

# CS 4650/7650

## Examples of Viterbi, Forward, and Backward algorithms

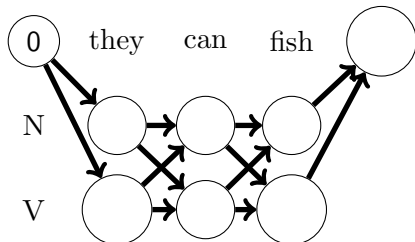
Jacob Eisenstein

October 18, 2015

## Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

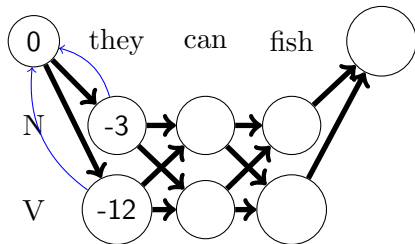
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

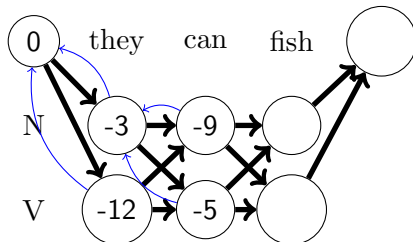
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

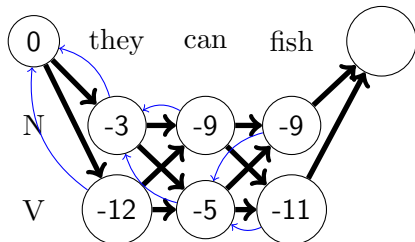
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

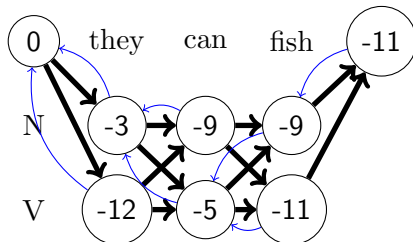
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



# Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

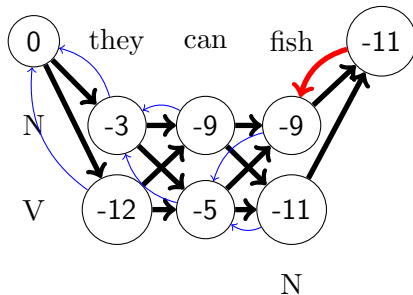
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



# Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

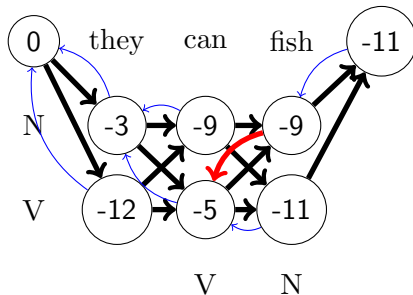
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3

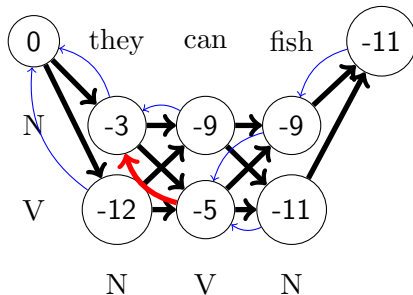




# Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

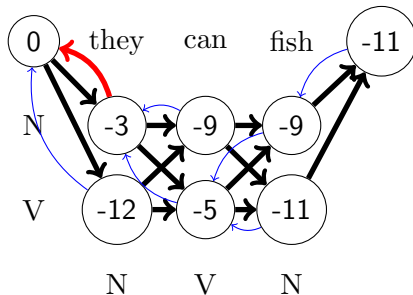
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



# Example: Viterbi algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3

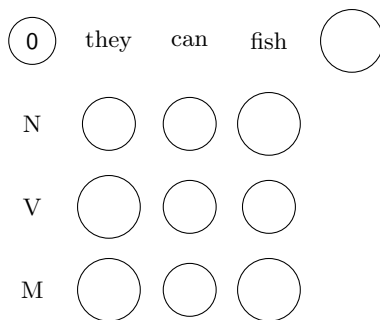


Now let's add a tag M for modal verbs.

# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

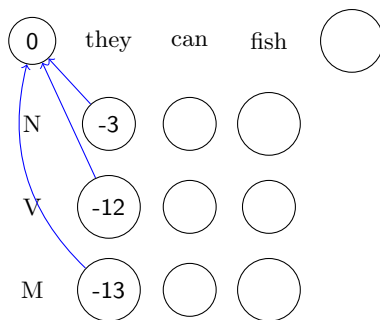
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

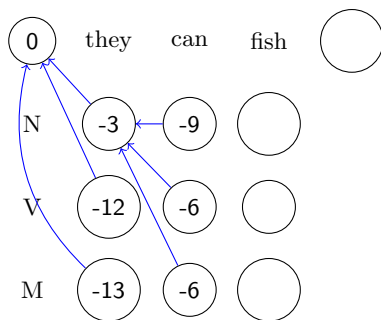
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

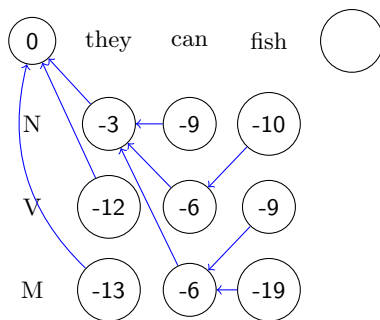
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

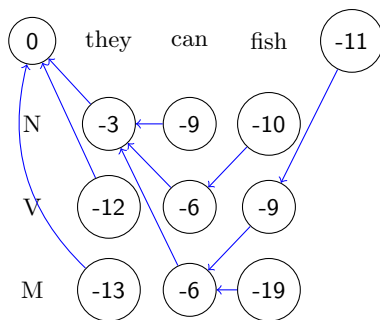
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10

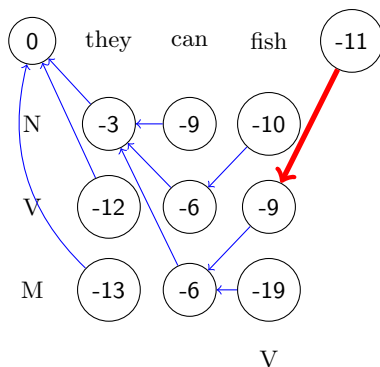




# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

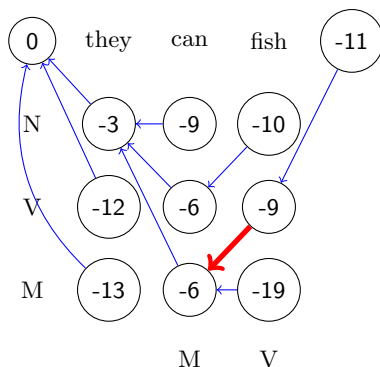
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

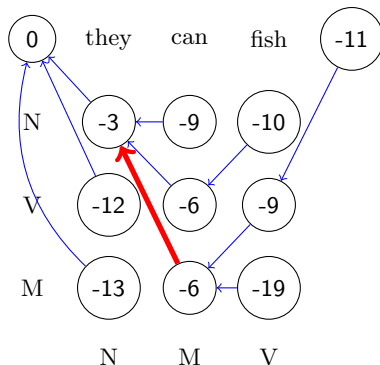
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

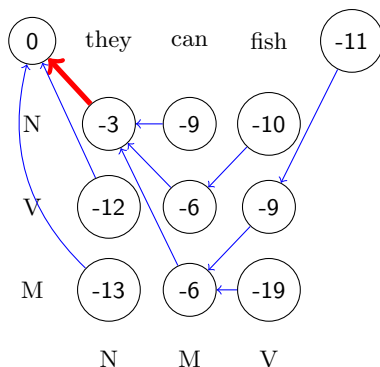
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



# Viterbi example

	Transition			
	N	V	M	END
N	-3	-1	-2	-2
V	-1	-2	-5	-2
M	-10	0	-3	-10
Start	-1	-2	-3	

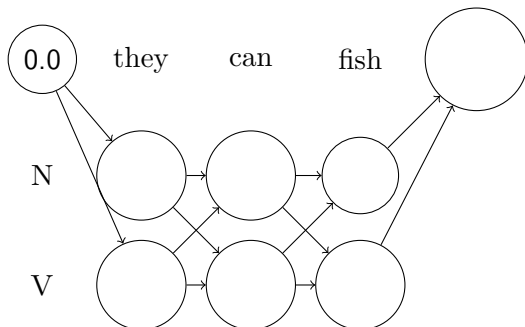
	Emission		
	they	can	fish
N	-2	-3	-3
V	-10	-2	-3
M	-10	-1	-10



## Example: forward algorithm

Transitions			
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

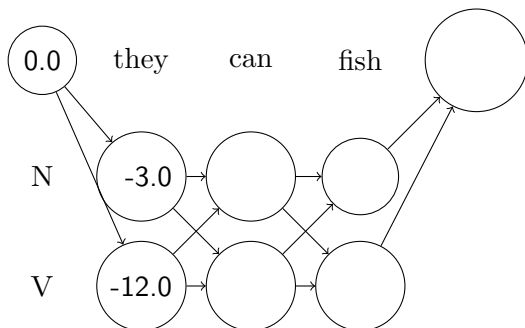
Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: forward algorithm

Transitions			
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

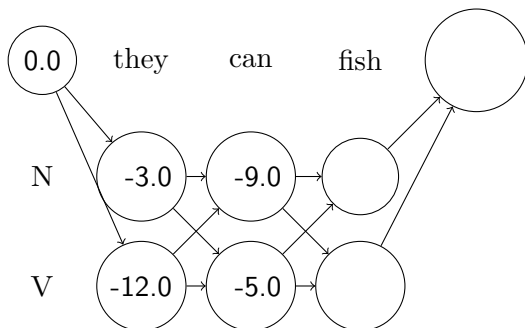
Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: forward algorithm

Transitions			
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

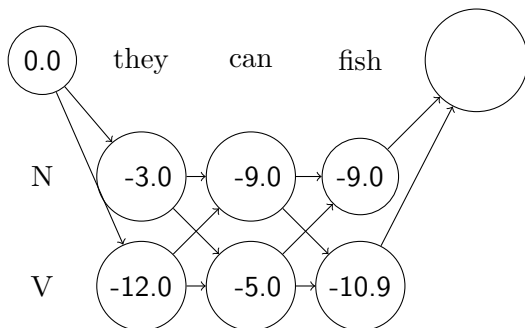
Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: forward algorithm

Transitions			
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3

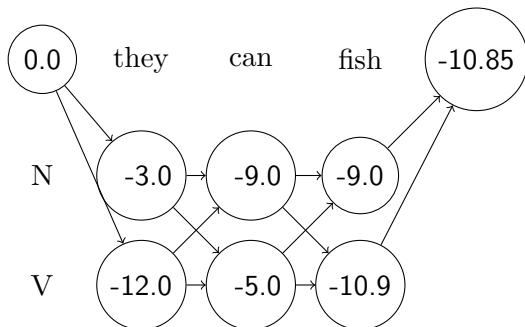




## Example: forward algorithm

Transitions			
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: backward algorithm

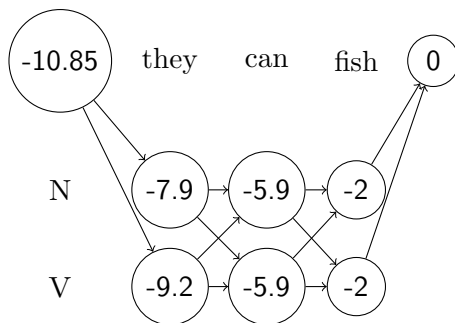
Transitions			
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3

## Example: backward algorithm

	Transitions		
	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

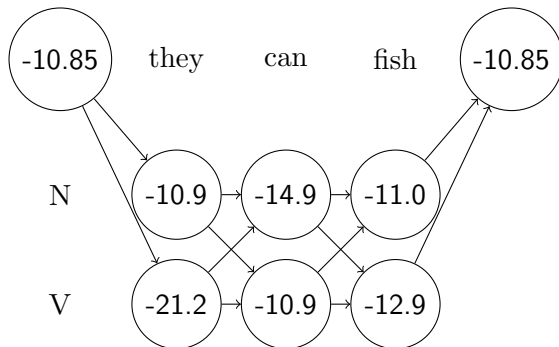
	Emissions		
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: marginal probabilities

	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

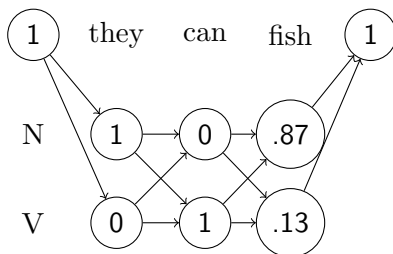
Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: marginal probabilities

	N	V	END
N	-3	-1	-2
V	-1	-3	-2
START	-1	-2	

Emissions			
	they	can	fish
N	-2	-3	-3
V	-10	-1	-3



## Example: marginal probabilities

Transition weights  
(log-probabilities)

	N	V	END
N	-2	-1	-2
V	-2	-3	-2
START	-1	-2	

Emission weights  
(log-probabilities)

	they	can	fish
N	-2	-3	-3
V	-6	-1	-2

$$\log P(\text{they}/N \text{ can}/V \text{ fish}/V) = -1 - 2 - 1 - 1 - 3 - 2 - 2 = -12$$

$$\log P(\text{they}/N \text{ can}/V \text{ fish}/N) = -1 - 2 - 1 - 1 - 2 - 3 - 2 = -12$$

$$\log P(\text{they}/V \dots) \approx -\infty$$

$$\log \sum_y \exp P(y_1, y_2 = V, y_3, x_{1:3}) = \log(e^{-12} + e^{-12} + e^{-\infty} + e^{-\infty})$$

$$= -11.3 = f_2(V) + b_2(V)$$