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Channels for Agent Communication

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Institutions for Agent Communication

 Formalizing Institutions Channel Theory Institutions in Channel Theory

Agent Communication Languages

- Multiagent systems as a "technological extension of human society" ([2])
- Many aspects of agent societies and interaction modeled after the "real" world
 - Epistemic logic, belief revision, ...
- ► Protocols (ACLs) for agent interaction
 - Theory of Speech acts (Austin, Searle)

ACLs and Speech Acts

ACL semantics usually defined in terms of agents' **mental attitudes** (beliefs, intentions, desires, . . .)

Example: FIPA definition of the *inform* speech act:

$$< i, inform(j, \phi) >$$

[**FP**] $B_i \phi \land \neg B_i (B_j \phi \lor B_j \neg \phi)$
[**RE**] $B_j \phi$

Mentalistic Semantics of Speech Acts

Problems with this approach (Singh, Colombetti et al.)

- Long-standing problems with the formalization of intensional concepts like belief
- Tension between **public** nature of communication and **private** nature of agent beliefs
 - FP and RE should be verifiable and transparent
 - Belief updates do not capture the *social* updates triggered by speech acts
- Speech acts as moves in a **dialogue game**

Social Semantics for Speech Acts

But: social semantics for actions is substantially different!

► Requires *collective intensionality*

Given in terms of normative and constitutive rules

- Normative rules
 - Regulate *existing* forms of behaviour
 - E.g. "inform $(i, j, \phi) \rightarrow \mathcal{O}_i(\text{defend}(i, j, \phi))$ "
- Constitutive rules
 - Establish *new* social realities
 - Often classificatory in nature: "assert $(i, j, \phi) \rightarrow inform(i, j, \phi)$ "

Social Semantics for Speech Acts

Institutions

- ► [...] "institutions" are systems of constitutive rules. Every institutional fact is underlain by a (system of) rule(s) of the form "X counts as Y in context C". (J. Searle, [3]:)
- Constitutive rules as "count-as" conditionals:

$$X \Rightarrow_c Y$$

Virtual institutions in normative MAS

Institutions

Logical Properties

Multiple levels of **context dependence** in a statement " $X \Rightarrow_c Y''$

- ► *X* stems from an ontology of so-called "brute facts"
- ► *Y* denotes some "social" aspect of reality
- ► *C* lives in the realm of "institutions"

Institutions for Agent Communication

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Preliminaries: Channel Theory

- ► *Qualitative* information theory
- ► Born out of situation semantics in 1990's
- Information Flow: The Logic of Distributed Systems (Barwise and Seligman, [1])

Classifications

A classification $C = \langle S, \Sigma, \models \rangle$ consists of

- ► A non-empty set *S* of situations (events, actions,...)
- ► A non-empty set ∑ of situation *types* (attributes, properties, ...),
- A classification relation $\models \subseteq S \times \Sigma$, such that $s \models \sigma$ when *s* is of type σ .

A classification C is **boolean** when Σ is closed under boolean connectives, and \models is classical satisfaction inductively defined on the structure of formulae $\phi \in \Sigma$

Classifications Support Information

A sequent $\langle \Gamma, \Delta \rangle$ is a pair of sets $\Gamma, \Delta \subseteq \Sigma$

- $\Gamma \models_s \Delta$ iff, when $s \models \gamma$ for all $\gamma \in \Gamma$, then $s \models \delta$ for some $\delta \in \Delta$
- *Theorem*: For situations S' ⊆ S, the theory of S' given by {⟨Γ, Δ⟩ | Γ ⊨_{S'} Δ} is regular, meaning it satisfies:

Identity: $\sigma \models \sigma$ $(\sigma \in \Sigma)$ Weakening:if $\Gamma \models \Delta$ then $\Gamma, \Gamma' \models \Delta, \Delta'$ $(\Gamma, \Gamma', \Delta, \Delta' \subseteq \Sigma)$ Global Cut:if $\Gamma, \Sigma_0 \models \Delta, \Sigma_1$ for all partitions
 $\langle \Sigma_0, \Sigma_1 \rangle$ of Σ' , then $\Gamma \models \Delta$ $(\Gamma, \Delta, \Sigma' \subseteq \Sigma)$

Information Contexts

A **local logic** *L* is a tuple $\langle C, \vdash, N \rangle$ where

- ► *C* is a classification,
- ► $\vdash \subseteq \mathcal{P}ow(\Sigma_{\mathcal{C}}) \times \mathcal{P}ow(\Sigma_{\mathcal{C}})$ is a regular consequence relation on the types of \mathcal{C} , and
- ▶ $N \subseteq S$ are called "normal situations", i.e. situations the theory \vdash is "about". Thus, $\Gamma \models_N \Delta$ when $\Gamma \vdash \Delta$

L is **sound** when $N = S_A$

L is (locally) **complete** iff $\Gamma \vdash \Delta$ whenever $\Gamma \models_N \Delta$ (*globally* when $N = S_A$)

Information Contexts

Properties

Given two contexts $L_1 = \langle \mathcal{C}, \vdash_1, N_1 \rangle$ and $L_2 = \langle \mathcal{C}, \vdash_2, N_2 \rangle$

- $L_1 \sqsubseteq L_2$ iff $\vdash_1 \subseteq \vdash_2$ and $N_1 \supseteq N_2$
- ⟨CXT(C), ⊑⟩ forms a complete lattice of local logics, with meet and join operations

$$a. \ L_1 \sqcap L_2 =_{def} \langle \mathcal{C}, \ Reg(\vdash_1 \cap \vdash_2), \ N_1 \cup N_2 \rangle$$
$$b. \ L_1 \sqcup L_2 =_{def} \langle \mathcal{C}, \ Reg(\vdash_1 \cup \vdash_2), \ N_1 \cap N_2 \rangle$$

Formalizing Institutions

$\underset{\left\langle \mathsf{CXT}(\mathcal{C}),\sqsubseteq\right\rangle }{\text{Logics on }\mathcal{C}}$



Information Flow between Classifications

Given classifications *A* and *B*, an **infomorphism** $f : A \rightleftharpoons B$ from *A* to *B* is a pair of contravariant functions $\langle f^{\wedge}, f^{\vee} \rangle$ such that:

$$\forall s \in S_B, \ \sigma \in \Sigma_A : f^{\vee}(s) \models_A \sigma \ \text{iff} \ s \models_B f^{\wedge}(\sigma)$$



Moving Logics over Infomorphisms

Given an infomorphism $f : A \rightleftharpoons B$, and local logics $L_A = \langle A, \vdash_A, N_A \rangle$ and $L_B = \langle B, \vdash_B, N_B \rangle$:

►
$$f[L_A] = \langle B, \vdash'_A, N'_A \rangle$$
, where
 $a. \vdash'_A = \{\langle f^{\wedge}(\Gamma), f^{\wedge}(\Delta) \rangle \mid \Gamma \vdash_A \Delta \}$
 $b. N'_A = \{s \in S_B \mid f^{\vee}(s) \in N_A\}$
► $f^{-1}[L_B] = \langle A, \vdash'_B, N'_B \rangle$, where
 $a. \vdash'_B = \{\langle \Gamma, \Delta \rangle \mid f^{\wedge}(\Gamma) \vdash_B f^{\wedge}(\Delta) \}$
 $b. N'_B = \{f^{\vee}(s) \in S_A \mid s \in N_B\}$

Moving Logics over Infomorphisms



Reasoning Across Contexts

$$\frac{\Gamma \vdash_A \Delta}{f^{\wedge}(\Gamma) \vdash_B f^{\wedge}(\Delta)} f\text{-Intro} \qquad \frac{f^{\wedge}(\Gamma) \vdash_B f^{\wedge}(\Delta)}{\Gamma \vdash_A \Delta} f\text{-Elim}$$

- ► *f*-Intro: reasoning in the direction of *f*
 - Sound
 - Complete when f^{\vee} is surjective $(S_A = f^{\vee}(S_B))$
- ► *f*-Elim: reasoning against the direction of *f*
 - Sound when f^{\vee} is surjective
 - Complete

Institutions for Agent Communication

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First Approximation

A given event or situation *s* supports an institutional fact *Y* in a context *C* when:

- i. *s* has a physical property *X*, such that
- ii. X is a proxy for Y by virtue of some institution *I*, where
- iii. "X counts as Y in context C" is a constitutive rule of I.

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Example: Classifying "Physical" Reality

A boolean classification $C_P = \langle S_p, \Sigma_P, \models_P \rangle$ of physical reality (i.e. *brute facts*), where

- ► *S*_{*P*} is a non-empty set of "real-world" situations
- ► Σ_P is (at least) a propositional language built from types {raiseHand(x), scratchHead(y),...}
- For $s \in S_P$, $\sigma \in \Sigma_P$, $s \models \sigma$ when σ is true in s
- ► E.g. $s \models_P \text{scratchHead}(x) \lor \neg \text{scratchHead}(x)$

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Classifying "Social" Reality

Another classification $C_S = \langle S_S, \Sigma_S, \models_S \rangle$ modeling the *social* dimension, where

- ► *S*_S is a non-empty set of social situations
- ► Σ_S is a propositional (deontic?) language built from types {makeBid(x), purchase(x,y), ...}
- e.g. $s \models_S makeBid(x) \land purchase(x,y)$
- ► CXT(C_S) is the realm of normative rules makeBid(x,y) ⊢_{AUC} C_x(purchase(x,y))

Formalizing Institutions

A channel classification C_I connecting C_P and C_S

► Institutions as theories on C_I about how to align C_p and C_S

Formalizing Institutions

A channel classification C_I connecting C_P and C_S

► Institutions as theories on C_I about how to align C_p and C_S



Alignment Semantics

 $\mathcal{C}_I = \langle S_I, \Sigma_I, \models_I \rangle$ as the **sum classification** $\mathcal{C}_P + \mathcal{C}_S$

- A set of connection tokens $S_I = S_P \times S_S$
- Disjoint union $\Sigma_I = \Sigma_P \cup \Sigma_S$
- For $\langle s_0, s_1 \rangle \in S_I$:

 $\langle s_0, s_1 \rangle \models_I \sigma_P \text{ iff } s_0 \models_P \sigma$ $\langle s_0, s_1 \rangle \models_I \sigma_S \text{ iff } s_1 \models_S \sigma$

... with straightforward infomorphisms *f* and *g*, e.g.

$$f^{\wedge}(\sigma) = \sigma_P$$

$$f^{\vee}(\langle s_0, s_1 \rangle) = s_0$$

Institutions as Local Logics on C_I

Count-as conditionals defined in terms of constraints:

$$X \Rightarrow_C Y$$
 iff $f^{\wedge}(X) \vdash_{L_C} g^{\wedge}(Y)$

• raiseHand(x) \Rightarrow_{Auc} makeBid(x) iff

 $f^{\wedge}(\mathsf{raiseHand}(\mathsf{x})) \vdash_{\mathit{L_{Auc}}} g^{\wedge}(\mathsf{makeBid}(\mathsf{x}))$

• raiseHand(x)
$$\Rightarrow_{Vot}$$
 vote(x) iff

$$f^{\wedge}(\mathsf{raiseHand}(\mathsf{x})) \vdash_{L_{Vot}} g^{\wedge}(\mathsf{vote}(\mathsf{x}))$$

Logical Properties of the Count-as Relation Generally accepted desirables:

- ► Left / right logical equivalence
 - $(A \Rightarrow_{c} B) \land (A \equiv A') \vdash A' \Rightarrow_{c} B \not \ (A \Rightarrow_{c} B) \land (B \equiv B') \vdash A \Rightarrow_{c} B'$
- ► Left disjunction $(A \Rightarrow_c B) \land (A' \Rightarrow_c B) \vdash A \lor A' \Rightarrow_c B$
- Right conjunction $(A \Rightarrow_c B) \land (A \Rightarrow_c B') \vdash A \Rightarrow_c B \land B'$

Non-desirables:

- ► Left and right logical consequence $A \Rightarrow_c B \land A \supset A' \nvDash A' \Rightarrow_c B / A \Rightarrow_c B \land B \supset B' \nvDash A \Rightarrow_c B'$
- ► Left strengthening and right weakening $A \Rightarrow_c B \nvDash (A \land A') \Rightarrow_c (B \lor B')$

Count-as Conditionals

Nonmonotonicity

Problems with Weakening

 $raiseHand(x) \Rightarrow_{Auc} makeBid(x)$ $raiseHand(x), scratchHead(x) \neq_{Auc} makeBid(x)$

Thank You

J. Barwise and J. Seligman.

Information Flow. The Logic of Distributed Systems. Cambridge Tracts in Theoretical Computer Science, Cambridge University Press, 1997.

N. Fornara, F. Viganò, and M. Colombetti.

Agent communication and institutional reality.

In International Workshop on Agent Communication AC2004, pages 1–17, 2004.

J. R. Searle.

Speech Acts: An Essay in the Philosophy of Language. Cambridge University Press, Cambridge, 1969.