Artificial Neural Networks and Deep Learning

Week 5

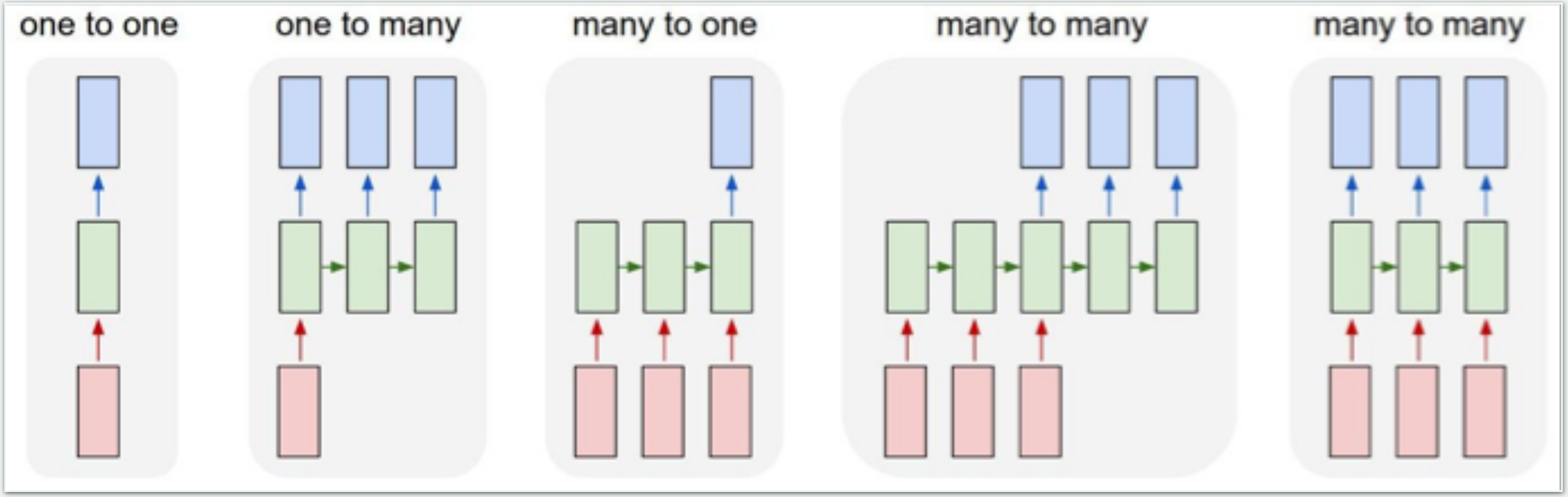
Recurrent neural networks

Recurrent Neural Networks

THE neural network architecture to use for sequential data

Recurrent neural networks

> Ways to process sequential data



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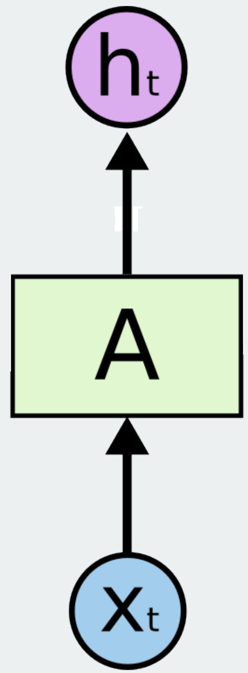
The **problem** with **all** feed forward neural networks

- Input and output must be of hard-assigned dimensions
- The network makes a fixed number of computations
- If input is sequence-like (video, sound, etc.) the network is ignorant to the order of samples



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

The **problem** with **all** feed forward neural networks

> **Solution:** *Recurrence!*

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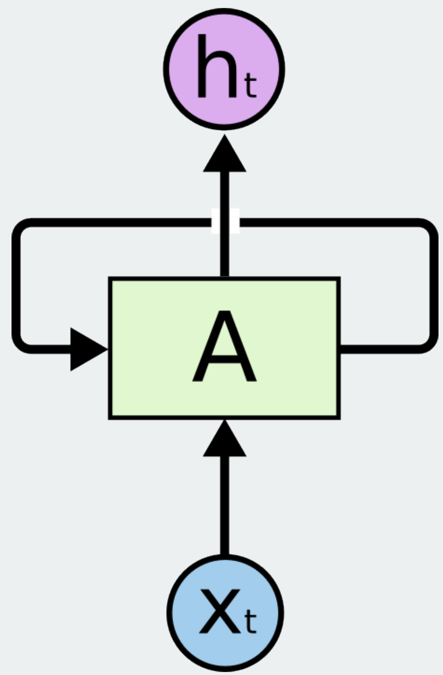

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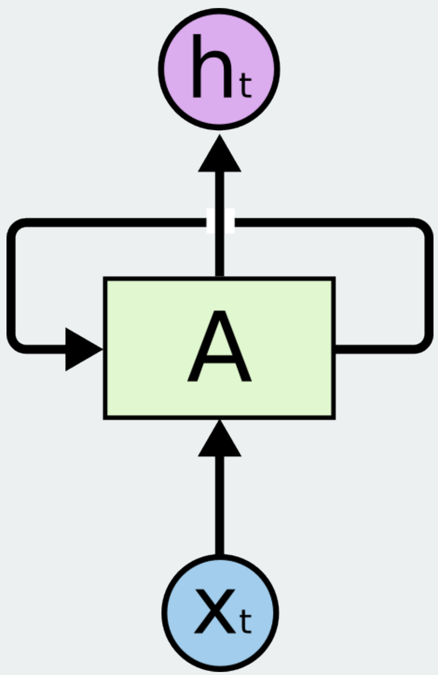
Recurrent neural networks
> Fundamental idea



$$h_t = f_W(h_{t-1}, x_t)$$

Notice: W is the same in each iteration

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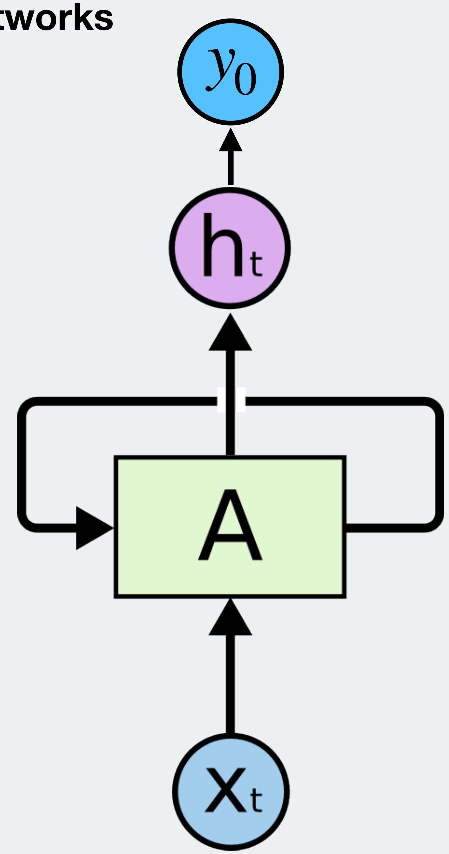
Recurrent neural networks

> Fundamental idea



$$h_t = f_W(h_{t-1}, x_t)$$

$$y_t = W_{hy} h_t$$

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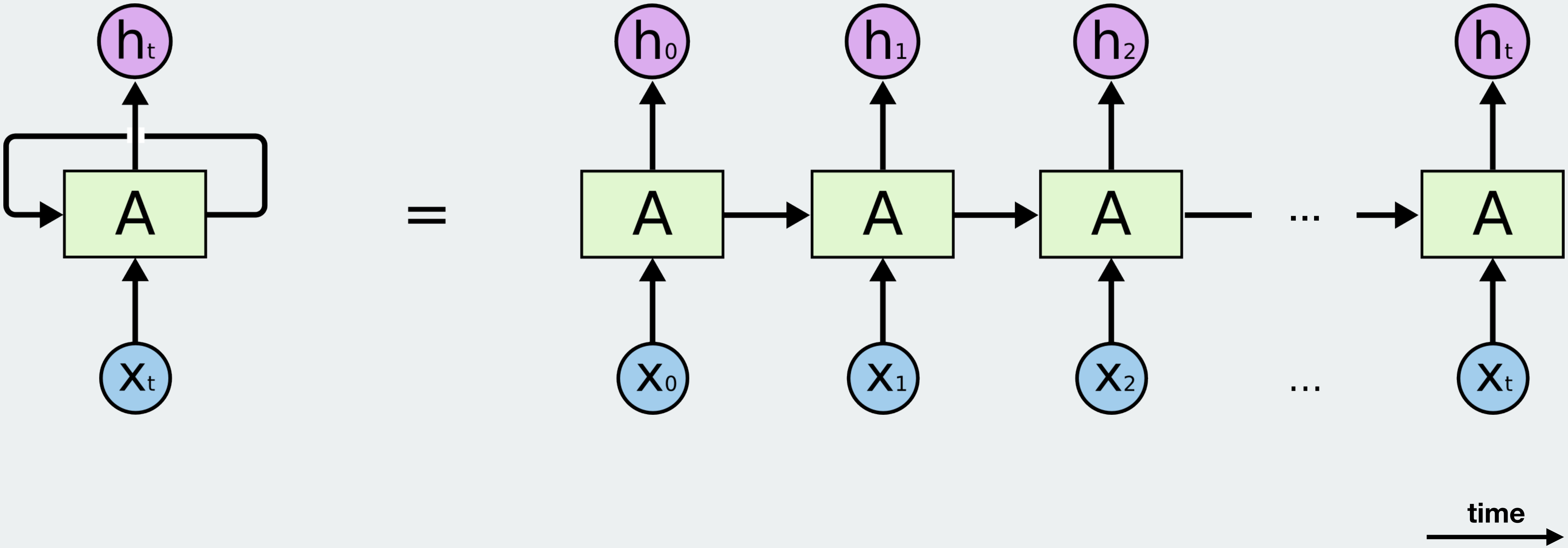
Recurrent neural networks

> Unrolled in time



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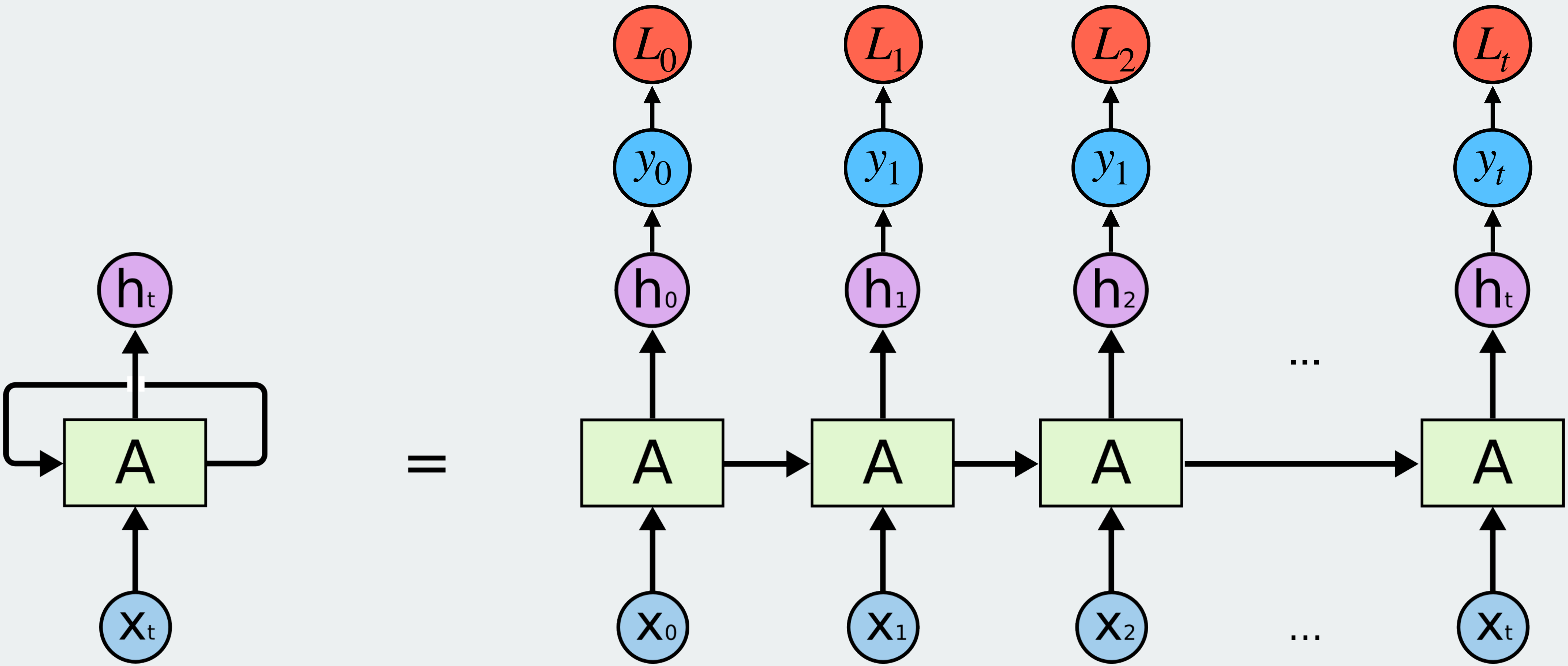
Recurrent neural networks

> Backpropagation



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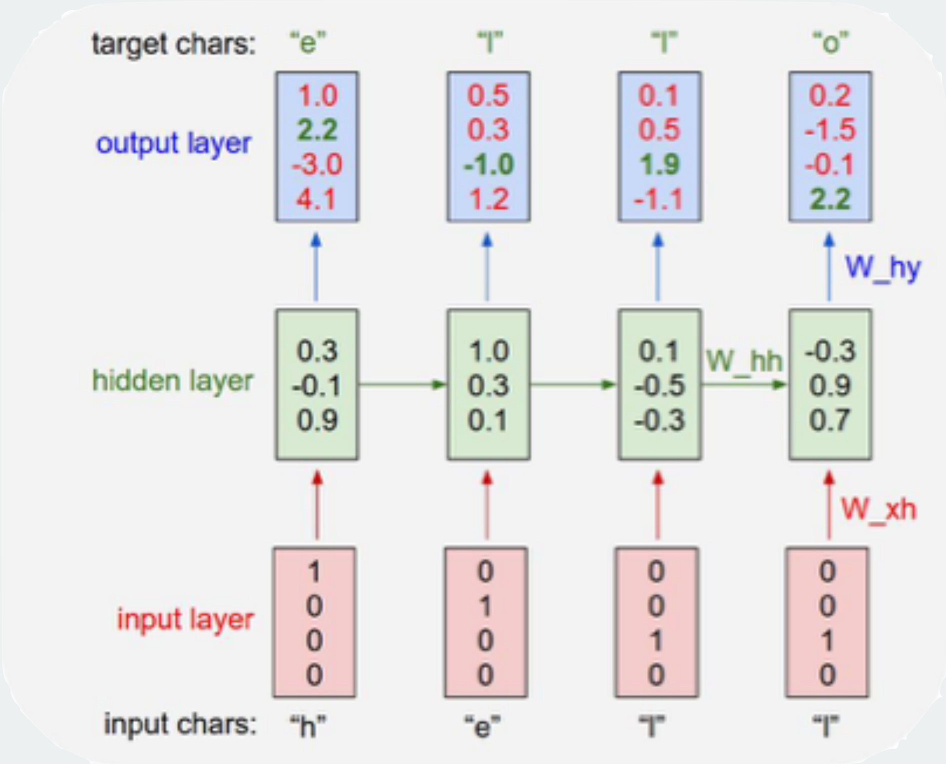
Recurrent neural networks

> Example: predicting next character

training sequence**: “hello”**



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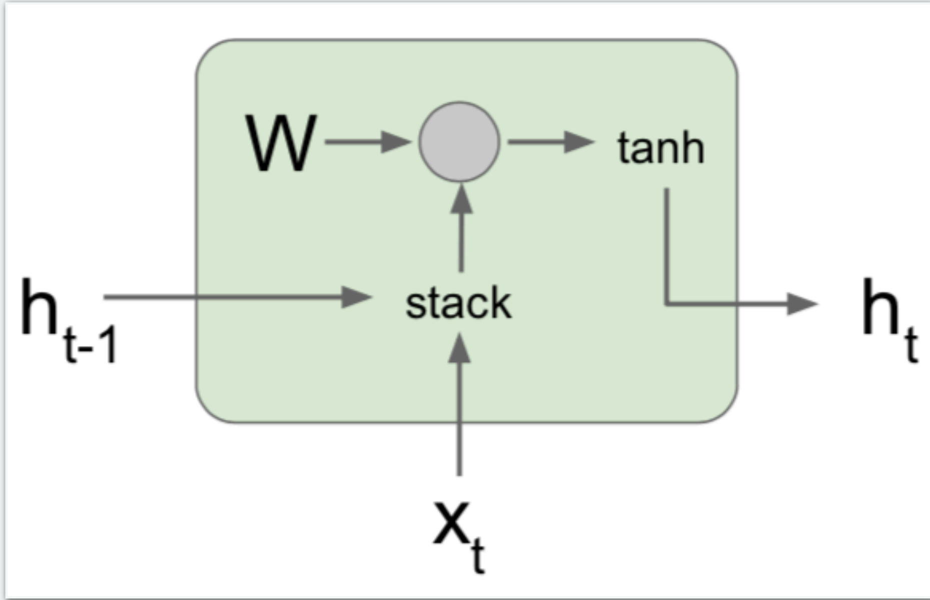
Recurrent neural networks

> Vanilla RNN, architecture



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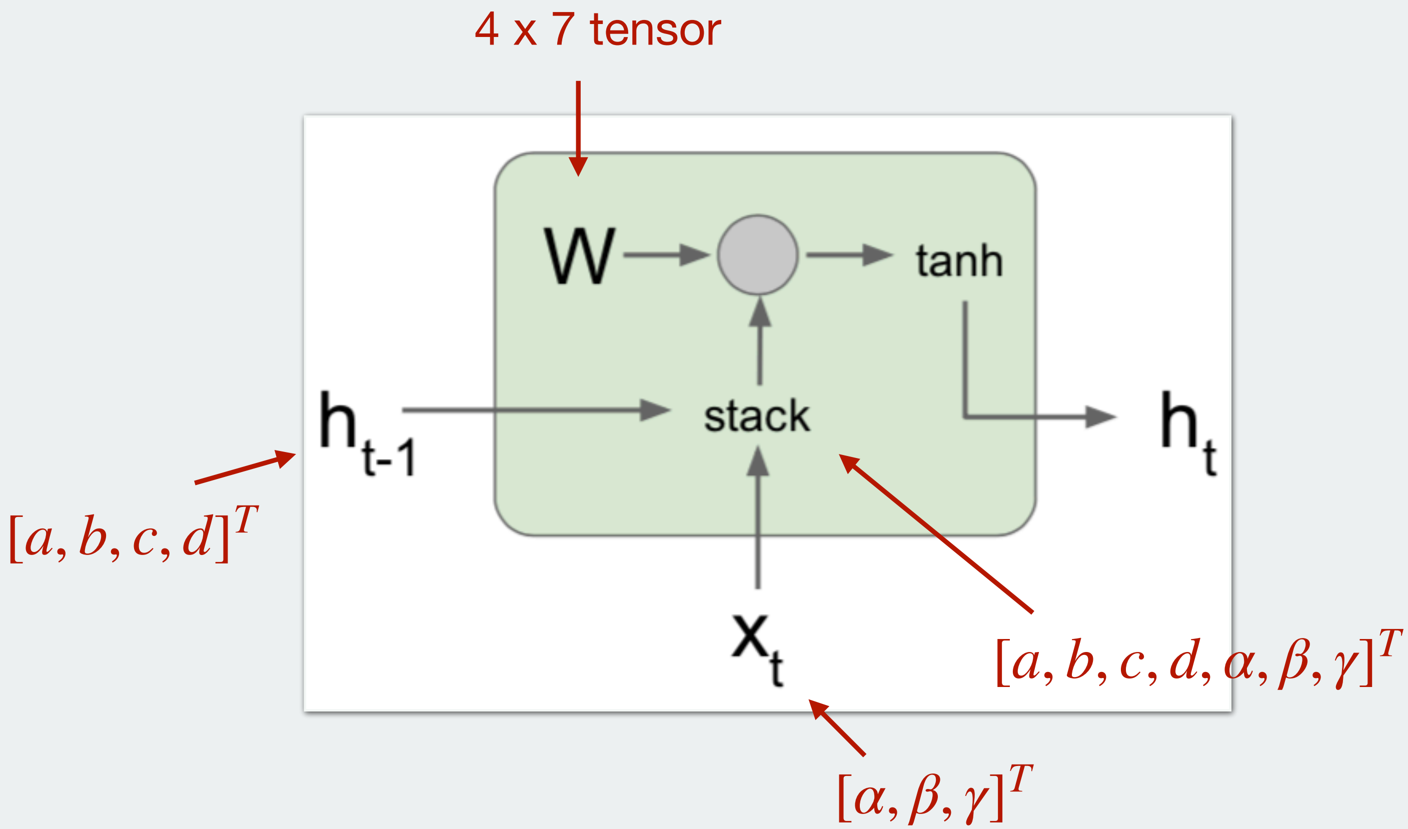
Recurrent neural networks

> Vanilla RNN, architecture

4: because dotting (h, t) onto it should result in a new vector with 4 elements

7: because the (h, t) vector we are dotting onto it has 7 elements in it



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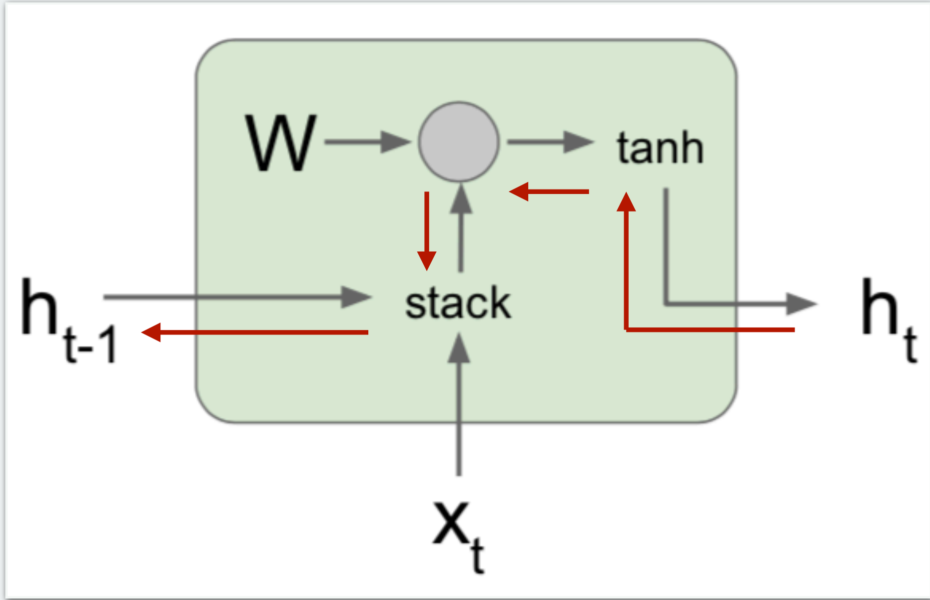
Recurrent neural networks

> Vanilla RNN, backpropagation



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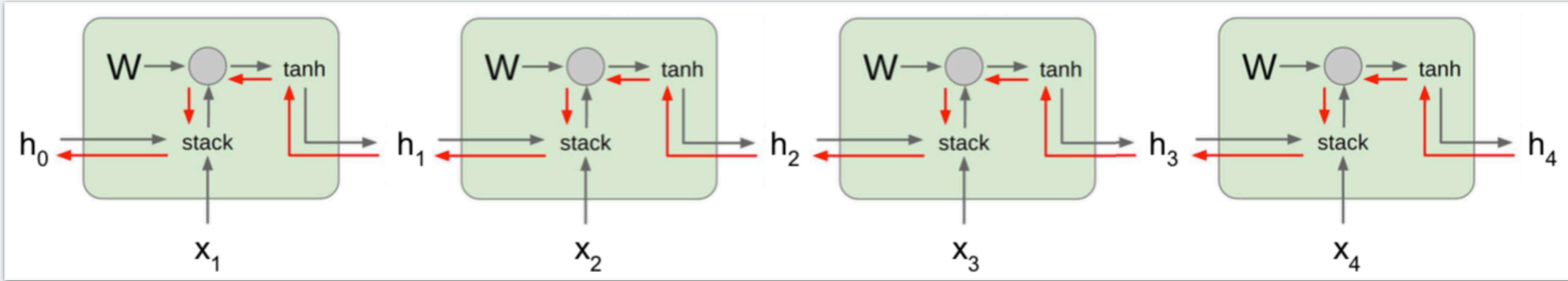
Recurrent neural networks

> Vanilla RNN, backpropagation



Problem: Repeated multiplications by **W** during backpropagation

Leads to: Exploding/vanishing gradients

Solution: Gradient clipping (solves exploding gradients), or **change architecture**

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Recurrent neural networks

> Vanilla RNN vs. LSTM

Vanilla RNN

$$h_t = \tanh\left(W\begin{bmatrix}h_{t-1}\\ x_t\end{bmatrix}\right)$$

Long Short Term Memory (LSTM)

$$\begin{bmatrix}i\\ f\\ o\\ g\end{bmatrix} = \begin{bmatrix}\sigma\\ \sigma\\ \sigma\\ \tanh\end{bmatrix} W\begin{bmatrix}h_{t-1}\\ x_t\end{bmatrix}$$

$$c_t = f \odot c_{t-1} + i \odot g$$

$$h_t = o \odot \tanh(c_t)$$

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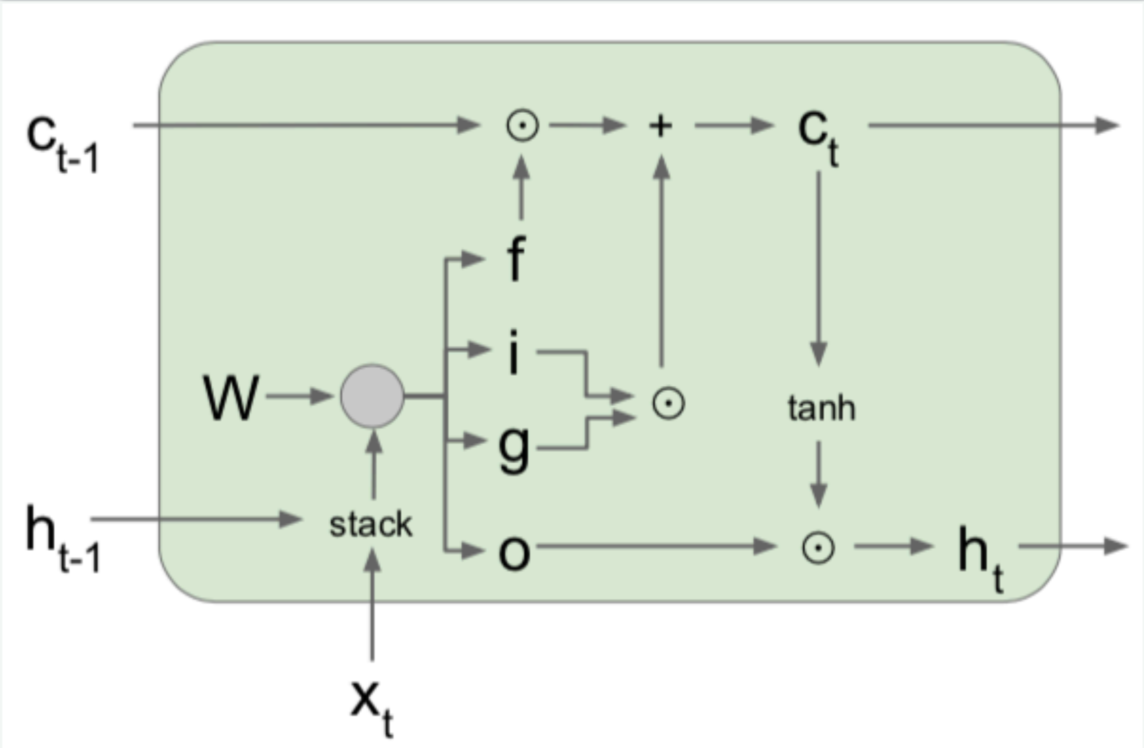
Recurrent neural networks

> Vanilla RNN vs. LSTM



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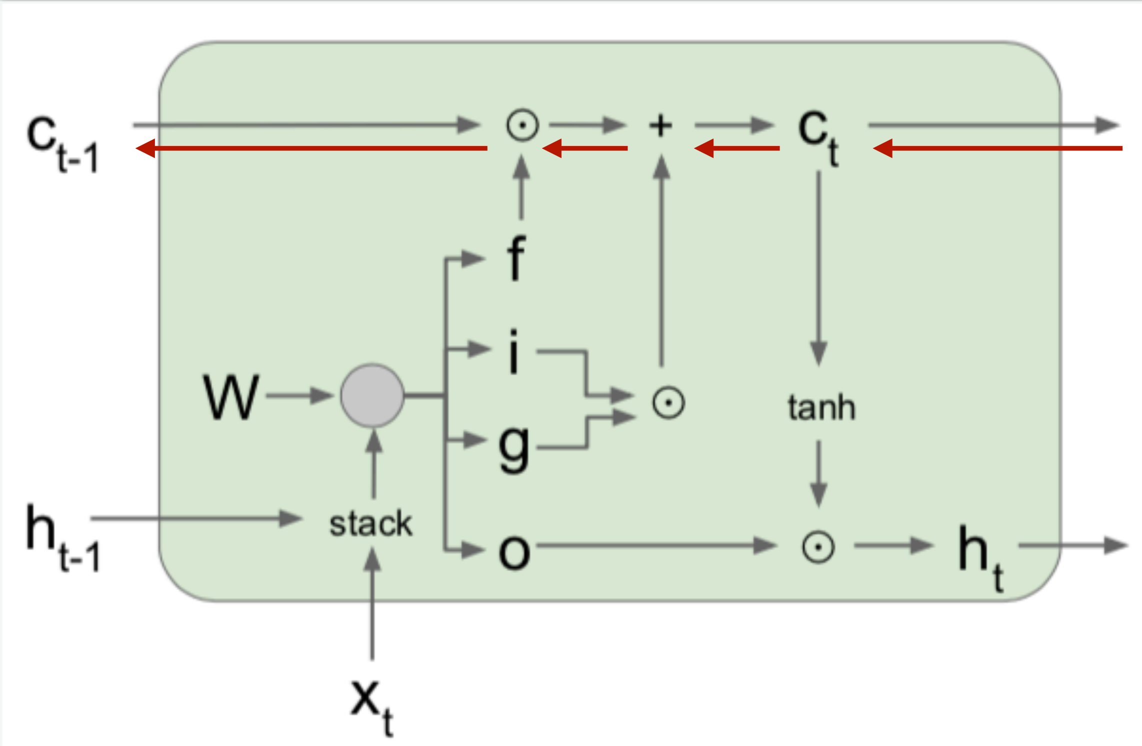
Recurrent neural networks
> Vanilla RNN vs. LSTM

"Gradient highway": solves vanishing/exploding gradient problems



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Recurrent neural networks

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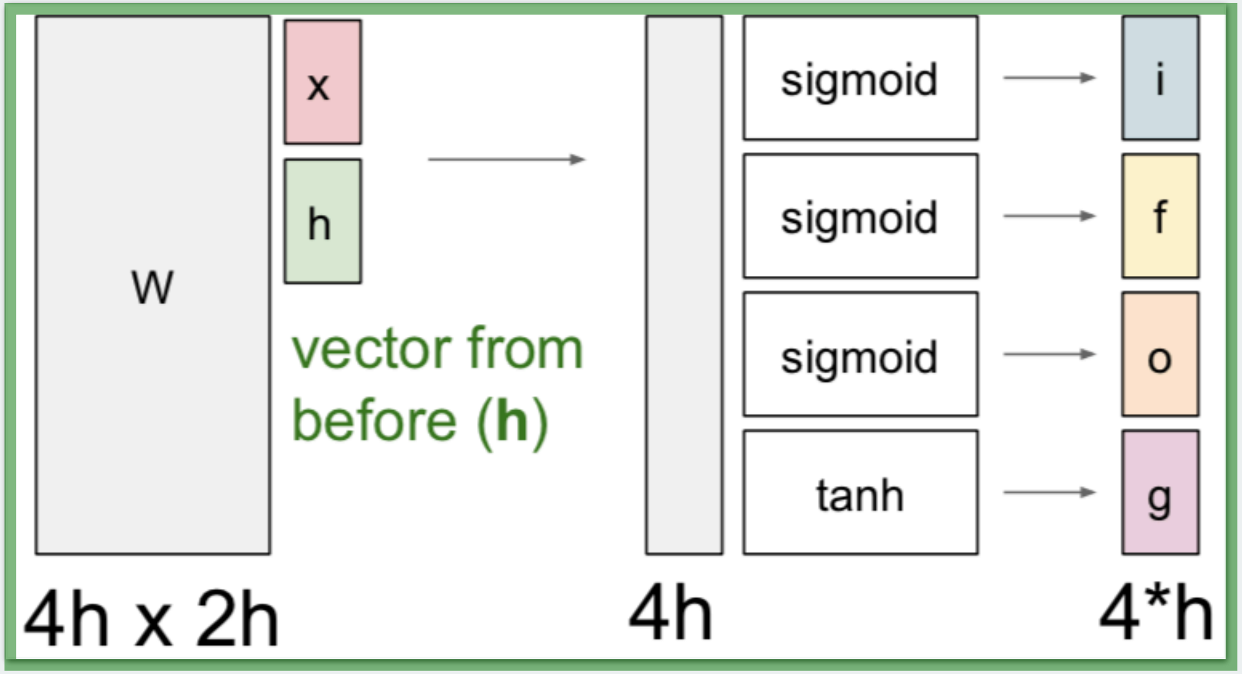

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