

# 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 words

## **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