REPORT

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1.

10 sentences:

the pickle ate a chief of staff .

the sandwich wanted the pickle under a sandwich under the president under every president on a pickle with every president under a president in every chief of staff with a sandwich on every chief of staff on a pickle with a perplexed president with every delicious sandwich on every pickle on every chief of staff under a floor on a sandwich with the chief of staff in every pickle .

a pickle understood every fine sandwich on a sandwich with a pickled president under a pickled president on the president under the chief of staff under the pickled floor on every president on a pickle with the sandwich in a sandwich under every floor under every floor with a sandwich under a pickle under a floor under a fine president in the fine chief of staff on a chief of staff with the pickled chief of staff with a fine sandwich in the fine floor under the pickle on a floor in a floor under a chief of staff on the pickle under every chief of staff with a floor in a pickle with a president under a delicious president under the chief of staff in every chief of staff under a sandwich with every fine floor with a sandwich on a sandwich under every pickled sandwich with the sandwich under the floor with a pickle in every perplexed chief of staff in the pickle on a floor under the president with the perplexed floor in every floor in the sandwich under a pickle with the chief of staff with every sandwich under a sandwich in a president on every pickle under every chief of staff with the pickled sandwich with the floor in the floor on every fine chief of staff in every floor with every chief of staff with every sandwich with the floor on every perplexed fine pickle with a fine president in every president with a president under a chief of staff under the sandwich in the floor under the chief of staff with the president in every floor in a perplexed president with every pickle under every pickle with every floor on the sandwich under the delicious pickle in a chief of staff under the pickle under a chief of staff on a president under a pickle with every pickle with a perplexed sandwich under a chief of staff under the president under every chief of staff with a perplexed president in a pickle in every floor with every pickle in the delicious president with every sandwich under the perplexed sandwich with every floor on every pickled pickle with every pickle under a fine chief of staff in every floor with every sandwich on a president with a sandwich in every floor with the chief of staff in the pickled chief of staff in a floor on the fine pickled sandwich on every pickle with every floor with a pickle on the pickle under every chief of staff under the pickle with every pickle on a president on the floor under the floor in every pickle with a floor in a pickle in the floor on the floor on every floor in a president with a perplexed perplexed pickle in the president on the floor on a sandwich in the pickled floor under every pickled chief of staff under the fine president on a sandwich in the pickle on every sandwich in a chief of staff on a delicious pickled fine floor under every president with a chief of staff with the floor on every president under every chief of staff under a sandwich

under the president on the sandwich with every sandwich with every chief of staff in the chief of staff in a chief of staff on every president in the president in a sandwich with a president with every president with every sandwich on every chief of staff in the sandwich with a president on the fine perplexed sandwich on a pickle with a president in a chief of staff on a sandwich under a floor in a delicious president under every floor on the chief of staff with a floor under a sandwich with a president with a pickled sandwich in the floor on every sandwich with a perplexed floor on a pickled pickle under a floor under every president in every perplexed sandwich in the fine pickle in every pickled floor in a president in every floor on the president on every pickled pickle in every floor in every floor with every president on every perplexed president in the chief of staff with the chief of staff in the president with a sandwich under the perplexed sandwich on the delicious pickle on a pickle in the fine president in the chief of staff under every president with a pickle under the chief of staff with the president with the sandwich in every president under the president on a floor under the chief of staff with every chief of staff under every floor with every pickled perplexed chief of staff under every delicious floor under every floor with every floor with the president on every president in the chief of staff with every sandwich with the pickle on a president in a delicious pickle in the pickle under every perplexed pickle on the president in the sandwich in the sandwich under every perplexed chief of staff under every delicious chief of staff under the chief of staff with every pickle in the chief of staff with a pickled pickle with a chief of staff under the floor with a floor under the floor under a pickle on the sandwich on every sandwich with a chief of staff on the floor under the chief of staff with the sandwich on the president with a chief of staff on the sandwich under the delicious sandwich in the president on the fine floor with a president on every president with the sandwich under the pickle with a pickled sandwich in the sandwich in the floor in the pickle under every floor on a pickle on the chief of staff in a perplexed president in the president with a president with a pickle with every delicious floor with every chief of staff on the president with the chief of staff with a delicious sandwich in the fine delicious perplexed pickle in a floor with a sandwich on the chief of staff with the pickle with a chief of staff under a sandwich on the sandwich in the pickle on the sandwich in the sandwich with every president under every pickle in every pickle in every pickled pickle in a perplexed president with every floor in every pickle on the fine chief of staff in a sandwich under every fine sandwich in the perplexed pickle on every floor on a president in the sandwich under a chief of staff in the chief of staff under a president on every president under a pickle under the sandwich in a chief of staff on a fine sandwich with the pickle in a president under the chief of staff in the sandwich under a sandwich on a sandwich on a pickle with the president in every president in a chief of staff with the floor on the chief of staff with every fine floor under every sandwich with a perplexed floor under every chief of staff under every floor with every sandwich in every president with the delicious president on a sandwich with a floor with every sandwich with a fine floor with every sandwich in a floor under a chief of staff in every president with a sandwich with a sandwich on every delicious president in every chief of staff with the chief of staff in every sandwich under every chief of staff under the floor with the pickle in every sandwich with a floor under the pickle under the chief of staff in the president on the chief of staff under the pickle with the sandwich under a pickle with the president with every president on the fine sandwich under every delicious chief of staff under the sandwich on every president in a pickled sandwich in the president in a pickled chief of staff under the floor in a sandwich with the president under the chief of staff on the pickle under every chief of staff in the

perplexed sandwich with every floor in every sandwich with every sandwich under a pickle with a floor with a chief of staff under the sandwich on every pickle in every sandwich in a president with the floor on every floor under a sandwich in a floor under every chief of staff under the pickle in every president on a president in every chief of staff with every chief of staff in the sandwich on every pickle with a sandwich under every pickled chief of staff on every sandwich in every chief of staff with the chief of staff under the chief of staff in a sandwich with the chief of staff in every chief of staff with every president under every chief of staff in a floor on every pickle under every chief of staff under a chief of staff in a fine floor in a president in a pickle on the president with every sandwich in the delicious pickled floor with every sandwich with the floor on the floor in a floor with a president with every sandwich with the chief of staff with the pickle in the pickled pickle with every pickle in a sandwich on a pickle under a pickle in a president with a floor under a floor with the chief of staff under every chief of staff under every fine chief of staff with every sandwich with a president under every pickled delicious sandwich on the pickle with a president in every floor on the chief of staff in a president with a delicious president under a floor on every chief of staff on the president in the president under a perplexed president under the chief of staff in every chief of staff in a pickle with every president on the delicious pickle on every pickle on the pickled sandwich in a fine president with a sandwich under the chief of staff in a chief of staff in the sandwich under every chief of staff with a sandwich under the president under every president in every chief of staff on every floor on the pickle on every perplexed floor under every president in every sandwich on the president on every floor with a delicious chief of staff with every pickled pickle under the president on the president on every pickle with the pickle on every pickle in every floor in a pickle on a president on every floor on the chief of staff under the sandwich on the sandwich in a chief of staff on every sandwich under every chief of staff in the pickle on the pickle in every chief of staff with every president under the delicious chief of staff under a floor under every perplexed president in the chief of staff in the pickle with every president on every pickle under the delicious pickle on the perplexed sandwich with a perplexed president under every president with a floor with the delicious chief of staff under the pickle with a pickle in the president on the chief of staff on the president in every pickle under every chief of staff in every president with every delicious fine delicious pickle in a sandwich under the chief of staff in the floor under a president under a pickled sandwich with every sandwich on every sandwich in a chief of staff on every chief of staff in every president with a chief of staff in every sandwich with a pickle in a president under a perplexed president on every floor under every pickle with a president with the floor in a sandwich with the chief of staff under a chief of staff on every pickle in every chief of staff in every fine pickle in a chief of staff with the floor under a president in every chief of staff in every chief of staff on every chief of staff on a president under every sandwich on a floor in the president with every pickled chief of staff with a chief of staff in a pickle on a pickle under a pickle with every chief of staff in a sandwich under a perplexed floor with the chief of staff in the sandwich with every perplexed perplexed president in the floor on every president with every fine president on every pickle with every delicious sandwich under a president under a chief of staff with a floor on a president with the president on a pickle on the pickle with every president with a chief of staff in a chief of staff in the president with every floor in a pickled floor with the pickled sandwich on the president in the fine pickle on every pickle on a pickle with a chief of staff in a president with a chief of staff with a sandwich on every president with the pickle with

every pickle with every fine pickled pickle in the sandwich in every president with the chief of staff on a floor on the president with a sandwich in every floor under a sandwich with a sandwich in the chief of staff in a floor with every floor in every president under every pickled fine president with every sandwich on a pickle in the floor on the floor in the floor in the pickle with the chief of staff in a president with a floor on every fine chief of staff under a chief of staff under a pickle in the president in a delicious pickled sandwich with every sandwich on every perplexed pickled chief of staff with the pickle in the chief of staff with every sandwich on every pickle on a floor in the chief of staff under every sandwich under a chief of staff with every chief of staff on a sandwich in a chief of staff under the sandwich in a chief of staff in a chief of staff with a delicious sandwich with every delicious floor on the sandwich with the chief of staff with a floor on the president .

is it true that a pickle under every chief of staff kissed a floor under every president on every chief of staff under every pickle ?

every chief of staff kissed a president !

the floor pickled a pickled pickle !

a pickle on the pickle pickled the pickle on every sandwich in a sandwich !

the sandwich kissed a floor with the chief of staff under the floor with a president !

a sandwich with every floor under the fine chief of staff with every pickled pickle with the floor kissed every chief of staff !

is it true that every pickle in every pickled president on the president in the pickle under a president on every floor under a pickle on the floor with the chief of staff in the perplexed floor under a president on the pickle in a sandwich in every sandwich with a president with a floor under the president in every president under every president on every floor in every president in every floor on a chief of staff with the president under every floor under the pickle in every pickled pickle kissed a floor on the perplexed president on a sandwich in every sandwich ?

2.

(a)
Very long sentences are generated because some rules are cyclic. For example,

1   NP   NP PP
1   PP   Prep NP

NP points to NP and PP,while PP points to Prep and NP. Thus, it will form a loop when generating the sentence according to those two rules, which may cause the sentence to be extremely long.

(b)

Multiple adjectives are allowed because there is a rule,"1　Noun　　Adj　Noun". Thus,　Noun points to Adj and Noun and the Noun in RHS can still points to Adj and Noun. So multiple adjectives are allowed. However, because any rule has the same probability of being chosen, and there are many other rules whose LHSs are Nouns too. For example, "1　Noun　　president", "1　Noun　　sandwich" and so on. Therefore, there is little chance that "1　Noun　　Adj Noun" can repeat multiple times,which means multiple adjectives happen rarely.

(d)

As for the problem in (a), in order to make the sentence shorter, we must decrease the weight of "1　NP　NP PP" which causes the loop when generating the sentence.

As for the problem in (b),in order to make the sentence have more adjectives, we must increase the weight of "1　Noun　　Adj Noun".

(e)

grammar2.gr:

the floor ate a fine sandwich .

the chief of staff wanted a chief of staff with the floor .

a floor wanted the delicious floor in a floor .

the floor wanted a pickle .

a floor wanted a fine pickled fine sandwich .

the fine president pickled a president !

the delicious floor wanted the sandwich .

the chief of staff pickled the fine president under the chief of staff in the floor !

a sandwich ate the sandwich .

the chief of staff ate every delicious fine floor .

3.

#Analysis:

#Firstly, I analyse the syntax of sentences (a)-(h) and express each sentence in the form of POS(part of speech) in order to #discover all syntaxes needed to generate sentences (a)-(h).

#Syntax:

#1 S(NP(Propernoun)+VP(Verb(Verb_transitive)+NP(Det+Noun)))

#2 S(NP(NP(proper noun)+coordinate conjunction+NP(Det+Noun))+VP(VP(Verb(Verb_transitive))+coordinate conjunction+VP(Verb(Verb_tansitive)+NP(Det+Noun))))

#3 S(NP(Det+Noun)+VP(Verb(Verb_intransitive)))

#4 S(NP(Det+Noun)+VP(Verb(Verb_with_complement))+that+S(NP(Det+Noun)+VP(Verb_intransitive)))

#5 S(NP(Pronoun)+VP(Verb_with_explanation+NP+that+S(NP(Det+Noun)+VP(Verb(Verb_transitive)+NP(Propernoun)))))

#6

S(NP(that+NP(Det+Noun)+VP(Verb(Verb_transitive)+NP(Propernoun)))+VP(Verb(Verb_transitive)
+NP(Det+Noun)))

#7 S(NP(Det+Adv(Adv+Adv)+Adj+Noun)+VP(Verb_transitive+NP(Det+Noun)))

#8

S(NP(Det+Noun)+VP(Verb_intransitive+PP(Prep+NP(NP(Det+Noun)+PP(Prep+NP(Det+Noun))))))

#Modifications:

#1 Verb is divided into Verb_trans,Verb_intrans,Verb_with_complement,Verb_with_explanation

#2 Use Conj to connect two Verb_trans

#3 Add Propernoun(proper noun)

#4 Add pronoun

#5 Add Adv

#6 Add new grammars needed to generate sentences (a)-(h)

10 sentences:

the very delicious pickle perplexed it .

it ate and ate it .

a desk worked .

a very very pickled pickled chief of staff perplexed every proposal that the chief of staff worked .

a desk sighed .

the floor understood that Sally ate a pickle .

the desk worked with a very pickled pickled delicious president .

Sally perplexed a desk that the pickle sighed on a floor .

every proposal sighed on a desk .

the pickled sandwich thought that it worked in it .

4.

5 Sentences:

```
(ROOT (S (NP (NP that
                (NP (Det the)
                    (Noun (Adj delicious)
                        (Noun (Adj pickled)
                            (Noun president))))
                (VP (Verb_with_complement thought)
                    that
                    (S (NP (Det a)
                            (Noun desk))
                        (VP (Verb_trans ate)
                            (NP (Det the)
                                (Noun sandwich))))))
            (PP (Prep with)
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                                (NP (Pronoun it))))
                    (VP (Verb_intrans worked)))
          .)
(ROOT (S (NP (Det the)
                (Noun president))
          (VP (Verb_with_explanation perplexed)
              (NP (Det the)
                    (Noun sandwich))
              that
              (S (NP (Det the)
                        (Noun president))
                  (VP (Verb_intrans sighed)
                      (PP (Prep in)
                          (NP (Det a)
                                (Noun pickle)))))))
          !)
(ROOT (S (NP (Det a)
                (Noun (Adj fine)
                        (Noun (Adj delicious)
                                (Noun pickle))))
          (VP (Verb_trans perplexed)
              (Conj and)
              (Verb_trans perplexed)
              (NP (Det the)
                    (Noun chief
                            of
                            staff))))
          .)
(ROOT (S (NP (Propernoun Sally))
          (VP (Verb_trans perplexed)
              (NP (Det a)
                    (Noun desk))))
          .)
(ROOT (S (NP (Det the)
                (Noun chief
                        of
                        staff))
          (VP (Verb_with_explanation perplexed)
              (NP (NP (Pronoun it))
                  (PP (Prep in)
                      (NP (Det a)
                            (Noun (Adj fine)
                                    (Noun proposal)))))
              that
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```
        (S (NP (Det the)
                (Noun (Adj delicious)
                        (Noun (Adj fine)
                                (Noun (Adj delicious)
                                        (Noun desk)))))
                (VP (Verb_with_explanation perplexed)
                        (NP (Det the)
                                (Noun president))
                        that
                        (S (NP (Det the)
                                (Adv very)
                                (Adj delicious)
                                (Noun sandwich))
                                (VP (Verb_intrans sighed)))))))
    .)
```

5.

```
(a) (ROOT (S (NP (NP (Det every) (Noun sandwich))
                (PP (Prev with)
                        (NP (NP (Det a)
                                (Noun pickle))
                                (PP (Prev on)
                                        (NP (Det the)
                                                (Noun floor))))))
                (VP (Verb wanted)
                        (NP (Det a)
                                (Noun president))))
        .)
```

(b) Yes. For the first derivation, the "on the floor" prepositional phrase is used to decorate the sandwich, while for the second one, we treat it combining "a pickle" together as a noun phrase. In this case, it means the pickle is on the floor not the sandwich.

6.

(a)
No, because some of the phrase can be generated within different process. For example, the

noun phrase "a sandwich with a pickle on the floor" can have different derivation. Just look at the order of preposition "with" and "on" 's generation. If "on" is the outer most preposition, this phrase can be treated as :

```
(NP (NP (NP (Det a)
            (Noun sandwich))
        (PP (Prep with)
            (NP (Det a)
                (Noun pickle))))
    (PP (Prep on)
        (NP (Det the)
            (Noun floor)))),
```

while if "with" is the outer most preposition, we can consider the noun phrase as:

```
(NP (NP (NP (Det a)
            (Noun sandwich)))
        (PP (Prep with)
            (NP (Det a)
                (Noun pickle))))
    (PP (Prep on)
        (NP (Det the)
            (Noun floor))))
```

(b)

5 ways. We can focus on the sequence of prepositions generation. If "with" is firstly generated, there are two orders which are {"with", "on", "under"} and {"with", "under", "on"}. Similarly, is we regard "under" as the first generated preposition, we can have two orders {"under", "on", "with"} and {"under", "with", "on"}. While if "on" is the first one, since "with" and "under" are in different sides of "on", they can not spring from the same NP. There is one order {"on", "with/under"}. So, the total number of ways is 2 + 2 + 1 = 5.

(c)

Eg. "the fine delicious pickled fine delicious president on a fine fine pickle and Sally understood that it sighed."

The number of ways of generation is 2. Since as for "and" the former NP can generate either "the fine delicious pickled fine delicious president on a fine fine pickle" or just "pickle".

Therefore, based on this example and that from last problem, we find when there are "and" and multiple prepositions, we can have different derivations. As for "and", if its former or latter noun phrase is complicated, the NP can be extended to either the simple noun or the complex noun phrase. For multiple prepositions, their generated order lead to different derivations.

(d)
1.
(1)

It is the sum of probability of all the ways to generate the sentence, each of which is the multiplication of branch's probability during expansion. Since for the branches generated by the same root, the probability is evenly distributed, the multiplication of them is small.

(2) Since there is only one way to generate this sentence, the probably of the sentence is equal to the best parser policy.

(3) P(best_parse, sentence) = P(best_parse), this is because if we have the best parse, it is able to generate the sentence. In other words, sentence includes all the events in best_parse. So P(best_parse | sentence) = P(best_parse, sentence) / P(sentence) = 1.

2.
If the sentence is generated, there are 50% chance we use the best_parser parse policy. Since there are two parsers that can get the sentence, and they are equally possible.

3.
-(log(p(sentence1) * p(sentence2))) / 18 = –(log(5.144032922e-05 * 1.240362877e-09) / 18 = -(-43.8333312 / 18) = 2.435

4.
2 ^(2.435)

5.
Since "the president ate ." cannot be generated. "ate" is a transitive verb which must be followed by a noun phrase. So the cross entropy here is: - (log(0) / 18) = positive infinity

(e)
(1)
Entropy(grammar2) = SUM(-log(p(words[i]))) / N
where words array is a list of all possible words existing in the grammar3 and N is the number of these words.
So Entropy(grammar2) = -log(5.018 * 10 -17) / 21 = 57.4 / 21 = 2.73

(2)
The Entropy of grammar 2 is greater than grammar 3, this is because the weight in grammar3 is distributed more evenly than grammar2. As a result, the probability product of all words for grammar3 is larger than grammar2. By calculating the negative log of the probability product, the entropy value of grammar2 is greater than that of grammar3.

(3)
Entropy(grammar) = -log(5.7 * 10 -4) / 21 = 43.99/21 = 2.095
We treat all kinds of words equally, but in fact for different kinds of words, they may appear with different probability.

(f)

True. Since both grammar3 and grammar distribute the weight more evenly that grammar2, which leads to a lower entropy for grammar2.

7.

I handled (a) and (c).

#Modifications:
#1 Add Det_vowel,Det_non_vowel,Det_other. Det_vowel is the determiner that must be used before a vowel word. Det_non_vowel is the determiner that must be used before non-vowel word.Det_other indicates other determiners.
#2 Add Noun_vowel,Noun_non_vowel
#3 Add Relative_clause ,VP_without_object

16 sentences:
every very delicious delicious proposal ate and wanted a pickled sandwich .
the delicious sandwich ate an apple .
the proposal and a very delicious apple that an apple perplexed that thought that it sighed perplexed the amazing amazing ear that the ear sighed in it .
it worked under every very elegent president .
the pickle perplexed and pickled the perplexed fine sandwich .
it perplexed the floor that every chief of staff ate every pickle .
the chief of staff understood that the island perplexed it that a very amazing island wanted every ear .
the fine president that perplexed the apple that the apple perplexed it that that a delicious desk pickled and wanted the president perplexed the island that the pickle pickled and wanted every pickle that ate it understood that the pickle worked .
the very amazing pickle perplexed Sally that Sally wanted every chief of staff !
a very very very delicious proposal perplexed every ear that the island perplexed and ate an ear .
it perplexed the ear that the ear sighed .
the apple sighed .
every very elegent apple worked .
the very fine delicious desk worked .
the very very pickled elegent amazing apple that a president perplexed ate a very very very delicious floor !
the apple perplexed a very amazing sandwich .

8.

I added imperative sentences into my grammar.

#Modifications:
Add VP_imperative,Verb_present

6 sentences:

the apple wanted it .

open Sally .

Sally understood that the very amazing island perplexed the amazing ear !

it ate and perplexed an elegent amazing island .

eat the sandwich .

come the floor .