ISE 540 Text Analytics

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Natural Language Processing

- NLP is the branch of computer science focused on developing systems that allow computers to communicate with people using everyday language.
- Also called Computational Linguistics
  - Also concerns how computational methods can aid the understanding of human language

Related Areas

- Artificial Intelligence
- Formal Language (Automata) Theory
- Machine Learning
- Linguistics
- Psycholinguistics
- Cognitive Science
- Philosophy of Language

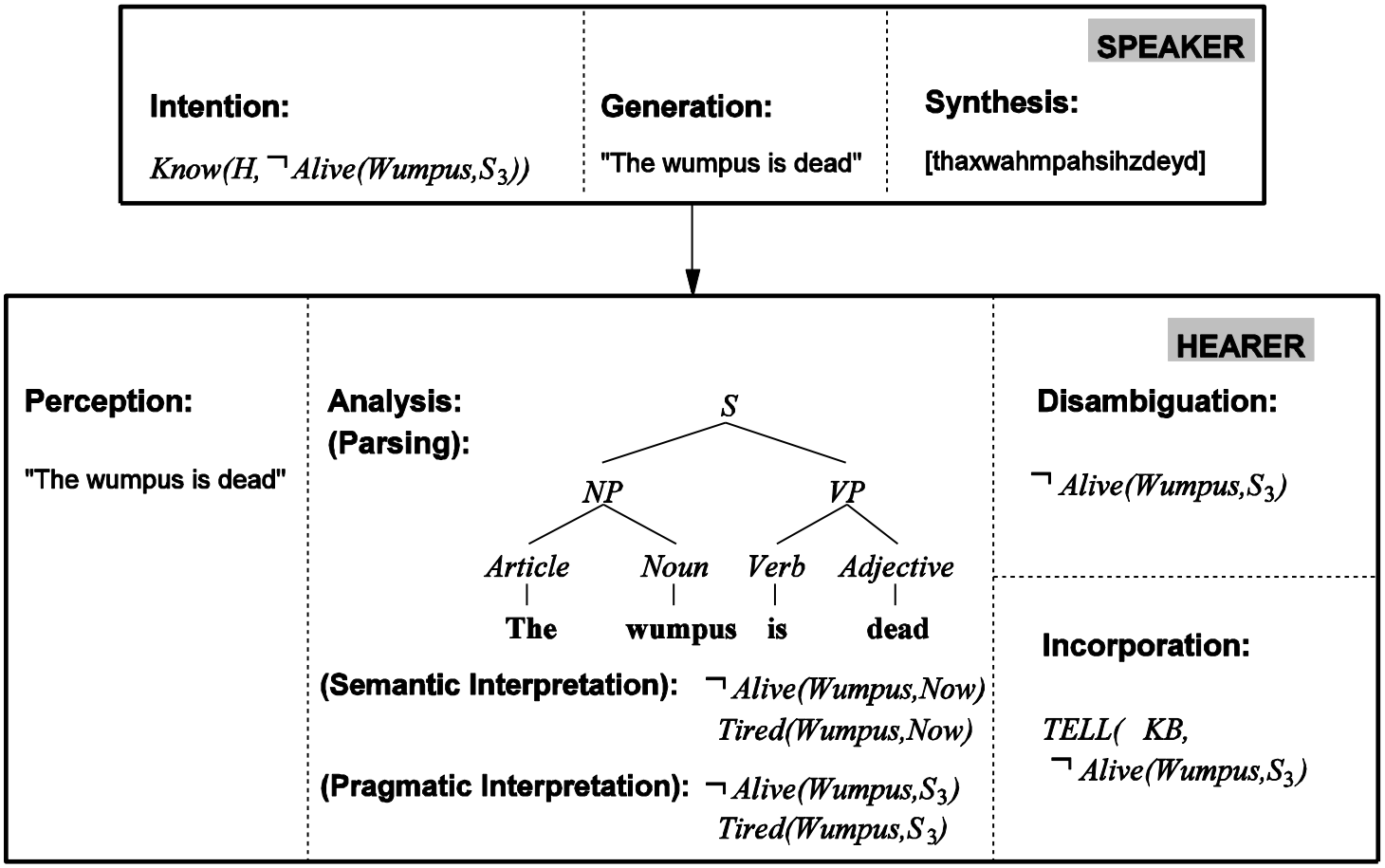
Communication

- The goal in the production and comprehension of natural language is communication.
- Communication for the speaker:
  - **Intention**: Decide when and what information should be transmitted (a.k.a. *strategic generation*). May require planning and reasoning about agents' goals and beliefs.
  - **Generation**: Translate the information to be communicated (in internal logical representation or "language of thought") into string of words in desired natural language (a.k.a. *tactical generation*).
  - **Synthesis**: Output the string in desired modality, text or speech.

Communication (cont)

- Communication for the hearer:
  - **Perception**: Map input modality to a string of words, e.g. *optical character recognition* (OCR) or *speech recognition*.
  - **Analysis**: Determine the information content of the string.
    - **Syntactic interpretation (parsing):** Find the correct parse tree showing the phrase structure of the string.
    - **Semantic Interpretation**: Extract the (literal) meaning of the string (*logical form*).
    - **Pragmatic Interpretation**: Consider effect of the overall context on altering the literal meaning of a sentence.
  - **Incorporation**: Decide whether or not to believe the content of the string and add it to the KB.

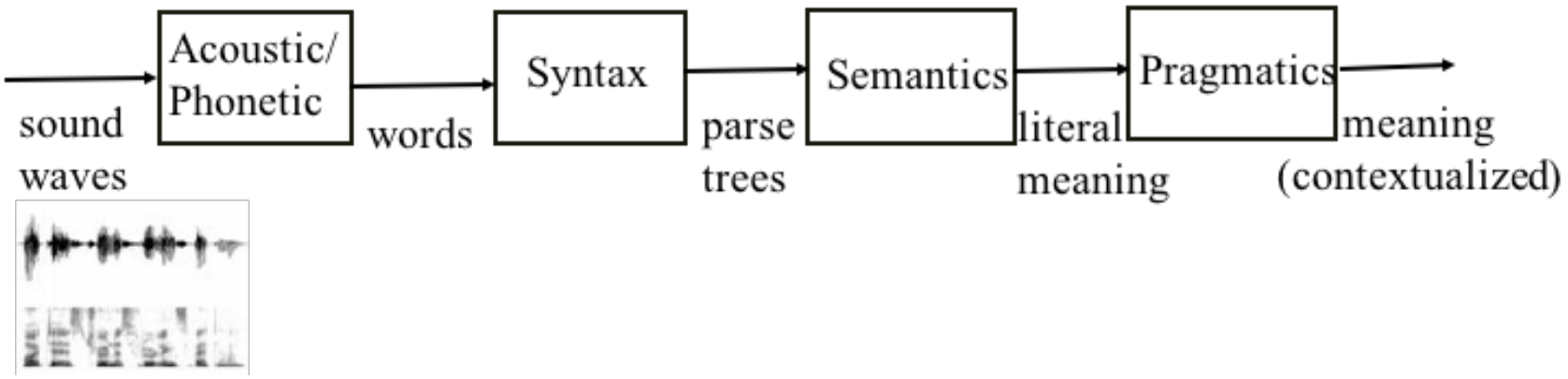
Communication (cont)



Syntax, Semantic, Pragmatics

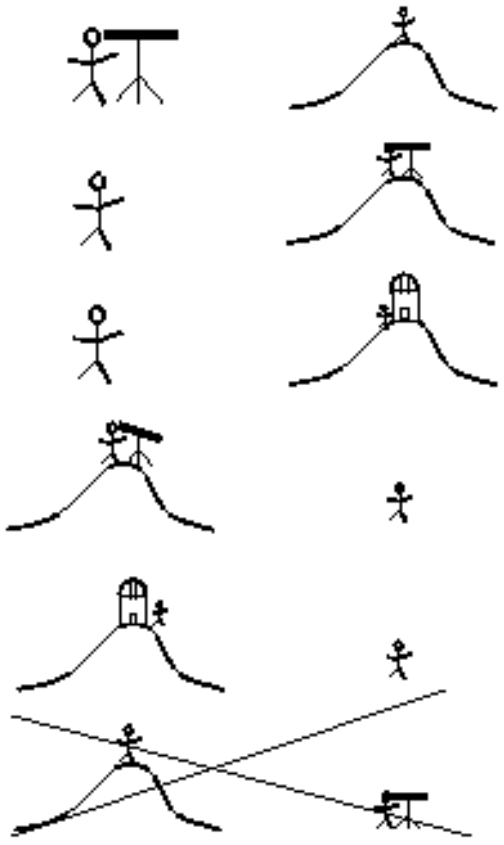
- Syntax concerns the proper ordering of words and its affect on meaning.
  - The dog bit the boy.
  - The boy bit the dog.
  - * Bit boy dog the the.
  - Colorless green ideas sleep furiously.
- Semantics concerns the (literal) meaning of words, phrases, and sentences.
  - “plant” as a photosynthetic organism
  - “plant” as a manufacturing facility
  - “plant” as the act of sowing
- Pragmatics concerns the overall communicative and social context and its effect on interpretation.
  - The ham sandwich wants another beer. (co-reference, anaphora)
  - John thinks vanilla. (ellipsis)

Modular Comprehension



Ambiguity

- Natural language is highly ambiguou
  and must be *disambiguated*.
  - I saw the man on the hill with a telescope.
  - I saw the Grand Canyon flying to LA.
  - Time flies like an arrow.
  - Horse flies like a sugar cube.
  - Time runners like a coach.
  - Time cars like a Porsche.



Ambiguity is Ubiquitous

- Speech Recognition
  - "recognize speech" vs. "wreck a nice beach"
  - "youth in Asia" vs. "euthanasia"
- Syntactic Analysis
  - "I ate spaghetti with chopsticks" vs. "I ate spaghetti with meatballs."
- Semantic Analysis
  - "The dog is in the pen." vs. "The ink is in the pen."
  - "I put the plant in the window" vs. "Ford put the plant in Mexico"
- Pragmatic Analysis
  - **From "The Pink Panther Strikes Again":**
  - **Clouseau**: Does your dog bite?
    Hotel Clerk: No.
    Clouseau: [*bowing down to pet the dog*] Nice doggie.
    [*Dog barks and bites Clouseau in the hand*]
    Clouseau: I thought you said your dog did not bite!
    Hotel Clerk: That is not my dog.

Ambiguity is Explosive

- Ambiguities compound to generate enormous numbers of possible interpretations.
- In English, a sentence ending in *n* prepositional phrases has *over* 2^n syntactic interpretations (cf. Catalan numbers).
  - "I saw the man with the telescope": 2 parses
  - "I saw the man on the hill with the telescope.": 5 parses
  - "I saw the man on the hill in Texas with the telescope": 14 parses
  - "I saw the man on the hill in Texas with the telescope at noon.": 42 parses
  - "I saw the man on the hill in Texas with the telescope at noon on Monday" 132 parses

Humor and Ambiguity

- Many jokes rely on the ambiguity of language:
  - Groucho Marx: One morning I shot an elephant in my pajamas. How he got into my pajamas, I'll never know.
  - She criticized my apartment, so I knocked her flat.
  - Noah took all of the animals on the ark in pairs. Except the worms, they came in apples.
  - Policeman to little boy: "We are looking for a thief with a bicycle." Little boy: "Wouldn't you be better using your eyes."
  - Why is the teacher wearing sun-glasses. Because the class is so bright.

Why is Language Ambiguous?

- Having a unique linguistic expression for every possible conceptualization that could be conveyed would make language overly complex and linguistic expressions unnecessarily long.
- Allowing resolvable ambiguity permits shorter linguistic expressions, i.e. data compression.
- Language relies on people's ability to use their knowledge and inference abilities to properly resolve ambiguities.
- Infrequently, disambiguation fails, i.e. the compression is lossy.

Natural Languages vs. Computer Languages

- Ambiguity is the primary difference between natural and computer languages.
- Formal programming languages are designed to be unambiguous, i.e. they can be defined by a grammar that produces a unique parse for each sentence in the language.
- Programming languages are also designed for efficient (deterministic) parsing, i.e. they are deterministic context-free languages (DCLFs).
  - A sentence in a DCFL can be parsed in O(n) time where n is the length of the string.

Relevant Scientific Conferences

- Association for Computational Linguistics (ACL)
- North American Association for Computational Linguistics (NAACL)
- International Conference on Computational Linguistics (COLING)
- Empirical Methods in Natural Language Processing (EMNLP)
- Conference on Computational Natural Language Learning (CoNLL)
- International Association for Machine Translation (IMTA)