Intelligent Agents

Dynamic Epistemic Logic – Part 1

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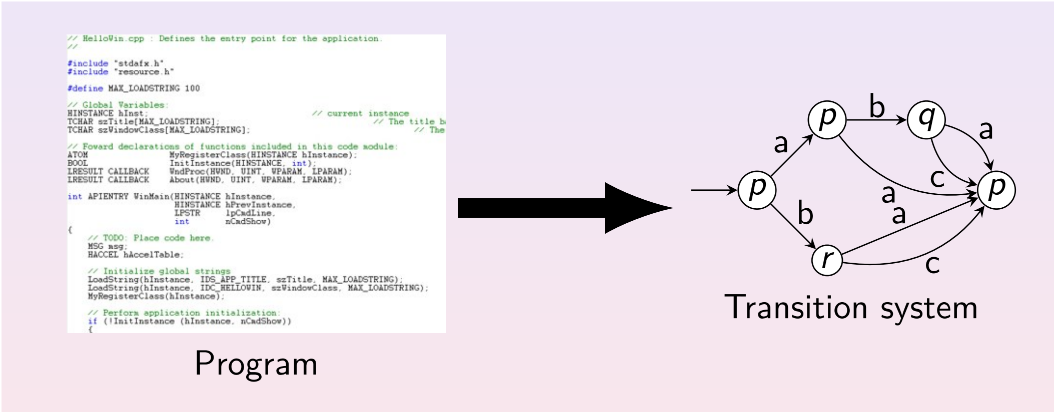
Todays lecture based on

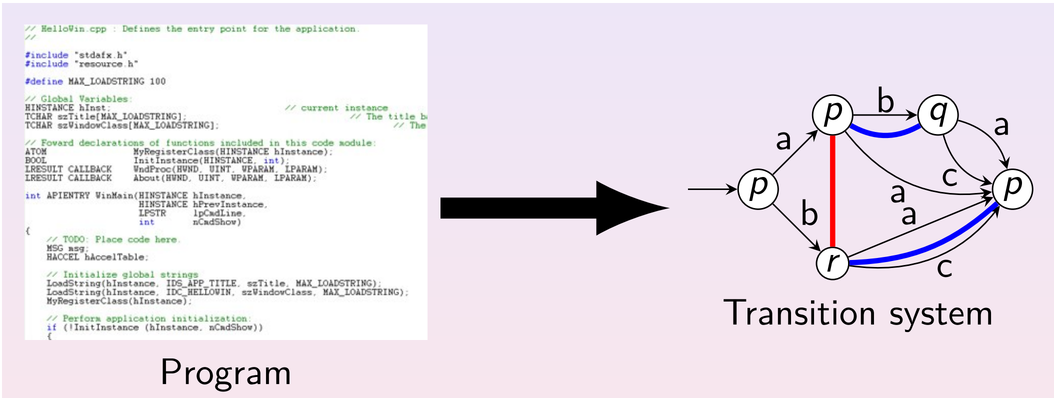
- The AAMAS 2019 Tutorial **„EPISTEMIC REASONING IN MULTI-AGENT SYSTEMS“, Part 4: Dynamic Epistemic Logic**
  http://people.irisa.fr/Francois.Schwarzentruber/2019AAMAStutorial/

MODELING ACTIONS

In the verification/model checking community



Action = an edge →



Action = an edge →

Epistemic =

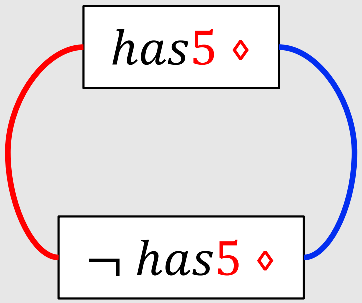
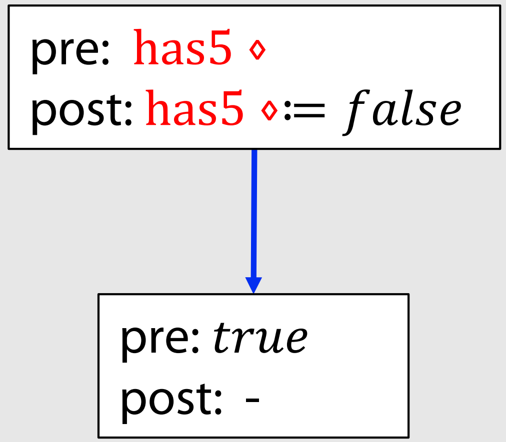
In philosophy and AI

Type of mechanism of actions is important

Type of mechanism	Example
Public /private announcement	She knows you hold 5 ◊
Public action	Play card 5 ◊
Private action	Secretely remove card 5 ◊
Belief revision	Revise believes (entailing $\neg p$) after being told p

- There is a dedicated logic for the first type of announcementes: PAL (Public announcement logic)
- What kind of formalism to use to handle all of them?

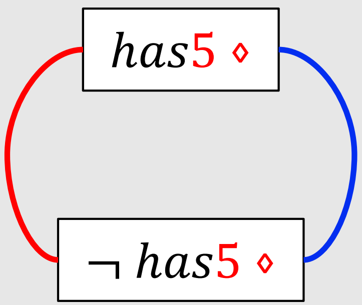
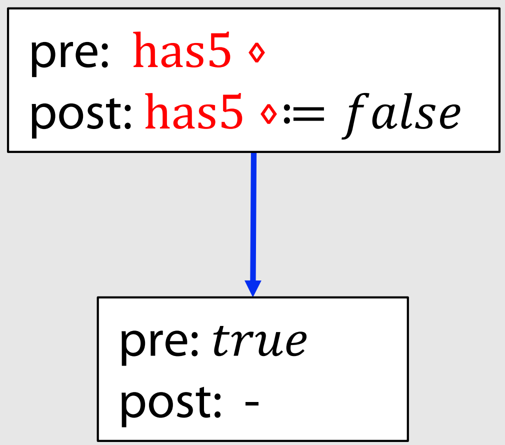
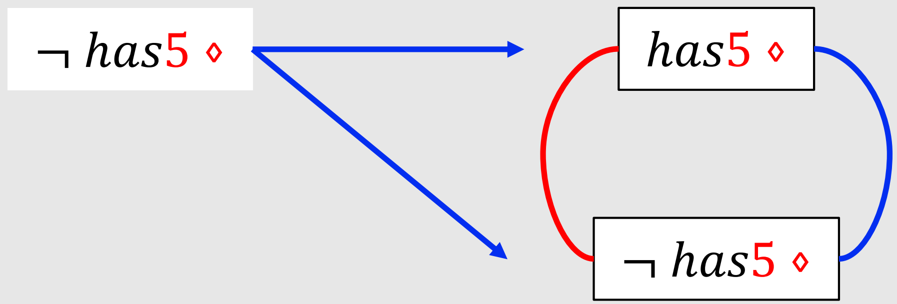
Dynamic Epistemic Logic (DEL)

	State	Action
Classical planning	*has*5 ◊	pre: has5 ◊ post: has5 ◊:= *false*
Logic DEL[1),2)] = Kripkean models of classical planning		

- Action: remove 5 ◊
- blue agent does not know

1) (Baltag et al., 1998)
2) (van Ditmarsch et al, 2007)

Computing the next state: product update

State	Action	Next State
(epistemic model)	(event model)	(updated epistemic model)
		

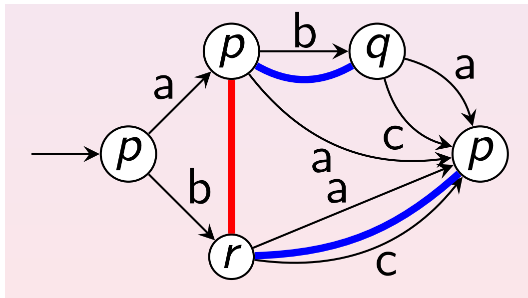
Some syntactic specifications/logics

Logic	Example sentence
Game description language (Love et al. 2008), (Thielscher, 2017)	Agent a sees the game position
Flatland (Babiani et al, 2021), (Gasquet et al. 2014), (Gasquet et al, 2016),	Agent a sees agent b
Visibility atoms (Charrier et al, 2016)	Agent a sees truth value of p
Paying attention to public announcements (Bolander et al, 2016)	$B_a payAtt(b) \rightarrow [p!]B_a B_b p$
Asynchronous announcements (Knight et al, 2019)	$[p!][read_a]K_a p$
Epistemic gossip (Ditmarsch et al 2017)	$[call_{ab}]K_a secret_b$

From DEL to Epistemic Logics

Syntactic Specification

Models of DEL



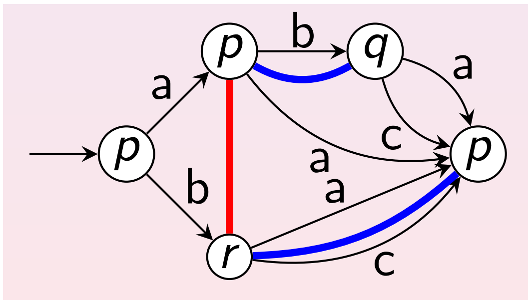
Epistemic temporal models

From DEL to Epistemic Logics

Syntactic Specification

+ Easy to specify
+ Succinct
- Ad-hoc languages
- Hand crafted semantics

Models of DEL

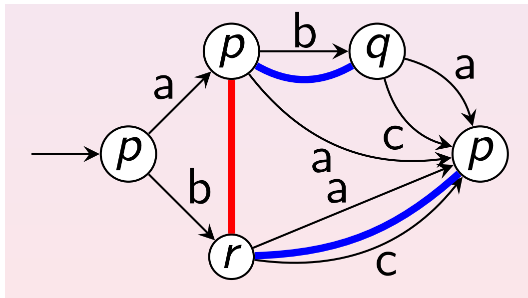


Epistemic temporal models

From DEL to Epistemic Logics

Syntactic Specification

+ Elegant Kripkean extension of classical planning
+ Succinct
+ Classification in terms of action types
+ Has probabilistic extension
+ Has extensions that encompass belief revision
- Perfect-recall only
- Synchronous only



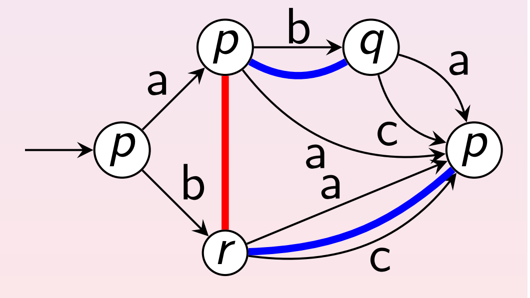
Models of DEL

Epistemic temporal models

From DEL to Epistemic Logics

Syntactic Specification

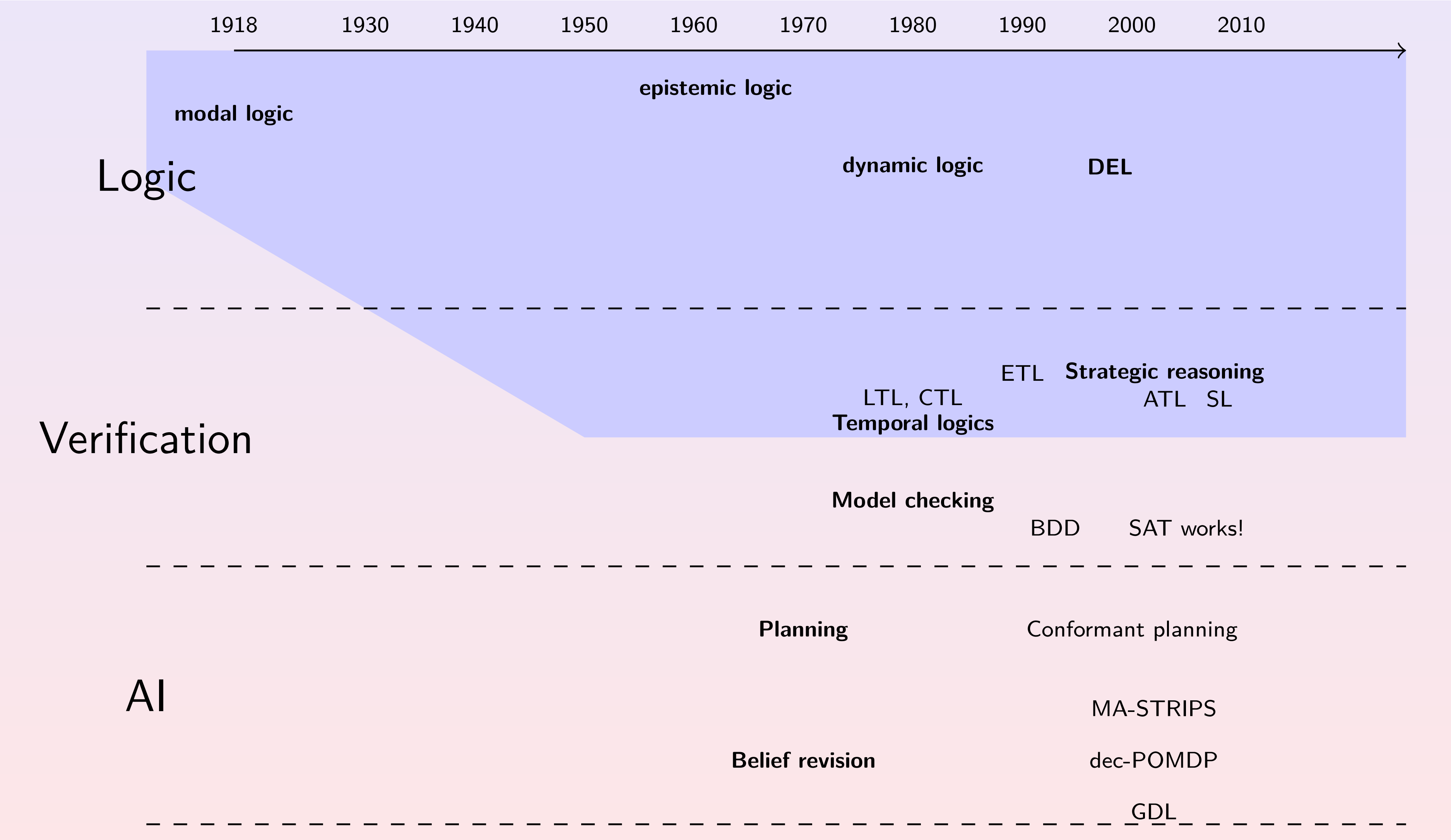
+ Elegant
+ Allows for async/no perfect recall semantics
-Type of actions lost
- Not succinct (usually infinite)



Models of DEL

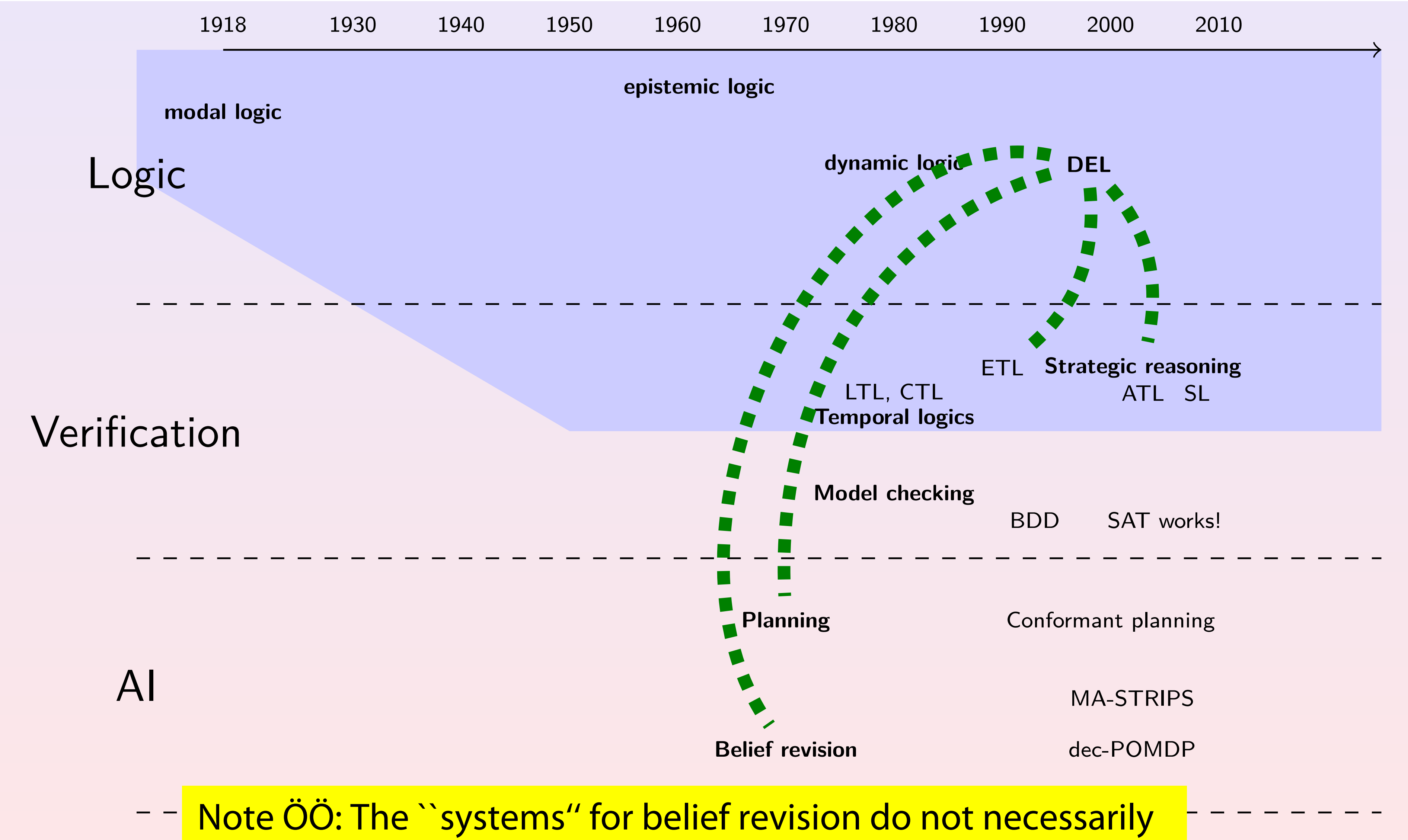
Epistemic temporal models

Timeline



1918
1930
1940
1950
1960
1970
1980
1990
2000
2010
epistemic logic
modal logic
Logic
dynamic logic
DEL
ETL
Strategic reasoning
LTL, CTL
ATL
SL
Temporal logics
Verification
Model checking
BDD
SAT works!
Planning
Conformant planning
AI
MA-STRIPS
Belief revision
dec-POMDP
GDL

Timeline



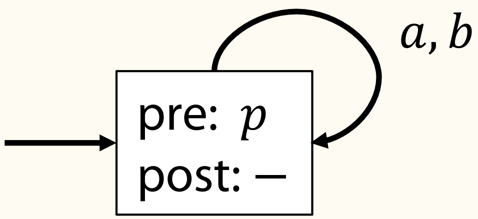
Note ÖÖ: The ``systems“ for belief revision do not necessarily reflect the classical approaches to belief revision

EVENT MODELS

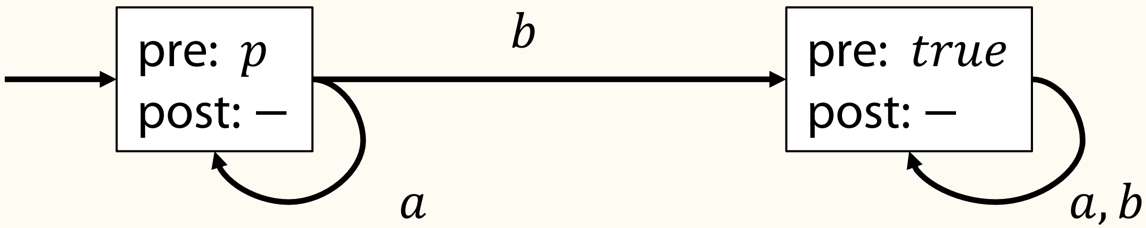
Examples of actions

(Baltag et al. 1998)

Example (public announcement of p)



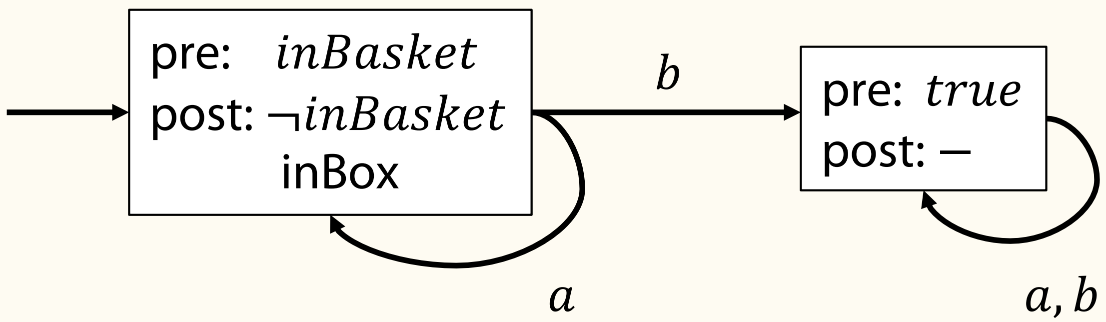
Example (Private announcement of p to a)



Examples of actions

Assume that agent a transfers a marble from a basket to a box - not seen by agent b

Example (Transfer marble from basket to box)

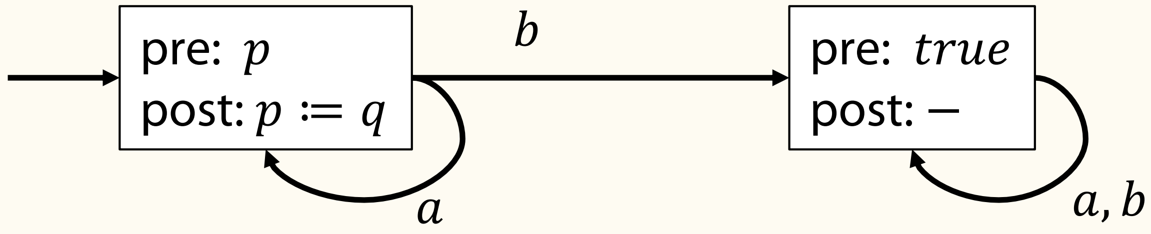


Formal Definition

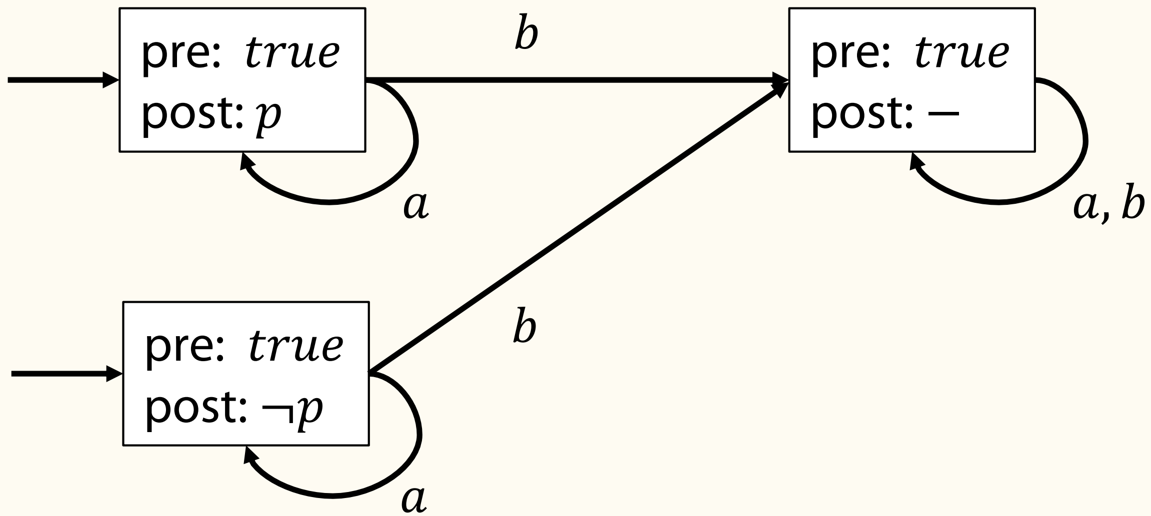
Definition

- An event model $\mathcal{E} = (E, (R_a^E)_{a \in AGT}, pre, post)$ is a tuple where
  - $E = \{e, e', \dots\}$ is a non-empty set of possible events
  - $R_a^{\mathcal{E}} \subseteq E \times E$ is an accessibility relation on E for agent a
  - $pre: E \to \mathcal{L}_{EL}$ is a precondition function
  - $post: E \times AP \to \mathcal{L}_{EL}$ is a postcondition function
- A pair $(\mathcal{E}, e)$ is called an action where e represents the actual event of $(\mathcal{E}, e)$
- A pair $(\mathcal{E}, E_0)$, for $E_0 \subseteq E$, is a non-deterministic action. The set E_0 is the set of triggerable events.

Example (Deterministic action= single-pointed event model)



Example (Non-deterministic action= multi-pointed event model)

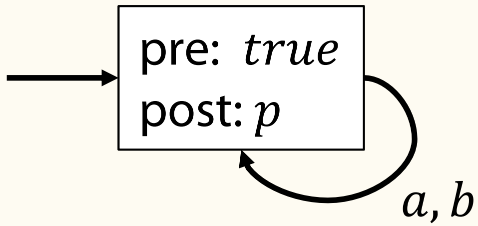


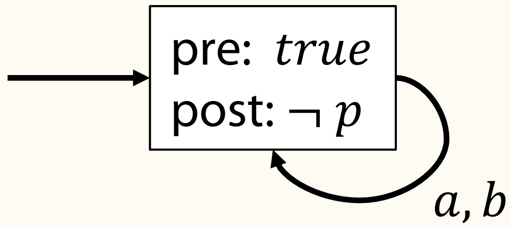
Public Actions

Definition

An action is said to be public if the accessibility relations in the underlying event model are self-loops

Example (public)



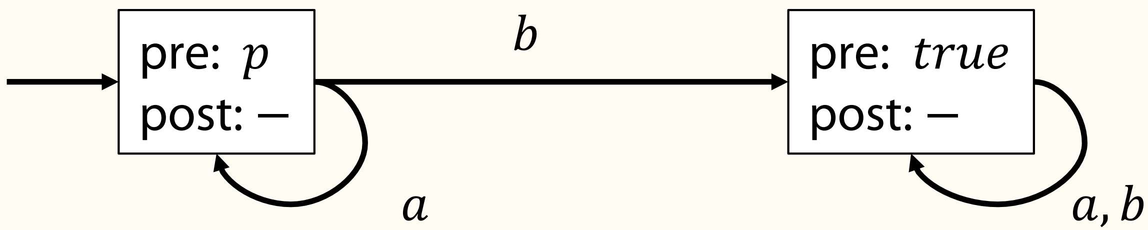


Non-ontic actions

Definition

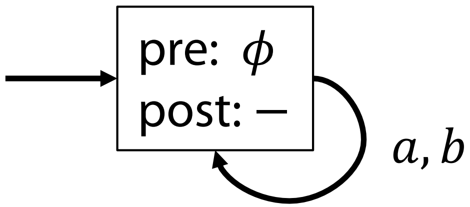
An action is said to be $non - ontic$ if the postconditions are trivial:
for all $e \in E$, for all propositions $p \in AP$: $post(e,p) = p$

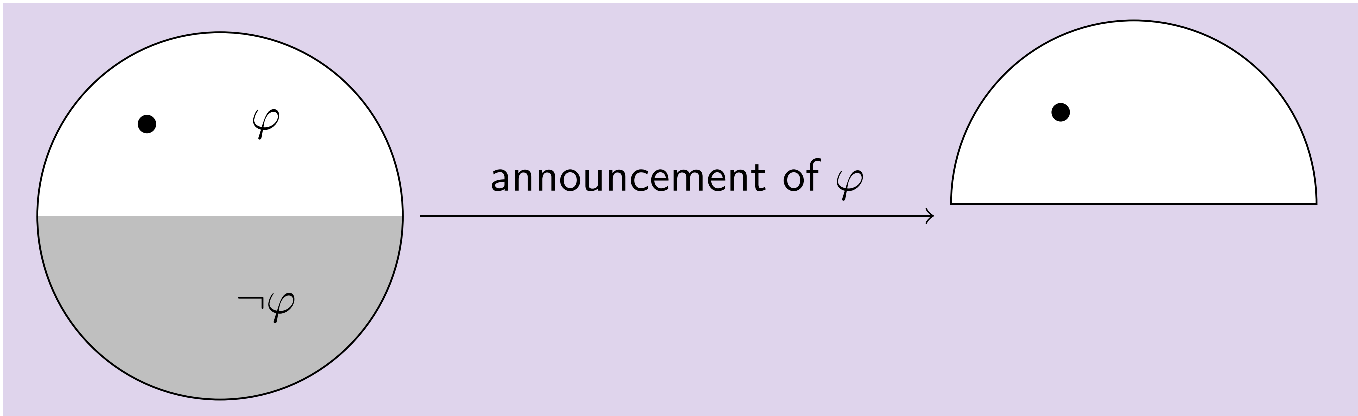
Example (non-ontic)



Effect of a public announcement

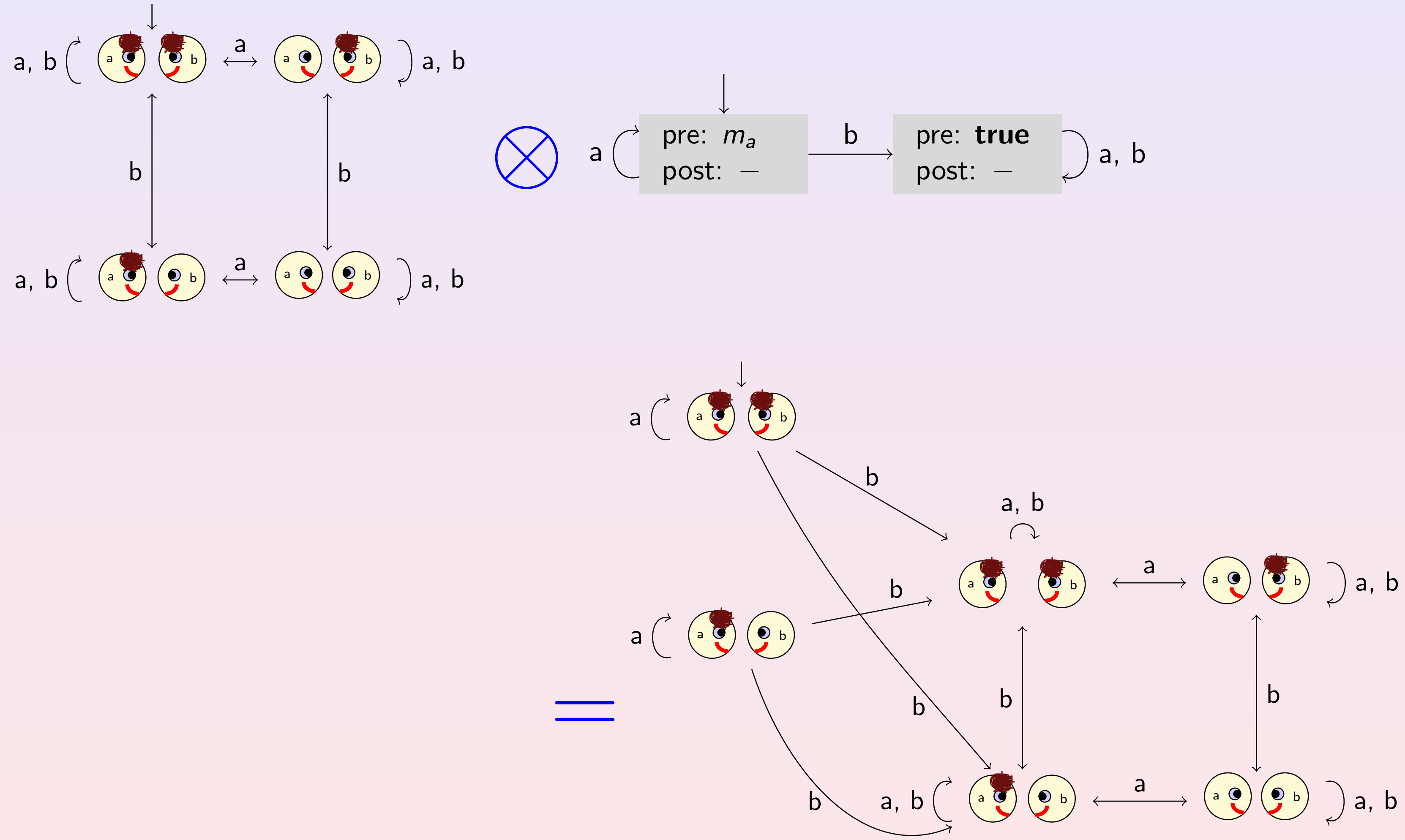
Publicly announcing ϕ leads to keeping only the ϕ worlds.





Can try this out on several examples in Hintikka's world.

Example (Update Product)



Formal Definition of Update Products

Definition

- Given
  - $\mathcal{M} = (W, \{R_a\}_{a \in AGT}, V)$ (epistemic model)
  - $\mathcal{E} = (E, (R_a^E)_{a \in AGT}, pre, post)$ (event model)

- define the update product of M and $\mathcal{E}$ as the epistemic model $\mathcal{M} \otimes \mathcal{E} = (W^{\otimes}, \{R_a^{\otimes}\}_{a \in AGT}, V^{\otimes})$ where
  - $W^{\otimes} = \{(w, e) \in W \times E \mid \mathcal{M}, w \vDash pre(e)\}$
  - $R_a^{\otimes} = \{(w', e') \in W^{\otimes} \mid w\, R_a\, w' \quad and \quad e\, R_a^{\mathcal{E}} e'\}$
  - $V^{\otimes}(w, e) = \{p \in AP \mid \mathcal{M}, w \vDash post(e, p)\}$

Pointed update products

Definition

The successor state of an epistemic state $(\mathcal{M}, w)$ by action $(\mathcal{E}, e)$ is

$$(\mathcal{M}, w) \otimes (\mathcal{E}, e) = (\mathcal{M} \otimes \mathcal{E}, (w, e))$$

if $(\mathcal{M}, w) \vDash pre(e)$, otherwise it is undefined.

Notation

- Write e for $(\mathcal{E}, e)$
- Write \`we' for (w, e)
- Write $\mathcal{M} \otimes \mathcal{E}^n$ for $\mathcal{M} \otimes \mathcal{E} \otimes \mathcal{E} \ldots \otimes \mathcal{E}$ (n-times)
- Write $we_1 \ldots e_n \vDash \phi$ for $\mathcal{M} \otimes \mathcal{E}^n, we_1 \ldots e_n \vDash \phi$,

Dynamic epistemic logic $\mathcal{L}_{DELCK}$

Definition

The language $\mathcal{L}_{DELCK}$ extends $\mathcal{L}_{ELCK}$ with dynamic (possibility) modalities $< \mathcal{E}, E_0 >$ according to the following BNF:

$$\phi ::= \top \mid p \mid \neg\phi \mid (\phi \vee \phi) \mid K_a\phi \mid C_G\phi \mid < \mathcal{E}, E_0 > \phi$$

Definition

The modelling relation $\vDash$ for $\mathcal{L}_{ELCK}$ is extended with the following clause:

$\mathcal{M}, w \vDash < \mathcal{E}, E_0 > \phi$ iff there exists $e \in E_0$ such that $\mathcal{M}, w \vDash pre(e)$ and $\mathcal{M} \otimes \mathcal{E}, (w, e) \vDash \phi$

Dual operator

Definition (Dual operator)

$$[\mathcal{E}, E_0]\phi \coloneqq \neg < \mathcal{E}, E_0 > \neg\phi$$

The induced semantics is

$\mathcal{M}, w \vDash [\mathcal{E}, E_0]\phi$ iff for all e $\in E_0$ we have:
If $\mathcal{M}, w \vDash pre(e)$ then $\mathcal{M} \otimes \mathcal{E}, (w, e) \vDash \phi$

Expressivity and Succinctness

Theorem (Baltag 98)

DEL and EL have the same expressivity

Proof idea: Remove dynamic operators $[\mathcal{E}, E]$ as demonstrated here for public announcements:

- Remember
  $[\phi!]\psi$: if ϕ holds then after having anounced ϕ publicly, ψ holds.
- $[\phi!]p$: says the same as $(\phi \rightarrow p)$
- $[\phi!](\psi \wedge \chi)$: says the same as $([\phi!]\psi \wedge [\phi!]\chi)$
- $[\phi!]\neg\psi$: says the same as $(\phi \rightarrow \neg[\phi!]\psi)$
- $[\phi!]K_a\psi$: says the same as $(\phi \rightarrow K_a[\phi!]\psi)$
- $[\phi!][\psi!]\chi$: says the same as $([\phi \wedge [\phi!]\psi!]\chi)$

Theorem (Lutz 2006)

DEL is more succinct

Uhhh, a lecture with a hoepfully useful

APPENDIX

References

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Color Convention in this course

- Formulae, when occurring inline
- Newly introduced terminology and definitions
- Important results (observations, theorems) as well as emphasizing some aspects
- Examples are given with standard orange with possibly light orange frame
- Comments and notes
- Algorithms