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Seriesly, Neural Networks

An Intro to RNNs, then LSTMs

Agenda

1. Administrative Meanderings (AM)
    a. RSO Update
    b. Coordinator Elections
    c. Future of SIGAI
2. Let's Review: Artificial & Convolutional Neural Nets
3. What is a Recurrent Neural Network?
4. Backpropagation Through Time
5. Long Short-Term Memory Networks

AM: RSO Update

- Constitution is written and submitted.
  - Currently deciding on where to publish it, but you'll have access to it by the end of the semester. :D
- We're on track to being an RSO in the fall semester.
  - Nothing should change for you, as a member; however, we'll let you know if anything does.

AM: Coordinator Elections

- Two stages:
  - **(Apr 05)** Pitches – RL P1 lecture
  - **(Apr 19)** Elections – MDP workshop
- Pitches:
  - 2-3 minute spiel about…
    - Your background
    - What part(s) of AI are you interested in?
    - What are some of the lecture/workshop content you'd like to bring?
- Coordinator meeting after finals **(May 02)**.
- We're looking to have 8-9 coordinators.

AM: Coordinator Roles (1-year commitment)

Coordinator:

- Must lecture at least 1 entire unit
- Expect to 10-15 hr commitment/week – may change if we get a graphic designer
- Preferable that you either do AI-related research, or work in AI
    - Overall, it's paramount that you're passionate about education and the field

Director:

- Same responsibilities as Coordinator, **plus:**
- You've previously been a Coordinator, *and* not been Director in the past year
- You're able to mentor Coordinators (e.g. you can pick up a lecture/workshop and be comfortable lecturing)
- You're simply a Coordinator who can occasionally `sudo`, and the external point of contact.

AM: Future of SIGAI

- We've secured access to Stokes! (The GPU cluster.)
  - This means more realistic workshops, among other things
- In the fall, we're looking to have two foci:
  - Industry (topics relating to Kaggle competitions, and generally data science)
  - Research (more advanced topics that haven't quite made it out labs)
- This is still somewhat open-ended, and will be a conversation that happens with new coordinators.

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Let's Review: ANNs and CNNs

- Great for independent data. *What does this mean?*
- **ANNs:**
  - Great for classification
  - Massage inputs to extract data from signal at each node
- **CNNs:**
  - Great feature extractors
  - Leverage convolution to enhance feature extraction
  - Attempt to keep only important values by pooling

Let's Review: Some Drawbacks

- We *assume* ***fixed*** input
- We *assume* ***independence*** of inputs and outputs
  - There is **no** sequential aspect to the data

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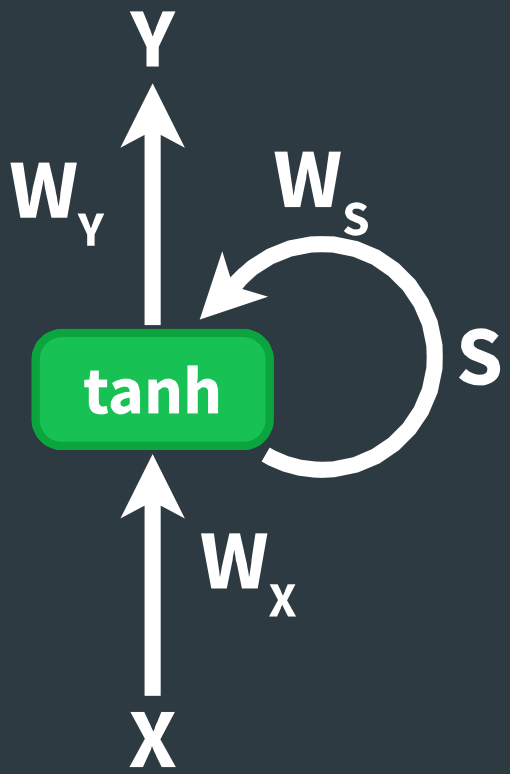
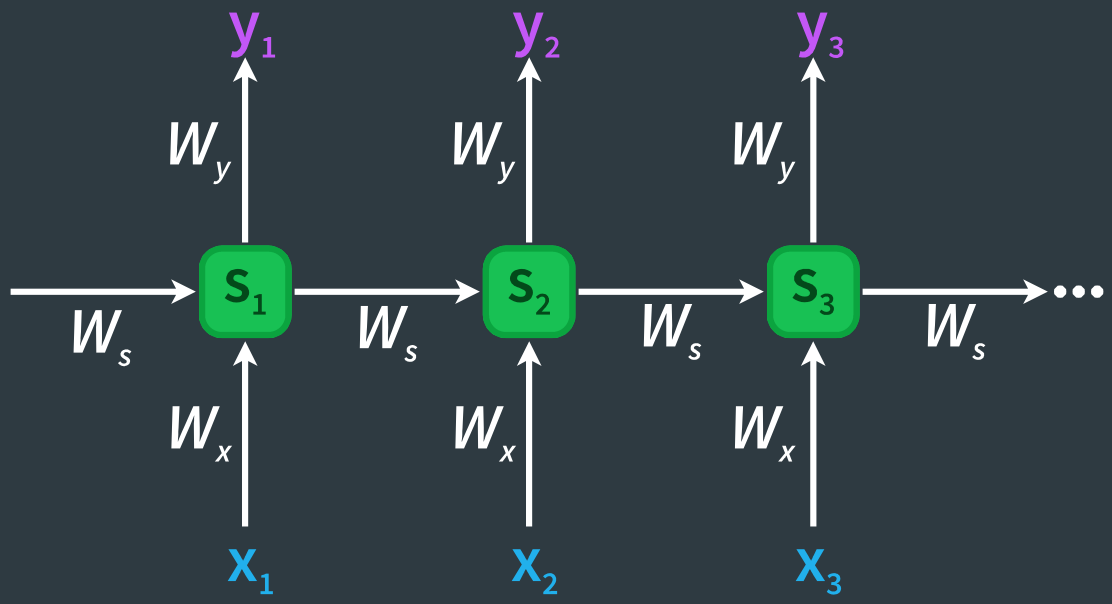
What is a Recurrent Neural Network? (RNN)



- X is our input
- Y is our output
- S is a hidden layer called “State”
- W_{...} is the weight matrix for each input/output

- We’ll expand this on the next slide

Expanding the RNN



Observations?

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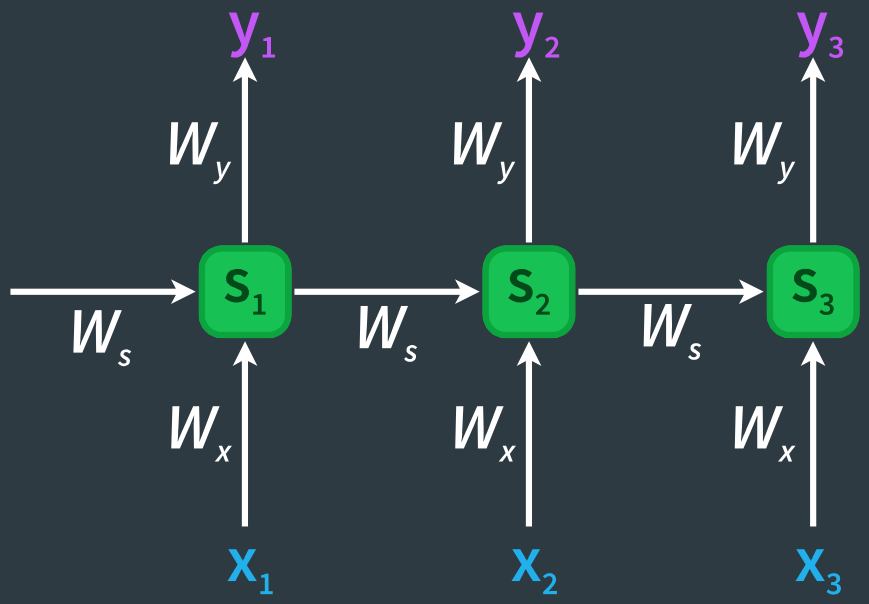
Let's Try Backprop



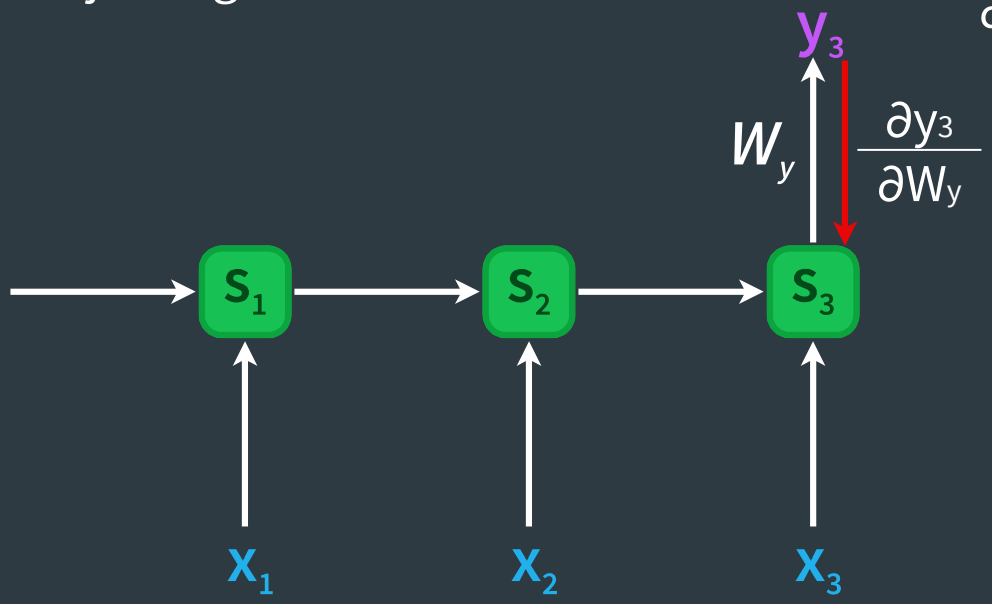
- We have 3 matrices to update.
- Taking the simplest case…
  - Let **t=3**

Let's Try Backprop

At time, **t=3**

Adjusting: W_y

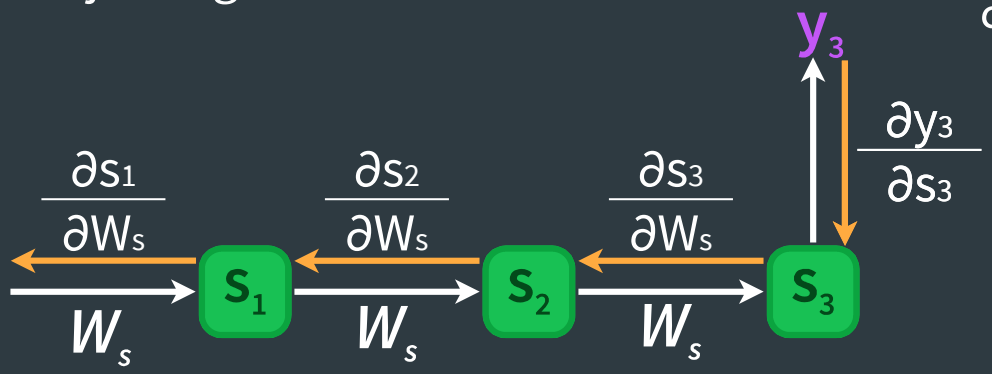
$$\frac{\partial E_3}{\partial W_y} = \frac{\partial E_3}{\partial y_3} \cdot \frac{\partial y_3}{\partial W_y}$$



Let's Try Backprop

At time, **t=3**

Adjusting: W_s



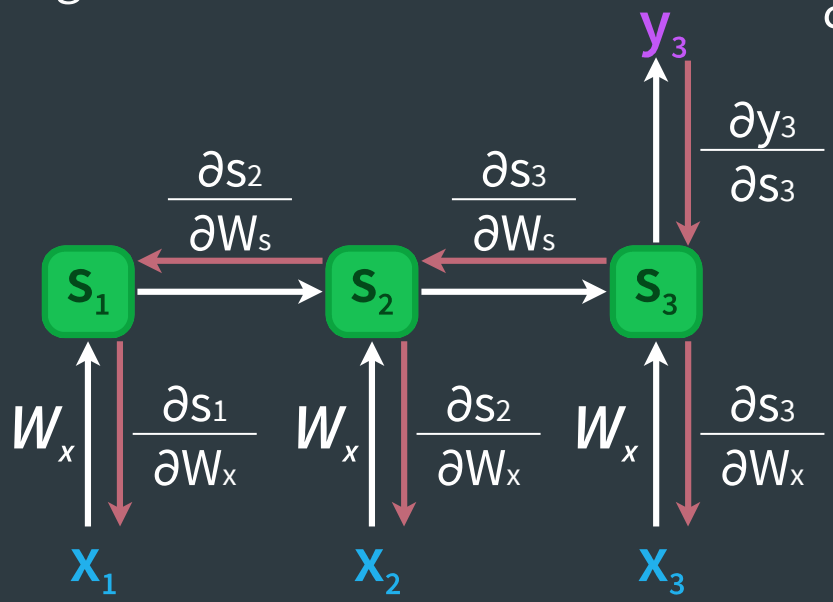
$$\frac{\partial E_3}{\partial W_s} = \frac{\partial E_3}{\partial y_3} \cdot \frac{\partial y_3}{\partial s_s} \cdot \frac{\partial s_3}{\partial W_s} +$$
$$\frac{\partial E_3}{\partial y_3} \cdot \frac{\partial y_3}{\partial s_s} \cdot \frac{\partial s_3}{\partial s_2} \cdot \frac{\partial s_2}{\partial W_s} +$$
$$\frac{\partial E_3}{\partial y_3} \cdot \frac{\partial y_3}{\partial s_s} \cdot \frac{\partial s_3}{\partial s_2} \cdot \frac{\partial s_2}{\partial s_1} \cdot \frac{\partial s_1}{\partial W_s}$$

This equation generalizes to a summation, we won't derive it though.[1]

Let's Try Backprop

At time, **t=3**

Adjusting: W_x



$$\frac{\partial E_3}{\partial W_x} = \frac{\partial E_3}{\partial y_3} \cdot \frac{\partial y_3}{\partial s_3} \cdot \frac{\partial s_3}{\partial W_x} +$$
$$\frac{\partial E_3}{\partial y_3} \cdot \frac{\partial y_3}{\partial s_3} \cdot \frac{\partial s_3}{\partial s_2} \cdot \frac{\partial s_2}{\partial W_x} +$$
$$\frac{\partial E_3}{\partial y_3} \cdot \frac{\partial y_3}{\partial s_3} \cdot \frac{\partial s_3}{\partial s_2} \cdot \frac{\partial s_2}{\partial s_1} \cdot \frac{\partial s_1}{\partial W_x}$$

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Some Notes on BPTT

- BPTT becomes extremely complex when you layer RNNs
  - You have to take all possible paths to the states and inputs
- We find two problems with BPTT
  - The Vanishing Gradient Problem[2]
  - The Exploding Gradient Problem[3]

- Information recall is difficult with only a single state, or even multiple in parallel (this ought to become clearer once we understand how LSTMs work)

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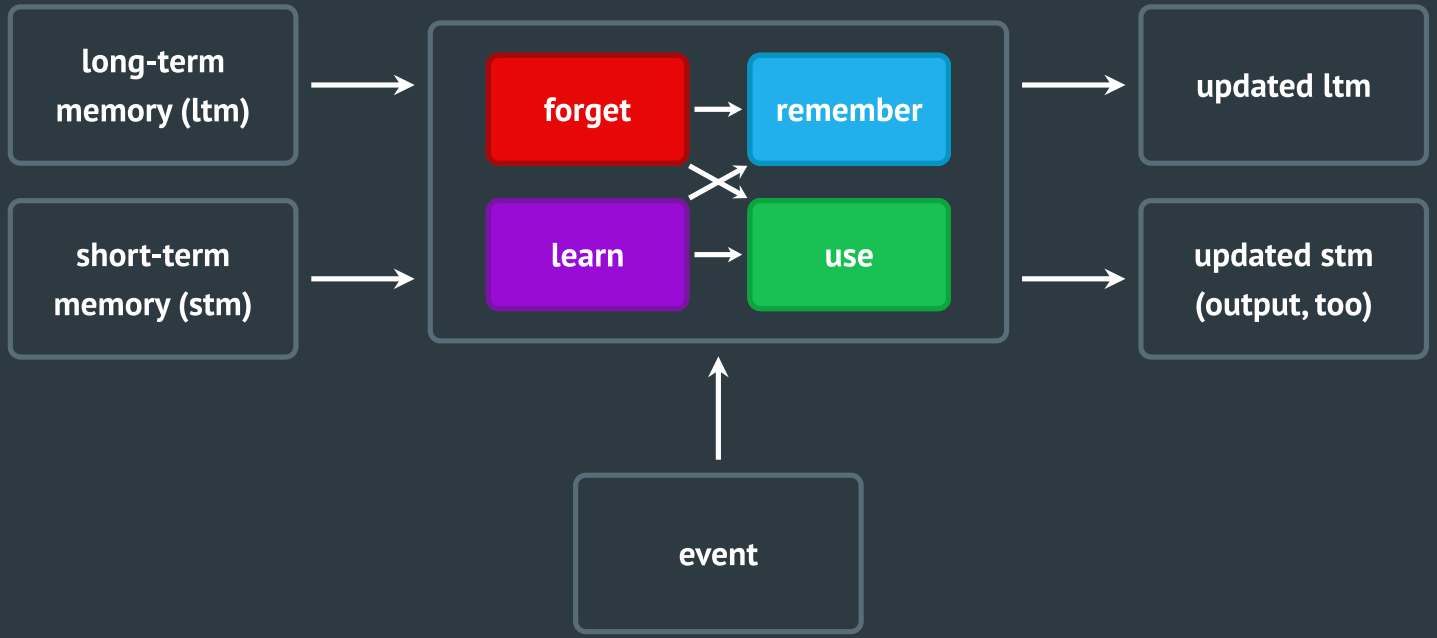
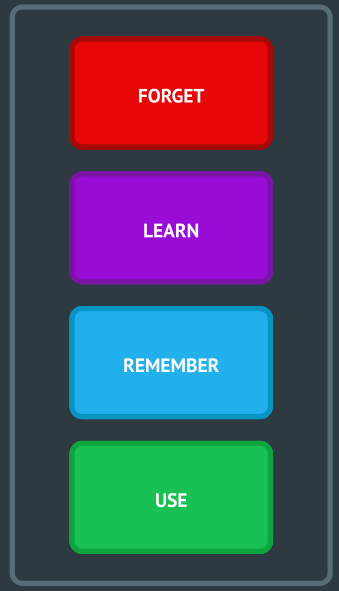
Long Short-Term Memory Networks (LSTMs)

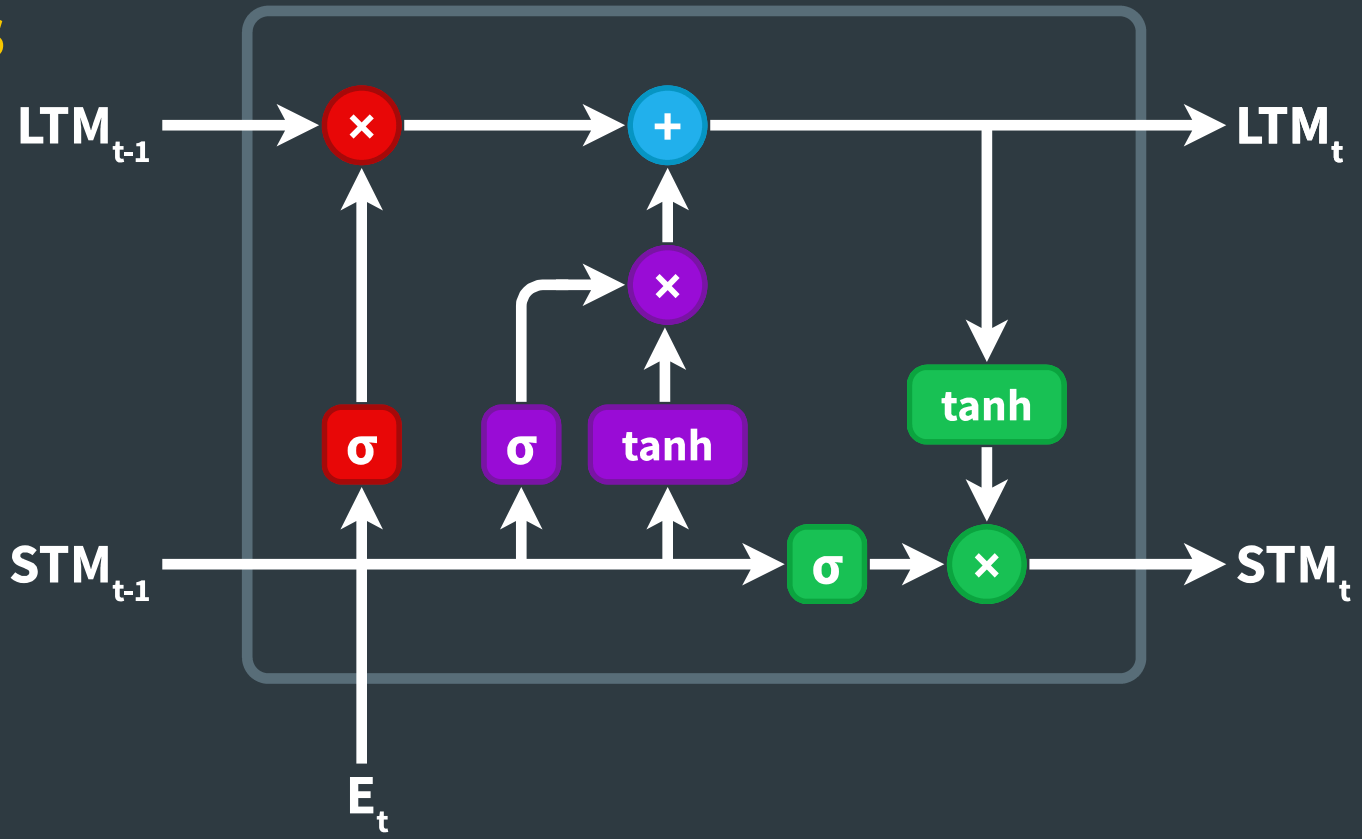
- Proposed in 1997[4]
  - Still heavily used today, as well as other gated architectures[5][6][7]
- Overcome the long-term dependency issue of RNNs
- Have an interesting architecture
  - Each “cell” is composed of 4 hidden layers
  - Layers act as “gates” to control the flow of information

Information Flow

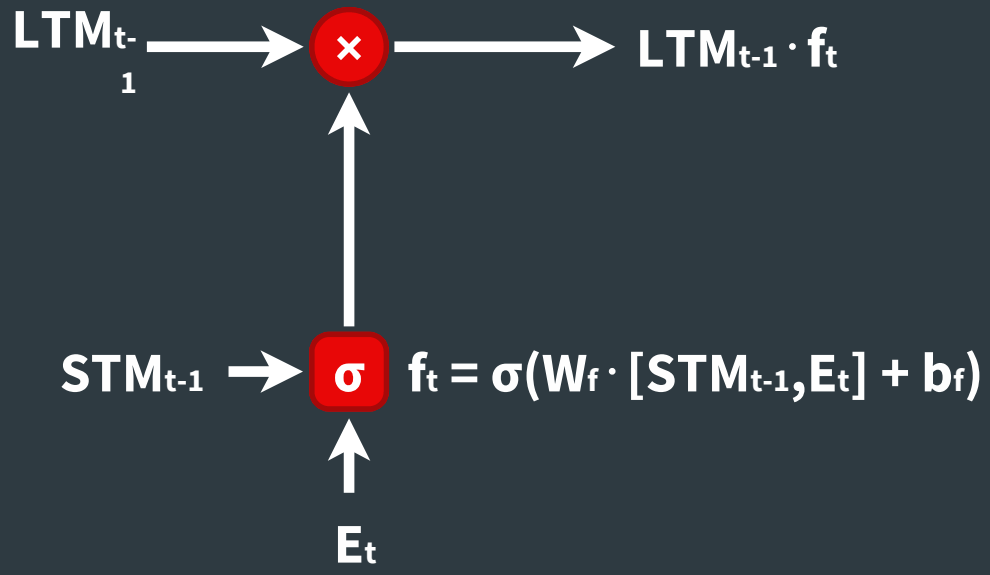


Cell Internals

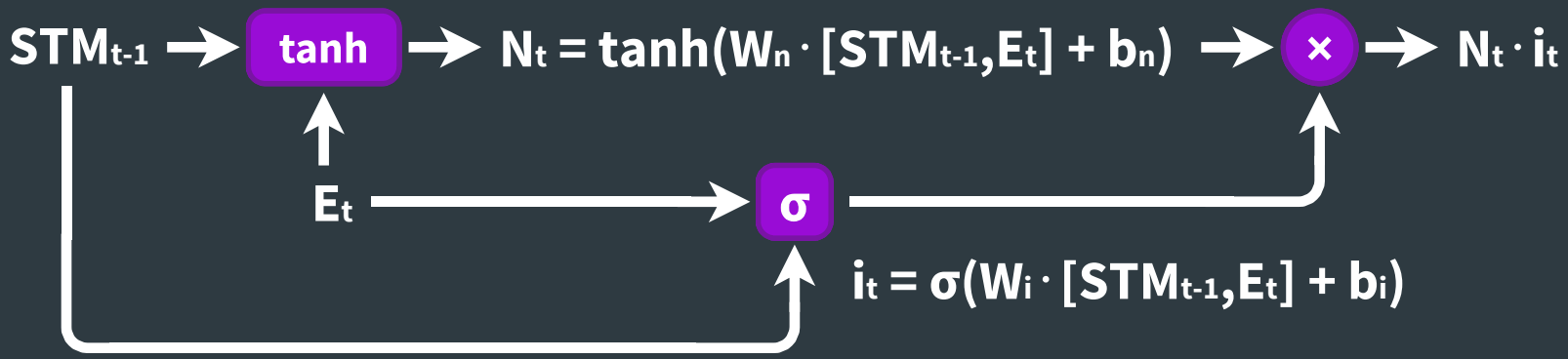




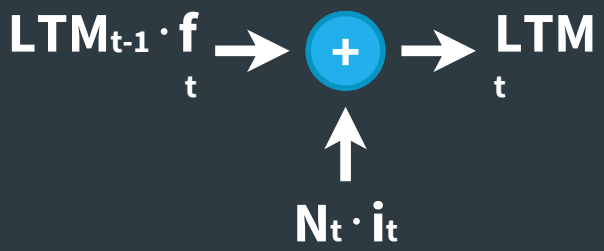
The Forget Gate



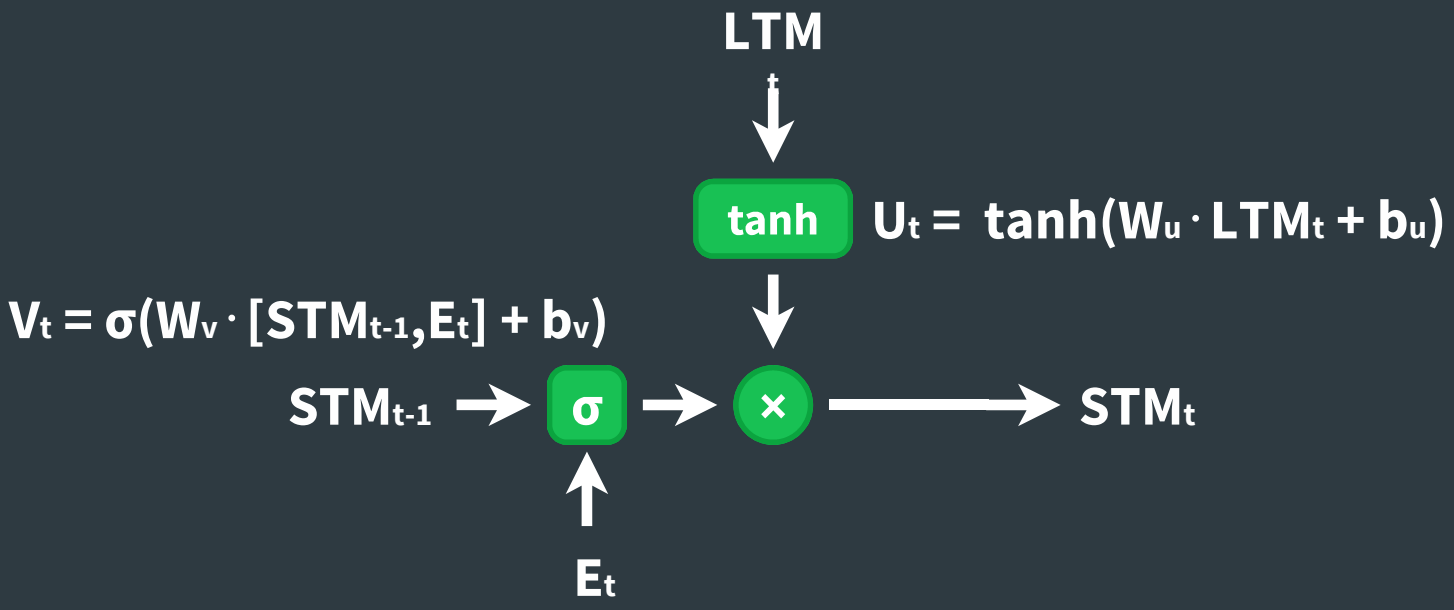
The Learn Gate



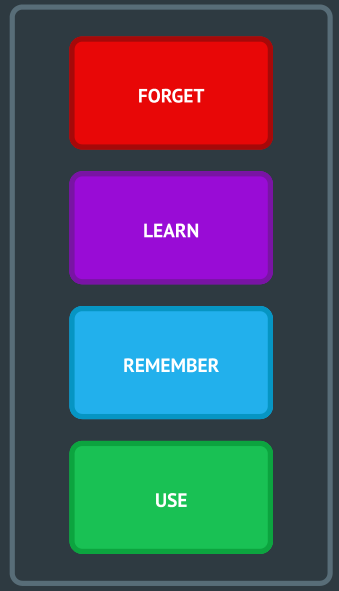
The Remember Gate

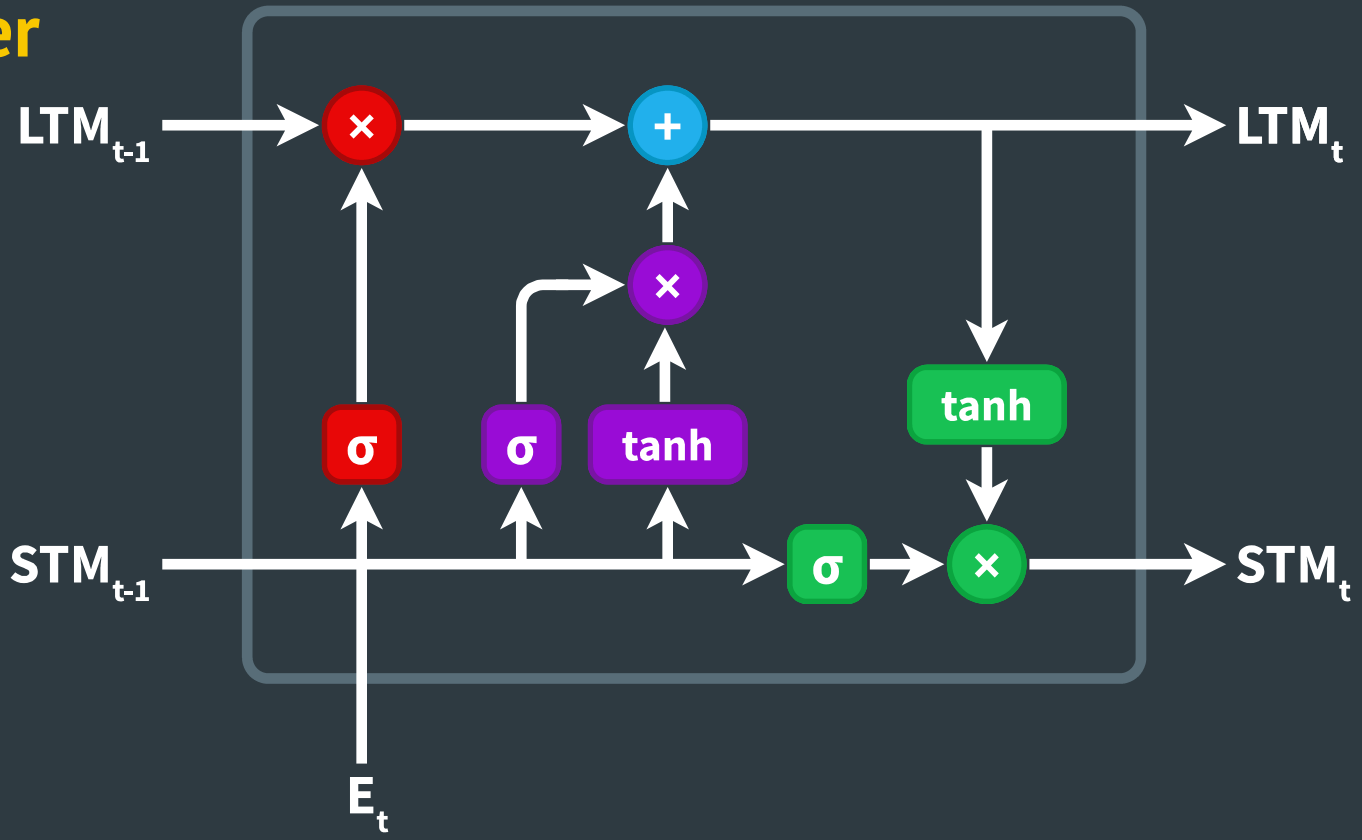


The Use Gate


LTM
t
tanh
$U_t = \tanh(W_u \cdot LTM_t + b_u)$
$V_t = \sigma(W_v \cdot [STM_{t-1}, E_t] + b_v)$
STM_{t-1}
σ
×
STM_t
E_t

Back Together





Extras & Looking Ahead

[1] Summations to calculate input and state weight matrix updates

[2] What is the vanishing gradient problem?

(Albeit Quora, this is a pretty good answer.)

[3] A Gentle Introduction to Exploding Gradients in Neural Networks

[4] Long Short-Term Memory

(original paper)

[5] Learning Phrase Representations using RNN Encoder–Decoder for Statistical Machine Translation

(Intro'd Gated Recurrent Units, alternative to LSTMs, comparable in capability)

[6] LSTM: A Search Space Odyssey

(Comparison of various gated architectures)

[7] Grid Long Short-Term Memory

Questions?