# CMPT-413
# Computational Linguistics

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# Context Free Grammars and Ambiguity

$$
\begin{array}{lcl}
S & \rightarrow & NP\ VP \\
VP & \rightarrow & V\ NP \\
VP & \rightarrow & VP\ PP \\
PP & \rightarrow & P\ NP \\
NP & \rightarrow & NP\ PP \\
NP & \rightarrow & \textit{Calvin} \\
NP & \rightarrow & \textit{monsters} \\
NP & \rightarrow & \textit{school} \\
V & \rightarrow & \textit{imagined} \\
P & \rightarrow & \textit{in}
\end{array}
$$

What is the analysis using the above grammar for:
*Calvin imagined monsters in school*

# Context Free Grammars and Ambiguity

*Calvin imagined monsters in school*

```
(S (NP Calvin)
   (VP (V imagined)
       (NP (NP monsters)
           (PP (P in)
               (NP school)))))

(S (NP Calvin)
   (VP (VP (V imagined)
           (NP monsters))
       (PP (P in)
           (NP school))))
```

Which one is more plausible?

# Ambiguity Kills (your parser)

*natural language learning course*
(run demos/parsing-ambiguity.py)

```
((natural language) (learning course))
(((natural language) learning) course)
((natural (language learning)) course)
(natural (language (learning course)))
(natural ((language learning) course))
```

- Some difficult issues:
  - Which one is more plausible?
  - How many analyses for a given input?
  - Computational complexity of parsing language

# Treebanks

- What is the CFG that can be extracted from this single tree:

```
(S    (NP (Det the) (NP man))
      (VP  (VP  (V played)
                (NP (Det a) (NP game)))
           (PP  (P with)
                (NP (Det the) (NP dog)))))
```

# PCFG

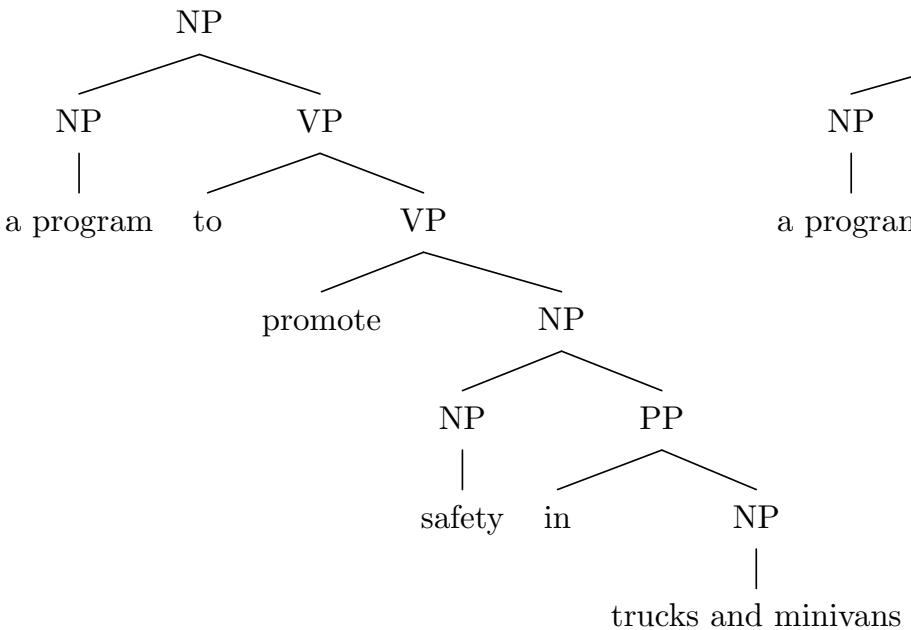
$$
\begin{array}{lcll}
S & \rightarrow & NP\ VP & c = 1 \\
NP & \rightarrow & Det\ NP & c = 3 \\
NP & \rightarrow & man & c = 1 \\
NP & \rightarrow & game & c = 1 \\
NP & \rightarrow & dog & c = 1 \\
VP & \rightarrow & VP\ PP & c = 1 \\
VP & \rightarrow & V\ NP & c = 1 \\
PP & \rightarrow & P\ NP & c = 1 \\
Det & \rightarrow & the & c = 2 \\
Det & \rightarrow & a & c = 1 \\
V & \rightarrow & played & c = 1 \\
P & \rightarrow & with & c = 1
\end{array}
$$

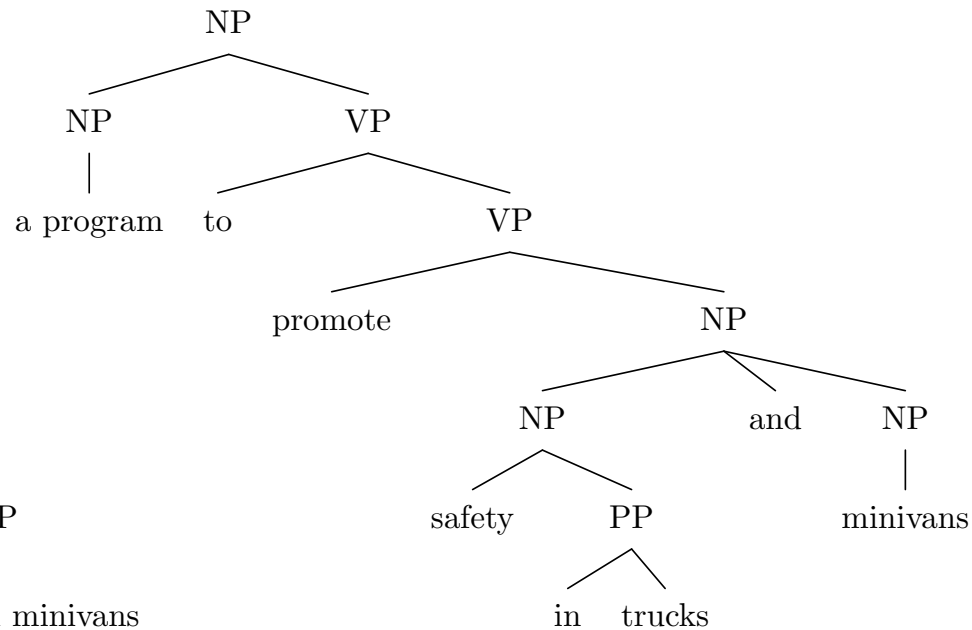
- We can do this with multiple trees. Simply count occurrences of CFG rules over all the trees.
- A repository of such trees labelled by a human is called a TreeBank.

# Ambiguity

- Part of Speech ambiguity
  `saw` → noun
  `saw` → verb
- Structural ambiguity: Prepositional Phrases
  `I saw (the man) with the telescope`
  `I saw (the man with the telescope)`
- Structural ambiguity: Coordination
  `a program to promote safety in ((trucks) and (minivans))`
  `a program to promote ((safety in trucks) and (minivans))`
  `((a program to promote safety in trucks) and (minivans))`

# Ambiguity ← attachment choice in alternative parses



# Ambiguity in Prepositional Phrases

- noun attach: *I bought the shirt with pockets*
- verb attach: *I washed the shirt with soap*
- As in the case of other attachment decisions in parsing: it depends on the meaning of the entire sentence – needs world knowledge, etc.
- Maybe there is a simpler solution: we can attempt to solve it using heuristics or associations between words

# Structure Based Ambiguity Resolution

- Right association: a constituent (NP or PP) tends to attach to another constituent immediately to its right (Kimball 1973)
- Minimal attachment: a constituent tends to attach to an existing non-terminal using the fewest additional syntactic nodes (Frazier 1978)
- These two principles make opposite predictions for prepositional phrase attachment
- Consider the grammar:

$$VP \rightarrow V\ NP\ PP \quad (1)$$

$$NP \rightarrow NP\ PP \quad (2)$$

for input: *I* $[_{VP}$ *saw* $[_{NP}$ *the man . . .* $[_{PP}$ *with the telescope* $]$, RA predicts that the PP attaches to the NP, i.e. use rule (2), and MA predicts V attachment, i.e. use rule (1)

# Structure Based Ambiguity Resolution

- Garden-paths look structural:
  *The emergency crews hate most is domestic violence*
- Neither MA or RA account for more than 55% of the cases in real text
- Psycholinguistic experiments using eyetracking show that humans resolve ambiguities as soon as possible in the left to right sequence using the words to disambiguate
- Garden-paths are caused by a combination of lexical and structural effects:
  *The flowers delivered for the patient arrived*

# Ambiguity Resolution: Prepositional Phrases in English

- Learning Prepositional Phrase Attachment: Annotated Data

| v | n1 | p | n2 | Attachment |
|---|---|---|---|---|
| join | board | as | director | V |
| is | chairman | of | N.V. | N |
| using | crocidolite | in | filters | V |
| bring | attention | to | problem | V |
| is | asbestos | in | products | N |
| making | paper | for | filters | N |
| including | three | with | cancer | N |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |

# Prepositional Phrase Attachment

| Method | Accuracy |
|---|---|
| Always noun attachment | 59.0 |
| Most likely for each preposition | 72.2 |
| Average Human (4 head words only) | 88.2 |
| Average Human (whole sentence) | 93.2 |

# Some other studies

- **Toutanova, Manning, and Ng, 2004**: 87.54% using some external knowledge (word classes)
- **Merlo, Crocker and Berthouzoz, 1997**: test on multiple PPs
  - generalize disambiguation of 1 PP to 2-3 PPs
  - 14 structures possible for 3PPs assuming a single verb
  - all 14 are attested in the Penn WSJ Treebank
  - 1PP: 84.3%  2PP: 69.6%  3PP: 43.6%
  - **This experiment is still only part of the real problem faced in parsing English**
  - Other sources of ambiguity in other languages