Natural Language Processing

Lecture 14: Beyond CFG Parsing
Today’s Outline

- Dependency parsing
- Tree adjoining grammar
- Categorial Grammar
- Unification-based grammar
Heads in CFGs
The luxury auto maker last year sold 1,214 cars in the U.S.
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Random PCFG Text (5 ancestors, lex.)

- it can remember one million truly inspiring teachers from Rainbow Technologies.
- I have been able *-1 to force *-2 to be more receptive to therapy, and to keep the committee informed *-2, usually in advance, of covert actions; the victims are large and costly machines.
- As their varied strategies suggest, Another suggestion would predict they will pay off.
- the two-day trip reportedly has said it would be done *-1.
- Others have soared to the car market well.
- A spokesman for * paying the bill declined *-1 to pay taxes, but the fact that *T*-84 adjusted payouts on behalf of preventative medicine in terms of 29 years could be distributed *-1.
- P&G, in the space of Orrick, Herrington & Sutcliffe, rarely rolls forward on a modest 1.1 million shares on the block.
- In the eight months last Friday, bond prices closed yesterday at $ 30.2 million, down 25 cents.
- Still, Honda says *T*-1 is calling for slight declines when there was posted *-1 within its pre-1967 borders.
- Moreover, Allianz's Mr. Jarrett also sees only a "internal erosion" of about 35 of St. Petersburg, Fla. due 1994.
- it *EXP*-1 is predicting negative third: and fourth-quarter growth.
- Grace said luxury-car sales increased 1.4% to 221.61 billion yen -LRB- $ 188.2 -RRB-, from $ 234.4 million a share, or $ 9.6 million, a year earlier.
- But AGIP already has been group vice president for such a gizmo at Texas Air.
- And when other rules are safeguarded *-232 by the Appropriations Committee *T*-1, the White House passed a $ 1.5765 billion loan market-revision bill providing the first construction funds for the economy's ambitious radio station in fiscal 1990 and incorporating far-reaching provisions affecting the erratic copper market.
- The urging also has yet opened in September in September.
- But Mr. Lorenzo is *-1 to elaborate on the latest reports of the line.
Some Related Rules

• $\text{NAC} \rightarrow \text{NNP} \ , \ \text{NNP} \ \text{NNP} \quad 0.002463$
• $\text{NAC} \rightarrow \text{JJ} \ \text{NNP} \ , \ \text{NNP} \ , \quad 0.002463$
• $\text{NAC} \rightarrow \text{NNP} \ , \ \text{NNP} \ \text{NNP} \ , \quad 0.002463$
• $\text{NAC} \rightarrow \text{NNP} \ \text{CD} \ , \ \text{CD} \ , \quad 0.002463$
• $\text{NAC} \rightarrow \text{NNP} \ \text{NNP} \ \text{NNP} \ , \ \text{NNP} \ , \quad 0.002463$
• $\text{NAC} \rightarrow \text{NNP} \ \text{NNP} \ , \ \text{NNP} \quad 0.004926$
• $\text{NAC} \rightarrow \text{NNP} \ \text{NNP} \ \text{NNPS} \ , \ \text{NNP} \ , \quad 0.007389$
• $\text{NAC} \rightarrow \text{NNP} \ , \ \text{NNP} \quad 0.019704$
• $\text{NAC} \rightarrow \text{NNP} \ , \ \text{NNP} \ \text{CD} \ , \ \text{CD} \ , \quad 0.024631$
• $\text{NAC} \rightarrow \text{NNP} \ \text{NNP} \ , \ \text{NNP} \ , \quad 0.125616$
• $\text{NAC} \rightarrow \text{NNP} \ , \ \text{NNP} \ , \quad 0.374384$
Bigram Model for NAC
Lexicalized Rules
Markovizing Lexicalized Rules

\[
\text{VP+dumped+VBD} \rightarrow \text{VBD+dumped+VBD} \\
\quad p(\text{Heir} = \text{VBD+dumped+VBD} \mid \text{Parent} = \text{VP+dumped+VBD})
\]

\[
\text{VP+dumped+VBD} \rightarrow ^\wedge \text{VBD+dumped+VBD} \\
\quad p(\text{left-stop} \mid \text{Parent} = \text{VP+dumped+VBD}, \text{Heir} = \text{VBD+dumped+VBD})
\]

\[
\text{VP+dumped+VBD} \rightarrow ^\wedge \text{VBD+dumped+VBD} \text{NP+sacks+NNS} \\
\quad p(\text{RightChild} = \text{NP+sacks+NNS} \mid \text{Parent} = \text{VP+dumped+VBD}, \text{Heir} = \text{VBD+dumped+VBD})
\]

\[
\text{VP+dumped+VBD} \rightarrow ^\wedge \text{VBD+dumped+VBD} \text{NP+sacks+NNS PP+into+P} \\
\quad p(\text{RightChild} = \text{PP+into+P} \mid \text{Parent} = \text{VP+dumped+VBD}, \text{Heir} = \text{VBD+dumped+VBD})
\]

\[
\text{VP+dumped+VBD} \rightarrow ^\wedge \text{VBD+dumped+VBD} \text{NP+sacks+NNS PP+into+P} $ \\
\quad p(\text{right-stop} \mid \text{Parent} = \text{VP+dumped+VBD}, \text{Heir} = \text{VBD+dumped+VBD})
\]
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Dependency vs Constituent

![Dependency](image1.png) ![Constituency](image2.png)

By Tjo3ya – Own Work – CC by SA 3.0 via Wikipedia
Dependency Trees

• Links between heads and their dependents
  – Head is a Linguistic notion
  – Sort of “most important part”

• Only one head, acyclic

• Why?
  – Can be simpler to parse
  – Can be simpler for later ML processes
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• CT -> DT easier than DT -> CT
What is the head?

• Auxiliaries or main verbs?
  – I have written a letter.

• Prepositions or nouns?
  – A picture of my son

• Clause-initial elements? (Complementizers)
  – Who yawned?
  – I wonder which people yawned.
  – The student who yawned.
  – I think that the student yawned.

• Parts, kinds, and quantities?
  – I drank a cup of tea.
  – I drank a kind of tea.
  – I talked to a number of people.
Which word is the head?

- Lexical words
  - the book
  - at school
  - has yawned

- Function words
  - the book
  - at school
  - has yawned

- Open class: you can make up new nouns and verbs

- Closed class: you cannot make up new determiners, prepositions, or auxiliary verbs (although new ones can develop over time)

Stanford Dependency Parser provides two versions: lexical heads or functional heads
What you see most often in dependency treebanks

- the **book**
- at **school**
- The student **has** yawned
- The student has **yawned**
- very **tall**
- **that** the student yawned
- that the student **yawned**
  - As in “I think that the student yawned”
So what is the definition of “head”?

• The word that provides the main meaning:
  – “this smart student of linguistics with long hair” is a student, not a smart or a hair or a long, etc. So “student” is the head.

• The word that provides the most important inflectional features
  – Inflection includes things like tense, number, and gender
Which noun phrases are plural?

**Singular**
- The teacher
- The short teacher
- The teacher of the class
- The teacher of the classes
- The children’s teacher
- The child’s teacher

**Plural**
- The teachers
- The short teachers
- The teachers of the class
- The teachers of the classes
- The children’s teachers
- The child’s teachers

Only the head “teacher/teachers” determines whether the noun phrase is singular or plural. The other nouns “class/classes” and “child/children” do not make the noun phrase singular or plural.
Dependency Parsing

- Standard CFG (with Heads) plus CKY
  - But more computationally expensive
- Graph Algorithms
  - e.g. McDonald’s MSTParse (Maximum Spanning Tree)
- Constraint satisfaction
  - Create all links and remove them (Karlsson 1990)
- Or actual parse the dependencies
  - Nivre et al 2008: MaltParser
- Neural dependency parses (Chen & Manning 2014)
Dependency Parsing

• Parse left to right
  – Make decisions about linking and shifting

• Use ML classifier to decide what to do
  – Condition on
    – Some lexical word links are more common [ chair -> the]
    – Dependency distance: mostly short links
    – Intervening material: rarely span over verbs, punc
    – Valency of heads: number of expect dependents of a head
Dependency Tree

ROOT Discussion of the outstanding issues was completed.
Ze hadden languit naast elkaar op de strandstoelen kunnen gaan liggen.
Other Grammar Formalisms
TAG: Substitution

- we thought
- we thought
we thought

that Alice would write a review
we thought that Alice would write a review
Bill bought a new house.

Hillary decided to run after buying a new house.
Bill bought a new house after Hillary decided to run.
Unification-Based Grammars

- \( S \rightarrow NP \ VP \)
  \[ [NP \ NUMBER] = [VP \ NUMBER] \]
- \( \text{Det} \rightarrow \text{these} \)
  \[ [\text{Det} \ NUMBER] = \text{plural} \]
- \( \text{MD} \rightarrow \text{does} \)
  \[ [\text{MD} \ NUMBER] = \text{singular} \]
  \[ [\text{MD} \ \text{PERSON}] = \text{third} \]
Categorial Grammar (CCG)

• 5 rules
• \(A/B + B = A\)
• \(B + A\backslash B = A\)
• \(A/B + B/C = A/C\)
• \(A \text{ CONJ } A' = A\)
• \(A = X/(X\backslash A)\)
• But the lexical items become more complex
Categorial Grammar (CCG)

John = np
Mary = np
likes = (s\np)/np

Forward application
X/Y Y => X
Backward application
Y X\Y => X

Thus
John   likes   Mary
np   (s\np)/np   np
           -------- Forward
           s\np
           -------- Backward
           s
Categorial Grammar (CCG)

a, the np/n
old n/n
in (np\np)/np
man, ball, park n
kicked (s\np)/np

the old man kicked a ball in the park
np/n n/n n (s\np)/np np/n n (np\np)/np np np/n n

n np
np
np

np
np

np

s\np

s
Advanced Grammars

• Standard CFG
• Lexicalized Grammars
• Other formalisms
  – Tree Adjoining Grammars
  – Unification Grammars
  – Categorial Grammars