

# Laboratory for Applied Ontology

## Formal Ontologies for Communicating Agents

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# Outline

## Approaches of Communication

- Mental Primitives
- Intention Recognition
- Social Primitives
- Dialogue Games and Protocols

## Current Relevant research

- Comprehensive theories of NL
- Meta-modeling

## The Missing Ontological Link

- Form and Content of Communication
- Semantic Coordination
- DOLCE

## Toward an ontology of linguistic communication

# Objectives of FOCA

- ▶ **Formal ontology of communication:**
  - ▶ Advances in the formal study of communication in various directions
  - ▶ Integration requires a deep ontological study aimed at better understanding the nature of relations among the approaches
  - ▶ Semantic Web interoperability increases interest in standard meta-models
- ▶ **Formal ontology and semantic coordination:**
  - ▶ Autonomous entities with heterogeneous knowledge structures (ontologies)
  - ▶ Ontology alignment, merging, mapping



# What is communication

[Lyons, 1977]: Restriction of communication: “intentional transmission of information by means of some established signaling-system”

Two perspectives on communication:

- ▶ **Sender side: communicative intention (communicative signal)**
- ▶ **Receiver side: informative (tells something new to the receiver independently from sender intentions)**

# Speech Acts(I)

- ▶ **Austin [Austin, 1962] analysis of performatives**
  - ▶ Uttering is always performing actions
  - ▶ Felicity conditions vs. truth conditions
  - ▶ Locutionary / illocutionary / perlocutionary acts
  - ▶ Distinction based on the effects: illocutions need to be taken up, while perlocutions are natural causes
- ▶ **Searle [Searle, 1969] developments**
  - ▶ Literal force hypothesis [Levinson, 1983]
  - ▶ Speech acts semantics in terms of speaker's and hearer's intentions
  - ▶ Formalized with Vanderveken [Searle and Vanderveken, 1975] (illocutionary logic)



## Speech Acts (II)

- ▶ Contextual approaches

[Gazdar, 1981, Lewis, 1979, Levinson, 1983]

- ▶ Illocutionary force is essentially pragmatic
- ▶ Speech acts effects are updates on the context
- ▶ Move the problem to the nature of context: mental, social, discursive?
- ▶ Dynamic semantics for discourse and dialogue (Kamp, Ginzburg)
- ▶ Common ground (general vs. conversational)  
[Clark and Schaefer, 1989, Clark, 1996]



# Mental Primitives

- ▶ **Bratman: the nature of intentions [Bratman, 1987]**
  - ▶ Irreducibility of intentions
  - ▶ Resource bounded agents have to internally commit at some point
- ▶ **Cohen and Levesque**  
**[Cohen and Levesque, 1990, Rao and Georgeff, 1991]**
  - ▶ Rational Agency
  - ▶ Persistent goal as intention (Cohen and Levesque)
  - ▶ Using modal operators (BDI)



# Intention Recognition

- ▶ **Grice's contribution [Grice, 1975]**
  - ▶ Non-natural meaning (passing by intention recognition)
  - ▶ Intention recognition principle: A intends its communicative intention to be achieved simply by B recognizing this very intention
  - ▶ Necessity of a (fixed) conventional meaning
- ▶ **Practical applications**
  - ▶ Plan recognition techniques for discourse and dialogue
  - ▶ Intentional structure [Grosz and Sidner, 1986, Asher, 1993]



# Social Primitives

- ▶ Issues with mental primitives, Hamblin [Hamblin, 1970, Hamblin, 1987]:
  - ▶ Beliefs = idealized indicative commitments
  - ▶ Intentions = idealized imperative commitments
  - ▶ In certain (argumentative) contexts, mental attitudes are not relevant, public commitment counts
- ▶ Applied by Singh [Singh, 2000], Colombetti [Colombetti, 2000]
  - ▶ Agents Communication Languages with social semantics
  - ▶ Complex issue: propositional vs. action commitment [Walton and Krabbe, 1995]
- ▶ Use Searle [Searle, 1995] “count-as” relation
- ▶ Take the social context into account [Colombetti et al., 2002]



# Dialogue Games

- ▶ Grounded in contextual (pragmatic) approaches
- ▶ Often participants do not perform the complex intention recognition process
- ▶ Conversation and Discourse Analysis (informal):
  - ▶ Preferred continuations (e.g Adjacency pairs, openings, closings) [Schegloff and Sacks, 1973]
  - ▶ A step further: Conventional macro-structure of moves
- ▶ Dialogue game = topic + sequence of preferred moves
- ▶ ≠ Lewis' signaling games and Game Theory (Anton Benz)



# Conversation Protocols

- ▶ Artificial communication tradition
- ▶ Fixed set of rules for managing communication
- ▶ Protocols as shortcuts for a set of rational mechanisms (intention recognition) [Kumar et al., 2002]



# Comprehensive theories of NL

SDRT [Asher, 1993, Asher and Lascarides, 2003]

- ▶ **Modular theory combining**
  - ▶ Dynamic semantics (DRT or DPL)
  - ▶ Discourse Structure (Discourse relations)
  - ▶ Weakened theory of rational agency (capturing Grice's principles)
  - ▶ Dynamic theory of the lexicon
  - ▶ World knowledge



# Meta-modeling and ACL

- ▶ Background: developing communication languages for artificial agents
- ▶ ACL, 1st generation : SA semantics expressed in terms of mental primitives
- ▶ ACL, 2nd generation : Social semantics, commitment
- ▶ How to ensure interoperability?
- ▶ ACL meta-models for interoperability (Bermudez et. al, Cordi and Mascardi)
- ▶ Different systems can reach a certain degree of interoperability while keeping some of their particular properties
- ▶ Specific vs. foundational systems



# Meta-modeling and linguistics

- ▶ Linguistic resources interoperability
- ▶ Different theoretical approaches
- ▶ Different levels addressed (lexicon including morphology, syntax, semantics,...)
- ▶ Different languages (multi-linguality challenge)
- ▶ Toward International standards (ISO TC37-4)
- ▶ Ontology of linguistic objects



# The structure: the problem of integrating different theories

Formal approaches on communication contain ontological ingredients such as

events, states, actions, speech acts, coherence relations, mental states, plans, propositions, arguments, facts, commitments, conventions, . . .

Nevertheless, these ingredients are either taken for granted, left unspecified or only partially addressed, thus general ontological considerations on these specific aspects are needed



# The connection between form and content of the communication

## Some methodologies

- ▶ to develop specific ontologies for language or communication (cf. GOLD (General Ontology for Linguistic Description) [Farrar and Langendoen, 2003], MMDO (Multi-Modal Discourse Ontology) [Niekrasz and Purver, 2006], ...)
- ▶ to integrate notions specific to interaction/communication within top level ontologies (cf. DOLCE, Cyc, BFO, ...)
- ▶ to compare different ontologies and their possible mappings



## Semantic Coordination (I)

If we take an ontology as the knowledge architecture inherent to an agent, in order to establish a communication between different agents, each single ontology must coordinate with:

- ▶ a shared pre-existing ontology, or
- ▶ different ontologies of the other agents, but all linked to a common upper ontology, or
- ▶ different ontologies of the other agents, directly mapped onto each other



## Semantic Coordination (II)

Semantic coordination can happen according different modalities, depending on the agents' capabilities of dynamically evolving:

- ▶ agents simultaneously keep a static ontology while managing a dynamic one
- ▶ agents recreate their static ontologies before every negotiation phase
- ▶ agents dynamically modify their ontologies during the interaction, working on a sort of provisional meaning shaped by the negotiation itself



## A proposal: DOLCE (I)

DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering), like other foundational ontologies, has the aim of characterizing the intended meaning of terms through different communities, in order to make agents capable of communicating and sharing information about their common environment

- ▶ the methodology
- ▶ modularity
- ▶ WonderWeb: a library of ontologies



## A proposal: DOLCE (II)

Modules of DOLCE that are being developed (work in progress) or need to be developed:

- ▶ ontology of mental states [Ferrario and Oltramari, 2004]
- ▶ ontology of action [Troquard et al., 2006]
- ▶ ontology of interaction and communication [Borgo et al., 2006]
- ▶ ontology of social reality [Bottazzi and Ferrario, 2006]



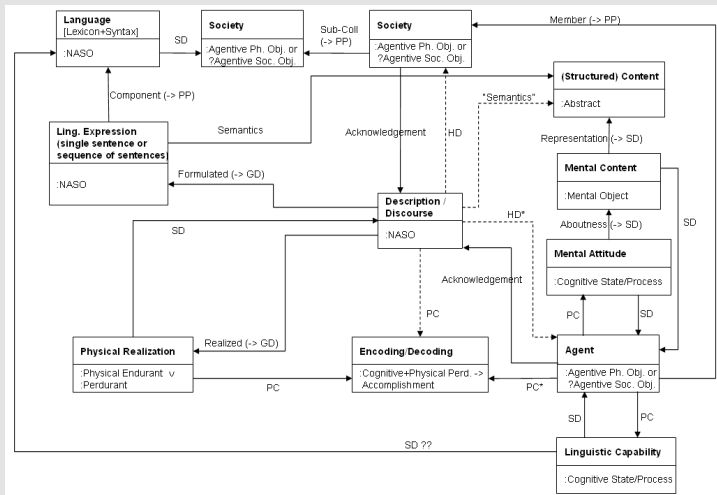
# Connections between the different modules

Links need to be established between different modules:

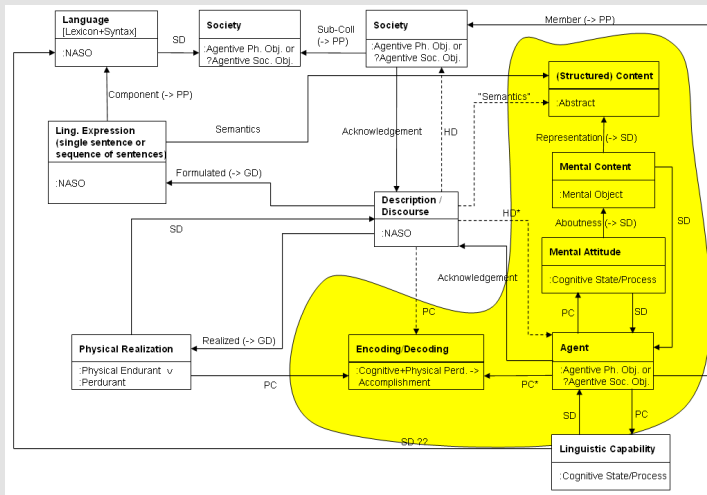
- ▶ mental states and actions
- ▶ mental states and interaction
- ▶ mental states and communication
- ▶ mental states and sociality
- ▶ action and interaction
- ▶ action and communication
- ▶ action and social reality
- ▶ interaction and society
- ▶ communication and social entities
- ▶ ...



# Toward an ontology of linguistic communication

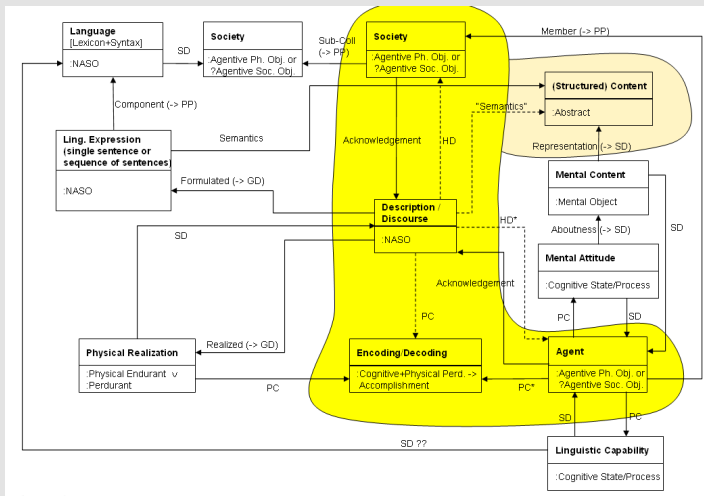


# Toward an ontology of linguistic communication





# Toward an ontology of linguistic communication



## Some relations of `do1ce`

### ► Dependence:

- avoids deep investigation of the causality relation
- “as far as we can go formally without too much philosophical shortcuts”

(Dd69)  $SD(x, y) \triangleq \Box(\exists t(PRE(x, t)) \wedge \forall t(PRE(x, t) \rightarrow PRE(y, t)))$  (*Specific Const. Dep.*)

(Dd70)  $SD(\phi, \psi) \triangleq DJ(\phi, \psi) \wedge \Box \forall x(\phi(x) \rightarrow \exists y(\psi(y) \wedge SD(x, y)))$  (*Specific Const. Dep.*)

(Dd71)  $GD(\phi, \psi) \triangleq DJ(\phi, \psi) \wedge \Box(\forall x(\phi(x) \rightarrow \exists t(PRE(x, t)) \wedge \forall x, t((\phi(x) \wedge At(t) \wedge PRE(x, t)) \rightarrow \exists y(\psi(y) \wedge PRE(y, t))))$  (*Generic Const. Dep.*)

(Dd72)  $D(\phi, \psi) \triangleq SD(\phi, \psi) \vee GD(\phi, \psi)$  (*Constant Dependence*)

- Participation: relate endurants ( $\sim$ objects) and perdurants ( $\sim$  processes)
- Part-or and Proper-Part: classical mereological relation



# Conclusion

- ▶ Embodied cognition and ontology of interaction (González)
- ▶ ACL meta-modeling:
  - ▶ Formal meta-model with social semantics, layered ontology (Bermúdez et al.)
  - ▶ Software-Engineering approach (Cordì and Mascardi)
- ▶ More pragmatic insights for ACL (Coleman et al.)
- ▶ Formal characterization for societies of communicating agents (Forcheri and Gentilini)
- ▶ OWL Description logic combined with (FIPA) ACL (Schiemann and Schreiber)



# Conclusion

Invited speakers:

- ▶ Formal approaches of communication based on game theory (Anton Benz)
- ▶ Ontological aspects in a modular theory of semantic/pragmatic interface (Nicholas Asher)



# Timetable

Monday 31st	
17.00-17.40	Introduction to the Workshop, Roberta Ferrario, Laurent Prévot
17.40-18.30	Invited Talk: Partial Blocking and Coordination on Meaning, Anton Benz
Tuesday 1st	
17.00-17.45	Interactive Fiat Objects, Juan C. González
17.45-18.30	A formal ontology framework for societies of communicating agents, Paola Forcheri, Paolo Gentilini
Wednesday, 2nd	
17.00-17.45	A communication acts ontology for agent interoperability, Jesús Bermúdez et. al
17.45-18.30	Meta-modeling communication and interaction inside MAS's with ontologies, Valentina Cordì, Viviana Mascardi
Thursday, 3rd	
17.00-17.45	Natural language pragmatics in ACL literature, Joe Coleman et al.
17.45 18.30	OWI-DL as a FIPA-ACL content language, Bernhard Schiemann, Ulf Schreiber
Friday, 4th	
17.00-18.10	Invited Talk, Ontological issues in SDRT, Nicholas Asher
18.10 18.30	Final discussion



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