Computational Interaction Frames

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currently also

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Outline

- Background
- Interaction Frames and Framing
- The InFFrA Architecture
- Frames vs. Communication Semantics
- Reasoning and Learning in InFFrA
- Applications and Future Research
- Conclusions

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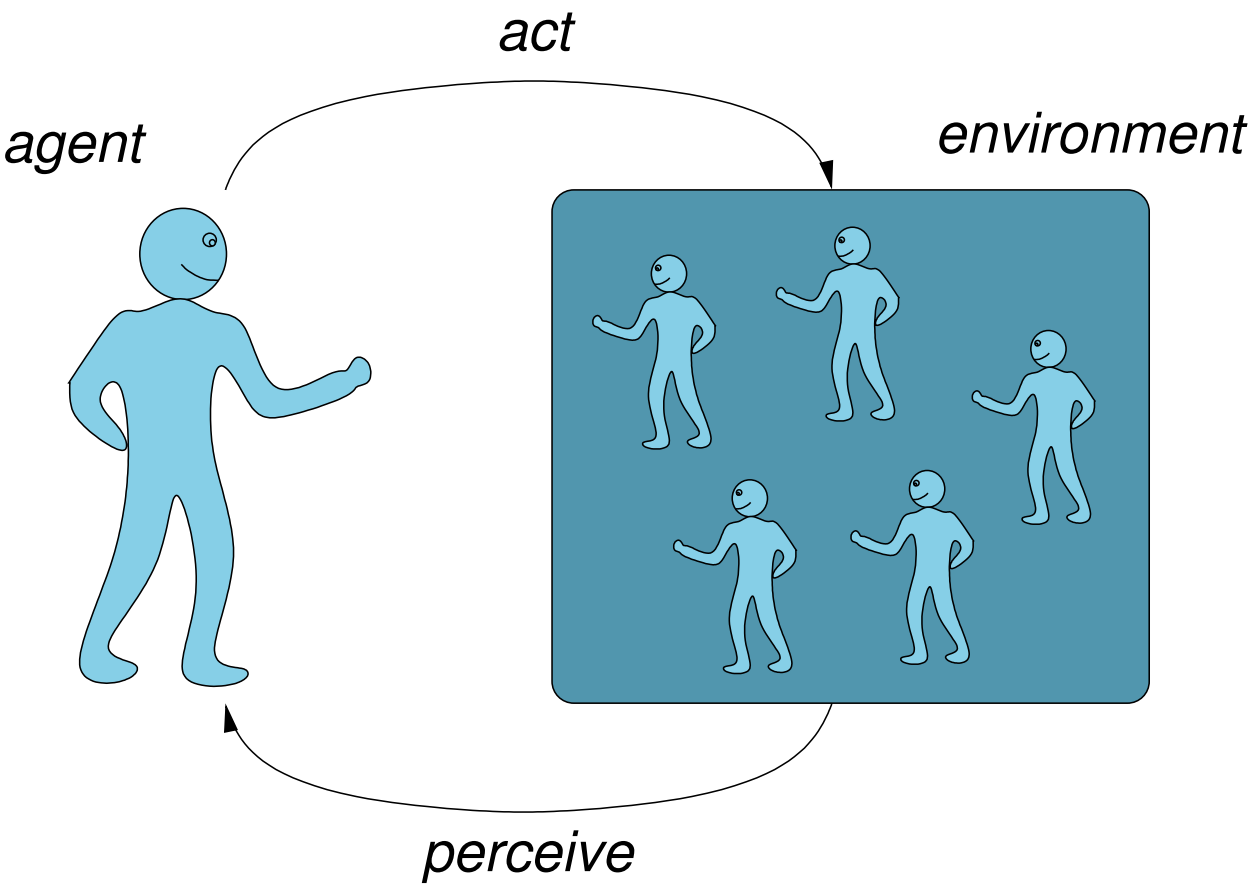
Background

- our group: “good old-fashioned **D**AI”
- “Socionics” project ➡ new perspectives
- why sociology?
  - open systems
  - communication-oriented
  - interpretative focus
- Socionics = empirical communication analysis
  + rational action
  - deliberative black-box agents
  - observation of interaction structures
  - strategic application of interaction knowledge

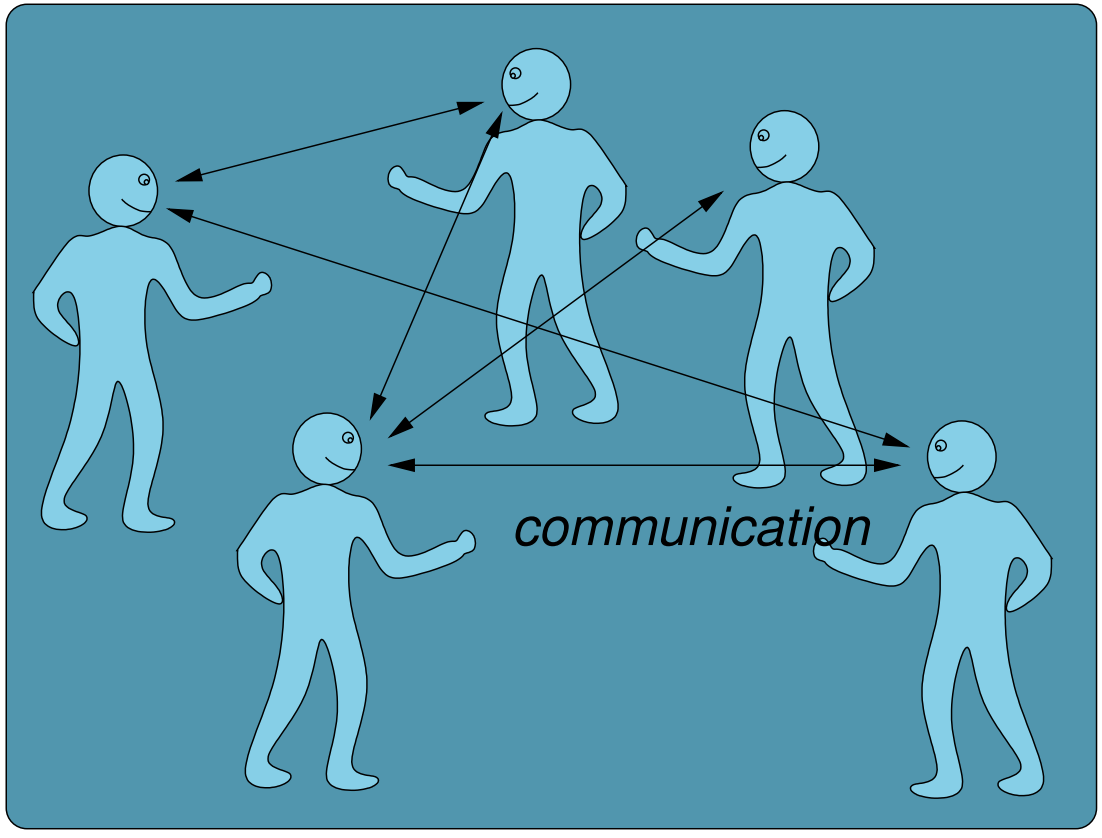
Communication Systems

- systems of evolving communication structures
- communication
  - publicly performed ➡ jointly observed
  - may include physical action
  - creates expectations that are rationally processed
- expectations
  - constructed from observation
  - generalised over different actors
  - exploited in a goal-directed fashion

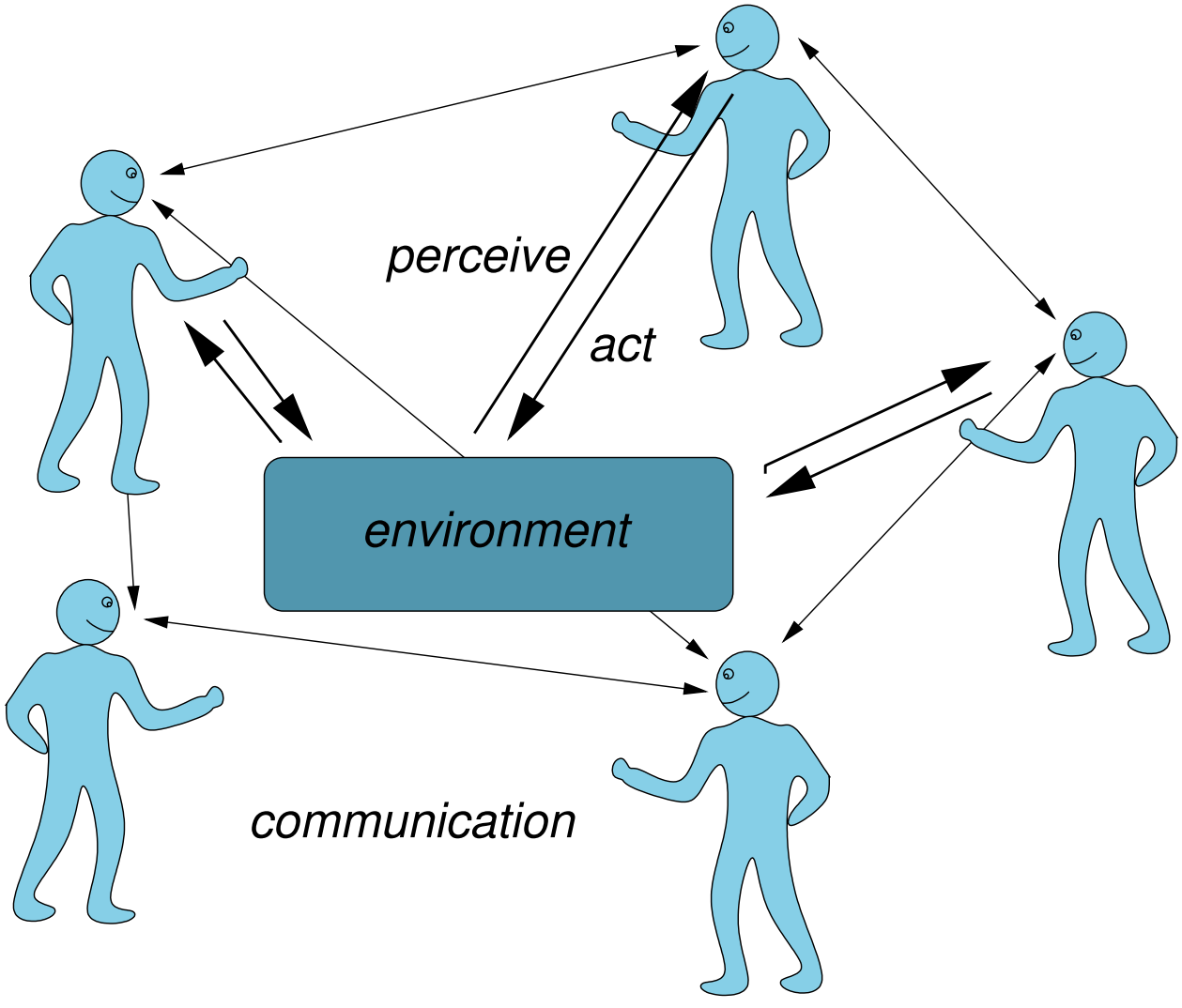
Single-agent view



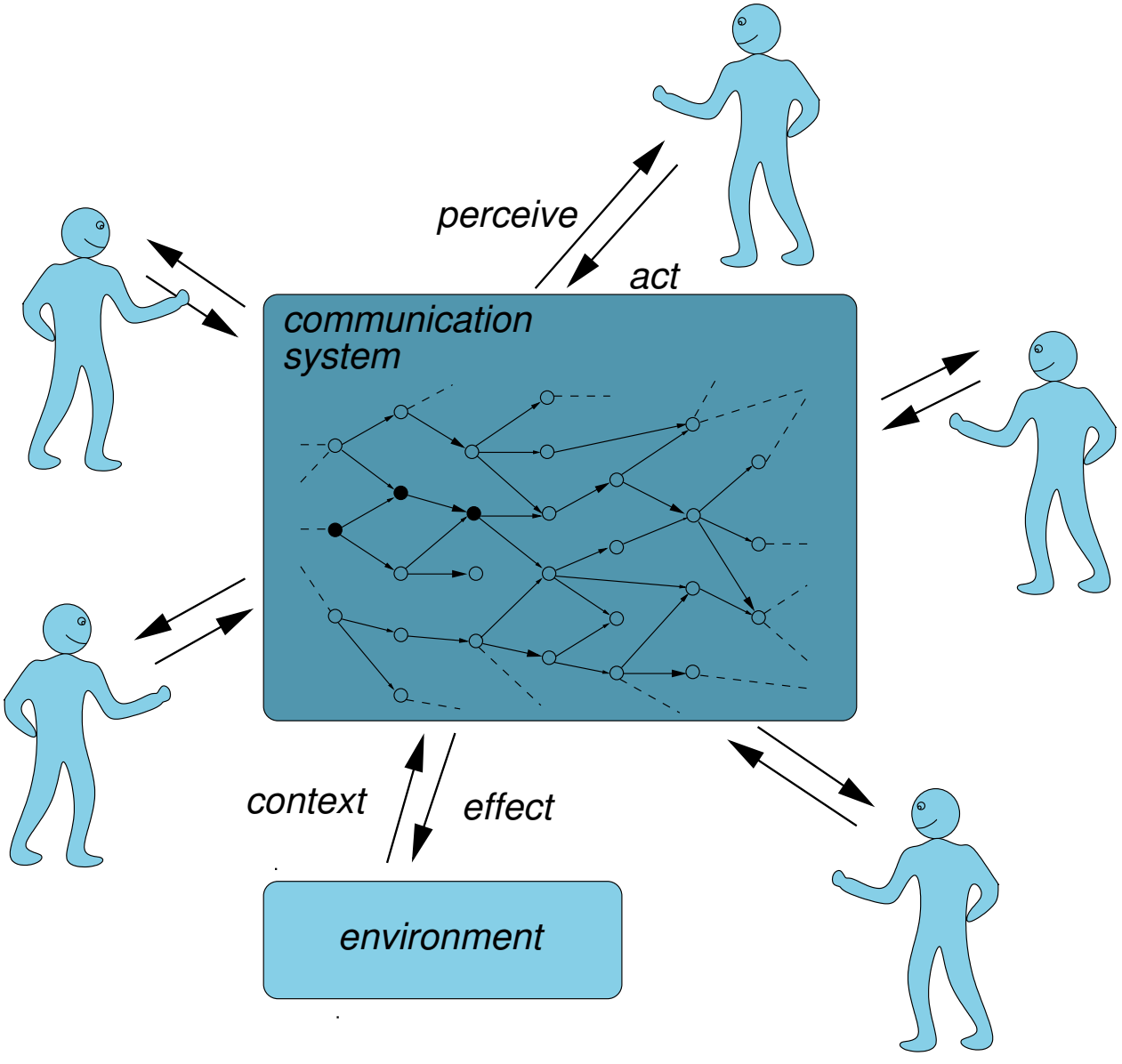
Multiagent view (1)



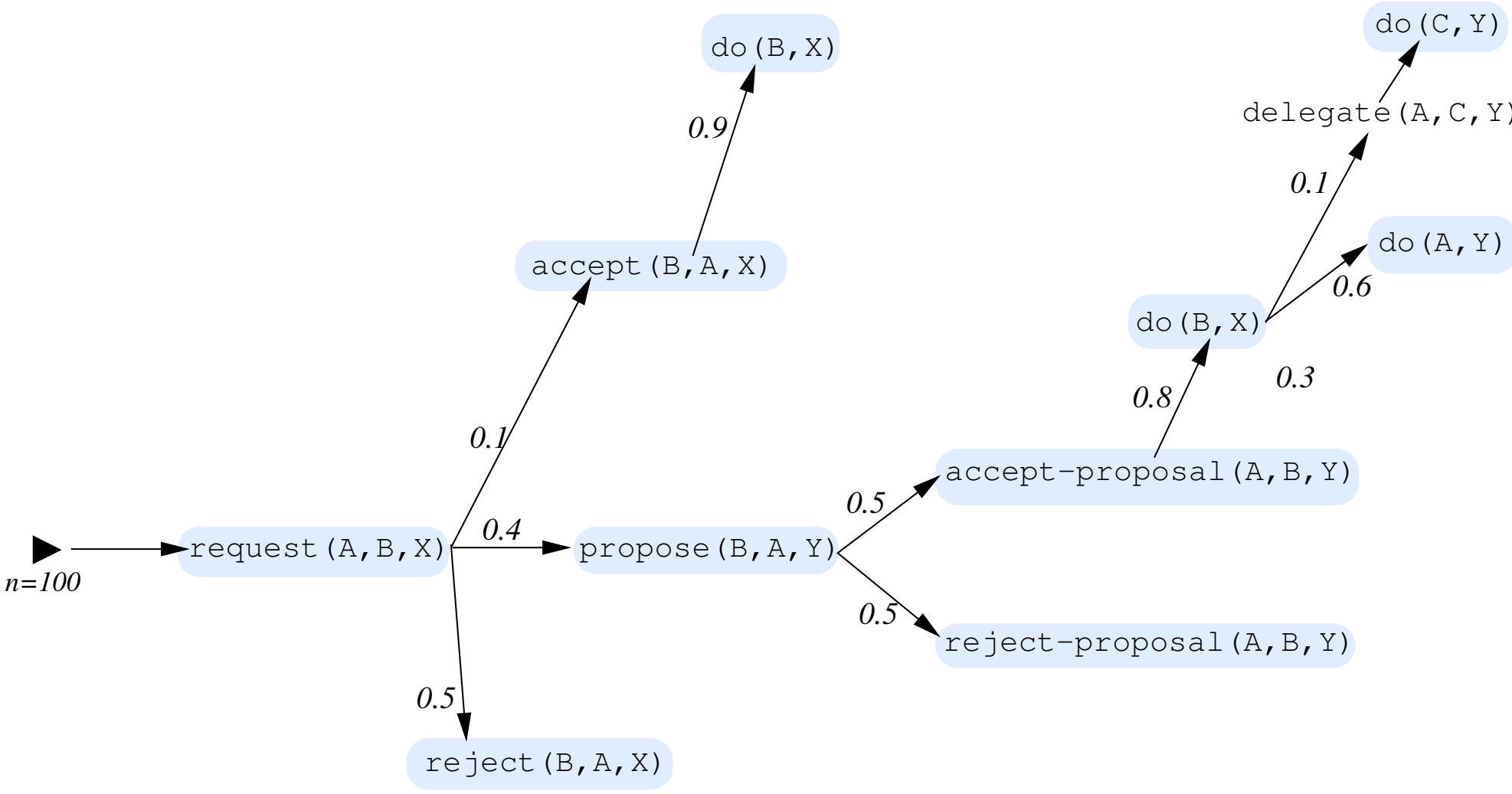
Multiagent view (2)



Communication systems view



Expectation networks



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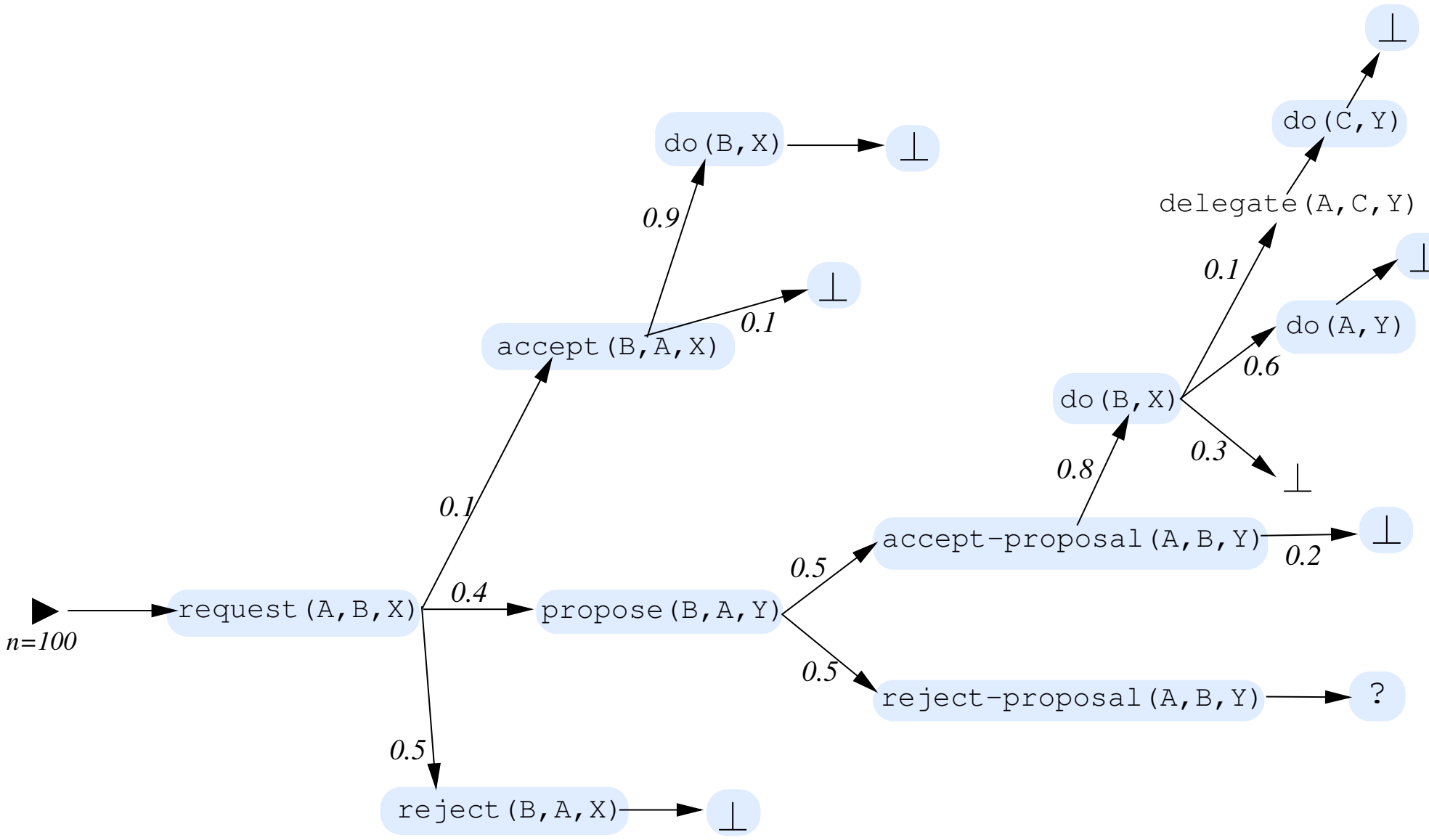

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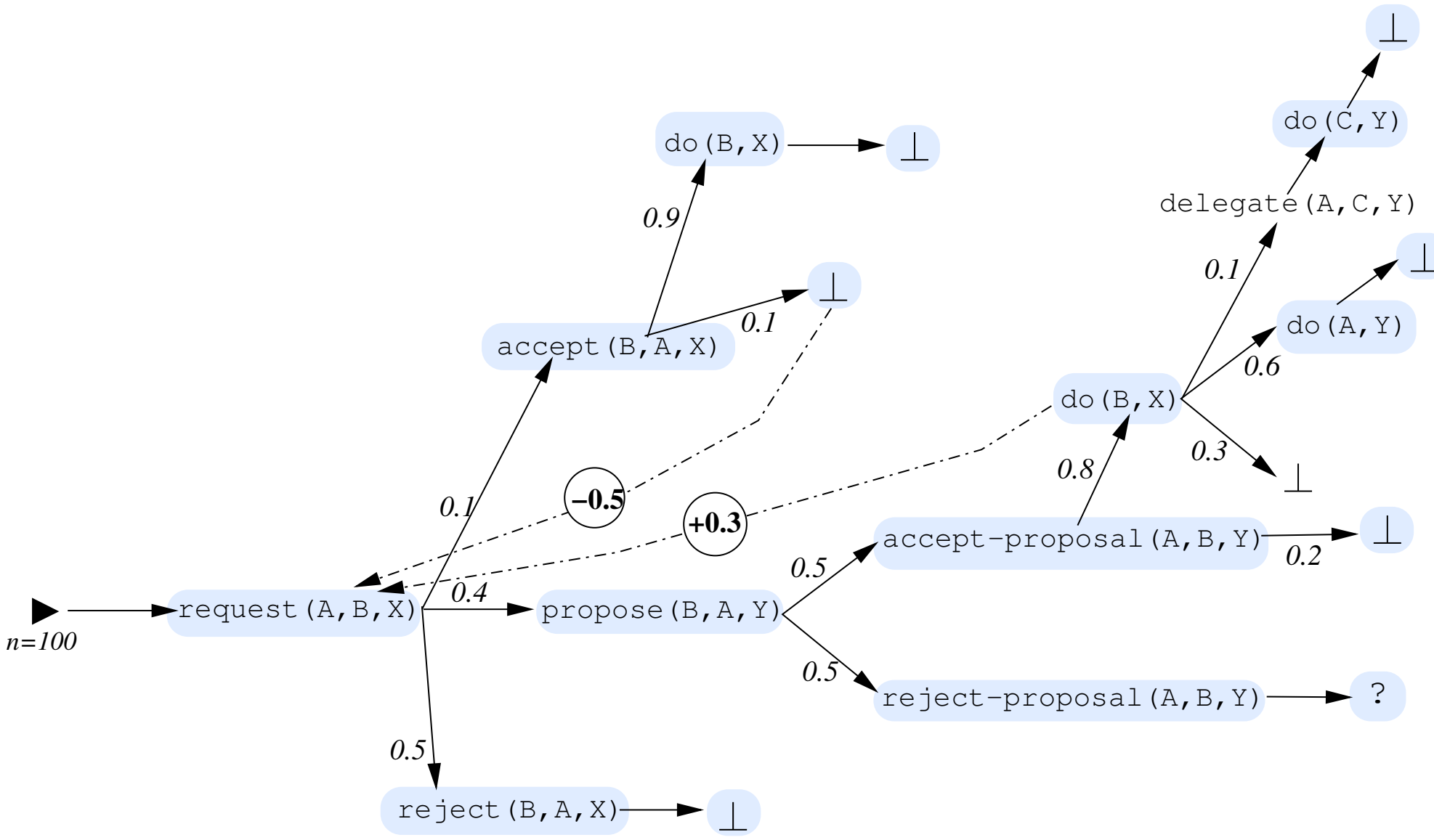

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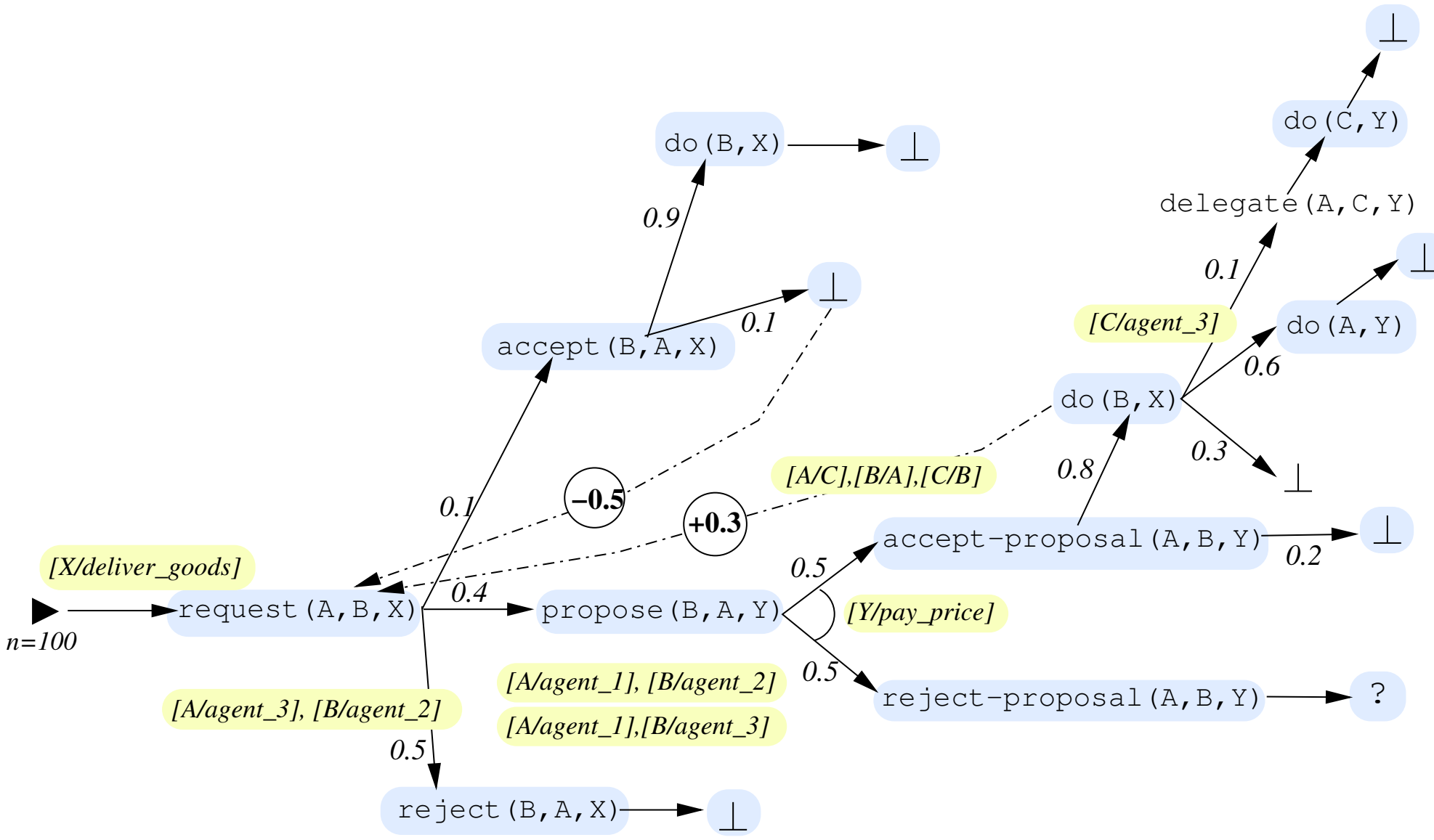

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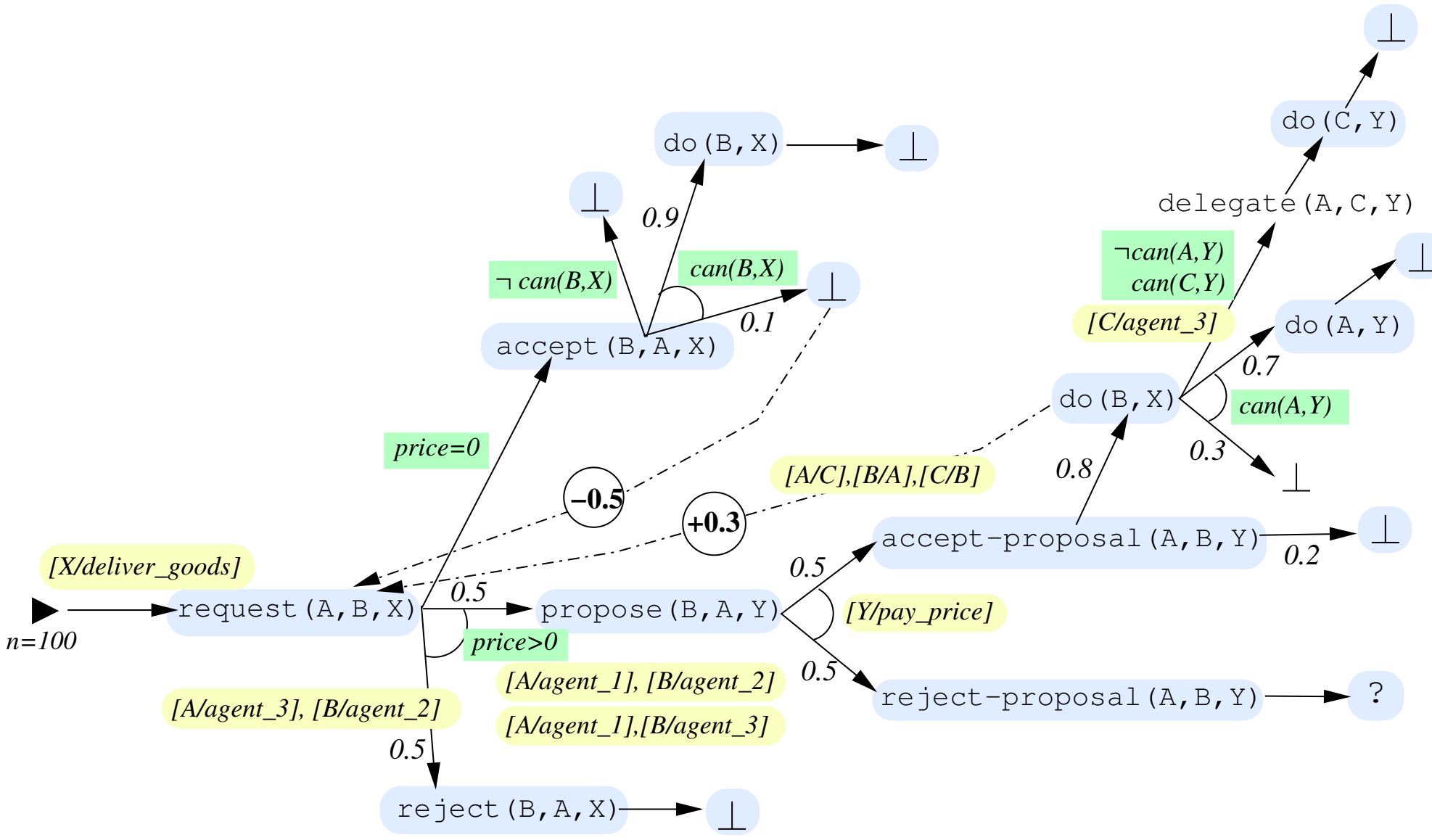
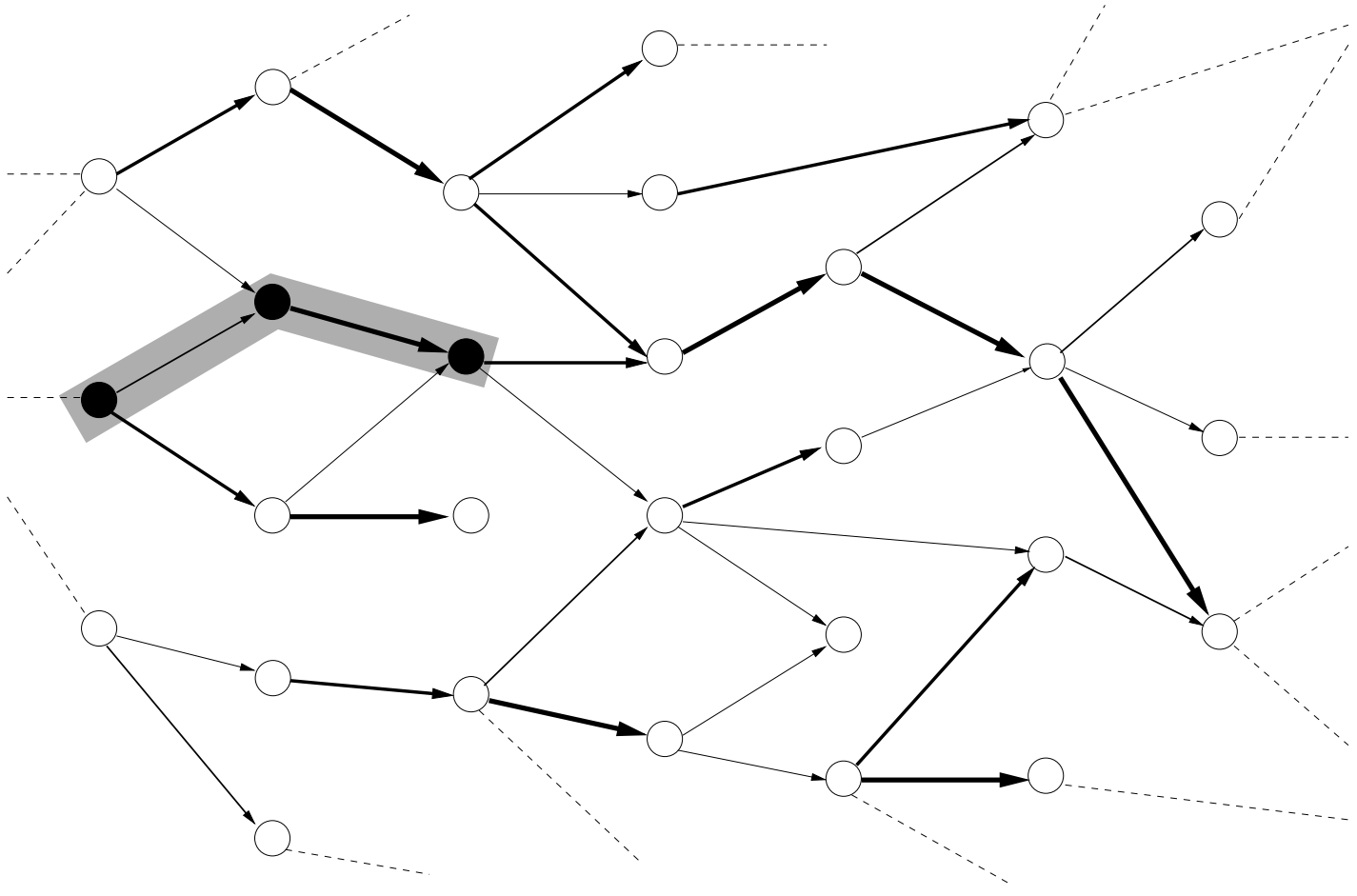


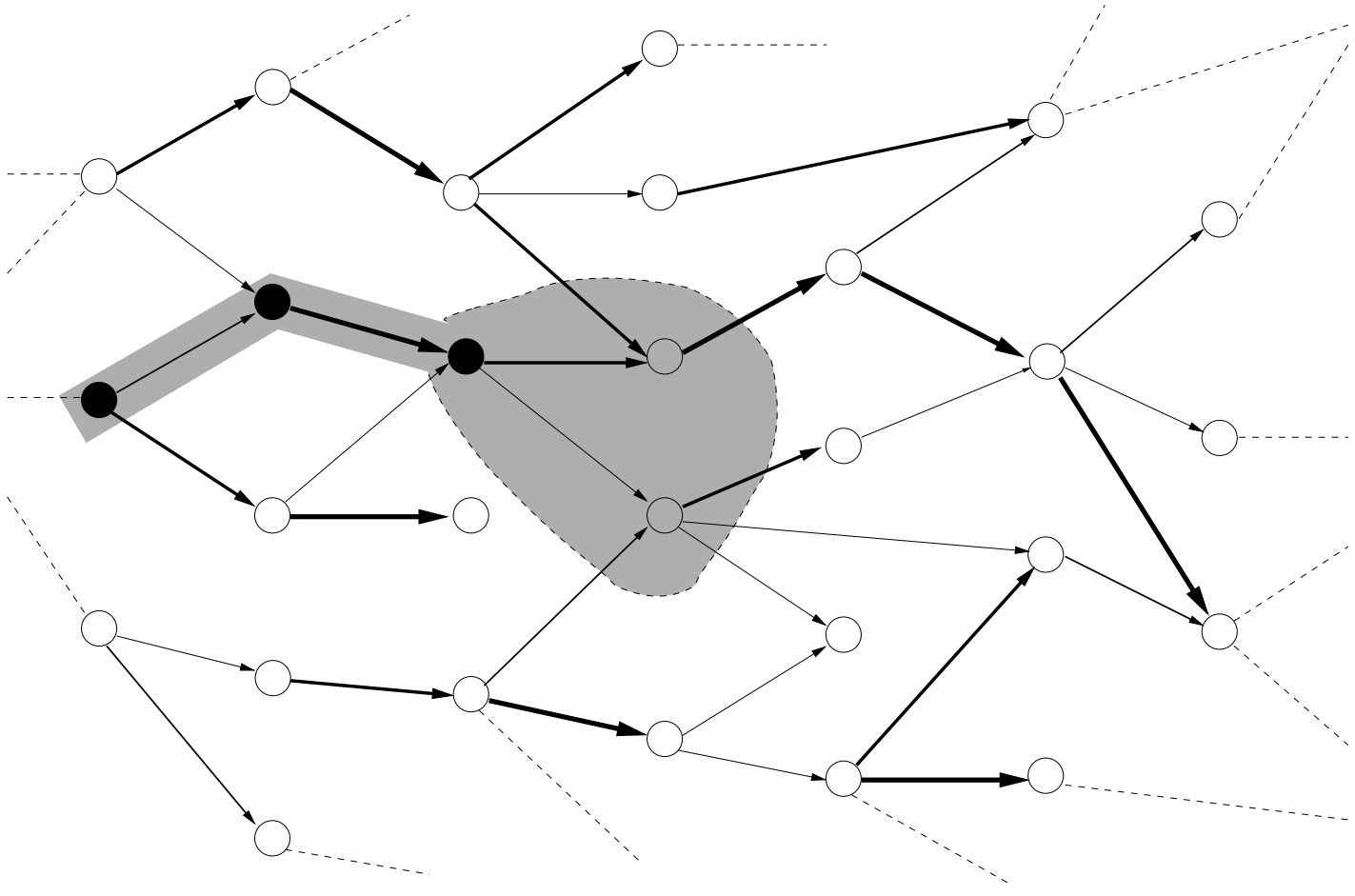
Communication Systems

- generic model for socially intelligent systems
- advantages over other models off communication semantics:
  - no mentalistic assumptions
  - can be used by agents/system observers
  - allows for context-sensitivity and uncertainty
  - captures the dynamics of evolving meaning
- expectation networks not the only possible formalism

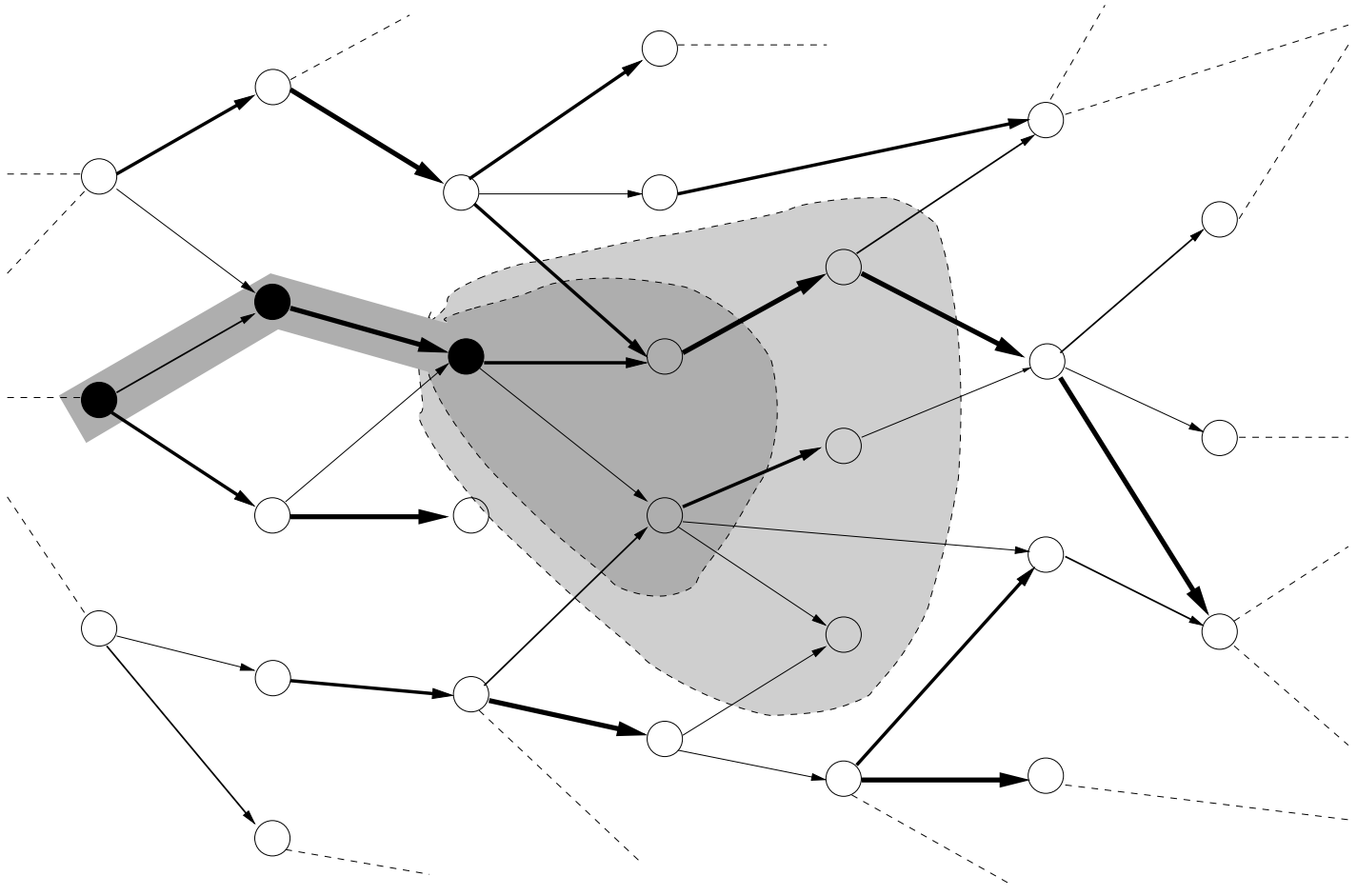
Empirical semantics



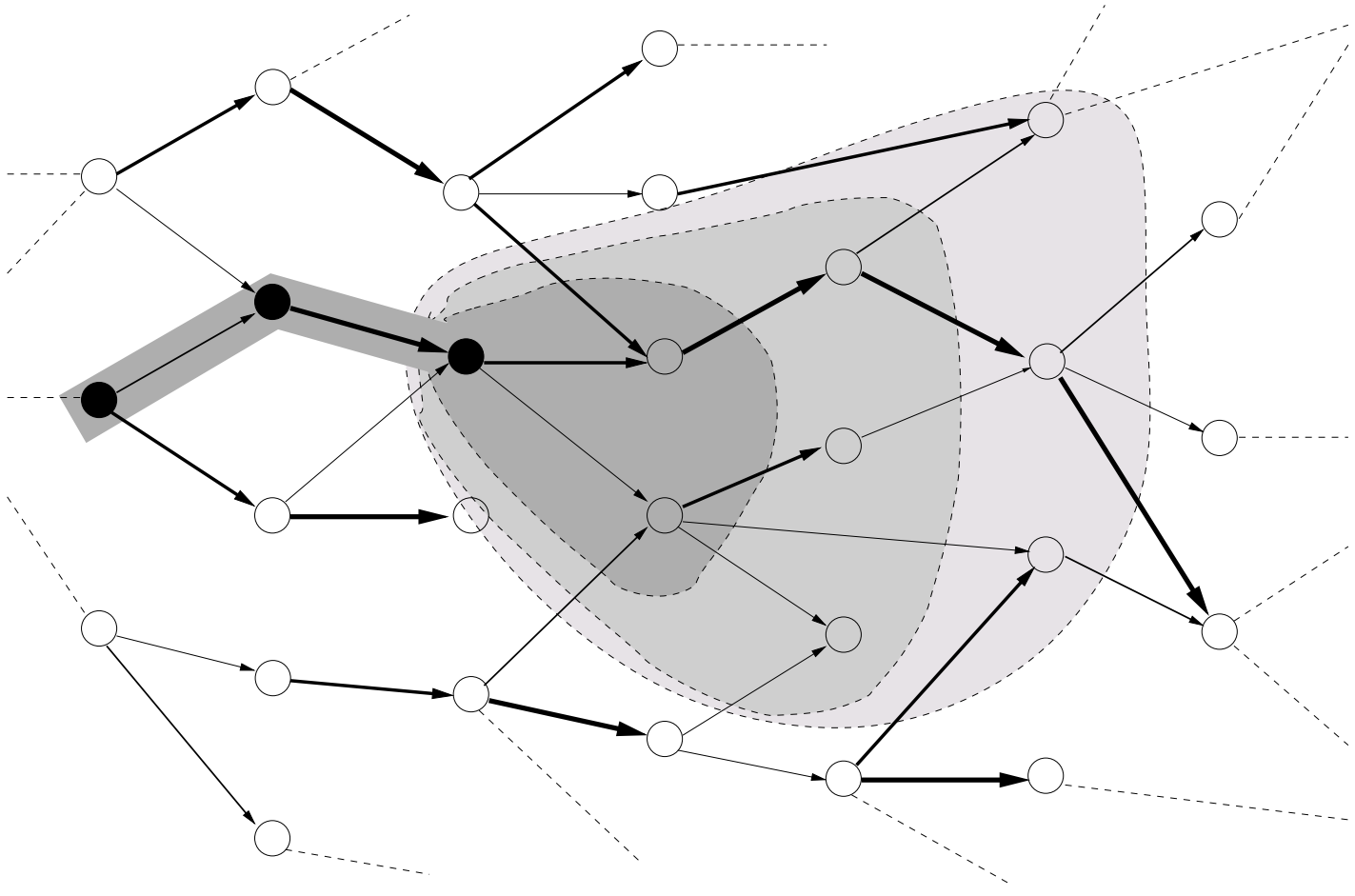
Empirical semantics



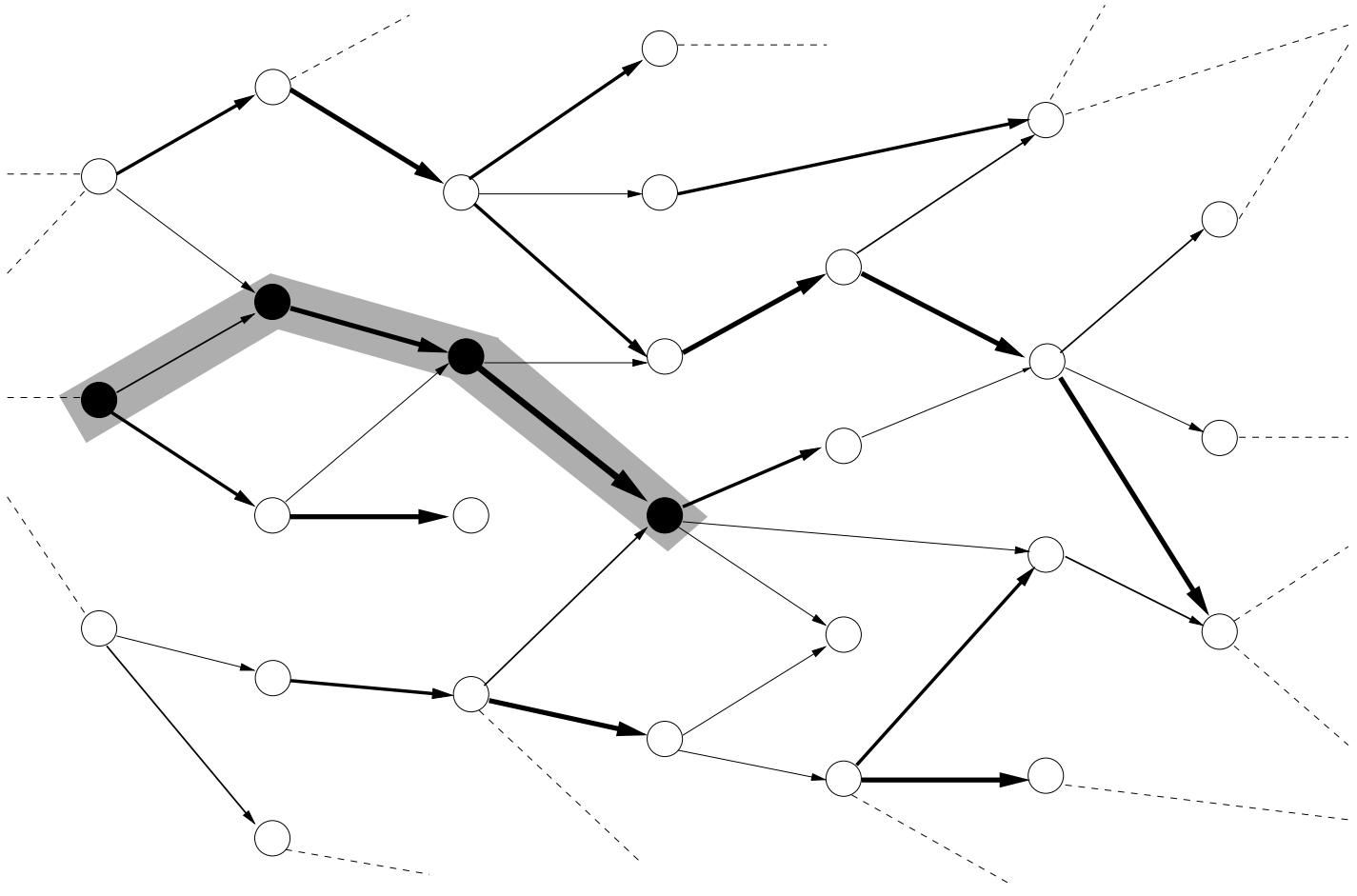
Empirical semantics



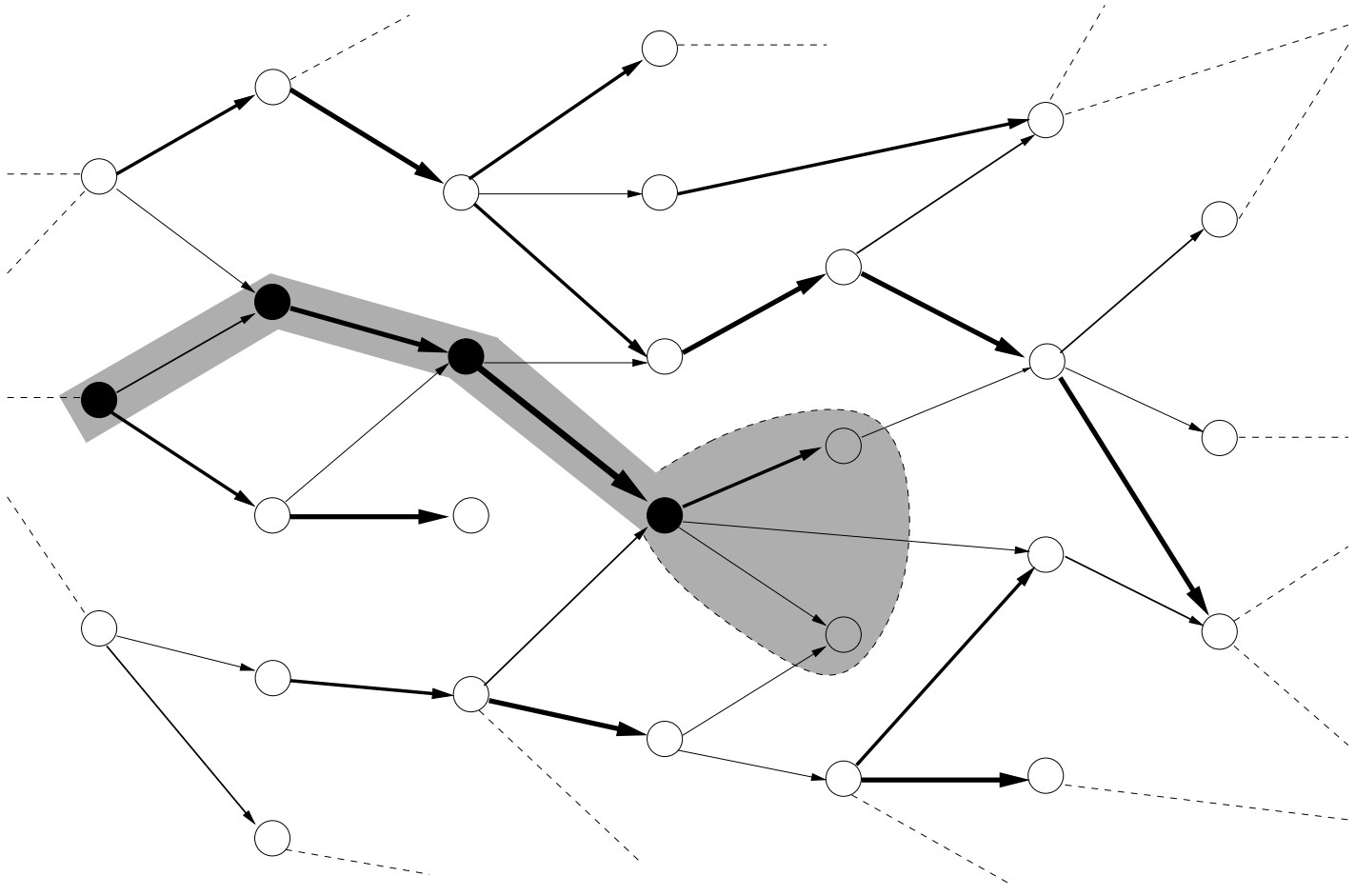
Empirical semantics



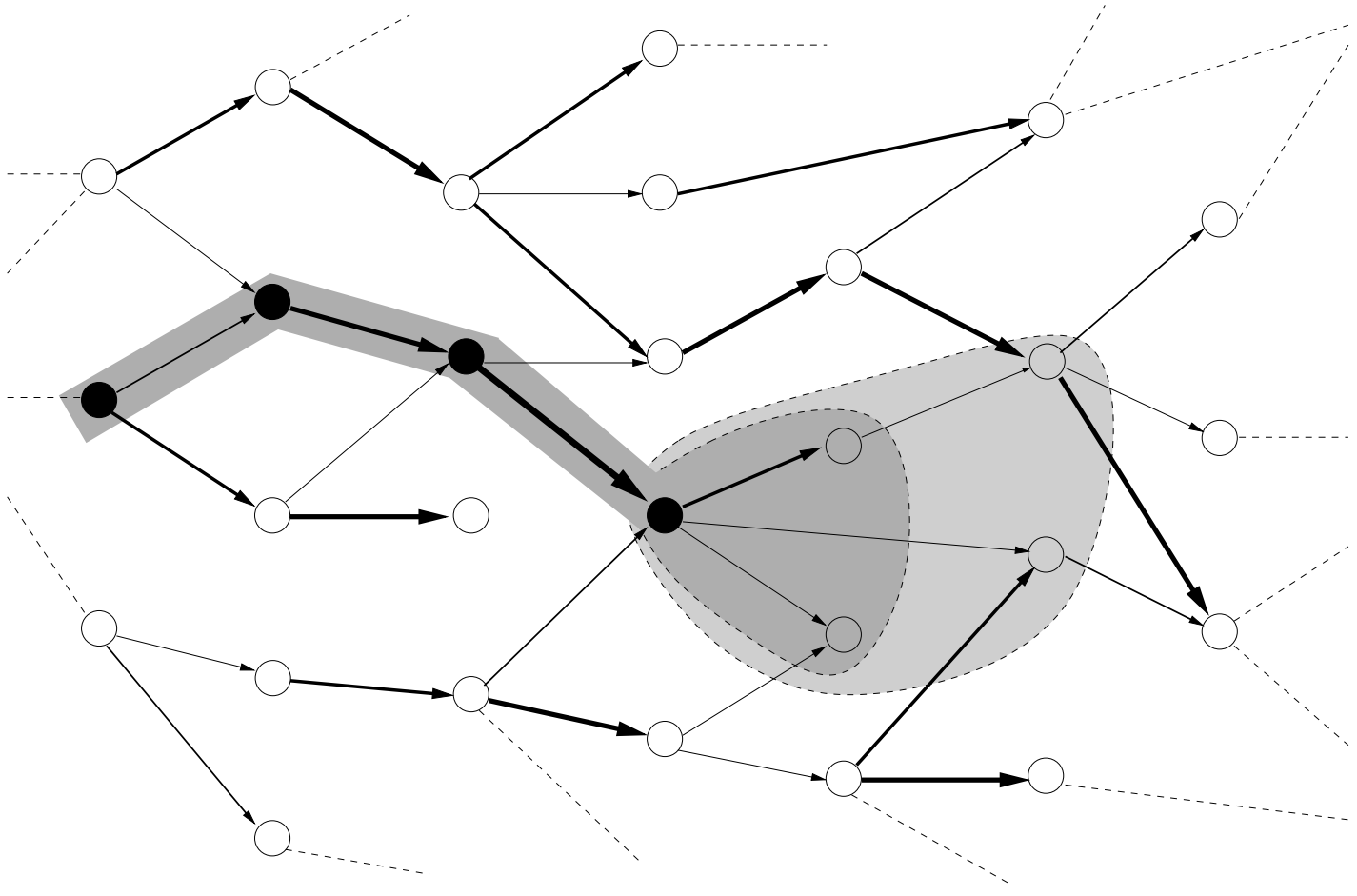
Empirical semantics



Empirical semantics



Empirical semantics



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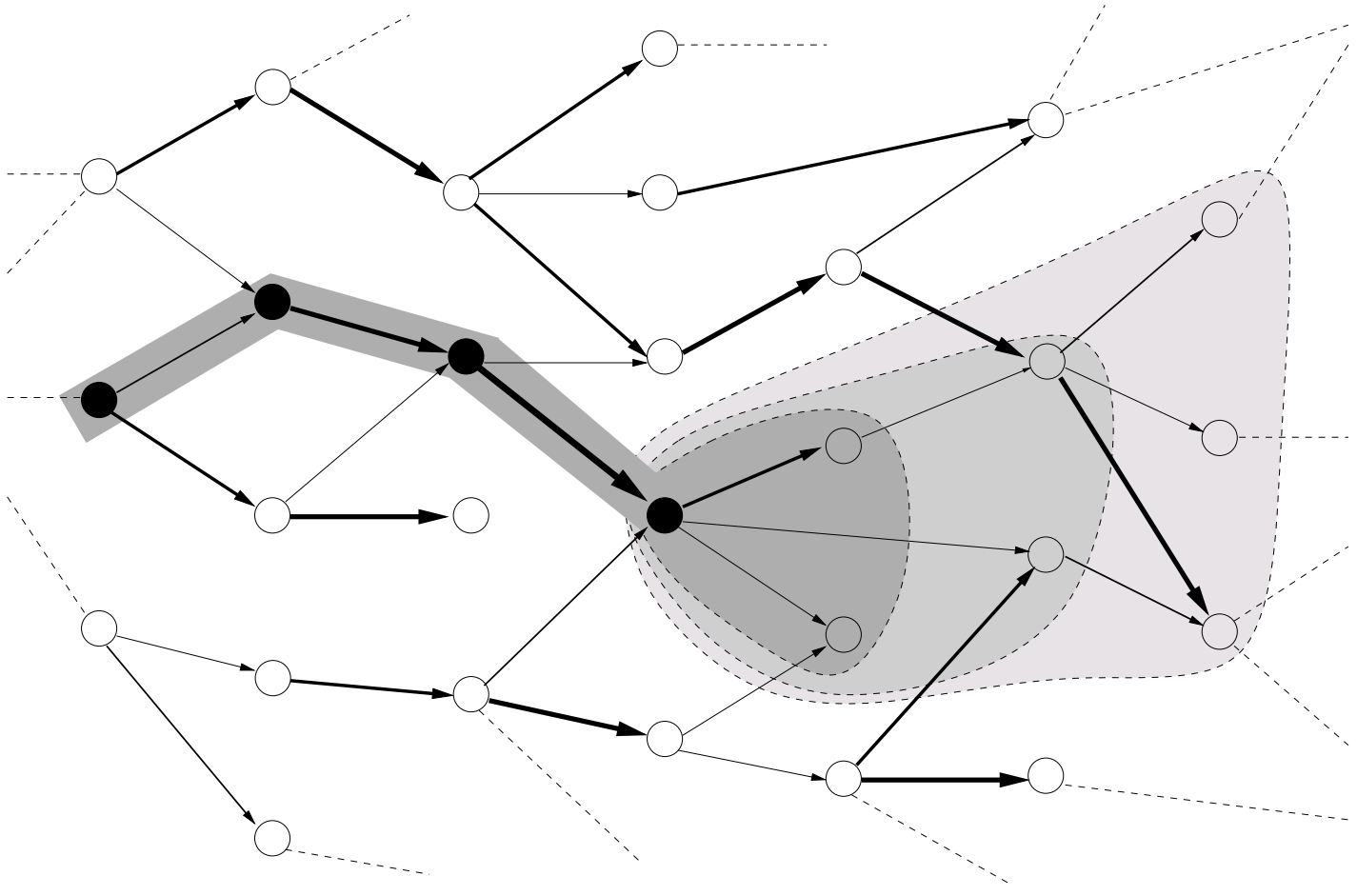

Applications

- EXPAND – EXPectation-Oriented Analysis aNd Design (Brauer et al., AOSE'01)
- RNS/cRNS – Roles, Norms and Sanctions (Weiss et al., AAMAS'03)
- Mirrors and Mirror-Holons (Nickles et al.)
- Open Ontologies (Nickles & Weiss, P2P'03)
- Social Performance Measurement (Rovatsos, Schillo, Fischer, Weiss, MATES'03)
- . . . and, of course, **Interaction Frames**

- Example: basic activity

```
ACT deliver ( material,quantity )
    { STATUS RANGE
        <IND> : NORM <P> <NO> + SANC <NO> <NO>
        <DEP EACH> : NORM <O> <quantity ≤ 100> + SANC <PU> <withdraw_role>
        <DEP AssemblyMg> : NORM <I> <material = steel> + SANC <PU> <pay_fine>
    }
```

- Example: request activity

```
ACT REQUEST ( EACH ; USsupplier, EUROsupplier ; NOT deliver ( material, quantity ) )
    { STATUS RANGE
        <IND> : NORM <P> < (material = steel) AND (rating(material) = poor)> +
                    SANC <NO> <NO>
      NORMATIVE IMPACT
        NORM <I> <material = steel>
    }
```

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Interaction Frames & Framing

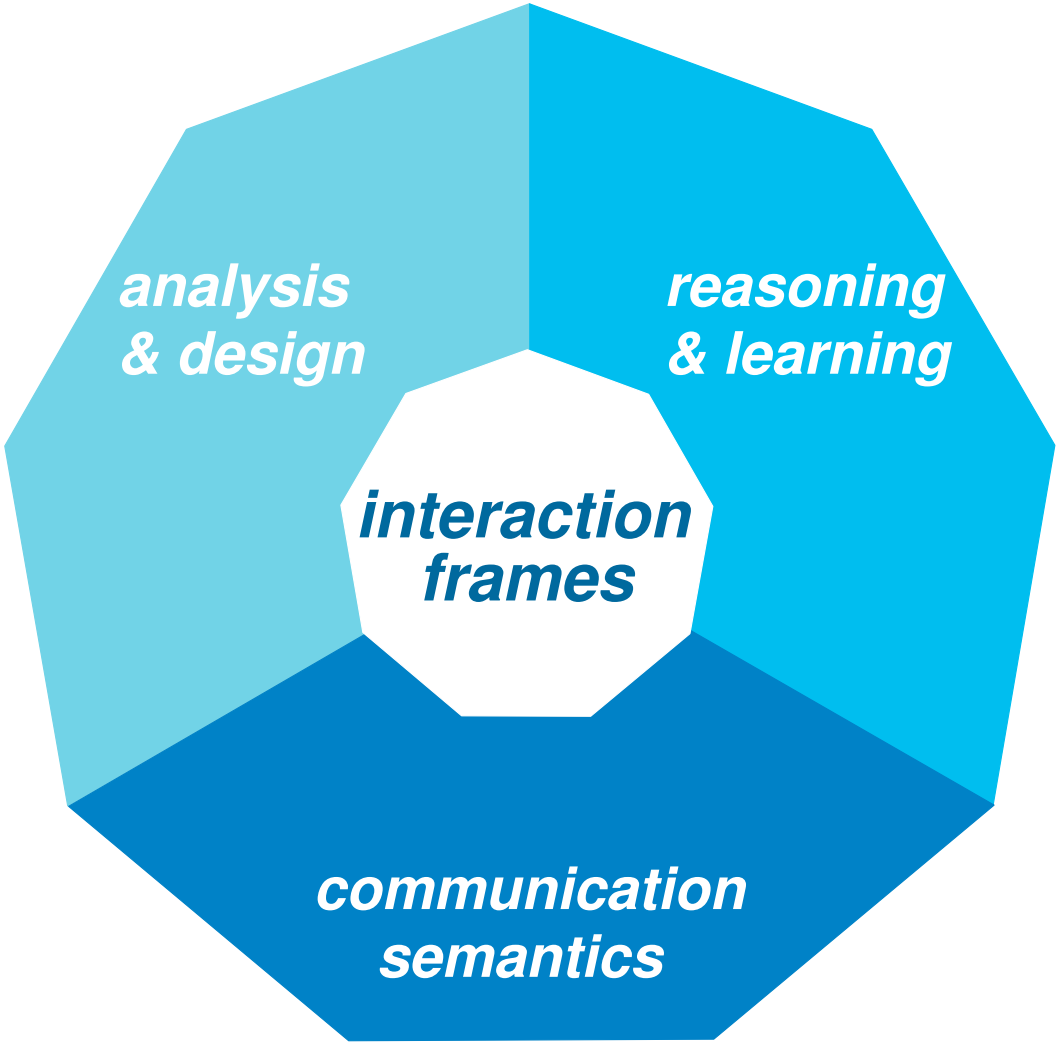
- “frame” & “framing” concepts grounded in the sociological theory of Erving Goffman (1922-1982)
- a frame is

  “the participants’ own conceptualisation of the structure within which they are interacting, which may change very quickly as the situation develops”

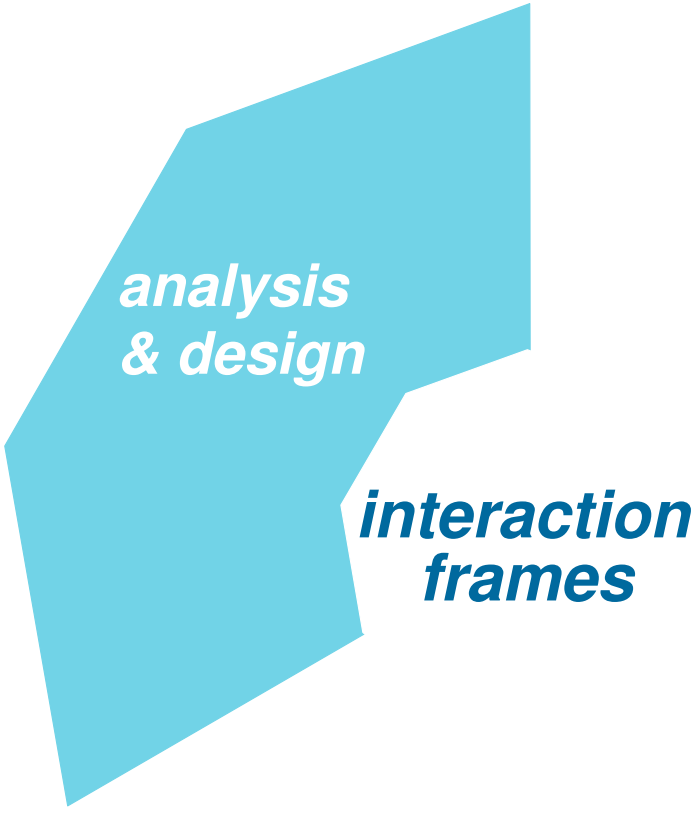
  or

  “the answer to the question ’what is going on here?’ that everyone poses to oneself in an interaction situation”
- framing = strategic application of frames

Interaction Frames



Interaction Frames



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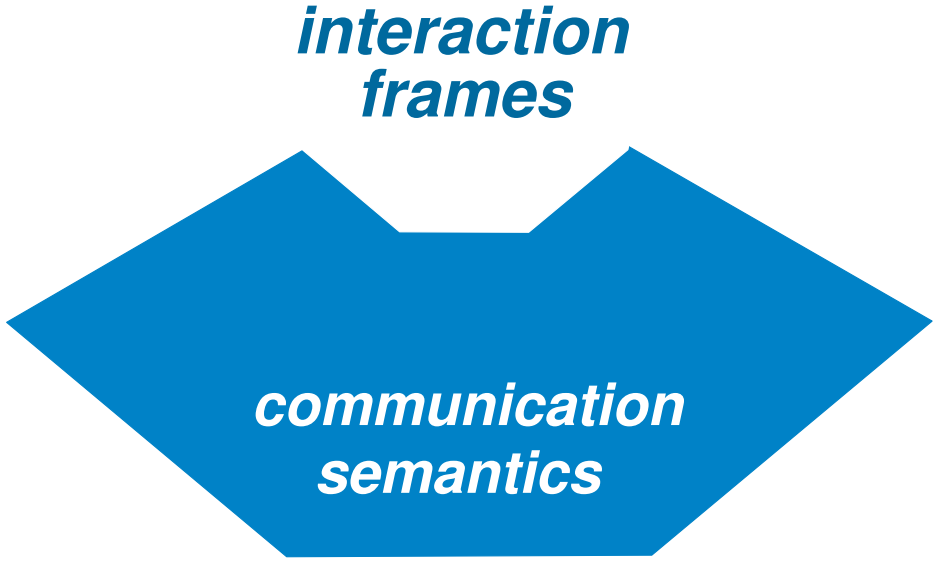
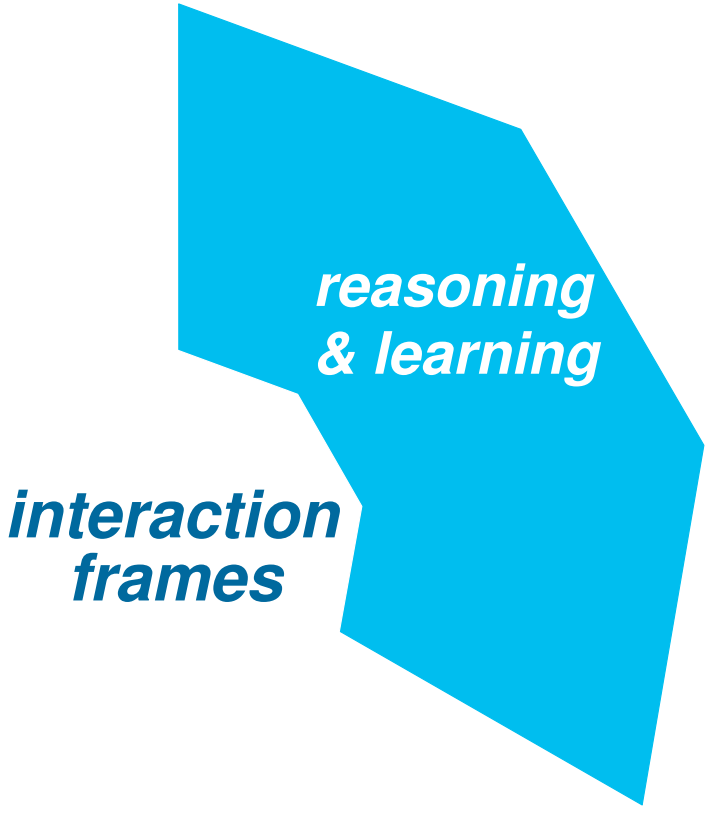
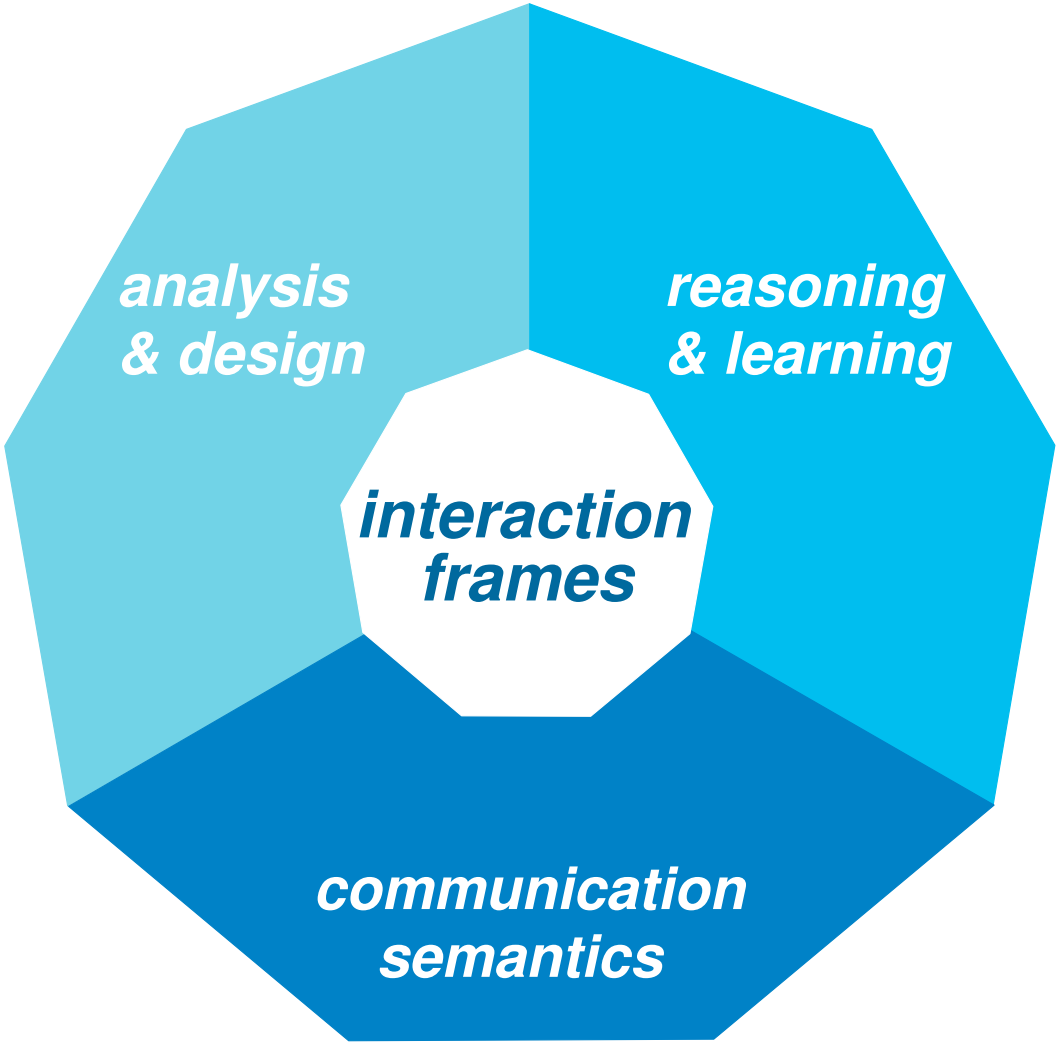


Interaction Frames



Interaction Frames



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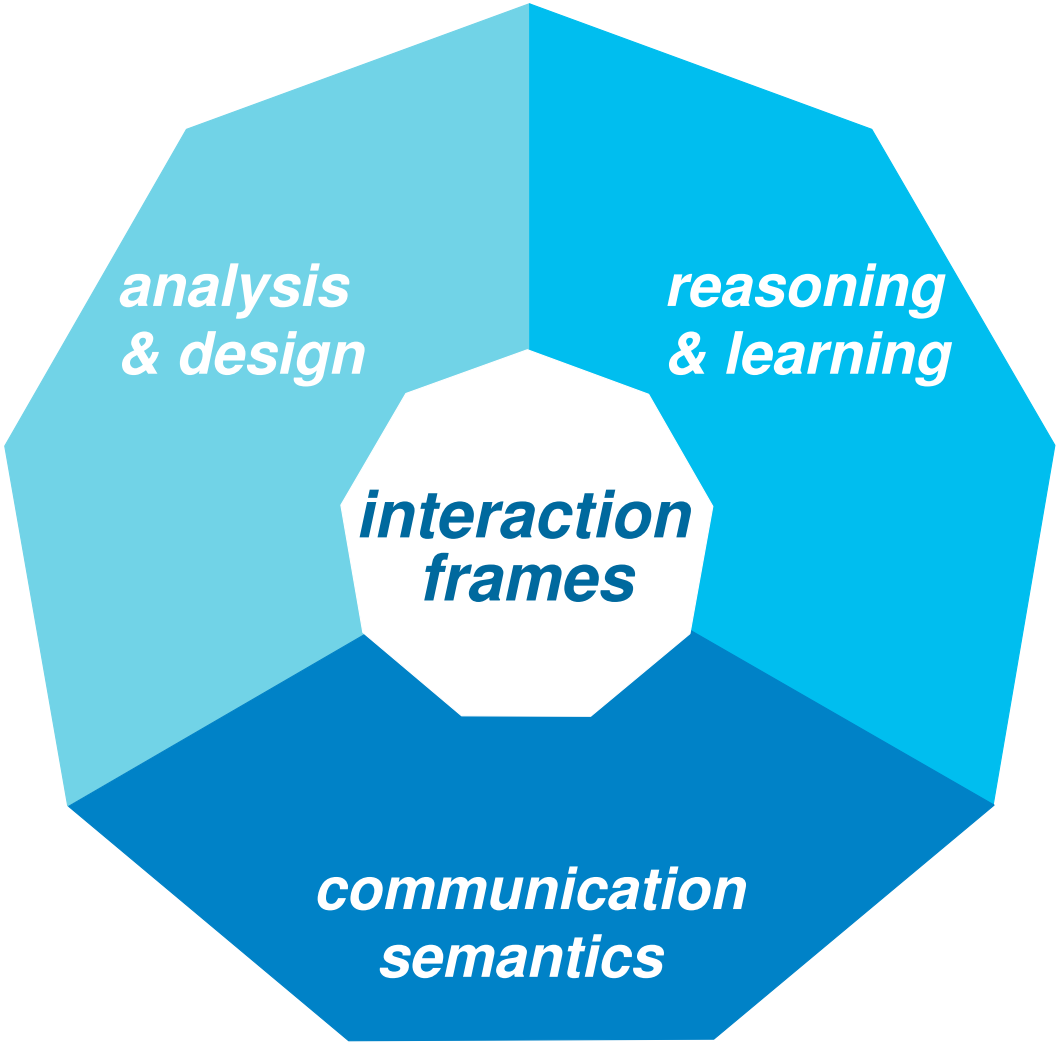
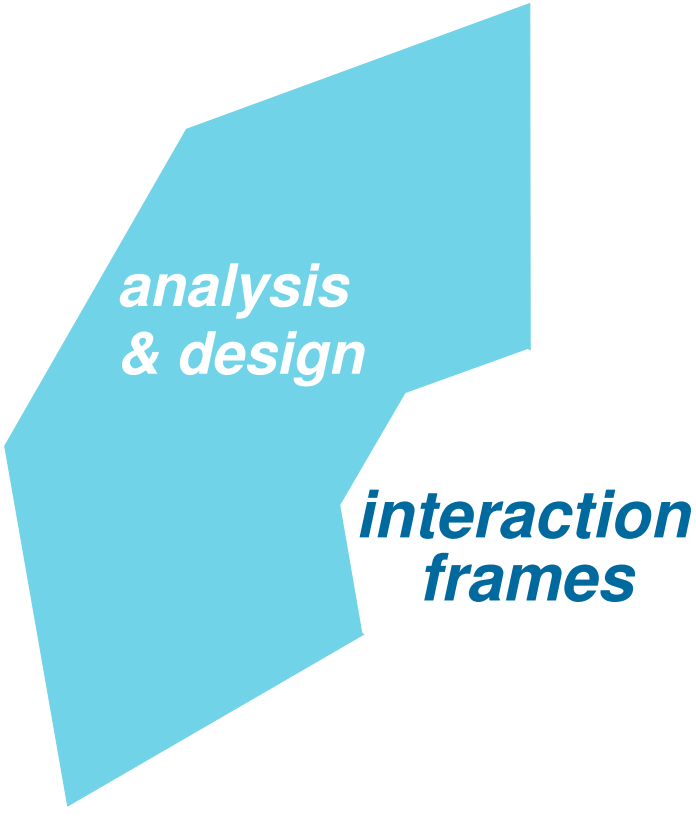

analysis
& design
reasoning
& learning
interaction
frames
communication
semantics

Views



(Rovatsos et al., AAMAS'02)

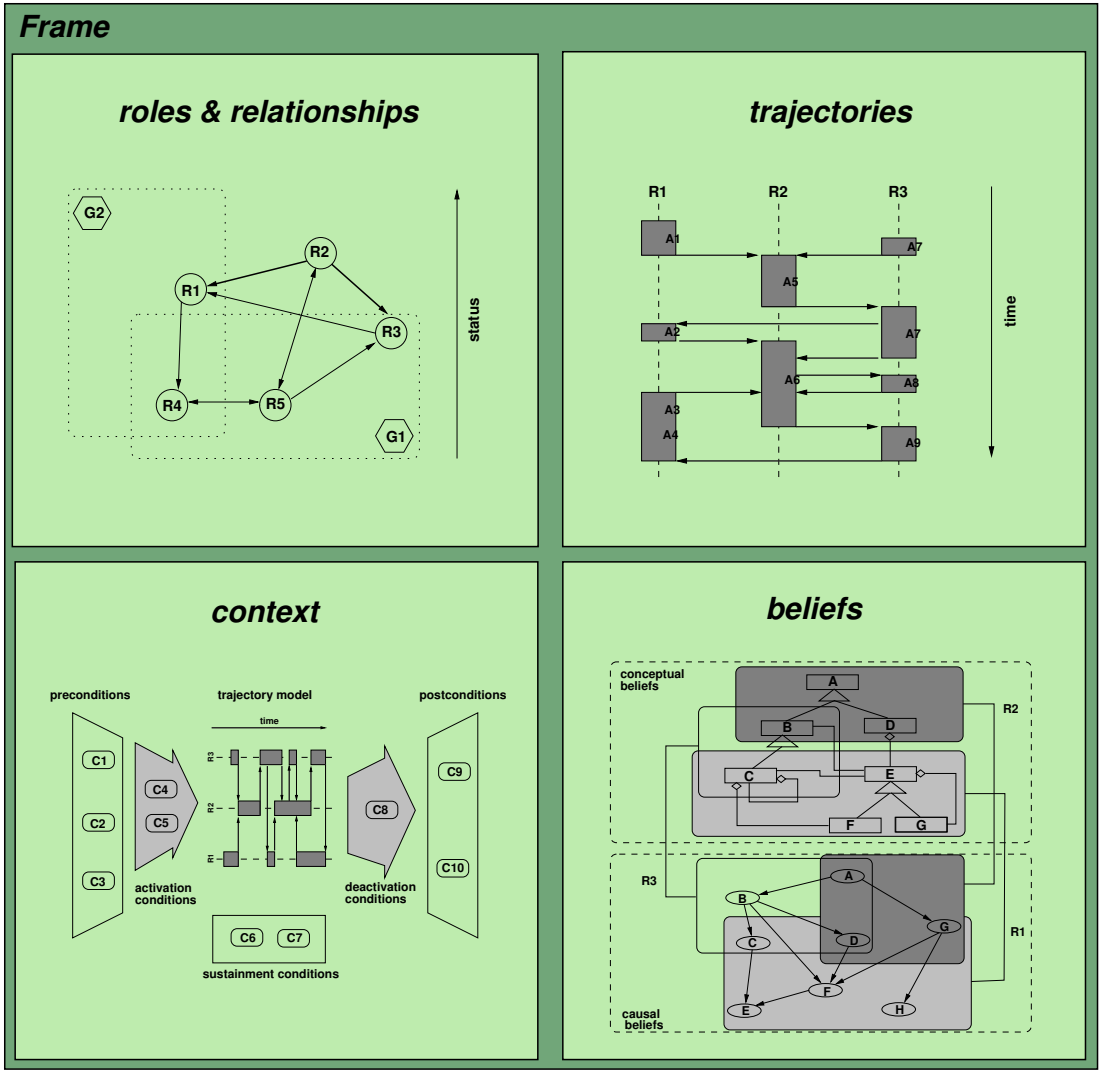
InFFrA

- InFFrA = Interaction Frames and Framing Architecture
- architecture for social reasoning and learning
- individualist perspective on communication systems
- socio-centric view with individualist “touch”
- interactions are not subject to agent control, but the application of frames is!
- InFFrA is an abstract architecture
  ➡ conceptual level description
- no modelling of human social behaviour

InFFrA – Frames

- capture the regularities of interaction processes
- descriptive attributes
  - roles & relationships,
  - trajectories (courses of interaction),
  - contexts & conditions,
  - beliefs.
- meta-level attributes
  - status (current state of frame attributes)
  - links (“alternative”, “variant”, etc.)
  - history (of frame evolution)
  - extension (distribution of frame knowledge)

InFFrA – Frames



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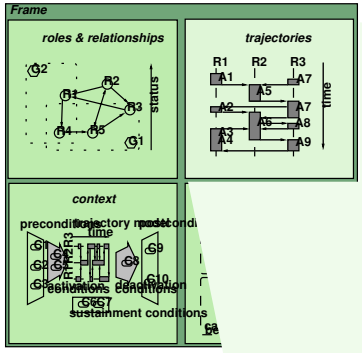
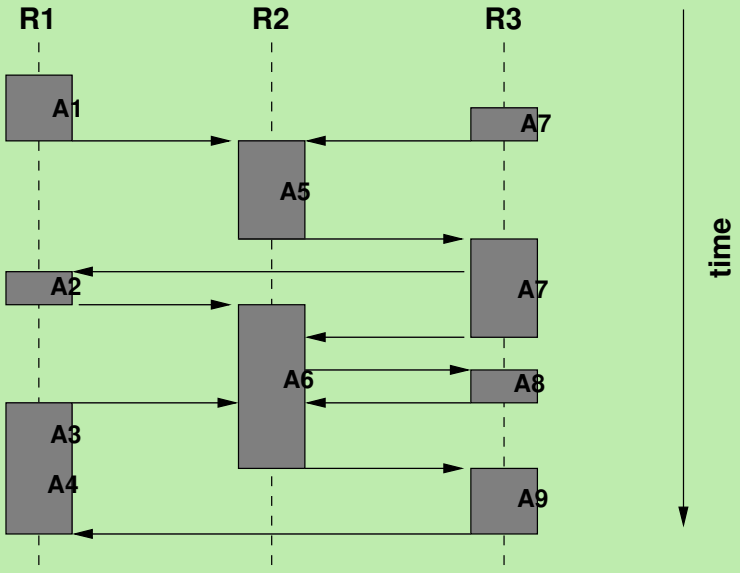


trajectories



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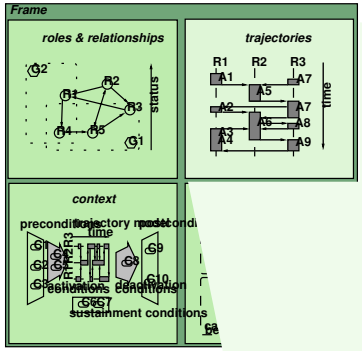

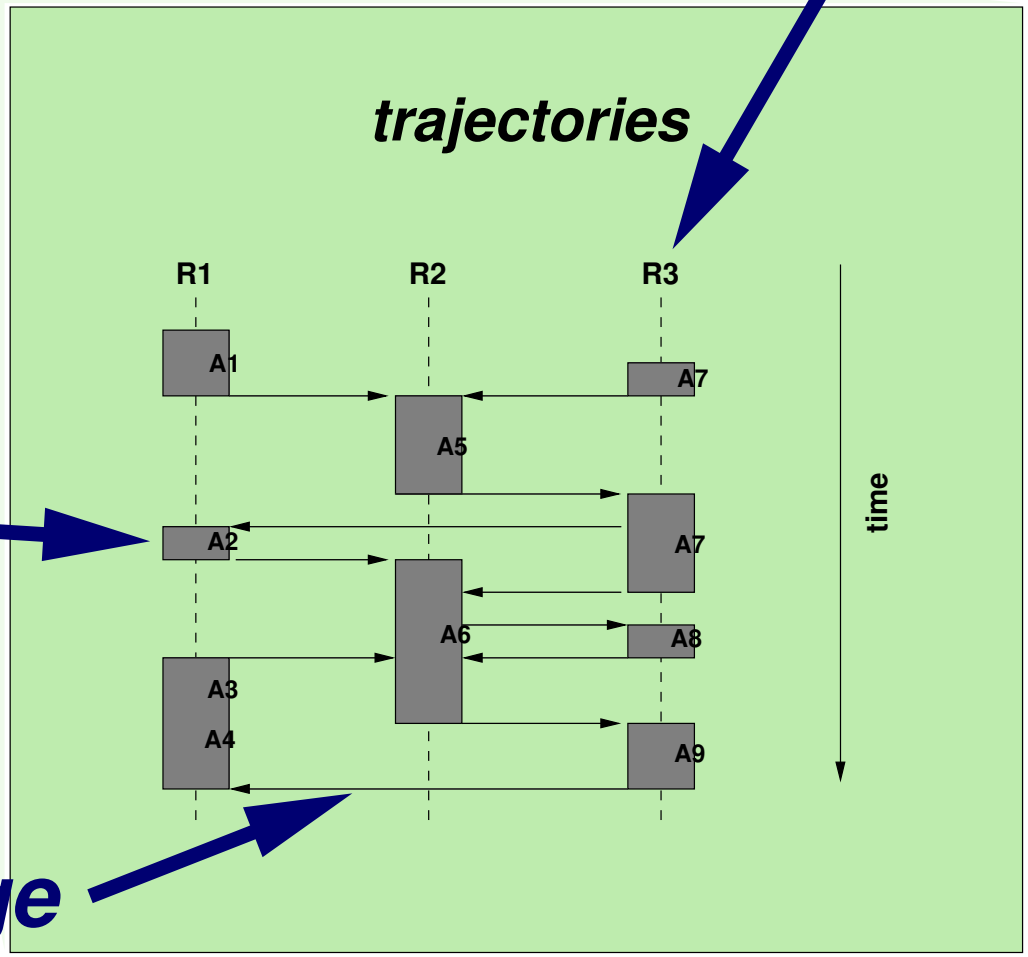

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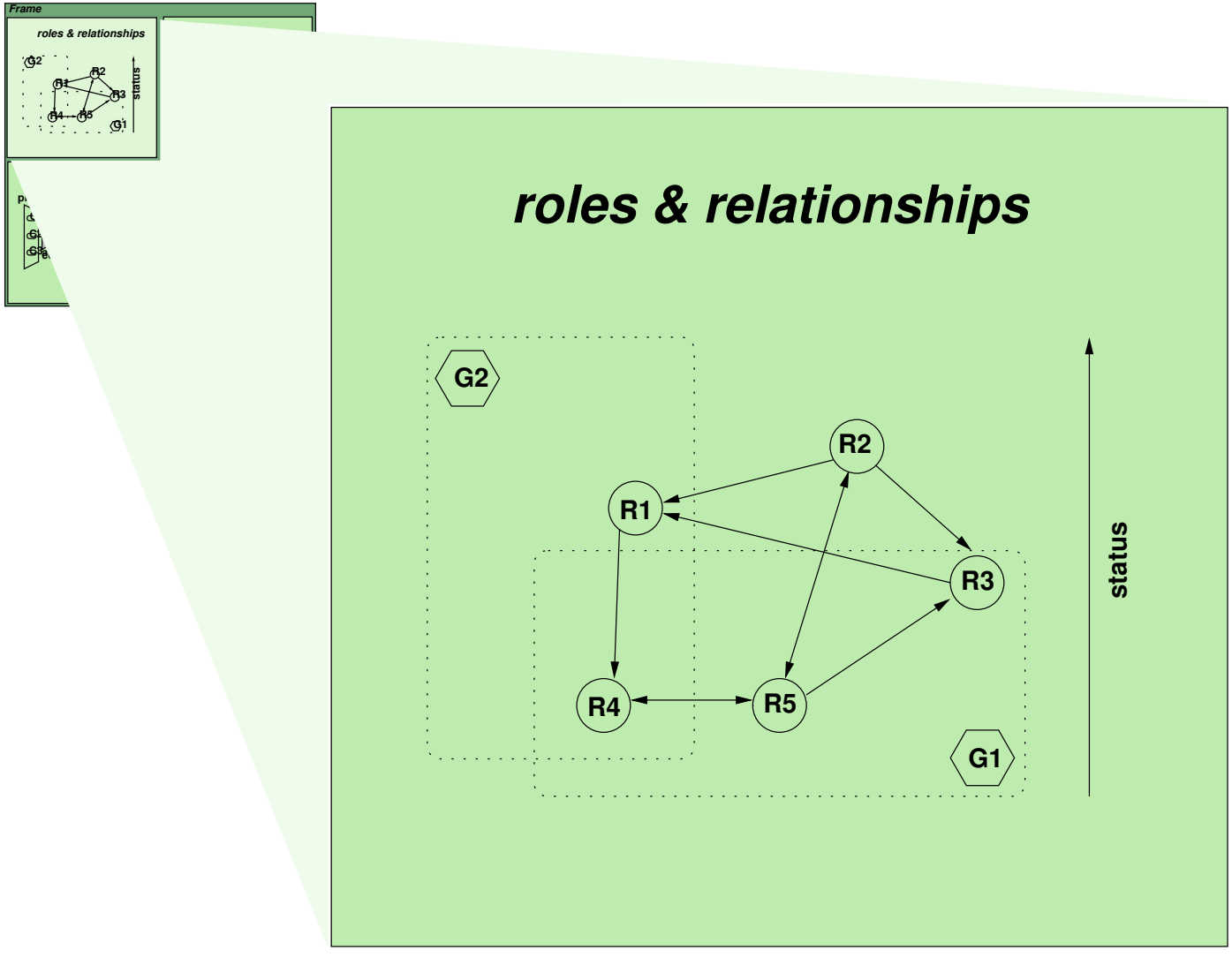

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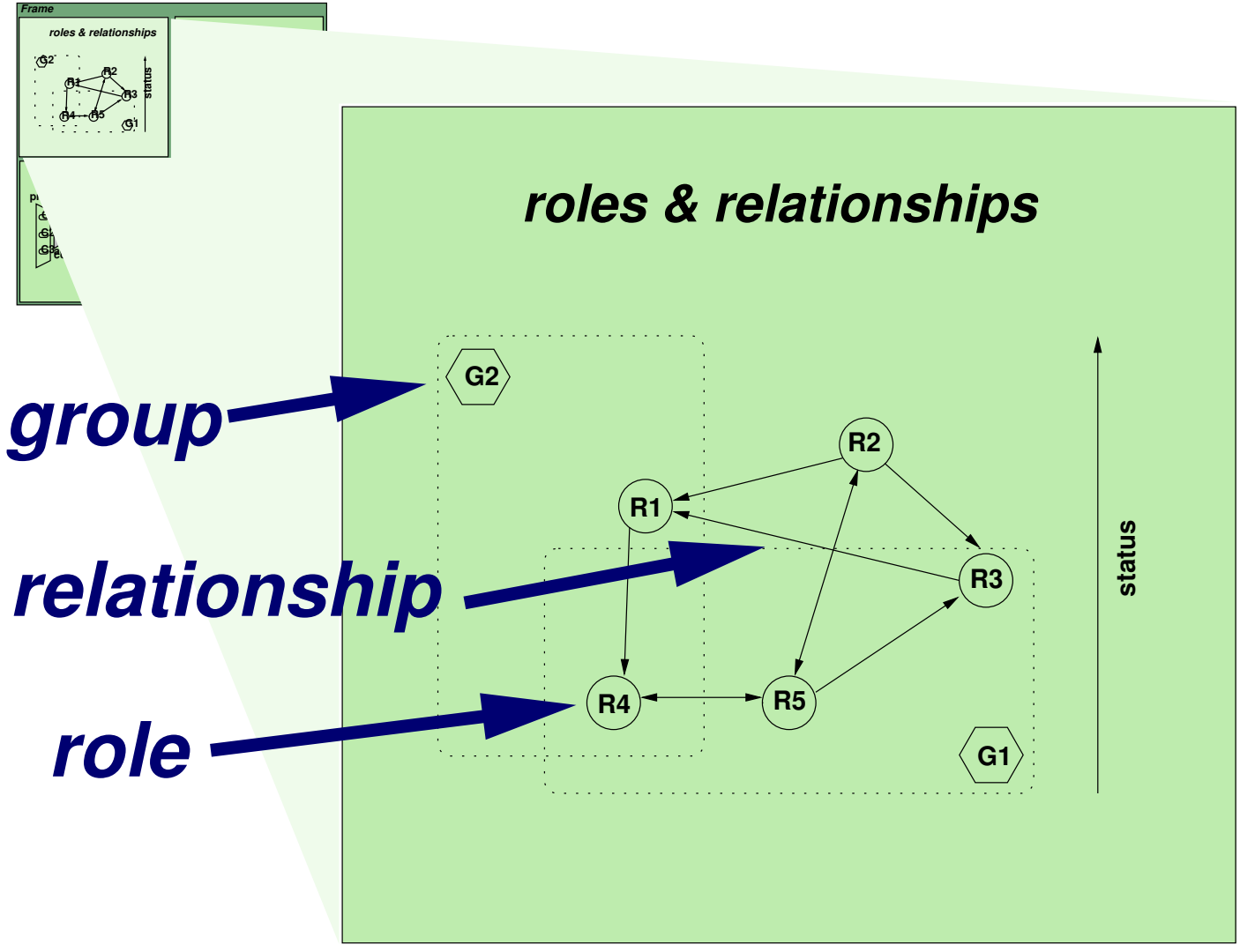

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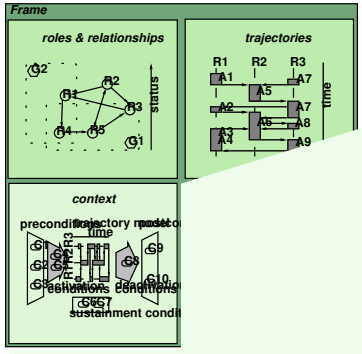


context

preconditions

trajectory model

postconditions

time

C1

C2

C3

C4

C5

R3

R2

R1

C8

C9

C10

activation conditions

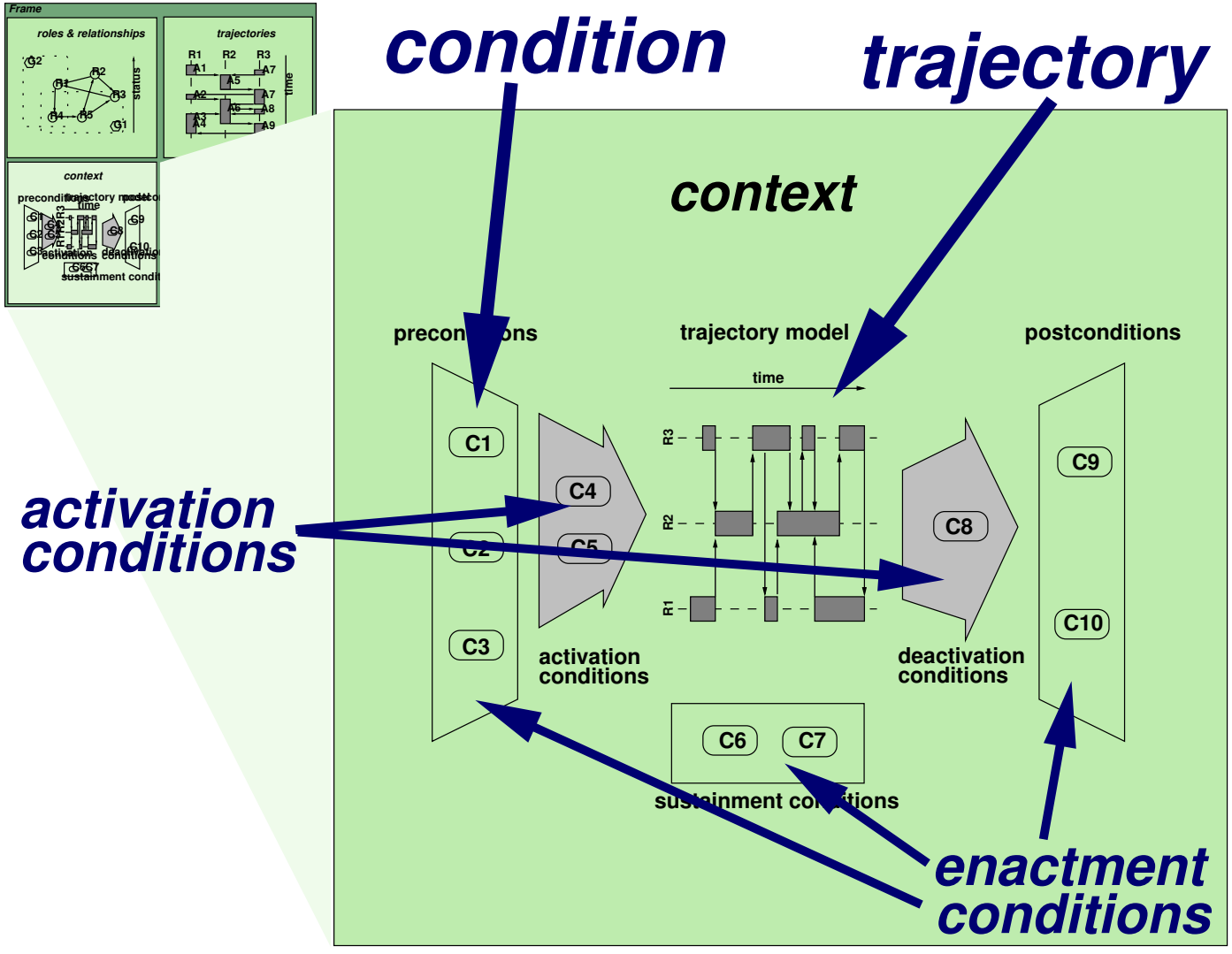
deactivation conditions

C6

C7

sustainment conditions

InFFrA – Frames



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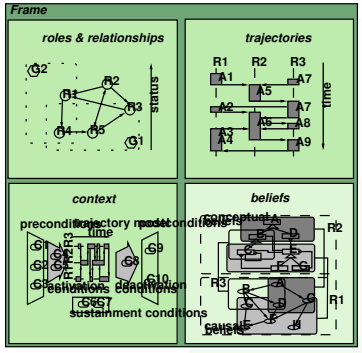

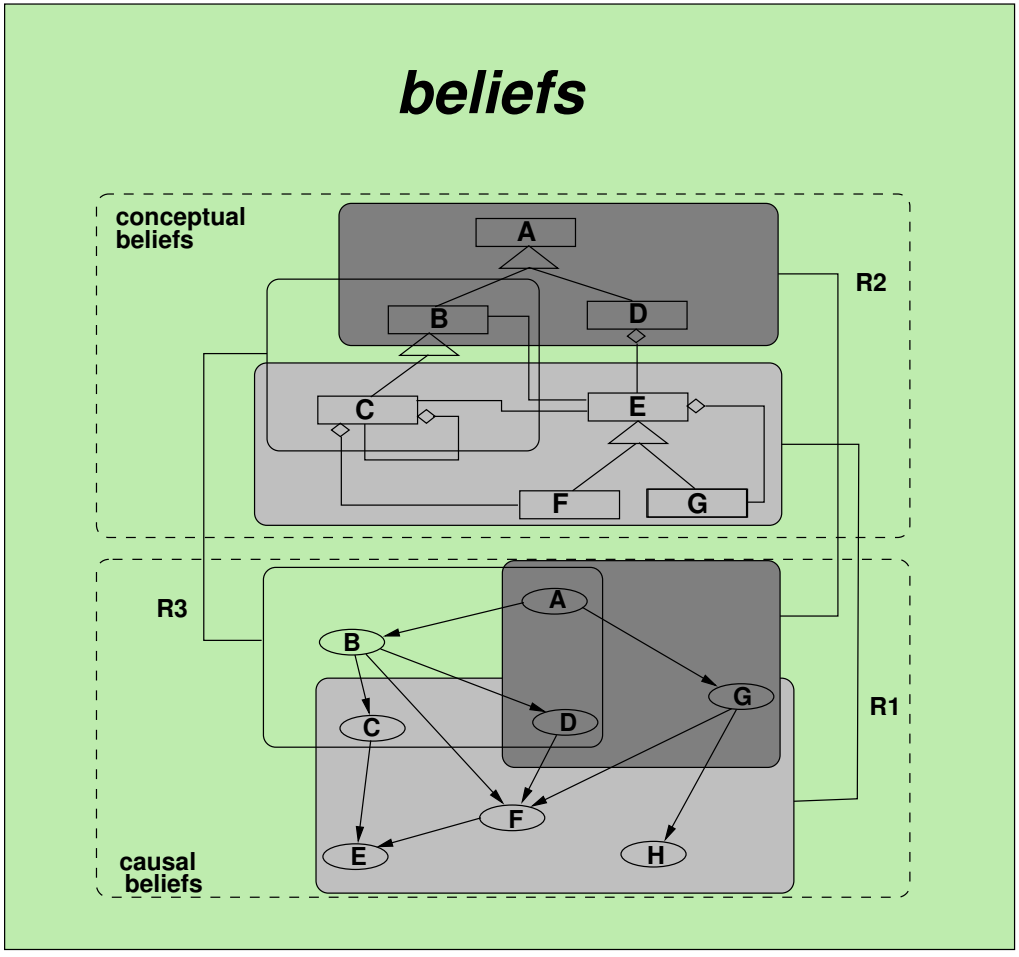

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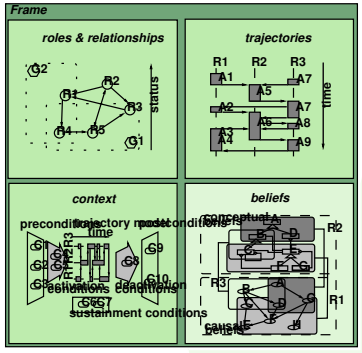
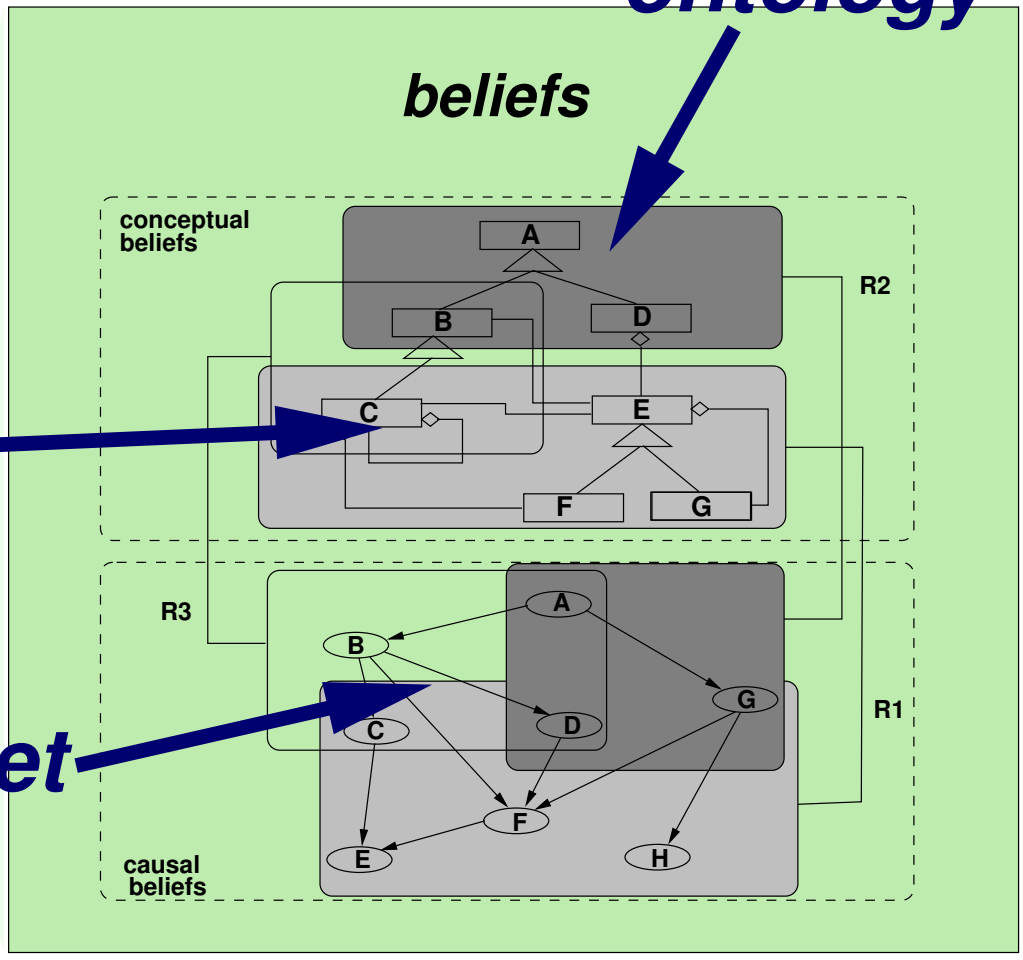


ontology

beliefs

role

belief net



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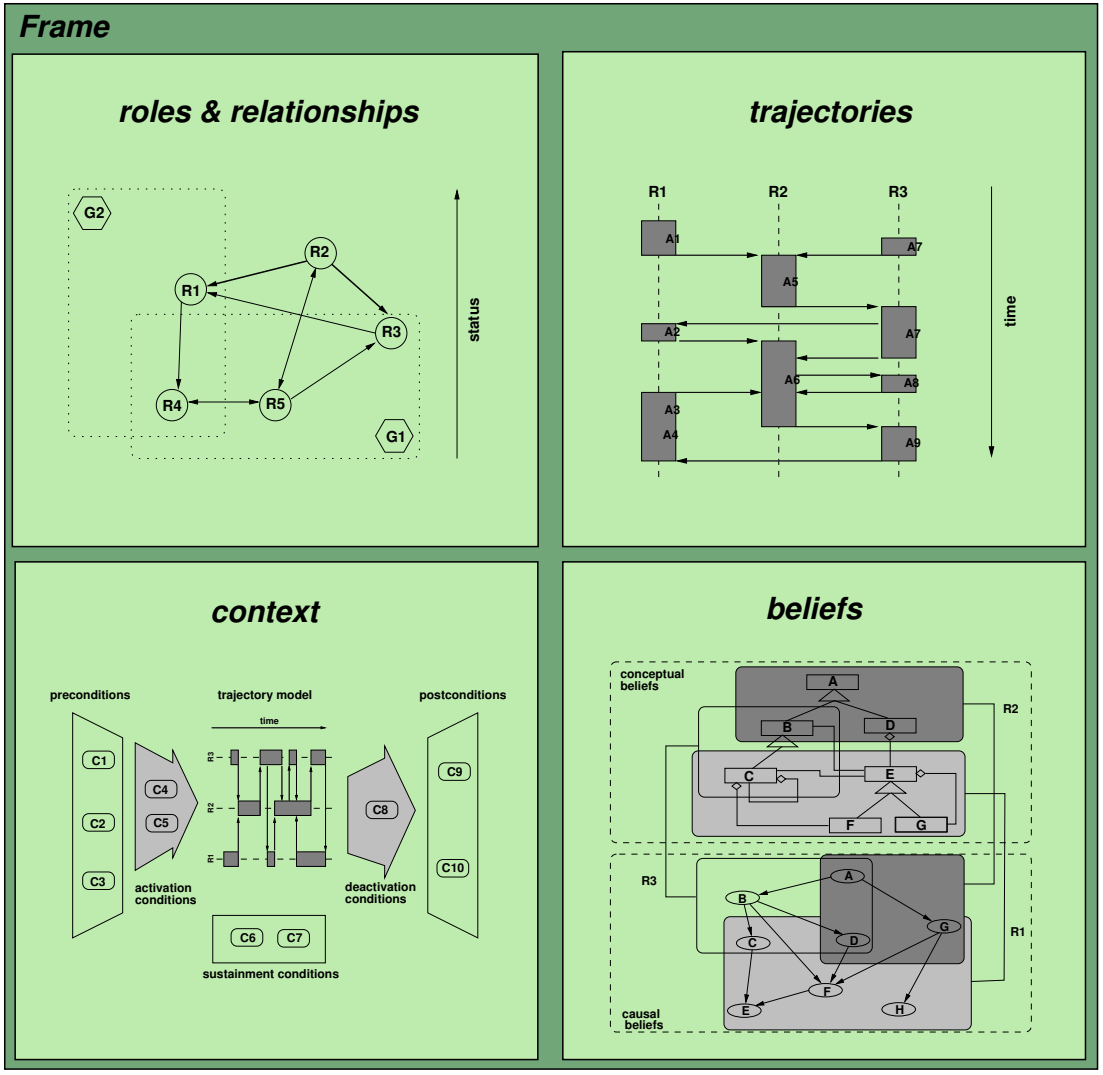


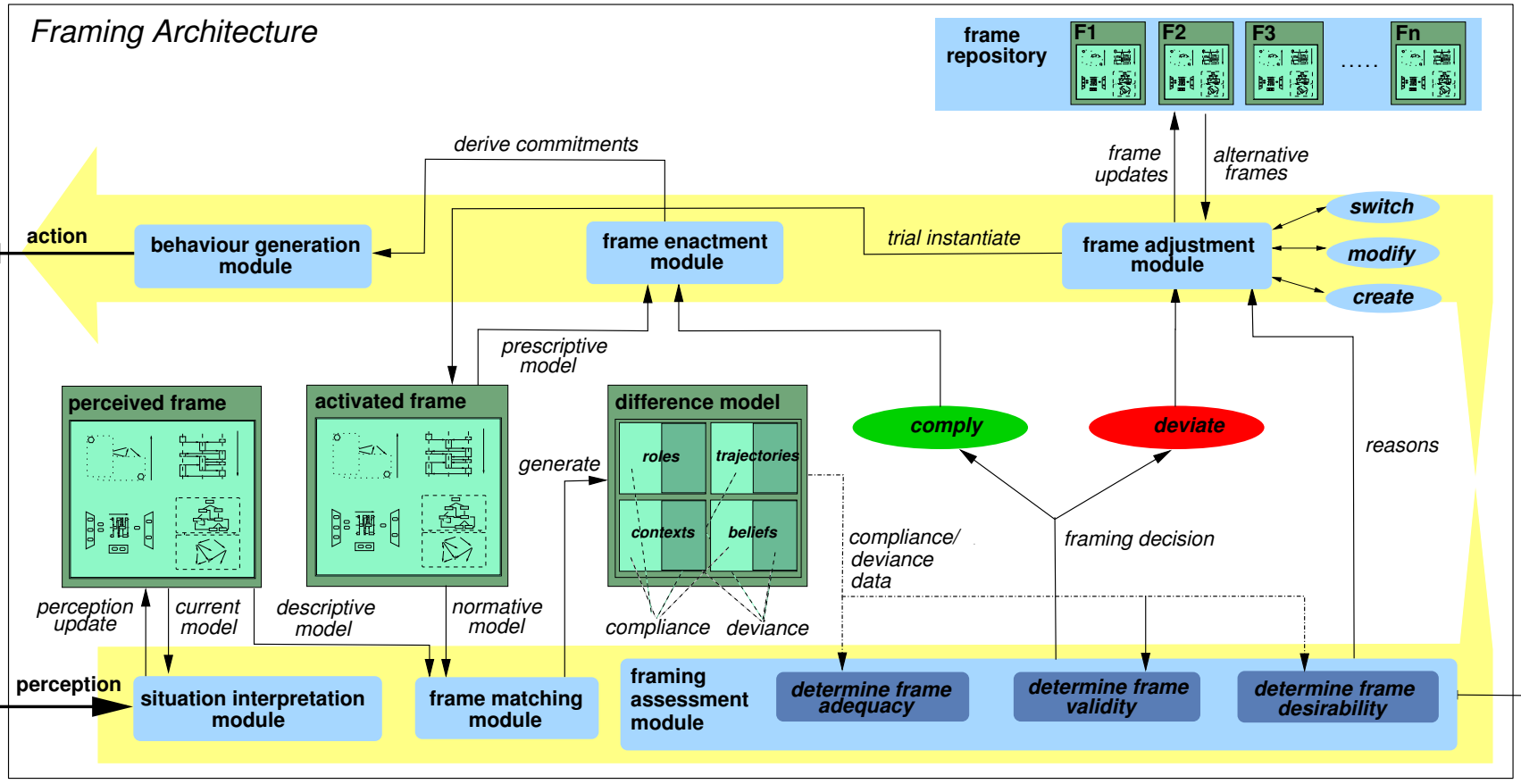
InFFrA – Framing

- framing is social reasoning that
  - interprets situations in terms of frames,
  - adapts frame conceptions,
  - strategically employs frames to guide interaction behaviour.
- data structures:
  - perceived frame
  - active frame
  - difference model
  - trial frame
  - frame repository

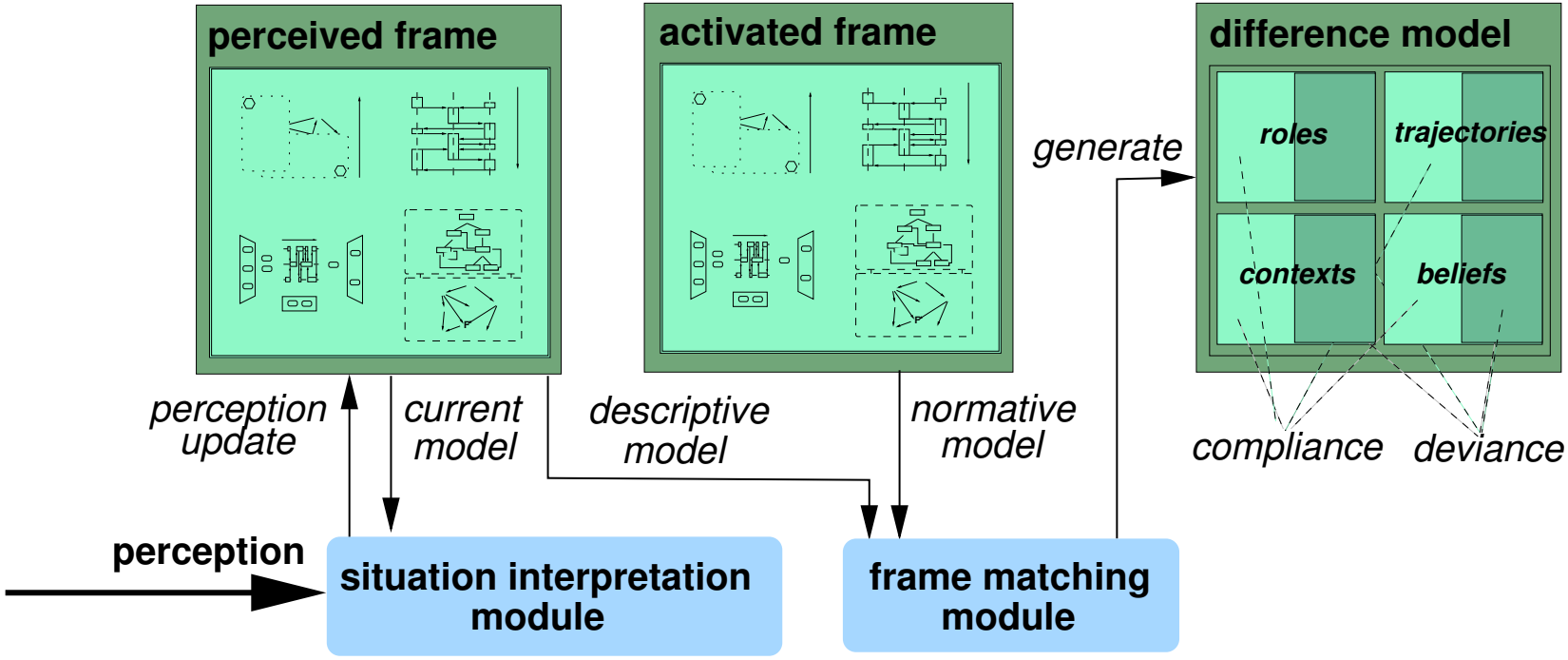
InFFrA – Framing

- inference steps:
  - situation interpretation
  - matching
  - assessment
  - framing decision
  - adjustment/re-framing
  - enactment
  - behaviour generation

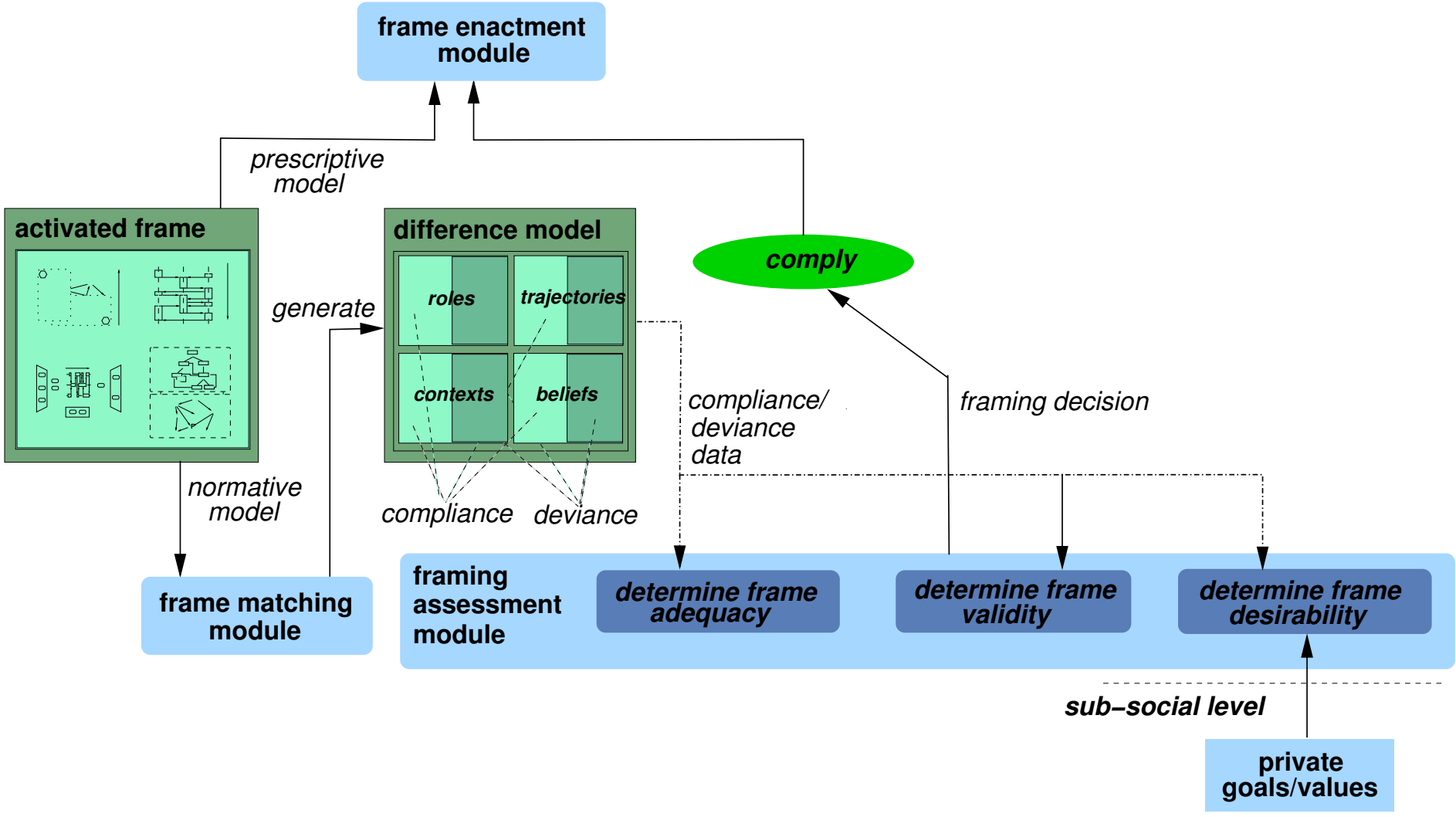
Framing


Framing Architecture
frame repository
F1
F2
F3
.....
Fn
derive commitments
frame updates
alternative frames
action
behaviour generation module
frame enactment module
trial instantiate
frame adjustment module
switch
modify
create
prescriptive model
perceived frame
activated frame
difference model
roles
trajectories
contexts
beliefs
comply
deviate
reasons
generate
compliance/ deviance data
framing decision
perception update
current model
descriptive model
normative model
compliance
deviance
sub–social level
perception
situation interpretation module
frame matching module
framing assessment module
determine frame adequacy
determine frame validity
determine frame desirability
private goals/values

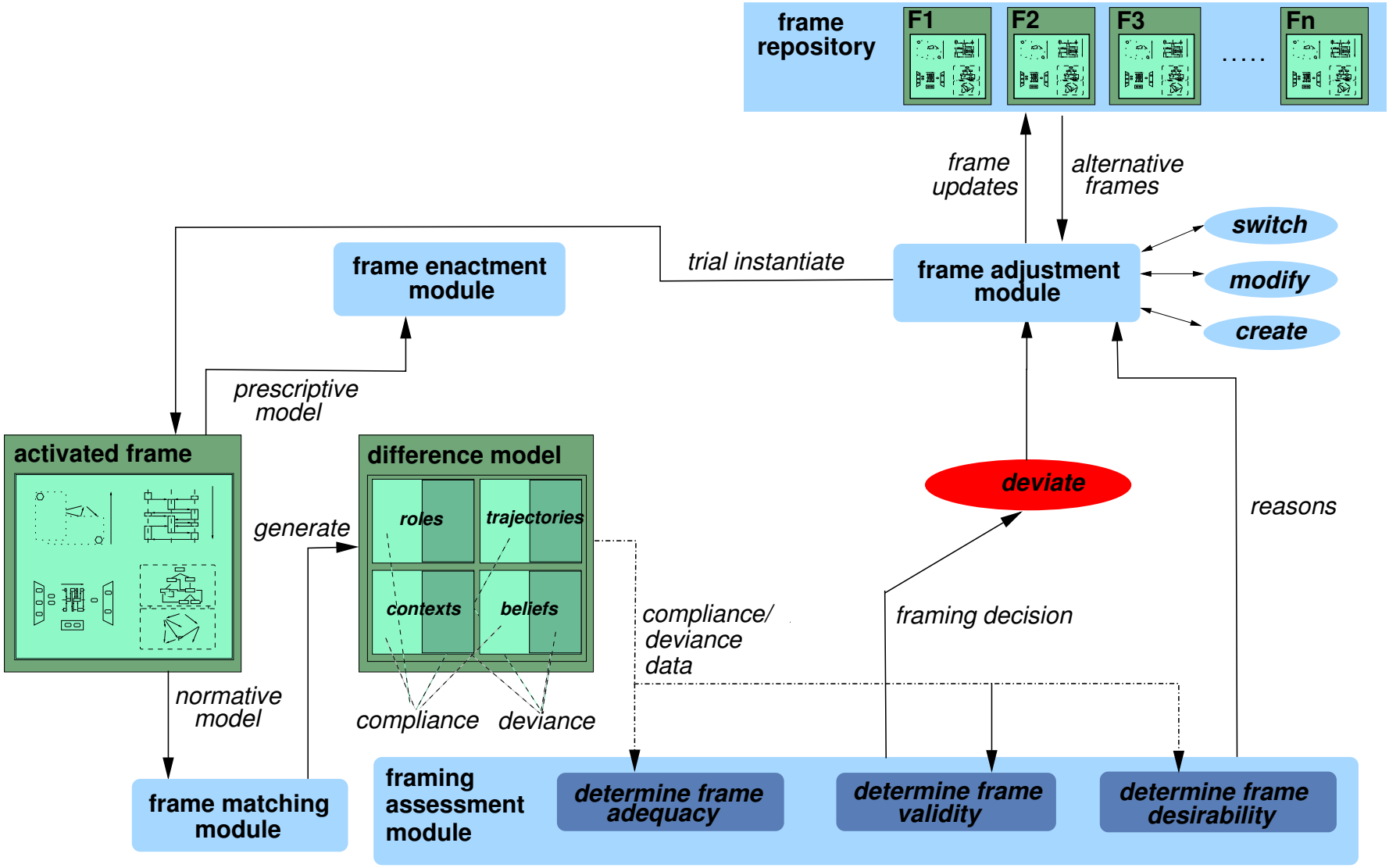
Interpretation & Matching



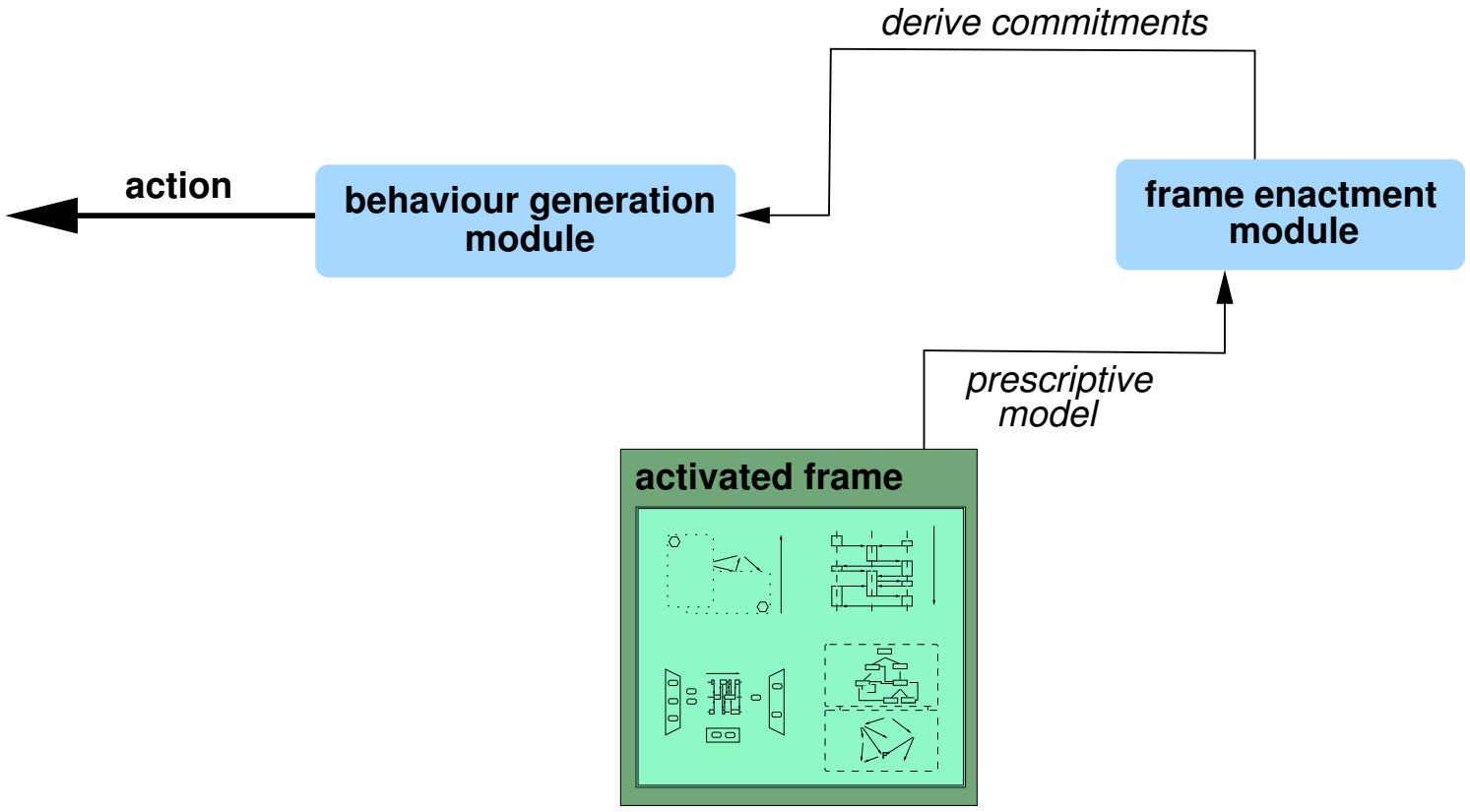
Assessment: “Comply Case”



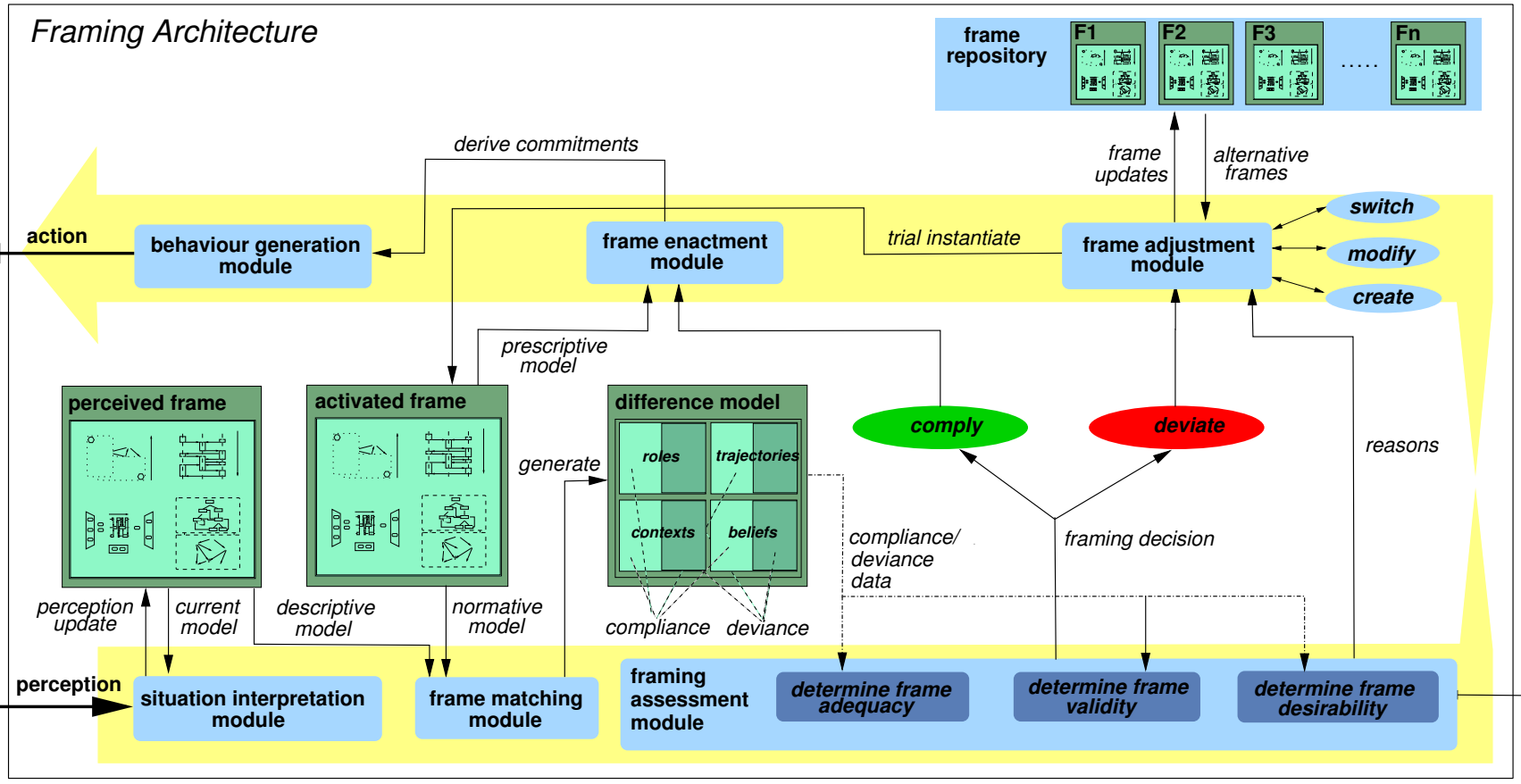
Assessment: “Deviate Case”



Enactment


derive commitments
action
behaviour generation module
frame enactment module
prescriptive model
activated frame

Framing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current model
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situation interpretation module
frame matching module
framing assessment module
determine frame adequacy
determine frame validity
determine frame desirability
private goals/values

InFFrA – Summary

- abstract architecture, many possible designs
- generic model for agent-level reasoning about interaction
- difference between frames and interaction protocols/conversation policies:
  - not fixed *a priori*, evolving
  - include information about context and experience
  - are vulnerable to manipulation (e.g. deception)
  - actors move fluidly rapidly between frames

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- Interaction Frames and Framing
- The InFFrA Architecture
- Frames vs. Communication Semantics
- Reasoning and Learning in InFFrA
- Applications and Future Research
- Conclusions

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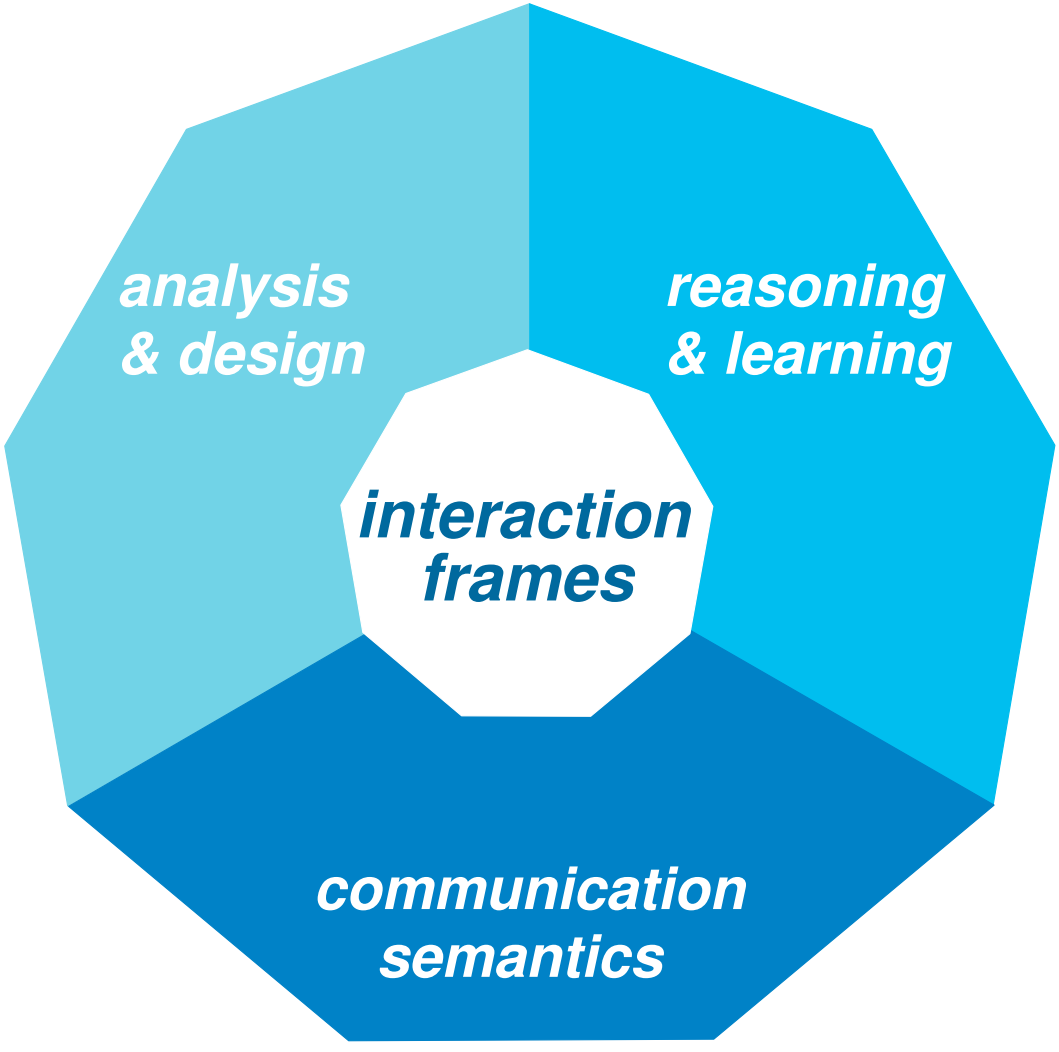
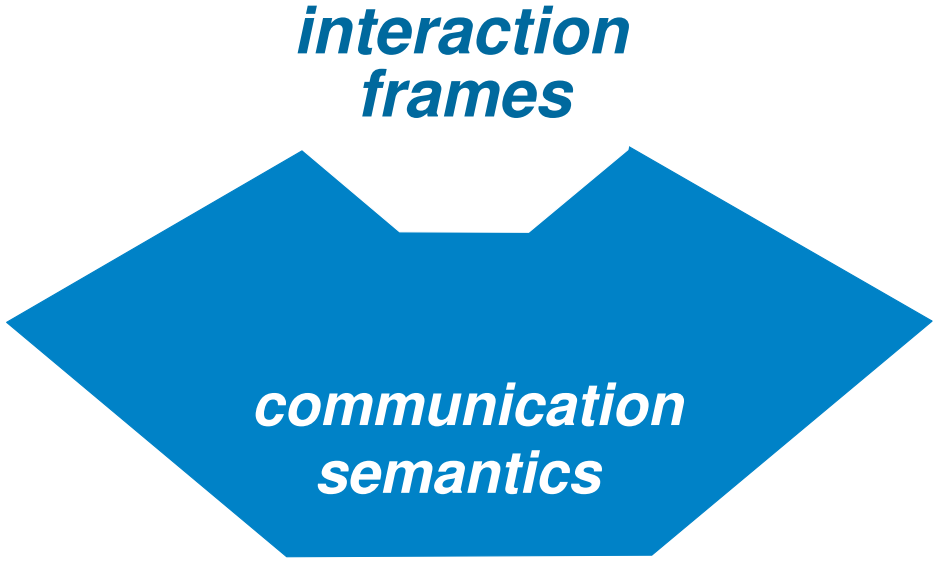
Views


analysis
& design
reasoning
& learning
interaction
frames
communication
semantics

Views

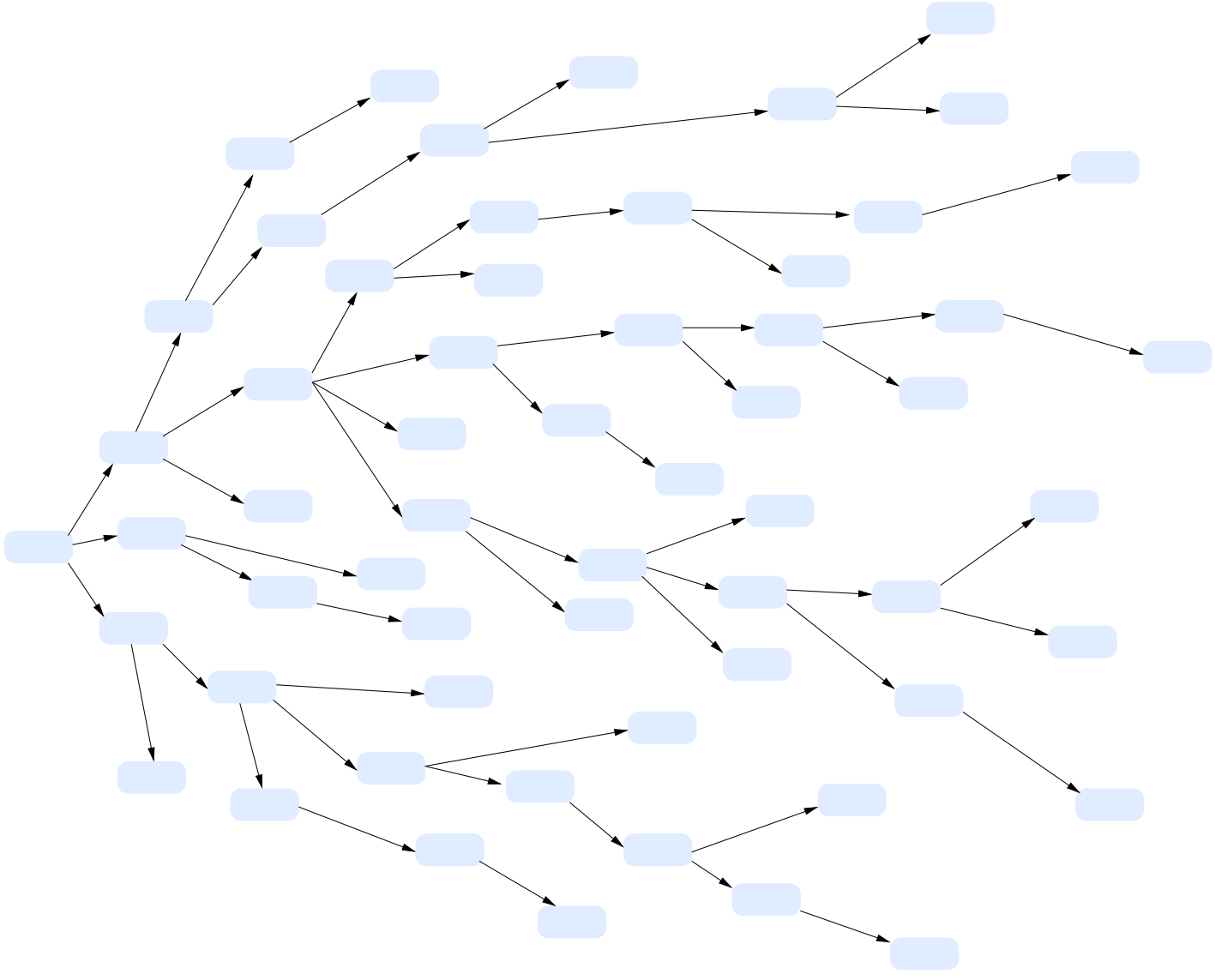


(Rovatsos et al., AAMAS'03)

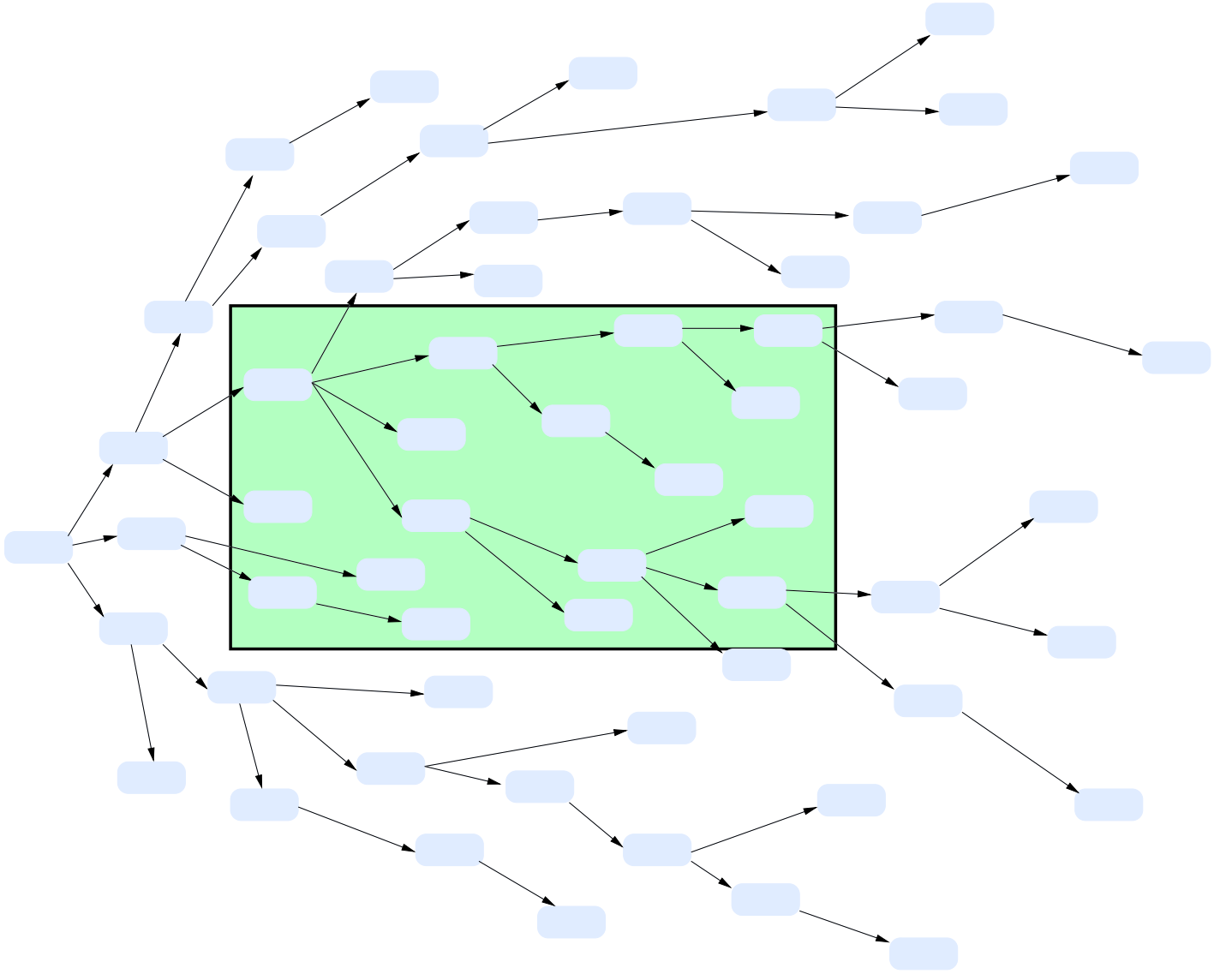
Communication Semantics

- frame repositories can be interpreted as communication system
  - ➡ agent-level modelling of meaning
- linking expectation structures to agent interests
- view essential for developing decision-making procedures
- enables entropy-based analysis methods
  - ➡ meta-heuristics for intelligent communicative behaviour

InFFrA vs. Com. Systems



InFFrA vs. Com. Systems

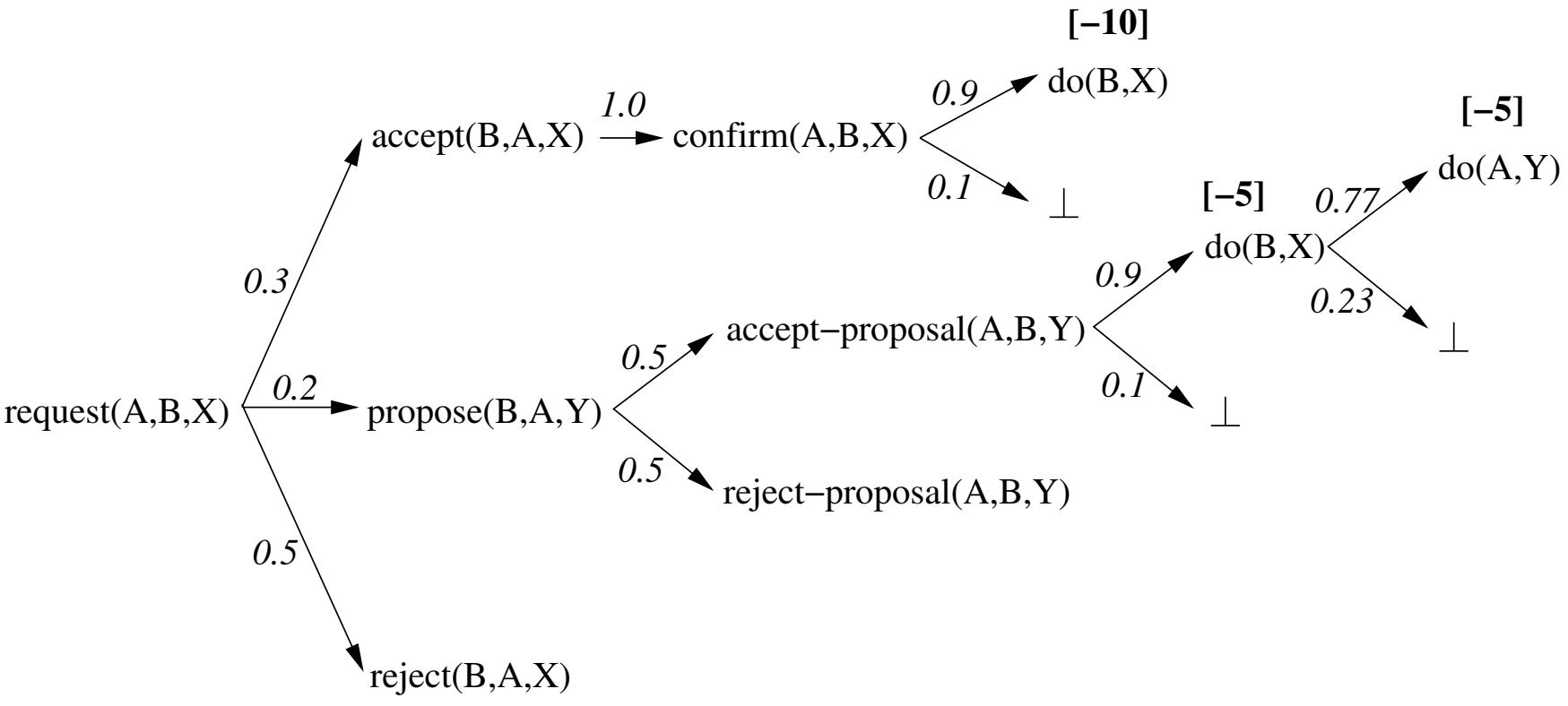


Minimal InFFrA Agents

- a simple variant of InFFrA
- agents that record (and count) two-party encounters
- frames = simple message sequences + counters + conditions
- roles/relationships, contexts and beliefs packed into conditions
- main goal: maximise expected utility
- entropy considerations useful?

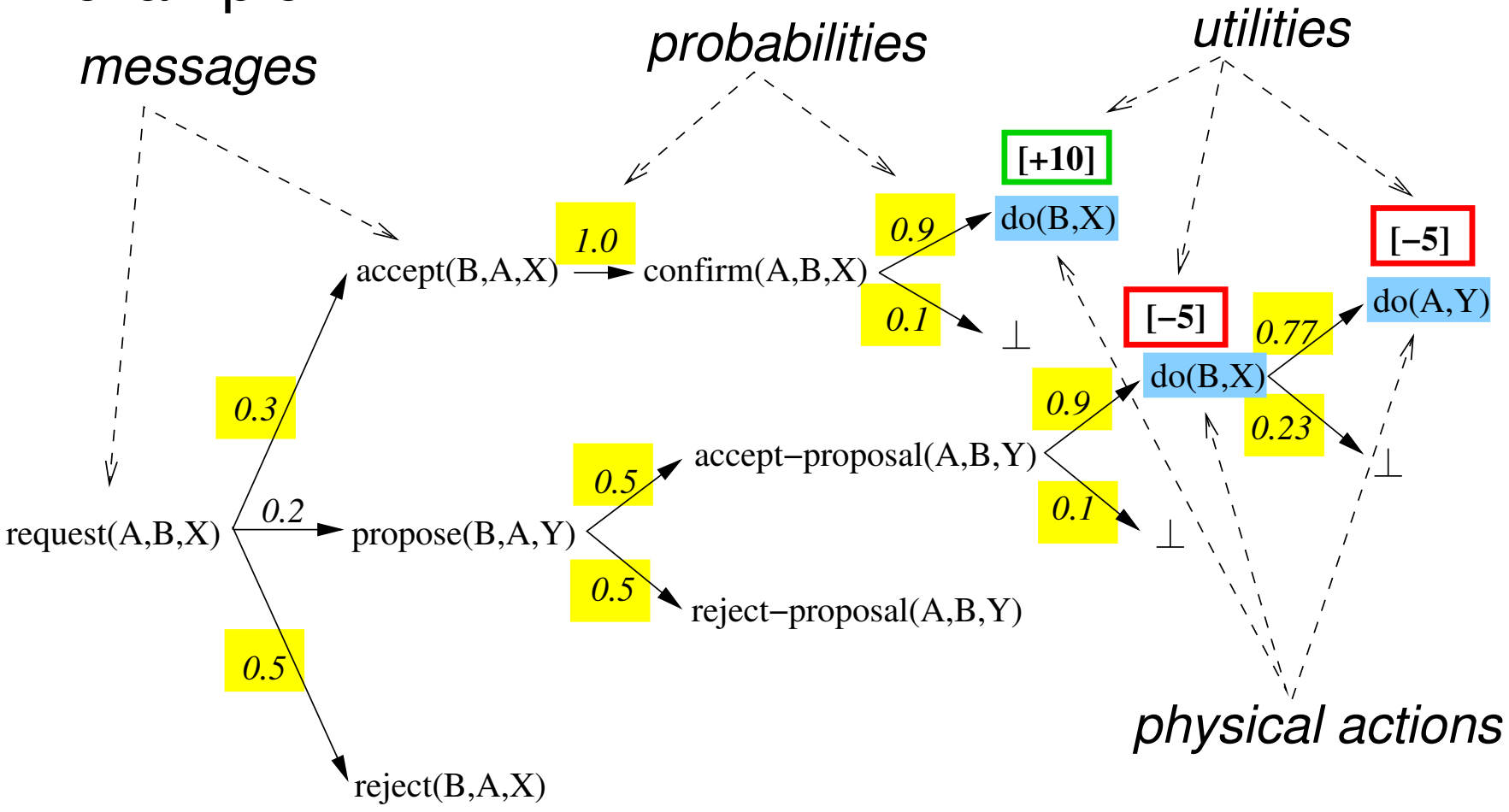
Probabilistic semantics

An example:



Probabilistic semantics

An example:



Probabilistic semantics

- assume agent maintains such a graph $\mathcal{F}$, and encounters (conversations) are sequences $w = w_1 w_2 \cdots w_n$
- ➡ easy to compute distribution $I_{\mathcal{F}}(w)$ of "continuations" for any current prefix w:

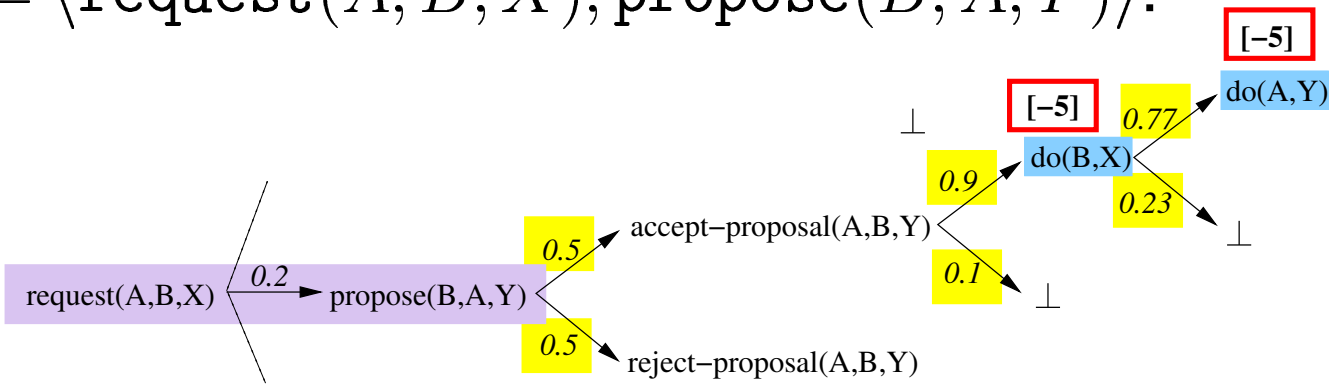
$$I_{\mathcal{F}}(w) = \lambda w'.P(w'|w)$$

- calculate expected utility after encounter prefix w:

$$\bar{u}(w) = \sum_{w'} I_{\mathcal{F}}(w)(w') \cdot u(w')$$

Example

Let $w = \langle \texttt{request}(A, B, X), \texttt{propose}(B, A, Y) \rangle$:



$$
\begin{aligned}
I_{\mathcal{F}}(w) \quad = \Big\{ & (\langle \texttt{accept-proposal}(A, B, Y), \texttt{do}(B, X), \texttt{do}(A, Y) \rangle, 0.3456) \\
& \langle \texttt{accept-proposal}(A, B, Y), \texttt{do}(B, X) \rangle, 0.1035), \\
& \langle \texttt{accept-proposal}(A, B, Y) \rangle, 0.05), \\
& \langle \texttt{reject-proposal}(A, B, Y) \rangle, 0.5) \Big\}
\end{aligned}
$$

$$
\bar{u}(w) \quad = -10 \cdot 0.3456 + (-5) \cdot 0.103 + (0 \cdot 0.05 + 0 \cdot 0.5) = -3.971
$$

Entropy Heuristics

- define measures to determine degree of ***uncertainty*** and own ***autonomy***

$$EE_{\mathcal{F}}(w) = \sum_{w'} -P(w') \log_2 P(w')$$

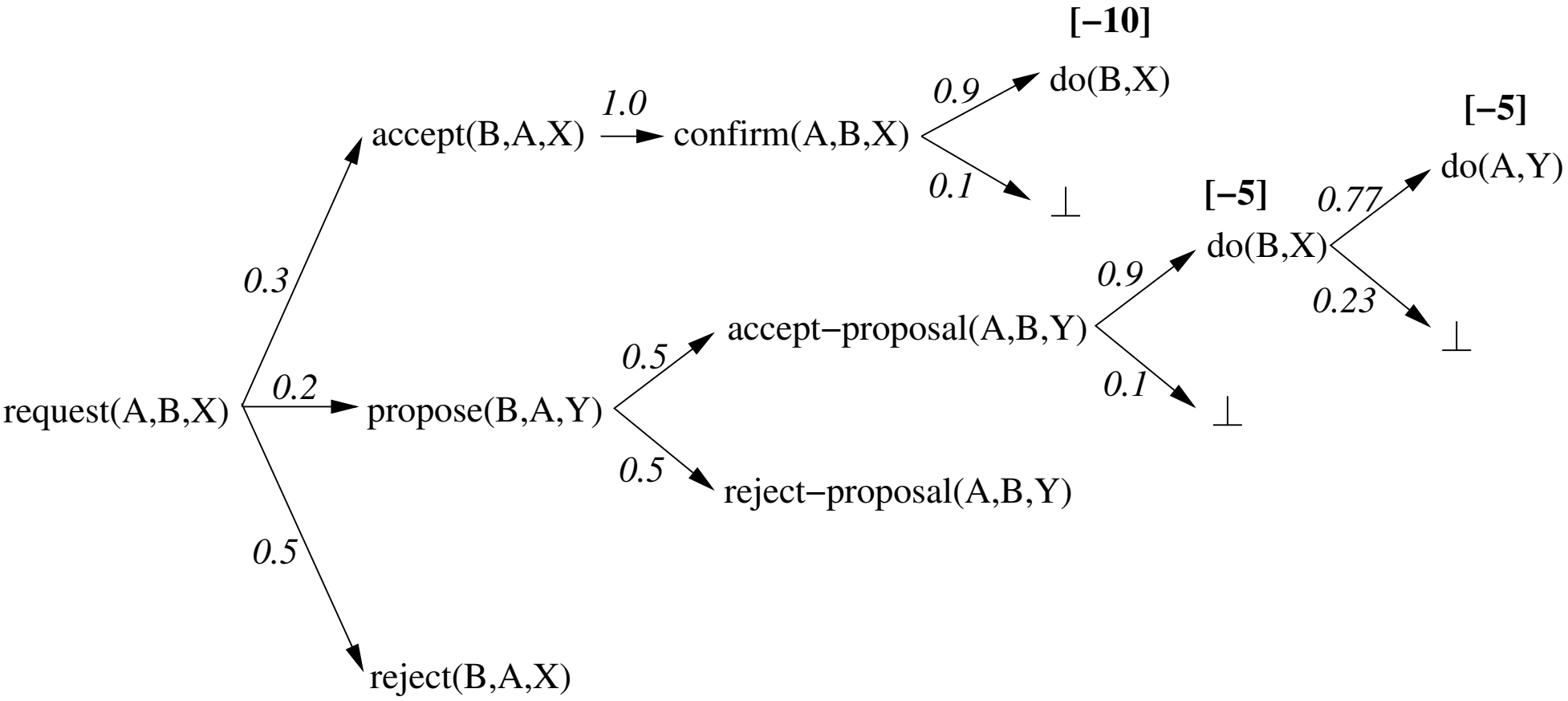
$$UD_{\mathcal{F}}(w) = \sqrt{\sum_{w'} \left(u(w') - \bar{u}(w')\right)^2}$$

- total ***entropy*** as combined measure:

$$\mathcal{E}_{\mathcal{F}}(w) = EE_{\mathcal{F}}(w) \cdot UD_{\mathcal{F}}(w)$$

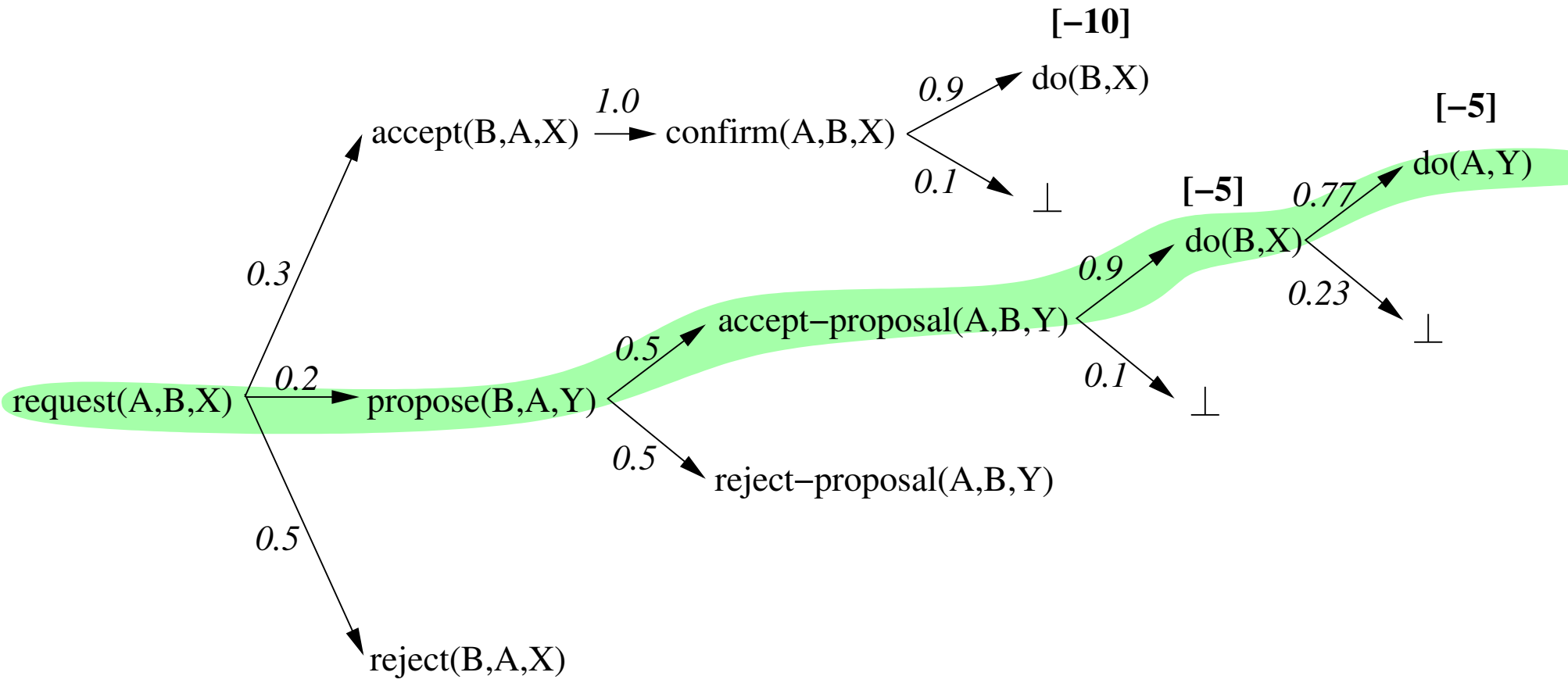
Example

Back to complex protocol:



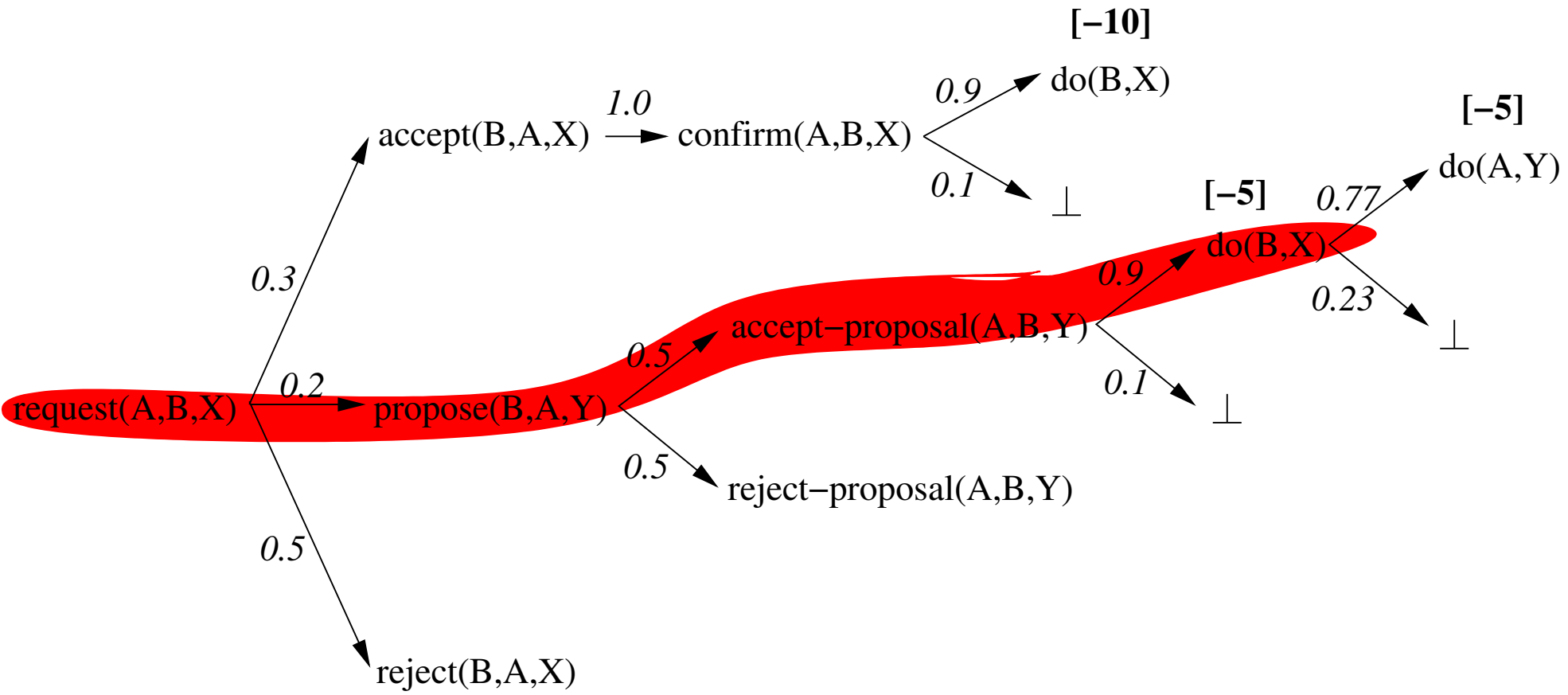
Example

Successful completion:



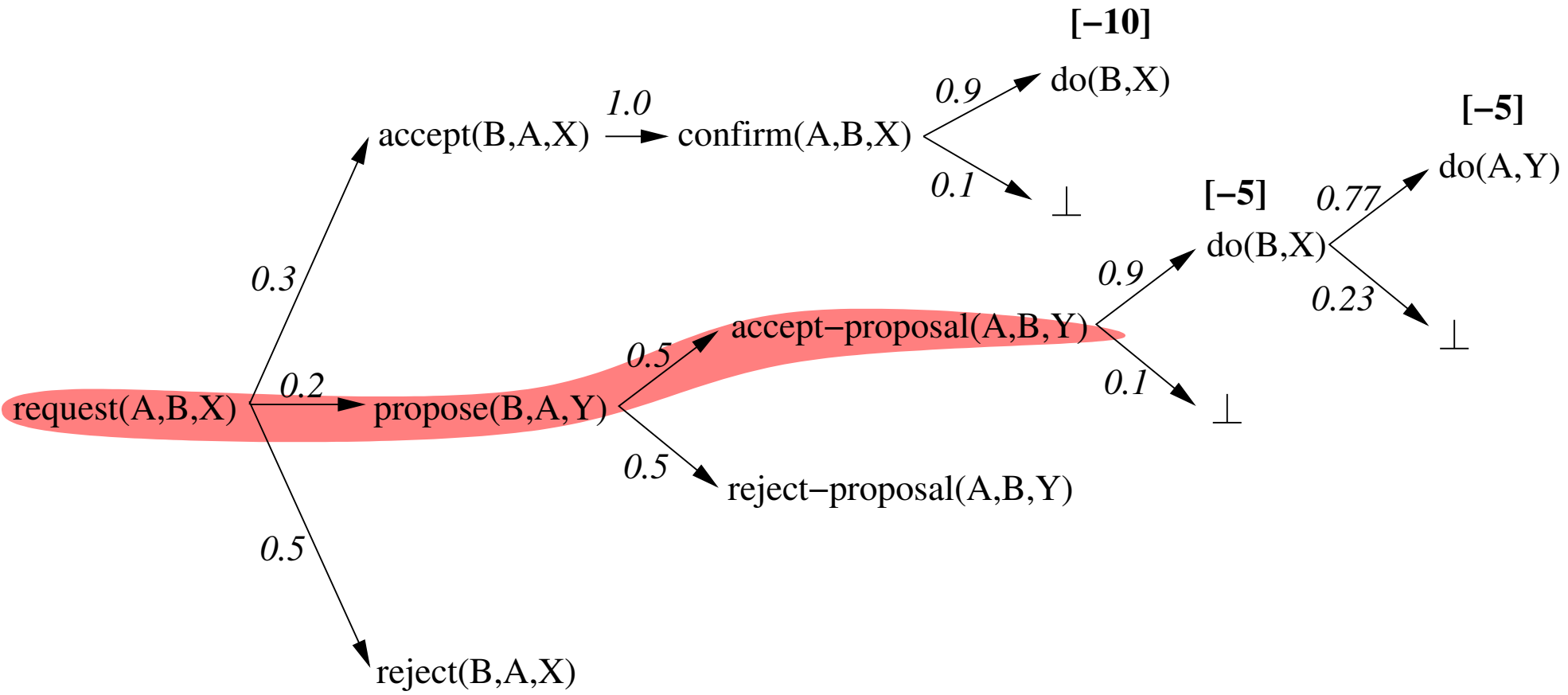
Example

A cheats:



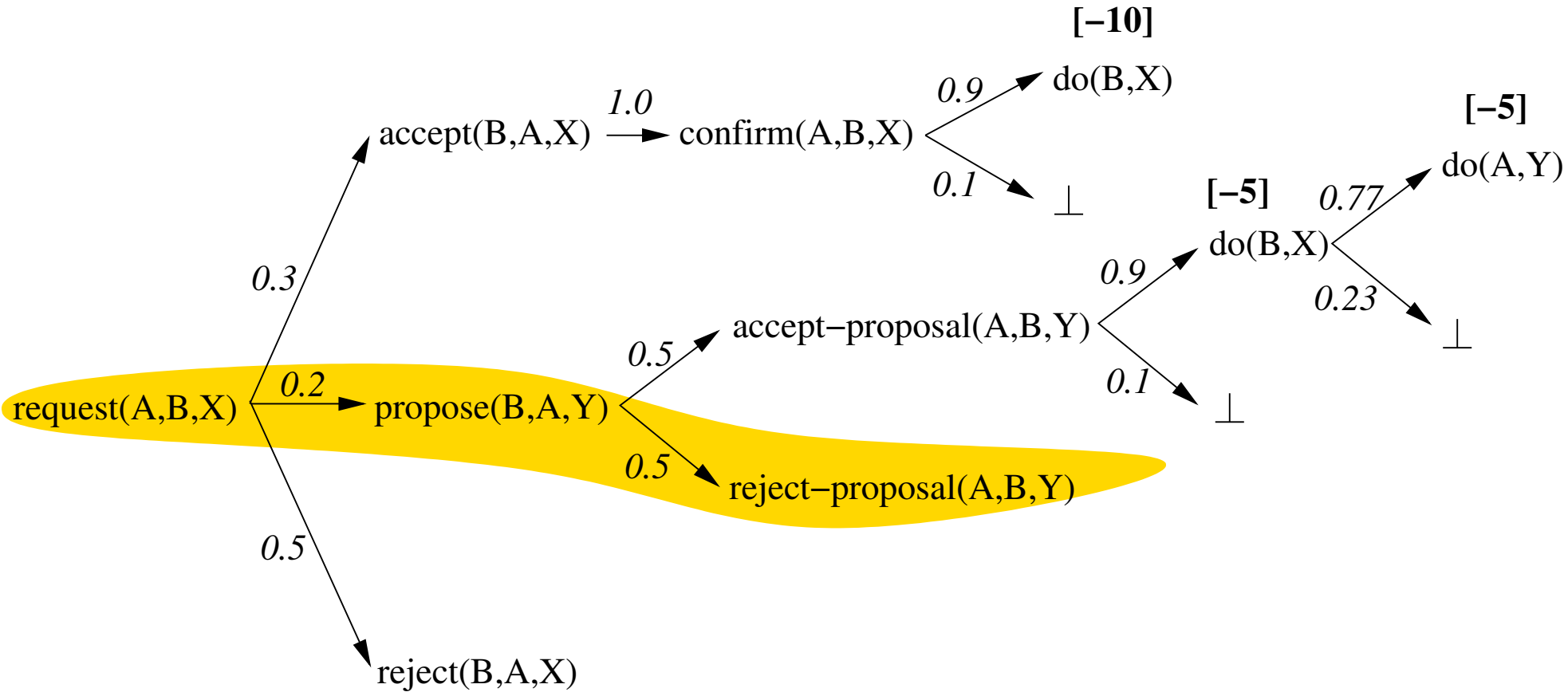
Example

B cheats:



Example

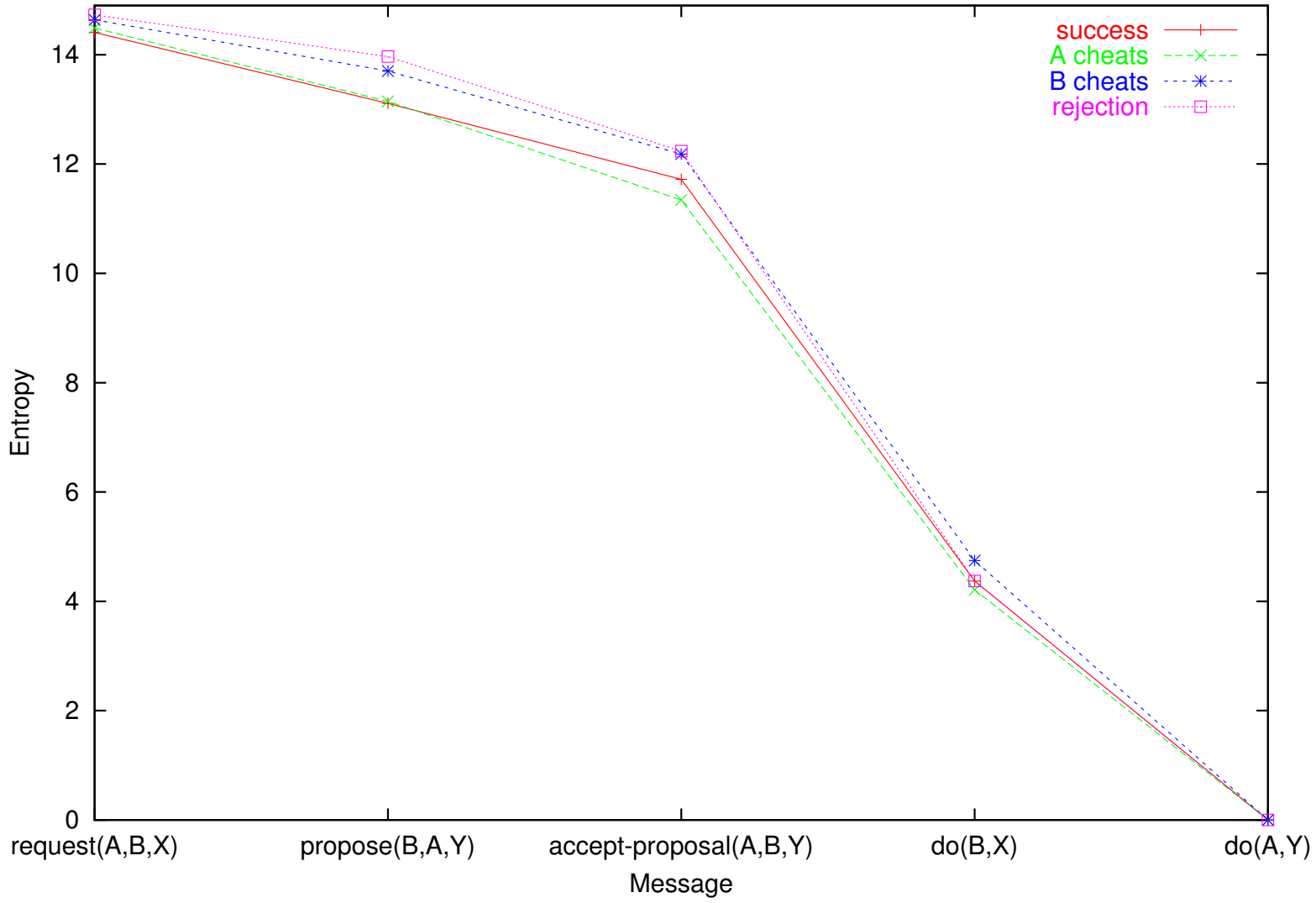
Rejection:



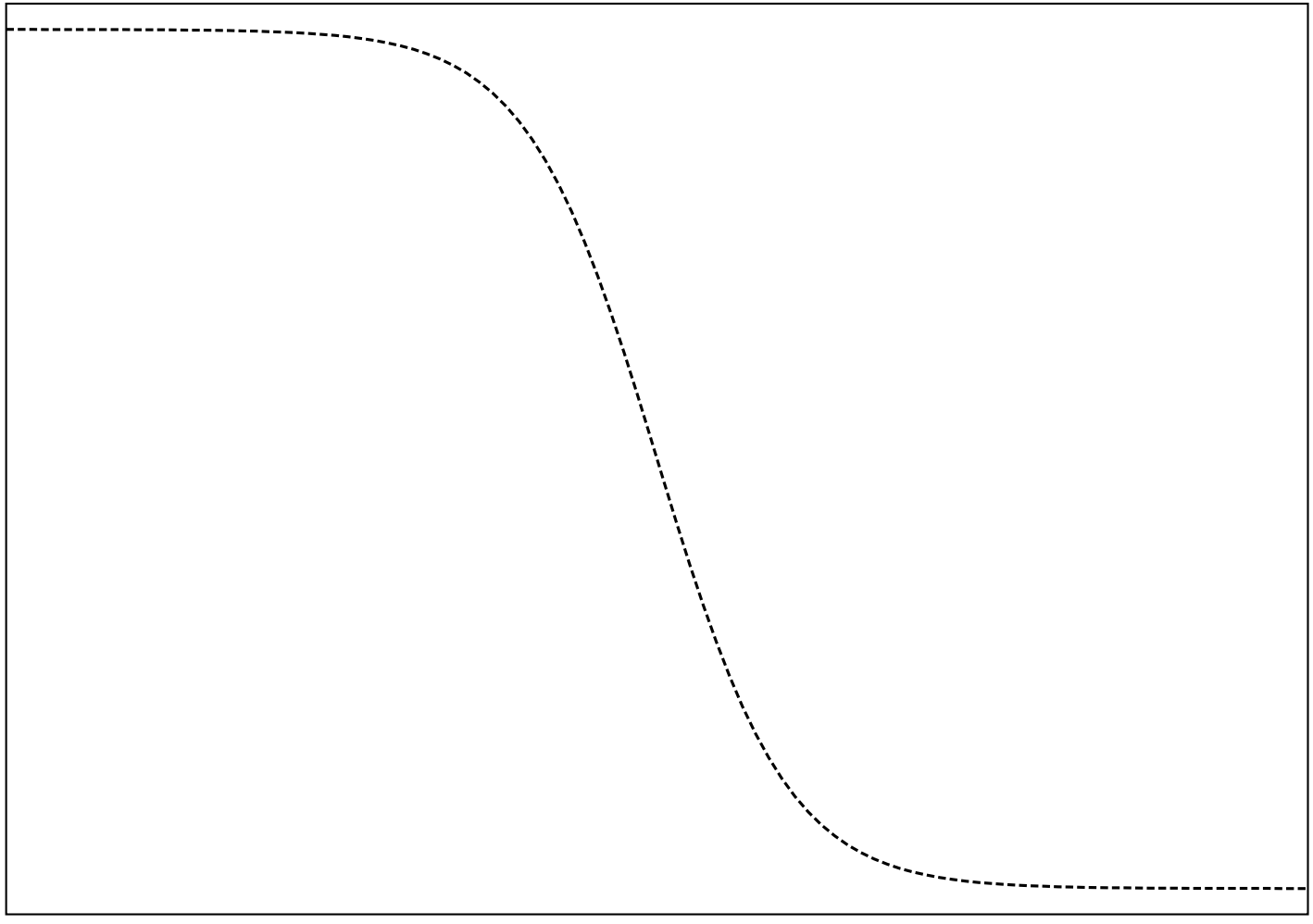
Trajectory Shapes

- analyse effects of each of the trajectories on $\texttt{propose}(A, B, X) \rightarrow \ldots \rightarrow \texttt{do}(A, Y)$
- Observations:
  - "perfect" entropy curves consist of **autonomy** and **commitment** part
  - effects of "A cheats" much worse than "B cheats"

Trajectory shapes



Trajectory shapes



Conflict Potential

- If $\mathcal{F}'$ is the product of v in $\mathcal{F}$, define:

$$\Delta\mathcal{E}_{\mathcal{F}}(w, v) = \mathcal{E}_{\mathcal{F}'}(w) - \mathcal{E}_{\mathcal{F}}(w)$$

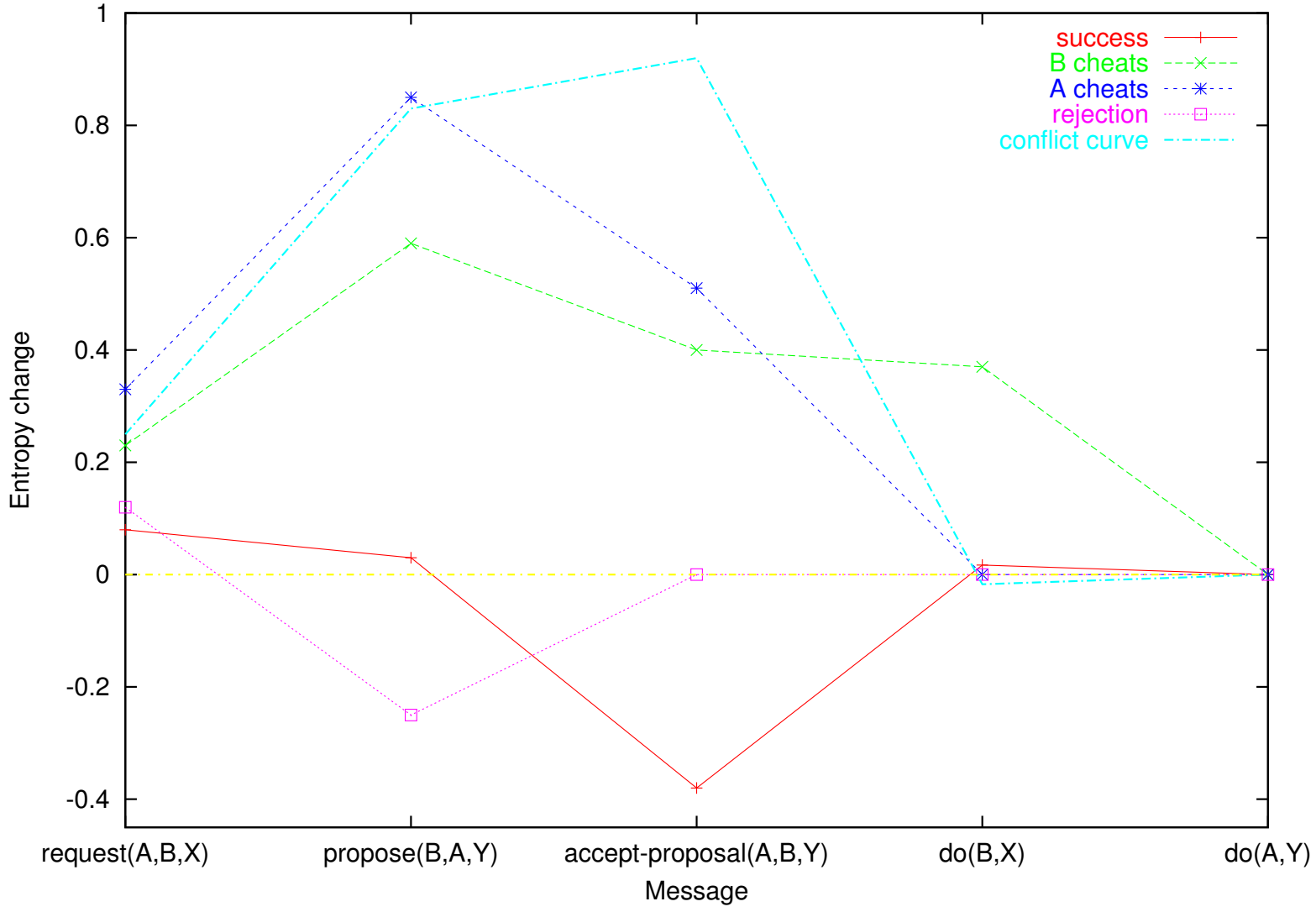
- If v was expected, and v' occured, define:

$$\mathcal{CP}_{\mathcal{F}}(v', v, w) = \int_{w[1]}^{w[|w|]} \Delta\mathcal{E}_{\mathcal{F}}(w, v') - \Delta\mathcal{E}_{\mathcal{F}}(w, v) dw_i$$

- Example:

$$\Delta\mathcal{E}(\text{“success”}, \text{“A cheats”}) - \Delta\mathcal{E}(\text{“success”}, \text{“success”})$$

Conflict Potential



Significance?

- application of communication systems approach to agent design
- "consequentialist" view enables decision-theoretic approach
- agents have to consider effects of utterances, i.e.
  - reactions of self and others to message ("first-order")
  - impact on expectation structures ("second-order")

  and reason about "utility" of semantics
- entropy measures can be useful with this respect (e.g. domain-independent notion of conflict)

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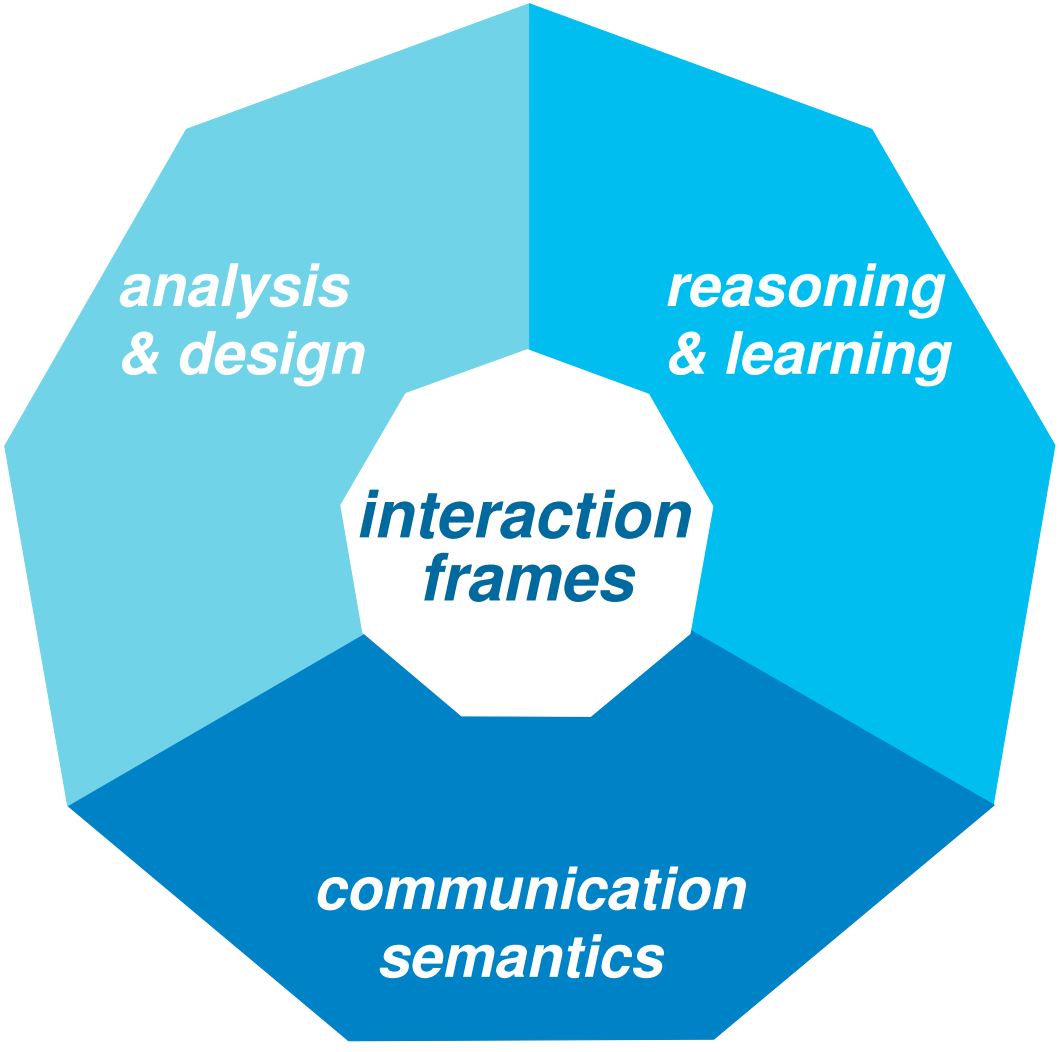
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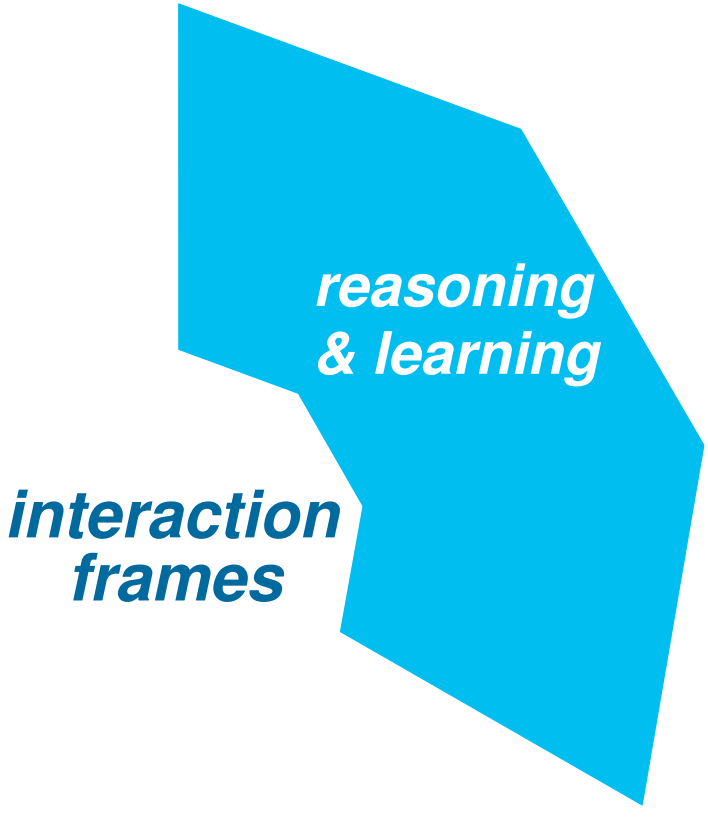
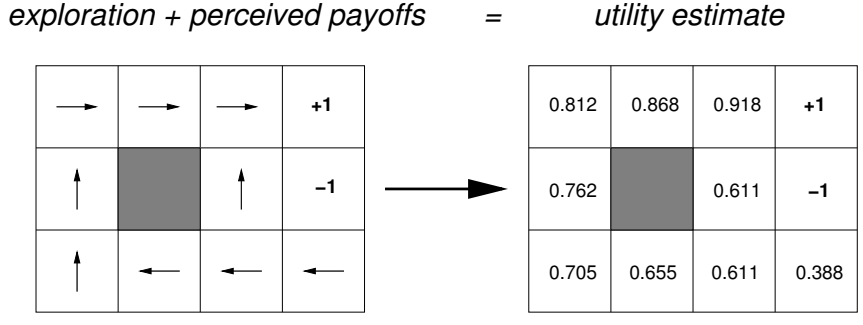
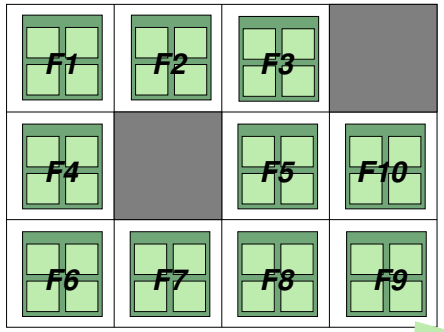


(Rovatsos & Fischer, upcoming TechReport)

- concrete instance of InFFrA for “almost-minimal” agents
- two-layer model for learning and employing frames
- realises two principles:
  - **social abstraction**
  - **transient social optimality**
- use of reinforcement-learning methods

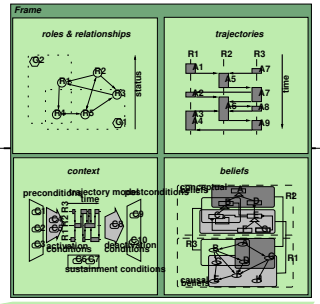


framing decisions + long–term payoffs = *framing utility*



0.812	0.868	0.918	
0.762		0.611	0.534
0.705	0.655	0.611	0.388

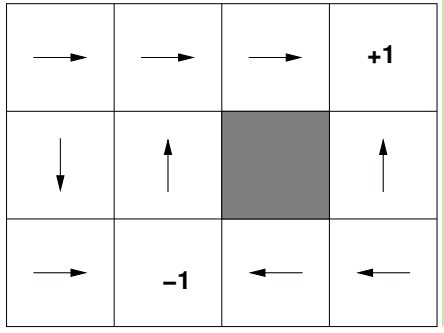
framing



frame level

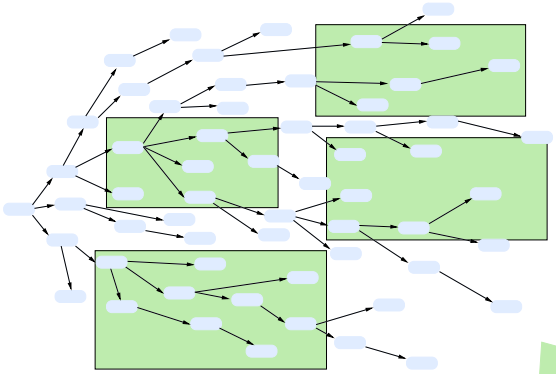
action level

in–frame action decisions + immediate payoffs = *action utility*



0.455	0.686	0.874	**+1**
0.512	0.112		0.766
0.377	**–1**	0.245	0.621

frame management + entropy considerations



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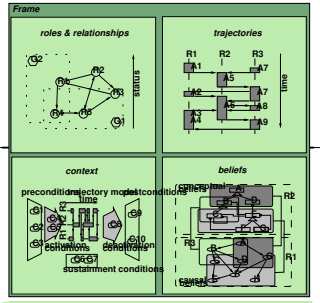
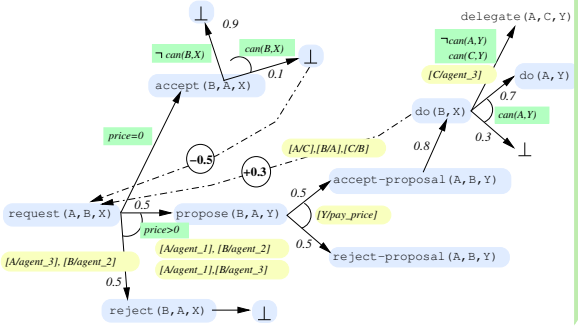
framing



frame level

action level

frame communication system



0.455	0.686	0.874	**+1**
0.512	0.112		0.766
0.377	**−1**	0.245	0.621

$$
\begin{aligned}
F = \Big\langle & \big\langle \xrightarrow{5} \texttt{propose}(A_1, A_2, \texttt{do}(A_1, X_1)) \xrightarrow{3} \texttt{accept}(A_2, A_1, \texttt{do}(A_1, X_1)) \\
& \quad \xrightarrow{2} \texttt{do}(A_1, X_1) \big\rangle, \\
& \big\langle \{self(A_1), other(A_2), can(A_1, \texttt{do}(A_1, X_1)\}, \\
& \quad \{agent(A_1), agent(A_2), action(X_1)\} \big\rangle, \\
& \big\langle \xrightarrow{4} \langle [A_1/\texttt{agent\_1}], [A_2/\texttt{agent\_2}] \rangle, \\
& \quad \xrightarrow{1} \langle [A_1/\texttt{agent\_3}], [A_2/\texttt{agent\_1}], [X_1/\texttt{deliver\_goods}] \rangle \big\rangle \Big\rangle
\end{aligned}
$$

- considers similarity between situations (similar to case-based reasoning)
- frame application connected to agent's knowledge base
- generalisation capabilities (frame merging)
- entropy considerations for frame repository management
- invention of new frames (underway)

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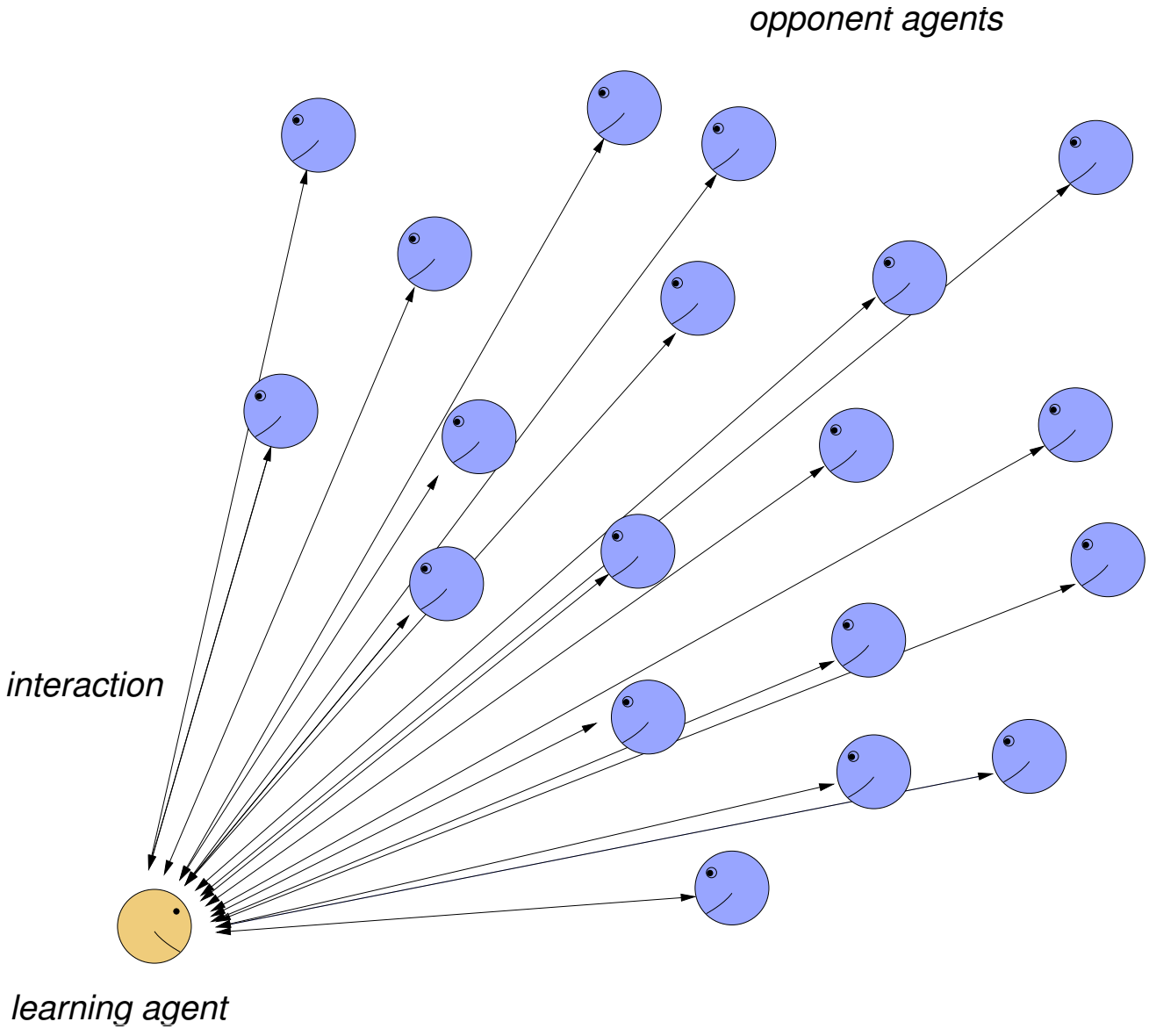
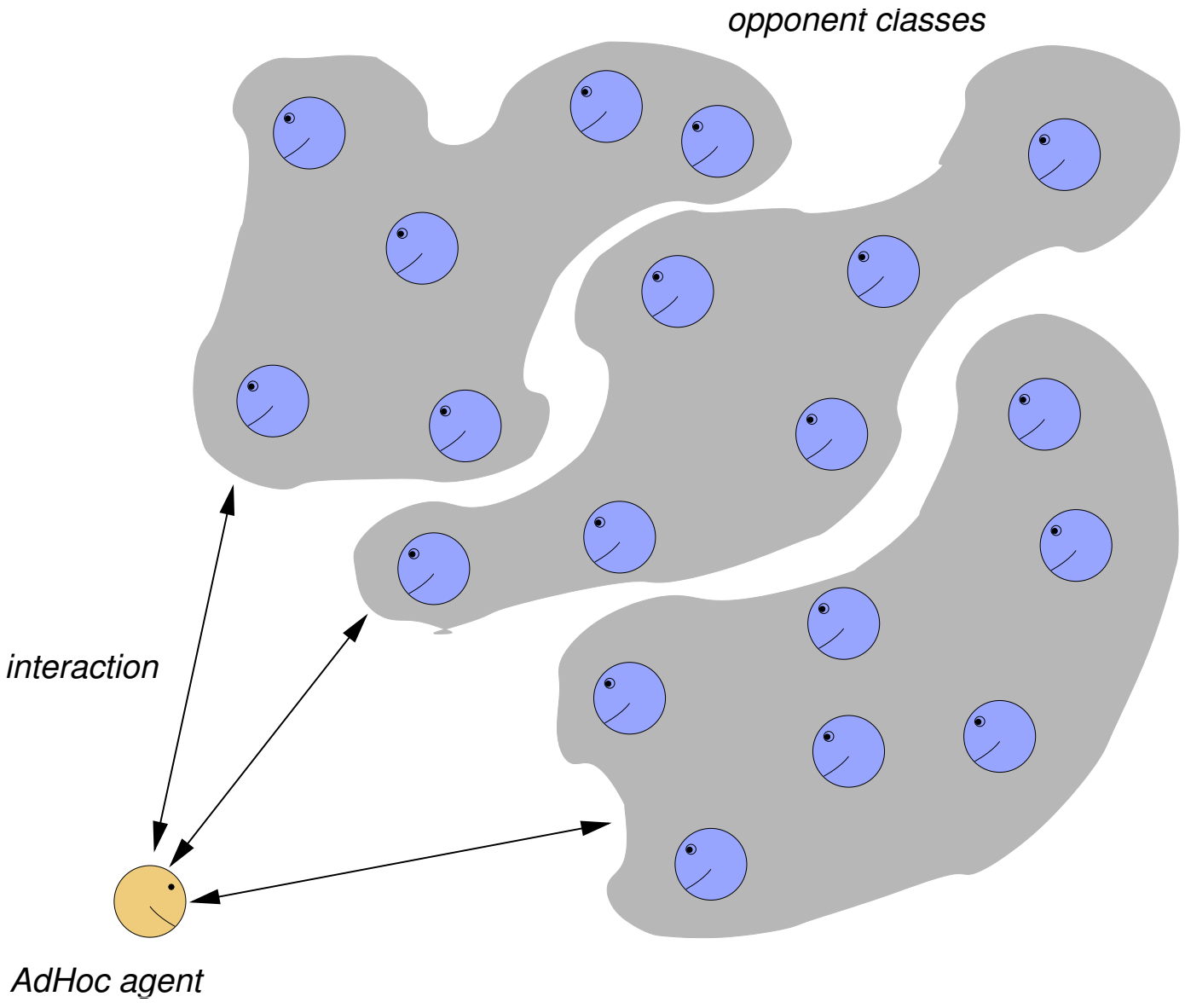
Applications – AdHoc

- Adaptive Heuristic for Opponent Classification
- goal: complexity reduction through opponent classification
- evolves dynamically changing set of opponent models and learns optimal counter-strategies
- opponent models = deterministic finite automata (approach of Carmel & Markovitch)
- strategy optimisation uses Q-learning
- successful experiments wrt classification
- “AdHoc vs. AdHoc”problem!

Applications – AdHoc



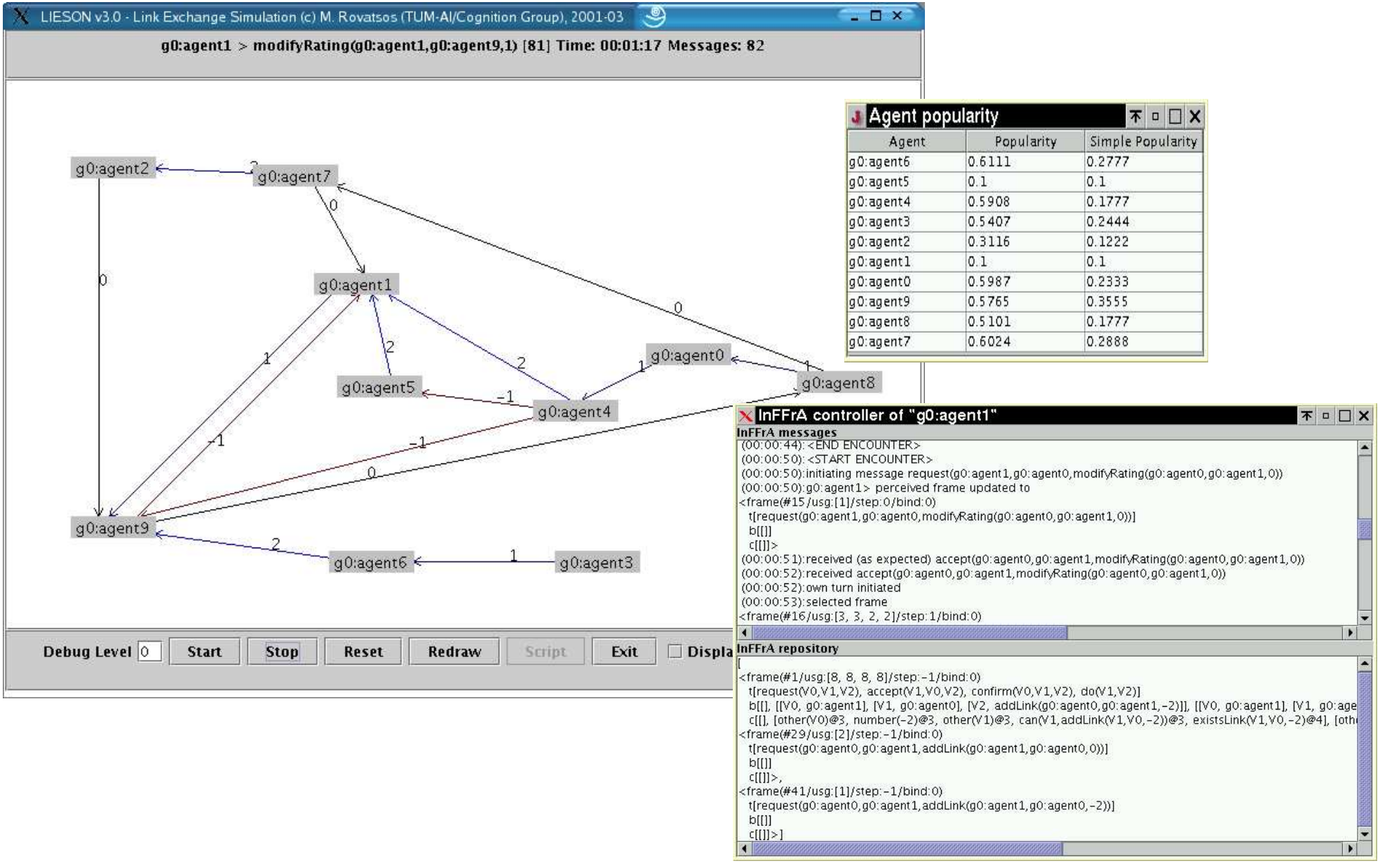
AdHoc



Applications – LIESON

- LInk Exchange SimulatiON System
- objective: increase linkage transparency on the WWW using automated link exchange
- includes implementation of BDI-like agents with m^2inffra engine
  - self-interested agents
  - maximise dissemination of own opinion
  - (highly) boundedly rational
- todo: agents that intelligently negotiate over linkage
- todo: study of macro-level effects

Applications – LIESON



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Outlook

- global impact of local expectation structures
- emergence of globally valid frames?
- conflict resolution (reification of expectation structures and negotiation)
- decision-theoretic framework for second-order utility of semantics
- “related topics”
  - frames vs. ontologies
  - interaction frame calculi
  - organisational interaction frames
  - empirical approach “on top of” other semantics

Thank you for your attention!