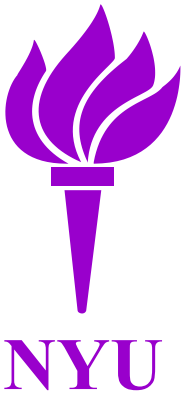


Viterbi Algorithm

CSCI-GA.2590 – Natural Language Processing

Ralph Grishman

Computing Probabilities

viterbi [s, t] =

$\max_{s'}$ (***viterbi*** [s', t-1] ×

transition probability

P(s | s') ×

emission probability

P (token[t] | s))

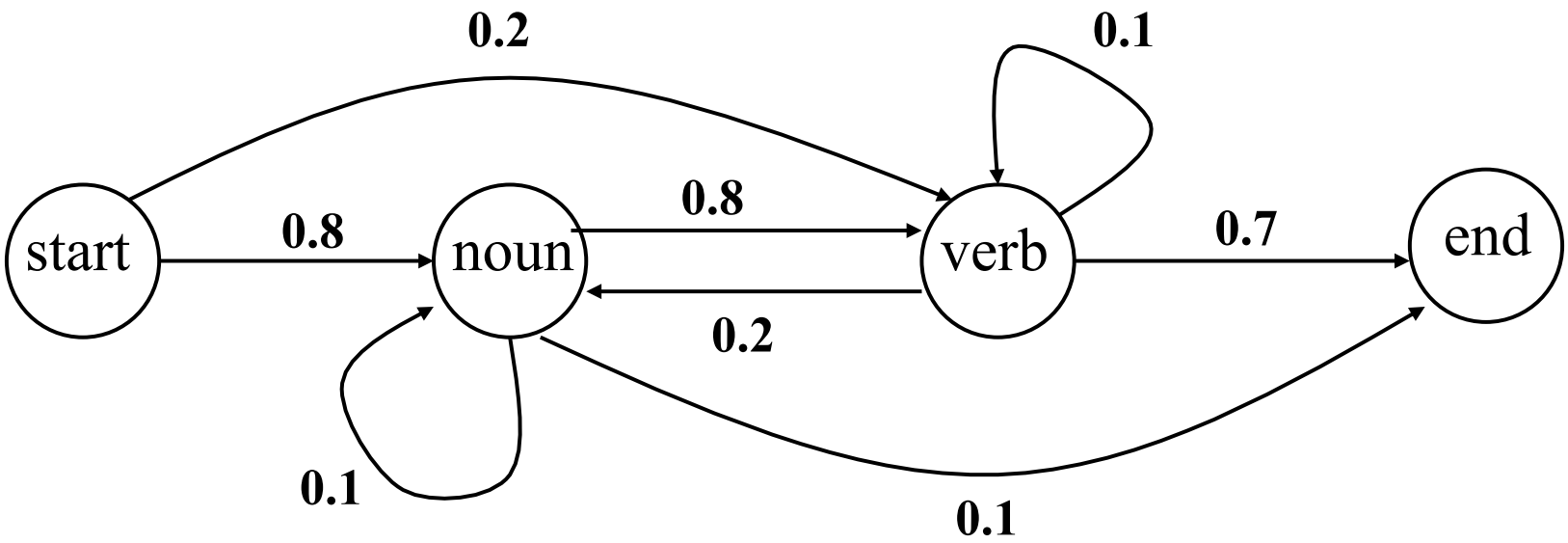
for each s, t:

record which s', t-1 contributed the maximum

Analyzing

Fish sleep.

A Simple POS HMM

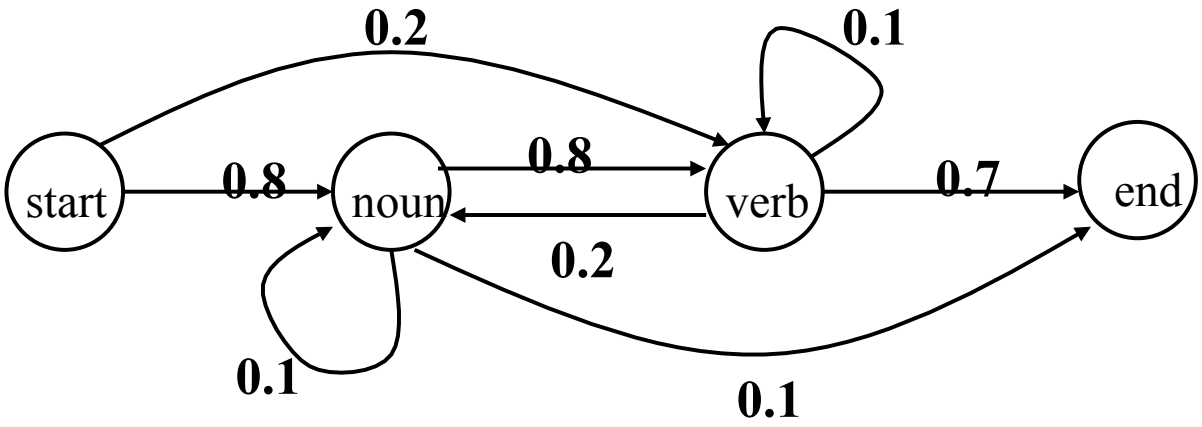


Word Emission Probabilities
P (word | state)

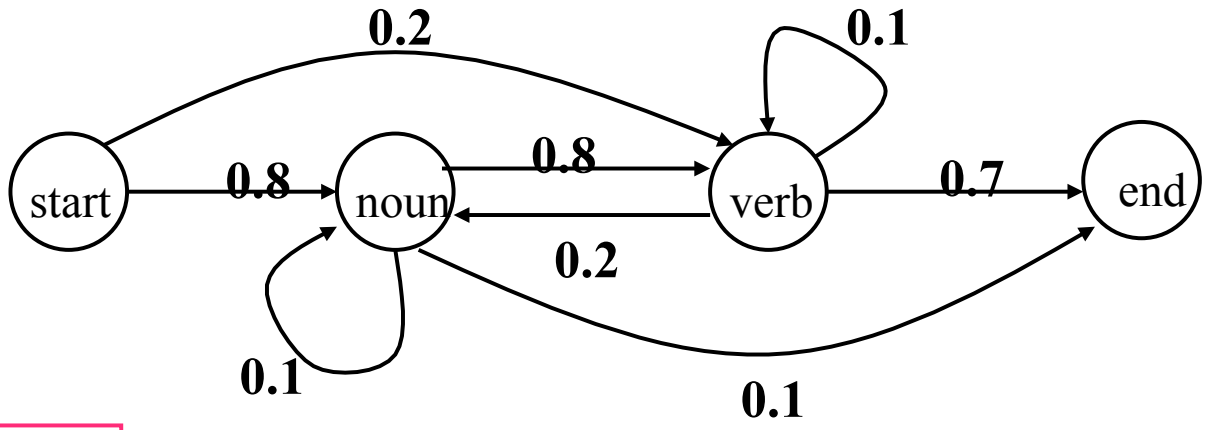
- A two-word language: "fish" and "sleep"
- Suppose in our training corpus,
  - "fish" appears 8 times as a noun and 5 times as a verb
  - "sleep" appears twice as a noun and 5 times as a verb
- Emission probabilities:
  - Noun
    - P(fish | noun) : 0.8
    - P(sleep | noun) : 0.2
  - Verb
    - P(fish | verb) : 0.5
    - P(sleep | verb) : 0.5

Viterbi Probabilities

	0	1	2	3
start				
verb				
noun				
end				

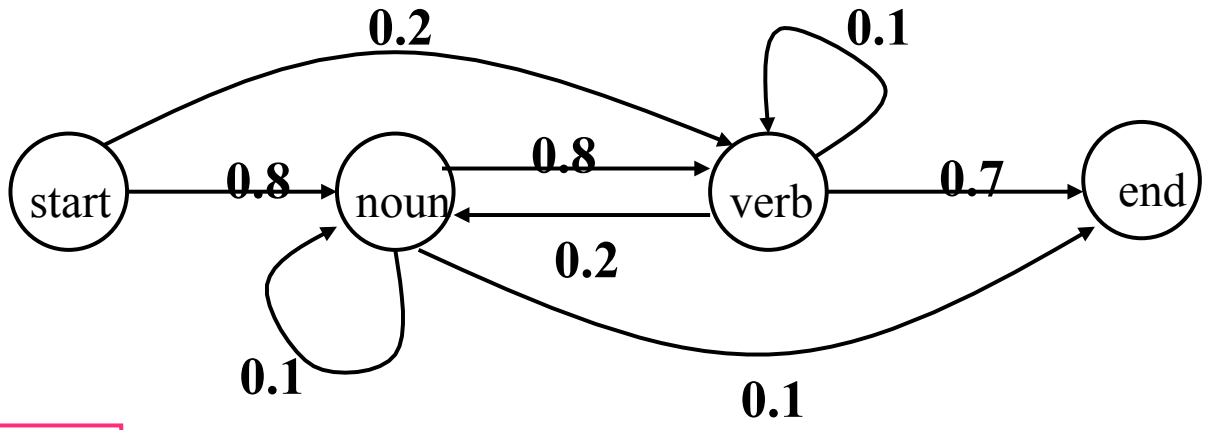


	0	1	2	3
start	1			
verb	0			
noun	0			
end	0			



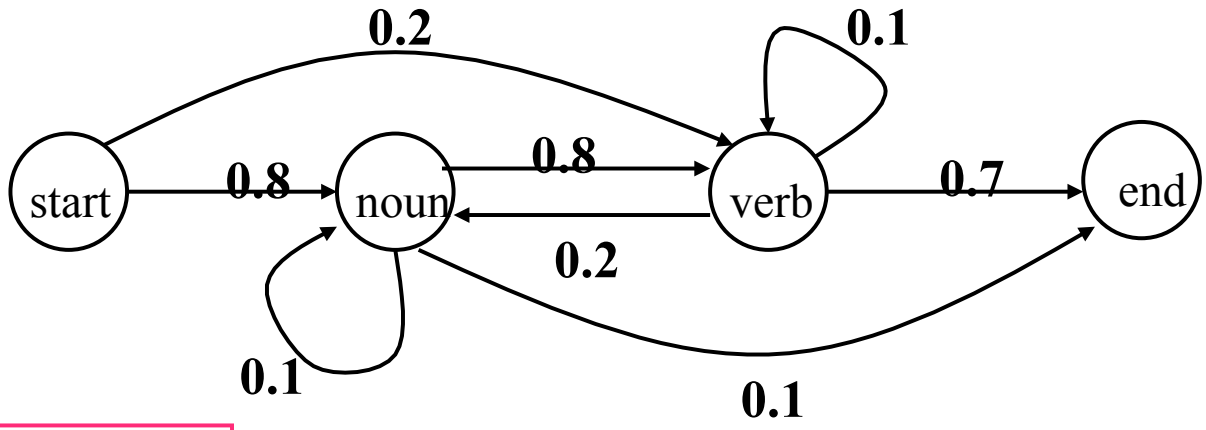
Token 1: fish

	0	1	2	3
start	1	0		
verb	0	.2 * .5		
noun	0	.8 * .8		
end	0	0		



Token 1: fish

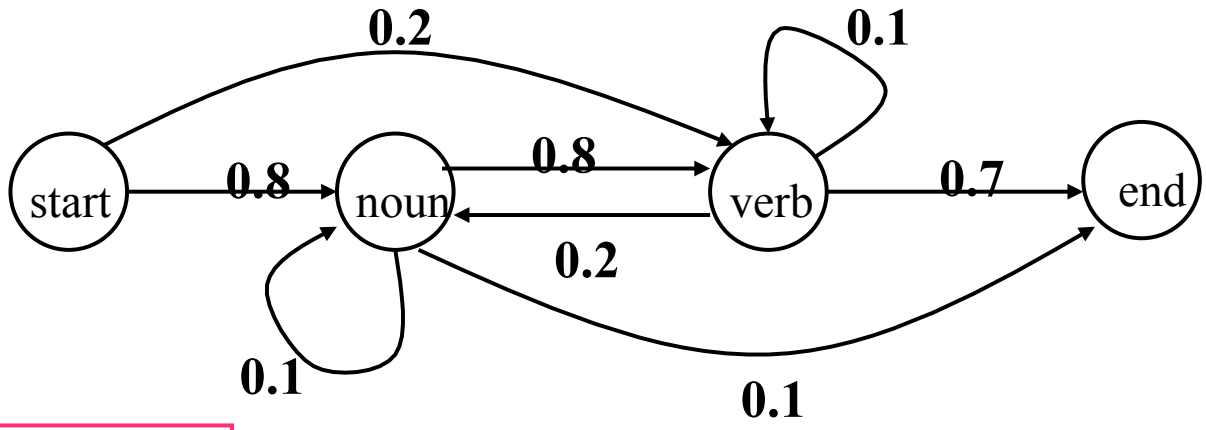
	0	1	2	3
start	1	0		
verb	0	.1		
noun	0	.64		
end	0	0		



Token 2: sleep

(if 'fish' is verb)

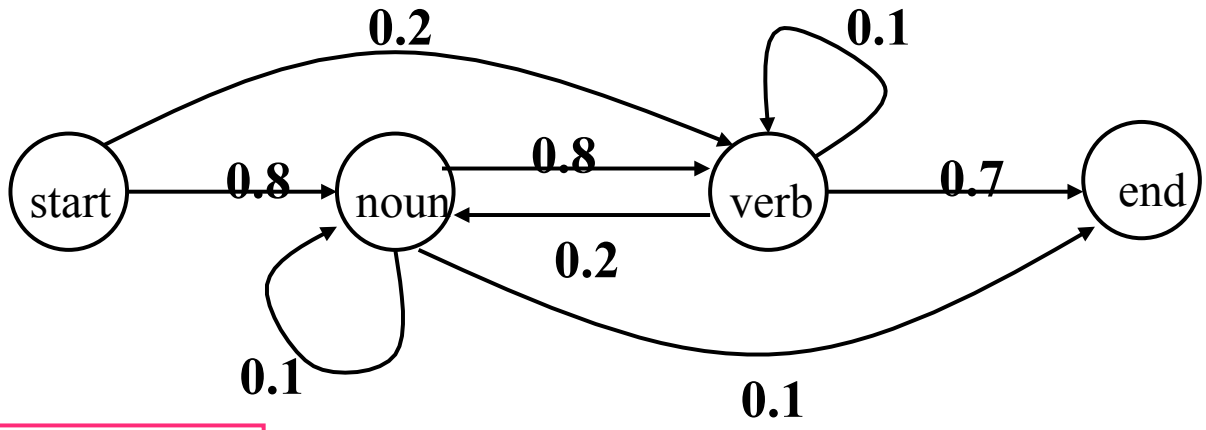
	0	1	2	3
start	1	0	0	
verb	0	.1	.1*.1*.5	
noun	0	.64	.1*.2*.2	
end	0	0	-	



Token 2: sleep

(if 'fish' is verb)

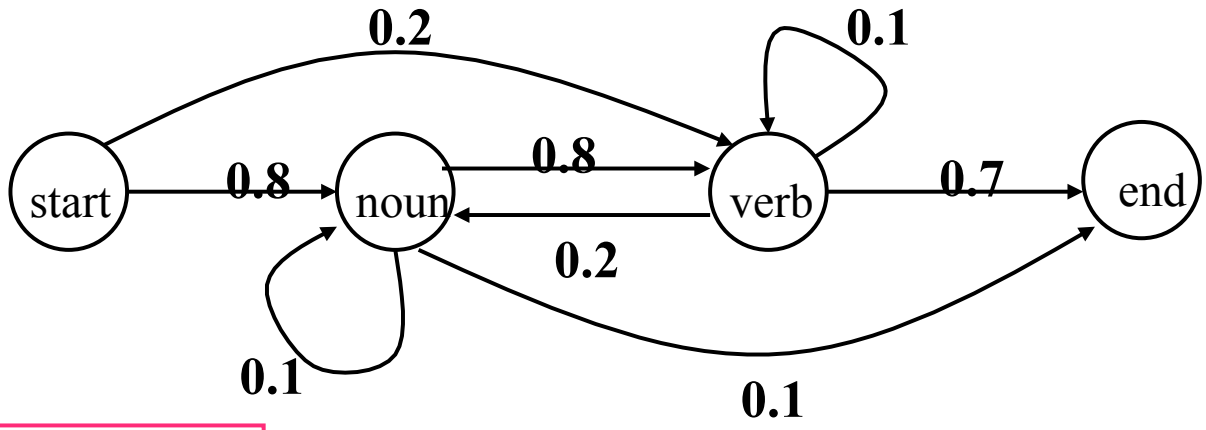
	0	1	2	3
start	1	0	0	
verb	0	.1	.005	
noun	0	.64	.004	
end	0	0	-	



Token 2: sleep

(if 'fish' is a noun)

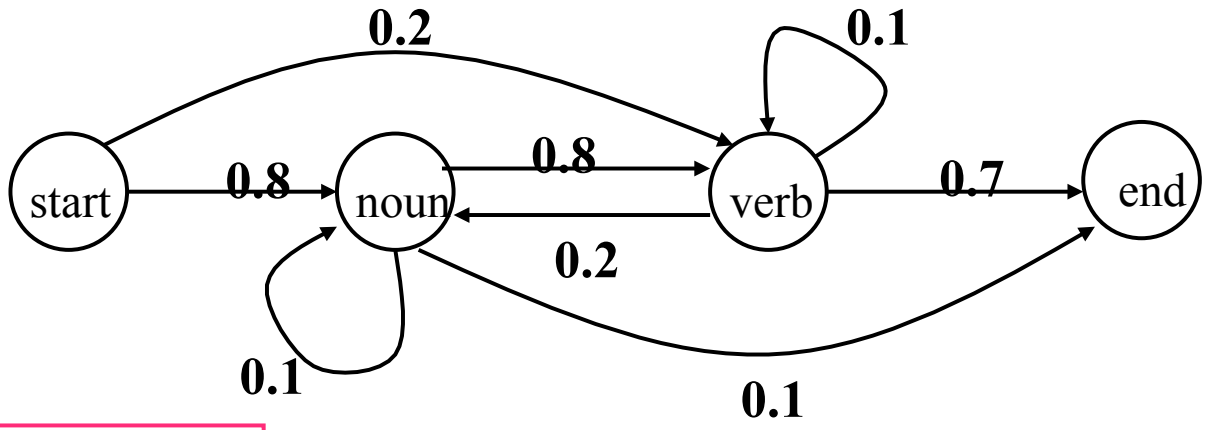
	0	1	2	3
start	1	0	0	
verb	0	.1	.005 .64*.8*.5	
noun	0	.64	.004 .64*.1*.2	
end	0	0	-	



Token 2: sleep

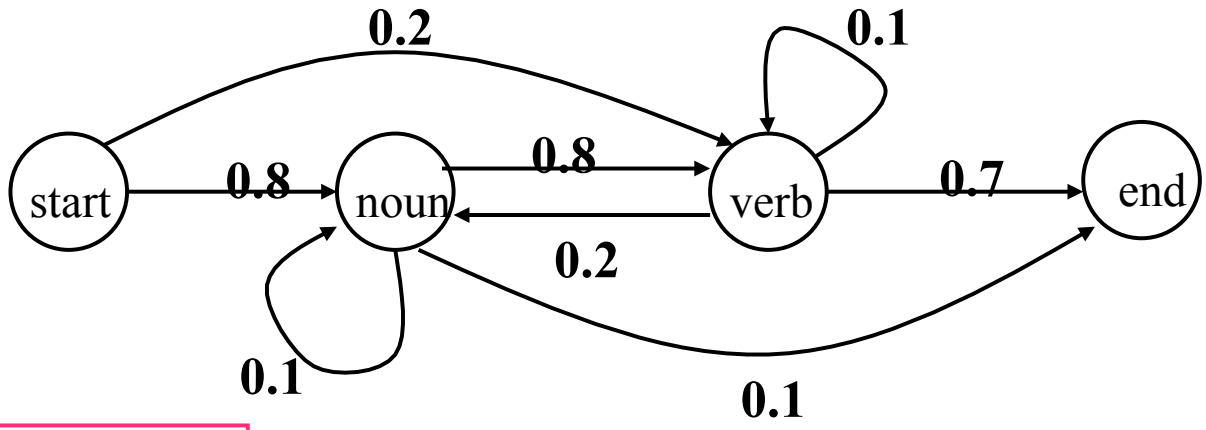
(if 'fish' is a noun)

	0	1	2	3
start	1	0	0	
verb	0	.1	.005 .256	
noun	0	.64	.004 .0128	
end	0	0	-	



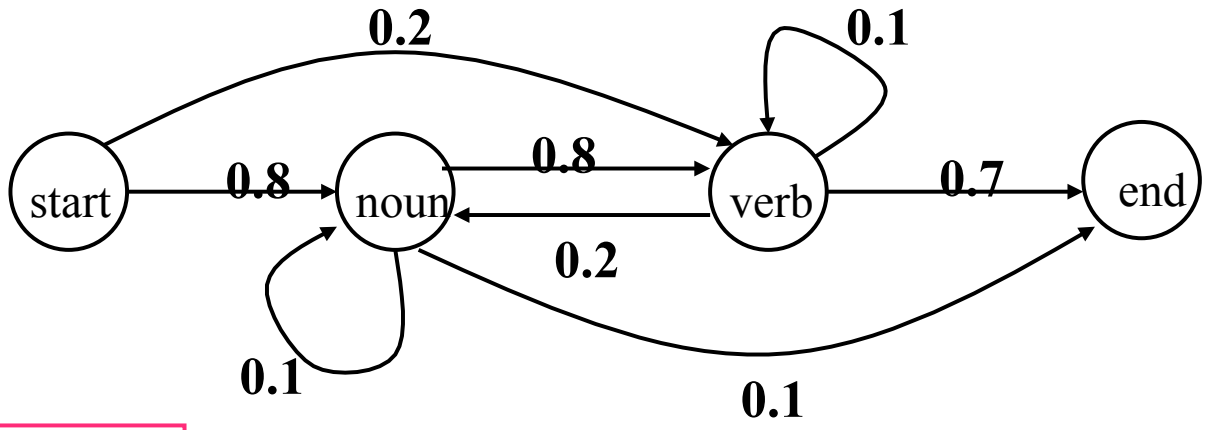
Token 2: sleep
take maximum,
set back pointers

	0	1	2	3
start	1	0	0	
verb	0	.1	~~.005~~ .256	
noun	0	.64	~~.004~~ .0128	
end	0	0	-	



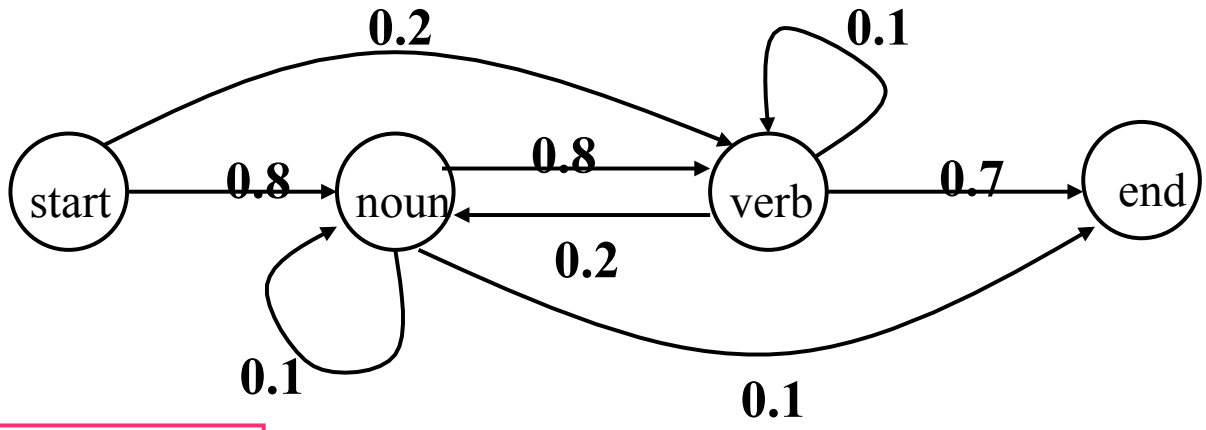
Token 2: sleep
take maximum,
set back pointers

	0	1	2	3
start	1	0	0	
verb	0	.1	.256	
noun	0	.64	.0128	
end	0	0	-	



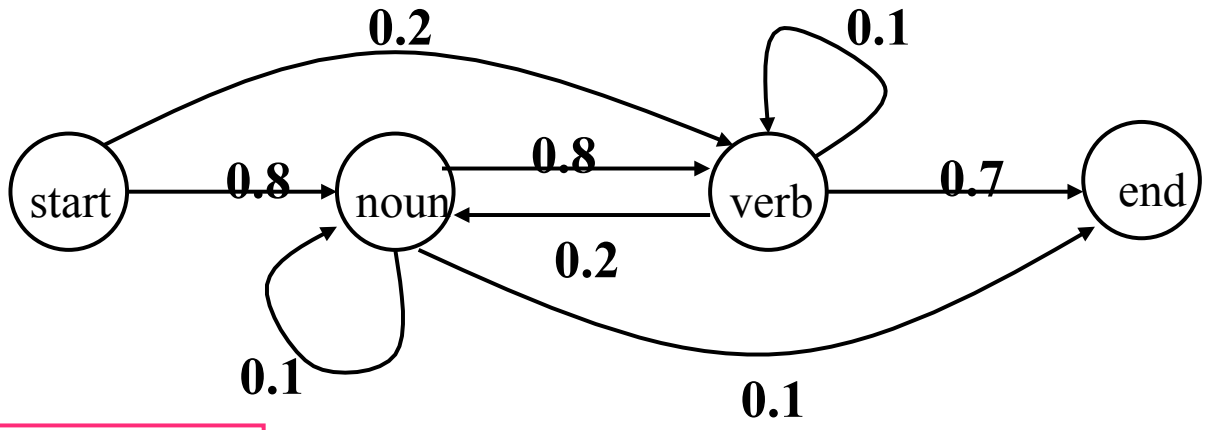
Token 3: end

	0	1	2	3
start	1	0	0	0
verb	0	.1	.256	-
noun	0	.64	.0128	-
end	0	0	-	.256*.7 .0128*.1



Token 3: end
take maximum,
set back pointers

	0	1	2	3
start	1	0	0	0
verb	0	.1	.256	-
noun	0	.64	.0128	-
end	0	0	-	.256*.7 ~~.0128*.1~~



Decode:
fish = noun
sleep = verb

	0	1	2	3
start	1	0	0	0
verb	0	.1	.256	-
noun	0	.64	.0128	-
end	0	0	-	.256*.7

Complexity?

- How does time for Viterbi search depend on number of states and number of words?

Complexity

time = $O (s^2 n)$

for s states and n words

(Relatively fast: for 40 states and 20 words, 32,000 steps)