COMP 6721 - Artificial Intelligence
Natural Language Processing

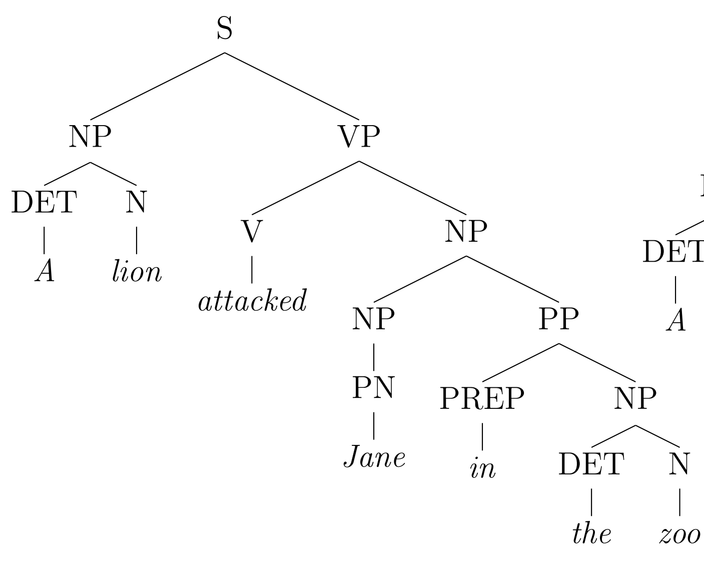
Solutions

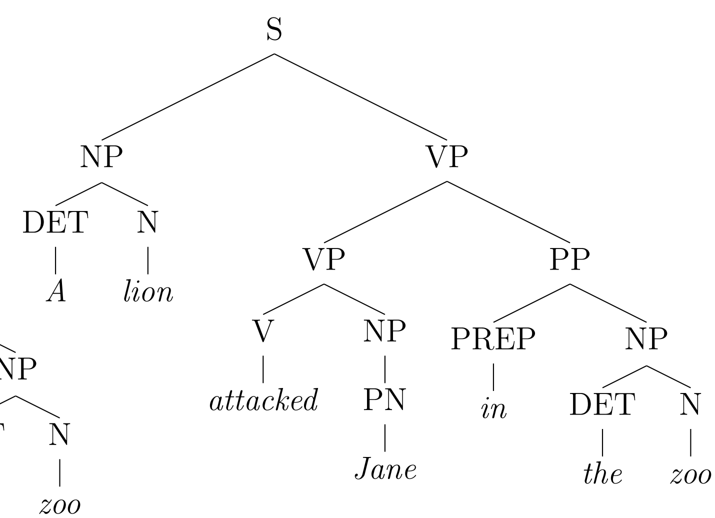
Question 1 Consider the following context-free grammar:

S → NP VP	N → lion
VP → V	N → knife
VP → V NP	N → zoo
VP → VP PP	V → attacked
NP → DET N	PN → Jane
NP → PN	DET → the
NP → NP PP	DET → a
PP → PREP NP	PREP → with
	PREP → in

(a) Generate all possible parse trees for the following sentences:

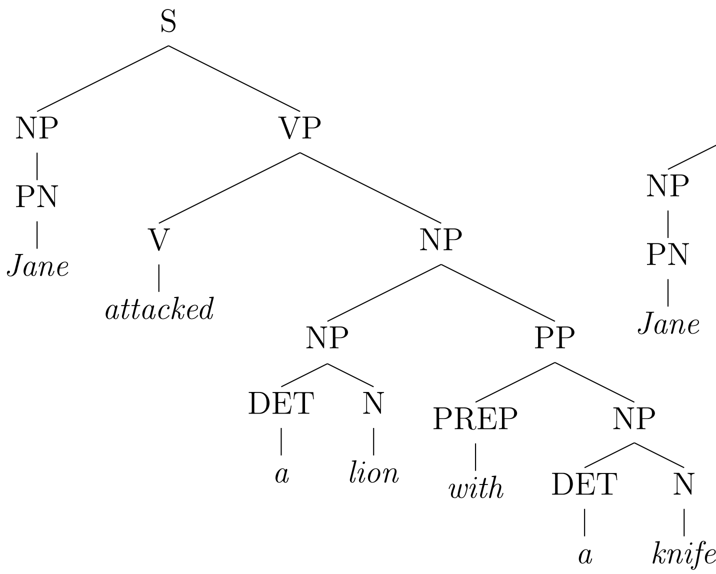
i *A lion attacked Jane in the zoo*
There are be two possible parse trees:

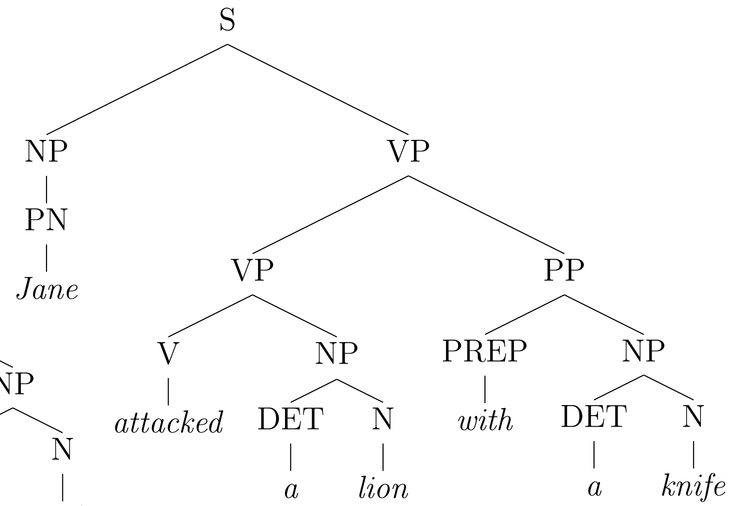




ii *Jane attacked a lion with a knife*

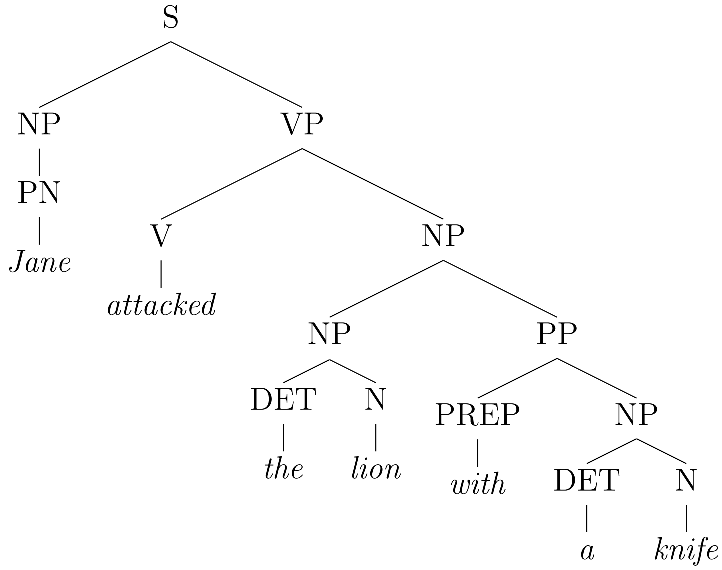
There are two possible parse trees:



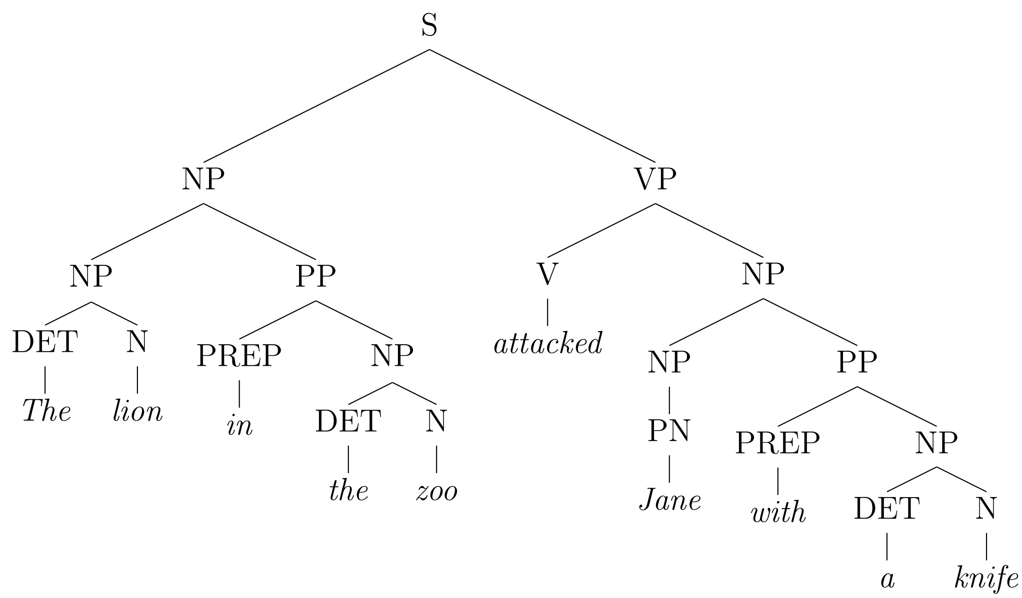


(b) Using the following parse trees as training set, generate a probabilistic context-free grammar.

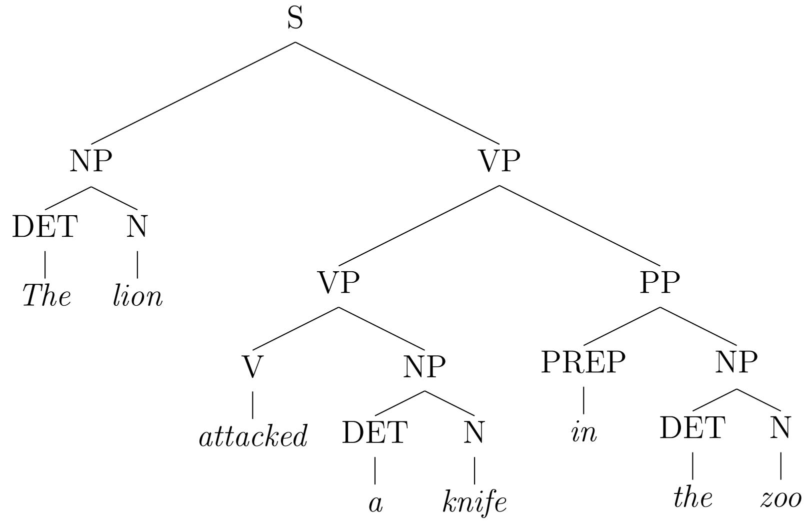
i. Jane attacked the lion with a knife



ii. The lion in the zoo attacked Jane with a knife



iii. The lion attacked a knife in the zoo



S → NP VP   Probability = 1

VP → V   Probability = 0
VP → V NP   Probability = 3/4 = 0.75
VP → VP PP   Probability = 1/4 = 0.25

NP → DET N   Probability = 8/13 = 0.62
NP → PN   Probability = 2/13 = 0.15
NP → NP PP   Probability = 3/13 = 0.23

PP → PREP NP   Probability = 1

N → lion   Probability = 3/8 = 0.375
N → knife   Probability = 3/8 = 0.375
N → zoo   Probability = 2/8 = 0.25

V → attacked   Probability = 1

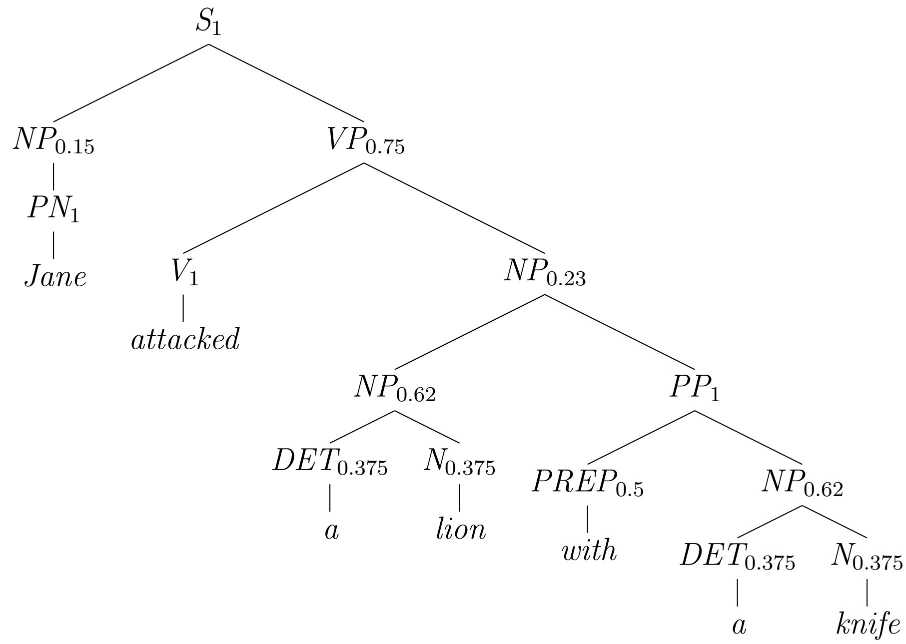
PN → Jane   Probability = 1

DET → the   Probability = 5/8 = 0.625
DET → a   Probability = 3/8 = 0.375

PREP → with   Probability = 2/4 = 0.50
PREP → in   Probability = 2/4 = 0.50

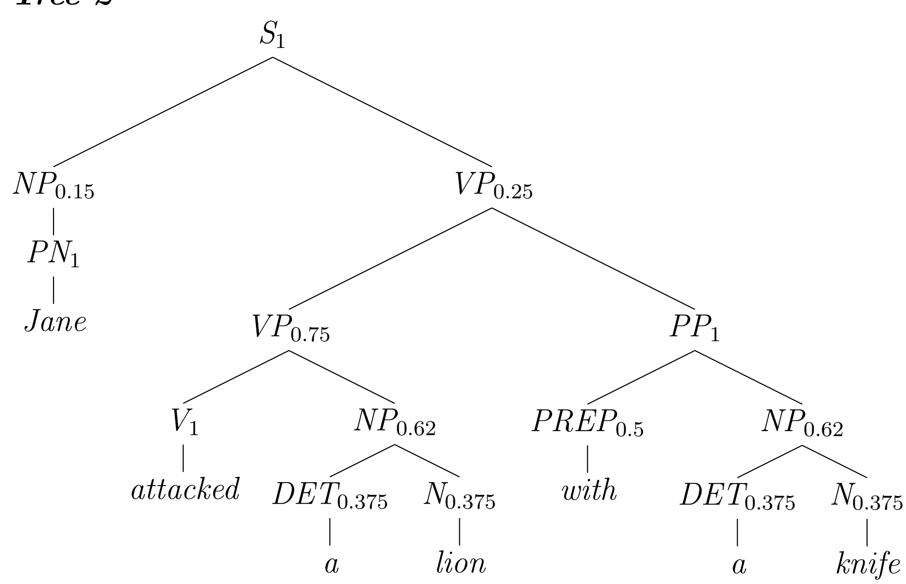
(c) Determine the most probable parse of sentence (a)ii above (*Jane attacked a lion with a knife*) using the PCFG from (b).

Tree 1



P(tree_1)$= 1 \times 0.15 \times 1 \times 0.75 \times 1 \times 0.23 \times 0.62 \times 0.375 \times 0.375 \times 1 \times 0.5 \times 0.62 \times 0.375 \times 0.375 = 9.83 \times 10^{-5}$

Tree 2



P(tree_2)$= 1 \times 0.15 \times 1 \times 0.25 \times 0.75 \times 1 \times 0.62 \times 0.375 \times 0.375 \times 1 \times 0.5 \times 0.62 \times 0.375 \times 0.375 = 1.07 \times 10^{-4}$

Thus Tree 2 is more probable.

Question 2 Consider the following sentences as training set for disambiguating the sense of the word *light*.

Sentence	Sense
There is a ray of light even if it is dim.	Sense1
This faint ray of light is barely enough to see.	Sense1
It needs to be light in weight to be portable.	Sense2
I can see dim red light coming from that room.	Sense1
This laptop is light enough to carry around.	Sense2
I am not hurt since I was hit by something as light as a candle.	Sense2
There is a faint hint of light at the end of the street.	Sense1
But the room was bright and light from the candle was warm as it fell on the surroundings.	Sense1
My bright red overcoat is light but fairly warm.	Sense2
This red candle stand is light enough to carry it to the room.	Sense2

Further consider this list of stop words:

a, and, are, as, at, be, for, from, in, is, it, if, of, that, this, the, to, was

Using a Naive Bayes approach with:

- a context window of ± 3 words,
- a vocabulary with the size of 31,
- smoothing with the value of 0.2, and
- stop-word removal

Calculate the scores of each possible sense and find the most probable sense of the word *light* in the following sentence:

In her dark red room, that dim light from the candle was warm enough.

~~In~~ her dark $\boxed{\textit{red}}$ $\boxed{\textit{room}}$, ~~that~~ $\boxed{\textit{dim}}$ ***light*** ~~from~~ ~~the~~ $\boxed{\textit{candle}}$ ~~was~~ $\boxed{\textit{warm}}$ $\boxed{\textit{enough}}$.

There ~~is~~ ~~a~~ ray ~~of~~ ***light*** even ~~if~~ ~~it~~ ~~is~~ $\boxed{\textit{dim}}$.

~~This~~ faint ray ~~of~~ ***light*** ~~is~~ barely $\boxed{\textit{enough}}$ ~~to~~ see.

~~It~~ needs ~~to~~ ~~be~~ ***light*** ~~in~~ weight ~~to~~ ~~be~~ portable.

I can see $\boxed{\textit{dim}}$ $\boxed{\textit{red}}$ ***light*** coming ~~from~~ ~~that~~ $\boxed{\textit{room}}$.

~~This~~ laptop ~~is~~ ***light*** $\boxed{\textit{enough}}$ ~~to~~ carry around.

I am not hurt since I ~~was~~ hit by something ~~as~~ ***light*** ~~as~~ ~~a~~ $\boxed{\textit{candle}}$.

There ~~is~~ ~~a~~ faint hint ~~of~~ ***light*** ~~at~~ ~~the~~ end ~~of~~ ~~the~~ street.

But ~~the~~ $\boxed{\textit{room}}$ ~~was~~ bright ~~and~~ ***light*** ~~from~~ ~~the~~ $\boxed{\textit{candle}}$ ~~was~~ $\boxed{\textit{warm}}$ ~~as~~ ~~it~~ fell on ~~the~~ surroundings.

My bright $\boxed{\textit{red}}$ overcoat ~~is~~ ***light*** but fairly $\boxed{\textit{warm}}$.

~~This~~ $\boxed{\textit{red}}$ $\boxed{\textit{candle}}$ stand ~~is~~ ***light*** $\boxed{\textit{enough}}$ ~~to~~ carry ~~it~~ ~~to~~ ~~the~~ $\boxed{\textit{room}}$.

$P(\mathit{Sense1}) = 5/10 = 1/2 = 0.5$
$P(\mathit{Sense2}) = 5/10 = 1/2 = 0.5$

$$P(\mathit{red}|\mathit{Sense1}) = \frac{1+0.2}{25+(31\times 0.2)} = \frac{1.2}{31.2} = 0.038461538$$
$$P(\mathit{room}|\mathit{Sense1}) = \frac{2+0.2}{25+(31\times 0.2)} = \frac{2.2}{31.2} = 0.070512821$$
$$P(\mathit{dim}|\mathit{Sense1}) = \frac{2+0.2}{25+(31\times 0.2)} = \frac{2.2}{31.2} = 0.070512821$$
$$P(\mathit{candle}|\mathit{Sense1}) = \frac{1+0.2}{25+(31\times 0.2)} = \frac{1.2}{31.2} = 0.038461538$$
$$P(\mathit{warm}|\mathit{Sense1}) = \frac{1+0.2}{25+(31\times 0.2)} = \frac{1.2}{31.2} = 0.038461538$$
$$P(\mathit{enough}|\mathit{Sense1}) = \frac{1+0.2}{25+(31\times 0.2)} = \frac{1.2}{31.2} = 0.038461538$$

$$P(\mathit{red}|\mathit{Sense2}) = \frac{2+0.2}{23+(31\times 0.2)} = \frac{2.2}{29.2} = 0.075342466$$
$$P(\mathit{room}|\mathit{Sense2}) = \frac{1+0.2}{23+(31\times 0.2)} = \frac{1.2}{29.2} = 0.04109589$$
$$P(\mathit{dim}|\mathit{Sense2}) = \frac{0+0.2}{23+(31\times 0.2)} = \frac{0.2}{29.2} = 0.006849315$$
$$P(\mathit{candle}|\mathit{Sense2}) = \frac{2+0.2}{23+(31\times 0.2)} = \frac{2.2}{29.2} = 0.075342466$$
$$P(\mathit{warm}|\mathit{Sense2}) = \frac{1+0.2}{23+(31\times 0.2)} = \frac{1.2}{29.2} = 0.04109589$$
$$P(\mathit{enough}|\mathit{Sense2}) = \frac{2+0.2}{23+(31\times 0.2)} = \frac{2.2}{29.2} = 0.075342466$$

score(Sense1)
$= log(Sense1) + log(P(red|Sense1)) + log(P(room|Sense1)) + log(P(dim|Sense1) + log(P(candle|Sense1) + log(P(warm|Sense1) + log(P(enough|Sense1)$
$= log(0.5) + log(0.038461538) + log(0.070512821) + log(0.070512821) + log(0.038461538) + log(0.038461538) + log(0.038461538)$
$= -8.264387214$

score(Sense2)
$= log(Sense2) + log(P(red|Sense2)) + log(P(room|Sense2)) + log(P(dim|Sense2) + log(P(candle|Sense2) + log(P(warm|Sense2) + log(P(enough|Sense2)$
$= log(0.5) + log(0.075342466) + log(0.006849315) + log(0.04109589) + log(0.075342466) + log(0.04109589) + log(0.075342466)$
$= -8.606666574$

Since score(Sense1) > score(Sense2), ***Sense1*** *is more probable.*