Organization-Oriented Programming in Multi-Agent Systems

Andreas Schmidt Jensen

DTU Informatics

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Outline

Agent-Centered Multi-Agent Systems

- Agents are free to communicate with any other agent.

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- All of the agent's services are available to every other agent.
- The agent itself is responsible for constraining its accessibility from other agents.
- The agent should itself define its relation and contracts with other agents.
- Agents are supposed to be autonomous and no constraints are put on the way they interact.

Organization-Centered Multi-Agent Systems

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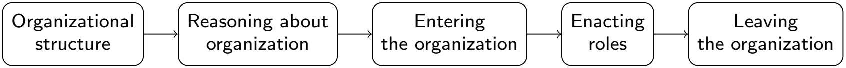

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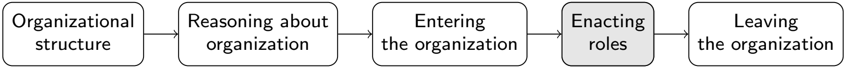
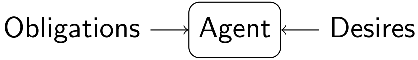


Conflicting decision influences



An agent, Alice, has a desire to stay at home, but an obligation towards her employer to go to work. What should she do? She knows that she will get fired if she violates her obligation.

Conflicting decision influences

Obligations ⟶ Agent ⟵ Desires

An agent, Alice, has a desire to stay at home, but an obligation towards her employer to go to work. What should she do? She knows that she will get fired if she violates her obligation.

Suggestion: A priori ordering.

- Desires before obligations $\rightarrow$ *Selfish agent*
- Obligations before desires $\rightarrow$ *Social agent*

Conflicting decision influences

Obligations $\longrightarrow$ Agent $\longleftarrow$ Desires

An agent, Alice, has a desire to stay at home, but an obligation towards her employer to go to work. What should she do? She knows that she will get fired if she violates her obligation.

Consider the *consequences* of bringing about a state.

- $work \rightarrow \neg fired$
- $\neg work \rightarrow fired$

If the agent prefers *not* getting fired, then clearly it should work.

A Logic for Qualitative Decision Theory

Idea: Order possible worlds according to

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Idea: Order possible worlds according to

- each agent's own preference
  - An agent prefers sunny weather.
- which worlds are most normal (or expected)
  - Normally it is not sunny when it is raining.

Extended QDT-model

$$M = \langle W, Ag, \leq_P^1, \ldots, \leq_P^n, \leq_N, \pi \rangle$$

Propositional operators: $\neg$, $\wedge$

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$\Diamond$-operators are defined as usual (i.e. $\Diamond_P^i \varphi = \neg \Box_P^i \neg \varphi$ etc).

Semantics

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$$
\begin{aligned}
M, w \models \quad & p & \iff \; & p \in \pi(w) \\
M, w \models \quad & \neg\varphi & \iff \; & M, w \not\models \varphi \\
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Abbreviations

$$I(B \mid A) \equiv \overleftrightarrow{\Box}^i_P \neg A \vee \overleftrightarrow{\Diamond}^i_P (A \wedge \Box^i_P (A \to B)) \quad \text{(Conditional preference)}$$

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$$A \leq^i_P B \equiv \overset{\leftrightarrow}{\Box}{}^i_P (B \rightarrow \Diamond^i_P A) \quad \text{(Relative preference)}$$

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$$A \Rightarrow B \equiv \overleftrightarrow{\Box}_N \neg A \vee \overleftrightarrow{\Diamond}_N (A \wedge \Box_N (A \to B)) \quad \text{(Normative conditional)}$$

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$$A \leq^i_{T(C)} B \equiv (T(A \mid C) \wedge \neg T(B \mid C)) \vee ((T(A \mid C) \leftrightarrow T(B \mid C)) \wedge (A \leq^i_P B \vee A \approx^i_P B)) \qquad \text{(Relative tolerance)}$$

Model

$$\mathcal{M}_C = \langle M, D, O, C, B \rangle,$$

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Model

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where

- M is an extended QDT-model as defined above,
- D is for each agent the set of desires,
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- C is for each agent the set of controllable propositions,
- B is the belief base for each agent.

Expected consequence

Define the the set of potential consequences $C'(i)$ for an agent i as follows:

- if $\varphi \in C(i)$ then $\varphi, \neg\varphi \in C'(i)$

The expected consequence(s) of bringing about φ is then:

$$EC_i(\varphi) = \bigwedge C_\varphi \text{ for all } C_\varphi \in \{C_\varphi \mid (B(i) \wedge \varphi \Rightarrow C_\varphi) \text{ where } C_\varphi \in C'(i)\}$$

Making a decision

The set of influences: $\mathcal{I}(i) = D(i) \cup O$

The set of best influences:

$$Dec(i) = \{A \mid \begin{array}{l} A \in \mathcal{I}(i), \text{ and} \\ \text{for all } B \in \mathcal{I}(i), B \neq A, \text{ either} \\ A <^i_P B, \text{ or} \\ A \approx^i_P B \text{ and } EC(A) \leq^i_{T(A \vee B)} EC(B)\} \end{array}$$

Example

$D(a) = \{\neg work\}$
$O = \{work\}$

Alice's preferences

- $I(\neg snow \mid \top)$
- $I(\neg work \mid snow)$

Expectation

- $\top \Rightarrow work$
- $snow \Rightarrow \neg work$

Example

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$$SW \downarrow S\overline{W} \downarrow \overline{SW}\ \overline{S}W$$

Expectation

- $\top \Rightarrow work$
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$$\overline{SW} \downarrow SW \downarrow S\overline{W} \downarrow \overline{S}W$$

$BB = \{\neg snow\}$

Alice's preferences

$$\begin{array}{c} SW \\ \downarrow \\ S\overline{W} \\ \downarrow \\ \overline{SW}\ \ \overline{S}W \end{array}$$

Expectation

$$\begin{array}{c} \overline{SW} \\ \downarrow \\ SW \\ \downarrow \\ S\overline{W} \\ \downarrow \\ \overline{S}W \end{array}$$

$BB = \{\neg snow\}$

Alice's preferences

SW

$\downarrow$

$S\overline{W}$

$\downarrow$

$\overline{SW}$ $\overline{S}W$

Expectation

$\overline{SW}$

$\downarrow$

SW

$\downarrow$

$S\overline{W}$

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$BB = \{\neg snow\}$

Alice's preferences

SW

↓

$S\overline{W}$

↓

$\overline{SW}$ $\overline{S}W$

Expectation

$\overline{SW}$

↓

SW

↓

$S\overline{W}$

↓

$\overline{S}W$

$$Dec(a) = \{work, \neg work\}$$

$BB = \{snow\}$

Alice's preferences

$$SW \longrightarrow S\overline{W} \longrightarrow \overline{SW}\ \ \overline{S}W$$

Expectation

$$\overline{SW} \longrightarrow SW \longrightarrow S\overline{W} \longrightarrow \overline{S}W$$

$BB = \{snow\}$

Alice's preferences

$$SW$$
$$\downarrow$$
$$S\overline{W}$$
$$\downarrow$$
$$\overline{SW} \quad \overline{S}W$$

Expectation

$$\overline{SW}$$
$$\downarrow$$
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Alice's preferences

$$sw \rightarrow s\overline{w} \rightarrow \overline{sw}\ \overline{s}w$$

Expectation

$$\overline{sw} \rightarrow sw \rightarrow s\overline{w} \rightarrow \overline{s}w$$

$$Dec(a) = \{\neg work\}$$

Example — Revised

$D(a) = \{\neg work\}$, $O = \{work\}$

Alice's preferences

- $I(\neg snow \mid \top)$
- $I(\neg work \mid snow)$
- $I(\neg fired \mid \top)$

Expectation

- $\top \Rightarrow work$
- $snow \Rightarrow \neg work$
- $\neg work \wedge \neg snow \Rightarrow fired$

Example — Revised

$D(a) = \{\neg work\},\ O = \{work\}$

Alice's preferences

- $I(\neg snow \mid \top)$
- $I(\neg work \mid snow)$
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Expectation

- $\top \Rightarrow work$
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Alice's preferences

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\downarrow \\
\overline{F}SW \\
\downarrow \\
\overline{F}S\overline{W} \\
\downarrow \\
\overline{FSW} \;\; \overline{FS}W
\end{array}
$$

Expectation

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\overline{FSW} \;\; FSW \;\; F\overline{S}W \;\; FS\overline{W} \\
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$BB = \{\neg snow\}$

Alice's preferences

$FSW \quad F\overline{SW} \quad FS\overline{W} \quad F\overline{S}W$

$\downarrow$

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$\downarrow$

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$\downarrow$

$\overline{FSW} \quad \overline{FS}W$

Expectation

$\overline{FSW} \quad FSW \quad F\overline{S}W \quad FS\overline{W}$

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$BB = \{\neg snow\}$

Alice's preferences

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$$Dec(a) = \{work\}$$

“Social” or “Selfish”?

- In some cases the agent violates its obligation.

"Social" or "Selfish"?

- In some cases the agent violates its obligation.
- In other cases it ignores its desire.

“Social” or “Selfish”?

- In some cases the agent violates its obligation.
- In other cases it ignores its desire.
- E.g. leaving early does not have the consequence of getting fired.

A prototype in Prolog

```
?- decide([~s], Dec).
Dec = [w].

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Usable in the GOAL agent programming language.

```
main module {
  knowledge {
    #import "decision.pl"
  }
  ...
}
```

Conclusion

- Issues in agent-centered multi-agent systems

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- Organizations to the rescue

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- Prototype

Questions?