Introduction to Deep Processing Techniques for NLP

Deep Processing Techniques for Natural Language Processing
Ling 571
January 3, 2011
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Roadmap

• Motivation:
  • Applications

• Language and Thought

• Knowledge of Language
  • Cross-cutting themes
    • Ambiguity, Evaluation, & Multi-linguality

• Course Overview
Motivation: Applications

- Applications of Speech and Language Processing
  - Call routing
  - Information retrieval
  - Question-answering
  - Machine translation
  - Dialog systems
  - Spam tagging
  - Spell- , Grammar- checking
  - Sentiment Analysis
  - Information extraction....
Building on Many Fields

- Linguistics: Morphology, phonology, syntax, semantics,..
- Psychology: Reasoning, mental representations
- Formal logic
- Philosophy (of language)
- Theory of Computation: Automata,..
- Artificial Intelligence: Search, Reasoning, Knowledge representation, Machine learning, Pattern matching
- Probability..
Language & Intelligence

- Turing Test: (1949) – Operationalize intelligence
  - Two contestants: human, computer
  - Judge: human
  - Test: Interact via text questions
  - Question: Can you tell which contestant is human?

- Crucially requires language use and understanding
Limitations of Turing Test

- ELIZA (Weizenbaum 1966)
  - Simulates Rogerian therapist
    - User: You are like my father in some ways
    - ELIZA: WHAT RESEMBLANCE DO YOU SEE
    - User: You are not very aggressive
    - ELIZA: WHAT MAKES YOU THINK I AM NOT AGGRESSIVE...
  - Passes the Turing Test!! (sort of)
  - “You can fool some of the people....”

- Simple pattern matching technique
- True understanding requires deeper analysis & processing
Turing Test Revived

• “On the web, no one knows you’re a....”
  • Problem: ‘bots’
    • Automated agents swamp services
    • Challenge: Prove you’re human

• Test: Something human can do, ‘bot can’t

• Solution: CAPTCHAs
  • Distorted images: trivial for human; hard for ‘bot

• Key: Perception, not reasoning
Knowledge of Language

- What does HAL (of 2001, A Space Odyssey) need to know to converse?

  - *Dave*: Open the pod bay doors, HAL.
  - *HAL*: I'm sorry, Dave. I'm afraid I can't do that.
Knowledge of Language

- What does HAL (of 2001, A Space Odyssey) need to know to converse?

- *Dave: Open the pod bay doors, HAL.*

- *HAL: I'm sorry, Dave. I'm afraid I can't do that.*

- Phonetics & Phonology (Ling 450/550)
  - Sounds of a language, acoustics
  - Legal sound sequences in words
Knowledge of Language

What does HAL (of 2001, A Space Odyssey) need to know to converse?

Dave: Open the pod bay doors, HAL.

HAL: I'm sorry, Dave. I'm afraid I can't do that.

Morphology (Ling 570)
- Recognize, produce variation in word forms
- Singular vs. plural: Door + sg: -> door; Door + plural -> doors
- Verb inflection: Be + 1st person, sg, present -> am
Knowledge of Language

- What does HAL (of 2001, A Space Odyssey) need to know to converse?

- Dave: Open the pod bay doors, HAL.

- HAL: I'm sorry, Dave. I'm afraid I can't do that.

- Part-of-speech tagging (Ling 570)
  - Identify word use in sentence
  - Bay (Noun) --- Not verb, adjective
Knowledge of Language

- What does HAL (of 2001, A Space Odyssey) need to know to converse?

  - Dave: Open the pod bay doors, HAL.
  - HAL: I'm sorry, Dave. I'm afraid I can't do that.

- Syntax
  - (Ling 566: analysis; Ling 570 – chunking; Ling 571- parsing)
  - Order and group words in sentence
    - I’m I do , sorry that afraid Dave I can’t.
Knowledge of Language

- What does HAL (of 2001, A Space Odyssey) need to know to converse?
  
  - *Dave:* Open the pod bay doors, HAL.
  
  - *HAL:* I'm sorry, Dave. I'm afraid I can't do that.

- Semantics (Ling 571)
  - Word meaning:
    - individual (lexical), combined (compositional)
  
  - ‘Open’ : AGENT cause THEME to become open;
  
  - ‘pod bay doors’ : (pod bay) doors
Knowledge of Language

- What does HAL (of 2001, A Space Odyssey) need to know to converse?

- Dave: Open the pod bay doors, HAL. (request)
- HAL: I'm sorry, Dave. I'm afraid I can't do that. (statement)

- Pragmatics/Discourse/Dialogue (Ling 571)
  - Interpret utterances in context
  - Speech act (request, statement)
  - Reference resolution: I = HAL; that = ‘open doors’
  - Politeness: I’m sorry, I’m afraid I can’t
Shallow vs Deep Processing

- Shallow processing (Ling 570)
  - Usually relies on surface forms (e.g., words)
  - Less elaborate linguistics representations
  - E.g. HMM POS-tagging; FST morphology

- Deep processing (Ling 571)
  - Relies on more elaborate linguistic representations
    - Deep syntactic analysis (Parsing)
    - Rich spoken language understanding (NLU)
Cross-cutting Themes

- Ambiguity
  - How can we select among alternative analyses?

- Evaluation
  - How well does this approach perform:
    - On a standard data set?
    - When incorporated into a full system?

- Multi-linguality
  - Can we apply this approach to other languages?
  - How much do we have to modify it to do so?
Ambiguity

- “I made her duck”
- Means....
Ambiguity

- “I made her duck”
- Means....
  - I caused her to duck down
Ambiguity

- "I made her duck"
- Means....
  - I caused her to duck down
  - I made the (carved) duck she has
Ambiguity

“"I made her duck”"

Means....
- I caused her to duck down
- I made the (carved) duck she has
- I cooked duck for her
Ambiguity

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Means....

- I caused her to duck down
- I made the (carved) duck she has
- I cooked duck for her
- I cooked the duck she owned
Ambiguity

- “I made her duck”

- Means....
  - I caused her to duck down
  - I made the (carved) duck she has
  - I cooked duck for her
  - I cooked the duck she owned
  - I magically turned her into a duck
Ambiguity: POS

- “I made her duck”
- Means....
  - I caused her to duck down
  - I made the (carved) duck she has
  - I cooked duck for her
  - I cooked the duck she owned
  - I magically turned her into a duck
Ambiguity: Syntax

- “I made her duck”
- Means....
  - I made the (carved) duck she has
    - ((VP (V made) (NP (POSS her) (N duck)))
Ambiguity: Syntax

- “I made her duck”

- Means...
  - I made the (carved) duck she has
    - ((VP (V made) (NP (POSS her) (N duck)))

- I cooked duck for her
  - ((VP (V made) (NP (PRON her)) (NP (N (duck))))
Ambiguity: Semantics

- “I made her duck”
- Means....
  - I caused her to duck down
  - Make: AG **cause** TH to do sth
Ambiguity: Semantics

- “I made her duck”
- Means....
  - I caused her to duck down
    - Make: AG **cause** TH to do sth
  - I cooked duck for her
    - Make: AG **cook** TH for REC
Ambiguity: Semantics

- “I made her duck”

- Means....
  - I caused her to duck down
    - Make: AG *cause* TH to do sth
  - I cooked duck for her
    - Make: AG cook TH for REC
  - I cooked the duck she owned
    - Make: AG cook TH
Ambiguity: Semantics

“"I made her duck"

Means....

• I caused her to duck down
  • Make: AG cause TH to do sth
• I cooked duck for her
  • Make: AG cook TH for REC
• I cooked the duck she owned
  • Make: AG cook TH

• I magically turned her into a duck
  • Duck: animal
Ambiguity: Semantics

• “I made her duck”

• Means....
  • I caused her to duck down
    • Make: AG cause TH to do sth
  • I cooked duck for her
    • Make: AG cook TH for REC
  • I cooked the duck she owned
    • Make: AG cook TH
  • I magically turned her into a duck
    • Duck: animal
  • I made the (carved) duck she has
    • Duck: duck-shaped figurine
Ambiguity

- Pervasive
- Pernicious
- Particularly challenging for computational systems
- Problem we will return to again and again in class
Course Information

Syntax

Ling 571
Deep Processing Techniques for Natural Language Processing
January 5, 2006
Roadmap

- **Sentence Structure**
  - Motivation: More than a bag of words
    - Constituency

- **Representation:**
  - Context-free grammars
    - Chomsky hierarchy
    - Formal definition of context free grammars
      - Why not fi
    - Aside: Mildly context sensitive grammars: TAGs
More than a Bag of Words

- Sentences are structured:
  - Impacts meaning:
    - Dog bites man vs man bites dog

- Impacts acceptability:
  - Dog man bites
Constituency

- Constituents: basic units of sentences
  - word or group of words that acts as a single unit

- Phrases:
  - Noun phrase (NP), verb phrase (VP), prepositional phrase (PP), etc

- Single unit: type determined by head (e.g., N->NP)
Constituency

- How can we tell what units are constituents?
- On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
Constituency

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  - September seventeenth
Constituency

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- On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
  - September seventeenth
  - On September seventeenth
Constituency

- How can we tell what units are constituents?
- On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
  - September seventeenth
  - On September seventeen
  - Sea-Tac Airport
Constituency

- How can we tell what units are constituents?
- On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
  - September seventeenth
  - On September seventeen
  - Sea-Tac Airport
  - from Sea-Tac Airport
Constituency Testing

- Appear in similar contexts
  - PPs, NPs, PPs

- Preposed or Postposed constructions
  - On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
Constituency Testing

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- Preposed or Postposed constructions
  - On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
  - I’d like to fly from Sea-Tac Airport to Denver on September seventeenth.
Constituency Testing

- Appear in similar contexts
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- Preposed or Postposed constructions
  - On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
  - I’d like to fly from Sea-Tac Airport to Denver on September seventeenth.
  - Must move as unit
    - *I’d like to fly from Sea-Tac Airport to Denver on.
Constituency Testing

- Appear in similar contexts
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- Preposed or Postposed constructions
  - On September seventeenth, I’d like to fly from Sea-Tac Airport to Denver.
  - I’d like to fly from Sea-Tac Airport to Denver on September seventeenth.
  - Must move as unit
    - *I’d like to fly from Sea-Tac Airport to Denver on.
    - *I’d like to fly September from Sea-Tac Airport to Denver.
Sentence-level Knowledge: Syntax

- Different models of language
- Specify the expressive power of a formal language

Chomsky Hierarchy

Recursive Enumerable = Any

Context A -> aAb
Free $a^n b^n$

Sensitive

Context = AB -> CD $a^n b^n c^n$

Regular Expression S -> aB
$a*b*$

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Representing Sentence Structure

- Why not just Finite State Models?
  - Cannot describe some grammatical phenomena
  - Inadequate expressiveness to capture generalization

- Center embedding
  - Finite State: $A \rightarrow w^*; A \rightarrow w^*B$
  - Context-Free: $A \Rightarrow \alpha A \beta$
    - Allows recursion
      - The luggage arrived.
      - The luggage that the passengers checked arrived.
      - The luggage that the passengers that the storm delayed checked arrived.
Representing Sentence Structure

- Captures constituent structure
  - Basic units
    - Phrases

- Subcategorization
  - Argument structure
    - Components expected by verbs

- Hierarchical
Representation: Context-free Grammars

- CFGs: 4-tuple
  - A set of terminal symbols: $\Sigma$
  - A set of non-terminal symbols: $N$
  - A set of productions $P$: of the form $A \rightarrow \alpha$
    - Where $A$ is a non-terminal and $\alpha$ in $(\Sigma \cup N)^*$
  - A designated start symbol $S$

- $L = \{ w \mid w \text{ in } \Sigma^* \text{ and } S \Rightarrow^* w \}$
  - Where $S \Rightarrow^* w$ means $S$ derives $w$ by some seq
Representation: Context-free Grammars

- Partial example
  - $\Sigma$: the, cat, dog, bit, bites, man
  - $N$: NP, VP, AdjP, Nom, Det, V, N, Adj,
  - $P$: $S \rightarrow NP \ VP$; $NP \rightarrow$ Det Nom; Nom$\rightarrow$ N Nom|$N$, VP$\rightarrow$ V NP, N$\rightarrow$ cat, N$\rightarrow$ dog, N$\rightarrow$ man, Det$\rightarrow$ the, V$\rightarrow$ bit, V$\rightarrow$ bites
  - $S$