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

- $NAC \rightarrow NNP, NNP$ $NNP$ $0.002463$
- $NAC \rightarrow JJ NNP, NNP,$ $0.002463$
- $NAC \rightarrow NNP, NNP NNP,$ $0.002463$
- $NAC \rightarrow NNP CD, CD,$ $0.002463$
- $NAC \rightarrow NNP NNP NNP, NNP,$ $0.002463$
- $NAC \rightarrow NNP NNP, NNP,$ $0.004926$
- $NAC \rightarrow NNP NNPS, NNP,$ $0.007389$
- $NAC \rightarrow NNP NNP$, $NNP$ $0.019704$
- $NAC \rightarrow NNP, NNP$ $CD, CD,$ $0.024631$
- $NAC \rightarrow NNP NNP, NNP,$ $0.125616$
- $NAC \rightarrow NNP, NNP,$ $0.374384$
Bigram Model for NAC
Lexicalized Rules
Markovizing Lexicalized Rules

\[
\begin{align*}
\text{VP+dumped+VBD} & \rightarrow \text{VBD+dumped+VBD} \\
p(\text{Heir} = \text{VBD+dumped+VBD} \mid \text{Parent} = \text{VP+dumped+VBD})
\end{align*}
\]

\[
\begin{align*}
\text{VP+dumped+VBD} & \rightarrow ^{\text{VBD+dumped+VBD}} \\
p(\text{left-stop} \mid \text{Parent} = \text{VP+dumped+VBD}, \text{Heir} = \text{VBD+dumped+VBD})
\end{align*}
\]

\[
\begin{align*}
\text{VP+dumped+VBD} & \rightarrow ^{\text{VBD+dumped+VBD}} \text{NP+sacks+NNS} \\
p(\text{RightChild} = \text{NP+sacks+NNS} \mid \text{Parent} = \text{VP+dumped+VBD}, \text{Heir} = \text{VBD+dumped+VBD})
\end{align*}
\]

\[
\begin{align*}
\text{VP+dumped+VBD} & \rightarrow ^{\text{VBD+dumped+VBD}} \text{NP+sacks+NNS} \text{PP+into+P} \\
p(\text{RightChild} = \text{PP+into+P} \mid \text{Parent} = \text{VP+dumped+VBD}, \text{Heir} = \text{VBD+dumped+VBD})
\end{align*}
\]

\[
\begin{align*}
\text{VP+dumped+VBD} & \rightarrow ^{\text{VBD+dumped+VBD}} \text{NP+sacks+NNS} \text{PP+into+P} \$
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\end{align*}
\]
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Dependency vs Constituent

We are trying to understand the difference.

Dependency

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Constituency (BPS)

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
Dependency Trees

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

NP  VP  S
   V   SBAR
  thought

NP  VP  S
 PRN  V   SBAR
  we  thought

NP  PRN
   we
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 the event happened.
Bill bought a new house after Hillary decided to run.
Unification-Based Grammars

- \( S \rightarrow NP \ VP \)
  
  \([NP \ \text{NUMBER}] = [VP \ \text{NUMBER}]\)

- \( \text{Det} \rightarrow \text{these} \)
  
  \([\text{Det} \ \text{NUMBER}] = \text{plural}\)

- \( \text{MD} \rightarrow \text{does} \)
  
  \([\text{MD} \ \text{NUMBER}] = \text{singular}\)
  
  \([\text{MD} \ \text{PERSON}] = \text{third}\)
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

\[
\begin{array}{ccc}
\text{John} & \text{likes} & \text{Mary} \\
np & (s\np)/np & np \\
\end{array}
\]

\[
\begin{array}{cc}
\text{------------ Forward} & \\
s\np & \\
\text{------------ Backward} & \\
s & \\
\end{array}
\]
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/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