KU LEUVEN

DECISION CAMP 2022
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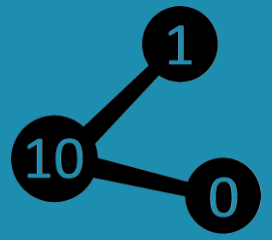
Deontic DMN: Representing deontic statement in DMN with bitstring semantics



Psychology of Inferences Laboratory

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VISION - AI - EMBEDDED

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Overview

- What is DMN?
- What are deontic terms (e.g. obligation, permission)?
- Lack of deontic specific representation in DMN
- Philosophical interpretation (with bitstring semantics)
- Alternative interpretation – Verification with Human Experiment
- Creating deontic DMN judgement templates
- Combine multiple judgements

What is DMN?

- Decision Model & Notation
  - Specification of business decisions and business rules
  - Easily readable by people in decision management
- Extensions
  - cDMN – constraint reasoning
  - pDMN – probabilistic reasoning
  - **dDMN – deontic reasoning**
  - NULL value in DMN

Light switch example		
A	**In the room**	**Light**
1	Yes	On
2	No	Off

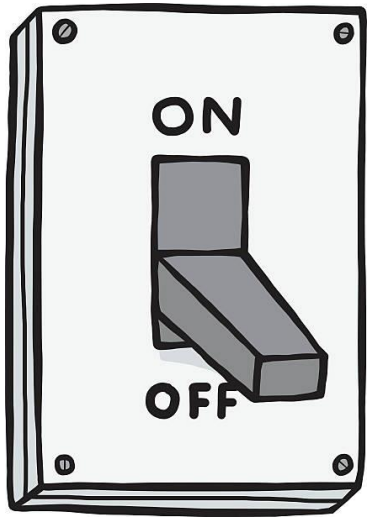
What are deontic terms?

- e.g. ‘obligatory’, ‘forbidden’, ‘permitted’

Light switch example

- When you are in the room, the light must be on. (Safety rule)
- When you are not in the room, the light must be off. (Eco-friendly rule)

Light switch example		
A	**In the room**	**Light**
1	Yes	On
2	No	Off



Safety rule

Light switch example

- Original phrasing
  - When you are in the room, the light must be on.

Original phrasing		
A	**In the room**	**Light**
1	Yes	On
2	No	?

- Alternative phrasing
  - When you are not in the room, the light can be off. (On is default)

Alternative phrasing		
A	**In the room**	**Light**
1	Yes	On?
2	No	Off

Safety rule

Light switch example

Safety rule		
A	**In the room**	**Judgement(Light)**
1	Yes	The light has to be on
2	No	The light can be off

- Original phrasing
  - When you are in the room, the light must be on.

Original phrasing			
A	**In the room**	**Light**	**Does the light have to be on?**
1	Yes	On	Yes
2	No	?	No

- Alternative phrasing
  - When you are not in the room, the light can be off. (On is default)

Alternative phrasing			
A	**In the room**	**Light**	**Can the light be off?**
1	Yes	On?	No
2	No	Off	Yes

Eco-friendly rule

Light switch example

Eco-friendly rule		
A	**In the room**	**Judgement(Light)**
1	Yes	The light can be on
2	No	The light has to be off

- Original phrasing
  - When you are not in the room, the light must be off.

Original phrasing			
A	**In the room**	**Light**	**Does the light have to be off?**
1	Yes	?	No
2	No	Off	Yes

- Alternative phrasing
  - When you are in the room, the light can be on. (Off is default)

Alternative phrasing			
A	**In the room**	**Light**	**Can the light be on?**
1	Yes	On	Yes
2	No	Off?	No

Both rules

Light switch example

- When you are in the room, the light must be on. (Safety rule)
- When you are not in the room, the light must be off. (Eco-friendly rule)

Safety rule		
A	**In the room**	**Judgement(Light)**
1	Yes	The light has to be on
2	No	The light can be off

Both rules		
A	**In the room**	**Judgement(Light)**
1	Yes	The light has to be on
2	No	The light has to be off

Eco-friendly rule		
A	**In the room**	**Judgement(Light)**
1	Yes	The light can be on
2	No	The light has to be off

Light switch example		
A	**In the room**	**Light**
1	Yes	On
2	No	Off

Definition vs Judgement

- When you are in the room, the light must be on. (Safety rule)
- When you are not in the room, the light must be off. (Eco-friendly rule)

- The light is on when the brightness level is above zero (Light on definition)

Both rules		
A	**In the room**	**Judgement(Light)**
1	Yes	The light has to be on
2	No	The light has to be off

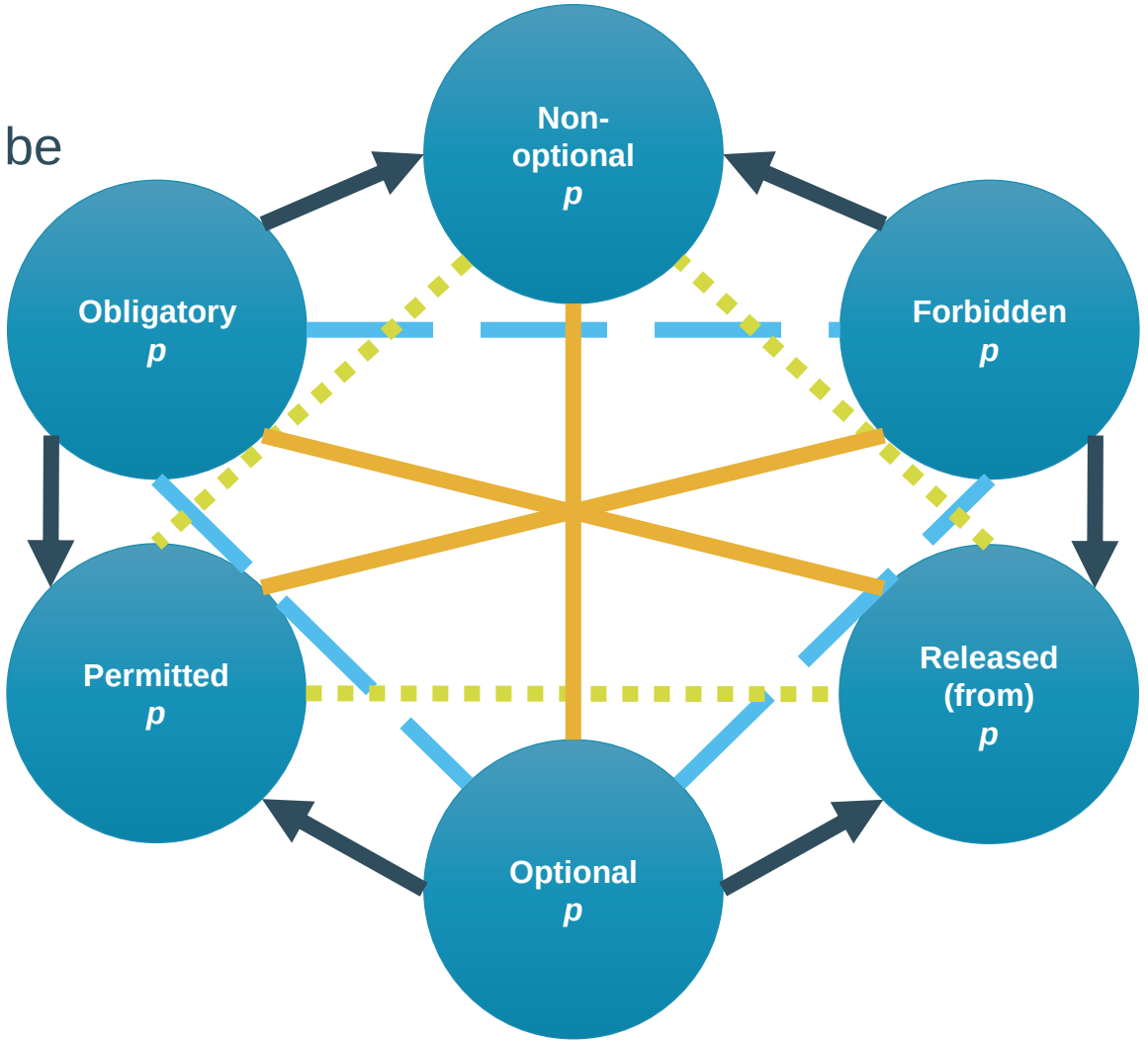
Light on definition		
A	**Brightness**	**Light**
1	>0	On
2	=0	Off

Light switch example		
A	**In the room**	**Light**
1	Yes	On
2	No	Off

Deontic terms relationship – Deontic hexagon

Aristotelian relations: two propositions are said to be

- contradictory (CD):
  iff they cannot be true together
  and they cannot be false together
- contrary (C):
  iff they cannot be true together
  but they can be false together
- subcontrary (SC):
  iff they can be true together
  but they cannot be false together
- in subalternation (SA):
  iff the first proposition entails the second
  but the second does not entail the first

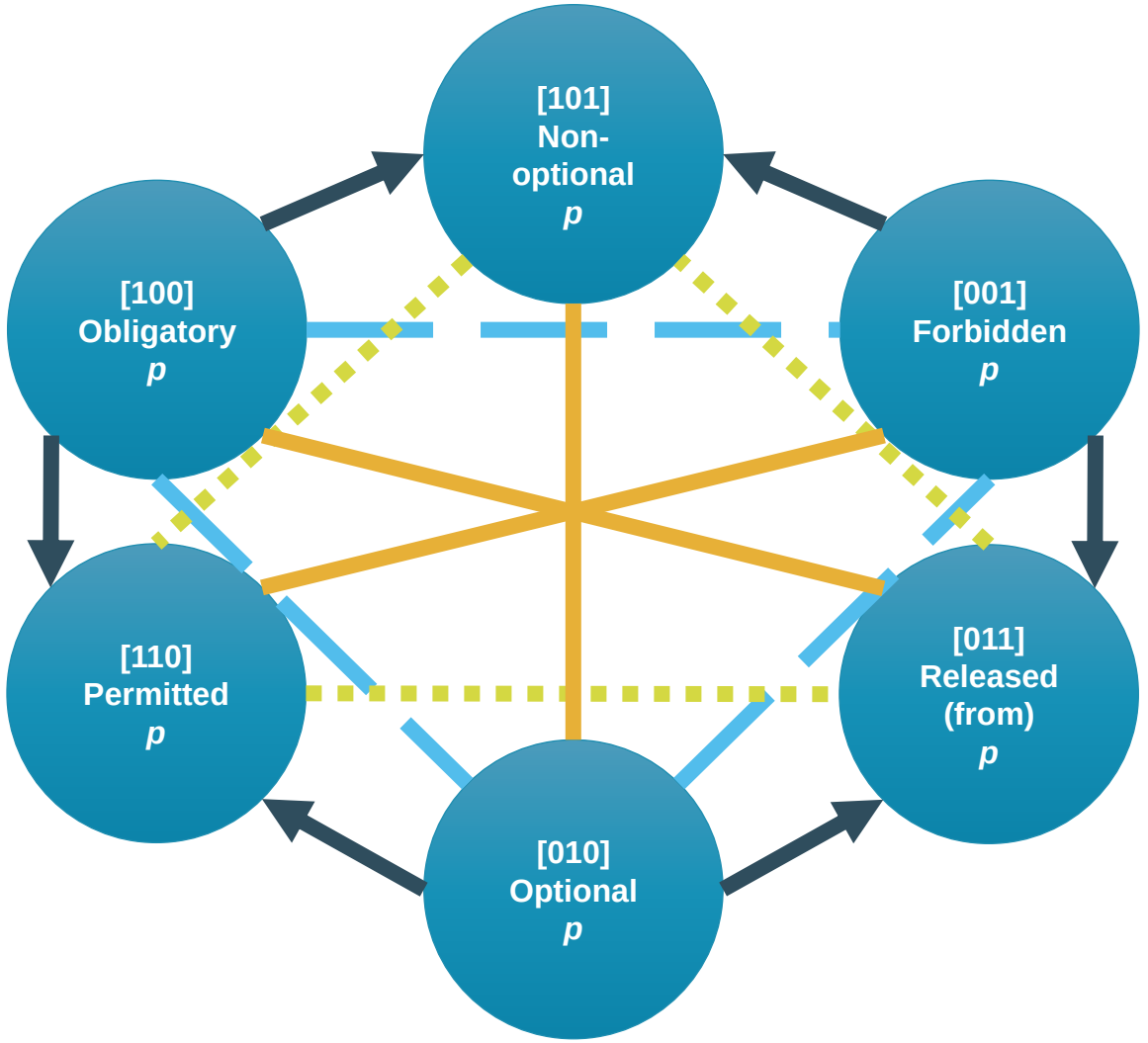


Deontic Judgement & Bitstring semantics

Bitstring semantics: a sequences of bits (0/1),

- ❑ each bit provides an answer to a meaningful (binary) question, e.g.
  - Can the deontic statement be fulfilled by *p*?
  - Can the deontic statement be neutral to *p*?
  - Can the deontic statement be violated by *p*?
- ❑ each question concerns a component of a scalar structure, e.g.

  Fulfilled | Neutral | Violated
- ❑ bitstring example:
  - β(Obligatory p) = 100 = <yes, no, no>
  - β(Permitted p) = 110 = <yes, yes, no>
  - β(Forbidden p) = 001 = <no, no, yes>



Bitstring interpretation of deontic hexagon

- Deontic terms can be represented in terms of obligatory and permitted

	Obligatory *p*	**Permitted *p***	**Optional *p***	**Released (from) *p***	**Forbidden *p***	**Non-optional *p***
	Obligatory *p*	Permitted *p*	Permitted *p* AND NOT Obligatory *p*	NOT Obligatory *p*	NOT Permitted *p*	Obligatory *p* OR NOT Permitted *p*

	Obligatory *p*	**Permitted *p***	**Optional *p***	**Released (from) *p***	**Forbidden *p***	**Non-optional *p***
When *p* is true (*p*)	[100] Fulfilled	[110] Not violated	[010] Neutral	[011] Not fulfilled	[001] Violated	[101] Not neutral

Philosophical interpretation

- Additional assumption Permitted p = NOT Obligatory NOT p,
  - e.g. Permitted to turn on the light = Not obligatory to turn off the light
  - deontic terms can be represented in terms of obligatory alone

	Obligatory *p*	**Permitted *p***	**Optional *p***	**Released (from) *p***	**Forbidden *p***	**Non-optional *p***
	Obligatory *p*	Permitted *p*	Permitted *p* AND NOT Obligatory *p*	NOT Obligatory *p*	NOT Permitted *p*	Obligatory *p* OR NOT Permitted *p*
	Obligatory *p*	NOT Obligatory NOT *p*	NOT Obligatory NOT *p* AND NOT Obligatory *p*	NOT Obligatory *p*	Obligatory NOT *p*	Obligatory *p* OR Obligatory NOT *p*

	Obligatory *p*	**Permitted *p***	**Optional *p***	**Released (from) *p***	**Forbidden *p***	**Non-optional *p***
When *p* is true (*p*)	[100] Fulfilled	[110] Not violated	[010] Neutral	[011] Not fulfilled	[001] Violated	[101] Not neutral
When *p* is false (NOT *p*)	[001] Violated	[011] Not fulfilled	[010] Neutral	[110] Not violated	[100] Fulfilled	[101] Not neutral
	Forbidden NOT *p*	**Released (from) NOT *p***	**Optional NOT *p***	**Permitted NOT *p***	**Obligatory NOT *p***	**Non-optional NOT *p***

Deontic DMN

Light switch example

- Obligation rule
  - The light must be on.

Obligation – light on		
	Light	**Deontic Judgement**
1	On	[100] Fulfilled
2	Off	[001] Violated

- Permission rule
  - The light can be off.

Permission – light off		
	Light	**Deontic Judgement**
1	On	[011] not(Fulfilled)
2	Off	[110] not(Violated)

Alternative interpretation

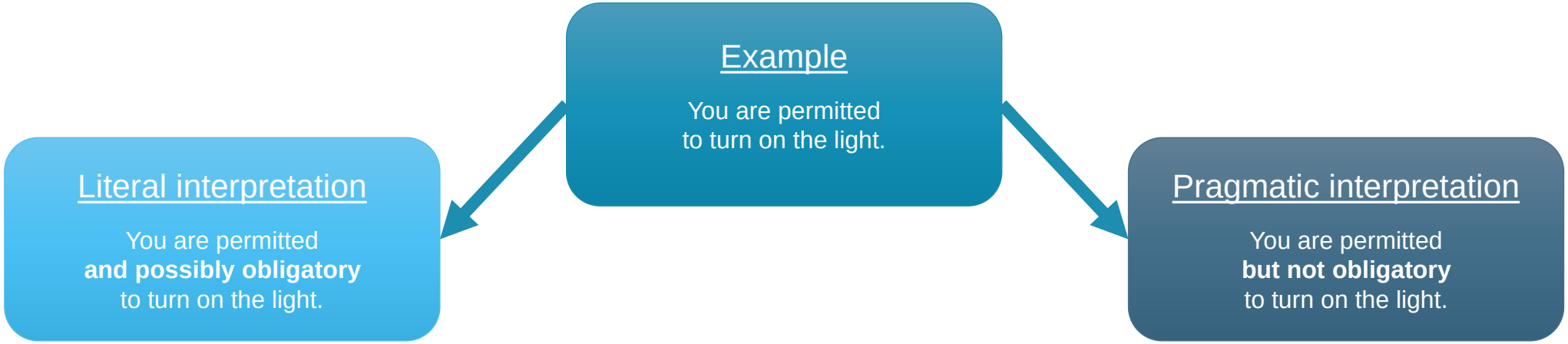
- E.g. When p is false, “Obligatory p” is of interpreted as
  - only [011] not fulfilled
  - rather than [001] violated
- Speculation: is the “[001] violated” interpretation a **pragmatic enrichment of meaning** in “[011] not fulfilled” interpretation, i.e. **scalar implicature**?

	Obligatory *p*	**Permitted *p***	**Optional *p***	**Released (from) *p***	**Forbidden *p***	**Non-optional *p***
When *p* is true (*p*)	[100] Fulfilled	[110] Not violated	[010] Neutral	[011] Not fulfilled	[001] Violated	[101]Not neutral
When *p* is false (NOT *p*)	**[001] Violated**	[011] Not fulfilled	[010] Neutral	[110] Not violated	[100] Fulfilled	[101]Not neutral
	Forbidden NOT *p*	**Released (from) NOT *p***	**Optional NOT *p***	**Permitted NOT *p***	**Obligatory NOT *p***	**Non-optional NOT *p***

Scalar implicature

Alternative interpretation

- attributes an implicit meaning beyond the explicit or literal meaning of an utterance
- suggests that the speaker had a reason for not using a more informative term (e.g. obligatory vs permitted) on the same scale



Judgement templates

Deontic DMN

- Strong obligation DMN template
  - “[001] violated” interpretation

Strong obligation		
A	**Action (Light)**	**Deontic Judgement**
1	True (On)	[100] Fulfilled
2	False (Off)	**[001] Violated**

- Weak obligation DMN template
  - “[011] not fulfilled” interpretation

Weak obligation		
A	**Action (Light)**	**Deontic Judgement**
1	True (On)	[100] Fulfilled
2	False (Off)	**[011] not(Fulfilled)**

64 templates in total!

Safety rule

Deontic DMN

Safety rule		
A	**In the room**	**Judgement(Light)**
1	Yes	The light has to be on
2	No	The light can be off

- Original phrasing
  - When you are in the room, the light must be on.

Safety rule – Deontic Judgement			
	In the room	**Light (Action)**	**Deontic Judgement**
1	Yes	On	[100] Fulfilled
2	Yes	Off	[001] Violated
3	No	On	[011] not(Fulfilled)
4	No	Off	[110] not(Violated)

- Alternative phrasing
  - When you are not in the room, the light can be off.

Eco-friendly rule

Deontic DMN

Eco-friendly rule		
A	**In the room**	**Judgement(Light)**
1	Yes	The light can be on
2	No	The light has to be off

- Original phrasing
  - When you are not in the room, the light must be off.

Eco-friendly rule – Deontic Judgement			
	In the room	**Light (Action)**	**Deontic Judgement**
1	Yes	On	[110] not(Violated)
2	Yes	Off	[011] not(Fulfilled)
3	No	On	[001] Violated
4	No	Off	[100] Fulfilled

- Alternative phrasing
  - When you are in the room, the light can be on.

Combined Judgement?

Deontic DMN

Both rules		
A	**In the room**	**Judgement(Light)**
1	Yes	The light has to be on
2	No	The light has to be off

Both rules – Deontic Judgement					
	In the room	**Light (Action)**	**Safety rule – Deontic Judgement**	**Eco-friendly rule – Deontic Judgement**	**Combined Judgement**
1	Yes	On	**[100] Fulfilled**	[110] not(Violated)	?
2	Yes	Off	**[001] Violated**	[011] not(Fulfilled)	?
3	No	On	[011] not(Fulfilled)	**[001] Violated**	?
4	No	Off	[110] not(Violated)	**[100] Fulfilled**	?

Combining Judgements

	[100]Fulfilled	[010]Neutral	[001]Violated
[100]Fulfilled	[100]Fulfilled	[100]Fulfilled	[001]Violated
[010]Neutral	[100]Fulfilled	[010]Neutral	[001]Violated
[001]Violated	[001]Violated	[001]Violated	[001]Violated

Combing multiple deontic judgements			
A	**Judgement 1**	**Judgement 2**	**Combined Judgement**
1	[100] Fulfilled	[100] Fulfilled	[100] Fulfilled
2	[100] Fulfilled	[010] Neutral	[100] Fulfilled
3	[100] Fulfilled	[001] Violated	[001] Violated
4	[010] Neutral	[100] Fulfilled	[100] Fulfilled
5	[010] Neutral	[010] Neutral	[010] Neutral
6	[010] Neutral	[001] Violated	[001] Violated
7	[001] Violated	[100] Fulfilled	[001] Violated
8	[001] Violated	[010] Neutral	[001] Violated
9	[001] Violated	[001] Violated	[001] Violated

Building on constraint reasoning: cDMN

- Standard DMN: a single solution
- cDMN: a solution space
  - Allowing to set constraints in the models

- Deontic Judgement:
  - either [100] Fulfilled,
  - [010] Neutral,
  - or [001] Violated

Both rules – Deontic Judgement					
	In the room	**Light (Action)**	**Safety rule – Deontic Judgement**	**Eco-friendly rule – Deontic Judgement**	**Combined Judgement**
1	Yes	On	[100] Fulfilled	**[110] not(Violated)**	[100] Fulfilled
2	Yes	Off	[001] Violated	**[011] not(Fulfilled)**	[001] Violated
3	No	On	**[011] not(Fulfilled)**	[001] Violated	[001] Violated
4	No	Off	**[110] not(Violated)**	[100] Fulfilled	[100] Fulfilled

Combined Judgement

Deontic DMN

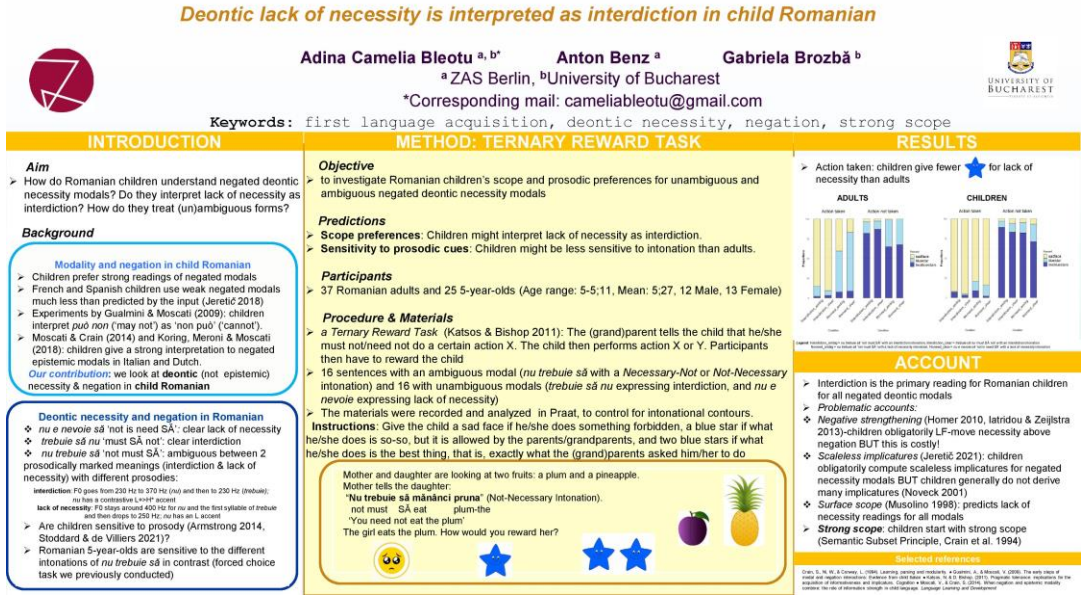
Both rules		
A	**In the room**	**Judgement(Light)**
1	Yes	The light has to be on
2	No	The light has to be off

	[100]Fulfilled	[010]Neutral	[001]Violated
[100]Fulfilled	[100]Fulfilled	[100]Fulfilled	[001]Violated
[010]Neutral	[100]Fulfilled	[010]Neutral	[001]Violated
[001]Violated	[001]Violated	[001]Violated	[001]Violated

Both rules – Deontic Judgement					
	In the room	**Light (Action)**	**Safety rule – Deontic Judgement**	**Eco-friendly rule – Deontic Judgement**	**Combined Judgement**
1	Yes	On	[100] Fulfilled	[110] not(Violated)	**[100] Fulfilled**
2	Yes	Off	[001] Violated	[011] not(Fulfilled)	**[001] Violated**
3	No	On	[011] not(Fulfilled)	[001] Violated	**[001] Violated**
4	No	Off	[110] not(Violated)	[100] Fulfilled	**[100] Fulfilled**

Human judgement experiments

- [011] Released can be interpreted as:
  - either [010] Neutral
  - or [001] Violated
- E.g. Mother said “You need not eat the plum”. The girl eats the plum.
  - Most adults judge the girl’s action neutral (One star)
  - Meanwhile most children judge it negatively (Sad Face)
- Further human judgement experiments
  - Compare the philosophical interpretation vs folk interpretation
  - Find the best labelling for the deontic judgement templates



Conclusion

Deontic DMN is building on

- Philosophical insights – deontic hexagon and bitstring semantics
- Constraint reasoning – cDMN
- Deontic judgement templates
- Deontic judgement composition rule

Goal

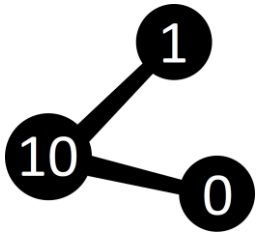
- Separation of deontic rule from factual consequence/definition
  - Hence, we can tell if the inconsistency
    - arise from deontic inference
    - rather than from the fact/definition.
- Reflecting human deontic judgement

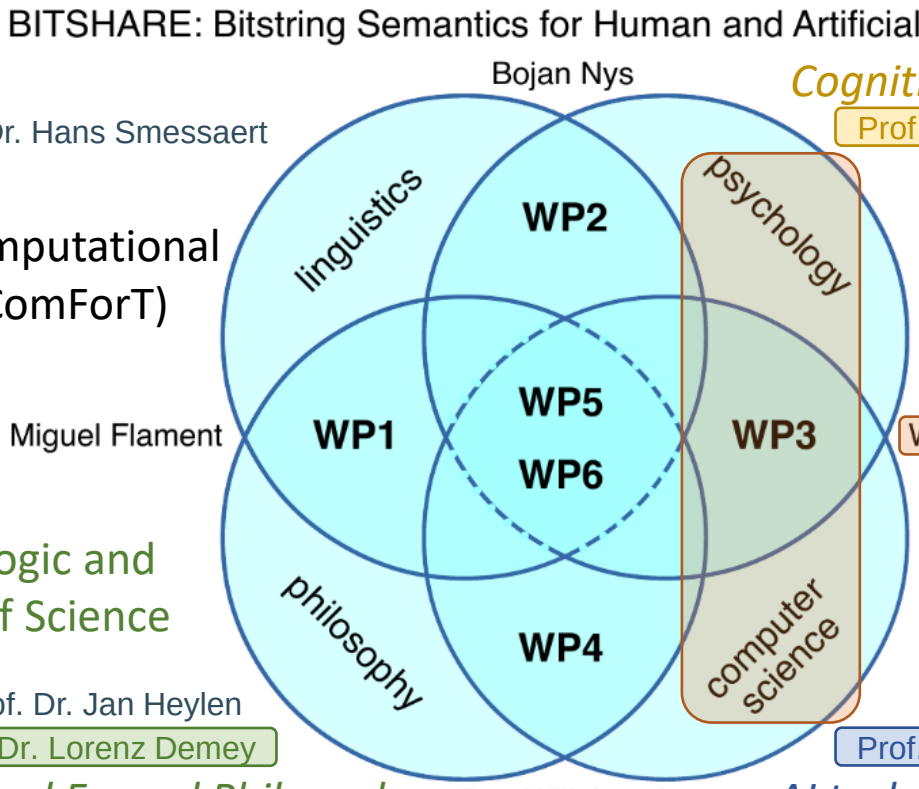
Human Judgement Experiment

- Finding the best representation in Deontic DMN

Team

BITSHARE project





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AI technology and its industrial applications

KU LEUVEN

Leuven.AI - KU Leuven Institute for Artificial Intelligence (Research lines: Reasoning)

References

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Q&A