Genome 540 Discussion

February 27th, 2024

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Genome Sciences
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Assignment 7 Questions?

- Part 1: Use your predicted D-segments from hw6 to
  - Generate a new scoring scheme
  - Simulate background sequence
- Part 2: Run your D-segment program on the background and compare to the real data
- Part 3: Answer some questions

Assignment 8

HMM Tasks

Rabiner 1989:

Likelihood: Given an HMM λ = (A, B) and an observation sequence O, determine the *likelihood* P(O|λ).

Decoding: Given an observation sequence O and an HMM λ = (A, B), discover the *best hidden state* sequence Q.

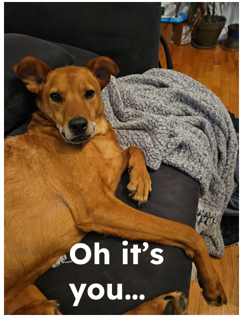
Learning: Given an observation sequence O and the set of states in the HMM, learn the HMM *parameters A and B.*

Example

Your dog is very moody and you want to know when they **like** or **hate** you so you start recording what they are doing when you get home everyday…

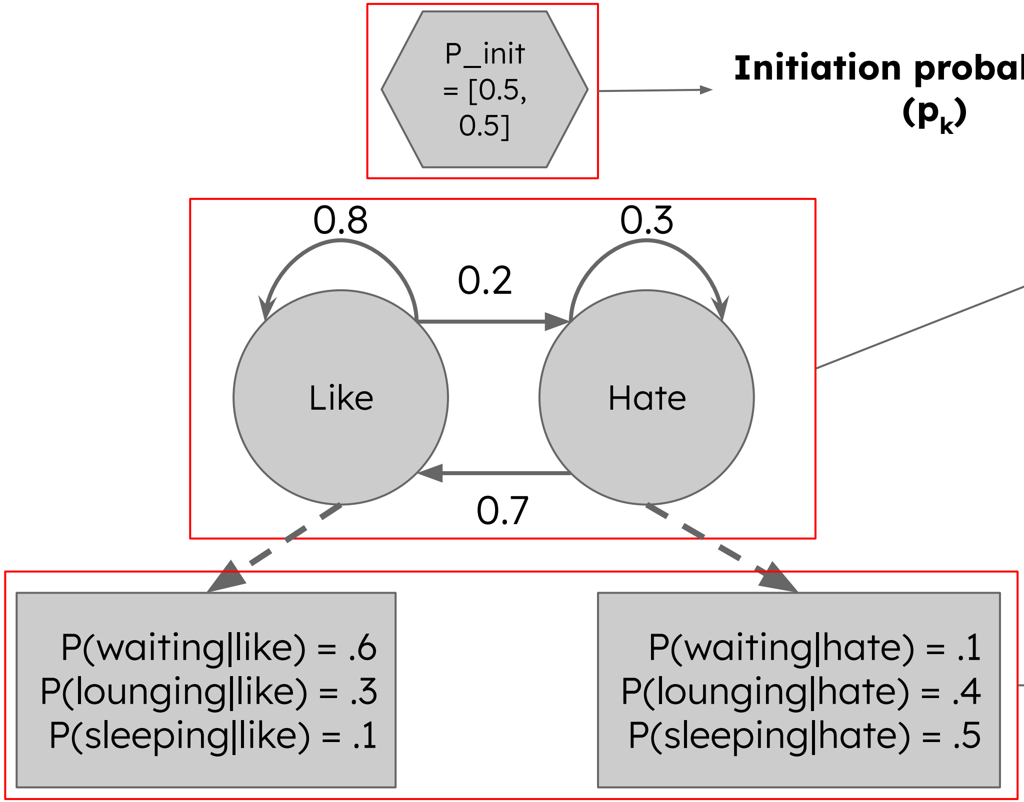
Waiting

Lounging



Sleeping

Model



Initiation probabilities (p_k)

Transition Matrix (A)

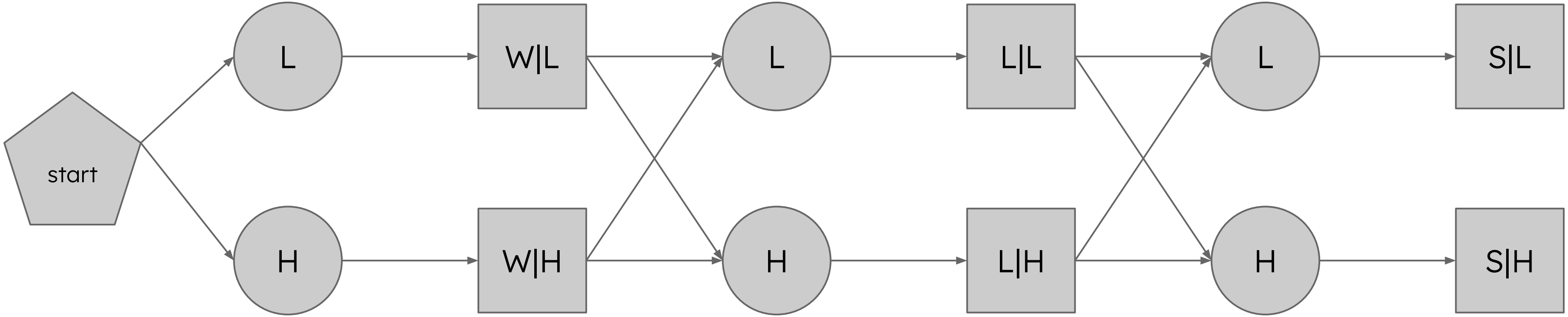
	L	H
L	0.8	0.2
H	0.7	0.3

a_{LH}

Set of Hidden States (S = {k})

Emission Probabilities of the observations (B = {b}) given the state

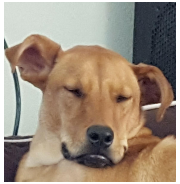
Graphical representation with data



Waiting

Lounging

Sleeping



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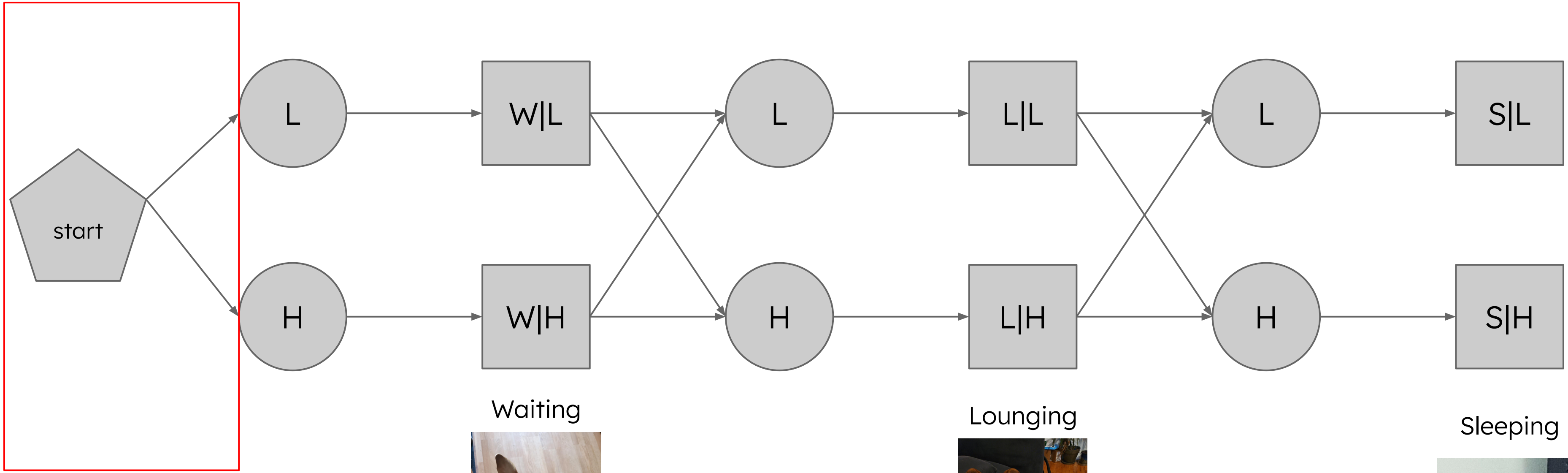
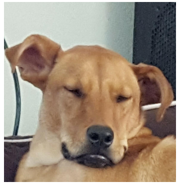


Initiation

Waiting

Lounging

Sleeping



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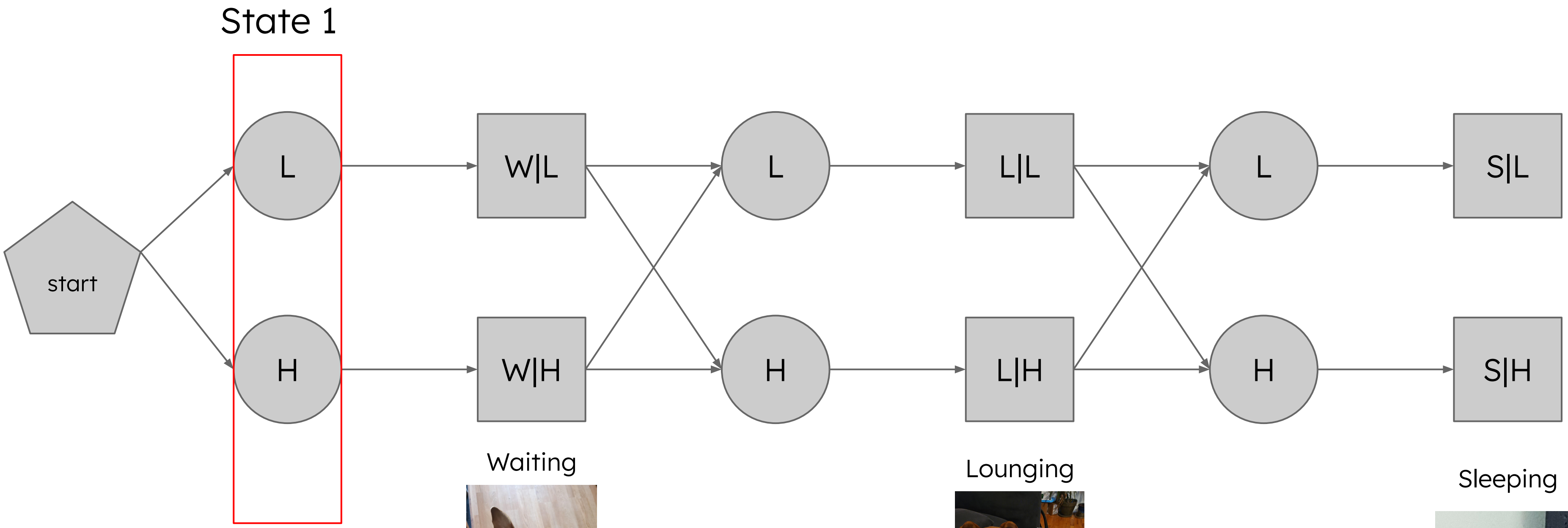

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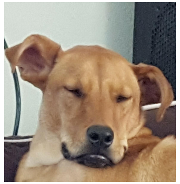

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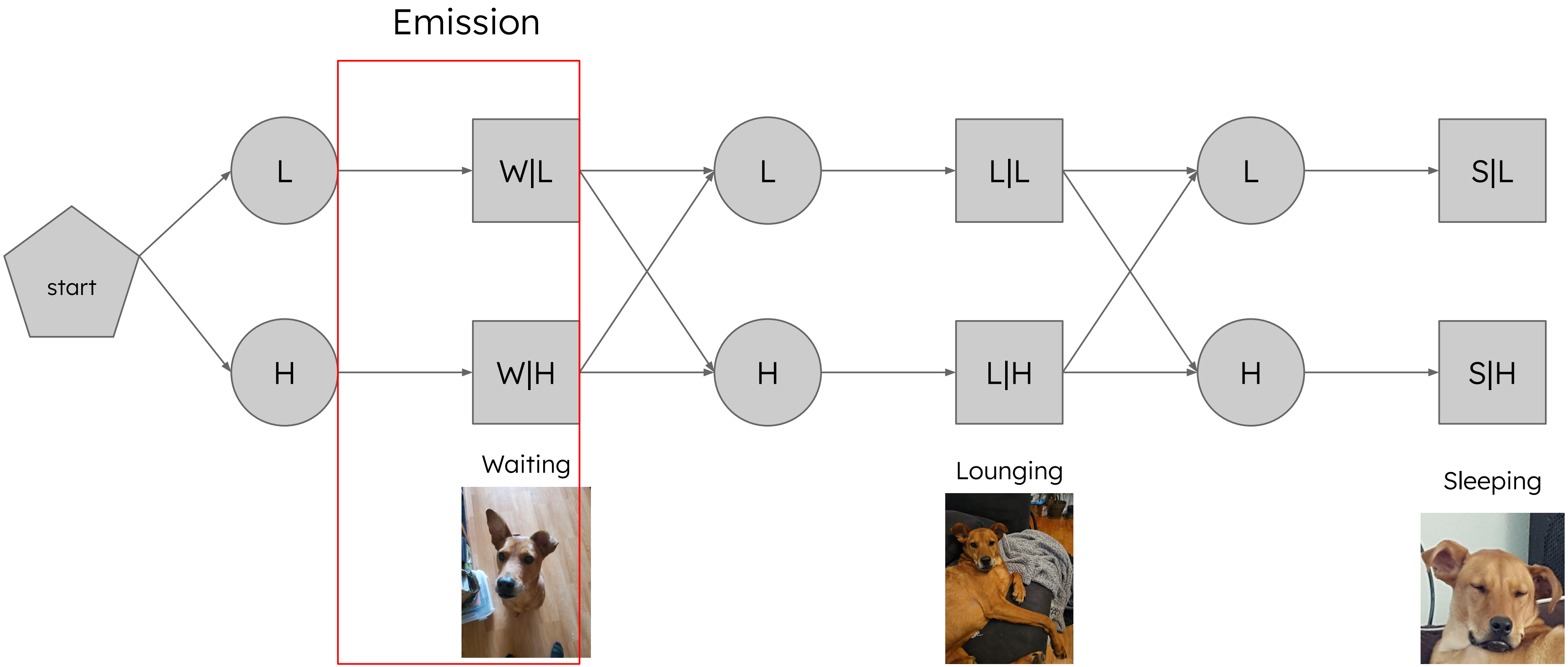

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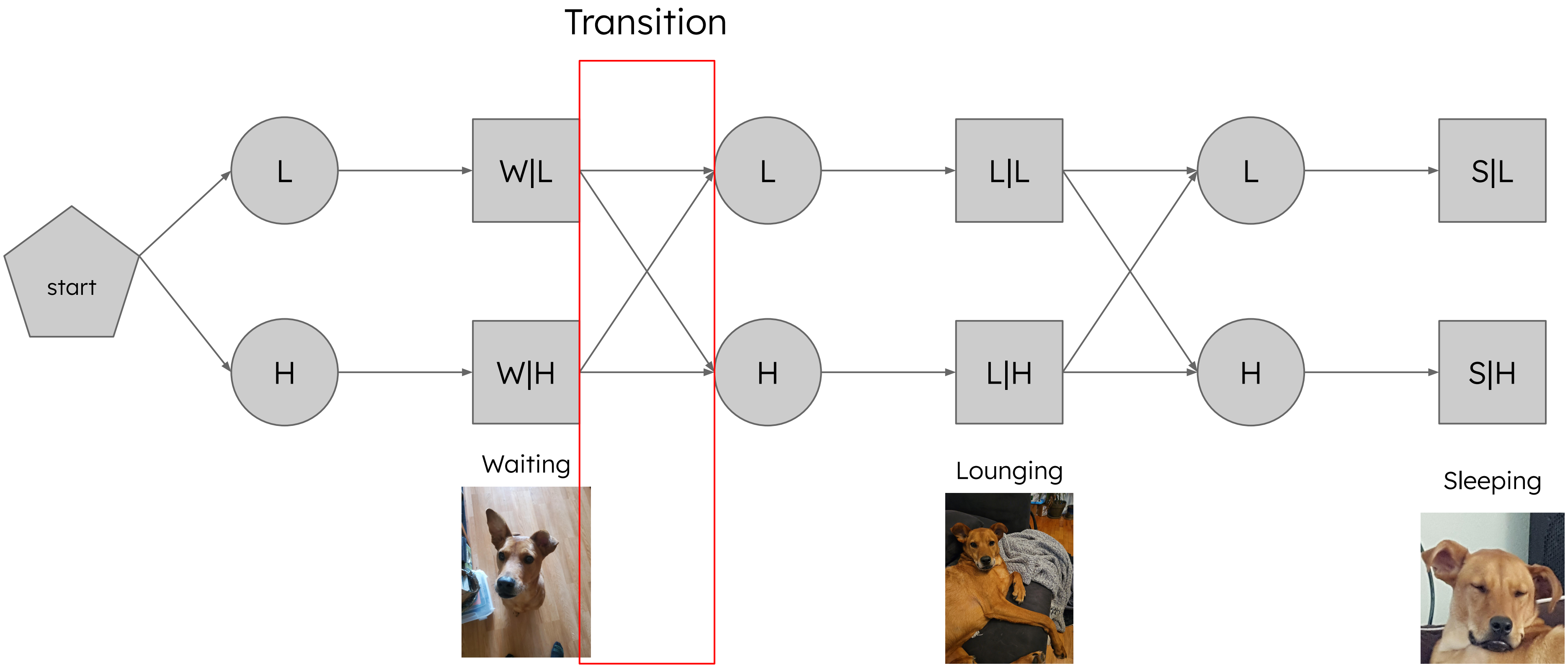


Baum Welch (Forward/Backward) - “Training” an HMM

1. Step 1: Expectation
   a. Compute the forward probabilities
   b. Compute the backward probabilities
2. Step 3: Maximization
   a. Update the transition and emission probabilities

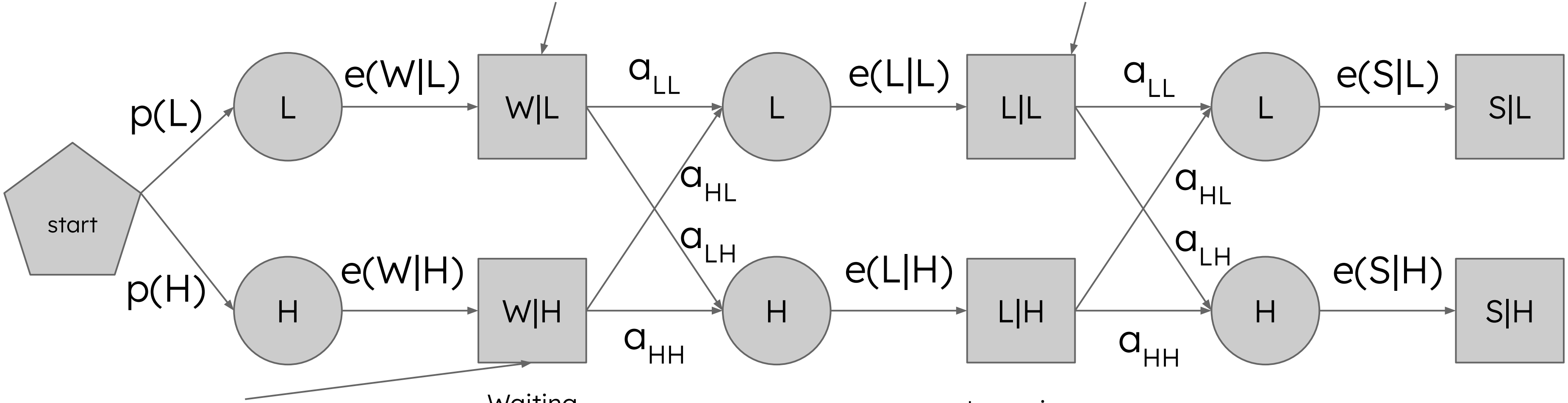
Forward Algorithm - **Likelihood** of an observed sequence

3 steps:

1. Initialization
2. Recursion
3. Termination

Forward Algorithm - **Likelihood** of an observed sequence

$f_1(L)=p(L)*e(W|L)$ $f_2(L)=(f_1(L)*a_{LL} + f_1(H)*a_{HL})*e(L|L)$



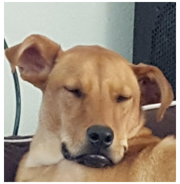
$f_1(H)=p(H)*e(W|H)$

***Emission may also be written $e_H(W)$

Waiting

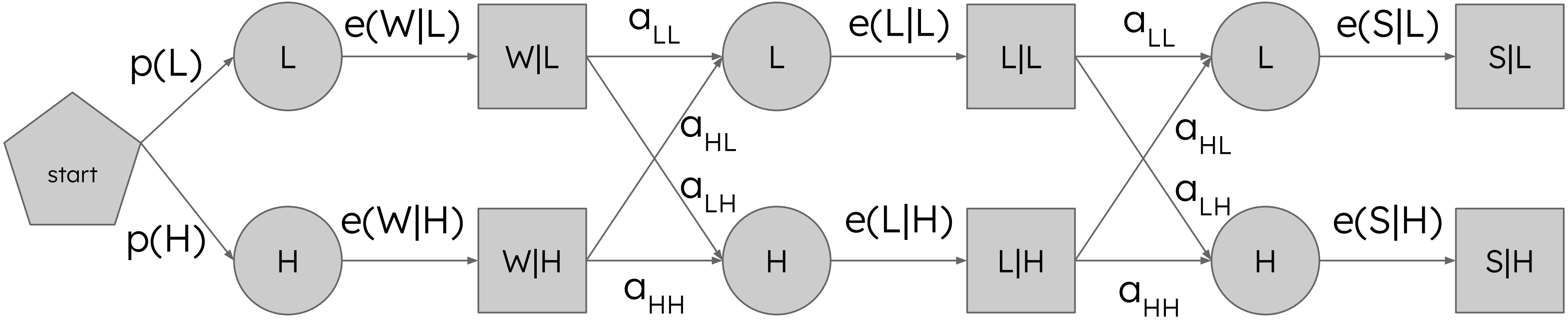
Lounging

Sleeping



Computing the backward probabilities

Backward probabilities: probability of seeing the observations from time t + 1 to the end



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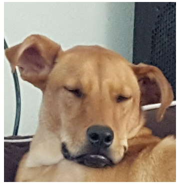

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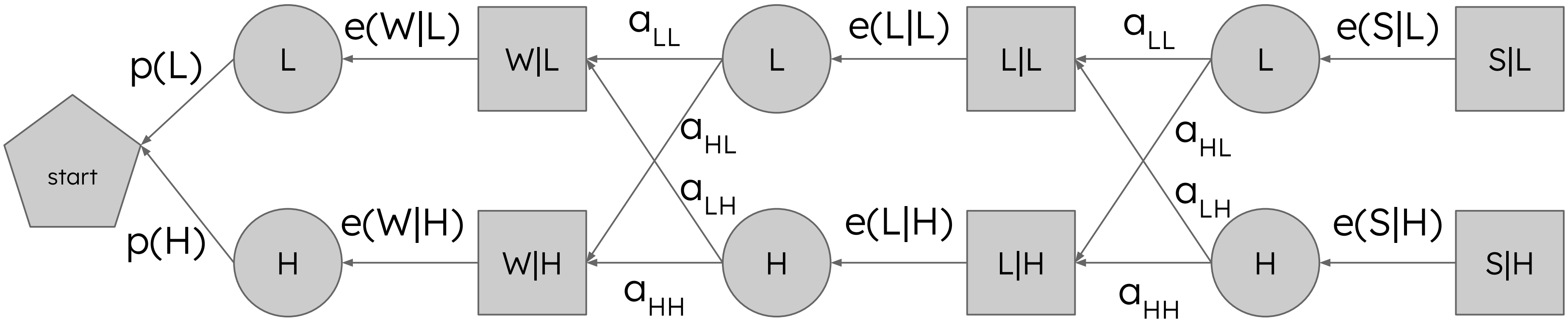

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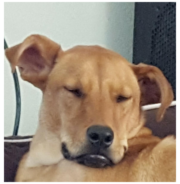
Sleeping



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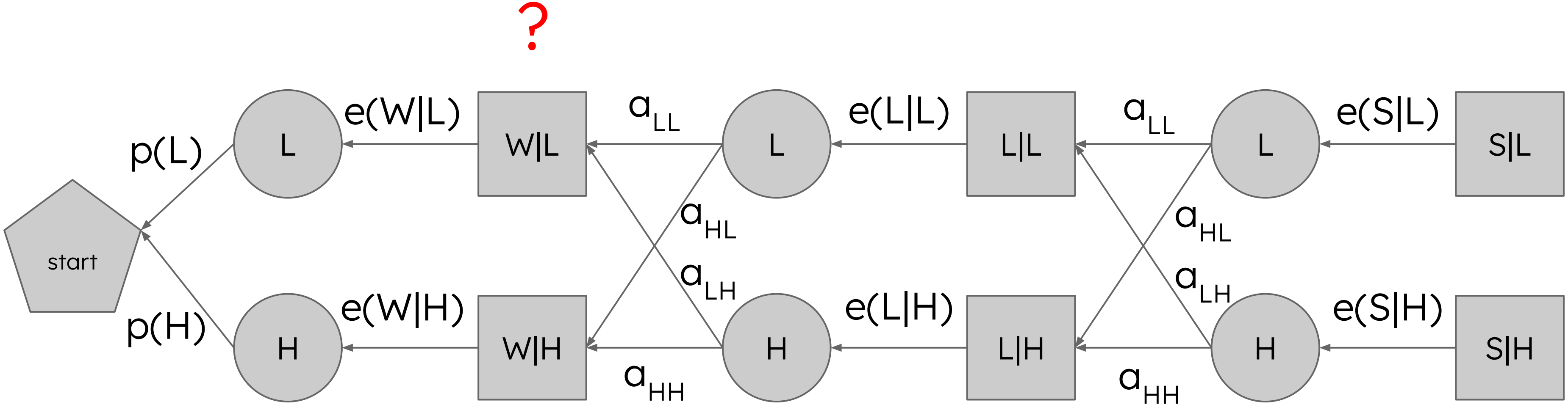

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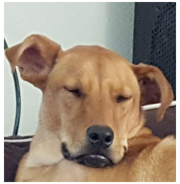
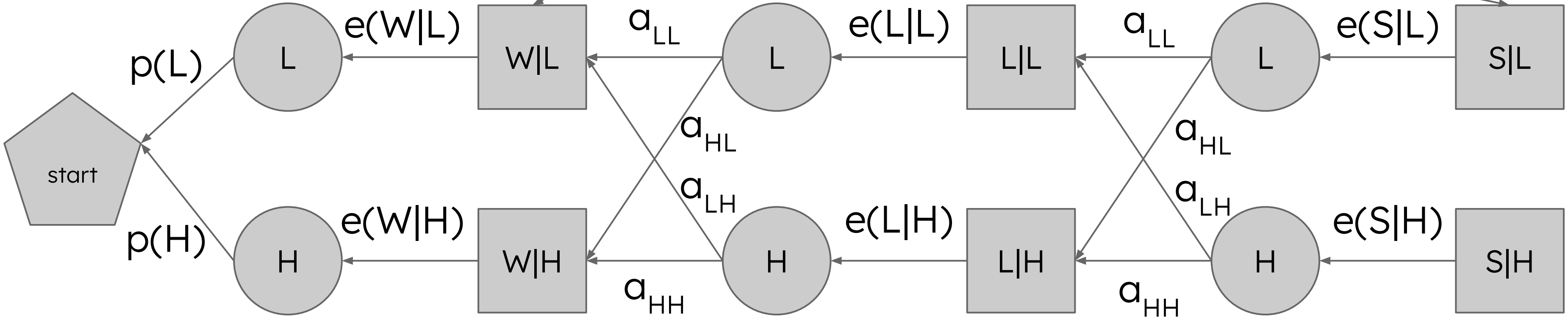


Computing the backward probabilities

$b_t(i) = b_{t+1}(L)*a_{LL}*e(L|L) + b_{t+1}(H)*a_{LH}*e(L|H)$ **Initialize assuming $b_T(i) = 1$



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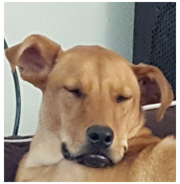
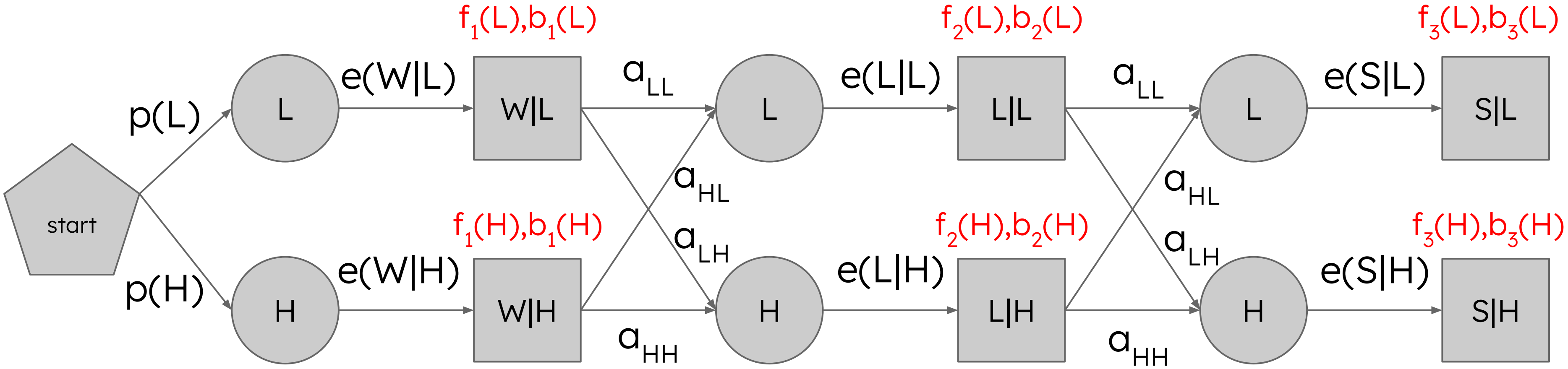


$b_t(i)=\Sigma_j b_{t+1}(j)*a_{ij}*e_j(t+1)$

Calculating the transition probabilities

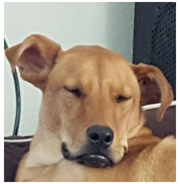


$$P_t(i,j) = \frac{f_t(i) * a_{ij} * e_j(o_{t+1}) * b_{t+1}(j)}{\Sigma^{N}_{j=1} f_t(j)b_t(j)}$$

Waiting

Lounging

Sleeping



Calculating the transition probabilities

$$P_t(i,j) = \frac{f_t(i) * a_{ij} * e_j(o_{t+1}) * b_{t+1}(j)}{\Sigma^{N}_{j=1} f_t(j) b_t(j)}$$

Probability of observations constrained on a specific transition (numerator)

Probability of observations given the model (denominator)

$$\underline{a}(i,j) = \frac{\Sigma^{T-1}_{t=1} P_t(i,j)}{\Sigma^{T-1}_{t=1} \Sigma^{N}_{k=1} P_t(i,k)}$$

Calculating the emission probabilities

$$\gamma_t(j) = \frac{f_t(j)b_t(j)}{P(O|\lambda)} = \frac{f_t(j)b_t(j)}{\Sigma^{N}_{j=1} f_t(j)b_t(j)}$$

← Probability of being in state j at time t given the observation sequence O and the model

$$e_t(v_k|j) = \frac{\text{expected number of times in state j and observing symbol } v_k}{\text{expected number of times in state j}}$$

$$e_t(v_k|j) = e_j(v_k) = \frac{\Sigma^{T}_{t=1,Ot=vk}\gamma_t(j)}{\Sigma^{T}_{t=1}\gamma_t(j)}$$

← Sum of all $\gamma_t(j)$ where the observed symbol = v_k

Avoiding vanishing probabilities

- Scaling
  - Good tutorial
- Work in log space
  - Mann 2006

Scaling

- When computing forward probabilities, also compute a scaling factor c_t

$$c_t = \frac{1}{\sum^{N}_{i=1} f_t(i)}$$

- New forward probabilities at time t are multiplied by c_t
- Use c_t for scaling backward probabilities as well
- To get back true forward/backward probabilities

$$f^*_t(i) = (\prod^{t}_{t=1} c_t) f_t(i)$$

Reminders

- HW7 due this Sunday, 11:59pm
- Please have your name in the filename of your homework assignment and match the template