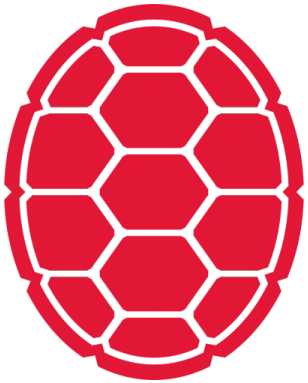


# Sequence Models

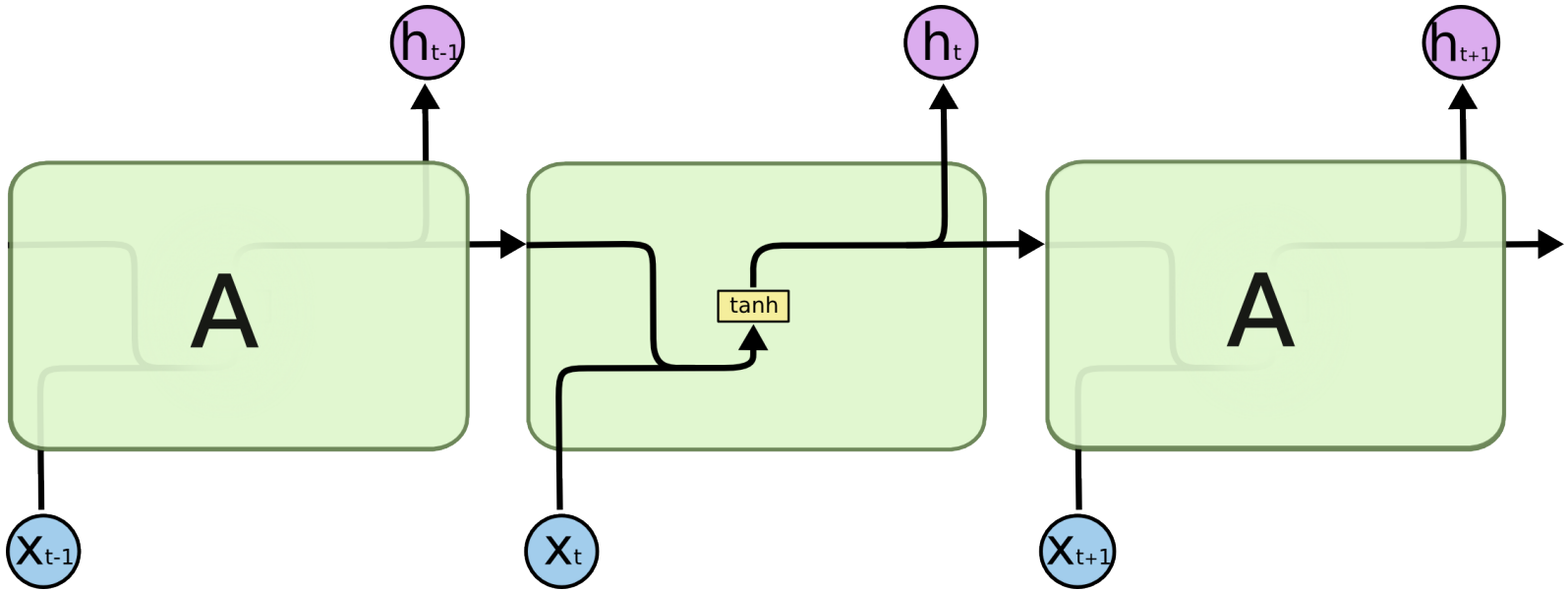
Machine Learning: Jordan Boyd-Graber
University of Maryland
LSTMS

Slides adapted from Christopher Olah

## The Model of Laughter and Forgetting

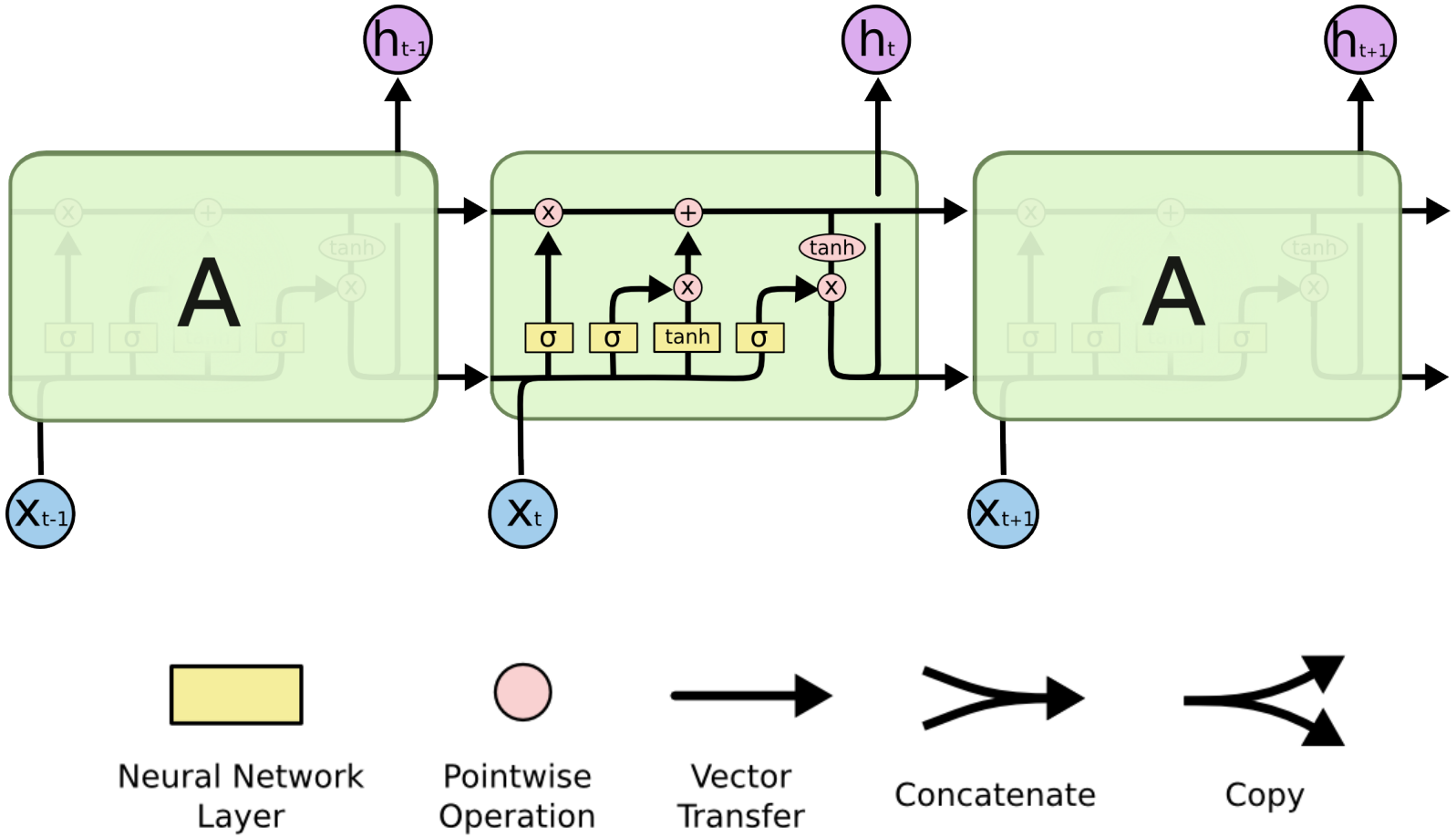
- RNN is great: can remember anything
- RNN stinks: remembers everything
- Sometimes important to forget: LSTM

## RNN transforms Input into Hidden

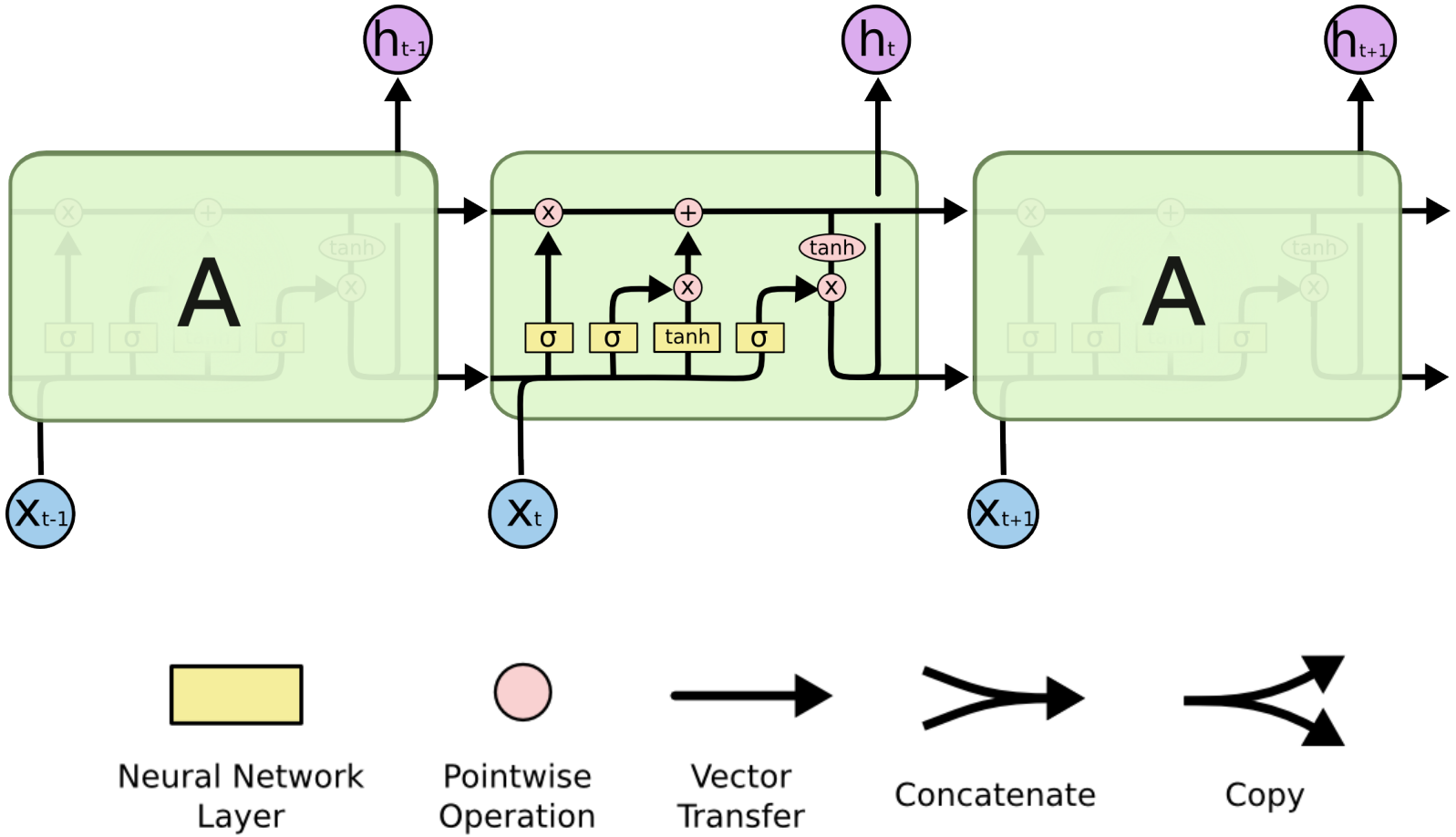



(Can be other nonlinearities)

## LSTM has more complicated innards

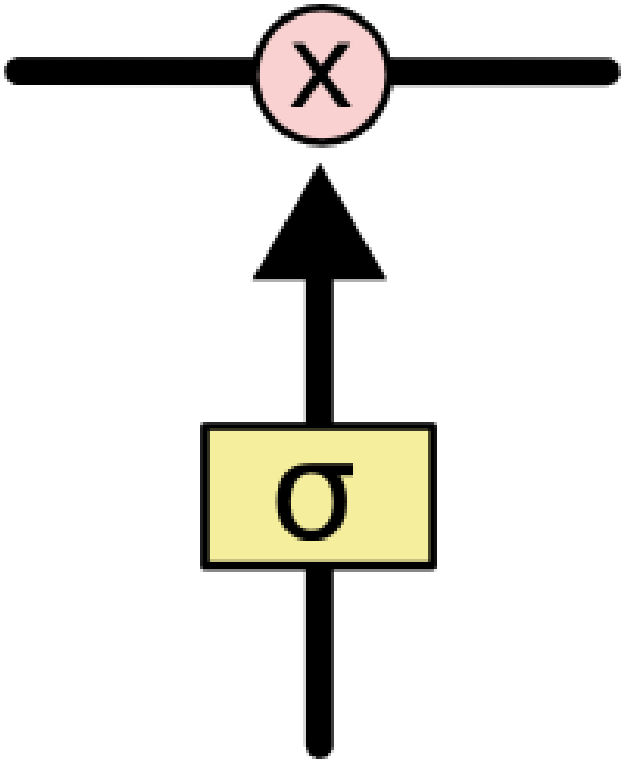


## LSTM has more complicated innards



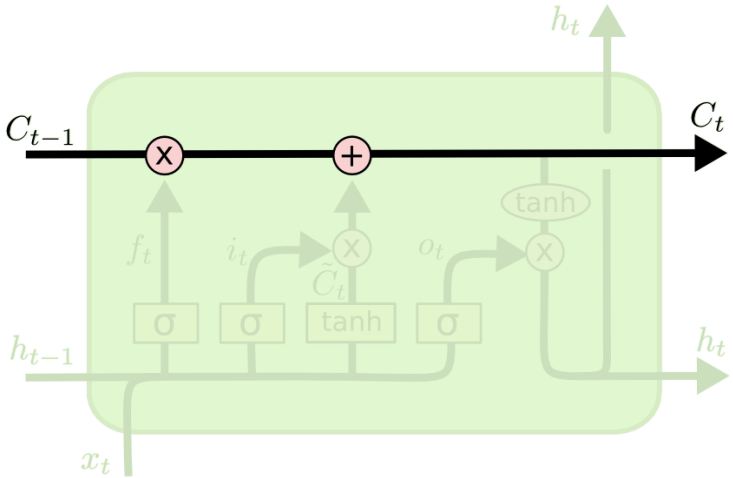

Built on gates!

## Gates



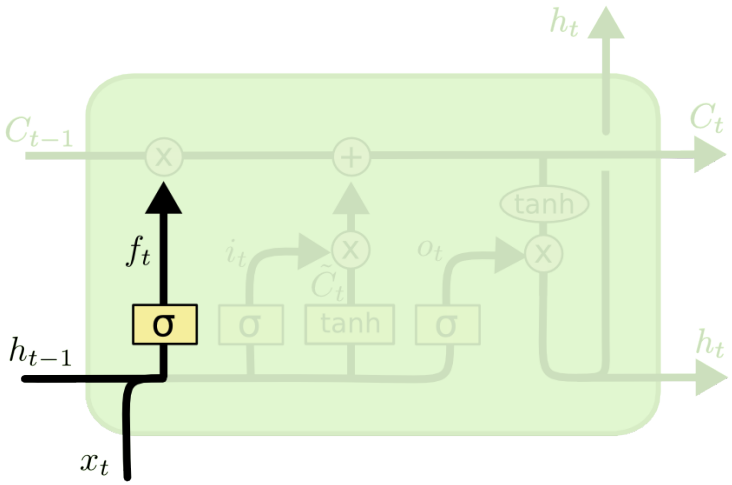

- Multiply vector dimension by value in $[0, 1]$
- Zero means: forget everything
- One means: carry through unchanged
- LSTM has three different gates

## Cell State




Can pass through (memory)

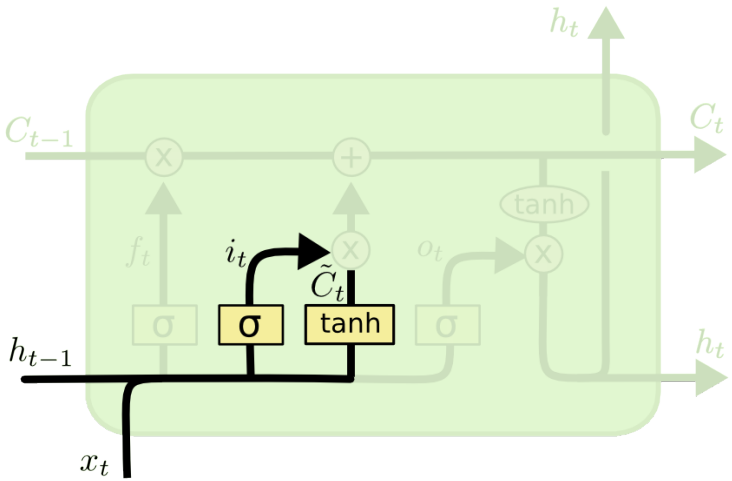
## Deciding When to Forget




$$f_t = \sigma\left(W_f \cdot [h_{t-1}, x_t] \; + \; b_f\right)$$

Based on previous hidden state $h_{t-1}$, can decide to forget past cell state

## Updating representation

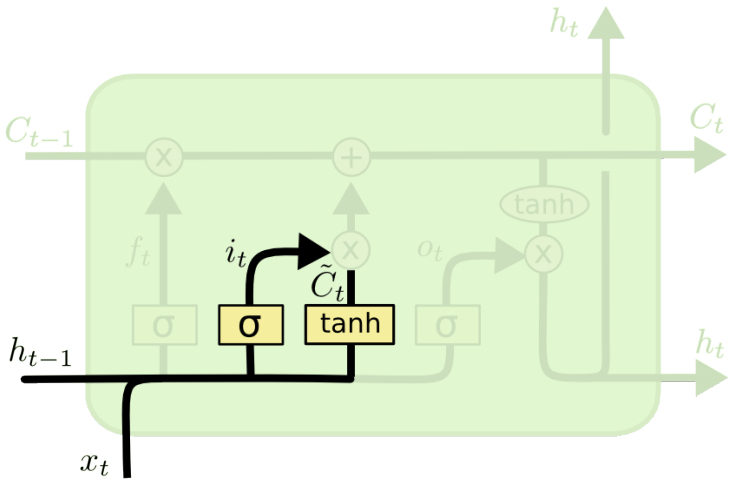



$$i_t = \sigma\left(W_i \cdot [h_{t-1}, x_t] \; + \; b_i\right)$$

$$\tilde{C}_t = \tanh(W_C \cdot [h_{t-1}, x_t] \; + \; b_C)$$

Compute new contribution to cell state based on hidden state $h_{t-1}$ and input $x_t$

## Updating representation

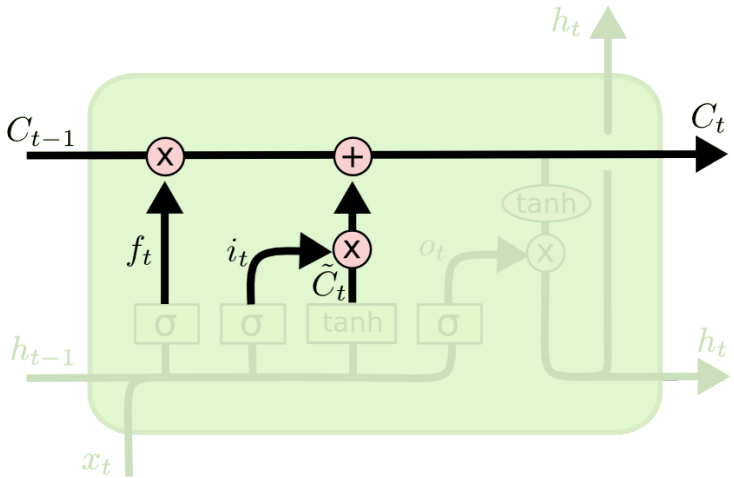



$$i_t = \sigma\left(W_i \cdot [h_{t-1}, x_t] \; + \; b_i\right)$$

$$\tilde{C}_t = \tanh(W_C \cdot [h_{t-1}, x_t] \; + \; b_C)$$

Compute new contribution to cell state based on hidden state $h_{t-1}$ and input $x_t$. Strength of contribution is $i_t$

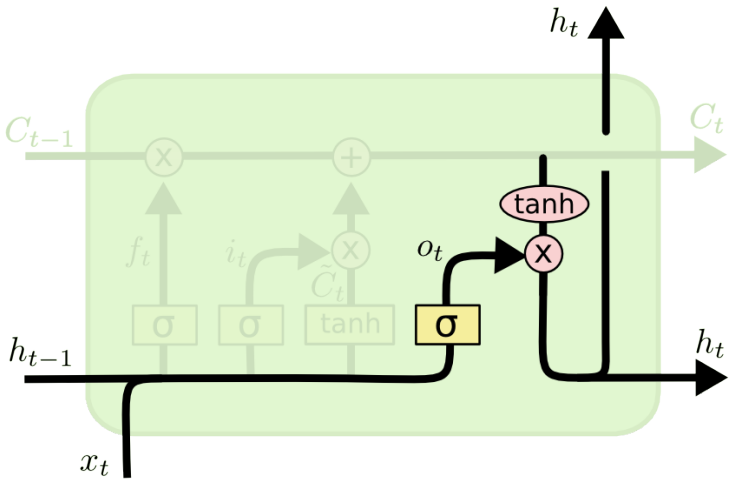
## Updating representation




$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t$$

Interpolate new cell value

## Output hidden




$$o_t = \sigma\left(W_o\left[h_{t-1}, x_t\right] + b_o\right)$$

$$h_t = o_t * \tanh\left(C_t\right)$$

Hidden layer is function of cell $C_t$, not $h_{t-1}$