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

natural language
  used by humans
  evolves over time
  examples: English, German, Mandarin, . . .

artificial language
  invented and designed
  may be intended for human or non-human use
  examples: Lojban, Esperanto, Klingon, . . . but
  also programming languages

formal language
  rigidly defined
  precise syntax
  often explicitly specified semantics
  examples: mathematical logic, programming
  languages
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
**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 words
grammar
rules describing correct sentences
often described via rewrite rules in BNF notation
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
cost 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