Natural Language Processing

Language

lexicon	the words and their types
syntax	rules for making compound structures with words
semantics	how words and structures map onto their intended meanings, associating the words with the conceptualization
pragmatics	use of words and structures in the context of communication acts

Language structures are not linear, all components interact.

Computational Linguistics (Chomsky) and Syntax

The syntax of a language can be structured using rewrite rules. (See the PARSE program) English language rewrite systems have about 200 rules and about 200 restrictions (special cases, constraints). To address verb tenses, subject number, sentence types and subject-verb agreement, Chomsky developed the theory of deep structure. Deep structure is what holds constant in an utterance independent of the tense, agreements, etc. A parser works with deep structure, then modifies the shallow structure to make the sentence parts agree.

Examples of ambiguity:

"I'll go when I see Sue and John leave(s)."
"The fish love(s) Mary."
"The {patient, janitor} left the operating room in good condition."
"I saw the man in the park with the telescope."
"I saw the ferry flying into Seattle."
"I ate dinner with a {fork, friend}."
"Can companies litter the environment {. ?}"
"Time flies like an arrow. Fruit flies lika a banana."

Semantics

Most grammars determine semantics by mapping the parsed syntax onto Predicate Calculus. Eg: "What is John's grade in Math-101?" ==> (grade ?x John Math-101) The essential question is whether or not what we talk about can be captured in predicate logic. The current prespective in the 1990s is: No, because

1. Most knowledge is uncertain and vague ("France is hexagonal")
2. We know too much, and we know what we don't know.
3. Language is contextual and culturally embedded.
4. Language inherently incorporates multiple perspectives.
5. Meaning is unique, interpretative, normative, interactive, conversational, evolutionary and wholistic.

The referents of pronouns are contextually determined. Examples:

"My name is Tom. I am hungry. I want to eat now."
"John can open Bill's safe. He knows the combination. He's going to change it."

Indexicals

Many words change meaning, or referent, every time they are utterred. Pronouns and words identifying relative time and place provide examples:

"I am hungry."	The 'I' is whomever utters the sentence.
"Give it to me."	The 'me' is whomever utters the sentence.
"Do it now."	The 'now' changes it temporal referent every time it is used.
"It is over there."	The 'there' can be a different place each time it is used.
"I am here; you are there."	'Here' and 'there' are defined by the context of usage.

Pragmatics

Contextual usage is very non-logical and elliptic. Eg:

"Use the racket-wrench. What's that? It's in the drawer."

The dialog aboves implies a model of the situation, something like: to fix an appliance, use a racket-wrench, so find one, recognize it, and ask how to use it when you can see it. More egs:

"Fred went into the market. He found the milk. He gave the clerk some money and left."
"Fred went to the market. He found the shelf with the milk. He paid for it and left."
"Sally needed some money.
{She bought a gun. She phoned her mother. She wrote a proposal for the NSF.}"
"He paid the ten dollars. He wouldn't let her give him five. So she bought the popcorn."
"Can you open the door? I'm cold."
"I want a hamburger. {Yes sir! No, not today. Me too.}"

Dialog Phenomena

anaphora: pronouns and words that refer to something prior in the dialog.

definite noun phrases: compound names with embedded semantics
(eg: outdated math books)

ellipsis: fragments of sentences, missing words in a terse dialog.

extragrammatical utterances: interjections, false starts, etc.

metalinguistic utterances: words about the conversations (eg: "I should have said...")

Taxonomy of Speech Processing

Generation (voice response)
Transmission (digital)
Language recognition
Speaker recognition (verify and identify)
Speaker analysis (speech pathologies, psychological state)
Speech recognition
    isolated word recognition
    word finding
    continuous speech recognition

Transformations to spoken words

microphone or channel characteristics
ambient noise in the environment
articulation
phonemic level
prosodic level (tempo, intonation)
lexicon
syntax level
discourse rules
sematics level
psychological state

Speech Acts

Some sentences are not descriptive or declarative, but are themselves actions. Eg: "I bet you $10 they win."

locutionary acts — making sounds (sighing, grunting, exclaming, etc.)

illocutionary acts — the intent of the sentence (asking, commanding, apologizing, etc.)

perlocutionary acts — the desired result of saying something (forgive me, do it, etc.)

indirect acts — not really questions
(can you pass the salt? will you open the jar?)

Dimensions of difficulty in speech processing

Form of speech	single word	...	continuous	...	conversational
Attitude	cooperative				hostile
Population	one		several		many
Vocabulary size	10		10^3		10^4
Environmental noise	40 db				90 db

Channel characteristics	high quality	radio
Syntactic constraint	simple task grammar	dictation
Semantic constraint	small world model	real world

Levels of Understanding and Utterance

signal	
segment or event	(waveform is always ambiguous for the levels which follow)
phoneme	(transitions between phonemes are difficult to determine)
demi-syllable	
syllable	
word	
phrase	
utterence (sentence)	
discourse	

Experiences of HEARSAY

Large project at CMU in the 1980s with major funding. The hierarchical model

- signal parameters (waveforms)
- normalization
- feature extraction
- lexical constraints
- syntactic constraints
- semantic constraints

did not work, since errors at each level compounded. So the model had to include feedback in a graph network. Evolved into the blackboard model: each level of analysis posted its partial results to a global dataspace, and demons representing each level triggered on posting, returning their own partial analyses. The HEARSAY processing model:

- knowledge sources, each independent and autonomous
- blackboard for communication across knowledge sources
- knowledge sources insert own hypotheses and tests asynchronously
- each knowledge source responds to blackboard postings regarding its own interests
- alternative or competing hypotheses were integrated on the blackboard and could be stated in multiple representational forms (for the different knowledge sources)