Natural Language Processing

Tutorial 4: POS tagging and HMM

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Question 1

- Find one tagging error in each of the following sentences that are tagged with the Penn Treebank tagset:

1. How/WRB do/VBP I/PRP get/VB to/TO Singapore/NN
2. Do/VBP you/PRP have/VB any/DT vacancies/NN
3. This/DT room/NN is/VBZ too/JJ noisy/JJ
4. Can/VB you/PRP give/VB me/PRP another/DT room/NN

Penn TreeBank POS Tagset

Review

Tag	Description	Example	Tag	Description	Example	Tag	Description	Example
CC	coord. conj.	*and, but, or*	NNP	proper noun, sing.	*IBM*	TO	"to"	*to*
CD	cardinal number	*one, two*	NNPS	proper noun, plu.	*Carolinas*	UH	interjection	*ah, oops*
DT	determiner	*a, the*	NNS	noun, plural	*llamas*	VB	verb base	*eat*
EX	existential 'there'	*there*	PDT	predeterminer	*all, both*	VBD	verb past tense	*ate*
FW	foreign word	*mea culpa*	POS	possessive ending	*'s*	VBG	verb gerund	*eating*
IN	preposition/ subordin-conj	*of, in, by*	PRP	personal pronoun	*I, you, he*	VBN	verb past participle	*eaten*
JJ	adjective	*yellow*	PRP$	possess. pronoun	*your, one's*	VBP	verb non-3sg-pr	*eat*
JJR	comparative adj	*bigger*	RB	adverb	*quickly*	VBZ	verb 3sg pres	*eats*
JJS	superlative adj	*wildest*	RBR	comparative adv	*faster*	WDT	wh-determ.	*which, that*
LS	list item marker	*1, 2, One*	RBS	superlatv. adv	*fastest*	WP	wh-pronoun	*what, who*
MD	modal	*can, should*	RP	particle	*up, off*	WP$	wh-possess.	*whose*
NN	sing or mass noun	*llama*	SYM	symbol	*+,%, &*	WRB	wh-adverb	*how, where*

Answer 1

- How/WRB do/VBP I/PRP get/VB to/TO Singapore/NN
  - **Singapore/NNP**
- Do/VBP you/PRP have/VB any/DT vacancies/NN
  - **vacancies/NNS**
- This/DT room/NN is/VBZ too/JJ noisy/JJ
  - **too/RB**
- Can/VB you/PRP give/VB me/PRP another/DT room/NN
  - **Can/MD**

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NN	sing or mass noun	*llama*	SYM	symbol	*+,%, &*	WRB	wh-adverb	*how, where*

Question 2

➢ Compute the best tag sequence for "I want to race" using the Viterbi algorithm with the provided HMM parameters, i.e., the transition probability and the word likelihood probabilities

	VB	TO	NN	PPSS
<s>	.019	.0043	.041	.067
VB	.0038	.035	.047	.0070
TO	.83	0	.00047	0
NN	.0040	.016	.087	.0045
PPSS	.23	.00079	.0012	.00014

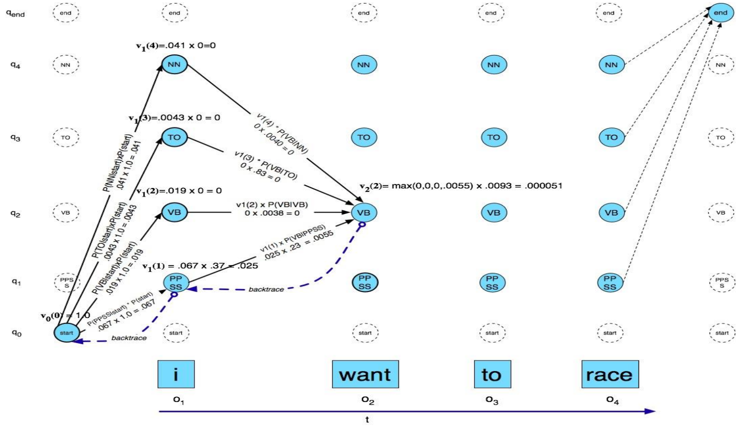
	I	want	to	race
VB	0	.0093	0	.00012
TO	0	0	.99	0
NN	0	.000054	0	.00057
PPSS	.37	0	0	0

Main Idea

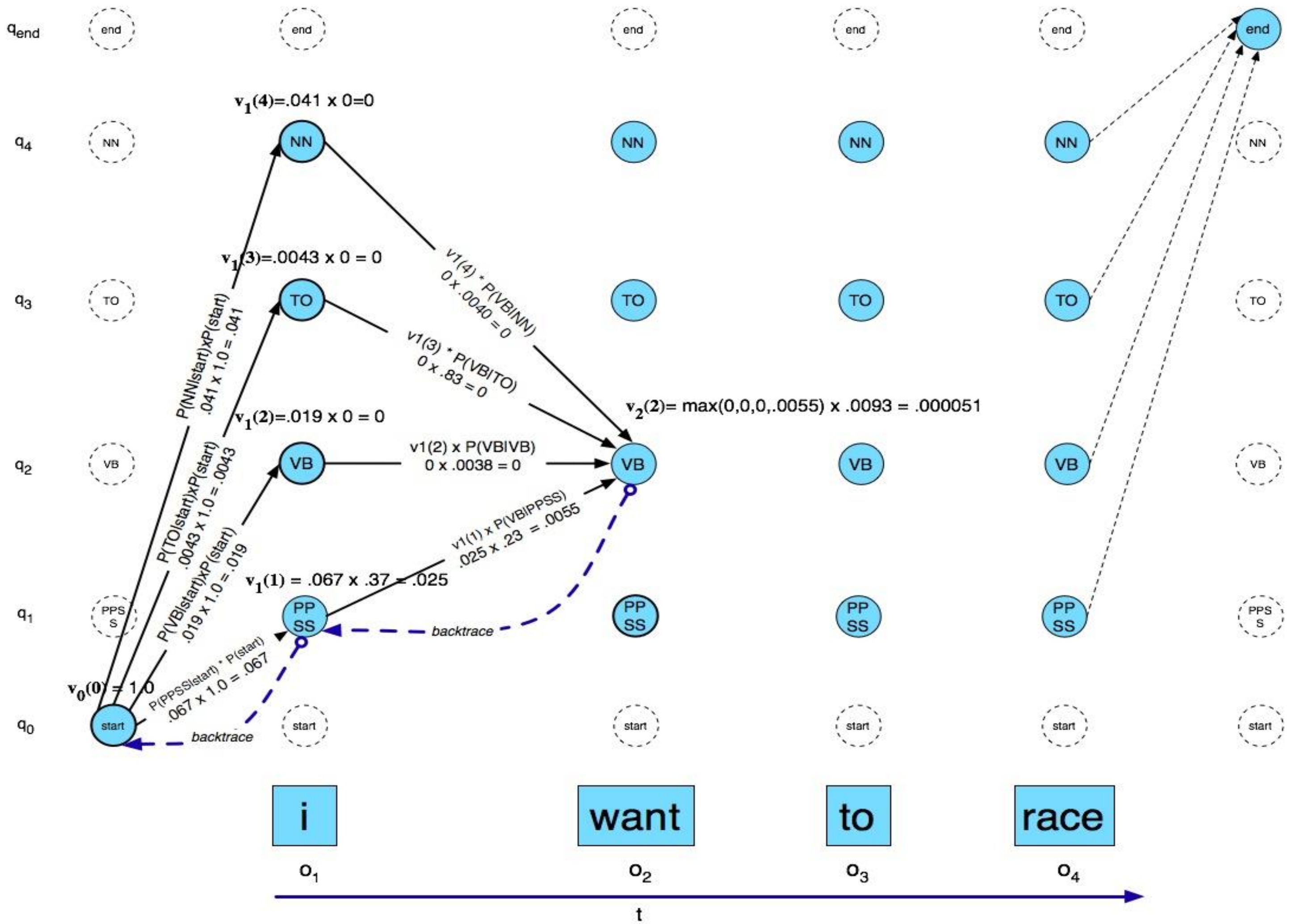
Review

- We also have a matrix.
  - Each column– a time ‘t’ (observation)
  - Each row – a state ‘i’
  - For each cell $v_t[i]$, we compute the probability of the **best path** to the cell

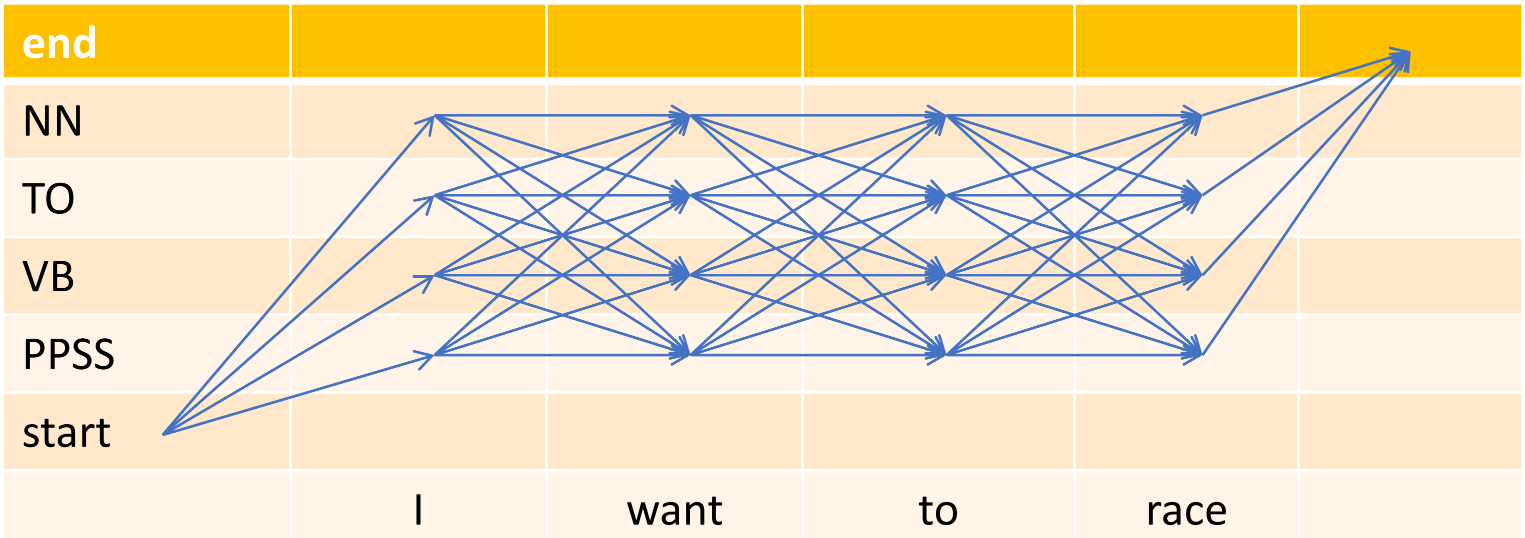
- the **Viterbi path probability** at time t for state i
  - there are $|Q|$ number of paths from $t-1$ to $v_t[i]$
  - if we know **the best path** to each cell in $t-1$, or $v_{t-1}[j]$
  - $\arg\max_j v_{t-1}[j] \times P(i|j) \times P(s_t|i)$



Viterbi Example



Required computations



(This figure does not show the backtrace pointers)

Answer 2

	VB	TO	NN	PPSS
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					end
NN	$p(NN \mid <s>) * p(I \mid NN) = 0$				
TO	0				
VB	0				
PPSS	$p(PPSS \mid <s>) * p(I \mid PPSS)$ $= 0.067 * 0.37 = 0.02479$				
start					
	I	want	to	race	

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PPSS	.37	0	0	0

					end
NN	0	$.02479 \times p(NN\|PPSS) * p(want\|NN) =$ $.02479 \times .0012 \times .000054 =$ 0.0000000160639			
TO	0	0			
VB	0	$.02479 \times p(VB\|PPSS) \times p(want\|VB) =$ $.02479 \times .23 \times .0093 =$ 0.00005302581			
PPSS	0.02479	0			
start					
	I	want	to	race	

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					end
NN	0	1.6×10^{-9}	0		
TO	0	0	$\max\left(1.6 \times 10^{-9} \times p(TO\|NN),\ 5.3 \times 10^{-5} \times p(TO\|VB)\right) * p(to\|TO) = \max(1.6 \times 10^{-9} \times .016, 5.3 \times 10^{-5} \times .035) * .99 = 1.84 \times 10^{-6}$		
VB	0	5.3×10^{-5}	0		
PPSS	0.02479	0	0		
start					
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	VB	TO	NN	PPSS
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					end
NN	0	1.6×10^{-9}	0	$1.84 \times 10^{-6} \times p(NN\|TO) \times p(race\|NN) = 1.84 \times 10^{-6} \times .00047 \times .00057 = 4.92 \times 10^{-14}$	
TO	0	0	1.84×10^{-6}	0	
VB	0	5.3×10^{-5}	0	$1.84 \times 10^{-6} \times p(VB\|TO) \times p(race\|VB) = 1.84 \times 10^{-6} \times .83 \times .00012 = 1.83 \times 10^{-10}$	
PPSS	0.02479	0	0	0	
start					
	I	want	to	race	

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					end
NN	0	1.6×10^{-9}	0	$1.84 \times 10^{-6} \times p(NN\|TO) \times p(race\|NN) = 1.84 \times 10^{-6} \times .00047 \times .00057 = 4.92 \times 10^{-14}$	
TO	0	0	1.84×10^{-6}	0	
VB	0	5.3×10^{-5}	0	$1.84 \times 10^{-6} \times p(VB\|TO) \times p(race\|VB) = 1.84 \times 10^{-6} \times .83 \times .00012 = 1.83 \times 10^{-10}$	
PPSS	0.02479	0	0	0	
start					
	I	want	to	race	

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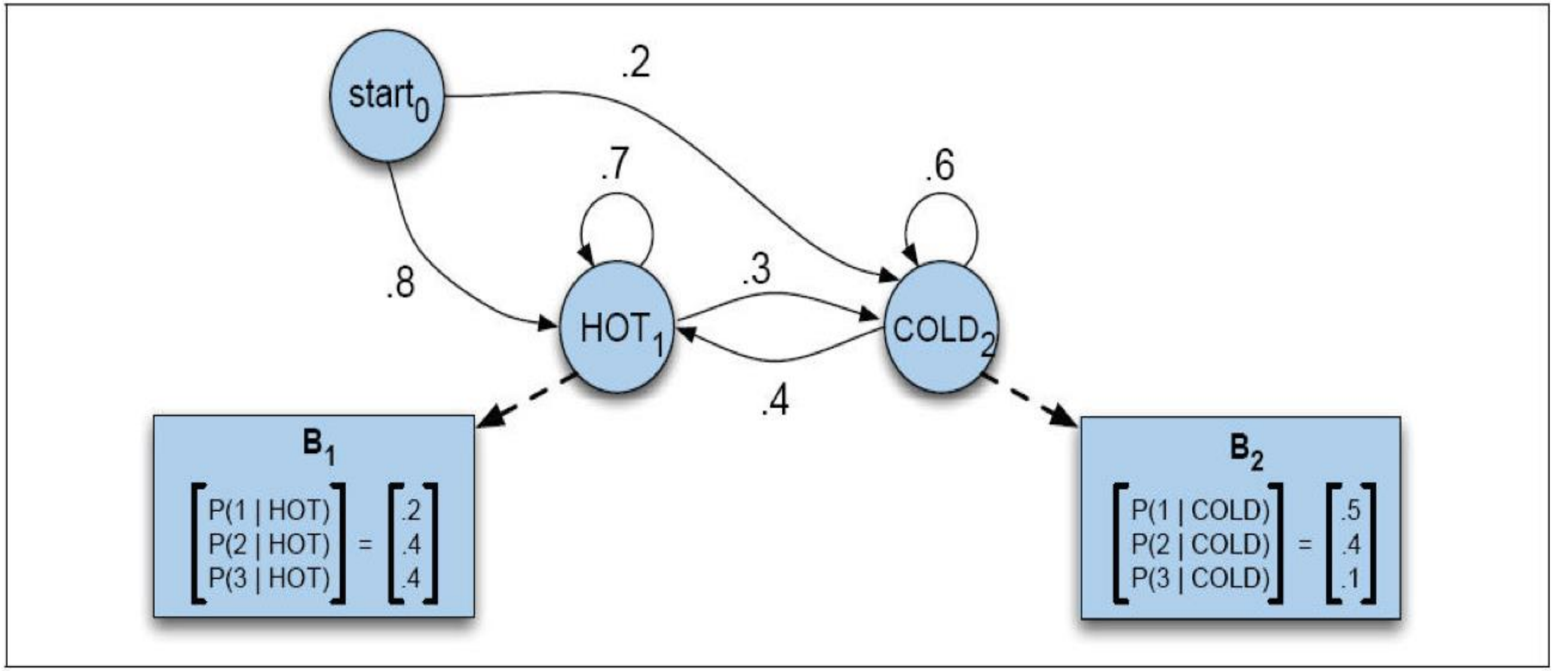
					end
NN	0	1.6×10^{-9}	0	$1.84 \times 10^{-6} \times p(NN\|TO) \times p(race\|NN) = 1.84 \times 10^{-6} \times .00047 \times .00057 = 4.92 \times 10^{-14}$	
TO	0	0	1.84×10^{-6}	0	
VB	0	5.3×10^{-5}	0	$1.84 \times 10^{-6} \times p(VB\|TO) \times p(race\|VB) = 1.84 \times 10^{-6} \times .83 \times .00012 = 1.83 \times 10^{-10}$	
PPSS	0.02479	0	0	0	
start					
	I	want	to	race	

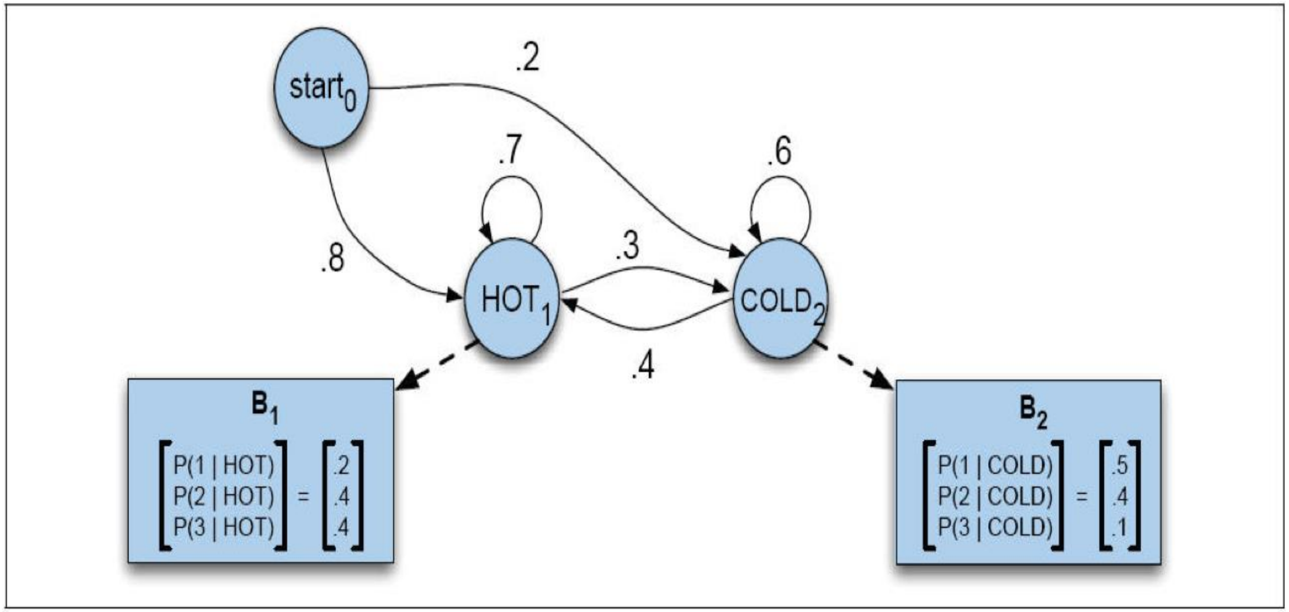
Question 3

- Run the Viterbi algorithm with the HMM below to compute the most likely weather sequences for each of the two observation sequences,
  - 312312312
  - 311233112.

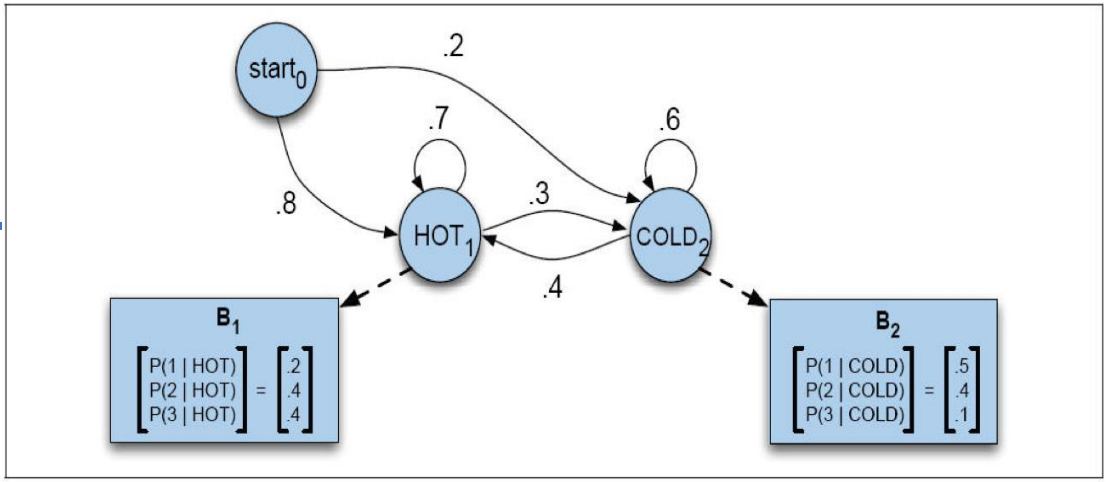


Hint 3

					end
H					
C					
start					
	3	1	2	3	…



Answer 3



- 3
  - H 0.8 *0.4 (P(3|H)) = 0.32
  - C 0.2 *0.1 (P (3|C)) = 0.02
- 1
  - H max (0.32*0.7*0.2, 0.02*0.4*0.2)
  - C max (0.32*0.3*0.5, 0.02*0.6*0.5)
- 2
- 3

https://hmmlearn.readthedocs.io/en/stable/index.html

Sequence 1: 3 1 2 3 1 2 3 1 2
Decoded states: -Hot--Hot--Hot--Hot--Hot--Hot--Hot--Hot--Hot-

Sequence 2: 3 1 1 2 3 3 1 1 2.
Decoded states: -Hot--Cold--Cold--Hot--Hot--Hot--Cold--Cold--Cold-

Question 4

- The task of **negation scope detection** is to extract the parts of a sentence that is being negated.
- For example, in the sentence "I have not submitted my assignment", the negation scope is "submitted my assignment".
- Formulate this problem as a sequence labelling task, and discuss how to apply Hidden Markov Model (HMM) to solve this problem.
- Clearly state the probabilities that need to be learned by the HMM.

Answer 4

- This question is similar to NER, a typical sequence labeling task

- We can use **BIO** label scheme
  - B marks the being of the negation scope.
  - I marks tokens within the negation scope.
  - O marks tokens NOT part of the negation scope.

O	O	O	B	I	I	O
I	have	not	submitted	my	assignment	yet

- In the HMM,
  - the hidden states are BIO (example above), and the word sequence is the observed.
  - We learn three probabilities:
    - transition probability between states BIO,
    - observation likelihood of observing a word given a label B, I, or O.
    - The initial probability of BIO in a sentence.

Question 4 → a bit of extension

- The task of **negation scope detection** is to extract the parts of a sentence that is being negated. For example, in the sentence "I have not submitted my assignment", the negation scope is "submitted my assignment".

- Consider these sentences:

  - He **seldom** makes mistake.
  - I do **not** know why he is **not** happy.
  - He must be very nervous, but he **denied**.
  - He **may or may not** join us for lunch.