Delegation as a communicative act: a logical analysis

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Delegation in MAS

In the context of agents' organization:

- Agent *i* might decide to exploit other agents in order to achieve his goal
- *i* delegates some elements in his multi-agent plan to agent *j* in the organization.

  → *j*'s tasks may be changed

  → *j*'s role will change on behalf of *i*

  → *j*'s obligation will also change

→ the organization's structure becomes dynamic!

Plan

Delegation as a request: a scenario

Agent *i*'s car is damaged and he decides to delegate to a mechanic the task of repairing the car. So:

- *i* relies on the mechanic's action of repairing the car
- *i*'s intention to ask the mechanic to repair the car and
- *i*'s intention to communicate the mechanic that he is granting him the permission to repair the car (on his behalf)
- *i*'s in the position to grant a permission to the mechanic to repair his car
- *i* also creates the permission for the mechanic to repair the car.

Delegation as a request

Agent *i* delegates agent *j* to do action α to brings about φ

(A) *i* intends that *j* will perform α so that φ will be achieved

(B) *i* thinks it is possible that *j* will perform α

(C) *i* intends to comunicate to *j* that *i*'s relying on *j*'s execution of α

(D) *i* intends to communicate to *j* that *j* has the permission to perform α

(E) *i* has the power and the authority to grant to *j* the permission to perform α

(F) It is forbidden for *j* to perform α.

Delegation as an order: a scenario

- agent *i* is the president of a company which must be represented at a journalist meeting
- agent *i* delegates to agent *j*, an employee of the company, the task of participating to this meeting

→ The employee *j* does have any refusal option!

Delegation as an order

Agent *i* delegates agent *j* to do action α to brings about φ

(A) *i* intends that *j* will perform α so that φ will be achieved

(B) *i* thinks it is possible that *j* will perform α

(C) *i* intends to comunicate to *j* that *i*'s relying on *j*'s execution of α

(D́) *i* intends to communicate to *j* that *j*'s obliged to perform α

(É) *i* has the power and the authority to oblige *j* to perform α

(F́) *j*'s not obliged to perform α but *j* has the obligation after having completed the delegation act.

Plan

1. Introduction
   - Motivation
   - Delegation: informal view
2. Formalisation of delegation act
   - Logic for delegation
   - Formalization of delegation
3. Conclusion

Syntax

Language:

$$\varphi ::= p \mid \neg\varphi \mid \varphi \vee \varphi \mid \texttt{Do}_{i:\alpha}\varphi \mid \texttt{After}_{i:\alpha}\varphi \mid \texttt{Bel}_i\varphi \mid \texttt{Choice}_i\varphi \mid \texttt{Oblig}\ \varphi$$

where p ranges over ATM, α ranges over ACT and i ranges over AGT.

$\texttt{After}_{i:\alpha}\varphi$: 'after agent i does α, it is the case that φ'
$\texttt{Do}_{i:\alpha}\varphi$: 'agent i is going to do α and φ will be true afterwards'
$\texttt{Bel}_i\varphi$: 'agent i believes that φ'
$\texttt{Choice}_i\varphi$: 'agent i has the chosen goal that φ'
$\texttt{Oblig}\ \varphi$: 'φ is obligatory'.

Syntax

Abbreviations:

$$\mathtt{Poss}_i\varphi \stackrel{\text{def}}{=} \neg\mathtt{Bel}_i\neg\varphi$$

$$\mathtt{Capable}_i(\alpha) \stackrel{\text{def}}{=} \neg\mathtt{After}_{i:\alpha}\bot$$

$$\mathtt{Int}(i, \varphi, \alpha) \stackrel{\text{def}}{=} \mathtt{Choice}_i\mathtt{Do}_{i:\alpha}\varphi$$

$$\mathtt{Power}_i(\varphi, \alpha) \stackrel{\text{def}}{=} \mathtt{Capable}_i(\alpha) \wedge \mathtt{After}_{i:\alpha}\varphi$$

$$\mathtt{Oblig}_i(\alpha) \stackrel{\text{def}}{=} \mathtt{Oblig}\ \mathtt{Do}_{i:\alpha}\top$$

$$\mathtt{Forbid}_i(\alpha) \stackrel{\text{def}}{=} \mathtt{Oblig}\ \neg\mathtt{Do}_{i:\alpha}\top$$

$$\mathtt{Perm}_i(\alpha) \stackrel{\text{def}}{=} \neg\mathtt{Oblig}\ \neg\mathtt{Do}_{i:\alpha}\top$$

Semantics: Frame

Frame $F = \langle W, B, C, O, A, D \rangle$:

- W is a nonempty set of possible worlds or states.
- $B : AGT \longrightarrow W \times W$ maps every agent i to a serial, transitive and Euclidean relation B_i between possible worlds in W.
- $C : AGT \longrightarrow W \times W$ maps every agent i to a serial relation C_i between possible worlds in W.
- O is a serial relation between possible worlds in W.
- $A : AGT \times ACT \longrightarrow W \times W$ maps every agent i and action α to a relation $A_{i:\alpha}$ between possible worlds in W.
- $D : AGT \times ACT \longrightarrow W \times W$ maps every agent i and action α to a deterministic relation $D_{i:\alpha}$ between possible worlds in W.

Semantics: Truth conditions

- $M, w \models \texttt{After}_{i:\alpha}\varphi$ iff $M, w' \models \varphi$ for all w' such that $(w, w') \in A_{i:\alpha}$.
- $M, w \models \texttt{Do}_{i:\alpha}\varphi$ iff there is $w' \in D_{i:\alpha}(w)$ such that $M, w' \models \varphi$.
- $M, w \models \texttt{Bel}_i\varphi$ iff $M, w' \models \varphi$ for all w' such that $(w, w') \in B_i$.
- $M, w \models \texttt{Choice}_i\varphi$ iff $M, w' \models \varphi$ for all w' such that $(w, w') \in C_i$.
- $M, w \models \texttt{Oblig}\ \varphi$ iff $M, w' \models \varphi$ for all w' such that $(w, w') \in O$.

Axiomatization

All principles of modal logic KD45 for every $\mathtt{Bel}_i$

All principles of modal logic KD for every $\mathtt{Choice}_i$ and $\mathtt{Oblig}$

All principles of modal logic K for every $\mathtt{After}_{i:\alpha}$ and $\mathtt{Do}_{i:\alpha}$

$$\mathtt{Do}_{i:\alpha}\varphi \rightarrow \neg \mathtt{Do}_{j:\beta}\neg\varphi$$

$$\bigvee_{i \in AGT, \alpha \in ACT} \mathtt{Do}_{i:\alpha}\top$$

$$\mathtt{Do}_{i:\alpha}\varphi \rightarrow \neg \mathtt{After}_{i:\alpha}\neg\varphi$$

$$(\mathtt{Choice}_i\mathtt{Do}_{i:\alpha}\top \wedge \mathtt{Capable}_i(\alpha)) \rightarrow \mathtt{Do}_{i:\alpha}\top$$

$$\mathtt{Do}_{i:\alpha}\top \rightarrow \mathtt{Choice}_i\mathtt{Do}_{i:\alpha}\top$$

$$\mathtt{Bel}_i\varphi \rightarrow \neg \mathtt{Choice}_i\neg\varphi$$

$$\mathtt{Choice}_i\varphi \rightarrow \mathtt{Bel}_i\mathtt{Choice}_i\varphi$$

$$\neg\mathtt{Choice}_i\varphi \rightarrow \mathtt{Bel}_i\neg\mathtt{Choice}_i\varphi$$

Plan

Communicative intention & Rely

Communicative intention

$$\mathtt{CommInt}(i, j, \varphi, \alpha) \overset{\text{def}}{=} \mathtt{Int}(i, \mathtt{Bel}_j \mathtt{Choice}_i \mathtt{Bel}_j \varphi, \alpha)$$

Rely

$$\mathtt{Rely}(i, j, \alpha) \overset{\text{def}}{=} \mathtt{Choice}_i \mathtt{X}\ \mathtt{Do}_{j:\alpha} \top$$

Formalization of delegation as a request

$$\begin{aligned}\texttt{ReqDel}(i,j,\alpha,\beta) \stackrel{\text{def}}{=} \; & \texttt{Do}_{i:\beta}\top \wedge \texttt{Rely}(i,j,\alpha) \\ & \wedge \texttt{CommInt}(i,j,\texttt{Rely}(i,j,\alpha) \wedge \texttt{Perm}_j(\alpha),\beta) \\ & \wedge \texttt{Power}_i(\texttt{Perm}_j(\alpha),\beta) \wedge \texttt{Forbid}_j(\alpha)\end{aligned}$$

Formalization of delegation as an order

$$\begin{aligned}\mathtt{OrdDel}(i, j, \alpha, \beta) \stackrel{\text{def}}{=}\ & \mathtt{Do}_{i:\beta}\top \wedge \mathtt{Rely}(i, j, \alpha) \\ & \wedge \mathtt{CommInt}(i, j, \mathtt{Rely}(i, j, \alpha) \wedge \mathtt{Oblig}_j(\alpha), \beta) \\ & \wedge \mathtt{Power}_i(\mathtt{Oblig}_j(\alpha), \beta) \wedge \neg \mathtt{Oblig}_j(\alpha)\end{aligned}$$

Sumary

- A logic for delegation act
- Delegation as a request
- Delegation as an order

Thanks for your attention!

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