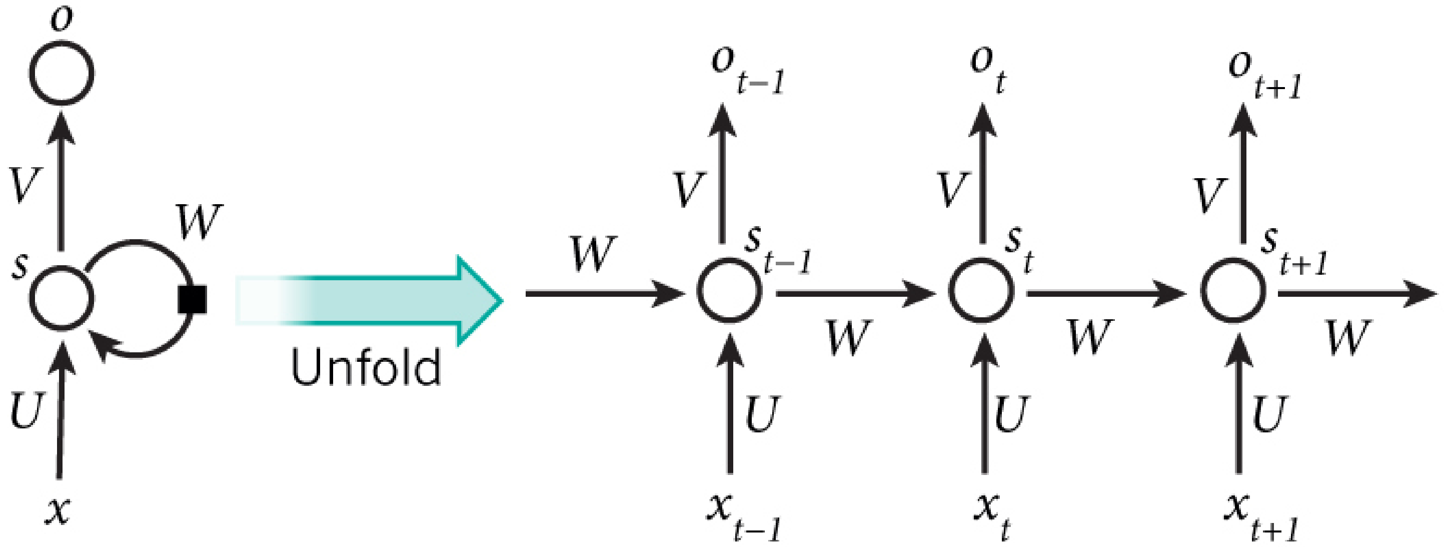
Recurrent Neural Networks

By: Leena Shekhar
Slides from: Heeyoung Kwon
Noah Weber
Stanford CS224N

Recurrent Neural Network

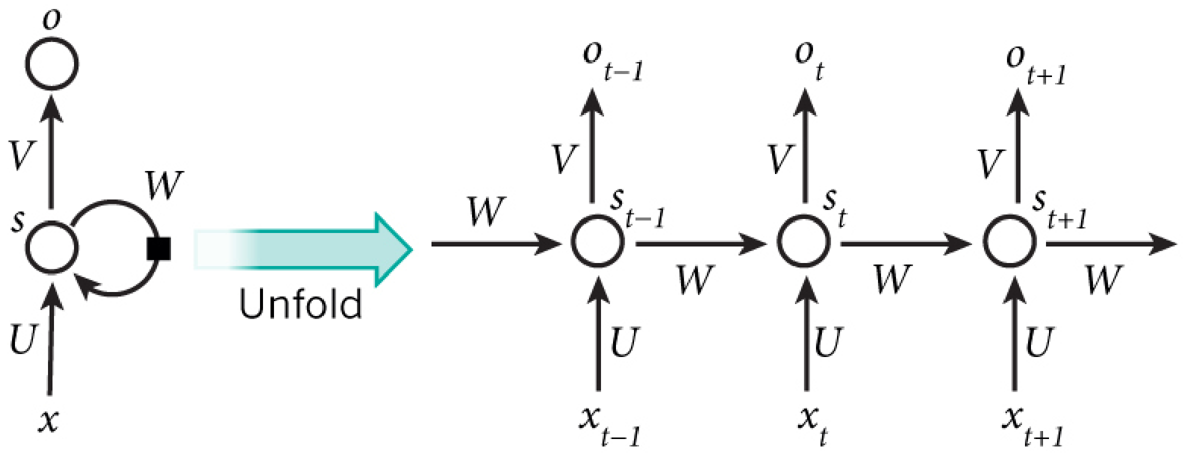
- A recurrent neural network (RNN) is a class of artificial neural network where connections between units form a directed cycle.



Picture from wildml.com

Recurrent Neural Network

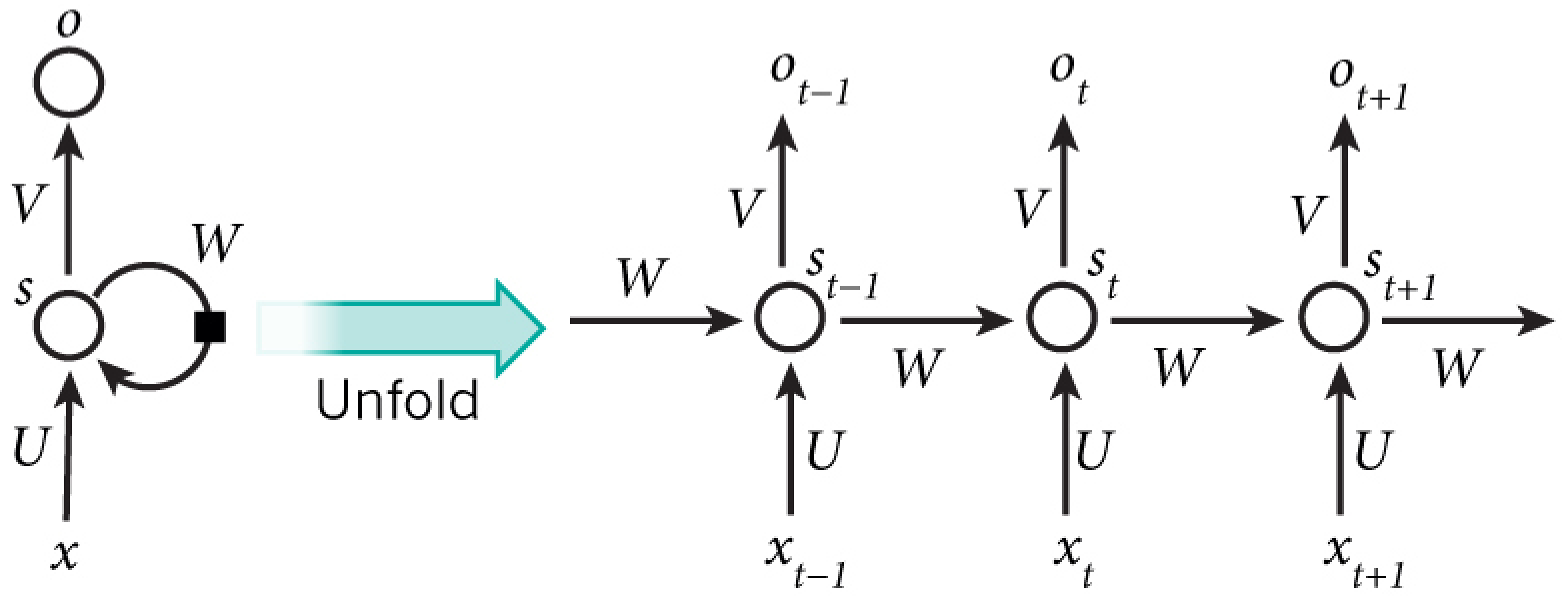
- At its simplest: A NN whose activations can be used again as input (s)
- Can think of it as the neural network keeping some type of state/memory of previous inputs
- Can be used for tasks involving sequential input/output



Recurrent Neural Network – Mathematical form

$$h_t = \phi(Ux_t + Wh_{t-1})$$

$$y_t = \phi(Vh_t)$$



Training RNNs to do good things

- We can unroll the RNN to get feed forward NN
- But the weight matrices , , are shared across all timesteps
- For each time step, compute the error, compute the gradient w respect to this error
- To get final gradient, sum over all gradients for each time step

Training RNNs to do good things is HARD

- RNNS are hard to train
  - Specifically, they don’t do what they expected to do (capture long term dependencies)

- Our gradients are vanishing or exploding!

Vanishing and Exploding Gradients

- There are many many multiplications of the same matrix
- If weights too small, vanishing gradients
- If weights too big….

RNN is not suitable for long-term dependencies

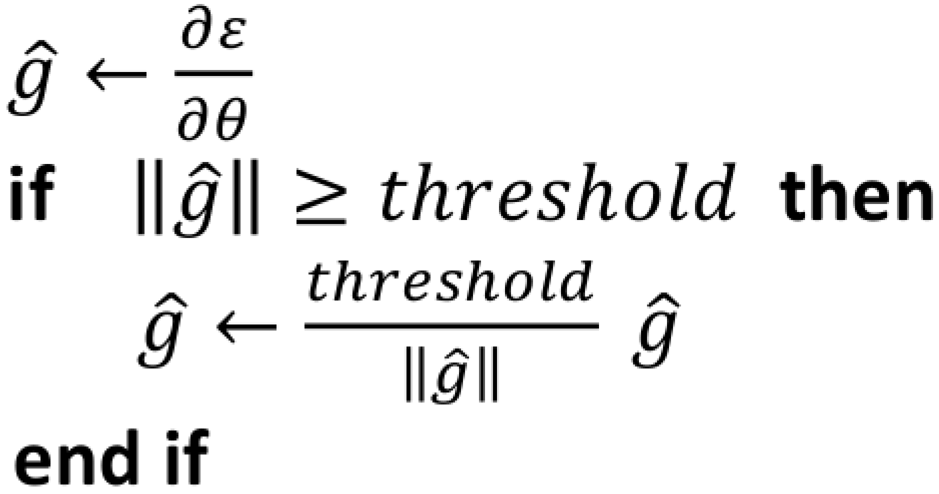
- Gradient Explodes
  - Large increase in the norm of the gradient
  - May lead to oscillating weights

- Gradient Vanishes
  - Long term components go exponentially fast to norm 0
  - Will learn nothing for long-term dependencies

https://weberna.github.io/blog/2017/11/15/LSTM-Vanishing-Gradients.html

Exploding Gradient

- Gradient Clipping
  - Rescale gradients

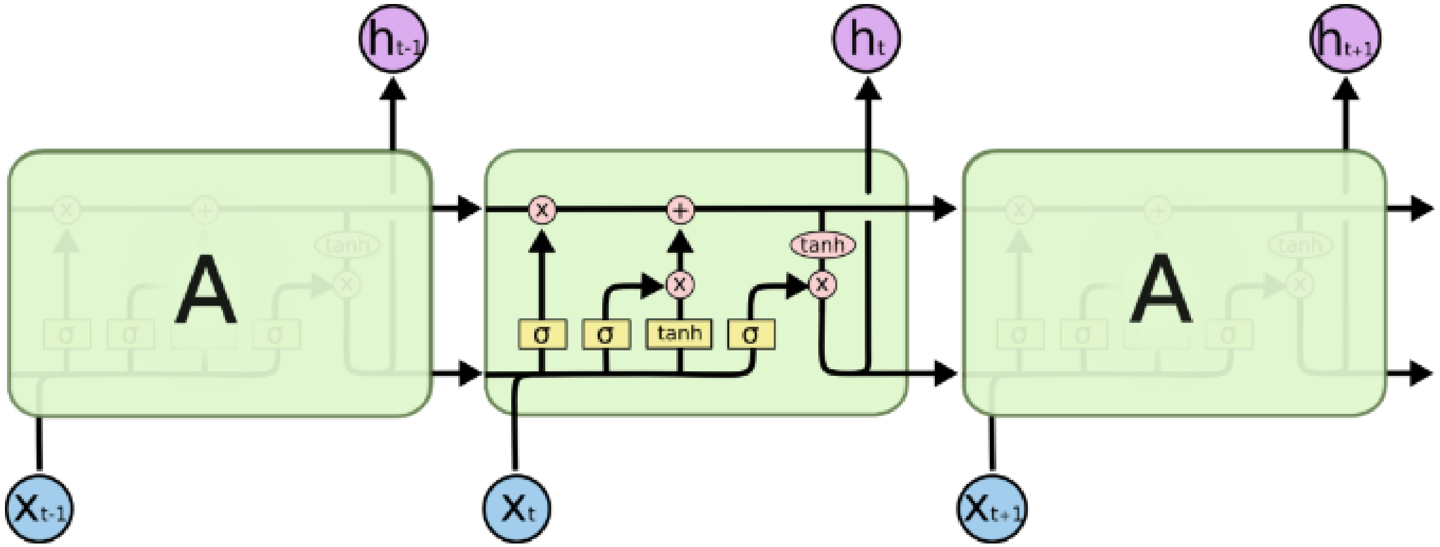


```
$\hat{g} \leftarrow \frac{\partial \varepsilon}{\partial \theta}$
if   $\|\hat{g}\| \geq threshold$  then
    $\hat{g} \leftarrow \frac{threshold}{\|\hat{g}\|} \hat{g}$
end if
```

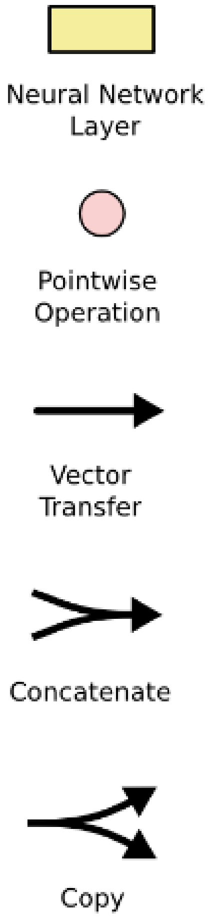
Vanishing Gradient

- More challenging as we cannot tell whether:
  - No dependency between t and t+n in data, or
  - Wrong configuration of parameters
- As remedy, LSTM was introduced

Structure of LSTM Cells



The repeating module in an LSTM contains four interacting layers.



Neural Network Layer

Pointwise Operation

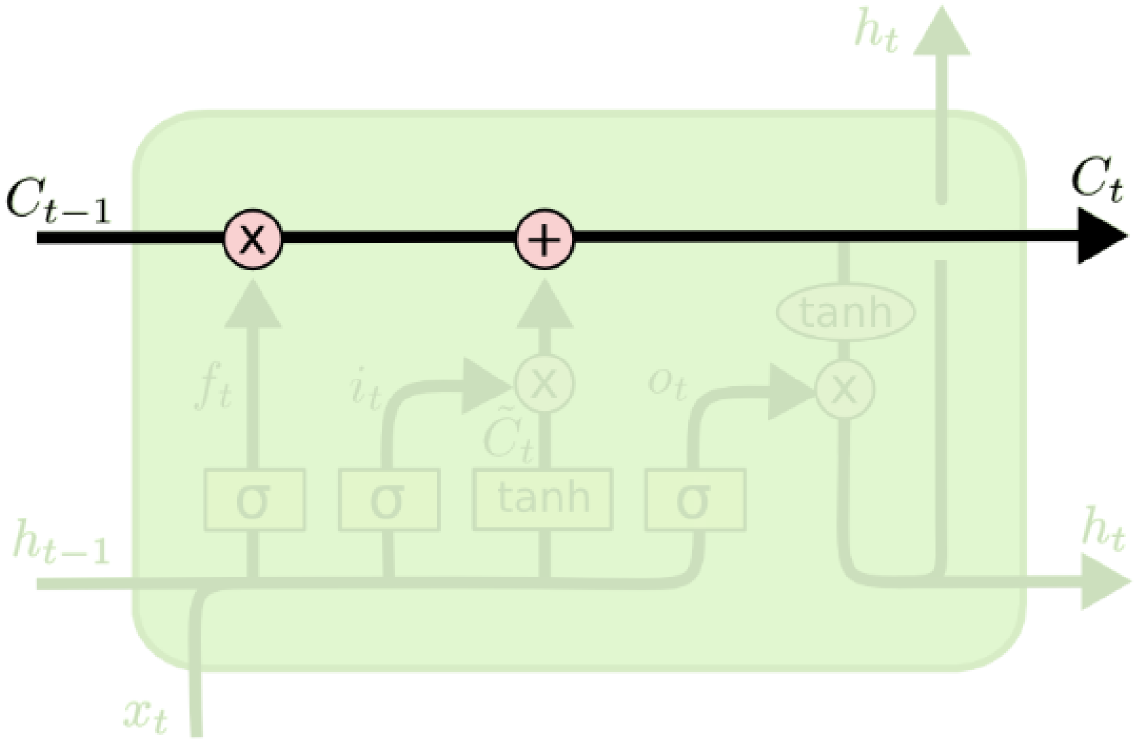
Vector Transfer

Concatenate

Copy

Images are from http://colah.github.io/posts/2015-08-Understanding-LSTMs/

Core Idea – Cell State



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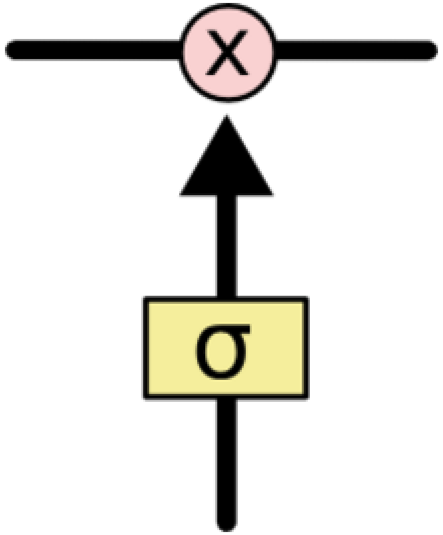
Core Idea – Gates



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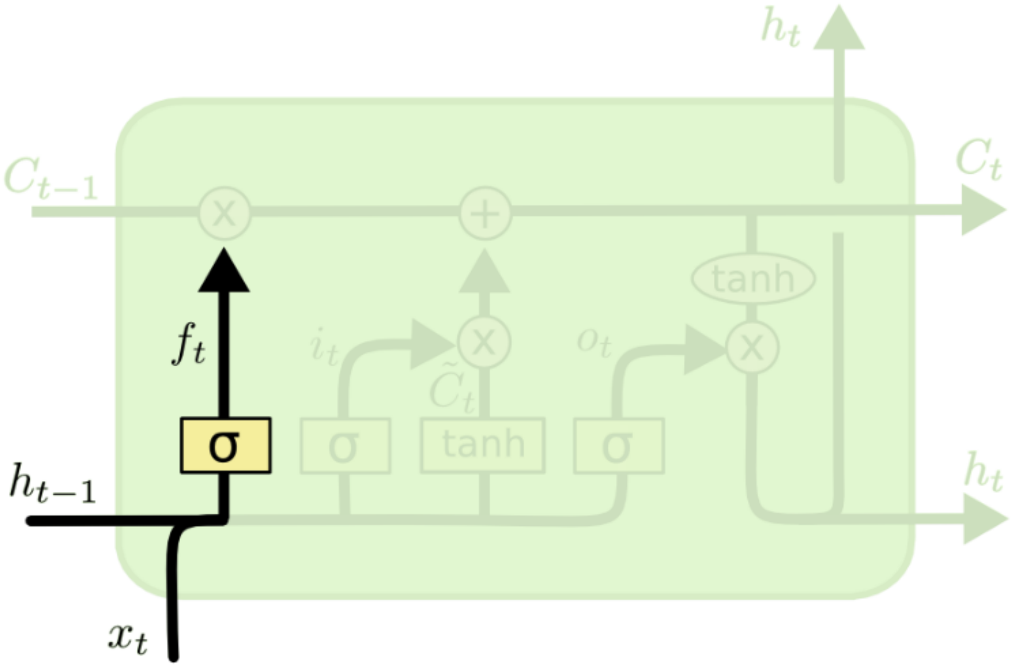
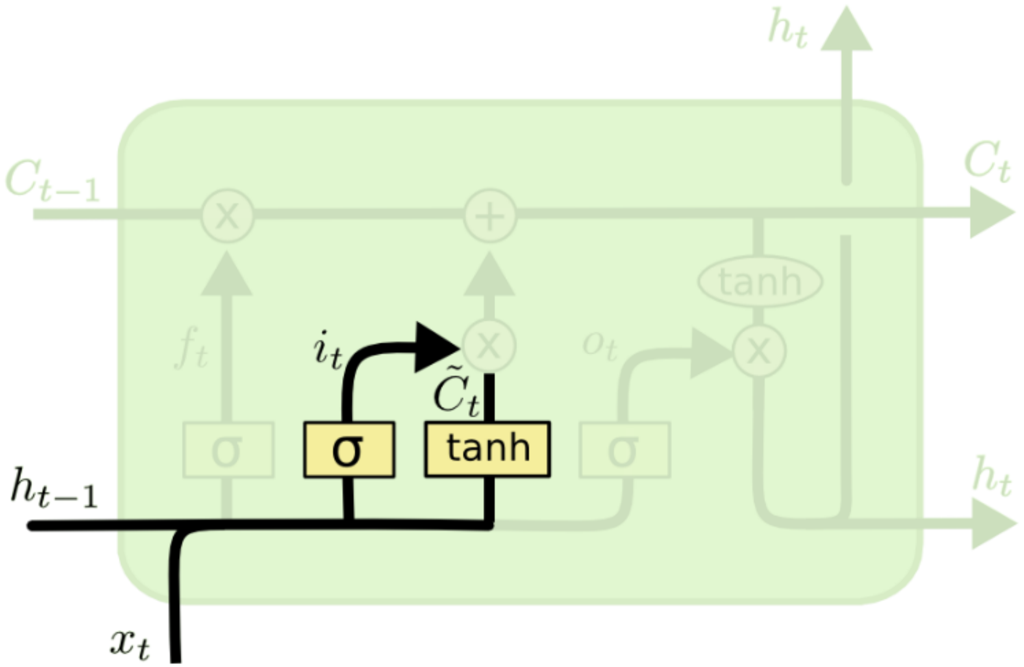
Forget gate



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

Images are from http://colah.github.io/posts/2015-08-Understanding-LSTMs/

Input Gate



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

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

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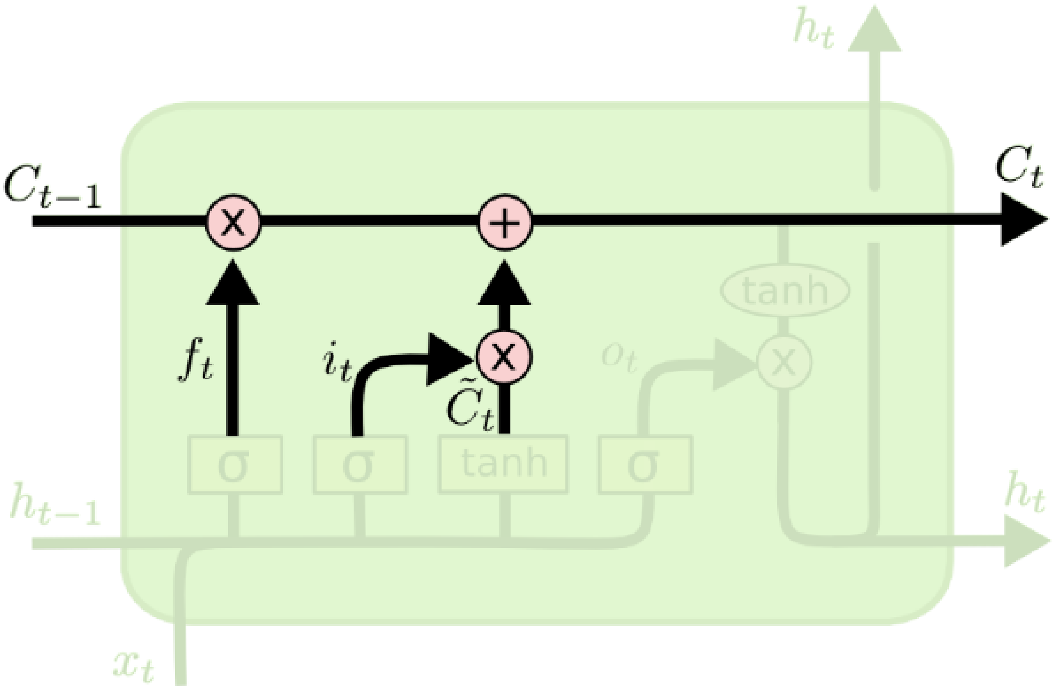
Update Cell State



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

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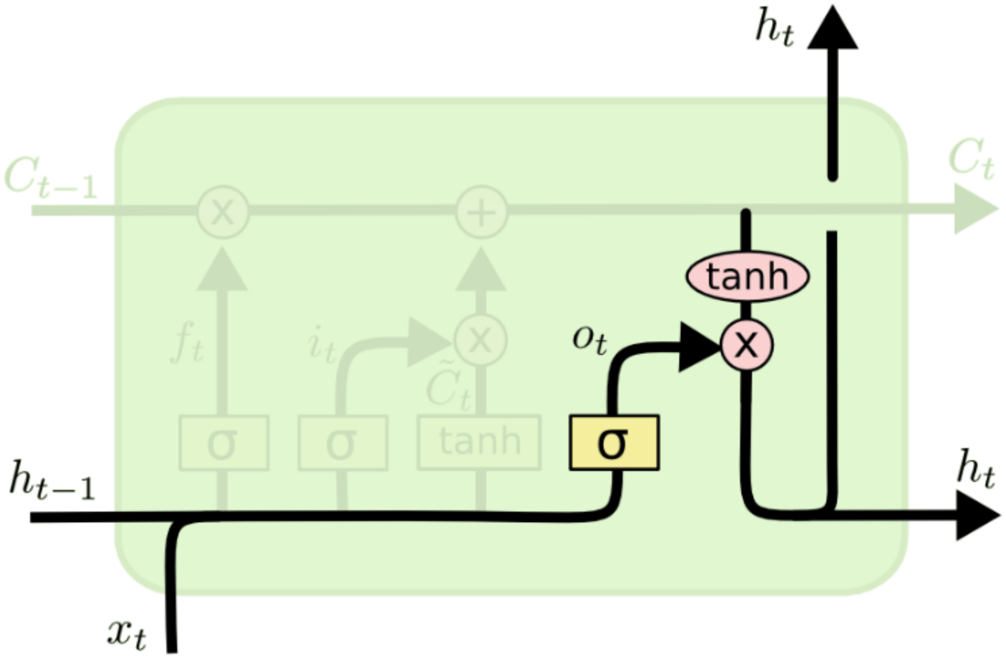
Output Gate



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

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

Images are from http://colah.github.io/posts/2015-08-Understanding-LSTMs/

Applications

- Language Modeling
- Machine Translation
- Image Captioning
- Hand writing recognition / generation
- Question Answering (Answer Sentence Selection)
- Video to text

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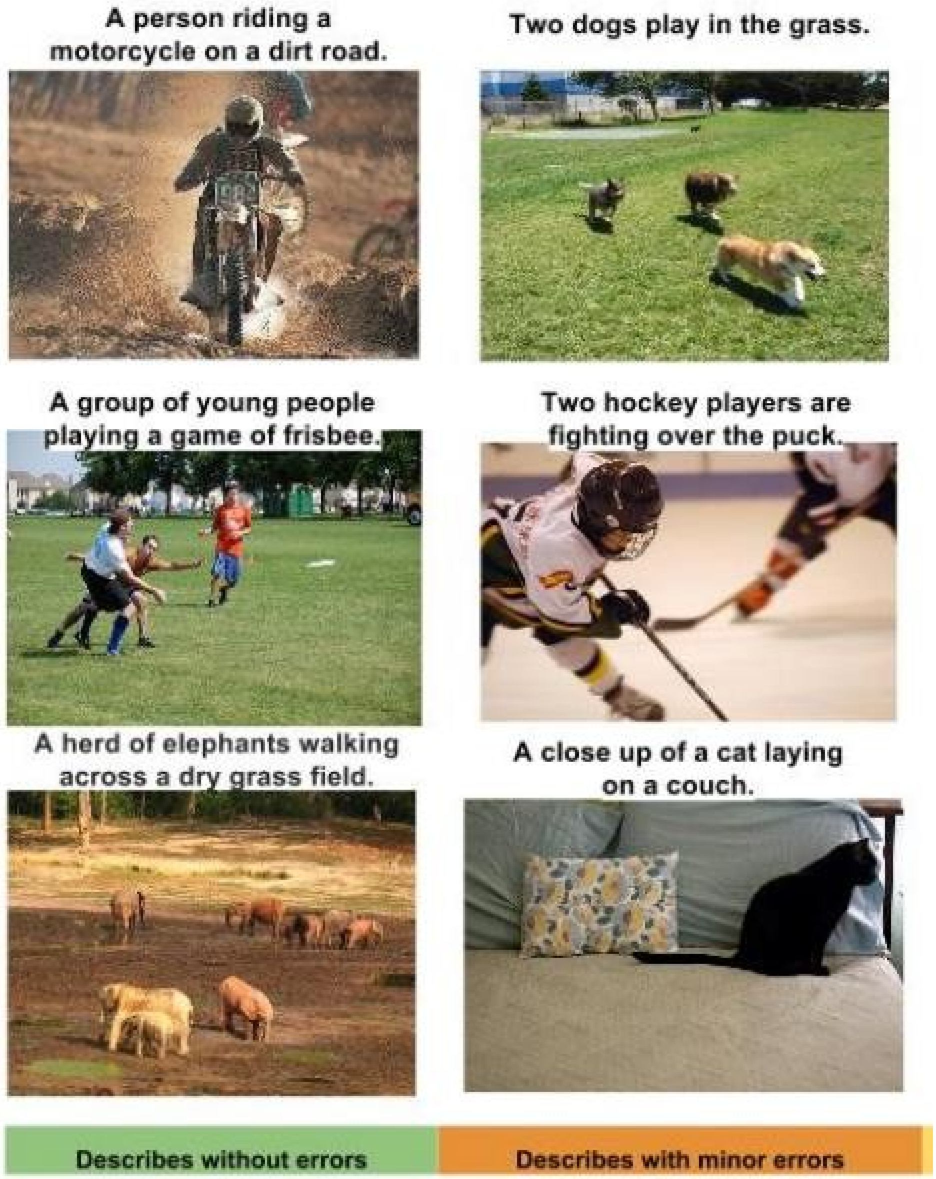

A person riding a motorcycle on a dirt road.

Two dogs play in the grass.

A group of young people playing a game of frisbee.

Two hockey players are fighting over the puck.

A herd of elephants walking across a dry grass field.

A close up of a cat laying on a couch.

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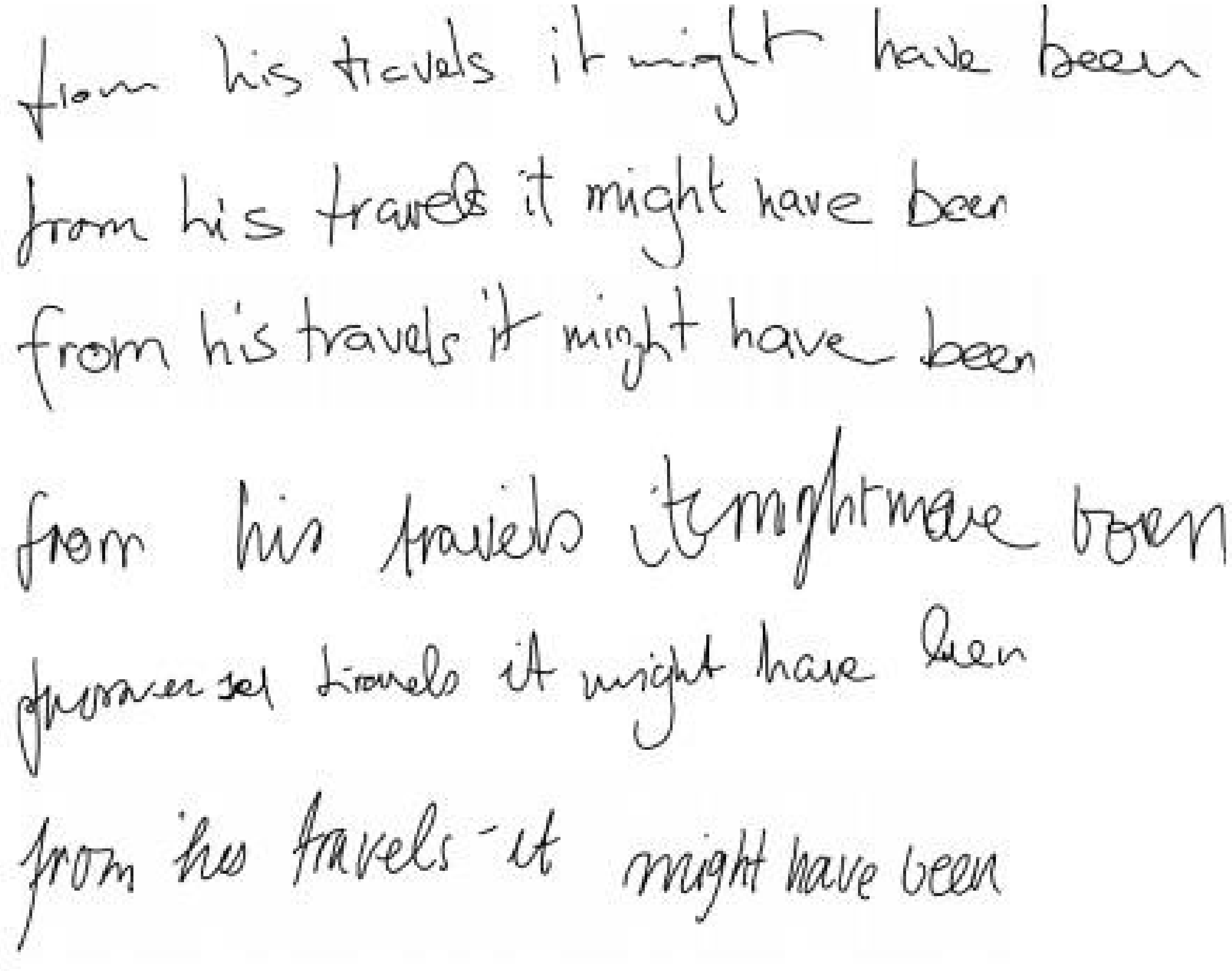

from his travels it might have been

from his travels it might have been

from his travels it might have been

from his travels itmightmave been

[illegible] travels it might have been

from his travels - it might have been

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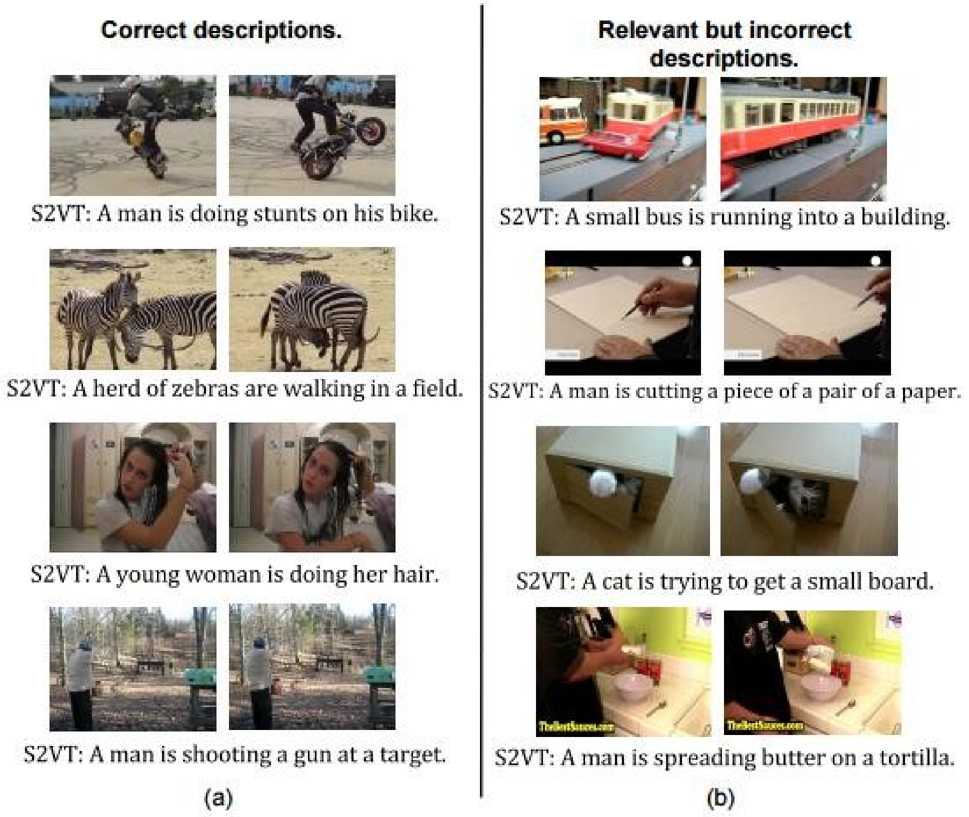

Correct descriptions.

S2VT: A man is doing stunts on his bike.

S2VT: A herd of zebras are walking in a field.

S2VT: A young woman is doing her hair.

S2VT: A man is shooting a gun at a target.

(a)

Relevant but incorrect descriptions.

S2VT: A small bus is running into a building.

S2VT: A man is cutting a piece of a pair of a paper.

S2VT: A cat is trying to get a small board.

S2VT: A man is spreading butter on a tortilla.

(b)

Reference

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