ACS Introduction to NLP

Lecture 4: Search in Tagging and Introduction to Parsing

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Tagging: Why is there a search problem?

$$T^* = \arg\max_T P(T|W) = \arg\max_T P(W|T)P(T)$$

- Number of tag sequences for a sentence of length n is $O(T^n)$ where T is the size of the tagset
- OK, but why is there a non-trivial search problem?
  - e.g. for a unigram model we can just take the most probable tag for each word, an algorithm which runs in $O(nT)$ time

Tagging: Why is there a non-trivial search problem?

$$T^* = \arg\max_T P(T|W) = \arg\max_T P(W|T)P(T)$$

- But what about a bigram model?
- Intuition: suppose I have two competing tags for word w_i, t_i^1 and t_i^2
- Compare:

$$\text{Score}(t_i^1) = P(t_i^1|t_{i-1})P(w_i|t_i^1))$$
$$\text{Score}(t_i^2) = P(t_i^2|t_{i-1})P(w_i|t_i^2))$$

Suppose Score$(t_i^1) >$ Score(t_i^2); can we be sure t_i^1 is part of the highest scoring tag *sequence*?

Viterbi Algorithm

- Dynamic Programming (DP) algorithm, so requires the "optimal sub-problem property"
  - i.e. optimal solution to the complete problem can be defined in terms of optimal solutions to sub-problems
- So what are the sub-problems in this case?
  - intuition: suppose we want the optimal tag sequence ending at w_n, and we know the optimal sub-sequence ending at w_{n-1}, for all possible tags at w_{n-1}

Viterbi Algorithm (for a bigram tagger)

$$\delta_{t_j}(n+1) = \max_{t_i} \delta_{t_i}(n) P(t_i|t_j) P(w_i|t_i)$$

where $\delta_{t_j}(n+1)$ is the probability of the most probable tag sequence ending in tag t_j at position $n+1$

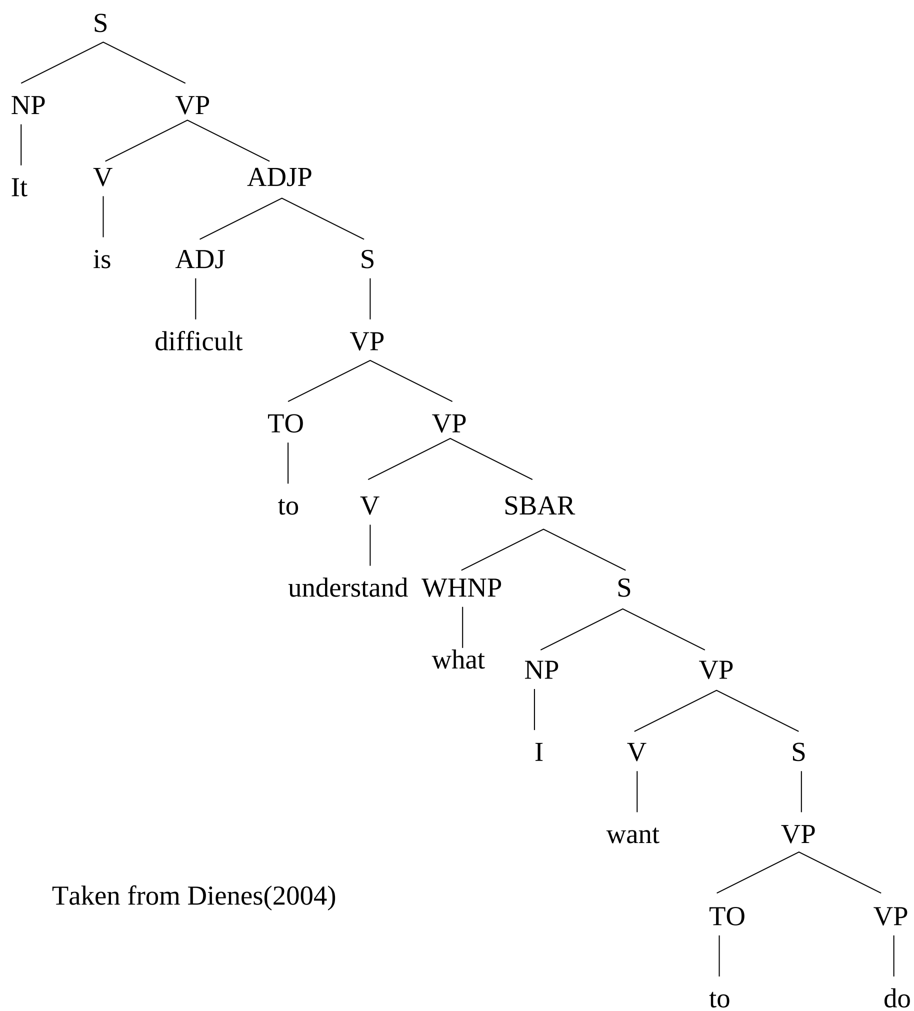
- Recursion bottoms out at position 1 in the sentence
- Most probable tag sequence can be obtained by following the recursion from the right backwards
- Time complexity is $O(T^2 n)$ where T is the size of the tagset

[See Chs. 9 and 10 of Manning and Schutze for a more rigorous presentation]

Practicalities

- Choice of tags to be assigned to a particular word usually governed by a “tag dictionary”
- Accuracy measured by taking a manually created “gold-standard” for a set of held-out test sentences
- Accuracy of POS taggers on newspaper data is over 97%, close to the upper bound represented by human agreement (and existence of noise in the data)
- Linear time process (in length of sentence) means tagging can be performed very fast, e.g. hundreds of thousands of words per second

Parsing - Phrase Structure Trees



Taken from Dienes(2004)

Parsing - Dependency Trees

- More direct representation of how the words in a sentence are related, in terms of (labelled) edges between words
- Currently a popular form of parsing:
  - interesting algorithmic and learning problems;
  - useful for applications;
  - applicable to all languages (including eg free word order languages)
  - theory-neutral (to a large extent)

[picture on board]

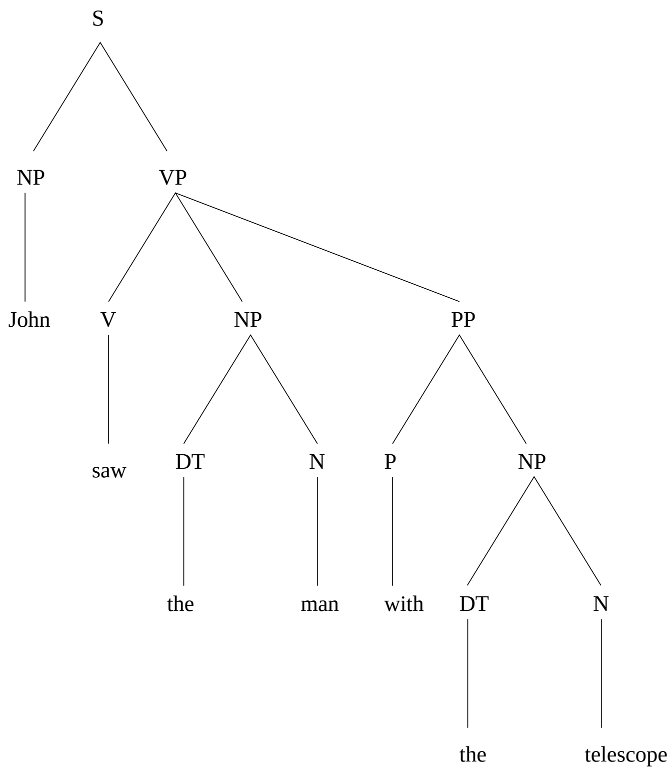
Characterisation of Parsing - 3 key questions

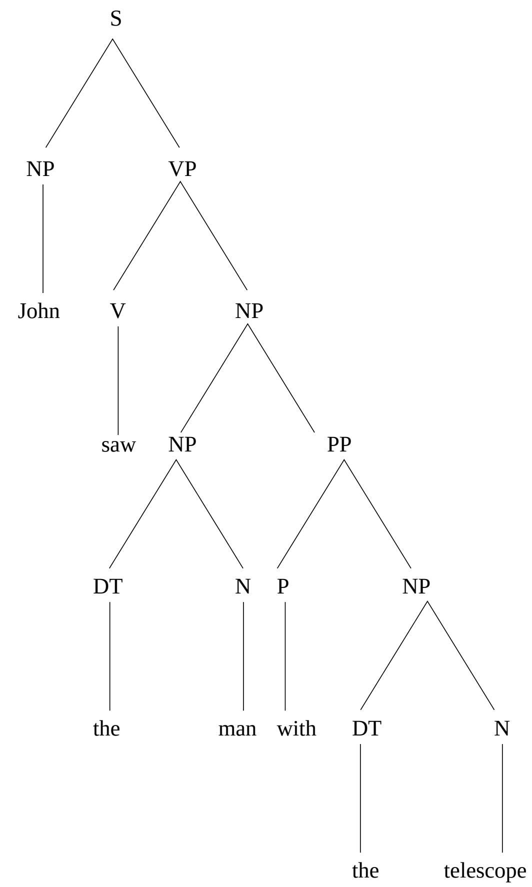
- What is the grammar of the natural language in question? Where does it come from?
- What is the algorithm which builds the possible parses for a sentence?
- What is the model for determining the plausibility of the parses (because there may be lots of alternatives)?

Why is Parsing Difficult?

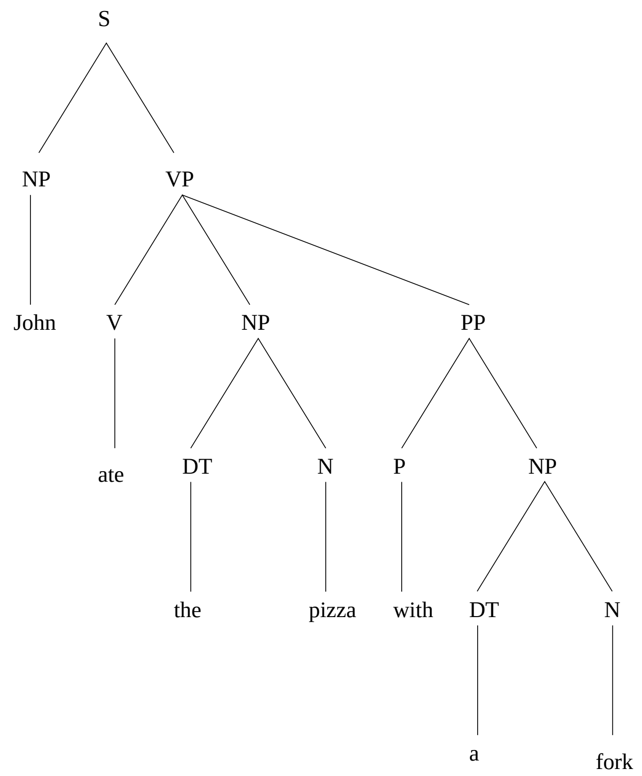
- Obtaining a *wide-coverage* grammar which can handle arbitrary real text is challenging
- Natural language is surprisingly **ambiguous**

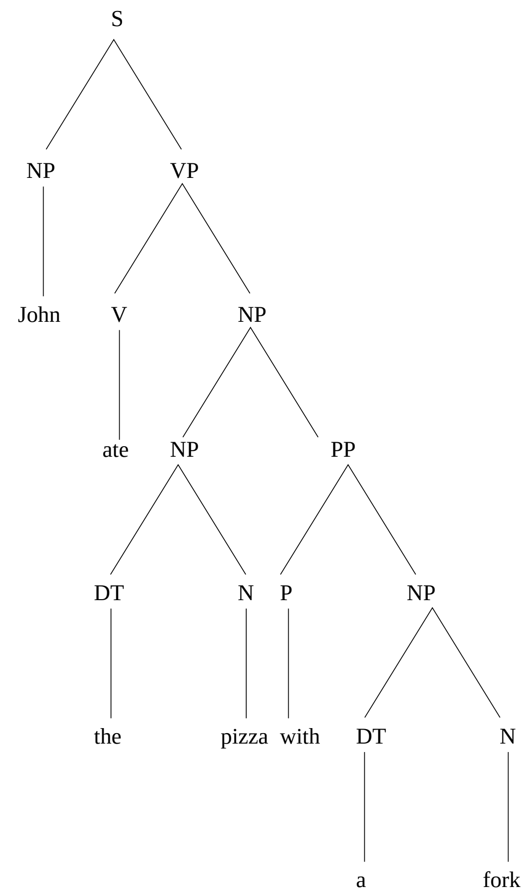
Syntactic Ambiguity





Syntactic Ambiguity: the problem is worse than you think





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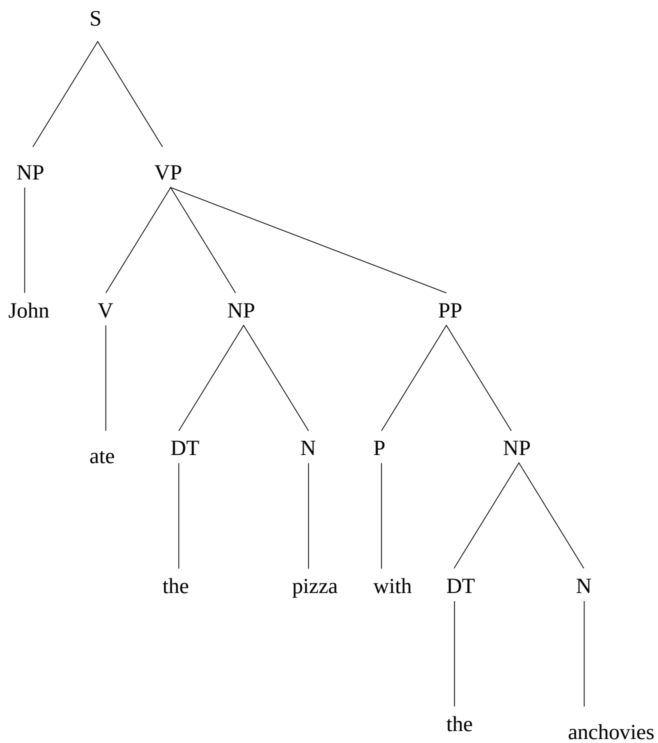

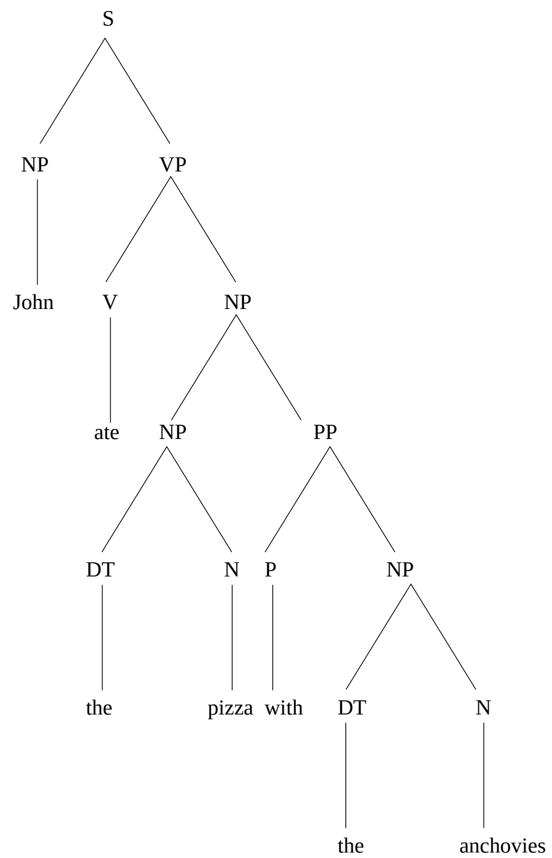

Syntactic Ambiguity: the problem is even worse than that

- Put the block in the box on the table 2 analyses
- Put the block in the box on the table beside the chair 5 analyses
- Put the block in the box on the table beside the chair before the table 14 analyses
- Put the block in the box on the table beside the chair before the table in the kitchen 42 analyses
- . . . 132 analyses
- . . . 469 analyses
- . . . 1430 analyses
- . . . 4862 analyses

Syntactic Ambiguity: the problem is even worse than that

- Previous sequence was the Catalan sequence; grows exponentially with the number of PPs
- Question: Ok, but we never see PPs stacked up like that in real sentences?
- Answer: but we do see other constructions with similar behaviour, eg coordination, and these various constructions stack up against each other

Syntactic Ambiguity: the problem is even worse than that

- Wider grammar coverage $\Rightarrow$ more analyses
- In practice this could mean millions (or more) of parses for a single sentence
  - difficult to imagine how productive these wide-coverage grammars can be without looking carefully at the output of a parser which uses one
- We need an efficient representation of this parse space
- And an efficient way to search it

[show crazy analysis from online demo]

Reading for Today's Lecture

- Chapters 9 and 10 of Manning and Schutze