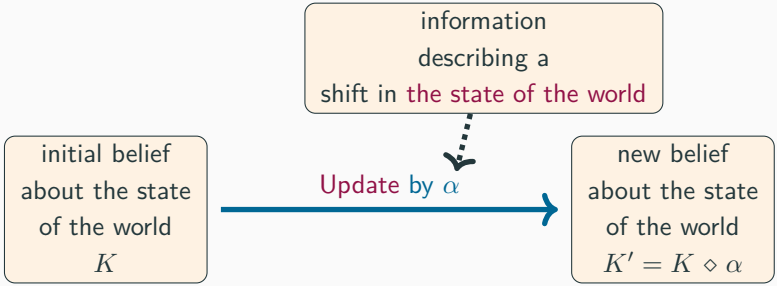
- incompleteness
- inconsistency
- change : we learn a new piece of information α
  Two cases identified by [Winslett, 1988]:
  - revision
  - update

Belief change theory



change of beliefs about the state of the world

Belief change theory



change of state of the world

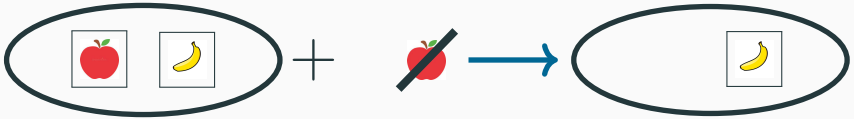
Belief change theory: Example

- There is either an apple or a banana in the box but not both.
- I hear that there is no apple in the box.

initial beliefs about the state of the world $a \oplus b = (a \wedge \neg b) \vee (\neg a \wedge b)$

Revision by $\neg a$

new belief of the world $(a \oplus b) \circ \neg a = \neg a \wedge b$



$(\neg a \wedge b)$

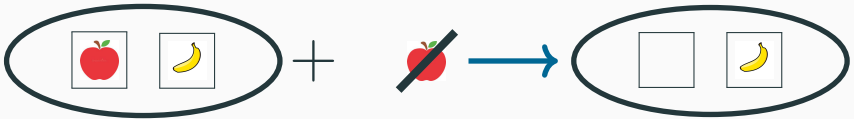
Belief change theory: Example

- There is either an apple or a banana in the box but not both.
- I hear that the apple thief has been there

initial beliefs about the state of the world $a \oplus b =$ $(a \wedge \neg b) \vee (\neg a \wedge b)$

Update by $\neg a$

new state of the world $(a \oplus b) \diamond \neg a$



$(\neg a \wedge \neg b) \vee (\neg a \wedge b)$

Representation theorem for belief revision

(R1): Success $K \circ \alpha \models \alpha$

(R2): Vacuity If $K \wedge \alpha$ consistent, then $K \circ \alpha \equiv K \wedge \alpha$

(R3): Consistency If α consistent, then $K \circ \alpha$ consistent

(R4): Syntax indep. If $K_1 \equiv K_2$ and $\alpha_1 \equiv \alpha_2$ then $K_1 \circ \alpha_1 \equiv K_2 \circ \alpha_2$

(R5): $(K \circ \alpha) \wedge \psi \models K \circ (\alpha \wedge \psi)$

(R6): If $(K \circ \alpha) \wedge \psi$ is consistent then $K \circ (\alpha \wedge \psi) \models (K \circ \alpha) \wedge \psi$

Representation Theorem for Belief Revision [Katsuno and Mendelzon, 1991b]

$\circ$ satisfies (R1) - (R6) postulates iff there exists a faithful assignments.t.:

$$Mod(K \circ \alpha) = \min(Mod(\alpha), \preceq_K)$$

Faithful assignment = mapping K to a total pre-order $\preceq_K$ "distance to K" s.t. :

1) If $\omega \models K$ and $\omega' \models K$ then $\omega =_K \omega'$.
2) If $\omega \models K$ and $\omega' \not\models K$ then $\omega \prec_K \omega'$.
3) If $K \equiv K'$ then $\preceq_K = \preceq_{K'}$.

Belief change theory: Unripe fruits

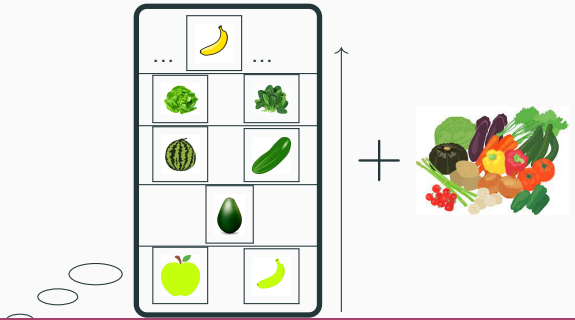
- There's only one thing in the box – it's a round or long fruit, and it's green.
- I hear that it is a vegetable.

K: initial belief about the world

$fruit \quad (round \oplus long) \quad green$

Revision by $vegetable$

new belief about the world



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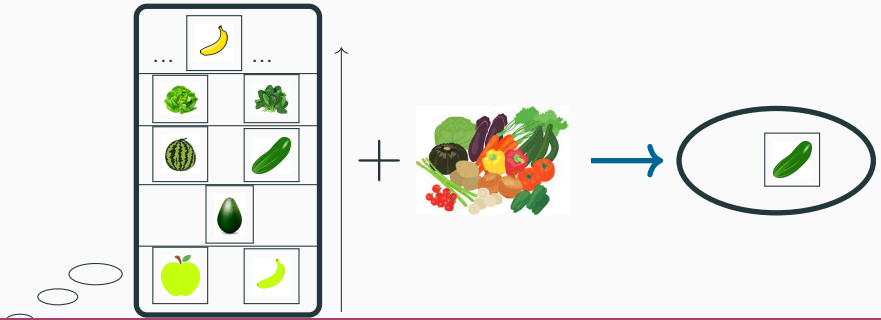

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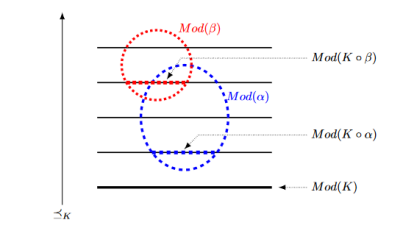

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$$Mod(K \circ \alpha) = \min(Mod(\alpha), \preceq_K)$$

Faithful assignment = mapping K to a total pre-order $\preceq_K$ "distance to K" s.t. :

1) If $\omega \models K$ and $\omega' \models K$ then $\omega =_K \omega'$.
2) If $\omega \models K$ and $\omega' \not\models K$ then $\omega \prec_K \omega'$.
3) If $K \equiv K'$ then $\preceq_K = \preceq_{K'}$.

Representation theorem for update

U1 Success $(K \diamond \alpha)$ implies α.
U2 Inertia If K implies α then $(K \diamond \alpha)$ is equivalent to K
U3 Accessibility If K and α consistent then $(K \diamond \alpha)$ consistent
U4 Syntax indep If $K_1 \leftrightarrow K_2$ and $\alpha_1 \leftrightarrow \alpha_2$ then $(K_1 \diamond \alpha_1) \leftrightarrow (K_2 \diamond \alpha_2)$.
U5 $(K \diamond \alpha) \wedge \psi$ implies $(K \diamond (\alpha \wedge \psi))$.
U6 If $(K \diamond \alpha_1)$ implies α_2 and $(K \diamond \alpha_2)$ implies α_1 then $(K \diamond \alpha_1) \leftrightarrow (K \diamond \alpha_2)$.
U7 If K is complete then $(K \diamond \alpha_1) \wedge (K \diamond \alpha_2)$ implies $(K \diamond (\alpha_1 \vee \alpha_2))$.
U8 Update $(K1 \vee K2) \diamond \alpha$ equivalent to $(K1 \diamond \alpha) \vee (K2 \diamond \alpha)$.
U9 If $(K \diamond \alpha_1) \wedge \alpha_2$ consistent then $(K \diamond (\alpha_1 \wedge \alpha_2))$ implies $((K \diamond \alpha_1) \wedge \alpha_2))$.

Representation theorem for Update [Katsuno and Mendelzon, 1991a]

$\diamond$ satisfies (U1) - (U9) postulates iff there exists a faithful assignment (mapping each ω to $\preceq_\omega$ "distance to ω" which favors ω):

$$Mod(K \diamond \alpha) = \bigcup_{\omega \models K} \min(Mod(\alpha), \preceq_\omega)$$

Belief change theory: unripe fruits

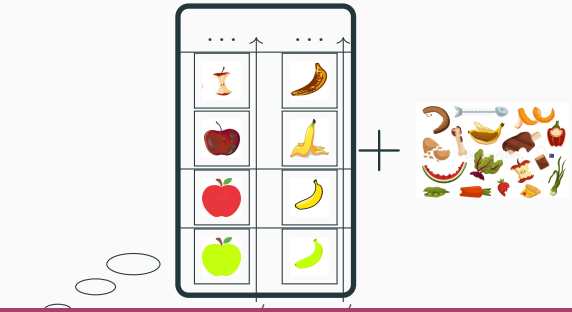
- There's only one thing in the box – it's a round or long fruit, and it's green.
- I hear that all that's left are scraps.

K: initial state of the world

$fruit \quad (round \oplus long) \quad green$

Update by *scraps*

new state of the world



Belief change theory: unripe fruits

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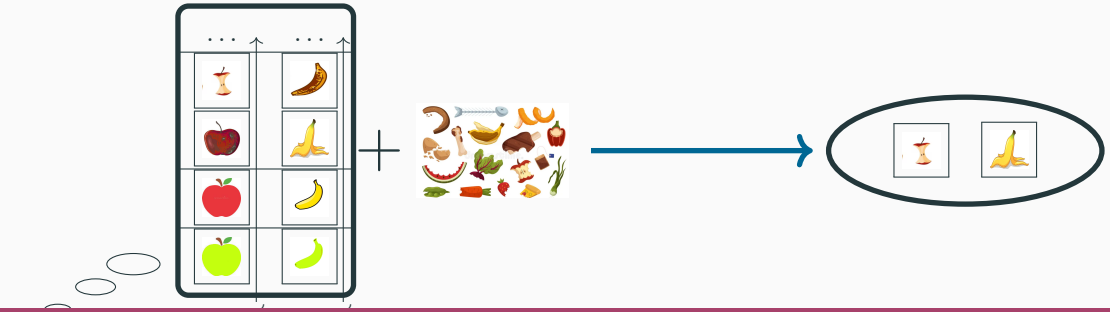
$fruit \quad (round \oplus long) \quad green$

Update by *scraps*

new state of the world

banana peal or apple core



Non-monotonic reasoning: the other side[3] of belief revision

- Inference System avoiding classical logic monotonicity

$$\text{if } \varphi \vdash \psi \quad \text{then for all } \alpha,\ \varphi \wedge \alpha \vdash \psi \quad \text{(Monotonicity)}$$

Définition (System P [Kraus et al., 1990] and rational monotony [Gärdenfors and Makinson, 1994])

An inference relation $\mid\sim$ satisfies System P iff $\forall \alpha, \beta \in \mathcal{L}$:

$\alpha \mid\sim \alpha$	*(Reflexivity)*
If $\alpha \equiv \alpha'$ *and* $\alpha \mid\sim \beta$ *then* $\alpha' \mid\sim \beta$	*(Left Logical Equivalence)*
If $\beta \models \beta'$ *and* $\alpha \mid\sim \beta$ *then* $\alpha \mid\sim \beta'$	*(Right weakening)*
If $\alpha \mid\sim \gamma$ *and* $\beta \mid\sim \gamma$ *then* $\alpha \vee \beta \mid\sim \gamma$	*(Or)*
If $\alpha \mid\sim \beta$ *and* $\alpha \mid\sim \gamma$ *then* $\alpha \wedge \beta \mid\sim \gamma$	*(Cautious Monotony)*
If $\alpha \wedge \beta \mid\sim \gamma$ *and* $\alpha \mid\sim \beta$ *then* $\alpha \mid\sim \gamma$	*(Cut)*
If $\alpha \not\mid\sim \neg\beta$ *and* $\alpha \mid\sim \gamma$ *then* $\alpha \wedge \beta \mid\sim \gamma$	*(Rational Monotony)*

[3] Belief revision and nonmonotonic logic are two sides of the same coin [Gärdenfors, 1990].

- Plausibility ranking of the world :
  - most "normal" worlds
  - those that best align with my beliefs

Théorème (Representation theorem [Kraus et al., 1990])

Define a non-monotonic inference operator $\mid\!\sim$ satisfying system P

$\Leftrightarrow$

Define a plausibility ranking on worlds $\preceq$ (hence a Revision operator)

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Funny stories

A “funny story”

Exemple

A man has just been hit by a car. The driver gets out of the car and says:
“You’re in luck—we’re right in front of the doctor’s office.”

From a collection of funny stories [Nègre, 1970].

A “funny story”

Exemple

A man has just been hit by a car. The driver gets out of the car and says:
“You’re in luck—we’re right in front of the doctor’s office.”
“Great! Except that I’m the doctor!”

From a collection of funny stories [Nègre, 1970].

Listening to a story involves non-monotonic reasoning

Listening to a story triggers a belief revision.

Définition (A listener)

A listener is characterized by
- *their belief base K and*
- *a revision mechanism $\circ$*

- The listener is thus characterized by a plausibility relation $\preceq_K$
- Recall: $K \circ \varphi$: revise K by φ = compute the closest worlds for $\preceq_K$ that satisfy φ

Définition (simple story)

simple story $=_{def}$ *pair* (α, β) *of formulas*
- α: *the context*
- β: *the punchline*

Formalization of a funny story

Définition (a surprising story)

A story (α, β) *is surprising for a listener* $(K, \circ)$ *iff*$_{def}$

$(K \circ \alpha)$ *is consistent but* $(K \circ \alpha)$ *is inconsistent with* $(K \circ (\alpha \wedge \beta))$

Except that I am the doctor

$\alpha = injured \wedge doctorNearby$

$\beta = injured \wedge doctorHimself$

$$K = \left| \begin{array}{l} injured \wedge doctorNearby \rightsquigarrow treatedRapidly \\ injured \wedge \neg treatingDoctor \rightsquigarrow \neg treatedRapidly \\ doctorHimself \rightsquigarrow doctorNearby \\ injured \wedge doctorHimself \rightsquigarrow \neg treatingDoctor \end{array} \right.$$

$$\left.\begin{array}{ll} K \circ \alpha \vdash & treatedRapidly \\ K \circ (\alpha \wedge \beta) \vdash & \neg treatingDoctor \wedge \neg treatedRapidly \end{array}\right\} \text{Contradiction}$$

therefore the story is surprising.

Revealing Punchline

Définition (A Revealing Punchline)

The punchline β of the story (α, β) is revealing to the listener $(K, \circ)$ iff$_{def}$

$$(K \circ \beta) \text{ is consistent and } K \circ \beta \models \alpha$$

(β is perfectly acceptable and explains the situation α)

Exemple

$\alpha = injured \wedge doctorNearby$,
$\beta = injured \wedge doctorHimself$,

$$\Sigma = \left| \begin{array}{l} injured \wedge doctorNearby \rightsquigarrow treatedRapidly \\ injured \wedge \neg treatingDoctor \rightsquigarrow \neg treatedRapidly \\ doctorHimself \rightsquigarrow doctorNearby \\ injured \wedge doctorHimself \rightsquigarrow \neg treatingDoctor \end{array} \right.$$

$$K \circ injured \wedge doctorHimself \vdash injured \wedge doctorNearby$$

therefore the conclusion is revealing.

A potentially funny story

Définition (a potentially funny story)

A potentially funny = surprising story with a revealing punchline.

Inspired by [Raccah, 2015]: we have "the feeling of having fallen into an unexpected and inevitable trap: it is the punchline that makes us fall into this trap."

Proposition (Do not reveal the punchline before the end!)

If (α, β) *is a potentially funny story for the listener* $(K, \circ)$
then (β, α) *is not potentially funny for* $(K, \circ)$.

More details in [Dupin de Saint-Cyr and Prade, 2023] (The shortest jokes, psychorigidity, Graduality of surprise or revelation, ...)

An essential ingredient: incongruity

Incongruity is linked to the violation of a (social) norm:

- not conforming to common practices
  - drinking water from the finger-rinsing basin
  - wearing shoes that are too big
- deliberately disregarding an obvious universal law
  - the riddle of the 4 elephants

Exemple

How do you fit 4 elephants into a 2CV?

An essential ingredient: incongruity

Incongruity is linked to the violation of a (social) norm:

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  - drinking water from the finger-rinsing basin
  - wearing shoes that are too big
- deliberately disregarding an obvious universal law
  - the riddle of the 4 elephants

Exemple

How do you fit 4 elephants into a 2CV?
Answer: two in front and two in back.

Formalization of Incongruity

Définition (incongruity)

The story (α, β) is considered incongruous by a listener if

- *a norm ρ known to the listener is violated:* $\alpha \wedge \beta \not\vdash_{K\setminus\{\rho\}} Not\rho$
- *when ignoring this norm, the conclusion is revealing:* $\beta \not\vdash_{K\setminus\{\rho\}} \alpha$

Exemple

α *: $i \wedge e$: 4 elephants in a 2CV*

β*: $tt \wedge e$: 2 elephants in front and 2 elephants in the back*

R1: $h \rightarrow \neg i$ *(Something huge cannot be inside a 2CV car)*

R2: $e \rightarrow h$ *(Elephants are huge)*

R3: $h \rightarrow \neg tt$ *(Something huge cannot be put in the rear and in the front)*

R4: $tt \rightarrow i$ *(Putting in the rear and in the front implies putting inside)*

$K \cup \{\alpha\}$ is inconsistent: violation of rule R2

$\{\beta\} \cup (K \setminus \{R2\}) \models \alpha$: revealing punchline by ignoring $R2$

therefore the story is considered incongruous by the listener.

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Narrative tension

Narrative tension= 3 emotions

According to [Baroni, 2007], there are 3 main ingredients:

- Suspense: a dramatic event may occur in the future
- Surprise: a deviation from expectations
- Curiosity: crucial information is omitted

Other emotional mechanisms can also have an impact:

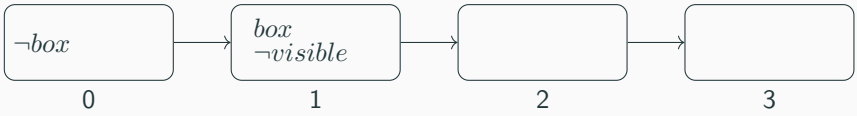
- Compassion/identification with a character
- Familiarity with the story's universe

A Story About a Box

"Cecilia walks into her office. She sees a closed box on the table that wasn't there when she left the room."

$A \vee E$

Hypothesis: this short story can create curiosity, suspense, and surprise.



A Box Story: Illustration

- Only 3 characters: Albert, Erwin, and Cecilia[4]

Actions	Fluents
• A : Albert • E : Erwin } places a closed box on the desk • C : Cecilia opens the box	• box: there is a box on the desk • $empty$: the box is empty • $visible$: Cecilia sees something in the box

- Belief State $S = (F, S_{\mathcal{L}}, S_{\Delta})$

Facts	Strict Rules	Default Rules
$\neg box_0$	$(\neg box_t \wedge box_{t+1}) \rightarrow (A_t \vee E_t)$	$\neg visible_t \wedge C_t \wedge empty_t \rightsquigarrow \neg visible_{t+1}$
box_1	$(\neg visible_t \wedge visible_{t+1}) \rightarrow C_t$	$\neg visible_t \wedge C_t \rightsquigarrow visible_{t+1}$
$\neg visible_1$		$\neg box_t \wedge (A_t \vee E_t) \rightsquigarrow box_{t+1}$
		$\neg box_t \rightsquigarrow \neg box_{t+1}$
		$box_t \rightsquigarrow box_{t+1}$
		$\neg visible_t \rightsquigarrow \neg visible_{t+1}$

[4] Einstein, Schrödinger, Payne-Gaposchkin

Awareness

Définition (Awareness)

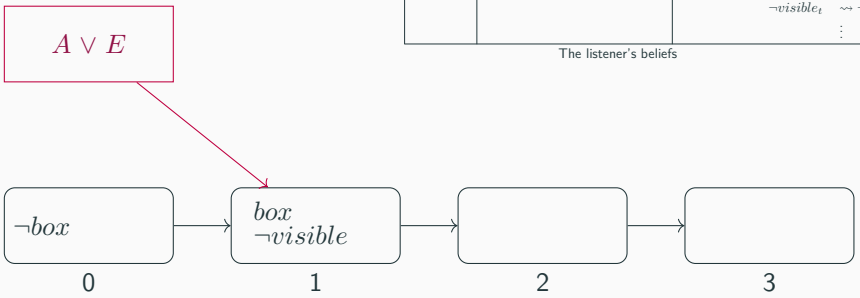
A listener $S = (F, S_{\mathcal{L}}, S_{\Delta})$,
is aware of the existence of a variable $v \in \mathcal{V}$ *if*

- v *appears in the facts* F *or*
- v *appears in a rule of* $S_L \cup S_{\Delta}$ *that contains a variable of which the listener is aware.*

The story of the box (continued)

Facts	Strict Rules	Default Rules
$\neg box_0$	$(\neg box_t \wedge box_{t+1}) \rightarrow (A_t \vee E_t)$	$\neg visible_t \wedge C_t \wedge empty_t \rightsquigarrow \neg visible_{t+1}$
box_1	$(\neg visible_t \wedge visible_{t+1}) \rightarrow C_t$	$\neg visible_t \wedge C_t \rightsquigarrow visible_{t+1}$
$\neg visible_1$		$\neg box_t \wedge (A_t \vee E_t) \rightsquigarrow box_{t+1}$
		$\neg box_t \rightsquigarrow \neg box_{t+1}$
		$box_t \rightsquigarrow box_{t+1}$
		$\neg visible_t \rightsquigarrow \neg visible_{t+1}$
		$\vdots$

The listener's beliefs



- The listener is aware of box and $visible$, and therefore,
- based on their beliefs of A, E, C, and $empty$, the listener can infer $A_0 \vee E_0$

Curiosity

Définition (curiosity)

A listener S is curious about $\varphi \in \mathcal{L}$ at time $t \in T$ if,

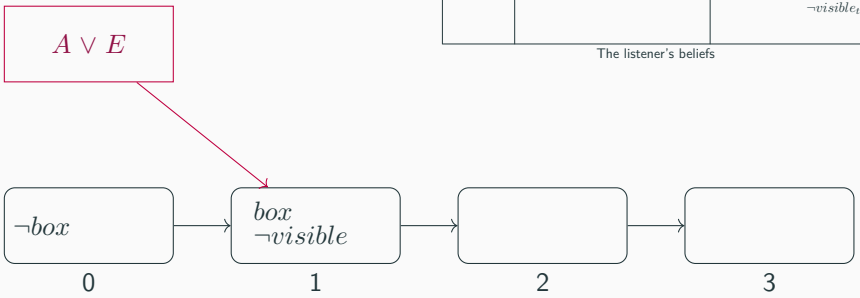
1. *according to $S_{\rightarrow t}$ (S up to t), S is aware of (all the variables in) φ and*
2. *at time t, he cannot know whether φ is true or false:*
   - $\not\vdash_{S_{\rightarrow t}} \varphi$ *and*
   - $\not\vdash_{S_{\rightarrow t}} \neg\varphi$

$\vdash_S$ *being the listener's non-monotonic inference based on his beliefs S*

Curiosity (example)

Facts	Strict Rules	Default Rules	
$\neg box_0$	$(\neg box_t \wedge box_{t+1}) \rightarrow (A_t \vee E_t)$	$\neg visible_t \wedge C_t \wedge empty_t$	$\rightsquigarrow \neg visible_{t+1}$
box_1	$(\neg visible_t \wedge visible_{t+1}) \rightarrow C_t$	$\neg visible_t \wedge C_t$	$\rightsquigarrow visible_{t+1}$
$\neg visible_1$		$\neg box_t \wedge (A_t \vee E_t)$	$\rightsquigarrow box_{t+1}$
		$\neg box_t$	$\rightsquigarrow \neg box_{t+1}$
		box_t	$\rightsquigarrow box_{t+1}$
		$\neg visible_t$	$\rightsquigarrow \neg visible_{t+1}$
		$\vdots$	

The listener's beliefs



- The listener is curious to know who placed the box (A or $\neg A$?)
- The listener is curious about the contents of the box ($empty$ or $\neg empty$?)

Suspense

Définition (suspense)

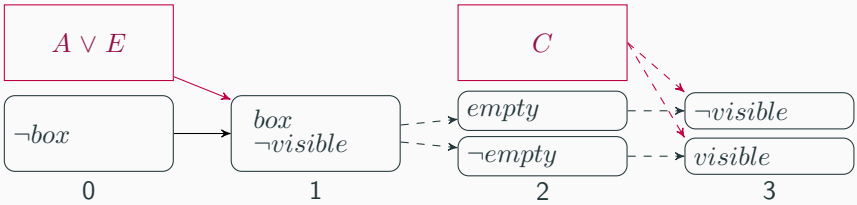
A listener $S = (F, S_{\mathcal{L}}, S_{\Delta})$ feels suspense regarding $\varphi \in \mathcal{L}$ at time t if

- *according to S, the listener is curious about φ at t and*
- *the listener is aware of the formula ψ consistent with S up to t and*
- *ψ allows one to infer φ or $\neg\varphi$ at time $t' > t$*
  i.e., $\mid\!\sim_{S'} \varphi_{t'}$ or $\mid\!\sim_{S'} \neg\varphi_{t'}$, where $S' = (F \cup \{\psi\}, S_{\mathcal{L}}, S_{\Delta})$.

Suspense (example)

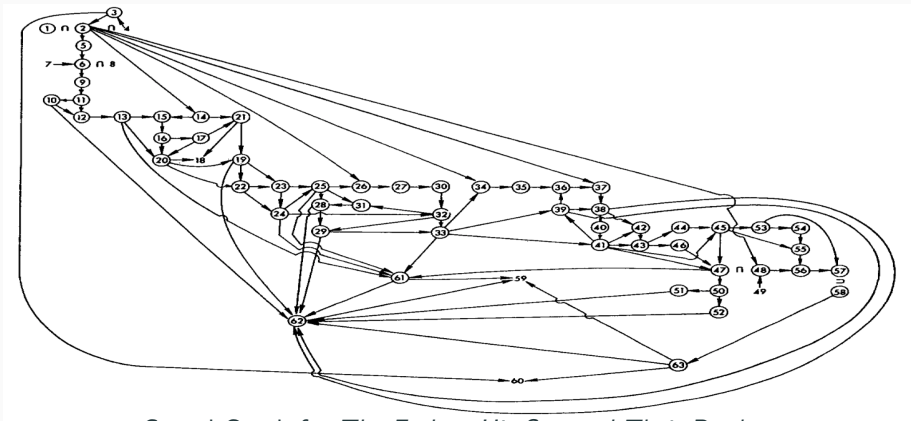
Faits	Règles Strictes	Règles par défaut
$\neg box_0$	$(\neg box_t \wedge box_{t+1}) \rightarrow (A_t \vee E_t)$	$\neg visible_t \wedge C_t \wedge empty_t \rightsquigarrow \neg visible_{t+1}$
box_1	$(\neg visible_t \wedge visible_{t+1}) \rightarrow C_t$	$\neg visible_t \wedge C_t \rightsquigarrow visible_{t+1}$
$\neg visible_1$		$\neg box_t \wedge (A_t \vee E_t) \rightsquigarrow box_{t+1}$
C_2		$\neg box_t \rightsquigarrow \neg box_{t+1}$
$visible_3$		$box_t \rightsquigarrow box_{t+1}$
		$\neg visible_t \rightsquigarrow \neg visible_{t+1}$
		$\vdots$

The listener's beliefs



At time 1, the listener feels a sense of suspense about whether they will find out if the box is empty or not.

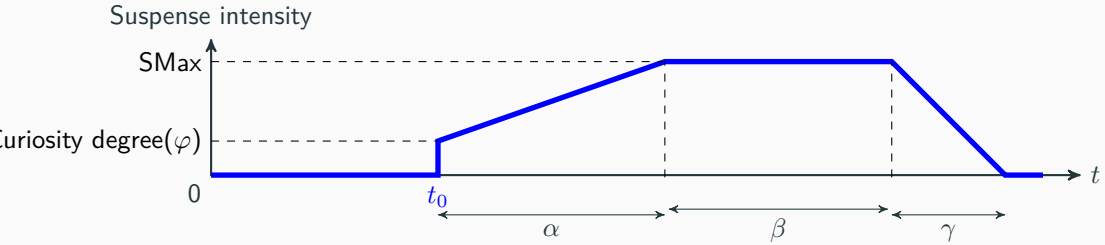
The importance of events



Causal Graph for *The Father, His Son and Their Donkey*

The perceived importance of events in a story is related to the degree of the vertices in the causal graph [Trabasso and Sperry, 1985].

Towards a Definition of Intensity Measures



Définition

Given an epistemic state $S = (F, S_{\mathcal{L}}, S_{\Delta})$ and a suspense profile $p = (\alpha, \beta, \gamma, \mathrm{SMax})$

Without revival nor resolution, suspense degree(φ) follows the pattern

where t_0 = earliest time where the agent was curious about φ.

Conclusion

Conclusion

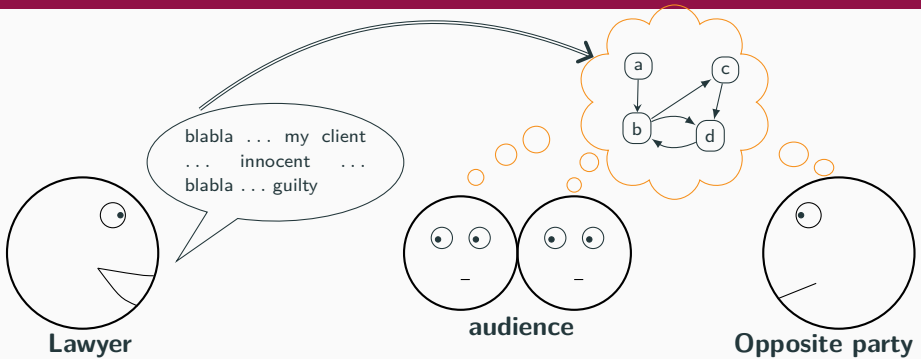
Conclusion

- Old theoretical tools from the 1990s:
  - *Revision* = a tool for reasoning about changes in beliefs
  - *Update* = a tool for reasoning about changes in the world
  - *Extrapolation* = tool for reasoning about a story, comparison of trajectories
  - *Non-monotonicity* = allows representing dynamic or static laws by default
- Applications with Explicit knowledge about social laws and laws of the world:
  - Ingredients for understanding a joke or a story:
    - surprise and revelation: requires incompleteness (+ knowledge of the character/listener)
    - incongruity = violation of a norm + reasoning by ignoring it
    - curiosity = incompleteness but awareness (+desire to know)
    - suspense = possibility of knowing later (+hope and fear + estimated utility for the hero)
  - These ingredients can all be gradual (degree of uncertainty, importance of the violated norm, importance of the event, suspense increases then plateaus and finally (without revival) fades away
  - Many ingredients remain to be formalized (superiority, empathy, ...)

Perspectives:

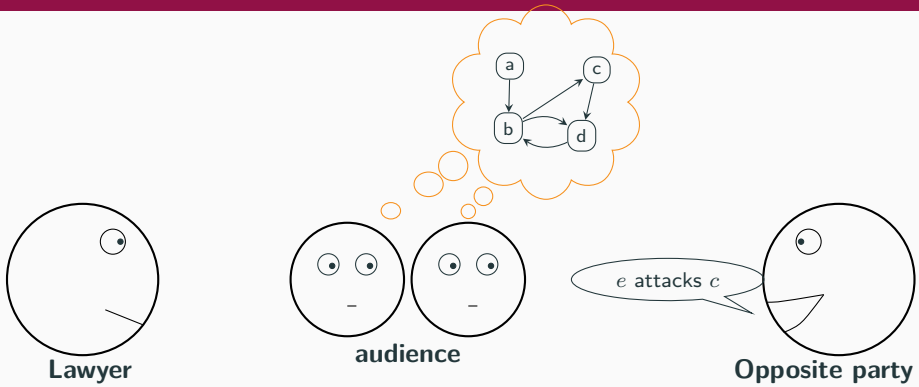
- Causality and computational narration: imagination
  - compute what the listener imagines (as in Suspenser [Cheong and Young, 2015])
  - counterfactual "imagining what would have happened if" = scenario update [Dupin de Saint-Cyr, 2008]
  - what would have happened if I had (not) said that? argumentation update [Dupin de Saint-Cyr et al., 2016]
- Ethical persuasion = transparent and consistent with shared values
- Empowering citizens against influence campaigns (DEMA^{2}IN project)

A lawyer during a trial



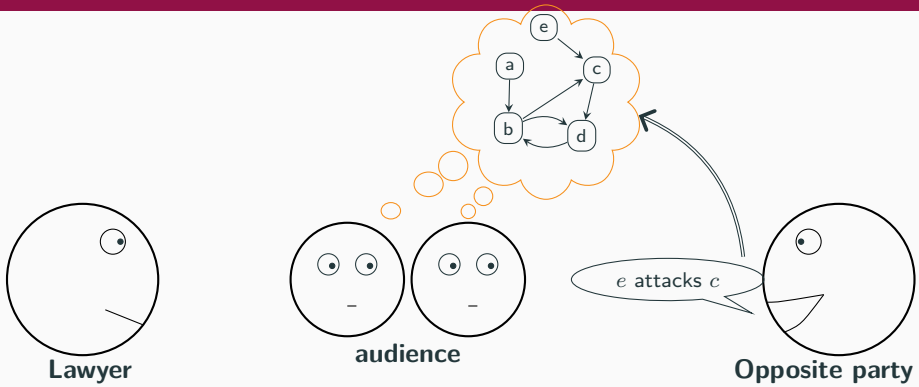
- A lawyer makes her final address to an audience;
- O (opposite party) knows the corresponding argumentation system (AS).
- O can compute the accepted arguments in AS.

Lawyer's example



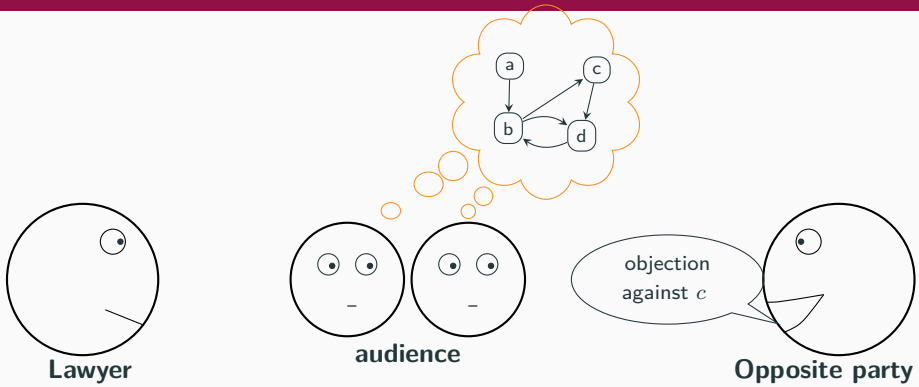
- O wants to force the audience to accept specific arguments.
- She has to make a change to the public system:
  - by adding an argument

Lawyer's example



- O wants to force the audience to accept specific arguments.
- She has to make a change to the public system:
  - by adding an argument
  - or by doing an objection about an argument (to remove it)

Lawyer's example



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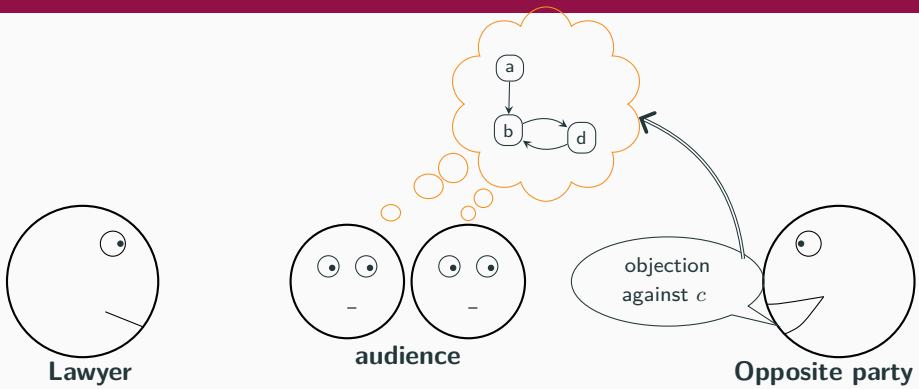

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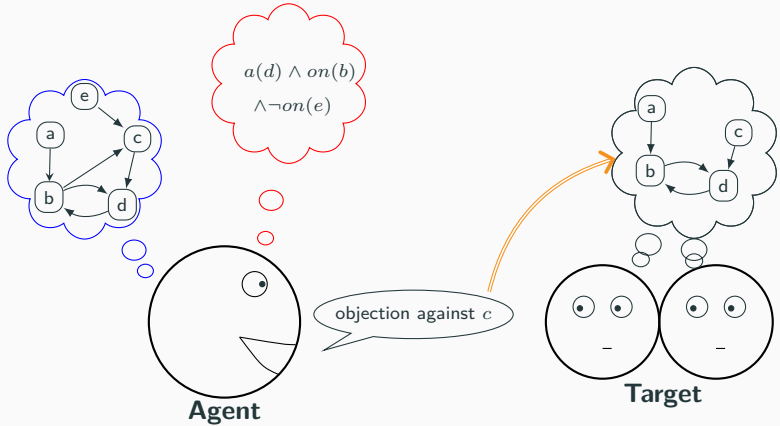

- Agent:
  - has a private argumentation system (her knowledge)
  - has a goal w.r.t. the target
  - agent should respect some constraints
    $\Rightarrow$ notion of executable operation
- Target = public argumentation system (state of the dialog)

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- Ethical persuasion = transparent and consistent with shared values
- Empowering citizens against influence campaigns (DEMA^{2}IN project - DEconstruction des Mécanismes Affectifs et Argumentatifs de persuasion dans les campagnes d'Influence Numérique)

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