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 workd

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
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