

# Natural Language Processing HW5: Syntax and Parsing

Due Wednesday Nov 27 on Canvas

In this assignment you will

1. train a probabilistic context-free grammar (PCFG) from a treebank (need binarization);
2. build a simple CKY parser (which handles unary rules), and report its parsing accuracy on test data.

Download <http://classes.engr.oregonstate.edu/eecs/fall2019/cs539-001/hw5/hw5-data.tgz>:

*corpora:*

`train.trees` training data, one tree per line  
`test.txt` test data, one sentence per line  
`test.trees` gold-standard trees for the test data (for evaluation)

*scripts:*

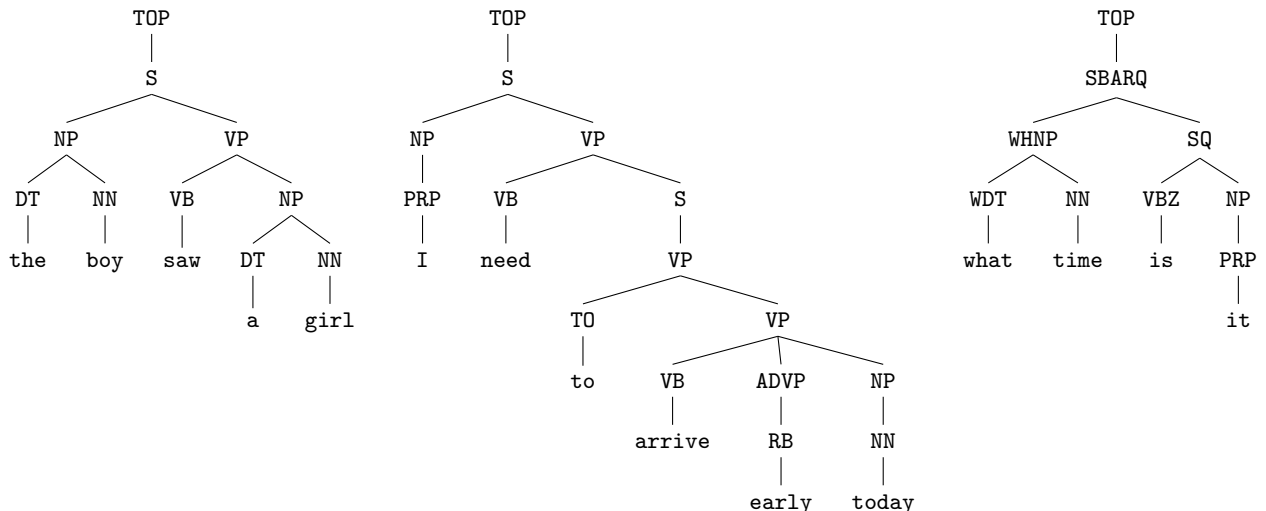
`tree.py` Tree class and reading tool  
`evalb.py` evaluation script

## 1 Learning a grammar (50 pts)

The file `train.trees` contains a sequence of trees, one per line, each in the following format:

```
(TOP (S (NP (DT the) (NN boy)) (VP (VB saw) (NP (DT a) (NN girl))))))  
(TOP (S (NP (PRP I)) (VP (VB need) (S (VP (TO to) (VP (VB arrive) (ADVP (RB early)) (NP (NN today))))))))))  
(TOP (SBARQ (WHNP (WDT what) (NN time)) (SQ (VBZ is) (NP (PRP it)))))
```

**N.B.** `tree.py` provides tools for you to read in these trees from file (building a `Tree` object from a string).



Note that these examples are interesting because they demonstrate

- unary rules on preterminals (POS tags) like `NP -> PRP` and `NP -> NN`;

- unary rules on nonterminals (constituents) like  $S \rightarrow VP$  and  $TOP \rightarrow S$ ;
- ternary rules like  $VP \rightarrow VB\ ADVP\ NP$  (so that you need binarization).
- NP can have (at least) three roles: subject (**the boy**), object (**a girl**), and temporal-adverbial (**today**). The Penn Treebank does annotate these roles (e.g., NP-SBJ, NP-TMP), but for simplicity reasons we removed them for you.
- a sentence can be a declarative sentence (S) or a wh-question (SBARQ), among others.

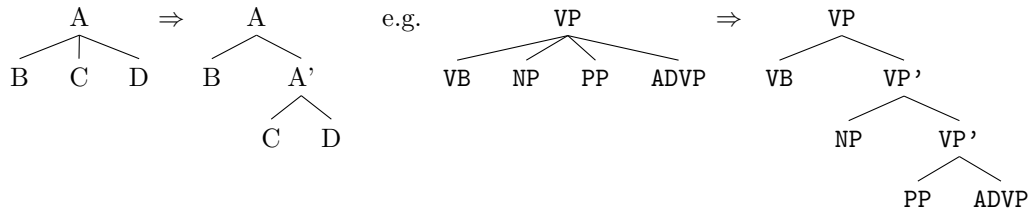
Your job is to learn a probabilistic context-free grammar (PCFG) from these trees.

Q1.a Preprocessing: replace all one-count words (those occurring only once, *case-sensitive*) with `<unk>`:

```
cat train.trees | python replace_onecounts.py > train.trees.unk 2> train.dict
```

where `train.trees.unk` is the resulting trees with `<unk>` symbols, and `train.dict` is a file of words which appear more than once (one word per line). **Explain why we do this.**

Q1.b Binarization: we binarize a non-branching tree (recursively) in the following way:



```
cat train.trees.unk | python binarize.py > train.trees.unk.bin
```

What are the properties of this binarization scheme? Why we would use such a scheme? (What are the alternatives, and why we don't use them?)

Is this binarized CFG in Chomsky Normal Form (CNF)?

Q1.c Learn a PCFG from trees:

```
cat train.trees.unk.bin | python learn_pcfg.py > grammar.pcfg.bin
```

The output `grammar.pcfg.bin` should have the following format:

```
TOP
TOP -> S # 1.0000
S -> NP VP # 0.8123
S -> VP # 0.1404
VP -> VB NP # 0.3769
VB -> saw # 0.2517
...
```

where the first line (`TOP`) denotes the start symbol of the grammar, and the number after `#` in each rule is its probability, with four digits accuracy.

We group rules into three categories: binary rules ( $A \rightarrow B\ C$ ), unary rules ( $A \rightarrow B$ ), and lexical rules ( $A \rightarrow w$ ). How many rules are there in each group?

## 2 CKY Parser (70 pts)

Now write a CKY parser that takes a PCFG and a test file as input, and outputs, for each sentence in the test file, the best parse tree in the grammar. For example, if the input file is

```
the boy saw a girl
I need to arrive early today
```

the output (according to some PCFG) could be:

```
(TOP (S (NP (DT the) (NN boy)) (VP (VB saw) (NP (DT a) (NN girl))))))
(TOP (S (NP (PRP I)) (VP (VB need) (S (VP (TO to) (VP (VB arrive) (ADVP (RB early)) (NP (NN today))))))))))
```

Q2.a Design a toy grammar `toy.pcfg` and its binarized version `toy.pcfg.bin` such that the above two trees are indeed the best parses for the two input sentences, respectively. **How many strings do these two grammars generate?**

Q2.b Write a CKY parser. Your code should have the following input-output protocol:

```
cat toy.txt | python cky.py toy.pcfg.bin > toy.parsed
```

Verify that you get the desired output in `toy.parsed`. **Note that your output trees should be debinarized (see examples above).**

Q2.c Now that you passed the toy testcase, apply your CKY parser to the real test set:

```
cat test.txt | python cky.py grammar.pcfg.bin > test.parsed
```

Your program should handle (any levels of) **unary rules** correctly, even if there are unary cycles.

How many sentences failed to parse? Your CKY code should simply output a line

NONE

for these cases (so that the number of lines in `test.parsed` should be equal to that of `test.txt`). What are main reasons of parsing failures?

Q2.d Now modify your parser so that it first replaces words that appear once or less in the training data:

```
cat test.txt | python cky.py grammar.pcfg.bin train.dict > test.parsed.new
```

Note that:

- `train.dict` should be treated as an **optional** argument: your CKY code should work in either case! (and please submit only **one version** of `cky.py`).
- your output tree, however, should use the original words rather than the `<unk>` symbol. Like binarization, it should be treated as internal representation only.

Now how many sentences fail to parse?

Q2.e Evaluate your parsing accuracy by

```
python evalb.py test.parsed test.trees
python evalb.py test.parsed.new test.trees
```

Report the labeled precisions, recalls and F-1 scores of the two parsing results. Do their differences make sense?