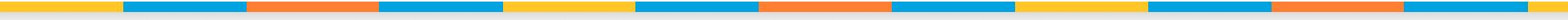

Long Short-Term Memory Networks

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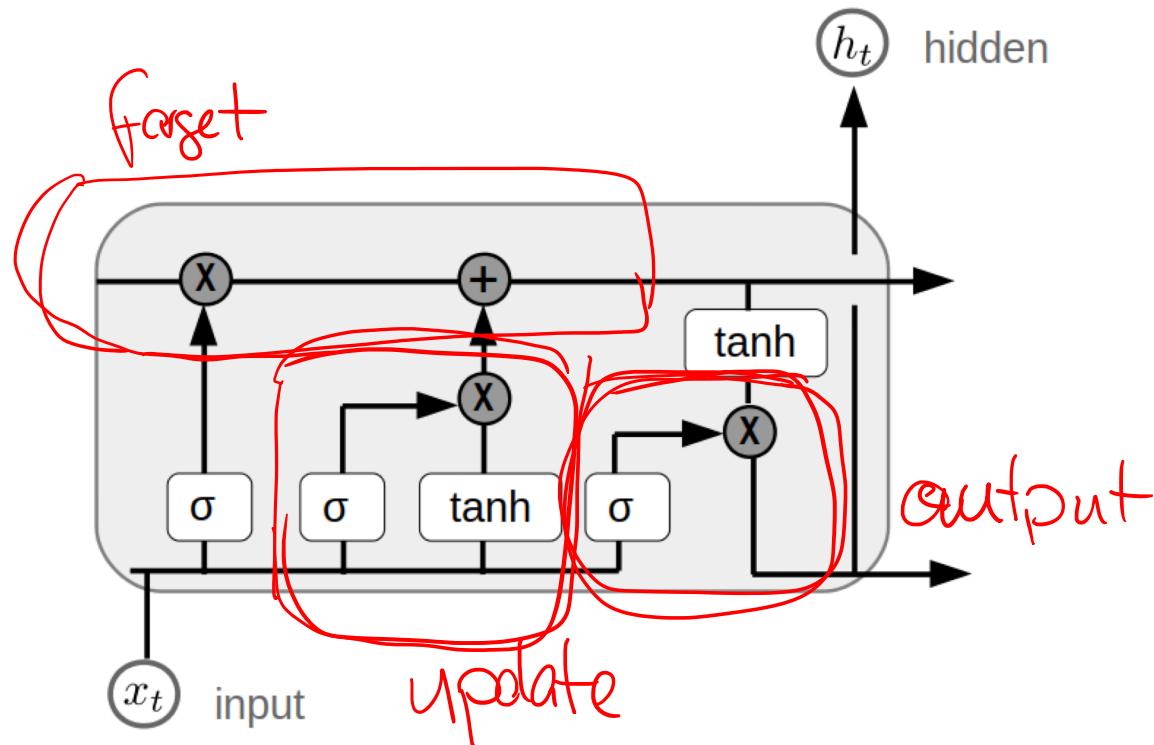
Long Short-Term Memory



- | **Long Short-Term Memory (LSTM)**
- | **Introduced by Hochreiter & Schmidhuber**
- | **Addresses the vanishing gradient problem**
- | **Stores and forgets data using gating units**
- | **Retain hidden state over extended time period**
- | **Many more parameters!**

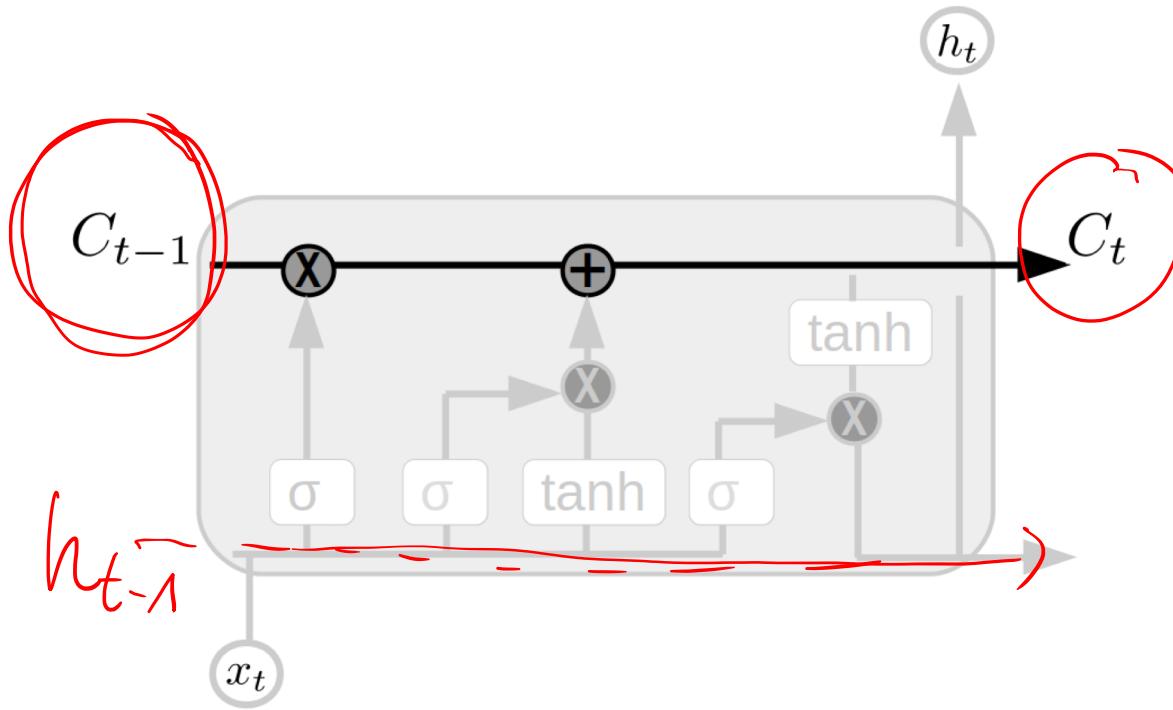
LSTM Neuron

| LSTM adds gating units to each neuron



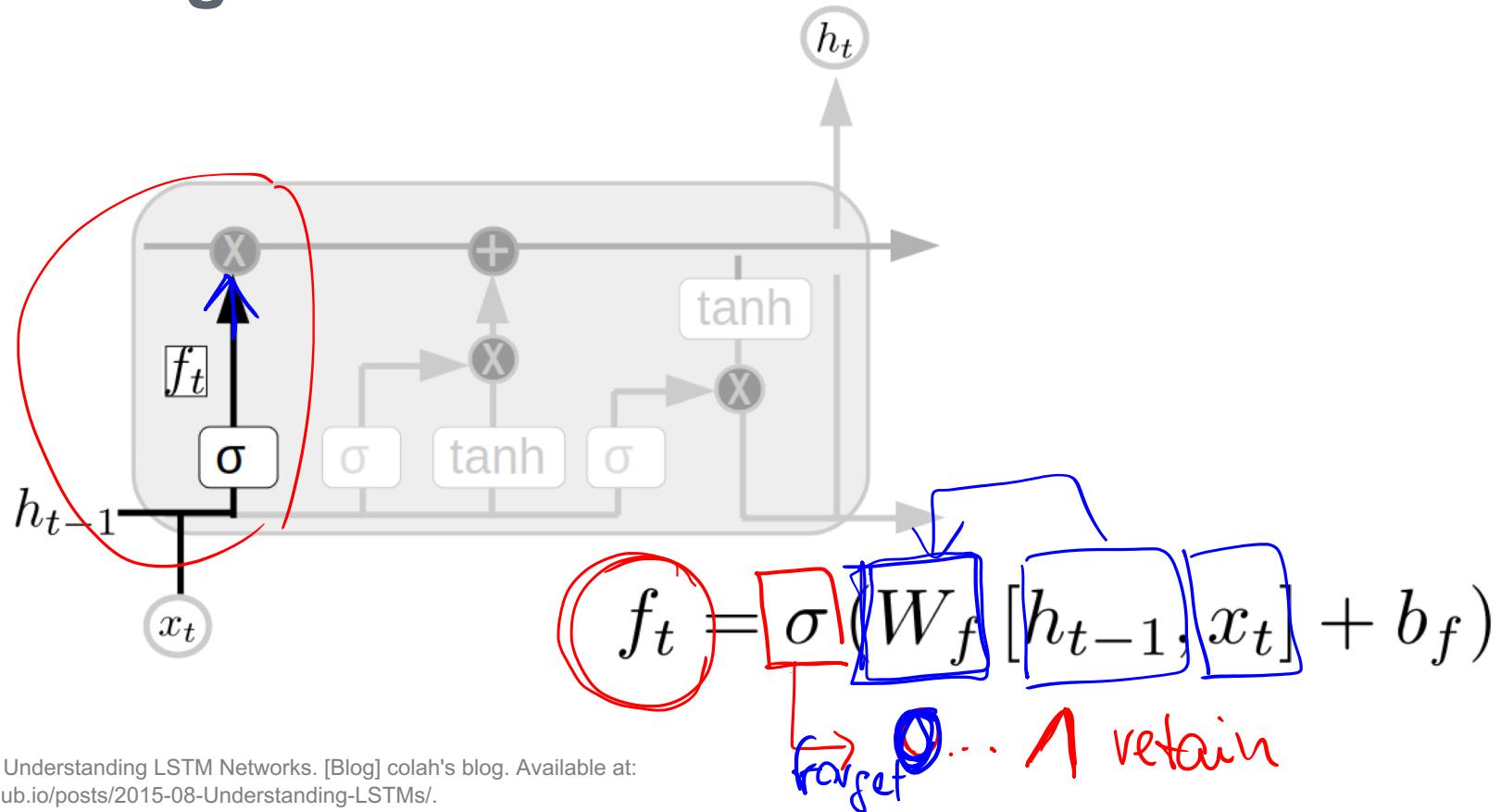
Cell State

- | Propagates information forward through time
- | State vector can store/delete information



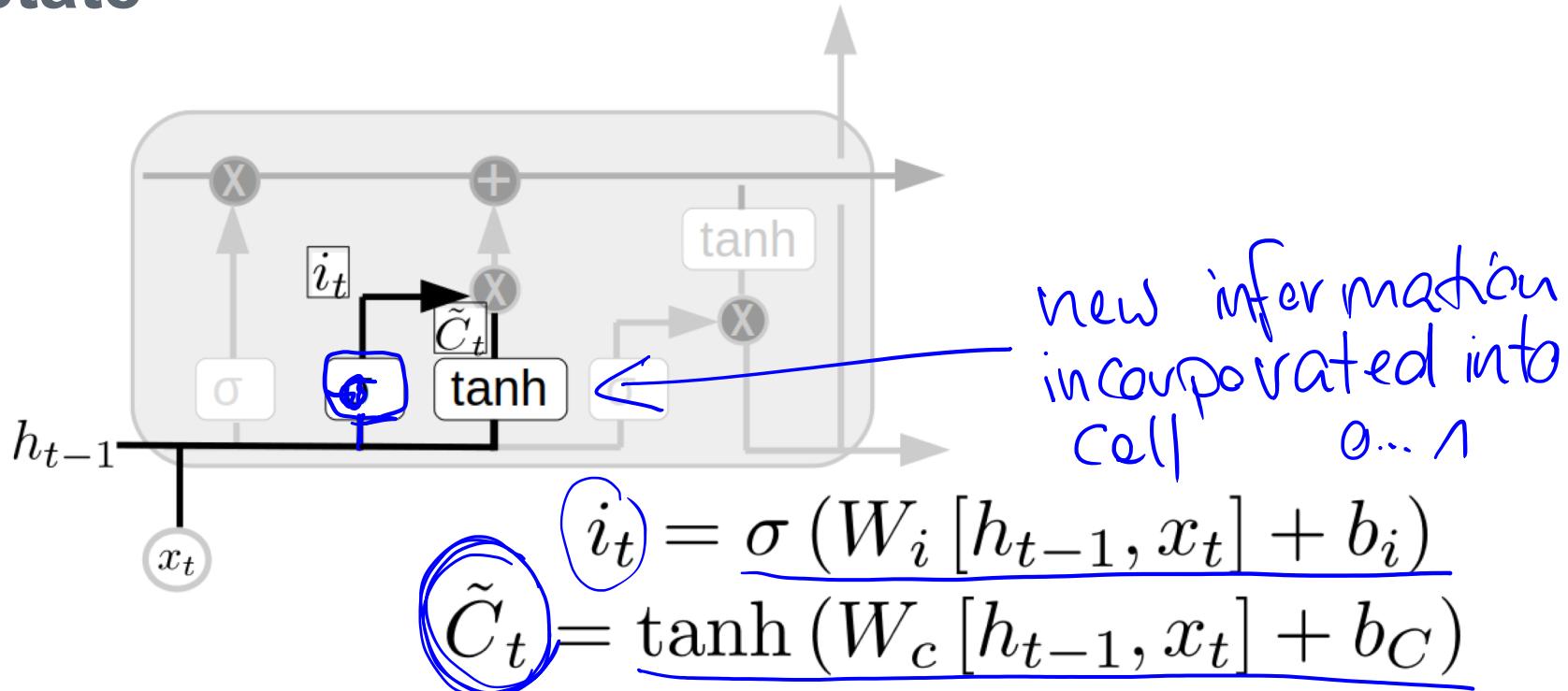
Forget Gate

- | Specifies how much information to keep.
- | Sigmoid output controls forgetting vs. storing



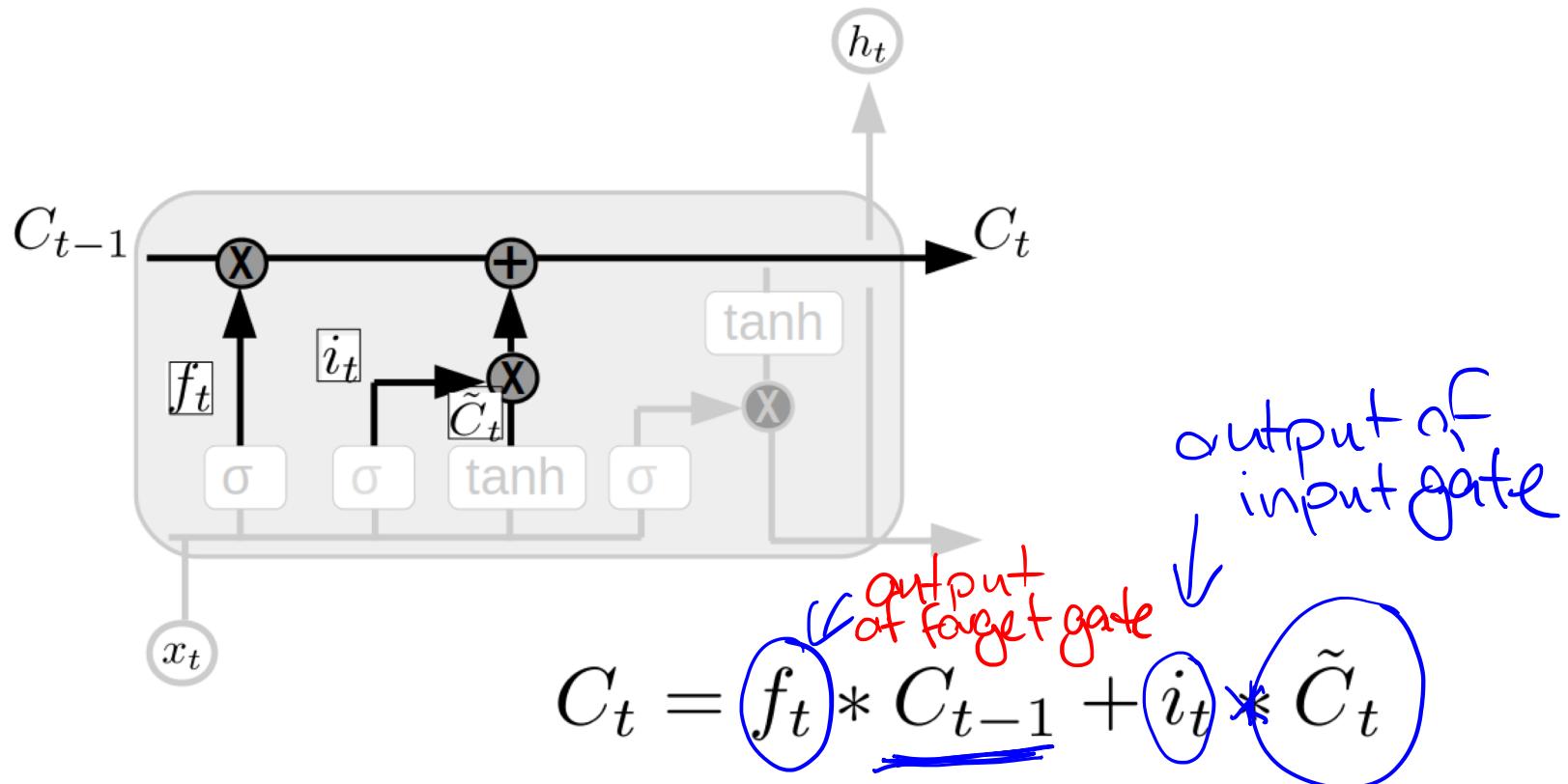
Input Gate

- | Decide what new information to store
- | Sigmoid layer decides which values to update
- | Tanh creates new candidate values for cell state



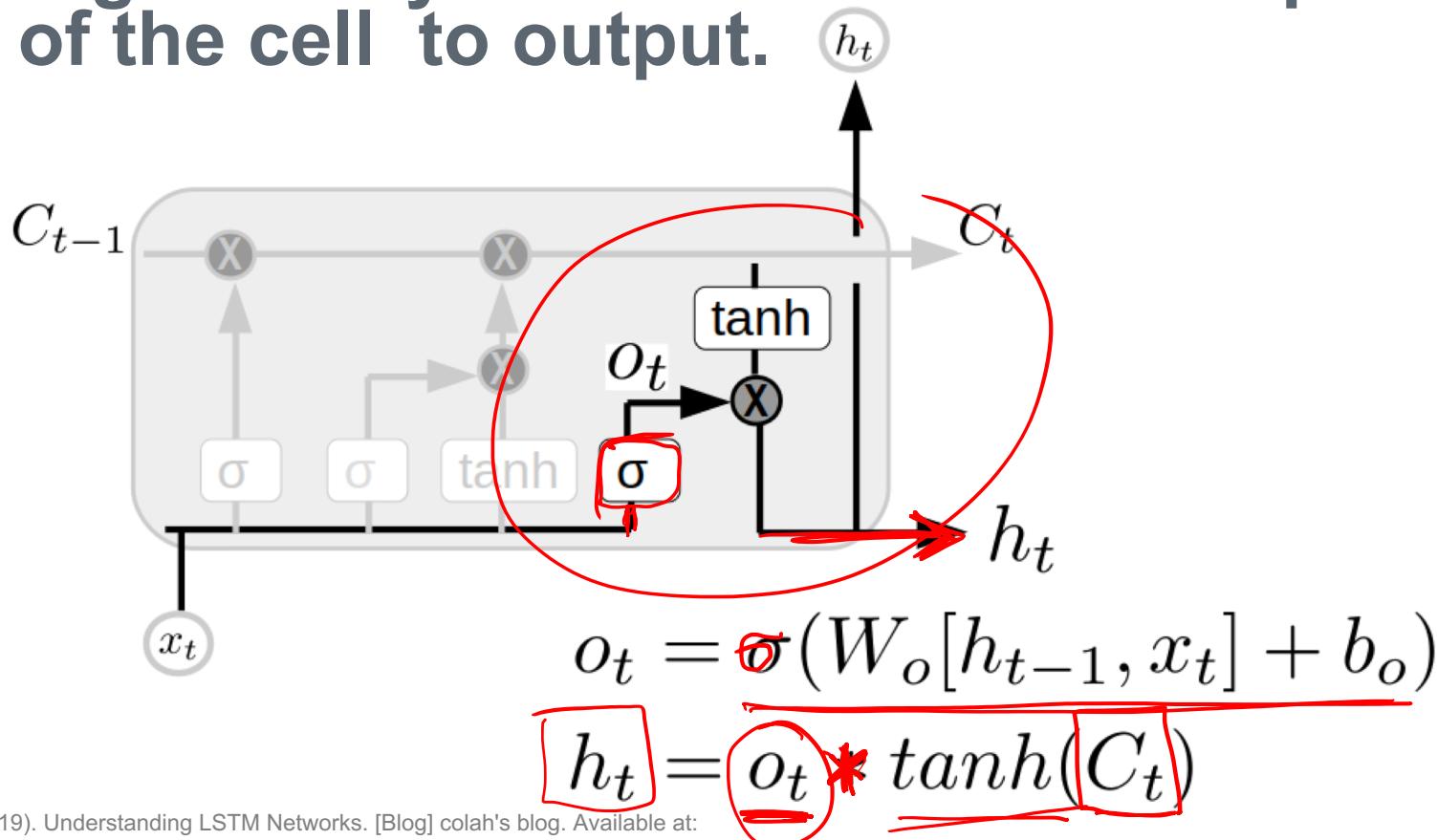
Cell State Update

- | Cell state is combination of old and new data
- | Both the forget gate and input gate affect it



Output Gate

- | This output is a filtered version of cell state
- | Sigmoid layer which decides what parts of the cell to output.



LSTM Update Equations

| Every time step t , apply update equations:

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

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

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

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

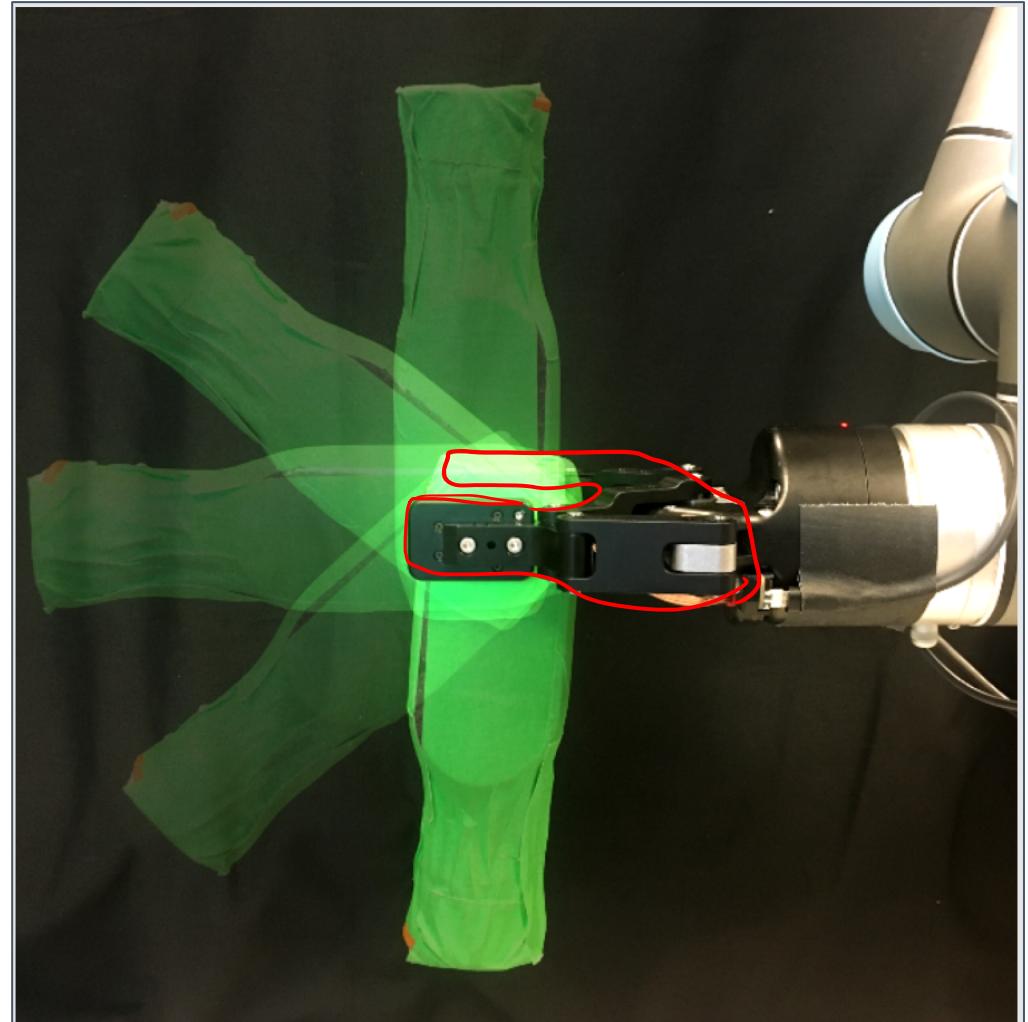
$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t$$

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

RNNs and Robotics

Goal

Utilize slip for dexterous
in-hand manipulation of
grasped objects

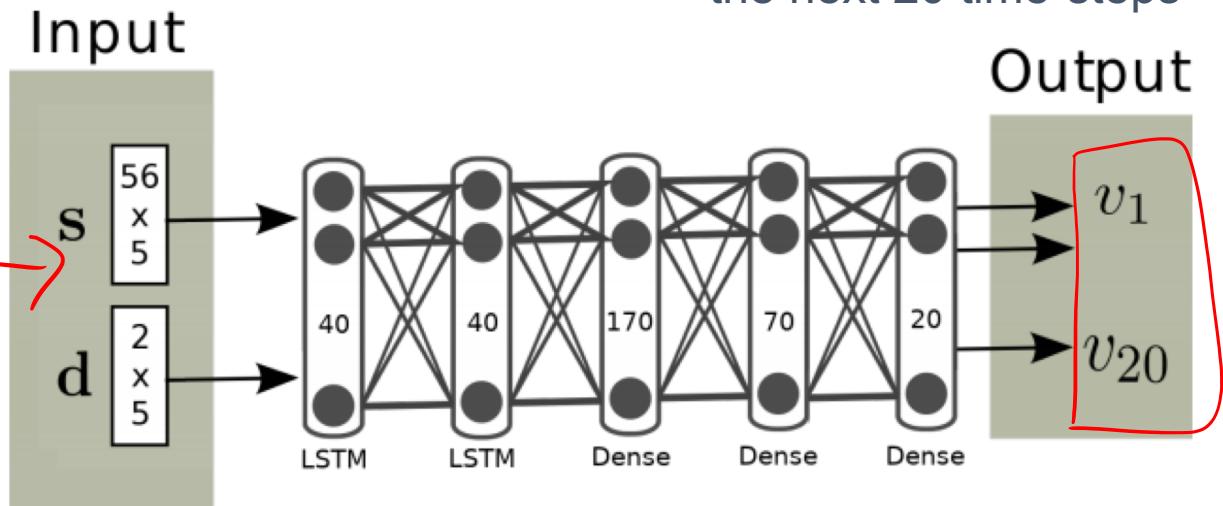
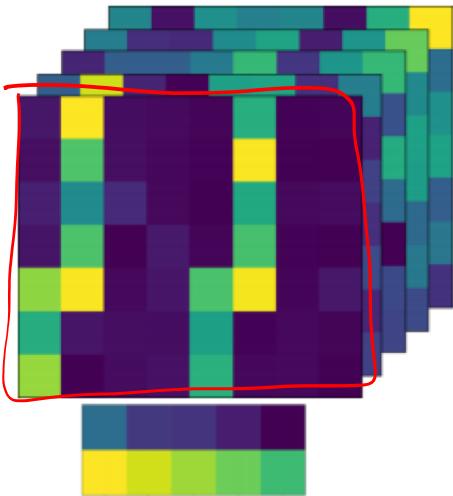


RNNs and Robotics

Solution

Predictive RNN model that estimates future poses of grasped object from past experiences

Static tactile data (s)



Dynamic tactile data (d)

Predicted future poses for the next 20 time-steps

Output

Ground truth captured by accelerometer

Video: Slip Prediction



Phase 3 Complex Bottle Slippage

Transporting multiple bottles with high speed



ASU Interactive Robotics Lab

Summary



- | We introduced Long Short-Term Memory
- | LSTM is a powerful variant of RNNs
- | Widely used in speech recognition
- | Deals with the vanishing gradient problem