CSCI-UA 472 Artificial Intelligence

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Homework 09

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Problem 1

The purpose of this assignment is to illustrate some of the difficulties in interpreting natural text. Do your best with it. I think this should not be too hard, but if you find that you're having trouble with one part or another just because the English is too difficult, make a note of that, and I'll make allowances in grading. Consider this sentence from the New York Times article "Virus Cases Rise, but Hazard Pay for Retail Workers Doesn't", November 19, 2020.

"Even as some companies have announced new hazard pay in recent days, some industry observers say many retailers are not sharing enough of the profits they have earned during the pandemic with their workers, but are instead benefiting shareholders through stock buy-backs."

A. There is a word here that is composed of four morphemes (morphological elements). Which word, and what are the morphemes?

B. What are the possible referents of "they"? Not to hand in: Think about what would be involved in finding the correct referent.

C. Syntactically, there are six possible attachments for the prepositional phrase "with their workers". Identify two of these. (You may describe them either in terms of a phrase structure grammar or in terms of a dependency grammar; the latter is simpler.)

D. There are three compound noun phrases in this sentence (phrases of two consecutive words that are both nouns). What are they? How does the meaning of the two word combine in the meaning of the phrase?

E. Word Net http://wordnetweb.princeton.edu/perl/webwn is a valuable, manually constructed, online resource for information about words in English. (Versions of Word Net also exist for quite a few other languages.) What parts of speech are listed for "even", and how many meanings does it have in each?

Optional, not to hand in: If this kind of thing interests you, you might like to compare this to the entry for "even" in the Oxford English Dictionary, "the definitive record of the English language". To get to the OED, go to the NYU online catalog http://bobcat.library.nyu.edu; log in using your NetId; and search for "Oxford English Dictionary". The first result will be labelled as a Database. Click on that, and you will get to the online OED. Search for "even". You will get to a page of "Quick search results"with 7 entries, but that's just the tip of the iceberg. Click on "view full entry" for entries 4, 5, and 7 (1, 2, 3, and 6 are rare and obscure.)

Solution to Problem 1

Note: English is my fourth language so please excuse any blunders.

A.

There are Four morphemes in the following word:

shareholders → share-hold-er-s

Types of Morphemes

share = root (lexical)

hold = stem (lexical)

er = agentive morpheme (suffix)

s = bound inflectional morpheme (affix)

B.

Possible referents of "they" are:

1. Industry observers
2. Retailers

C.

Using dependency grammar, possible attachments for the prepositional phrase "with their workers" could be:

1. Sharing
2. Earned
3. Retailors

D.

Three compound noun phrases in the given sentence are:

1. Hazard pay → It refers to "Extra payment"
2. Stock buybacks → It means "re-purchasing shares/stocks"

3. Industry Observers → It calls upon "Those who follow industry closely"

E.
For the word "even" in English, according to the Princeton Word Net, there are a total of 14 different meanings or parts of speech.
– Noun with 1 meaning
– Verb with 3 meanings
– Adjective with 6 meanings
– Adverb with 4 meanings

Problem 2

Consider the following Hidden Markov Model (trigram) for the language in problem set 8:

The states are:
S0: *START* *START*
S1: *START* Adj
S2: *START* Noun
S3: Adj Adj
S4: Adj Noun
S5: Adv *END*
S6: Noun Verb
S7: Noun *END*
S8: Verb Adj
S9: Verb Adv
S10: Verb Noun
S11: Verb *END*
S12: *END* *END*.

Let us write P(SX →SY) to mean, "the probability that the kth state is SY given that the k – 1st state is SX." We post the following probabilities.

P(S0 → S1) = 0.5.
P(S0 → S2) = 0.5.
P(S1 → S3) = 0.2.
P(S1 → S4) = 0.8.
P(S2 → S6) = 1.0
P(S3 → S4) = 1.0.
P(S4 → S6) = 0.4.
P(S4 → S7) = 0.6.
P(S5 → S12) = 1.0
P(S6 → S8) = 0.2.
P(S6 → S9) = 0.1.

P(S6 $\rightarrow$ S10) = 0.5.
P(S6 $\rightarrow$ S11) = 0.2.
P(S7 $\rightarrow$ S12) = 1.0
P(S8 $\rightarrow$ S3) = 0.3
P(S8 $\rightarrow$ S4) = 0.3
P(S9 $\rightarrow$ S5) = 1.0
P(S10 $\rightarrow$ S7) = 1.0
P(S11 $\rightarrow$ S12) = 1.0

The base probabilities of the tags are:
P(Adj) = 0.2. P(Adv) = 0.1. P(Noun) = 0.4. P(Verb) = 0.3.

The probabilities of the tags given the words, P(T—W) are given in this table

	fast	fish	long	swim
Noun	0.1	0.6	0	0.1
Verb	0.1	0.4	0.1	0.9
Adj	0.5	0	0.7	0
Adv	0.4	0	0.2	0

Given the sentence "long fast fish swim", what taggings have non-zero probabilities and what are their unnormalized probabilities?

Solution to Problem 2

Using the Hidden Markov Model (HMM), "long fast fish swim" sentence can be tagged differently. But first, let's check the elements, e_i, in this sentence under HMM. These elements will remain standard across all tags.

$$e_1 = \text{Long} \;,\; e_2 = \text{Fast} \;,\; e_3 = \text{Fish} \;,\; e_4 = \text{Swim}$$

For state transition in every tag, as shown in class slides, there will be t_{-1} and t_0 for *START* and t_5 and t_6 for *END*. In this case, there will also be e_5 and e_6 which do not have any probability.

To calculate probability for the Tags, use the following formula:

$$\alpha \prod_{i=1}^{n} \frac{P(t_i|e_i)}{P(t_i)} \cdot P(t_i|t_{i-2}, t_{i-1})$$

where α is a constant that depends on the e_i but not on the t_i.

Tag 1

Sentence	Long	Fast	Fish	Swim
Tag 1	Adj	Noun	Verb	Noun

Using this HMM tag, following are the tags (t_i):

$$t_1 = \text{Adj} \textbf{ , } t_2 = \text{Noun} \textbf{ , } t_3 = \text{Verb} \textbf{ , } t_4 = \text{Noun}$$

Use the **base probabilities** and $\mathbf{P(T-W)}$ **table** given in the question.

For each i, compute the probability:

– Probability for $t_1 = \text{Adj}$, e_1 =Long is:

$$\frac{P(t_1|e_1)}{P(t_1)} \cdot P(t_1|t_{1-2}, t_{1-1})$$

$$\therefore \frac{P(\text{Adj} \mid \text{Long})}{P(\text{Adj})} \cdot P(\text{Adj } |t_{-1}, t_0)$$

$$\therefore P(\text{Adj} \mid \text{Long}) = 0.7 \textbf{ , } P(\text{Adj}) = 0.2 \textbf{ , } P(\text{Adj } |t_{-1}, t_0) = P(S0 \to S1) = 0.5$$

$$\frac{P(t_1|e_1)}{P(t_1)} \cdot P(t_1|t_{-1}, t_0) = \frac{0.7}{0.2} \times 0.5 = 1.75$$

– Probability for $t_2 = \text{Noun}$, $e_2 = \text{Fast}$ is:

$$\frac{P(t_2|e_2)}{P(t_2)} \cdot P(t_2|t_{2-2}, t_{2-1})$$

$$\therefore \frac{P(\text{Noun} \mid \text{Fast})}{P(\text{Noun})} \cdot P(\text{Noun } |t_0, t_1)$$

$$\therefore P(\text{Noun} \mid \text{Fast}) = 0.7 \textbf{ , } P(\text{Noun}) = 0.2 \textbf{ , } P(\text{Noun } |t_0, t_1) = P(S1 \to S4) = 0.8$$

$$\frac{P(t_2|e_2)}{P(t_2)} \cdot P(t_2|t_0, t_1) = \frac{0.1}{0.4} \times 0.8 = 0.2$$

– Probability for $t_3 = \text{Verb}$, $e_3 = \text{Fish}$ is:

$$\frac{P(t_3|e_3)}{P(t_3)} \cdot P(t_3|t_{3-2}, t_{3-1})$$

$$\therefore \frac{P(\text{Verb} \mid \text{Fish})}{P(\text{Verb})} \cdot P(\text{Verb } |t_1, t_2)$$

$$\therefore P(\text{Verb} \mid \text{Fish}) = 0.4 \textbf{ , } P(\text{Verb}) = 0.3 \textbf{ , } P(\text{Verb } | t_1, t_2) = P(S4 \rightarrow S6) = 0.4$$

$$\frac{P(t_3|e_3)}{P(t_3)} \cdot P(t_3|t_{3-2}, t_{3-1}) = \frac{0.4}{0.3} \times 0.4 = 0.533$$

– Probability for $t_4 = \text{Noun}$, $e_4 = \text{Swim}$ is:

$$\frac{P(t_4|e_4)}{P(t_4)} \cdot P(t_4|t_{4-2}, t_{4-1})$$

$$\therefore \frac{P(\text{Noun} \mid \text{Swim})}{P(\text{Noun})} \cdot P(\text{Noun } |t_2, t_3)$$

$$\therefore P(\text{Noun} \mid \text{Swim}) = 0.1 \textbf{ , } P(\text{Noun}) = 0.4 \textbf{ , } P(\text{Noun } |t_2, t_3) = P(S6 \rightarrow S10) = 0.5$$

$$\frac{P(t_4|e_4)}{P(t_4)} \cdot P(t_4|t_{4-2}, t_{4-1}) = \frac{0.1}{0.4} \times 0.5 = 0.125$$

– Probability for t_5 and t_6 is:

$$\frac{P(t_5|e_5)}{P(t_5)} \cdot P(t_5|t_3, t_4) = \frac{P(t_5|e_5)}{P(t_5)} \times (S10 \rightarrow S7)$$

$$\frac{P(t_5|e_5)}{P(t_5)} \cdot P(t_5|t_3, t_4) = 1.0 \times 1.0 = 1.0$$

$$\frac{P(t_6|e_6)}{P(t_6)} \cdot P(t_6|t_4, t_5) = \frac{P(t_6|e_6)}{P(t_6)} \times (S7 \rightarrow S12)$$

$$\frac{P(t_6|e_6)}{P(t_6)} \cdot P(t_6|t_4, t_5) = 1.0 \times 1.0 = 1.0$$

Therefore, let's take the product of each i probability for **Tag 1**.

$$\prod_{i=1}^{n} \frac{P(t_i|e_i)}{P(t_i)} \cdot P(t_i|t_{i-2}, t_{i-1}) = 1.75 \cdot 0.2 \cdot 0.533 \cdot 0.125 \cdot 1.0 \cdot 1.0$$

$$P(\textbf{Tag 1}) = 0.02333$$

Tag 2

Sentence	Long	Fast	Fish	Swim
Tag 2	Adj	Adj	Noun	Verb

Using this HMM tag, following are the tags (t_i):

$$t_1 = \text{Adj} \textbf{ , } t_2 = \text{Adj} \textbf{ , } t_3 = \text{Noun} \textbf{ , } t_4 = \text{Verb}$$

Use the **base probabilities** and $\mathbf{P(T-W)}$ **table** given in the question.

For each i, compute the probability:

– Probability for $t_1 = $ Adj, $e_1 =$Long is:

$$\frac{P(t_1|e_1)}{P(t_1)} \cdot P(t_1|t_{1-2}, t_{1-1})$$

$$\therefore \frac{P(\text{Adj} \mid \text{Long})}{P(\text{Adj})} \cdot P(\text{Adj } |t_{-1}, t_0)$$

$$\therefore P(\text{Adj} \mid \text{Long}) = 0.7 \textbf{ , } P(\text{Adj}) = 0.2 \textbf{ , } P(\text{Adj } |t_{-1}, t_0) = P(S0 \to S1) = 0.5$$

$$\frac{P(t_1|e_1)}{P(t_1)} \cdot P(t_1|t_{-1}, t_0) = \frac{0.7}{0.2} \times 0.5 = 1.75$$

– Probability for $t_2 = $ Adj , $e_2 = $ Fast is:

$$\frac{P(t_2|e_2)}{P(t_2)} \cdot P(t_2|t_{2-2}, t_{2-1})$$

$$\therefore \frac{P(\text{Adj} \mid \text{Fast})}{P(\text{Adj})} \cdot P(\text{Adj } |t_0, t_1)$$

$$\therefore P(\text{Adj} \mid \text{Fast}) = 0.5 \textbf{ , } P(\text{Adj}) = 0.2 \textbf{ , } P(\text{Adj } |t_0, t_1) = P(S1 \to S3) = 0.2$$

$$\frac{P(t_2|e_2)}{P(t_2)} \cdot P(t_2|t_0, t_1) = \frac{0.5}{0.2} \times 0.2 = 0.5$$

– Probability for $t_3 = $ Noun , $e_3 = $ Fish is:

$$\frac{P(t_3|e_3)}{P(t_3)} \cdot P(t_3|t_{3-2}, t_{3-1})$$

$$\therefore \frac{P(\text{Noun} \mid \text{Fish})}{P(\text{Noun})} \cdot P(\text{Noun } |t_1, t_2)$$

$$\therefore P(\text{Noun} \mid \text{Fish}) = 0.6 \textbf{ , } P(\text{Noun}) = 0.4 \textbf{ , } P(\text{Noun } |t_1, t_2) = P(S3 \to S4) = 1.0$$

$$\frac{P(t_3|e_3)}{P(t_3)} \cdot P(t_3|t_{3-2}, t_{3-1}) = \frac{0.6}{0.4} \times 1.0 = 1.5$$

– Probability for $t_4 = $ Verb , $e_4 = $ Swim is:

$$\frac{P(t_4|e_4)}{P(t_4)} \cdot P(t_4|t_{4-2}, t_{4-1})$$

$$\therefore \frac{P(\text{Verb} \mid \text{Swim})}{P(\text{Verb})} \cdot P(\text{Verb } |t_2, t_3)$$

$$\therefore P(\text{Verb} \mid \text{Swim}) = 0.9 \text{ , } P(\text{Verb}) = 0.3 \text{ , } P(\text{Verb } |t_2, t_3) = P(S4 \rightarrow S6) = 0.4$$

$$\frac{P(t_4|e_4)}{P(t_4)} \cdot P(t_4|t_{4-2}, t_{4-1}) = \frac{0.9}{0.3} \times 0.4 = 1.2$$

– Probability for t_5 and t_6 is:

$$\frac{P(t_5|e_5)}{P(t_5)} \cdot P(t_5|t_3, t_4) = \frac{P(t_5|e_5)}{P(t_5)} \times (S6 \rightarrow S11)$$

$$\frac{P(t_5|e_5)}{P(t_5)} \cdot P(t_5|t_3, t_4) = 1.0 \times 0.2 = 0.2$$

$$\frac{P(t_6|e_6)}{P(t_6)} \cdot P(t_6|t_4, t_5) = \frac{P(t_6|e_6)}{P(t_6)} \times (S11 \rightarrow S12)$$

$$\frac{P(t_6|e_6)}{P(t_6)} \cdot P(t_6|t_4, t_5) = 1.0 \times 1.0 = 1.0$$

Therefore, let's take the product of each i probability for **Tag 2**.

$$\prod_{i=1}^{n} \frac{P(t_i|e_i)}{P(t_i)} \cdot P(t_i|t_{i-2}, t_{i-1}) = 1.75 \cdot 0.5 \cdot 1.5 \cdot 1.2 \cdot 0.2 \cdot 1.0$$

$$P(\textbf{Tag 2}) = 0.315$$

Therefore, using Hidden Markov Model, we get the following probabilities for each tagging.

Sentence	Long	Fast	Fish	Swim	**Probability**
Tag 1	Adj	Noun	Verb	Noun	0.0233
Tag 2	Adj	Adj	Noun	Verb	0.315

End of Assignment. Thank you!