Communicating Agents

Overview

Communication
exchange of information, shared system of signs, language

Agents and Communication
shared internal representation, language

Language
formal vs. natural languages

Language and Communication
syntax, grammar, parsing, semantics, interpretation, disambiguation, incorporation
Communication

intentional exchange of information

signs
  fixed set of signs (animals)
  complex, structured system of signs (humans)

production of signs
  action resulting in an utterance (sound, movement)

perception of signs
  identification of a percept as utterance

shared system of signs
  utterances must be understood by sender and receiver
Purpose

of communication

sharing of information
  among agents

query
  other agents for information

answer
  response to queries

request / command
  action to be performed for another agent

offer
  proposition for cooperation

acknowledgement
  confirmation of requests, offers

sharing
  of feelings, experiences
establishment of trust and social ties in addition to the exchange of information
Speech Act

production of language

generic terms

independent of the communication mode (talking, sign language, typing, flags, etc.)

• word: basic communicative sign
• utterance: speech act
• speaker: producer of an utterance
• hearer: consumer of an utterance
Communication Problems

**timing**
when is a speech act called for

**selection**
which speech act is right

**language**
what sign system should be used

**interpretation**
will the intended meaning be conveyed to the hearer

**ambiguity**
is there only one possible interpretation

parts of communicating problems can be handled by logical reasoning, others require uncertain reasoning
Language

fundamentals

formal language
invented, rigidly defined

natural language
used by humans
evolves over time
Formal Language

symbols
  terminal symbols: finite sets of basic words
  non-terminal symbols: intermediate structures composed of terminal or non-terminal symbols

strings
  sequence of symbols

phrases
  substrings grouping important parts of a string
  Examples: noun phrase (NP), verb phrase (VP)
  useful for describing allowable strings and for attaching semantic handles

sentences
allowable strings in a language
composed from phrases

**lexicon**
list of allowable vocabulary workd

**grammar**
rules describing correct sentences
often described via rewrite rules in BNF notation
Natural Language

human communication

formal description
very difficult; natural languages are
sometimes non-systematic, ambiguous,
change over time, etc

integration of knowledge
into the existing world model of an agent

context
communication depends on situations,
beliefs, goals of the agents involved
Communication Models

conversion between internal representation and communication language

encoded message model
a definite proposition of the speaker is encoded into signs which are transmitted to the hearer; the hearer tries to decode the signs to retrieve the original proposition

situated language model
the intended meaning of a message depends on the signals as well as the situation in which they were exchanged

in the first model, communication problems are due to noise or errors in encoding/decoding; the second model considers mis-interpretations
Types

of communicating agents

telepathic communication
  shared internal representation
  communication through Tell, Ask

language-based communication
  speaker agent produces signs that other agents can perceive and interpret
Telepathic Communication

shared internal representation

representation

- common representation format
- common set of symbols
- naming policy for symbols generated dynamically by different agents
- relations between symbols introduced by different agents
- reconciliations of agents’ knowledge bases

access to other agents’ knowledge bases
Language-Based Communication

*common language*

**speaker**
performs actions that produce signs which other agents can perceive and interpret

**hearer**
perceives, interprets, and incorporates signs from the speaker

**communication language**
different from the internal representation

**communication process**
mapping from internal representation of the speaker to the common communication language and to the internal representation of the hearer

**communication actions**
language generation
analysis and integration of perceived
signs
Communication Steps

activities by speaker and hearer

speaker

• intention: decision about producing a speech act
• generation: conversion of the information to be transferred into the chosen language
• synthesis: actions that produce the generated signs

hearer

• perception: reception of the signs produced by the speaker (speech recognition, lip reading, character recognition)
• analysis: syntactic interpretation
(parsing) and semantic interpretation

- disambiguation: selection of the probable intended meaning

- incorporation: the selected interpretation is incorporated into the existing world model as additional piece of evidence
Parsing

*syntactic analysis*

**parse tree**

- leaf nodes represent words
- interior nodes represent phrases
- links represent applications of grammar rules

result of the syntactic analysis

**general treatment**

logical inference problem

**specific treatment**

efficient algorithms for particular grammars

**context**

context-free languages are frequently too limited
definite clause grammar
allows extra arguments in rules for expressiveness, conciseness
Semantic Interpretation

identifies possible interpretations

compositional semantics
the semantics of a phrase can be constructed from the semantics of the subphrases, independent of previous or following phrases corresponds to context-free grammars

intermediate form or quasi-logical form used frequently to mediate between syntax and semantics structurally similar to the syntax of the sentence contains enough information for translation into first-order logic sometimes used for succinct representation of ambiguities
one of the hard problems in natural language understanding
Pragmatic Interpretation

adds contextual information

additional information
  current situation
  noncompositional, context-dependent

indexicals
  situation-dependent phrases
  speaker, location, time

anaphoric references
  phrases referring to previously mentioned objects

sometimes considered part of semantic interpretation
Ambiguity

*multiple possible interpretations*

**lexical ambiguity**

a word has more than one meaning

**syntactic ambiguity**

several parse trees exist

*I smelled a wumpus in 2,2*

**local ambiguity**

a substring can be parsed in several ways

**semantic ambiguity**

can be a consequence of lexical or syntactical ambiguity, or independent of the two

*coast road* follows the coast or leads to the coast

**referential ambiguity** special case of
semantic ambiguity
the reference of an anaphoric expression is unclear

pragmatic ambiguity
speaker and hearer disagree on the current situation
next Friday this week Friday, or next week Friday

speech act
what type of speech act has been performed
Do you know what time it is? — Yes.
Disambiguation

*diagnosis of multiple interpretations*

**hypothesis**

each possible interpretation is treated as a hypothesis, and added to the hearer’s world model

**uncertain reasoning**

used to decide on the best interpretation

**probabilistic context-free grammars**

add probabilistic information to the rewrite rules

**models** to be considered

- world model: probability that a fact occurs
- mental model: what do speaker/hearer believe
• language model: probability of selecting a particular sentence over another one

• acoustic model: probability of a particular sequence of sounds
Communicating Agent

practical considerations

language extensions
  commands, acknowledgements in
  addition to the statement type of speech

protocols
  meta-structures on top of a language
  tolerance of noise
  avoidance of mis-understandings

multi-modal communication
  sound, visual signs
Summary - Communicating Agents

exchange of information

Communication Basics
intentional exchange of information
shared system of signs, language

Language and Communication
formal vs. natural languages
syntax, grammar, parsing, semantics,
interpretation, disambiguation,
incorporation