Recurrent Neural Networks

성균관대학교 소프트웨어학과
이 지 형

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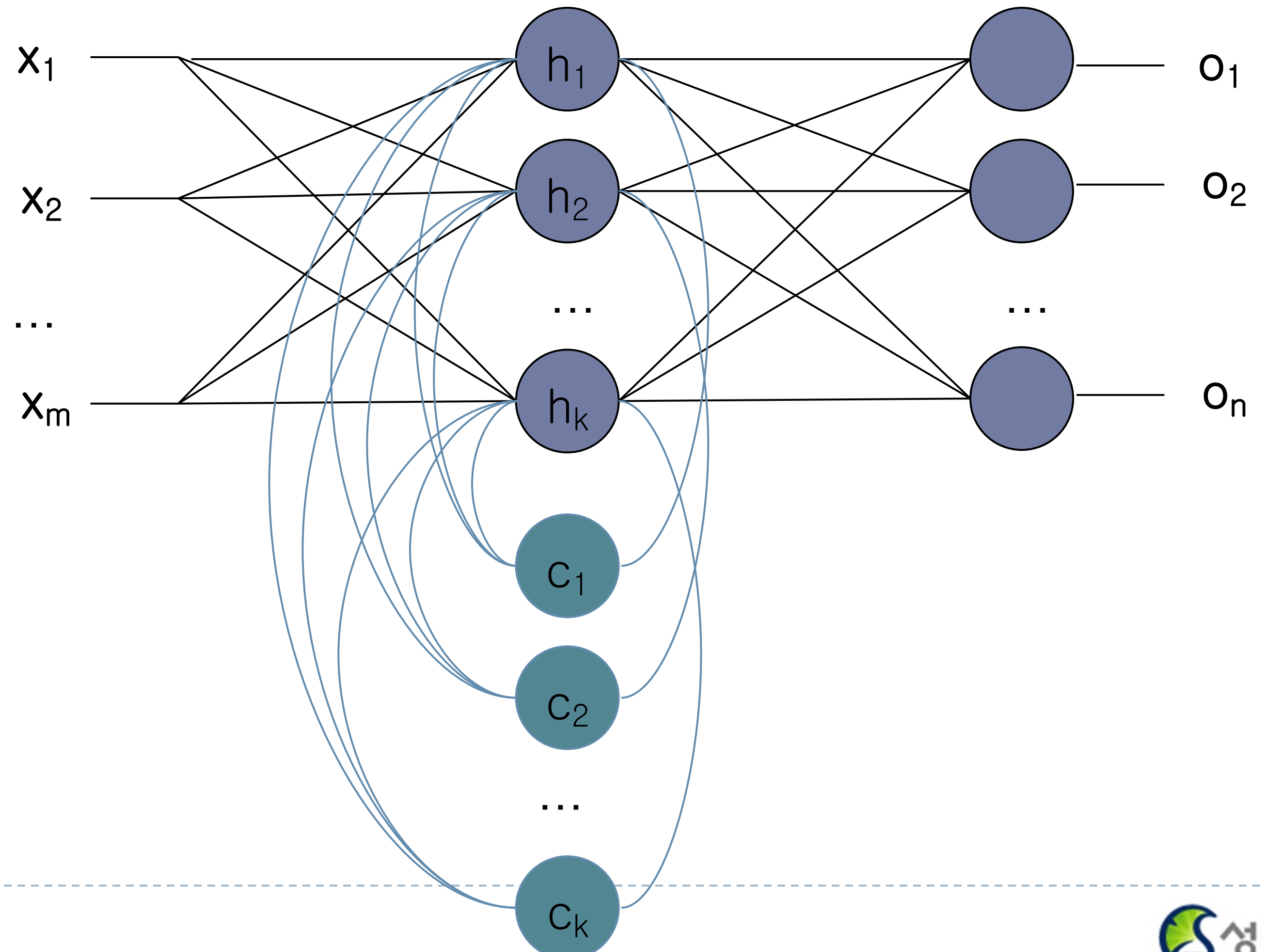
- **Connections form cycles**



Recurrent Neural Networks

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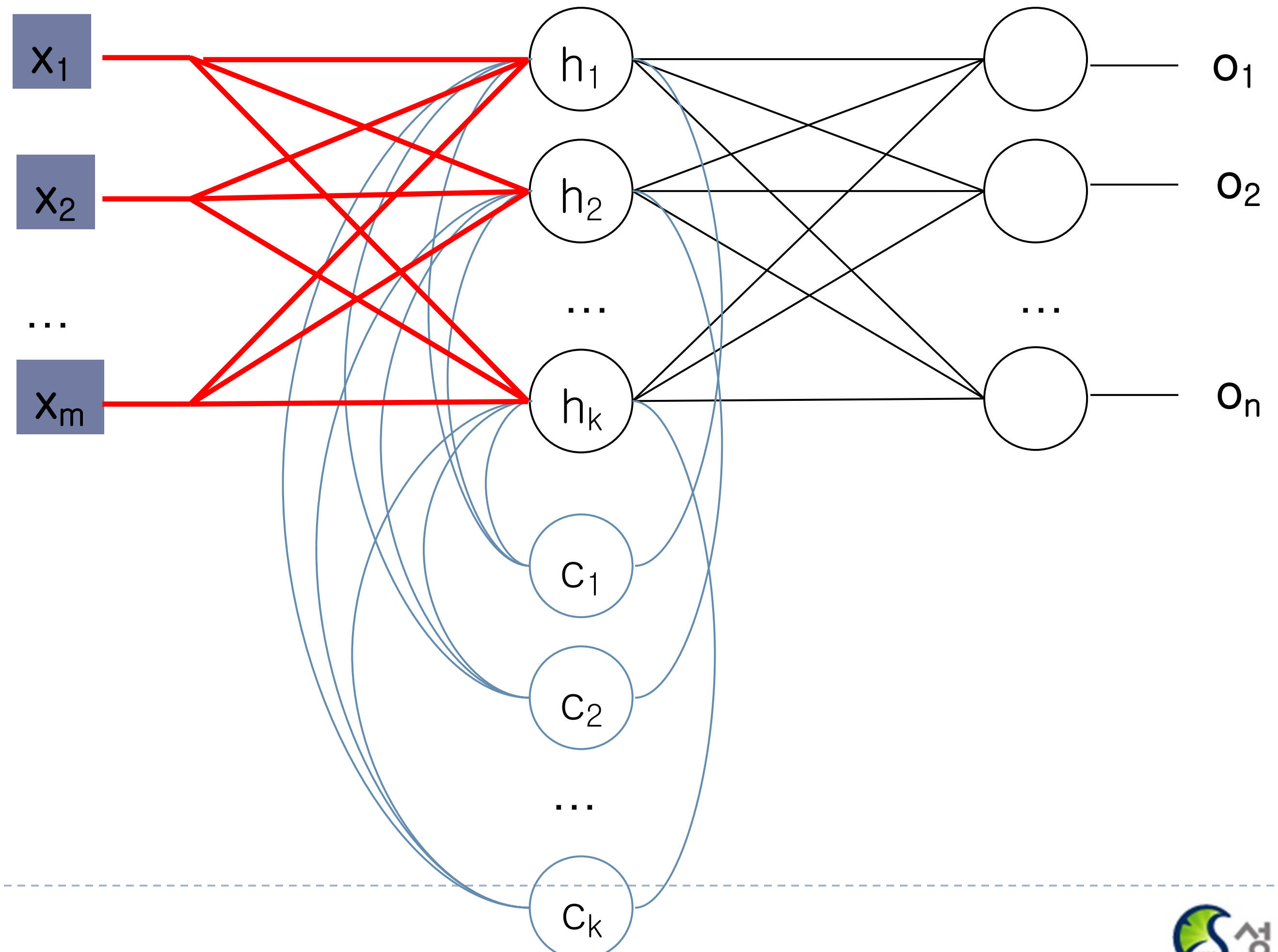

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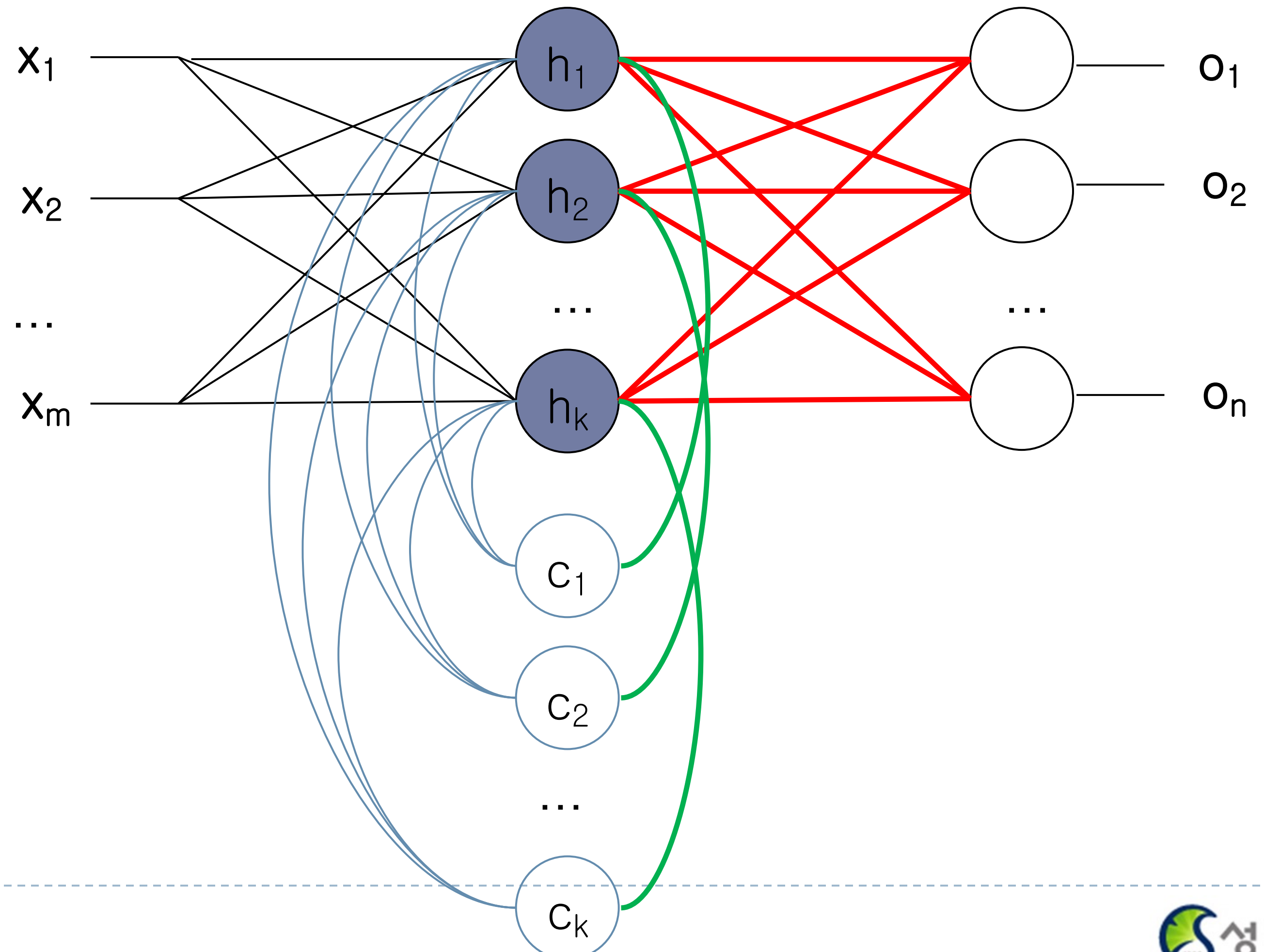

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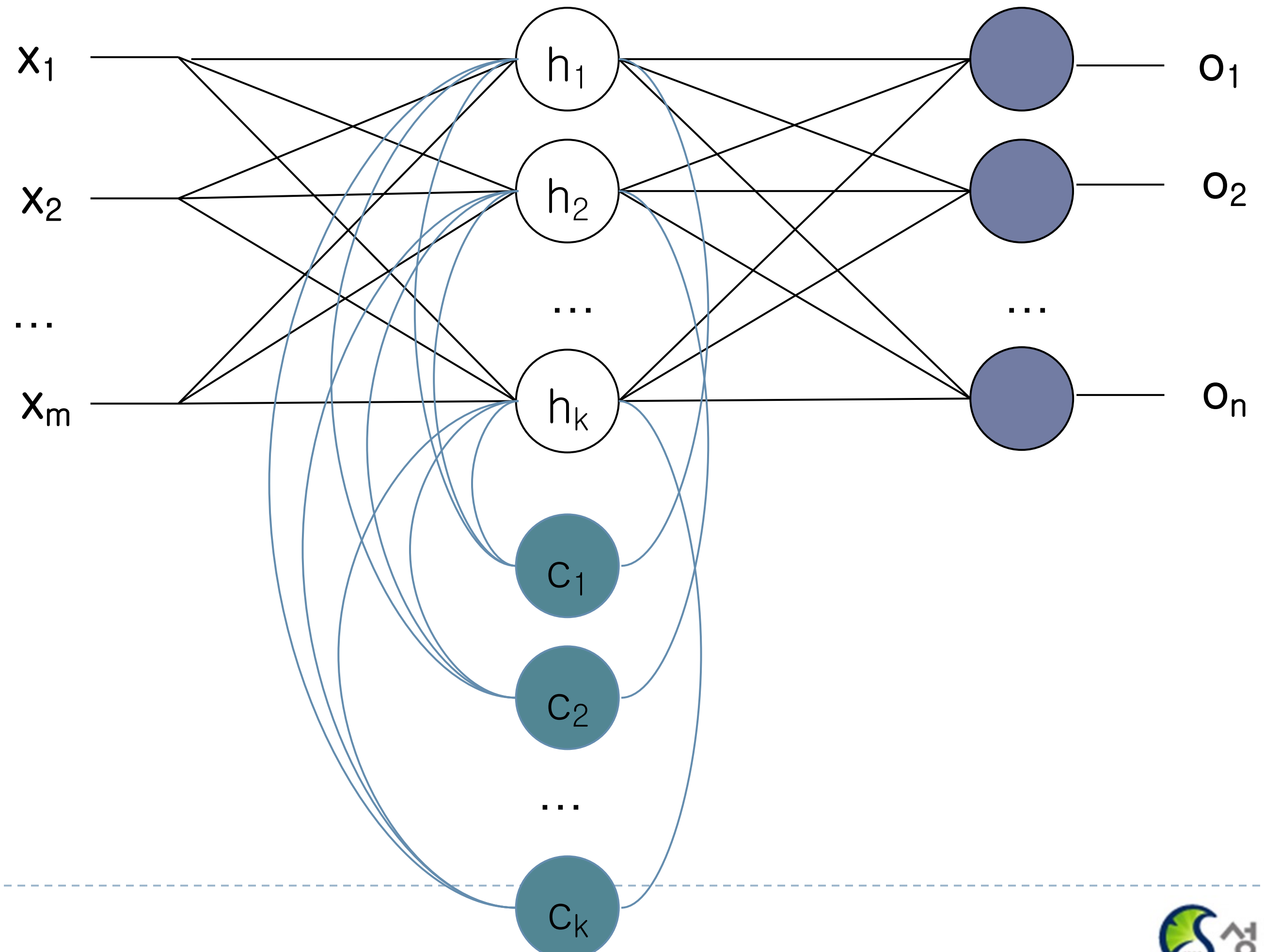

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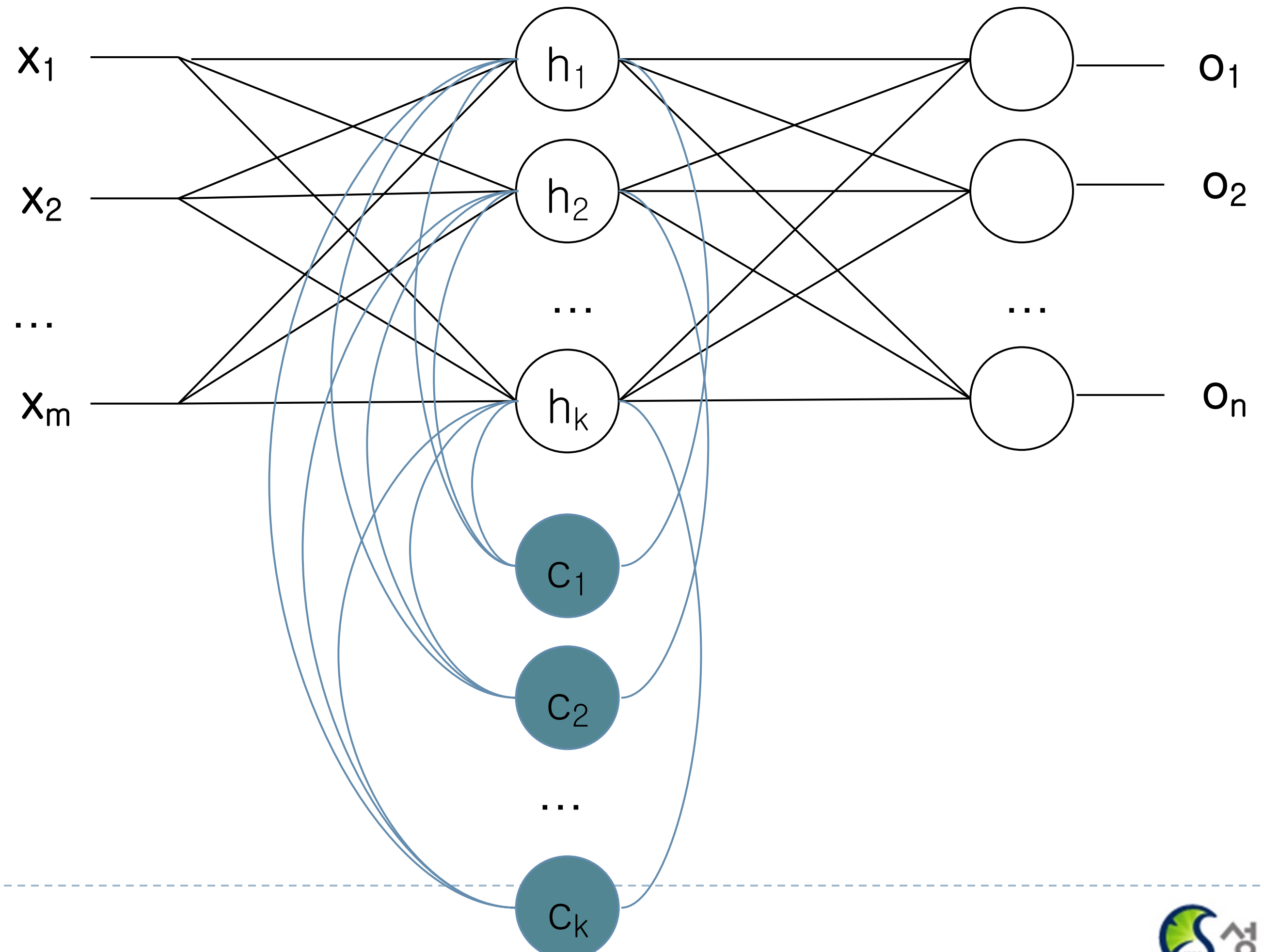

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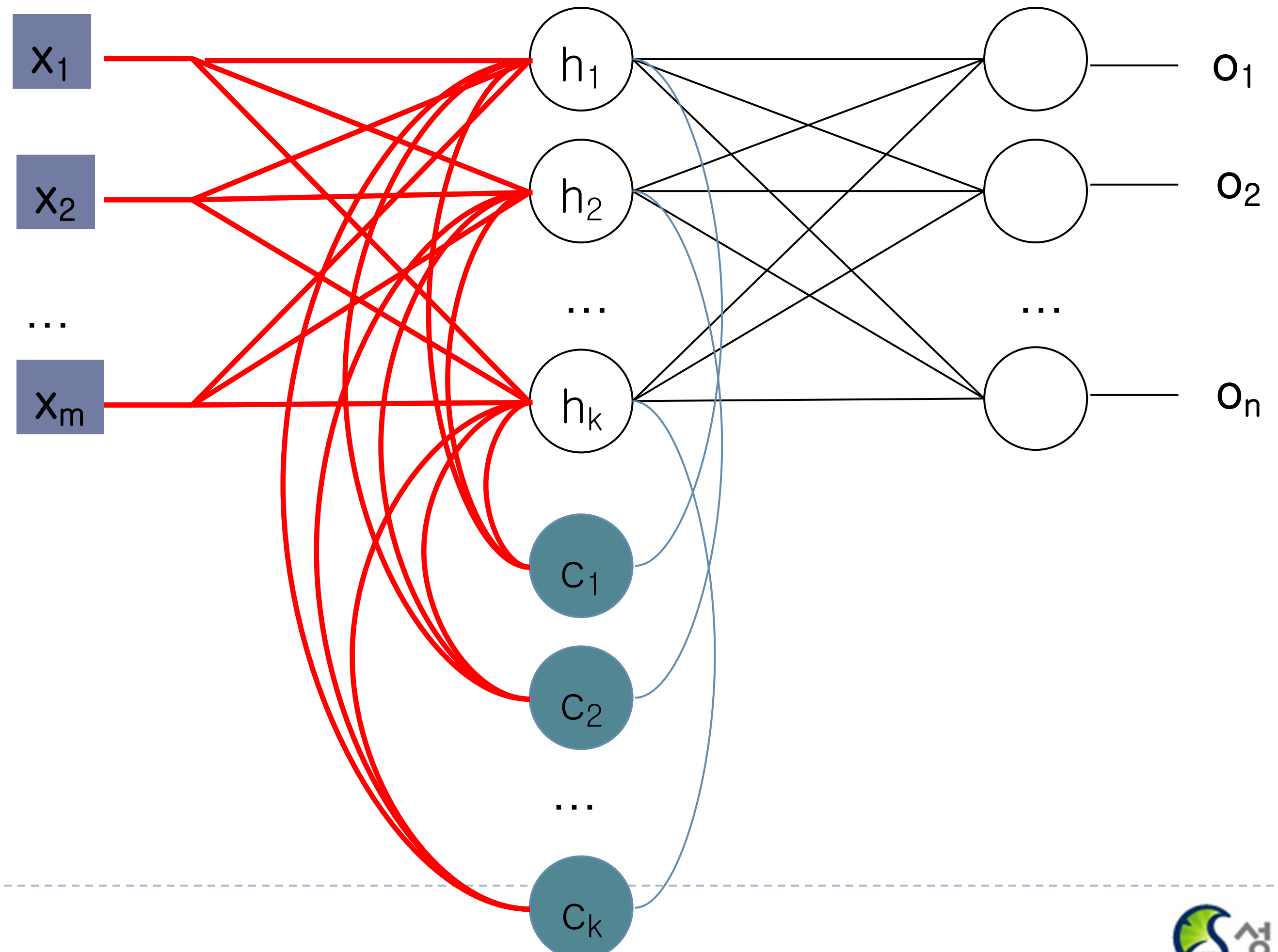

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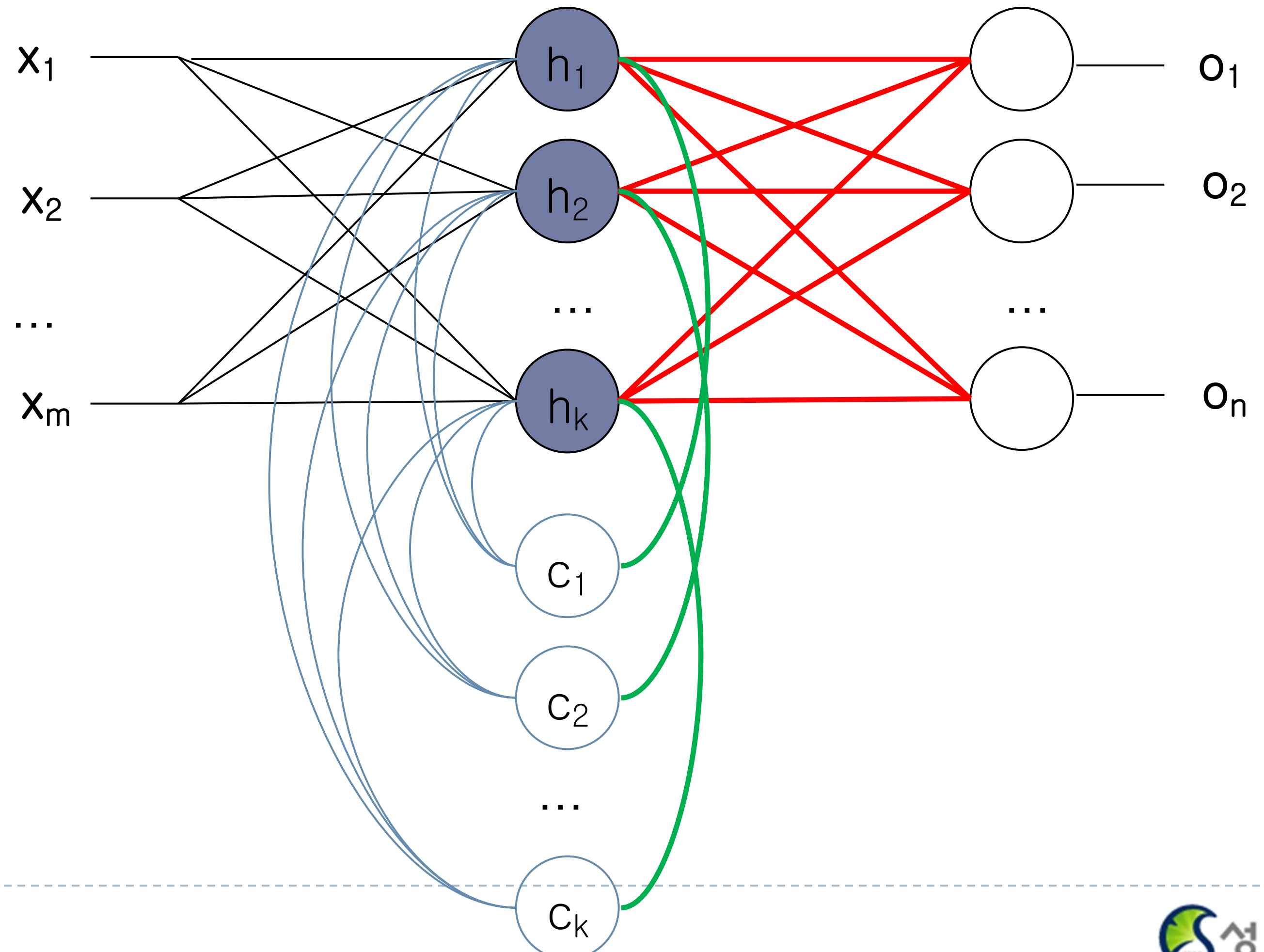

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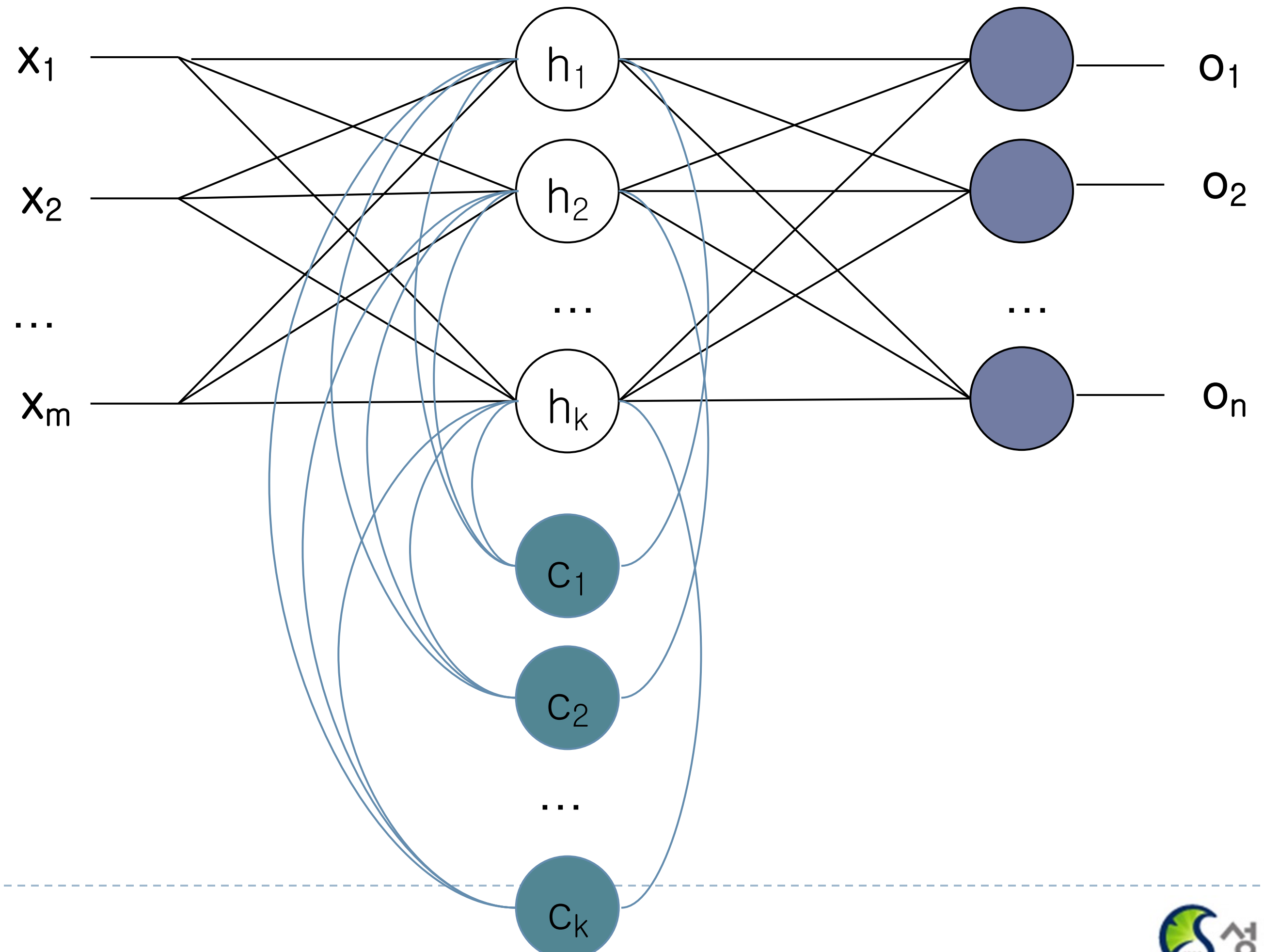

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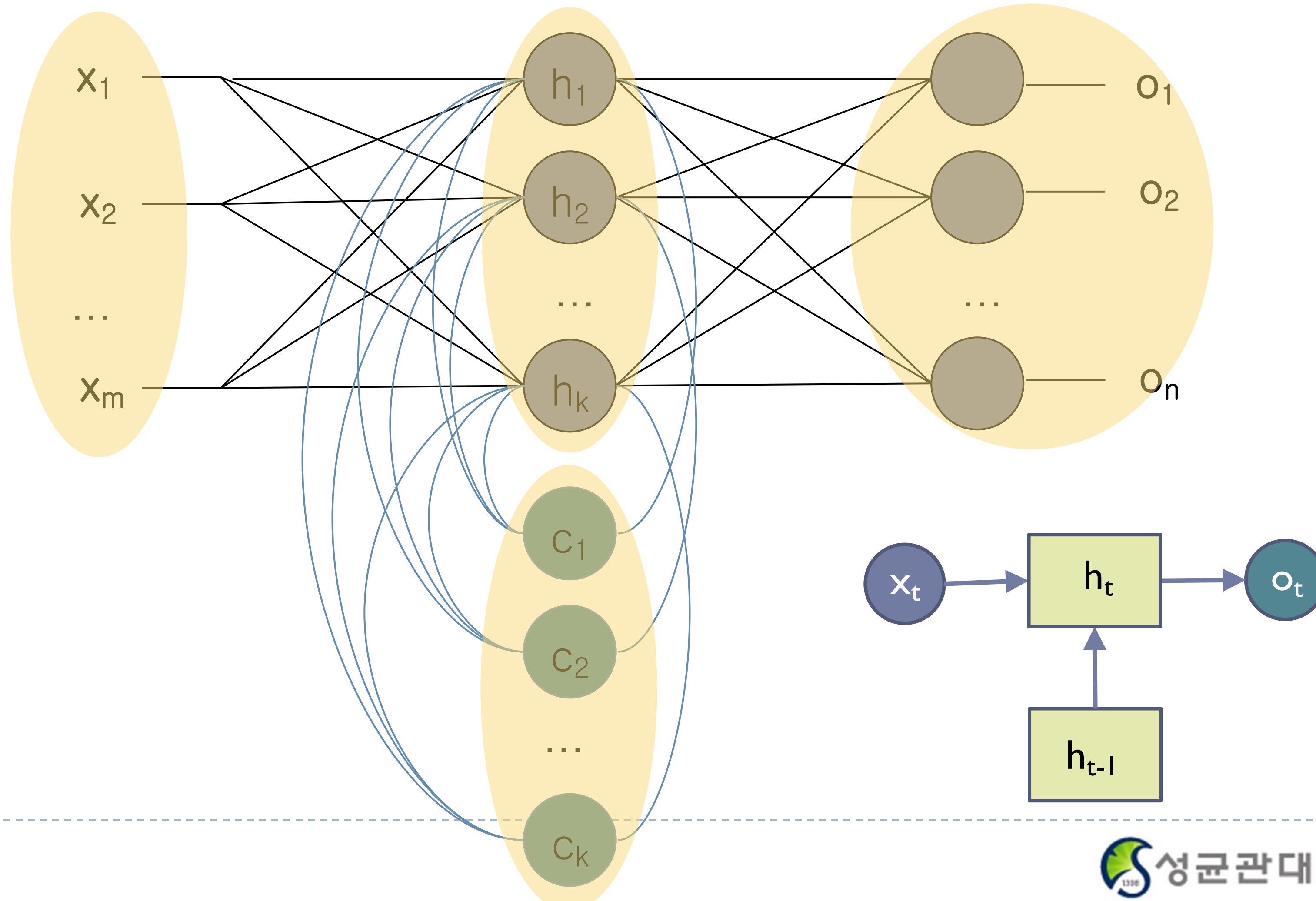

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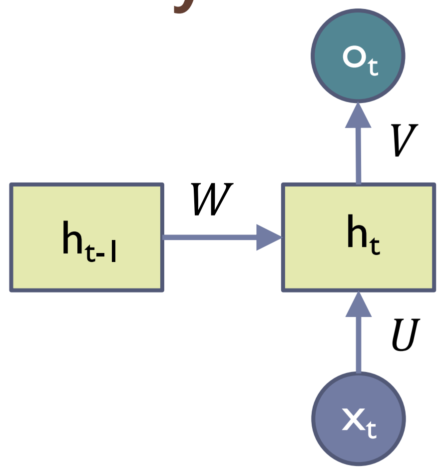

$$h_t = f(Ux_t + Wh_{t-1})$$
$$o_t = g(Vh_t)$$

- x_t: input at time t
- h_t: hidden state at time t
- f: is an activation function
- U, V, W: network parameters
  - RNN shares the same parameters across all time steps
- g: activation function for the output layer

Recurrent Neural Networks

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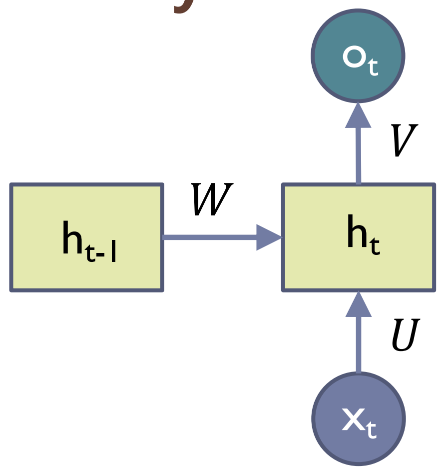

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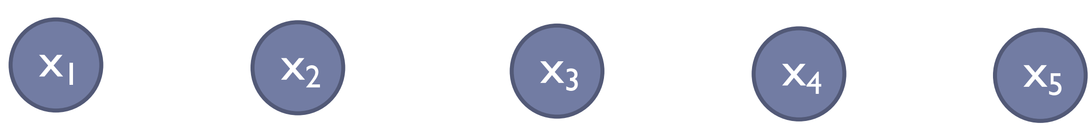

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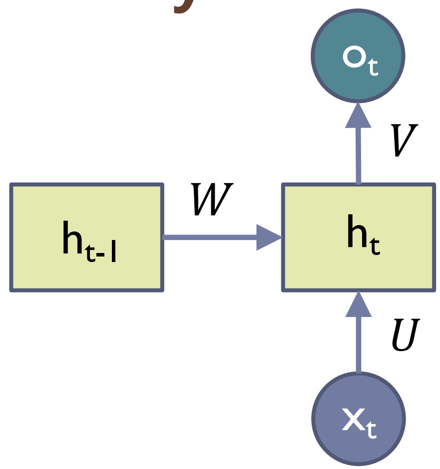

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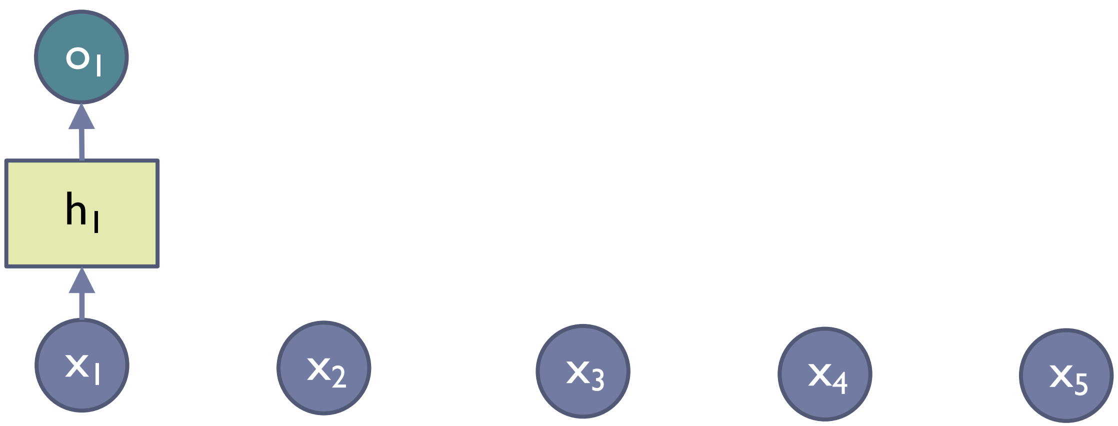

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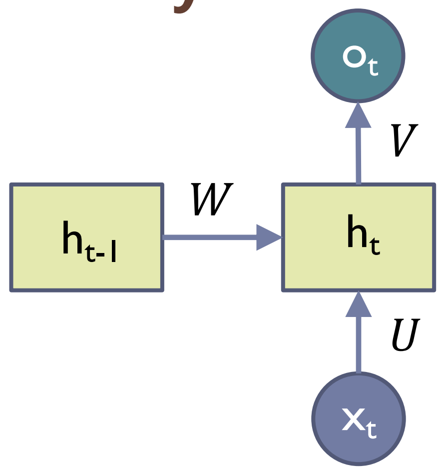

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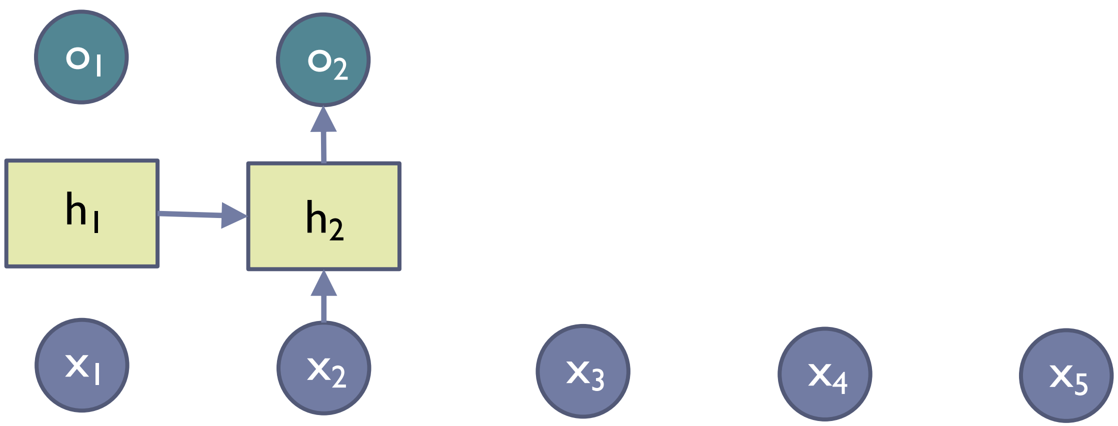

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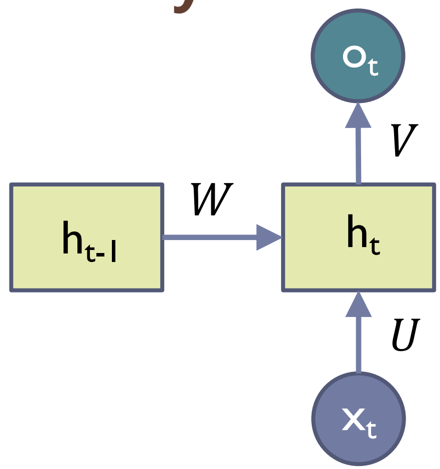

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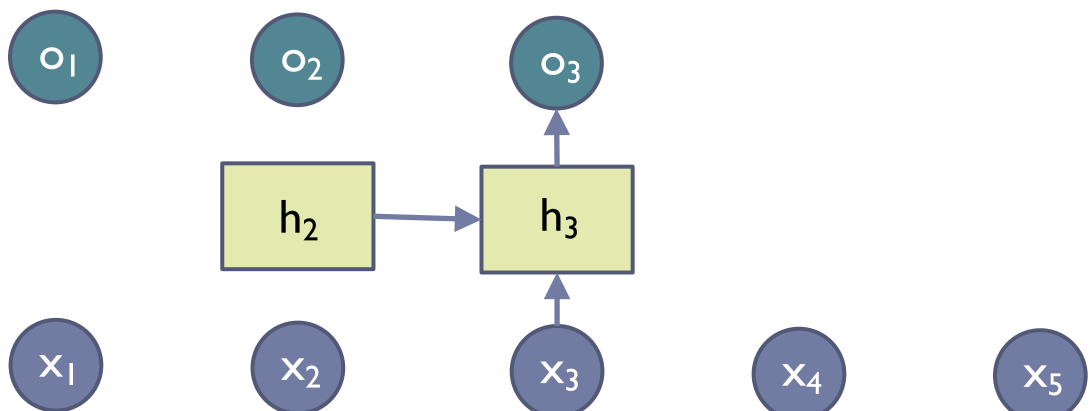

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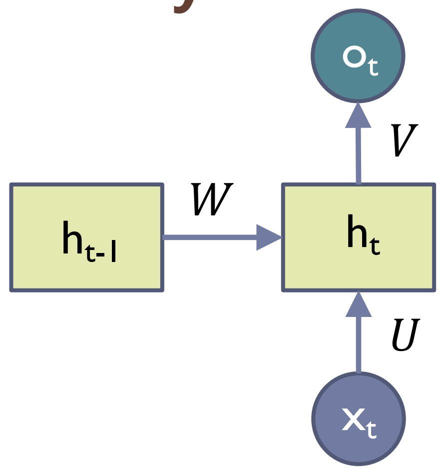

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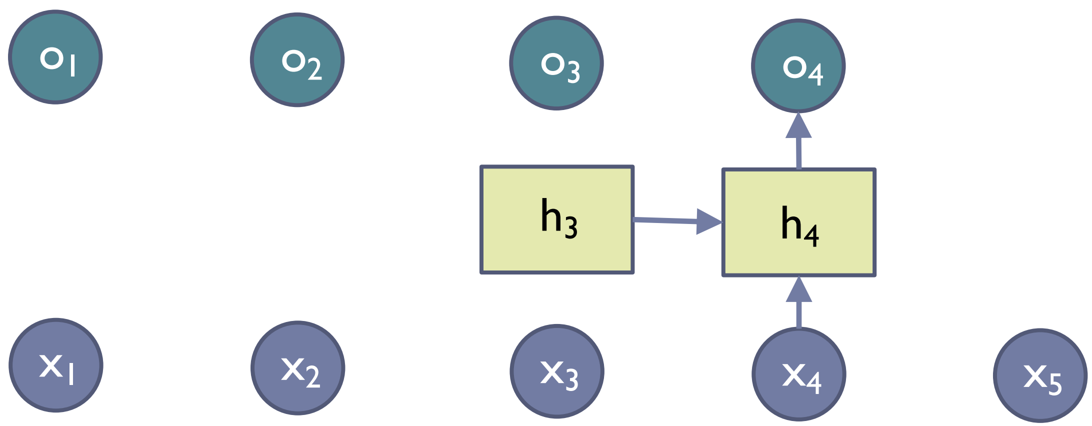

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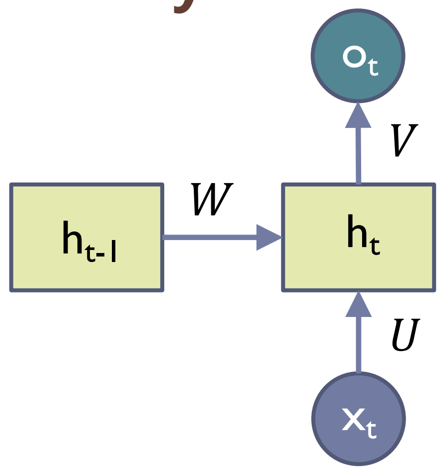

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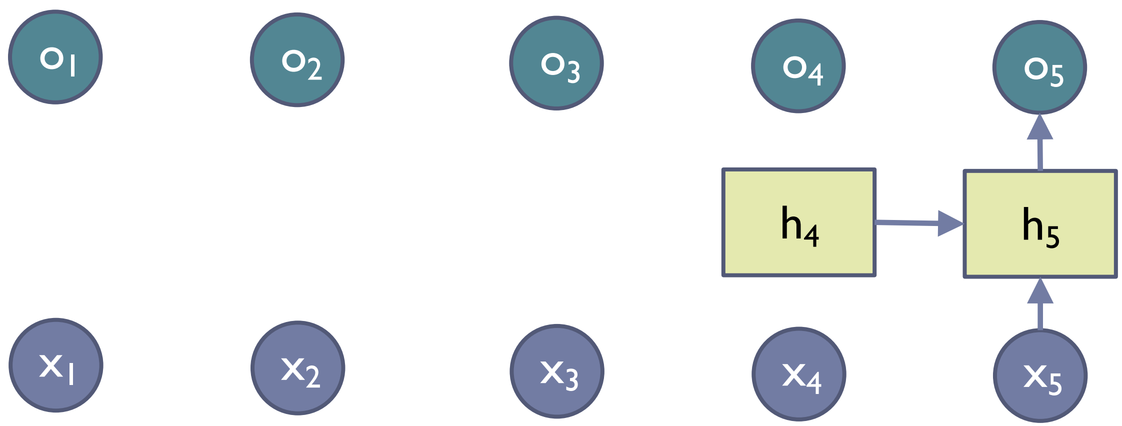

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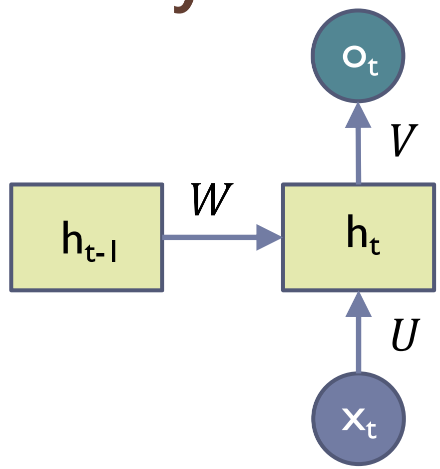

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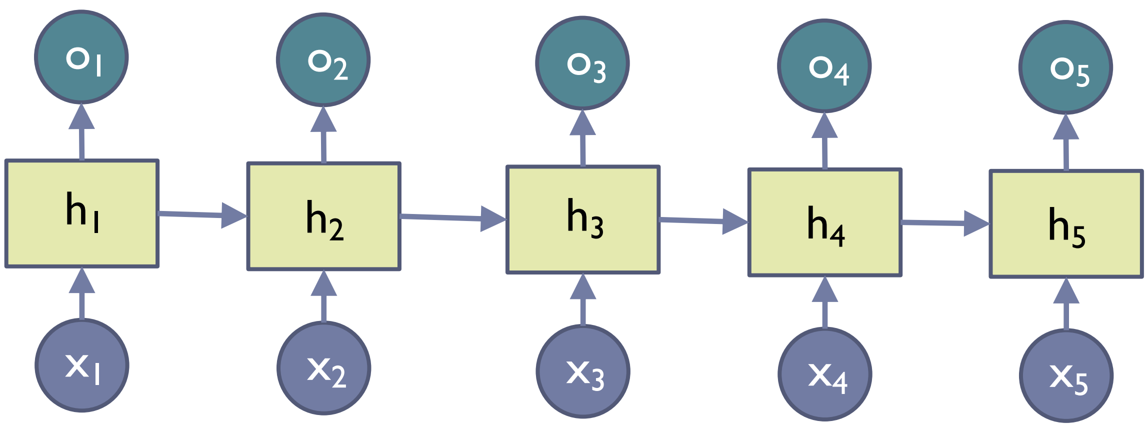
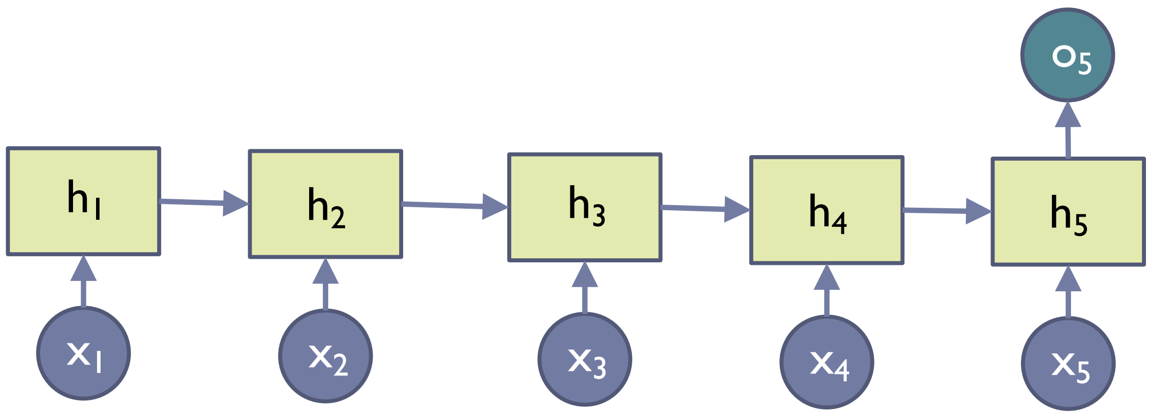


Recurrent Neural Networks

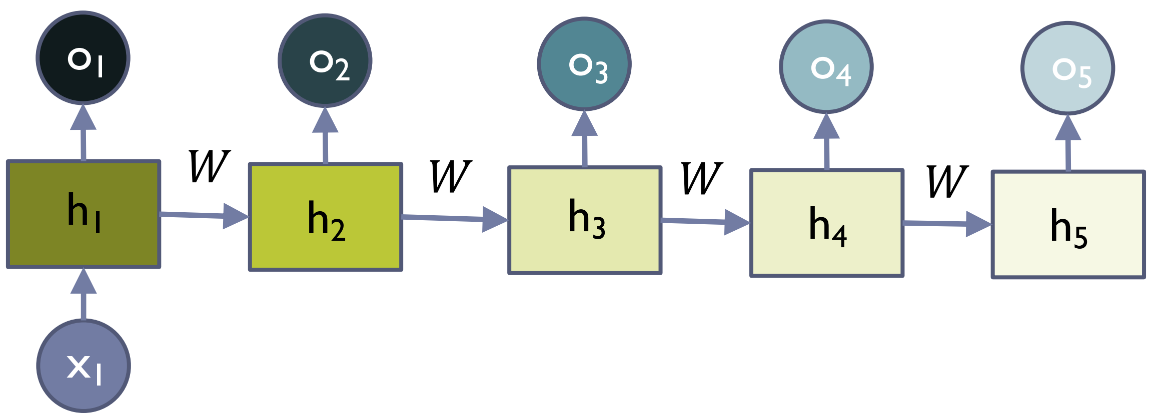
Long Term Dependency

- $x_1 \sim x_{t-1}$ are encoded into h_{t-1}
- h_{t-1} has the information on the past
- It is a context to process x_t



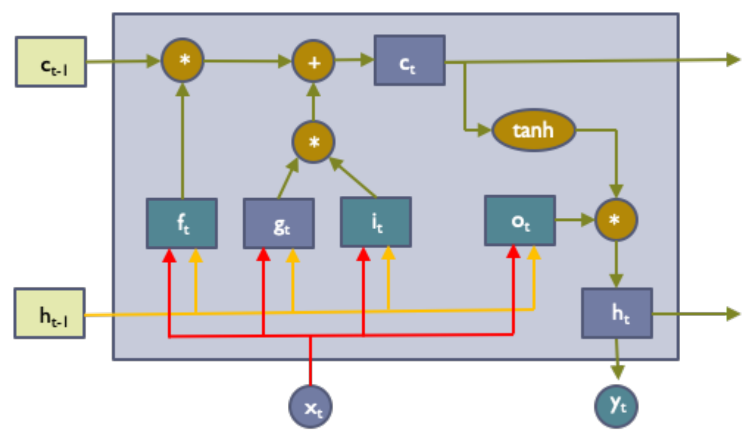
Recurrent Neural Networks

- **Long Term Dependency of Standard RNN**
  - However, it may exponentially decade or grow
  - Usually it is limited to 10 steps



Long Short-Term Memory (LSTM)

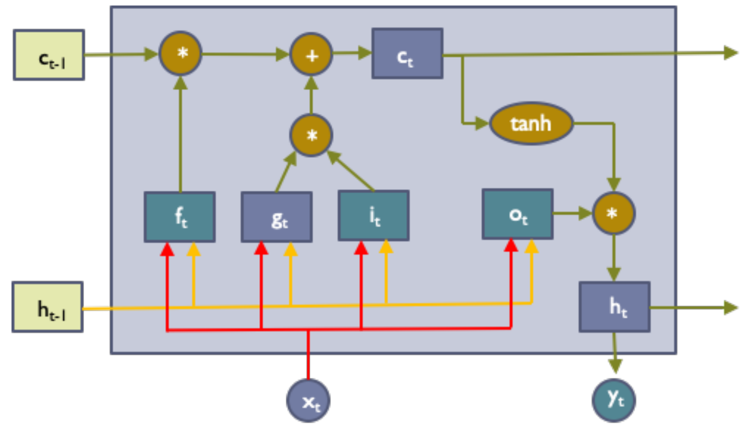
- **Capable of learning long-term dependencies.**
  - **LSTM networks introduce a new structure called a memory cell**
    - An LSTM can learn to bridge time intervals in excess of 1000 steps
  - **Gate units that learn to open and close access to the past**
    - Input gate
    - Forget gate
    - Output gate
    - Neuron with a self-recurrent



Long Short-Term Memory (LSTM)

Equations

- i: input gate
- f: forget gate
- o: output gate
- g: self-recurrent
- c_t: internal memory
- h_t: hidden state
- y: final output



$$i = \sigma\left(x_t U^i + h_{t-1} W^i\right)$$

$$f = \sigma\left(x_t U^f + h_{t-1} W^f\right)$$

$$o = \sigma(x_t U^o + h_{t-1} W^o)$$

$$g = \tanh(x_t U^g + h_{t-1} W^g)$$

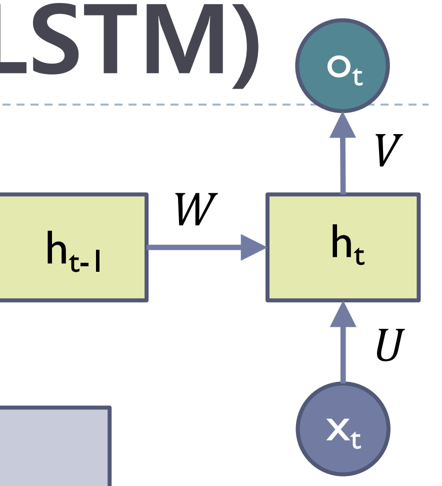
$$c_t = c_{t-1} \circ f + g \circ i$$

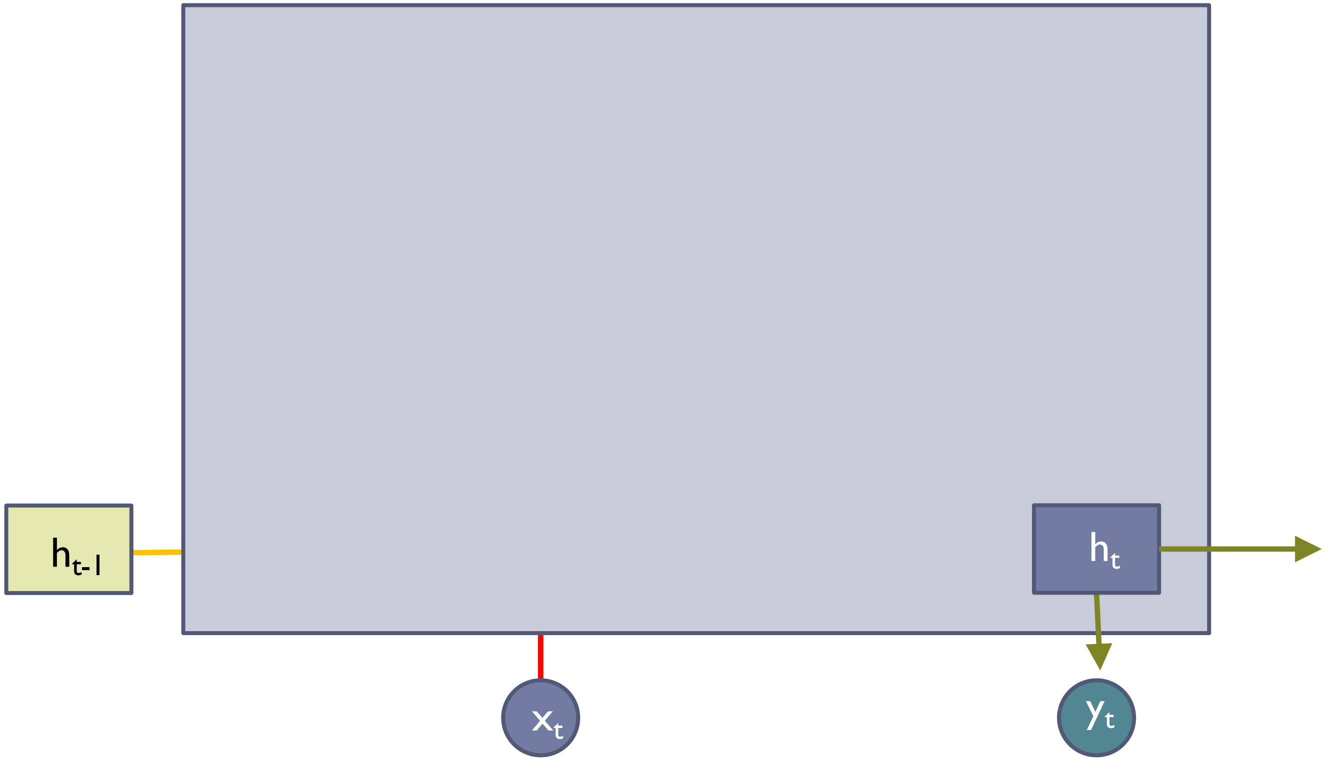
$$h_t = \tanh(c_t) \circ o$$

$$y = softmax(V h_t)$$

Long Short-Term Memory (LSTM)

- **How to work**





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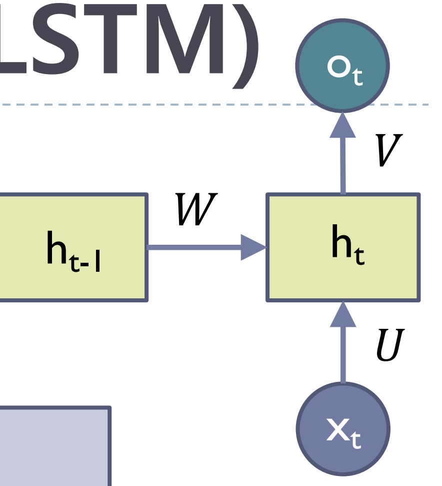

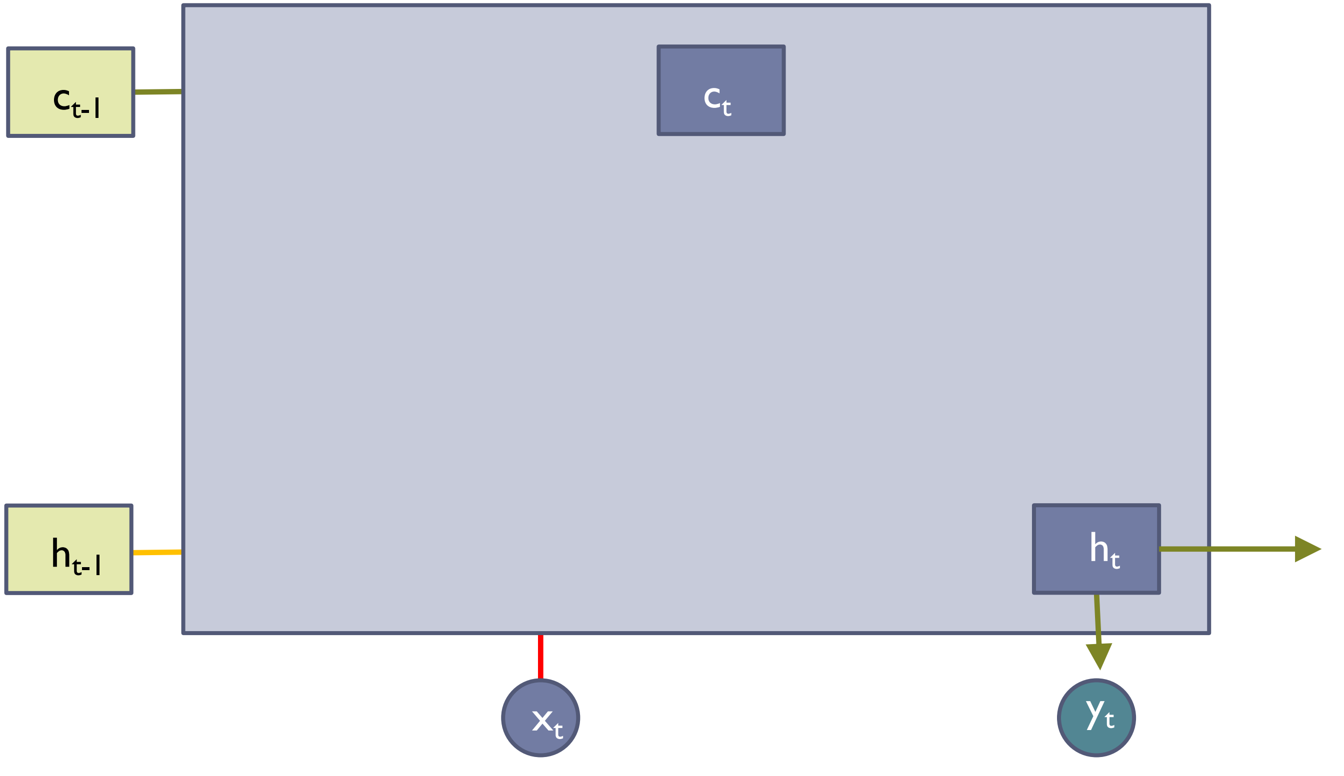

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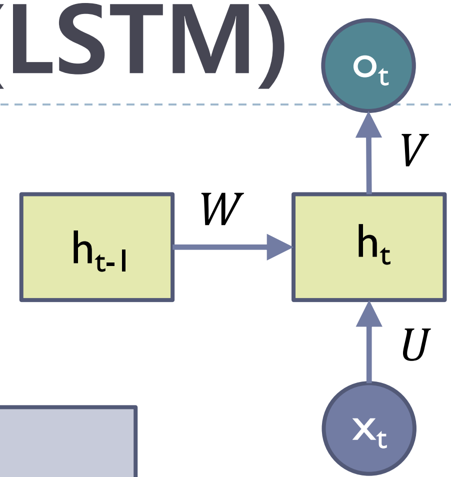

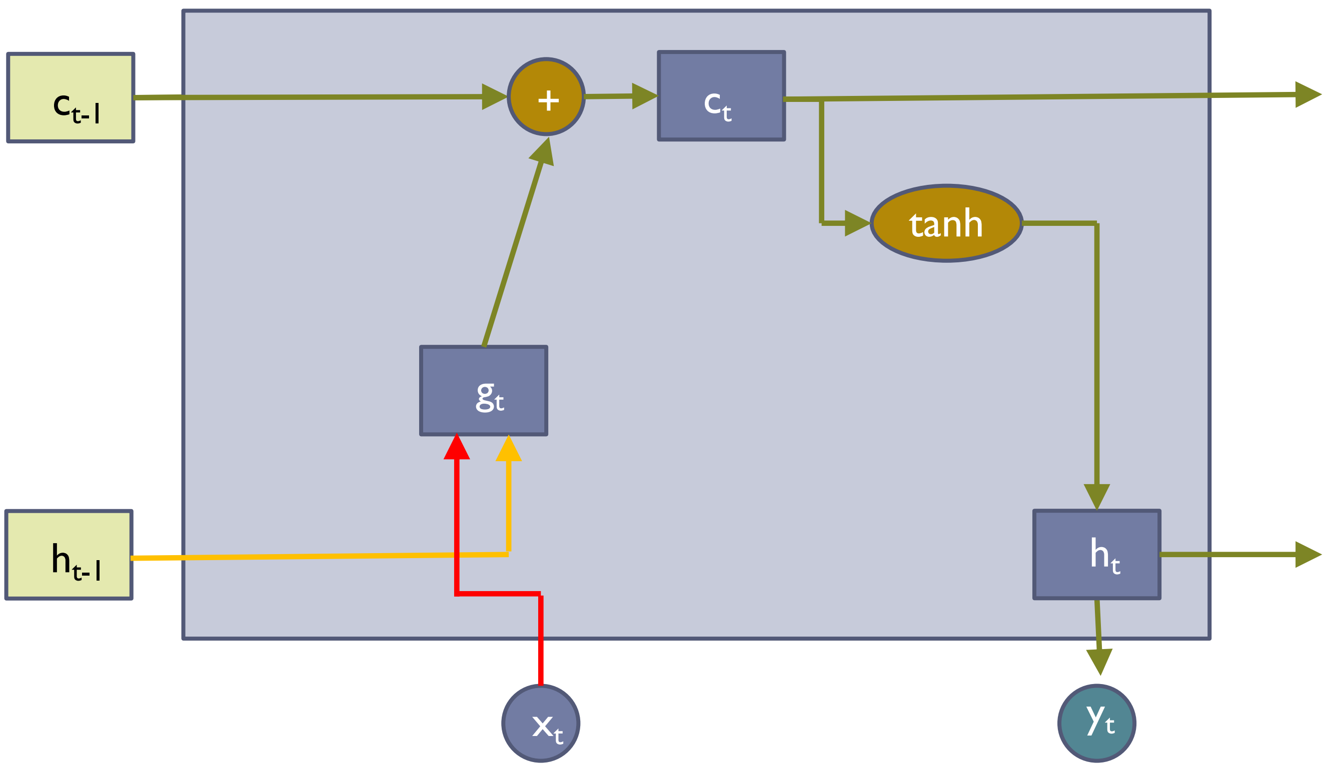

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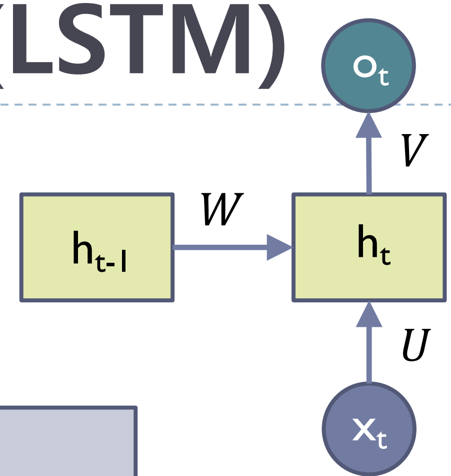

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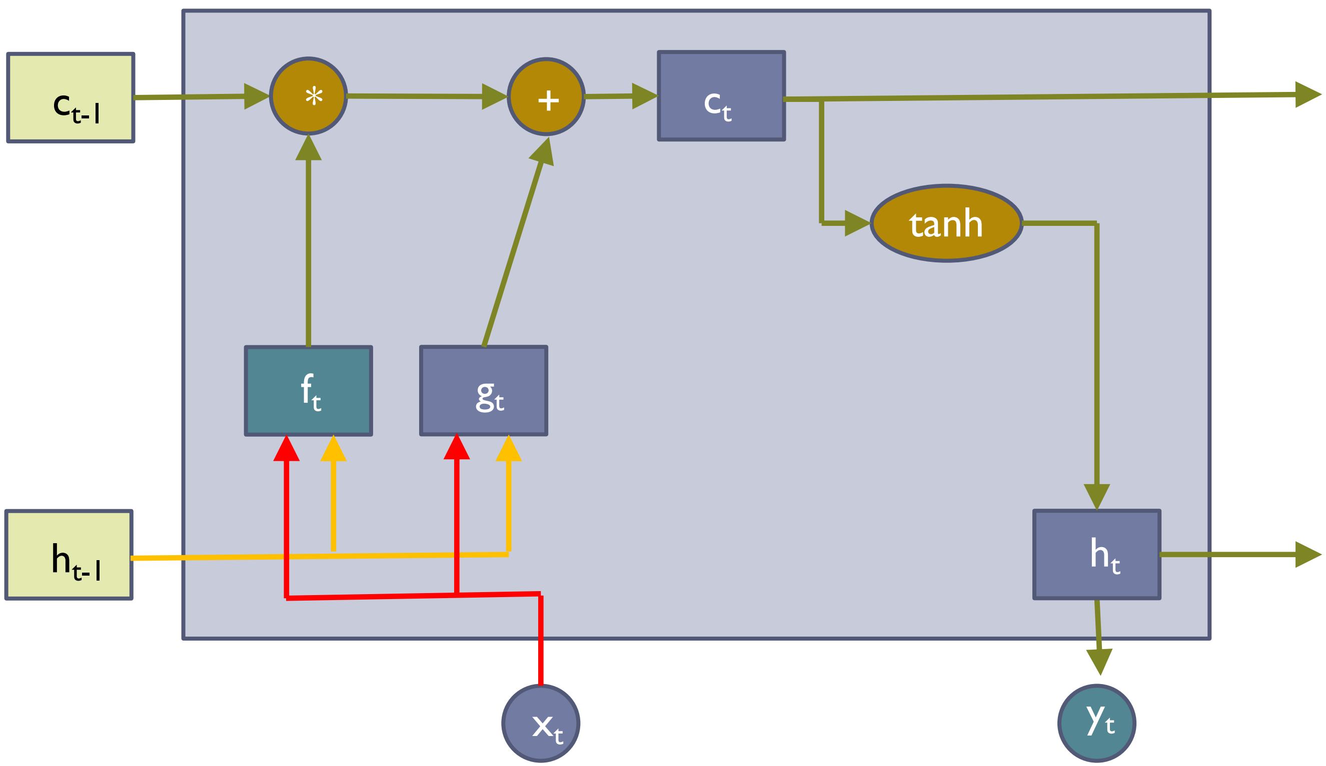

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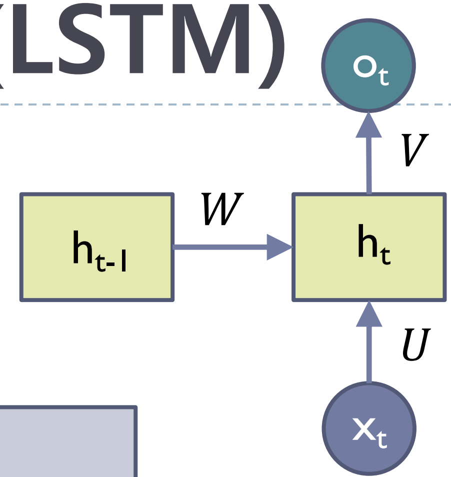

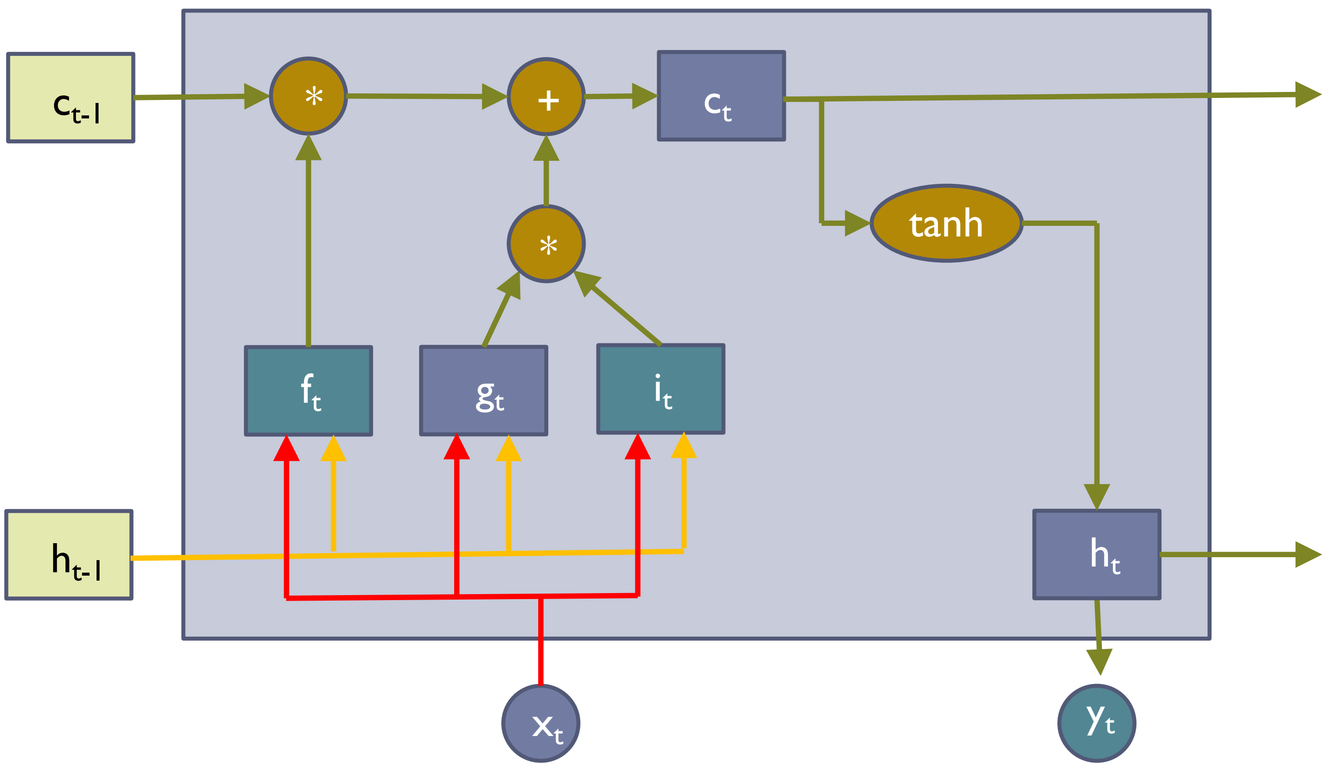

Long Short-Term Memory (LSTM)

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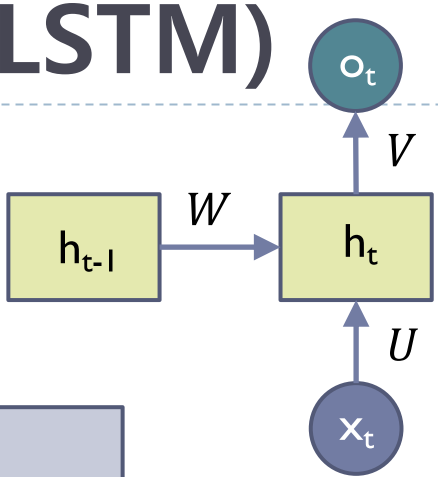

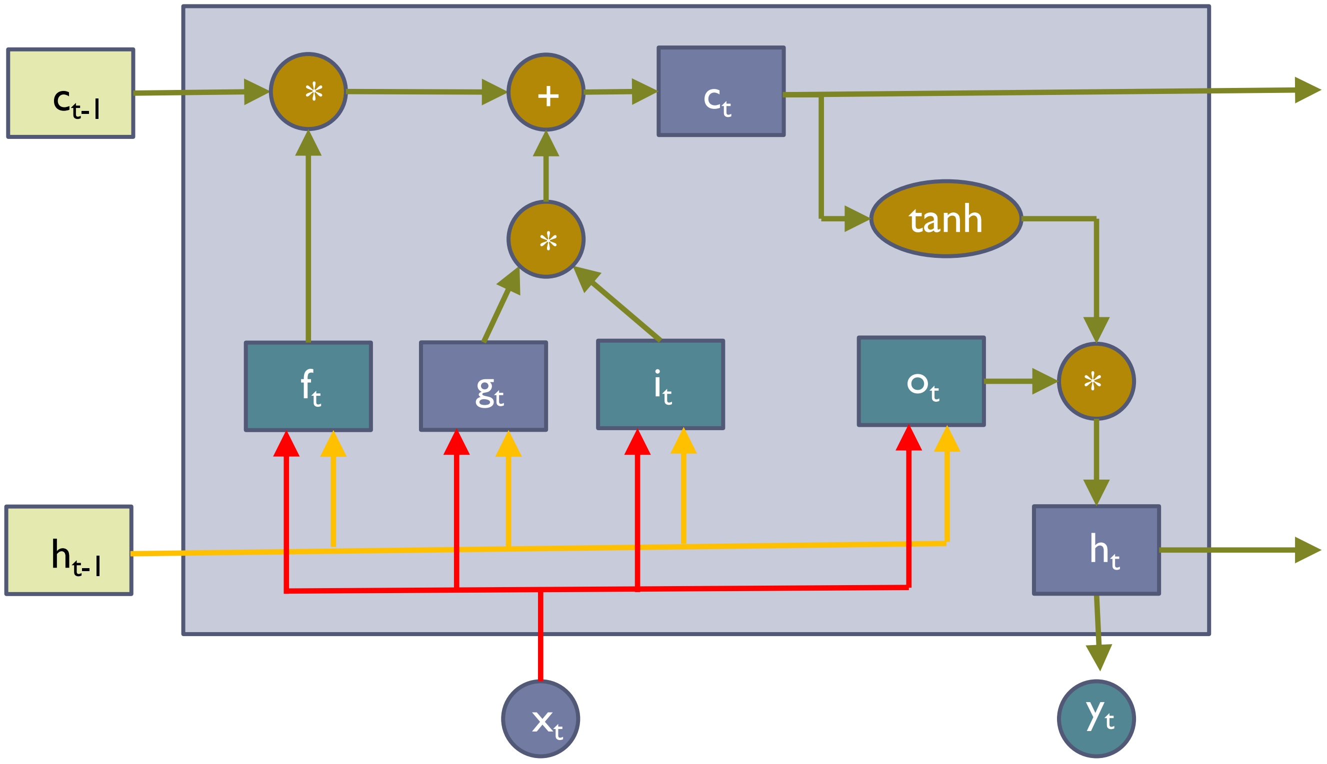

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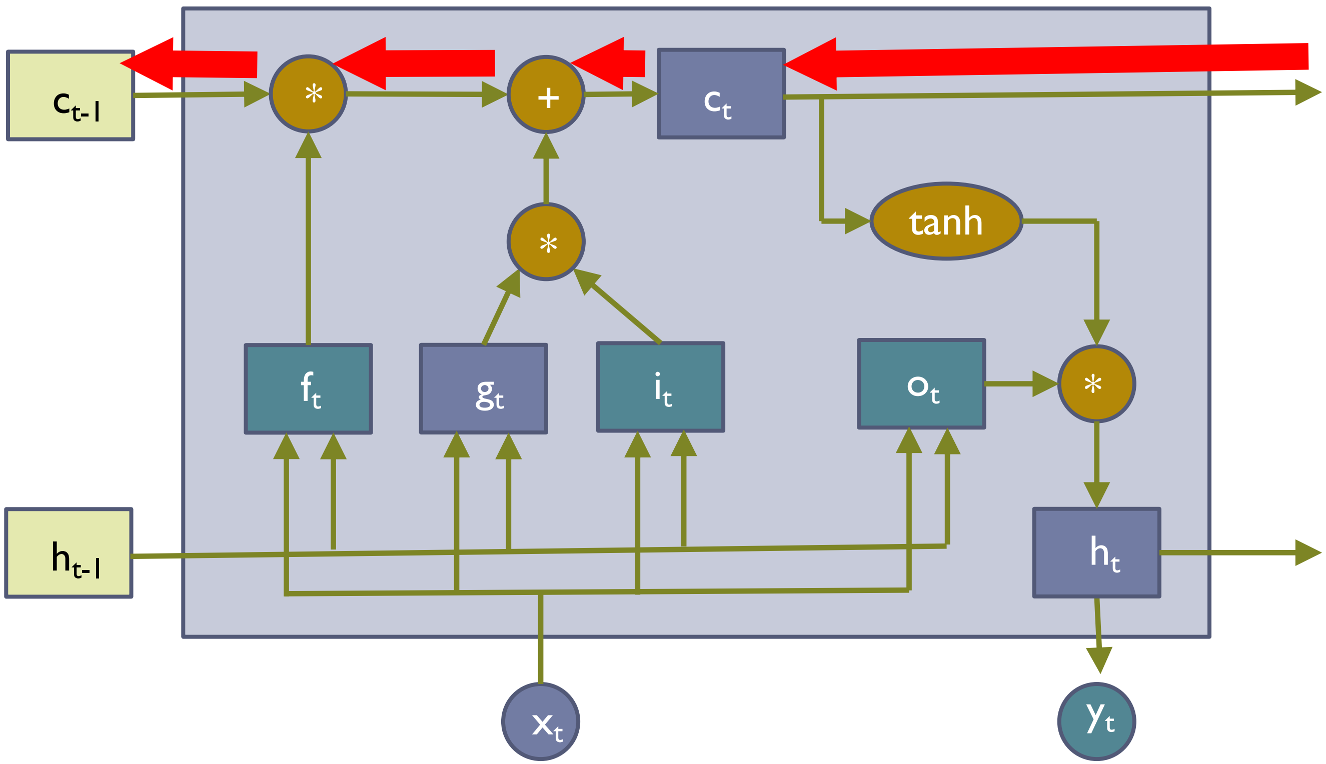
Long Short-Term Memory (LSTM)

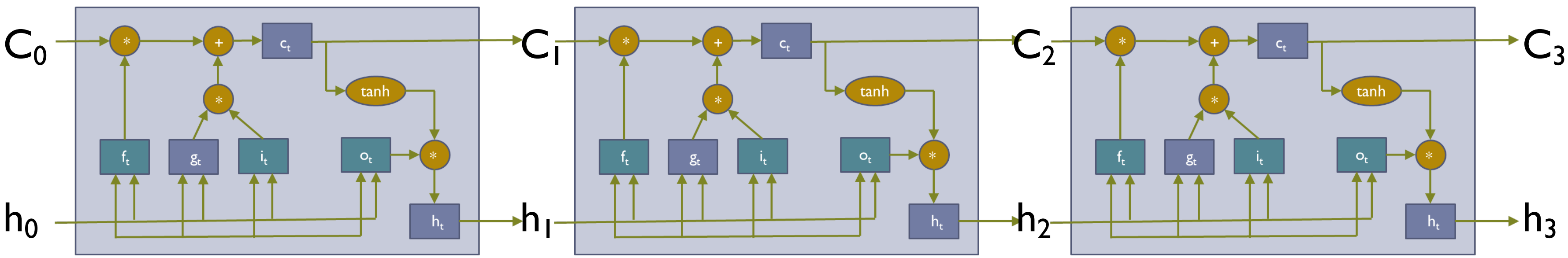
- **Gradient Flow**

Backpropagation from c_t to c_{t-1} only elementwise multiplication by f, no matrix multiply by W



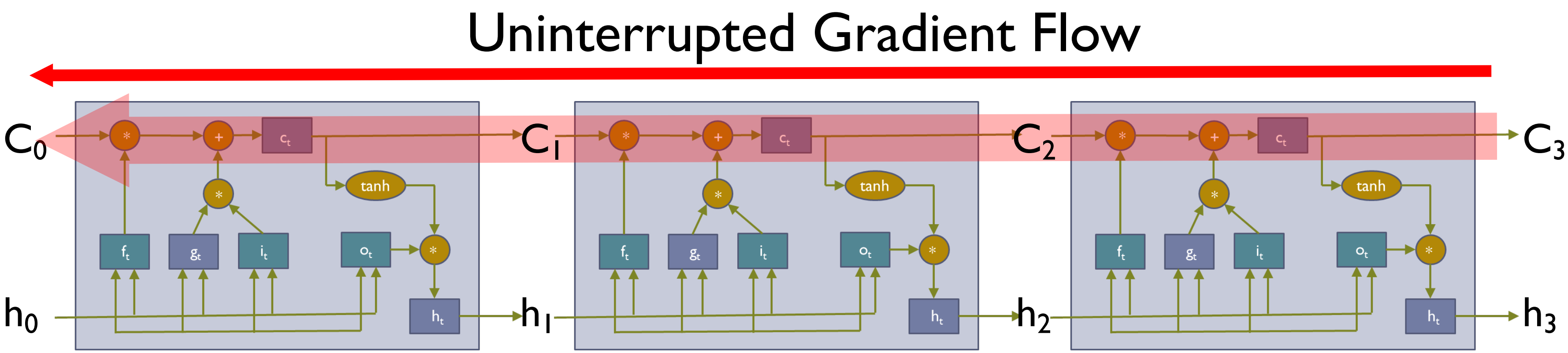
Long Short-Term Memory (LSTM)

- **Gradient Flow**

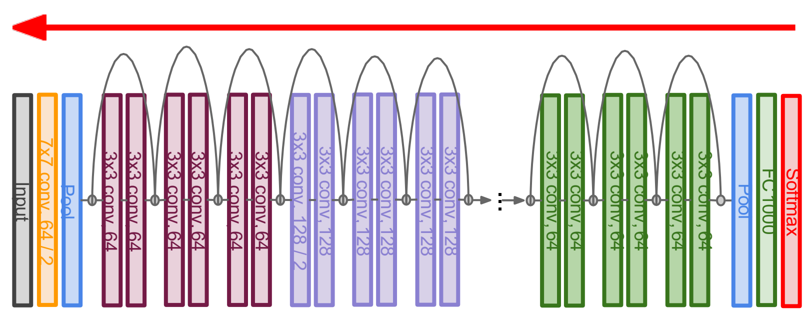


Long Short-Term Memory (LSTM)

Gradient Flow



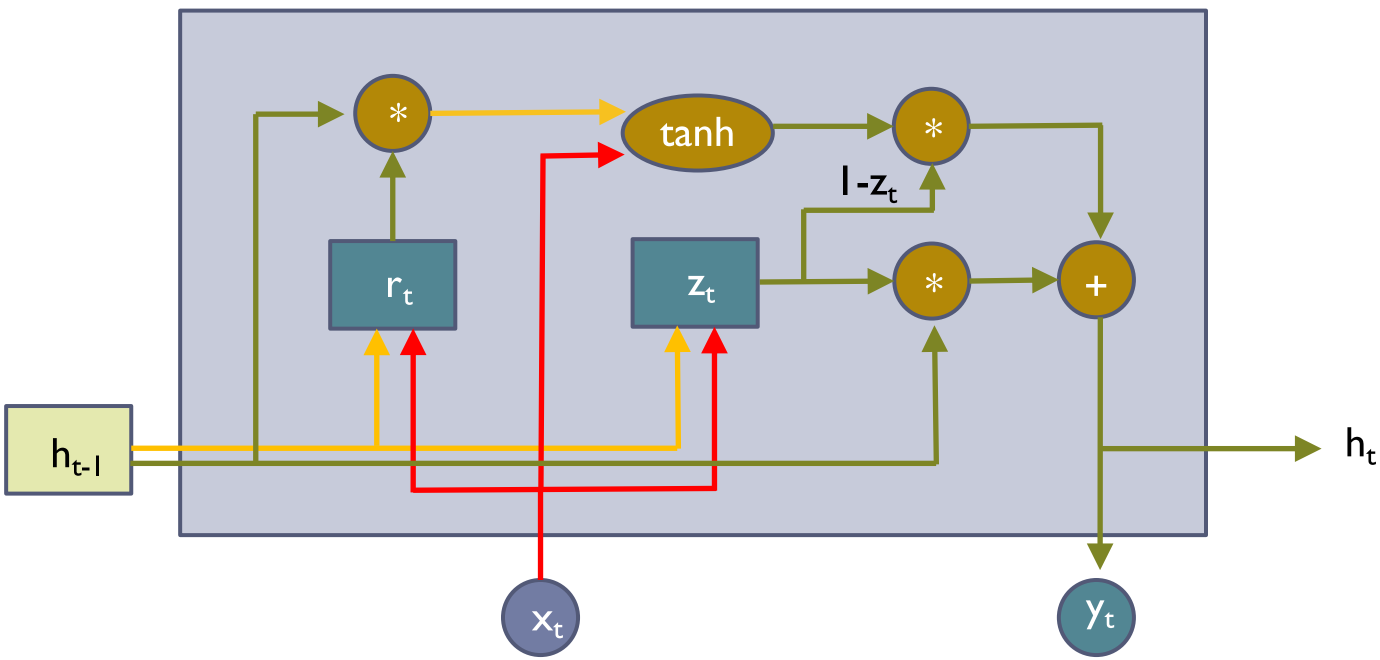
Similar to ResNet!



Gated Recurrent Units

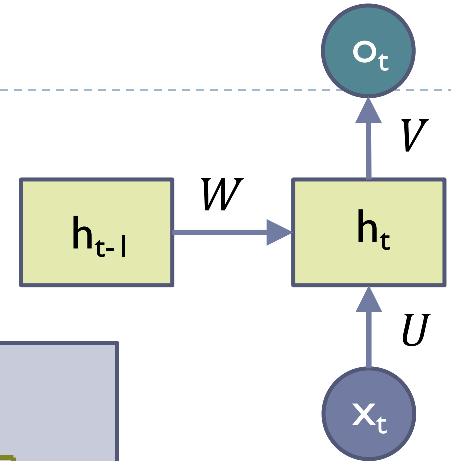
- **Structure**

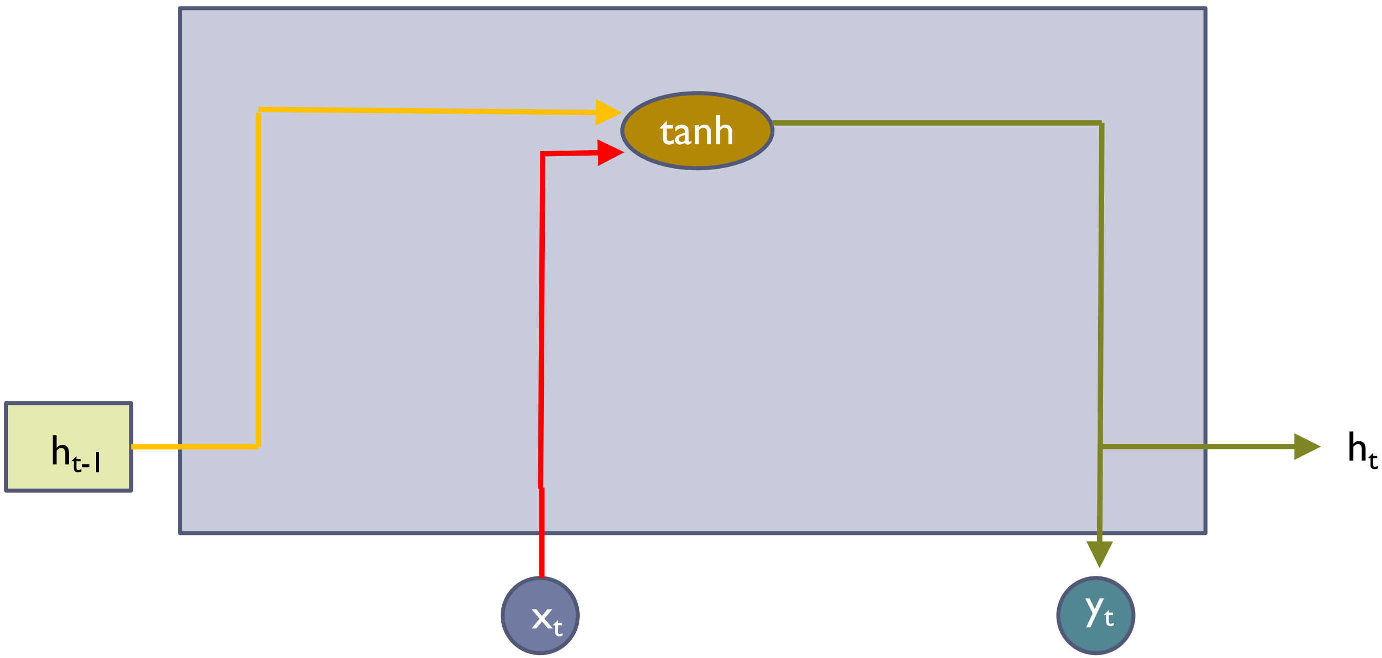
$$r_t = \sigma(W_{xr}x_t + W_{hr}h_{t-1} + b_r)$$
$$z_t = \sigma(W_{xz}x_t + W_{hz}h_{t-1} + b_z)$$
$$\tilde{h}_t = \tanh(W_{xh}x_t + W_{hh}(r_t \odot h_{t-1}) + b_h)$$
$$h_t = z_t \odot h_{t-1} + (1 - z_t) \odot \tilde{h}_t$$



Gated Recurrent Units

- ## How to work





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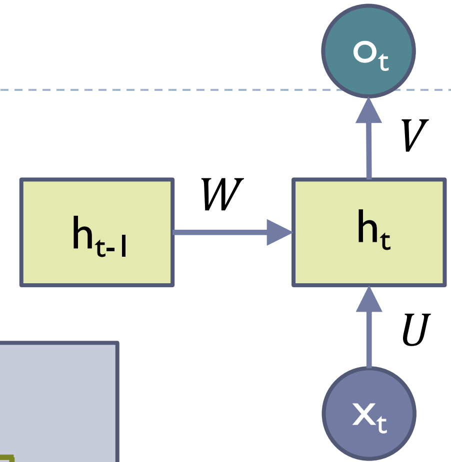

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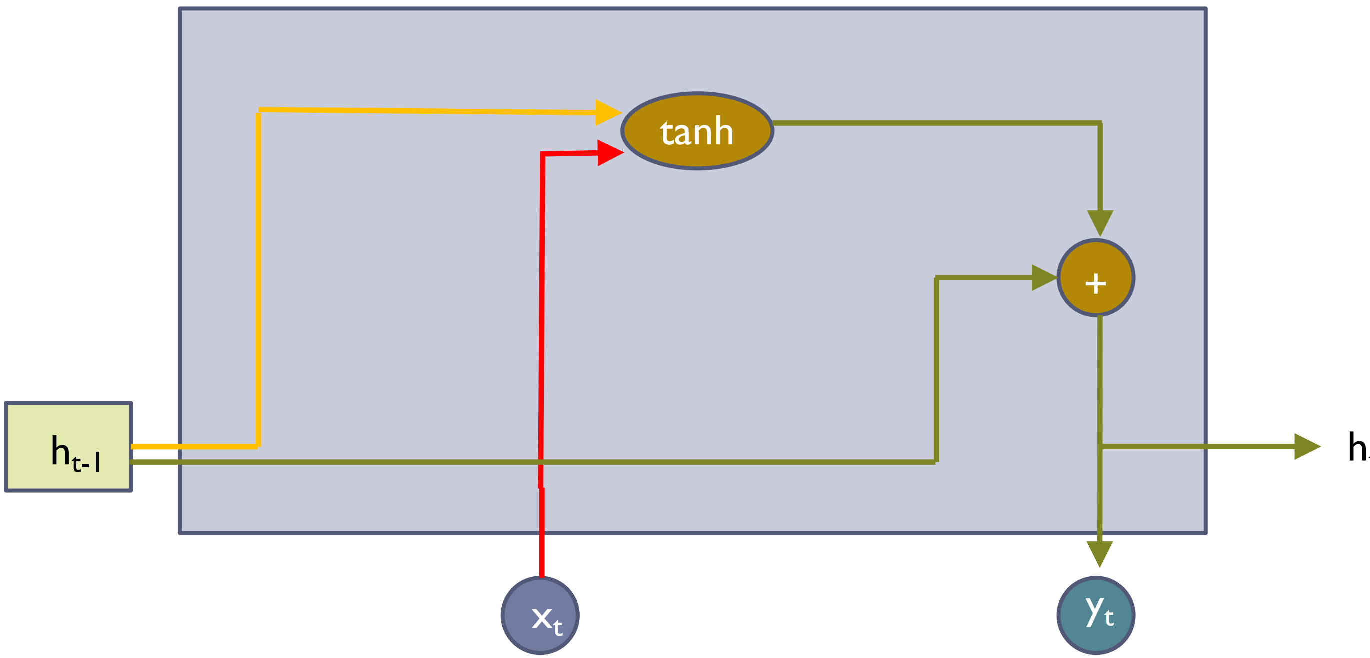

Gated Recurrent Units

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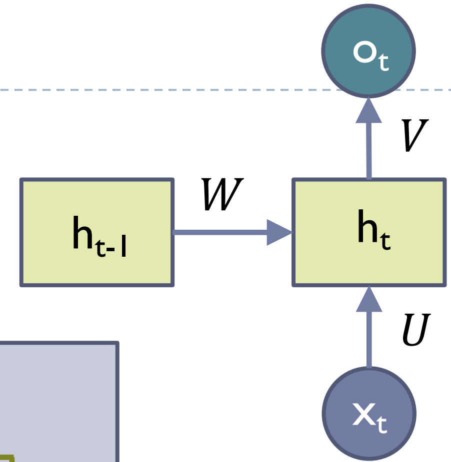

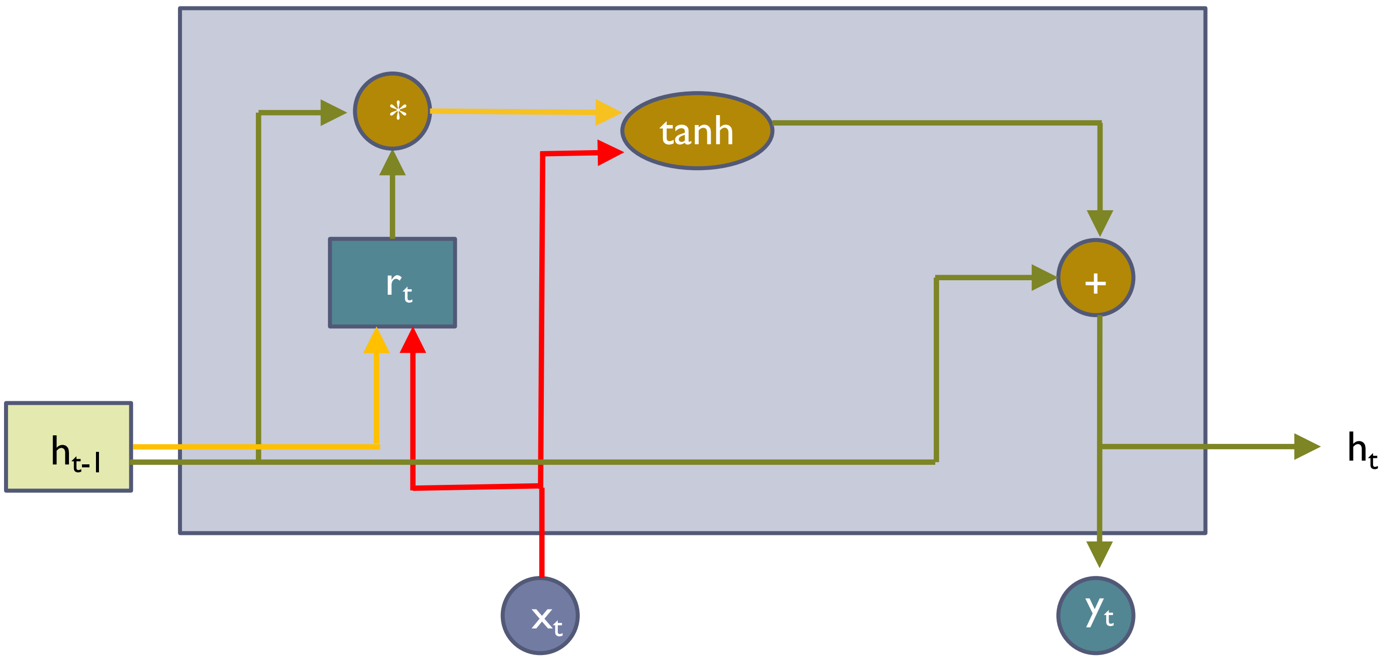

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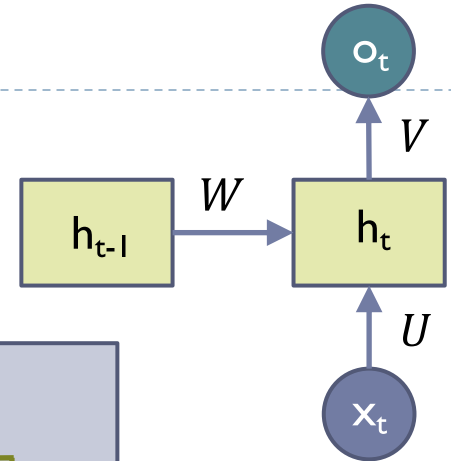

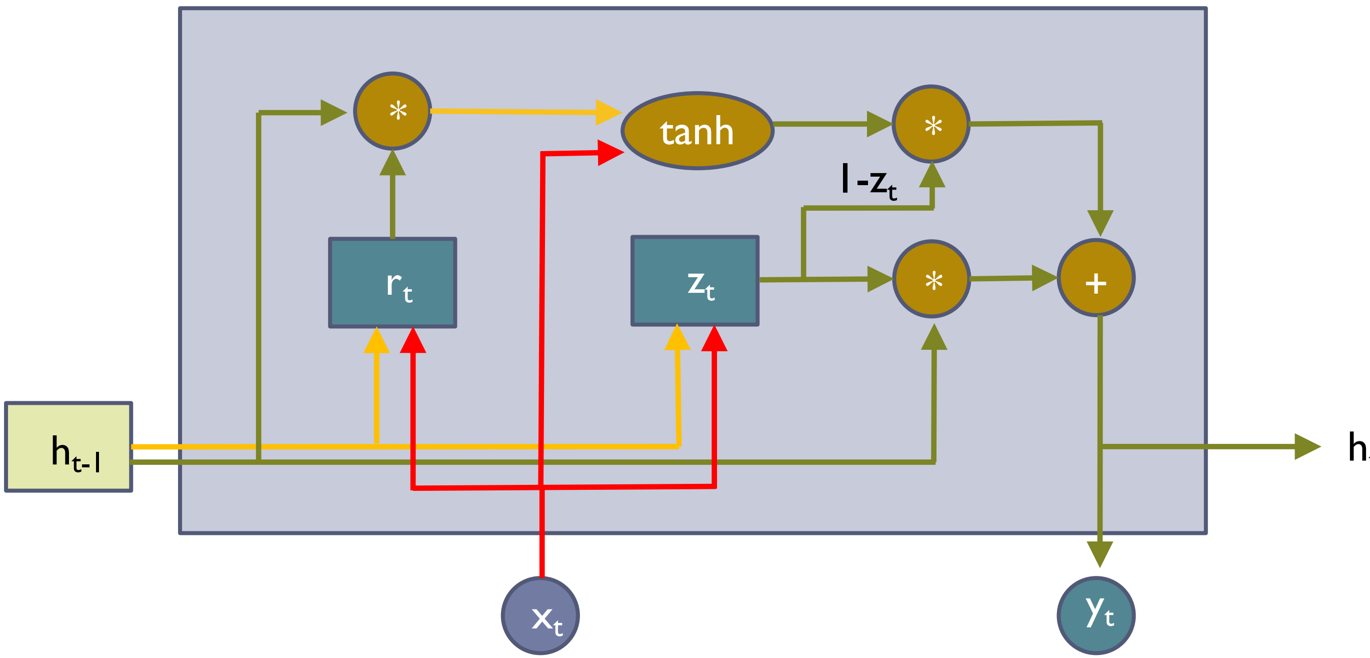

Question and Answer