Advanced PCFG Models

Sara Stymne

Syntactic Parsing
2022

Slides partly from Joakim Nivre

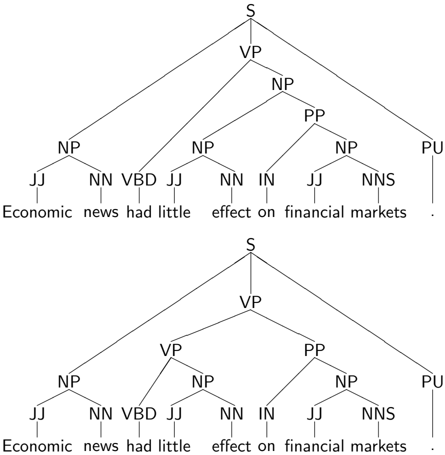
1. Problems with Treebank PCFGs
2. Parent Annotation
3. Lexicalization
4. Latent Variables
5. Other Parsing Frameworks

Lack of Sensitivity to Structural Context

Tree Context	NP PP	DT NN	PRP
Anywhere	11%	9%	6%
NP under S	9%	9%	21%
NP under VP	23%	7%	4%

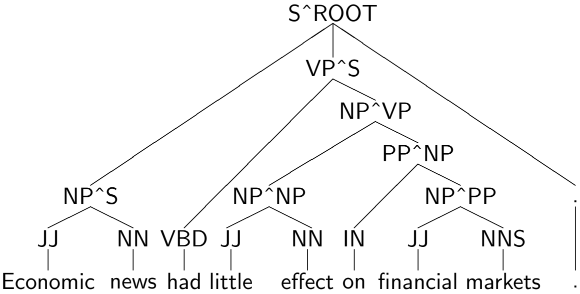
Lack of Sensitivity to Lexical Information

S	→	NP VP PU	1.00
VP	→	VP PP	0.33
VP	→	VBD NP	0.67
NP	→	NP PP	0.14
NP	→	JJ NN	0.57
NP	→	JJ NNS	0.29
PP	→	IN NP	1.00
PU	→	.	1.00
JJ	→	Economic	0.33
JJ	→	little	0.33
JJ	→	financial	0.33
NN	→	news	0.50
NN	→	effect	0.50
NNS	→	markets	1.00
VBD	→	had	1.00
IN	→	on	1.00



Parent Annotation

Replace nonterminal A with A$\hat{}B$ when A is child of B.

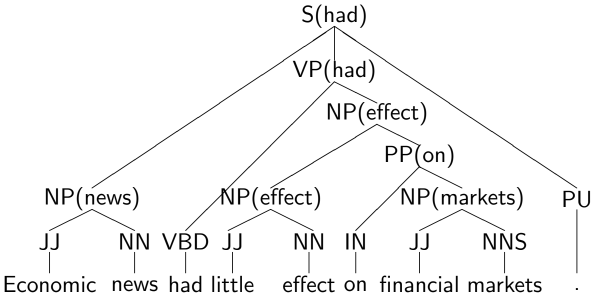


Lexicalization

Nonterminals: $N_{\text{lex}} = \{A(a) \mid A \in N, a \in \Sigma\}$

Rules: $A(a) \rightarrow \ldots B(a) \ldots$

$A(a) \rightarrow a$



Smoothing of the Lexicalized PCFG

$$
\begin{aligned}
q &= Q(\mathsf{A}(\mathsf{a}) \rightarrow \mathsf{B}(\mathsf{b})\ \mathsf{C}(\mathsf{a})) \\
&= P(\mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C}, \mathsf{b} \,|\, \mathsf{A}, \mathsf{a}) \\
&= P(\mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C} \,|\, \mathsf{A}, \mathsf{a}) \cdot P(\mathsf{b} \,|\, \mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C}, \mathsf{a})
\end{aligned}
$$

$$
\begin{aligned}
q_1 &= P(\mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C} \,|\, \mathsf{A}, \mathsf{a}) \\
&\approx \lambda \frac{\textsc{count}(\mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C}, \mathsf{a})}{\textsc{count}(\mathsf{A}, \mathsf{a})} + (1-\lambda) \frac{\textsc{count}(\mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C})}{\textsc{count}(\mathsf{A})}
\end{aligned}
$$

$$
\begin{aligned}
q_2 &= P(\mathsf{b} \,|\, \mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C}, \mathsf{a}) \\
&\approx \lambda \frac{\textsc{count}(\mathsf{b}, \mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C}, \mathsf{a})}{\textsc{count}(\mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C}, \mathsf{a})} + (1-\lambda) \frac{\textsc{count}(\mathsf{b}, \mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C})}{\textsc{count}(\mathsf{A} \rightarrow_2 \mathsf{B}\ \mathsf{C})}
\end{aligned}
$$

Non-lexicalized CKY Parsing

PARSE(G, x)
for j from 1 to n do
    for all $A : A \rightarrow x_j \in R$
        $\mathcal{C}[j-1, j, A] := Q(A \rightarrow x_j)$
for j from 2 to n do
    for i from $j-2$ downto 0 do
        for k from $i+1$ to $j-1$ do
            for all $A \rightarrow BC \in R$ and $\mathcal{C}[i,k,B] > 0$ and $\mathcal{C}[k,j,C] > 0$
                if $(\mathcal{C}[i,j,A] < Q(A \rightarrow B\ C) \cdot \mathcal{C}[i,k,B] \cdot \mathcal{C}[k,j,C])$ then
                    $\mathcal{C}[i,j,A] := Q(A \rightarrow B\ C) \cdot \mathcal{C}[i,k,B] \cdot \mathcal{C}[k,j,C]$
                    $\mathcal{B}[i,j,A] := (k, B, C)$
return BUILD-TREE($\mathcal{B}[0, n, S]$)

Lexicalized CKY Parsing

PARSE(G, x)
for j from 1 to n do
  for all A : $A(x_j) \rightarrow x_j \in R$
    $\mathcal{C}[j-1, j, j, A] := Q(A(x_j) \rightarrow x_j)$
for j from 2 to n do
  for i from $j-2$ downto 0 do
    for k from $i+1$ to $j-1$ do
      for h from $i+1$ to k do
        for m from $k+1$ to j do
          for all A : $A(x_h) \rightarrow B(x_h)C(x_m) \in R$ and $\mathcal{C}[i,k,h,B] > 0$ and $\mathcal{C}[k,j,m,C] > 0$
            if $(\mathcal{C}[i,j,h,A] < Q(A(x_h) \rightarrow B(x_h)C(x_m)) \cdot \mathcal{C}[i,k,h,B] \cdot \mathcal{C}[k,j,m,C])$ then
              $\mathcal{C}[i,j,h,A] := Q(A(x_h) \rightarrow B(x_h)C(x_m)) \cdot \mathcal{C}[i,k,h,B] \cdot \mathcal{C}[k,j,m,C]$
              $\mathcal{B}[i,j,h,A] := (k, B, h, C, m)$
      for h from $k+1$ to j do
        for m from $i+1$ to k do
          for all A : $A(x_h) \rightarrow B(x_m)C(x_h) \in R$ and $\mathcal{C}[i,k,m,B] > 0$ and $\mathcal{C}[k,j,h,C] > 0$
            if $(\mathcal{C}[i,j,h,A] < Q(A(x_h) \rightarrow B(x_m)C(x_h)) \cdot \mathcal{C}[i,k,m,B] \cdot \mathcal{C}[k,j,h,C])$ then
              $\mathcal{C}[i,j,h,A] := Q(A(x_h) \rightarrow B(x_m)C(x_h)) \cdot \mathcal{C}[i,k,m,B] \cdot \mathcal{C}[k,j,h,C]$
              $\mathcal{B}[i,j,h,A] := (k, B, m, C, h)$
return $\max_h \mathcal{C}[0, n, h, S]$, BUILD-TREE($\mathcal{B}[0, n, \text{argmax}_h\, \mathcal{C}[0, n, h, S], S]$)

Complexity

- Two extra loops in the algorithm, for the head of left and right trees
- Complexity is thus $O(n^5)$ instead of $O(n^3)$
- Too slow for many practical applications
- Pruning techniques often used
  - Means that we do not necessarily find the best tree, even given our model

Latent Variables

- Extract treebank PCFG
- Repeat k times:
    1. Split every nonterminal A into A_1 and A_2 (and duplicate rules)
    2. Train a new PCFG with the split nonterminals using EM
    3. Merge back splits that do not increase likelihood

Some Famous Parsers

	Par	Lex	Mark	Lat
Collins	+	+	+	−
Charniak	+	+	+	−
Stanford	+	−	+	−
Berkeley	+	−	+	+

Other Parsing Frameworks

- Shift-reduce parsing (transition-based)
  - Does not need a chart
  - Greedy
  - Linear time complexity
- Neural networks in parsing
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  - Typically gives better results

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- Shift-reduce parsing (transition-based)
  - Does not need a chart
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  - Can reduce independence assumptions
  - Typically gives better results
- The first seminar will cover a transition-based neural model

- Now: supervision with Paloma
  - Chomsky
  - Zoom (other Zoom link!)