Autonomy vs. Uncertainty:
Why agents are different and what we can do about it

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  - Anthropocentric (since anthropomorphous) design
  - Dealing with **uncertainty** in the environment
- In recent years building "intelligent agents" has become one of the main concerns of AI research

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- Replaces (vague, philosophical) notion of autonomy by a simple criterion emphasising the **observer** perspective
- Justifies distinction between agents and "ordinary" programs (encapsulation of **purpose** of software rather than its functionality)

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- In a sense, autonomy is dual to openness

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- This is true regardless of our highbrow academic theories of agents, it is happening in the real world!
- We need methods to deal with this kind of open systems
  ➡ focus of my research

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A framework for expectation-based architectures

Strategic learning of communication patterns

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The ESB Architecture

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- Concept of expectation used to bridge gap between cognitive and social system layer
- Suitable for integration with the Belief-Desire-Intention (BDI) architecture

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Semi-formal description:

> *We write* $(EXP\ a\ C\ E\ \varphi\ \rho^+\ \rho^-)$ *iff agent* a *expects* E *to hold true under condition* C*, and is going to verify this using test* φ*. If the expectation is fulfilled he will react with* ρ^+*, otherwise with* ρ^-*.*

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Example:

$$(EXP\ \underbrace{A}_{a}\ \underbrace{(DO\ A\ request(A,B,X))}_{C}\ \underbrace{(DO\ B\ X)}_{E}\ \underbrace{Done(X)}_{\varphi}\ \underbrace{nil}_{\rho^+}\ \underbrace{retract}_{\rho^-})$$

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- This makes them essential for reasoning about open systems!

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- Strategies define the "vocabulary of behaviours" that may affect expectations so that an assessment of the desirability of these behaviours can follow

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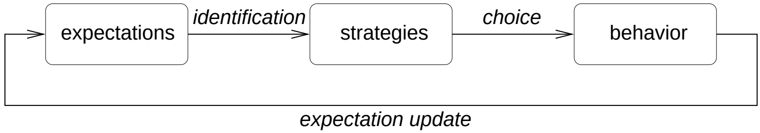
- (Hypothetical) "suspension of autonomy" of others

The ESB Feedback Loop



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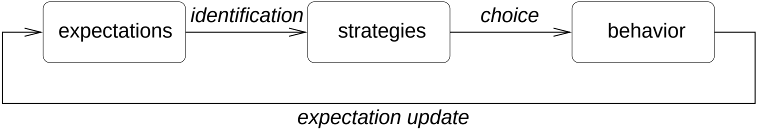

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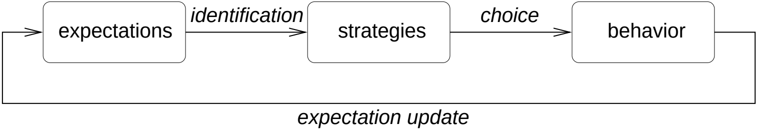

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- Agent-level (cognitive) vs. system-level (social) views (managing one's own interactions versus controlling open systems)
- A closer look reveals that this nothing but a learning loop for **interaction learning**

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  - a sequence of message patterns (speech-act like, augmented with variables)
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- Combine hierarchical reinforcement learning methods, case-based reasoning and clustering techniques to learn "framing", i.e. strategic use of frames

An example

$$
\begin{aligned}
F = \Big\langle \Big\langle & \xrightarrow{5} \mathtt{request}(A_1, A_2, X) \xrightarrow{3} \mathtt{accept}(A_2, A_1, X) \\
& \xrightarrow{2} \mathtt{confirm}(A_1, A_2, X) \xrightarrow{2} \mathtt{do}(A_2, X) \Big\rangle, \\
& \Big\langle \{ \mathit{self}(A_1), \mathit{other}(A_2), \mathit{can}(A_1, \mathtt{do}(A_1, X) \}, \\
& \ \{ \mathit{agent}(A_1), \mathit{agent}(A_2), \mathit{action}(X) \} \Big\rangle, \\
& \Big\langle \xrightarrow{4} \langle [A_1/\mathtt{agent\_1}], [A_2/\mathtt{agent\_2}] \rangle, \\
& \ \xrightarrow{1} \langle [A_1/\mathtt{agent\_3}], [A_2/\mathtt{agent\_1}], [X/\mathtt{deliver\_goods}] \rangle \Big\rangle \Big\rangle
\end{aligned}
$$

Frame semantics

- Given a conversation prefix w and a knowledge base KB, a set $\mathcal{F} = \{F_1, \ldots, F_n\}$ of frames induces a continuation probability

$$P(w'|w) = \sum_{F \in \mathcal{F}} P(w'|F, w)P(F|w) = \sum_{F \in \mathcal{F}, ww' = T(F)\vartheta} P(\vartheta|F, w)P(F|w)$$

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- Define probability of ϑ proportional to its *similarity* to F:

$$P(\vartheta|F, w) \propto \sigma(\vartheta, F) =$$

$$\sum_{i=1}^{|\Theta(F)|} \overbrace{\sigma(T(F)\vartheta, T(F)\Theta(F)[i])}^{\text{similarity}} \overbrace{h_\Theta(F)[i]}^{\text{frequency}} \overbrace{c_i(F, \vartheta, KB)}^{\text{relevance}}$$

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- Important: Architecture allows deviation from existing frames on both sides

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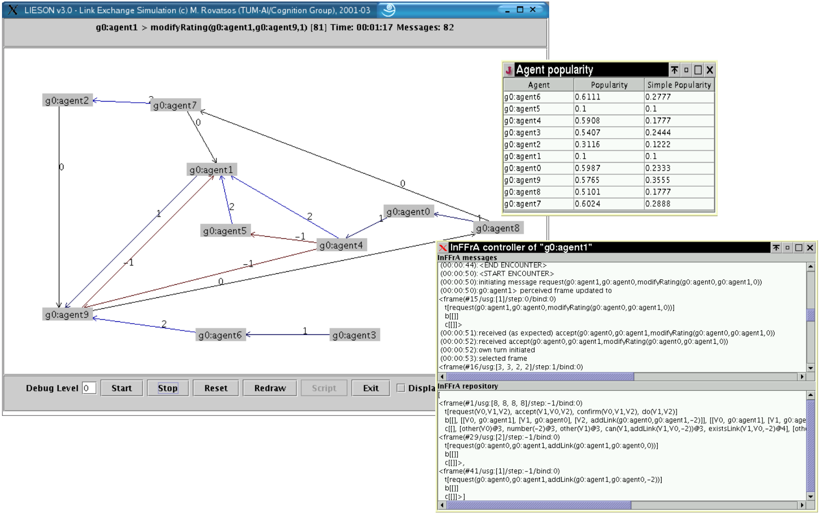
  - "Second-order" effect of own behaviour taken into account (heuristics for trading off long-term reliability of frames vs. short-term utility maximisation)
  - Incorporation of social behaviour in agents' general planning processes
- Successfully applied in complex multiagent negotiation scenarios

Application: A Link Exchange System



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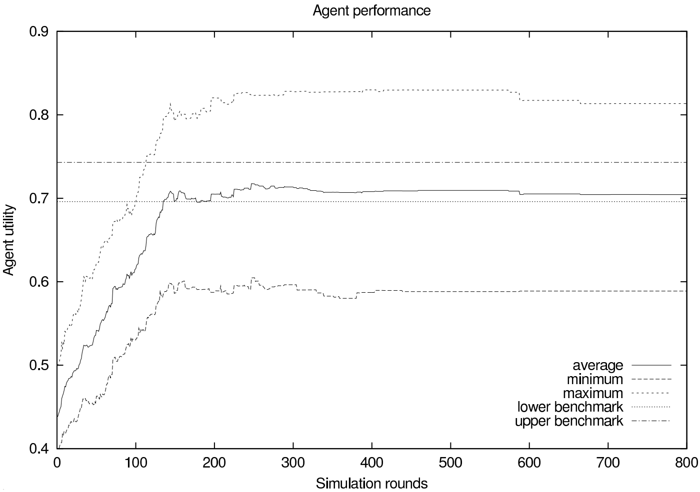
Without Frame Learning



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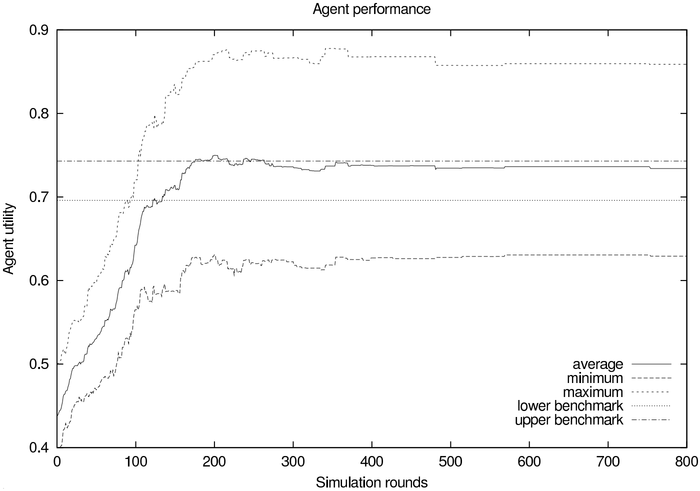

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    - Example: Mentalistic ACL semantics (e.g. in FIPA-ACL)
    - Problem: Not feasible in open systems
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  - Drop rationality assumptions in mechanism design if agents behave irrationaly

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- Apply these methods to the development of open systems in real-world applications

The End

Thank you for your attention!