Introduction to Deep Processing Techniques for NLP

Deep Processing Techniques for NLP
Ling 571
January 4, 2017
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Roadmap

- Motivation:
  - Applications
- Language and Thought
- Knowledge of Language
  - Cross-cutting themes
    - Ambiguity, Evaluation, & Multi-linguality
- Course Overview
- Introduction to Syntax and Parsing

Motivation: Applications

- Applications of Speech and Language Processing
  - Call routing
  - Information retrieval
  - Question-answering
  - Machine translation
  - Dialog systems
  - 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: (1950) – 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
  - "Completely Automated Public Turing Test To Tell Computers and Humans Apart"
  - Initially: distorted images: easy for human; hard for 'bot
    - Driven by perception
  - Drives improvements in AI – vision, audio, OCR
    - "Arms race": better systems, harder CAPTCHAs
      - Images, word problems, etc

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.*

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- 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.*
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- 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.*
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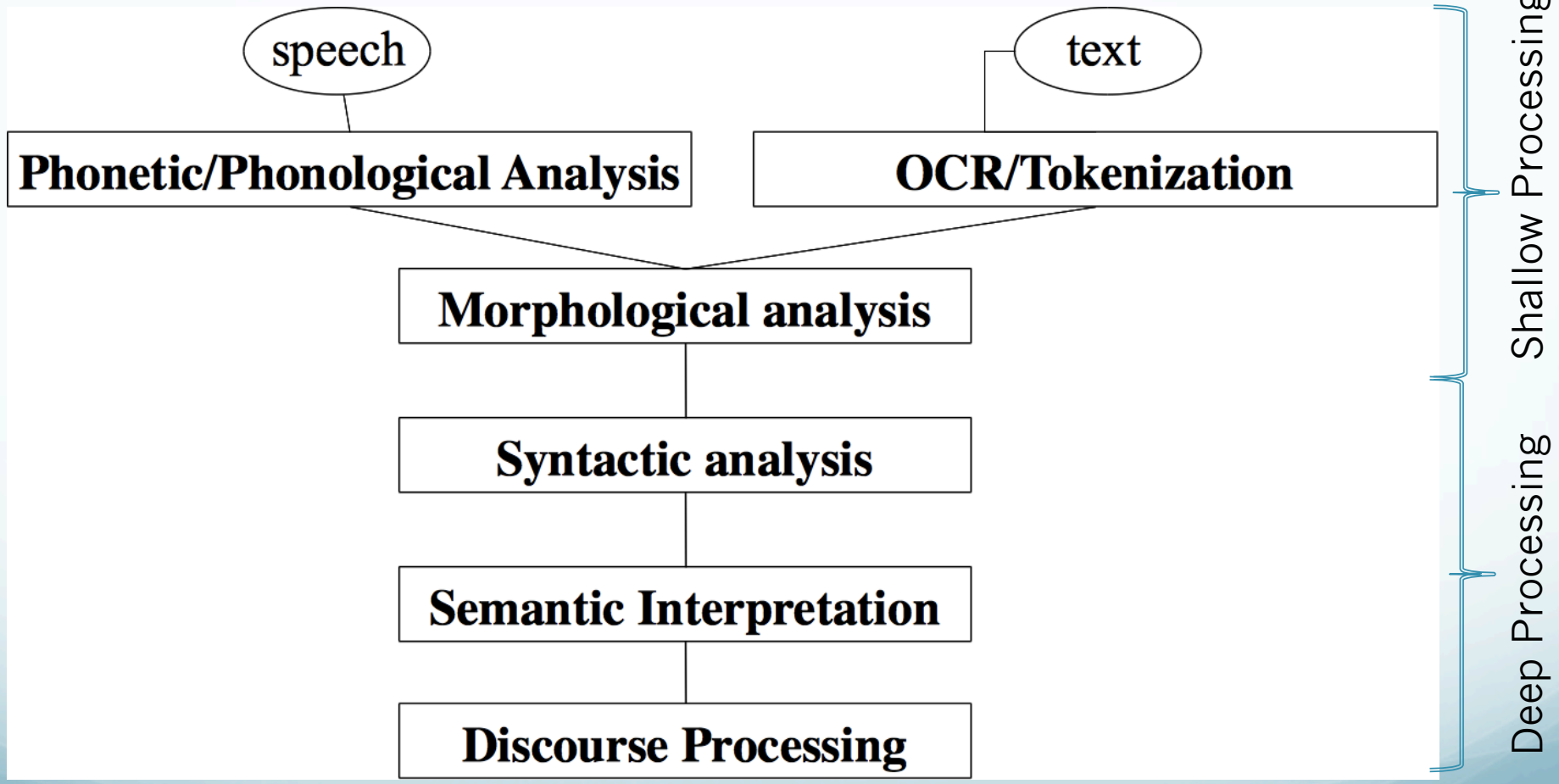
- Semantics (Ling 571)
  - Word meaning:
    - individual (lexical), combined (compositional)
- 'Open' : AGENT **cause** THEME to become *open*;
- 'pod bay doors' : (pod bay) doors

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

Language Processing Pipeline



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….
  - 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….
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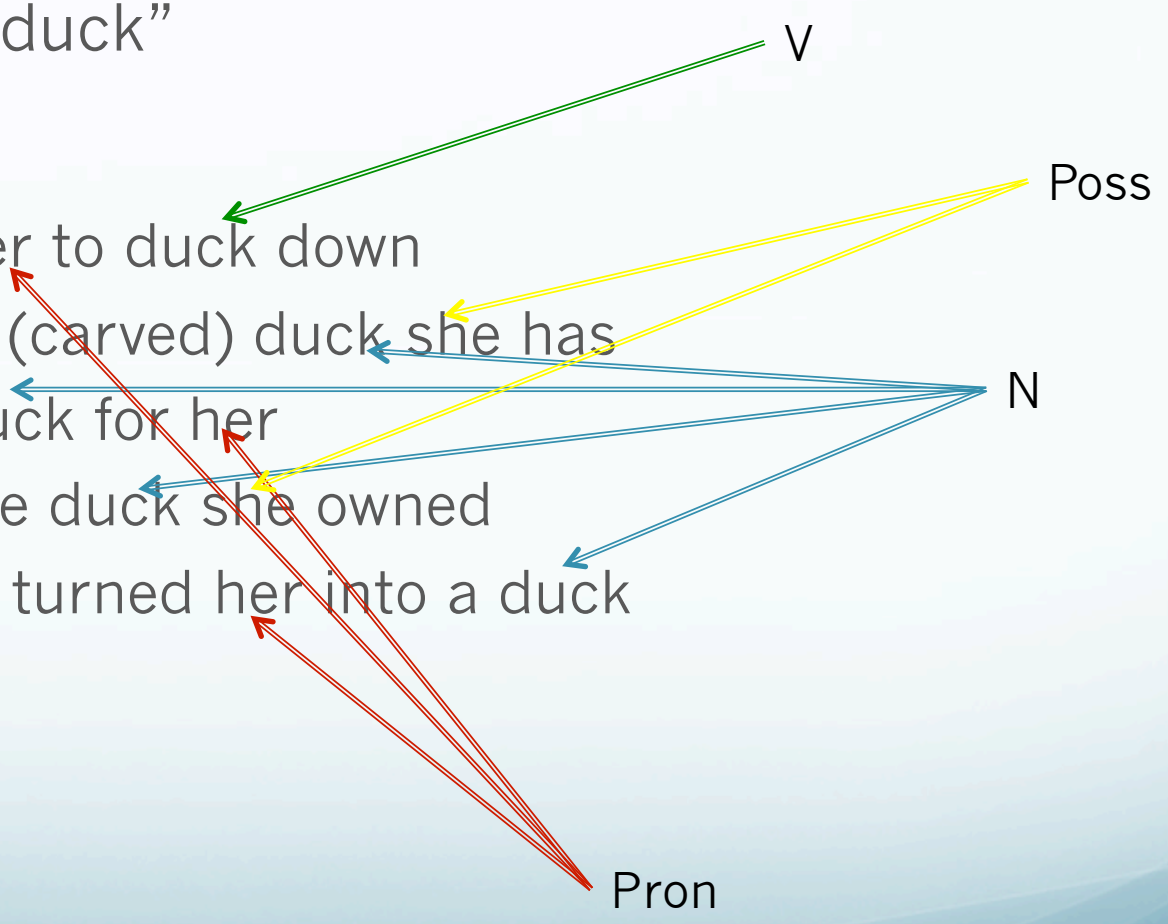


Ambiguity: Syntax

- “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
  - 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

- http://courses.washington.edu/ling571

Syntax

Ling 571
Deep Processing Techniques for Natural Language Processing
January 4, 2017

Roadmap

- Sentence Structure
  - Motivation: More than a bag of words
- Representation:
  - Context-free grammars
    - Formal definition of context free grammars

Applications

- Shallow techniques useful, but limited
- Deeper analysis supports:
  - Grammar-checking – and teaching
  - Question-answering
  - Information extraction
  - Dialogue understanding

Grammar and NLP

- Grammar in NLP is NOT prescriptive high school grammar
  - Explicit rules
  - Split infinitives, etc

- Grammar in NLP tries to capture structural knowledge of language of a native speaker
  - Largely implicit
  - Learned early, naturally

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)

Representing Sentence Structure

- Captures constituent structure
  - Basic units
    - Phrases
  - Subcategorization
    - Argument structure
      - Components expected by verbs
  - Hierarchical

Representation: Context-free Grammars

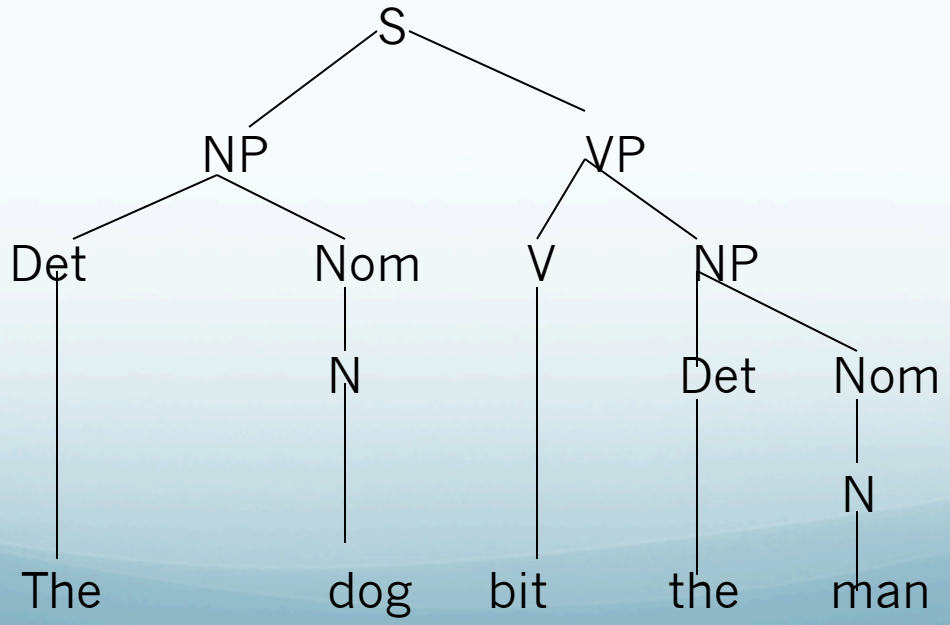
- CFGs: 4-tuple
  - A set of terminal symbols: Σ
  - A set of non-terminal symbols: N
  - A set of productions P: of the form A → α
    - Where A is a non-terminal and α in (Σ U N)*
  - A designated start symbol S
- L =W|w in Σ* and S =>* w
  - Where S =>* w means S derives w by some seq

CFG Components

- Terminals:
  - Only appear as leaves of parse tree
  - Right-hand side of productions (rules) (RHS)
  - Words of the language
    - Cat, dog, is, the, bark, chase
- Non-terminals
  - Do not appear as leaves of parse tree
  - Appear on left or right side of productions (rules)
  - Constituents of language
    - NP, VP, Sentence, etc

Representation: Context-free Grammars

- Partial example
  - Σ : the, cat, dog, bit, bites, man
  - N: NP, VP, Nom, Det, V, N, Adj
  - P: S→NP VP; NP → Det Nom; Nom → N Nom|N; VP→V NP, N→cat, N→dog, N→man, Det→the, V→bit, V→bites
  - S

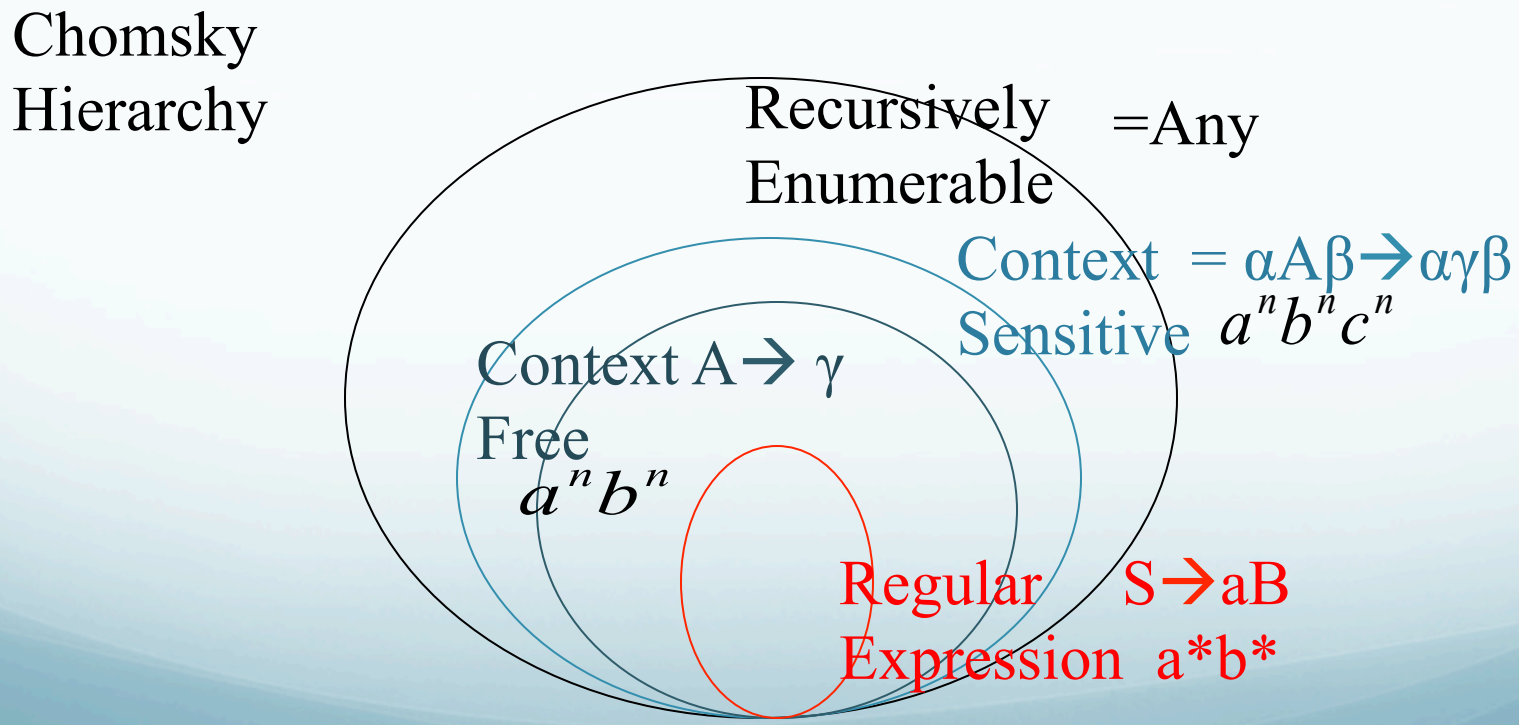


Parsing Goals

- Accepting:
  - Legal string in language?
    - Formally: rigid
    - Practically: degrees of acceptability
- Analysis
  - What structure produced the string?
    - Produce one (or all) parse trees for the string
- Will develop techniques to produce analyses of sentences
  - Rigidly accept (with analysis) or reject
  - Produce varying degrees of acceptability

Sentence-level Knowledge: Syntax

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

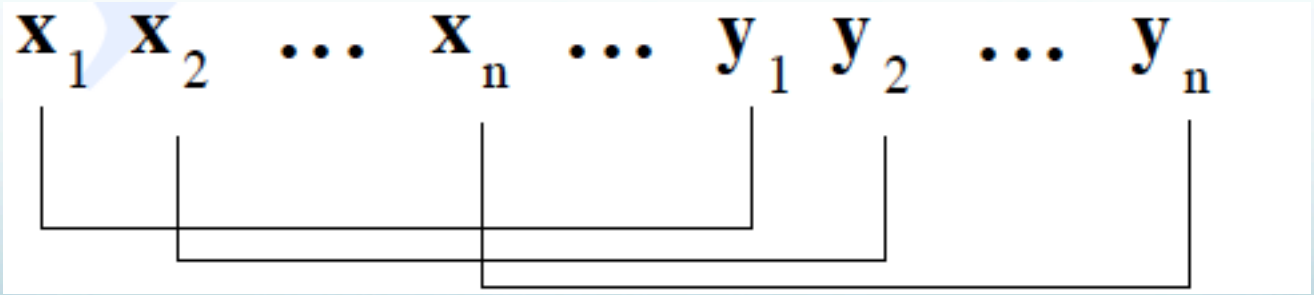


Representing Sentence Structure

- 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.

Is Context-free Enough?

- Natural language provably not finite state
- Do we need context-sensitivity?
  - Many articles have attempted to demonstrate
    - Many failed, too
    - Solid proofs for Swiss German (Shieber)
- Key issue: Cross-serial dependencies: $a^n b^m c^n d^m$



Examples

.mer em Hans es huus hälfed aastriiche.
.we Hans/DAT the house/ACC helped paint.

'. . . we helped Hans paint the house."

. . . mer d'chind em Hans es huus haend wele laa
. . . we the children/ACC Hans/DAT the house/ACC have wanted to let

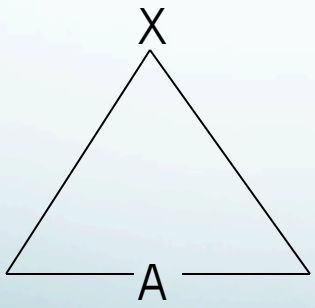
ıälfe aastriiche.
ıelp paint.

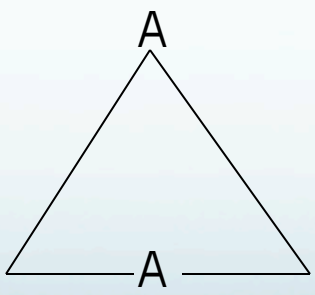
". . . we have wanted to let the children help Hans paint the house."

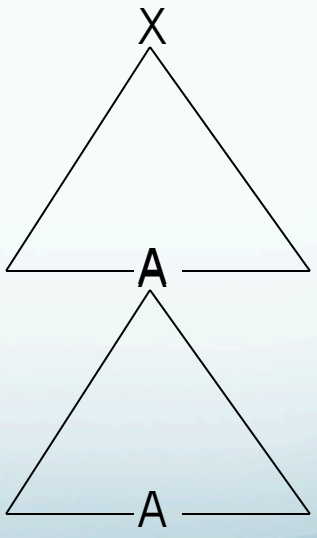
Verbs and their arguments can be ordered cross-serially
- arguments and verbs must match

Tree Adjoining Grammars

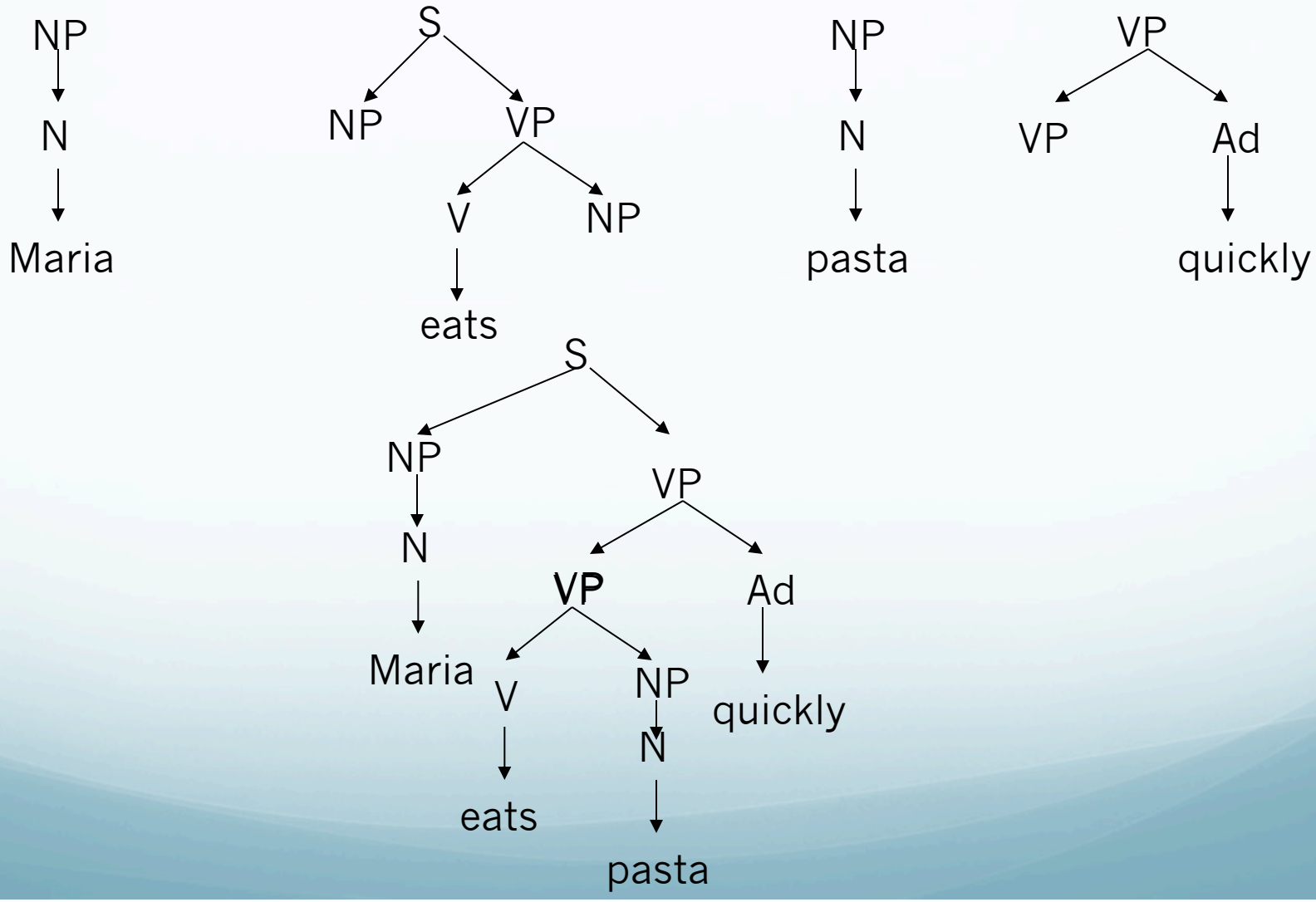
- Mildly context-sensitive (Joshi, 1979)
  - Motivation:
    - Enables representation of crossing dependencies
- Operations for rewriting
  - "Substitution" and "Adjunction"







TAG Example


NP
N
Maria
S
NP
VP
V
NP
eats
NP
N
pasta
VP
VP
Ad
quickly
S
NP
N
Maria
VP
VP
Ad
V
NP
N
eats
pasta
quickly