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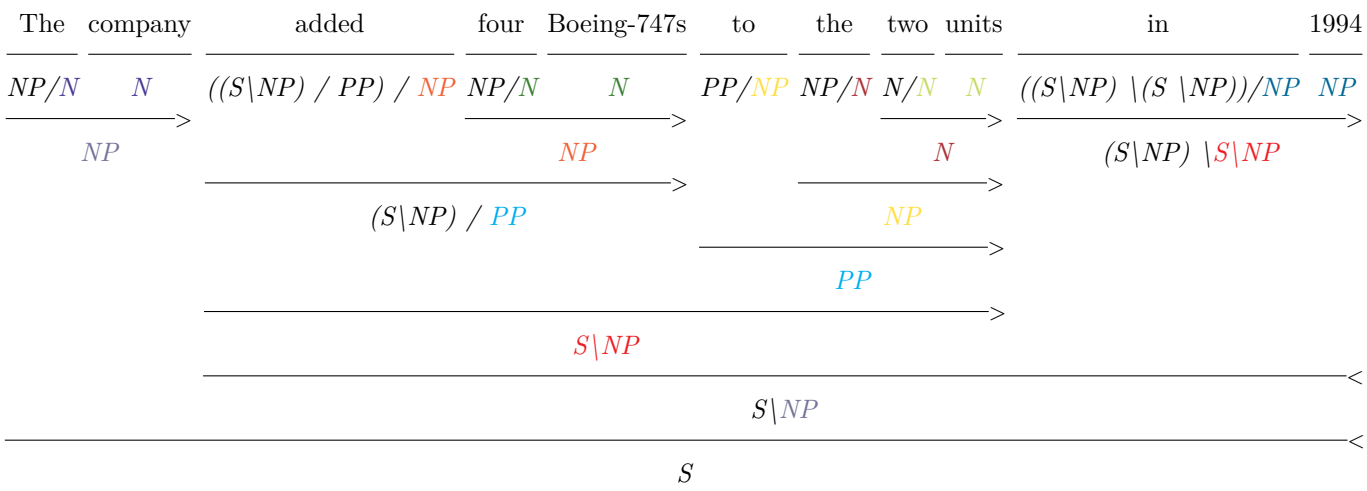
Homework Assignment 3
Natural Language Processing 1, 17/18

2017-12-06

Questions 1



Questions 2

1.

$$\ln(P(y \mid \mathbf{x})) = \ln\left(\frac{1}{Z}\exp\left(\sum_i w_i f_i(\mathbf{x}, y)\right)\right) \tag{1}$$

$$= -\ln(Z) + \sum_i w_i f_i(\mathbf{x}, y)) \tag{2}$$

$$\tag{3}$$

where Z is defined as the normalization constant: $\sum_{y'} \exp\left(\sum_i w_i f_i(\mathbf{x}, y')\right)$

We can work with log probabilities the same way we work with normal probabilities, as the same linear operators can be applied in log space as in the standard space.

2.

$$y = 1 : \sum_i w_i f_i(\mathbf{x}, y) = 2.0 \cdot f_1 - 0.1 \cdot f_7 \qquad \text{(Other } f_i \text{ are 0)} \tag{4}$$

$$= 2.0 \cdot 1 - 0.1 \cdot 1 = 1.9 \tag{5}$$

$$y = 2 : \sum_i w_i f_i(\mathbf{x}, y) = 1.8 \cdot f_2 + 1.1 \cdot f_8 \qquad \text{(Other } f_i \text{ are 0)} \tag{6}$$

$$= 1.8 \cdot 1 + 1.1 \cdot 1 = 2.9 \tag{7}$$

$$y = 3 : \sum_i w_i f_i(\mathbf{x}, y) = 0.3 \cdot f_3 + 2.7 \cdot f_9 \qquad \text{(Other } f_i \text{ are 0)} \tag{8}$$

$$= 0.3 \cdot 1 + 2.7 \cdot 1 = 3.0 \tag{9}$$

We then calculate the value for the normalization constant Z:

$$Z = \sum_{y'} \exp\left(\sum_i w_i f_i(\mathbf{x}, y')\right) \tag{10}$$

$$= \exp(1.9) + \exp(2.9) + \exp(3.0) \qquad = 44.946 \tag{11}$$

The value for $P(y \mid \mathbf{x})$ the becomes:

$$P(y = 1 \mid \mathbf{x}) = \frac{\exp\left(\sum_i w_i f_i(\mathbf{x}, y)\right)}{Z} \tag{12}$$
$$= \frac{\exp(1.9)}{Z} \tag{13}$$
$$\approx 0.149 \tag{14}$$
$$P(y = 2 \mid \mathbf{x}) = \frac{\exp\left(\sum_i w_i f_i(\mathbf{x}, y)\right)}{Z} \tag{15}$$
$$= \frac{\exp(2.9)}{Z} \tag{16}$$
$$\approx 0.404 \tag{17}$$
$$P(y = 3 \mid \mathbf{x}) = \frac{\exp\left(\sum_i w_i f_i(\mathbf{x}, y)\right)}{Z} \tag{18}$$
$$= \frac{\exp(3.0)}{Z} \tag{19}$$
$$\approx 0.447 \tag{20}$$

Questions 3

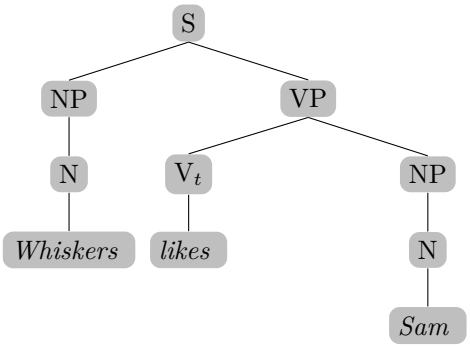
1. All bears are furry.
2. Sergii is eating pizza with a fork.
3. All students are lifting Marie
4. Marie is only lifted by students.

Questions 4

1. $$\forall x.pasta(x) \Rightarrow hates(Juan, x) \tag{21}$$

2. $$\exists x.student(x) \wedge \forall y.class(y) \Rightarrow likes(x, y) \tag{22}$$

Questions 5



Below we have explained the semantics bottom up:

$$N_1.sem = \text{Wiskers} \tag{23}$$

$$N_2.sem = \text{Sam} \tag{24}$$

$$V_t.sem = \lambda x.\lambda y.\exists e.Linging(e) \wedge Liker(e,y) \wedge Likee(e,x) \tag{25}$$

$$NP_1.sem = N_1.sem = \text{Wiskers} \tag{26}$$

$$NP_2.sem = N_2.sem = \text{Sam} \tag{27}$$

$$VP.sem = V_t.sem(NP.sem) = \lambda y.\exists e.Linging(e) \wedge Liker(e,y) \wedge Likee(e,\text{Sam}) \tag{28}$$

$$S.sem = VP.sem(NP.sem) = \exists e.Linging(e) \wedge Liker(e,\text{Wiskers}) \wedge Likee(e,\text{Sam}) \tag{29}$$