What is Comp. Psycholinguistics?

- Using computational methods to model cognitive processes of language
- Study these processes through simulation
  - Evaluate existing theories of language understanding
  - Explain the observed human behavior
  - Predict behavioral patterns that have not been experimentally investigated
- Provide insight on how people process language
Areas of Comp. Psycholinguistics

- Speech perception and articulation
- Representation of the mental lexicon
- Lexical access and lexical choice
- Sentence processing: syntactic, semantic, pragmatic
- Situated language processing: interaction of language with task/context
- Embodied language processing: intertwining of language with other cognitive and perceptual systems
The Focus of This Course

- How we learn the knowledge of language: Human Language Acquisition

- How we use the acquired knowledge in developing an interpretation for a sentence: Human Sentence Processing
Human Language Acquisition

- **Representation** of the linguistic knowledge
  - What is innate, what is learnable?
  - How is the knowledge organized in mind and brain?
    - Are there separate areas/levels for representing lexical/syntactic/semantic knowledge?

- **Acquisition** of the linguistic knowledge
  - What are the processes involved in language learning?
  - Are different types of knowledge acquired in order?
Learnability in Acquisition

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Modularity in Acquisition

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Computational modeling of human language acquisition:

- Providing cognitively plausible formalisms for representing linguistic knowledge
- Developing algorithms that can acquire knowledge of language from exposure to linguistic data
Human Sentence Processing

- Construction of an interpretation for a sentence
  - How does the human language processor work?
  - How is it realized in the brain?
  - How does language interact with other cognitive systems and the environment?
Mechanisms in HSP

- Construction of an interpretation for a sentence
  - How does the human language processor work?
  - How is it realized in the brain?
- How does language interact with other cognitive systems and the environment?
Modularity in HSP

- Construction of an interpretation for a sentence
  - How does the human language processor work?
  - How is it realized in the brain?
- How does language interact with other cognitive systems and the environment?
A Simple Example

S ⇒ NP VP

NP ⇒ Det N

VP ⇒ V NP

NP ⇒ Det N

deep reading

the man reads
every book

S

NP

VP

the

man

read

Det

N

V

NP

every

book
Characteristics of HSP

- People are highly accurate in understanding language
- People process language rapidly, in real-time
- People understand and produce language incrementally
- People rapidly adjust to context, and are robust
- People achieve this despite limitations on processing resources
Characteristics of HSP

• People are highly **accurate** in understanding language

• People process language **rapidly, in real-time**

• People understand and produce language **incrementally**

• People rapidly adjust to **context, and are robust**

• People achieve this despite **limitations on processing resources**
Computational HSP

- **Computational** modeling of human sentence processing:
  - Development of algorithms that can
    - recover the intended meaning of a sentence from its spoken or textual realization
    - reflect the characteristics of human sentence processing
Acquisition vs. Processing

• How is acquisition related to processing?

• Competence: what it means to “know” a language
  • syntactic and semantic rules and representations provided by a linguistic theory

• Performance: how is such knowledge used on-line to recover the meaning for a given sentence
  • a psychologically plausible parsing algorithm
The Competence Hypothesis

- **Assumptions:**
  - Linguistic theory is isomorphic to human linguistic knowledge
  - Comprehension and production share same knowledge

- **Variations**
  - **Weak competence:** people recover *representations* that are isomorphic to those of linguistic theories
  - **Strong competence:** people *directly* use grammatical knowledge and principles of linguistic theories
Competence vs. Performance

The horse raced past the barn fell.

• The sentence is perfectly grammatical according to grammar rules (competence)

• Many readers are unable to recover the correct meaning (performance)

• Compare with:

  The patient sent the flowers was pleased.
Why Computational Modeling?

- Implemented models are essential because
  - human language processing is highly complex
  - it involves interaction of diverse linguistic and non-linguistic constraints
  - it is inherently a dynamic process: recovery of meaning happens in real-time and is influenced by various sources of information

- Computational cognitive models should conform to psychological plausibility criteria.
Psychological Plausibility

- Incrementality: interpretations and expectations are developed word by word

“The man held at the station was innocent”

Psychological Plausibility

- Handling local and global ambiguity
Psychological Plausibility

- Memory limitations:

\[\text{The mouse that the cat that the dog chased bit died.}\]

\[\text{[the mouse [that the cat [that the dog chased] bit] died]}\]
Cognitive Modeling and NLP

- Early NLP (e.g. Winograd, 1983) viewed itself as building models of human understanding
  - Proposals were heavily informed by intuitions about how people understand language
  - Both shared assumptions regarding linguistic competence; concerned with developing algorithms which recover a linguistically adequate representation of a sentence as defined by current syntactic and semantic theories
Modern NLP has shifted emphasis

Focus on applications: do limited tasks accurately and robustly, often without real understanding (e.g., spam filtering, document clustering, text summarization, ...)

Deep NLU emphasizes on representations, coverage and efficiency, and is not concerned with cognitive plausibility
However, cognitive modeling of language is heavily informed by research in NLP

- Human syntactic processing is influenced by computational linguistics, specifically natural language parsing

- Computational modeling of language acquisition is influenced by machine learning techniques
Cognitive Modeling: Evaluation

• Cognitive models cannot be solely evaluated based on their accuracy in performing a task
  • The **behavior** of the model must be compared against observed human behavior
  • The **errors** made by humans must be replicated and explained

• Evaluation of cognitive models depends highly on **experimental studies of language**
Experimental Studies

• Collected data on child language development
  • CHILDES database (MacWhinney, 1995)

• Experimental methods
  • Reading times
  • Neuroscientific methods
  • Situated spoken sentence comprehension
Marr’s Levels of Modeling

- Theories often provide a relatively high-level characterization of a process

- Marr (1982) identifies three levels of describing cognitive processes:
  - **Computational** level: defines *what* is computed
  - **Algorithmic** level: specifies *how* computation takes place
  - **Implementation** level: states how the algorithms are actually *realized* in brain
What if the Model is Flawed?

(Stated at computational level)

Theory

Model

(Built at algorithmic level, therefore details of processing have to be specified)
Modeling Paradigms

- **Symbolic models**
  - computationally well-understood, transparent with respect to their linguistic basis, and scalable

- **Connectionist networks**
  - inspired by the structure of brain, can learn from sufficient exposure to language, use distributed representations that are hard to interpret

- **Probabilistic models**
  - transparent linguistic basis, combined with an experience-based mechanism
Roadmap

• Modularity in acquisition and processing
• Experimental studies/methods
• Parsing mechanisms
• Handling ambiguity in parsing
• Probabilistic accounts of language processing
• Multiple-constraint accounts of language processing
• Language acquisition
• Connectionist models of acquisition and processing
Course Details

• Weekly lectures: Monday 14:00-16:00

• Weekly tutorials: Wednesday 14:00-16:00 (CIP Room)

• Assessment

  • Final exam: 100%, week of February 15
  
  • Make-up exam: mid April 2009

  • Tutorial assignments must be completed to sit the exam

• Course materials (lecture slides and most readings) will be made available on the course homepage