Communicative Act Theory

Speech act theory in philosophy

- Communication is a form of action
  - Goes beyond traditional logic, which deals with assertions (true or false)
- Canonical example: when a judge declares a couple married, the judge
  - *Brings* the fact into existence
  - Does not merely report on some privately or publicly known fact
  - Assumption: the judge has suitable powers and acts autonomously
- The judge's statement is an example of a *declarative*

Performatives: 1

All communications can be expressed as declaratives

- Informatives
  - "The shipment will arrive on Wednesday" maps to
  - "I inform you that the shipment will arrive on Wednesday"
- Directives
  - "Send me these socks maps to
  - "I request that you send me these socks
- Commissives
  - "I'll pay you $5" maps to
  - "I promise that I'll pay you $5"

Performatives: 2

Related to Multiagent Systems

- Emphasizes autonomy of the sending agent (speaker)
  - May not control the real world
  - But controls when the speaker informs, requests, promises, ...
- The performative provides type information on a communication separately from its propositional content
- Consider the proposition "the door is open"
  - "I inform you that" + "the door is open"
  - "I request you that" + "the door is (be) open"
  - "I promise you that" + "the door is (will be) open"
- That is, we see a modular structure separating types from the content

Agent Communication Primitives

- Customary to consider a small set of primitives based on the performative types (with small variations)
  - FIPA ACL, KQML, ...
  - Give a unique meaning for the types (sometimes only informally)
- The above approach proves problematic
  - MAS applications are diverse
  - The standard, broad-brush meaning is rarely adequate
  - Developers build in additional layers of meaning but leave it undocumented
- Therefore, dispense with a fixed set of primitives
  - Define application-specific primitives
  - Provide suitable meaning based on social state primitives such as commitments

AI Approaches for Modeling Communication

Based on human languages and tools for assisting humans

- Assume cooperative settings
  - Seek to infer what the user wants
  - Assume the user wants to be helped
- Give prominence to mental or cognitive concepts
  - Model the user's cognitive state
  - Project a cognitive state to the user

Distributed Knowledge-Based Systems

- Expert systems that communicate with each other
- Leading to agents comprising a reasoner and a knowledge base
- Largely homogeneous, although potentially with different reasoning rules and knowledge
- Cooperative: Hence, not quite autonomous

KQML: Knowledge Query and Manipulation Language

- Underlying assumptions
  - Each agent maintains a knowledge (belief) base or KB
  - The agents are cooperative, sincere, credulous
  - Beliefs provide an abstraction over the implementation details of agents
- The name reflects a control perspective
  - An agent cannot query the knowledge of another
  - Much less manipulate it
- Small set of primitives, each defined in relation to the agents' KBs
  - *tell*: sender takes some beliefs from its KB and tells another; receiver adopts received beliefs (inserts into its KB)
  - *query*: receiver responds with a *tell* of the query result
- Evaluation
  - KQML doesn't provide a basis for choosing among the message types
  - Most times, developers would use *tell* and encode (in an ad hoc way) the necessary information within the body of the *tell*
  - Reduced interoperability because the language semantics is inadequate and application meanings are ad hoc and hidden in implementation

FIPA Agent Communication Language (ACL)

- Provides primitives for message types along with their syntax
- States the semantics of each primitive
  - In terms of beliefs and intentions of sender and receiver
  - Including their beliefs and intentions about each other's beliefs and intentions
  - That is, incorporating assumptions of sincerity and cooperation

Evaluating Cognitive Concepts for Communication

- Cognitive concepts provide a natural way to capture the internal representation and reasoning of an agent
  - Good way to capture stakeholder wishes
  - High-level way of describing agent reasoning independent of low-level details of data structures and such
- Cognitive concepts cannot be used as a basis for interoperation, which is what communication is about
  - Internally focused
  - One designer cannot determine the beliefs or intentions of another designer's agents
    - Without making unrealistic assumptions, e.g., one designer controls all designs, thereby abolishing heterogeneity
  - One agent cannot determine another agent's beliefs or intentions
    - Without making unrealistic assumptions, e.g., abolishing autonomy and heterogeneity

FIPA Evaluated

Split personality

- Practically valuable aspects
  - Discussion of multiagent architecture and interoperation
  - Implementation of powerful tools, such as JADE
  - Description (though limited in style and scope) of useful interaction protocols
- Nonsensical aspects
  - Misguided, cognitive approach to formal semantics
  - Irrelevant assumptions
- Not widely adopted, (un)fortunately
- What we should do: discard the second and strengthen the first

AI Approaches Evaluated

- Software engineering:
  - High-level abstractions are a positive
  - Mentalism in the abstractions is a negative
- Flexibility: curtailed through the assumptions underlying the semantics
  - In FIPA, to inform another agent the sender must believe the receiver doesn't already know the content
- Compliance: impossible under mentalism

Primacy of Meaning

Understand agent communication in terms of the participants' *social state*

- Helps avoid inadvertent dependencies upon implementation and yields flexibility
- Older meaning-based work combines meanings and operational details on message ordering and occurrence
  - Operational details interfere with reasoning about meaning
- No compelling natural situation where operational details, outside of commitments, are necessary
  - Occurrence of a message: requiring an agent to send a message violates its autonomy—it may choose to violate its commitments, for example
  - Nonoccurrence of a message: where it is necessary for integrity, we should model it via commitments
  - Ordering messages for conventions: reasonable and should be encoded within the antecedents and consequents of commitments
  - Ordering messages otherwise: almost never useful and merely included just by habit
- The Blindingly Simple Protocol Language declaratively captures the necessary operational details, facilitating assertions about social state

Verifying Compliance

Each protocol functions as a small standard

- Agents must be able to judge if their counterparties are interacting as codified in their agreed upon protocol
- Worthless otherwise
- The mentalist approaches preclude such verification
- Despite long research on this point, several researchers return to mentalism repeatedly
- Challenges
  - Design specification languages that promote the verification of compliance
  - Develop algorithms by which one or more cooperating agents could verify the compliance of others based on the communications they can monitor

Summary

Communication lies at the heart of multiagent systems

- Autonomous agents depend on each other, i.e., interoperate, to realize important real-world applications
- A multiagent system must be loosely coupled
- Communication is the highly elastic glue that keeps a MAS together

Digging Deeper

Relevant topics to explore further

- Philosophical foundations
- Organizations and institutions
- Norms, conventions, and commitments
- Software engineering