

# Recurrent Neural Networks

성균관대학교 소프트웨어학과  
이 지 형

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- ▶ **Sequential Data Processing**
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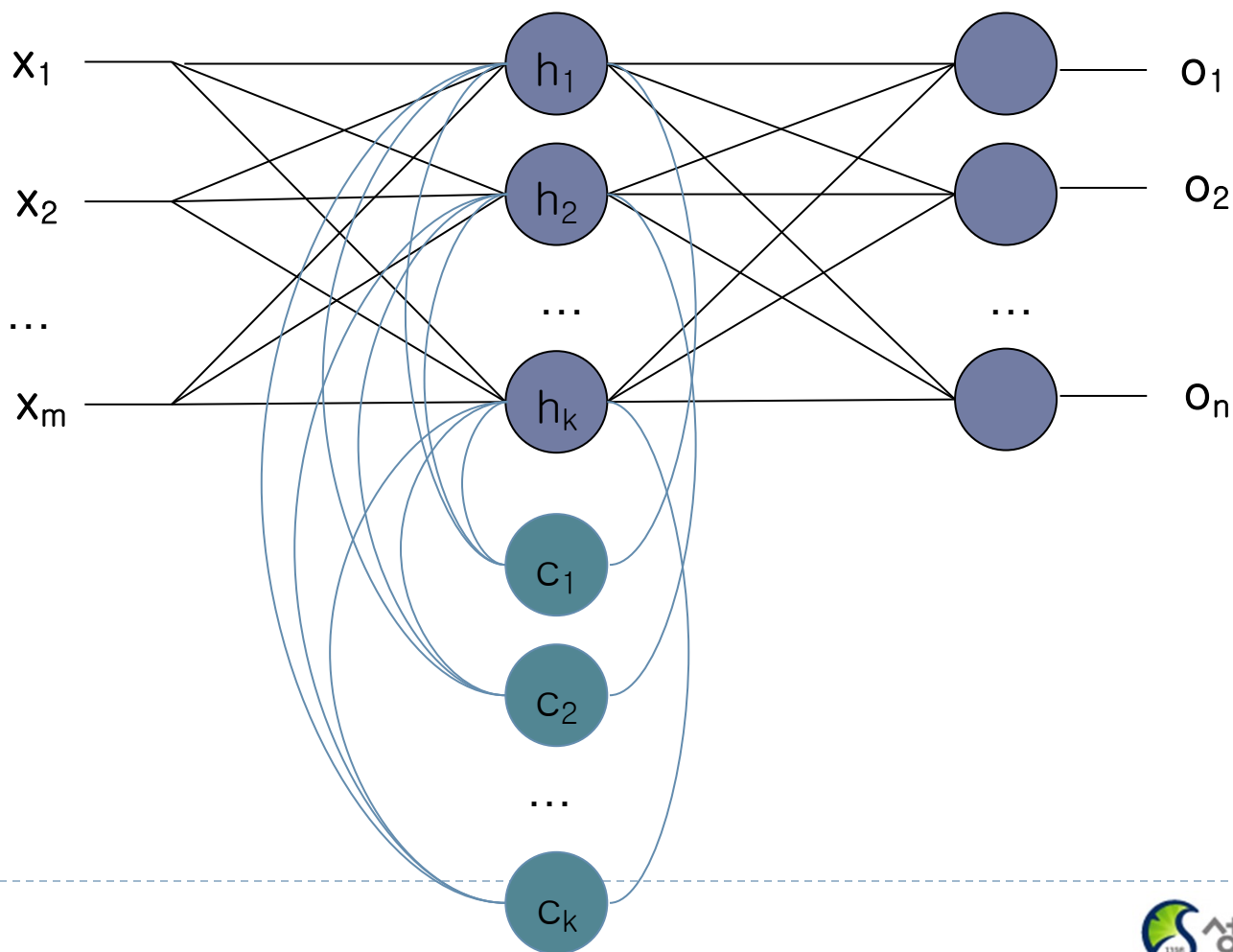
# Sequential Data Processing

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- ▶ What is sequential data?
- ▶ What do we have to consider for sequential data processing?

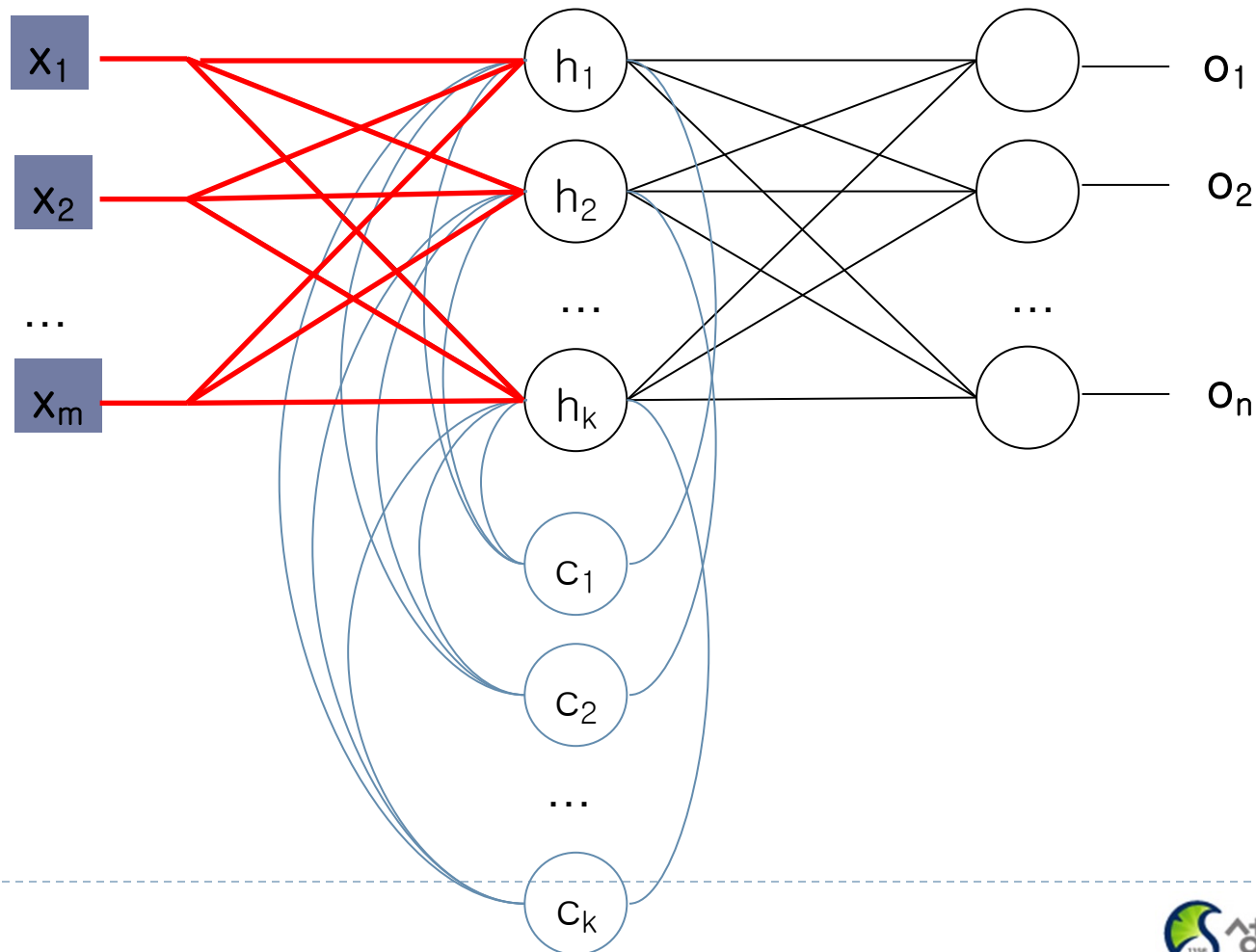
# Recurrent Neural Networks

## ► Connections form cycles



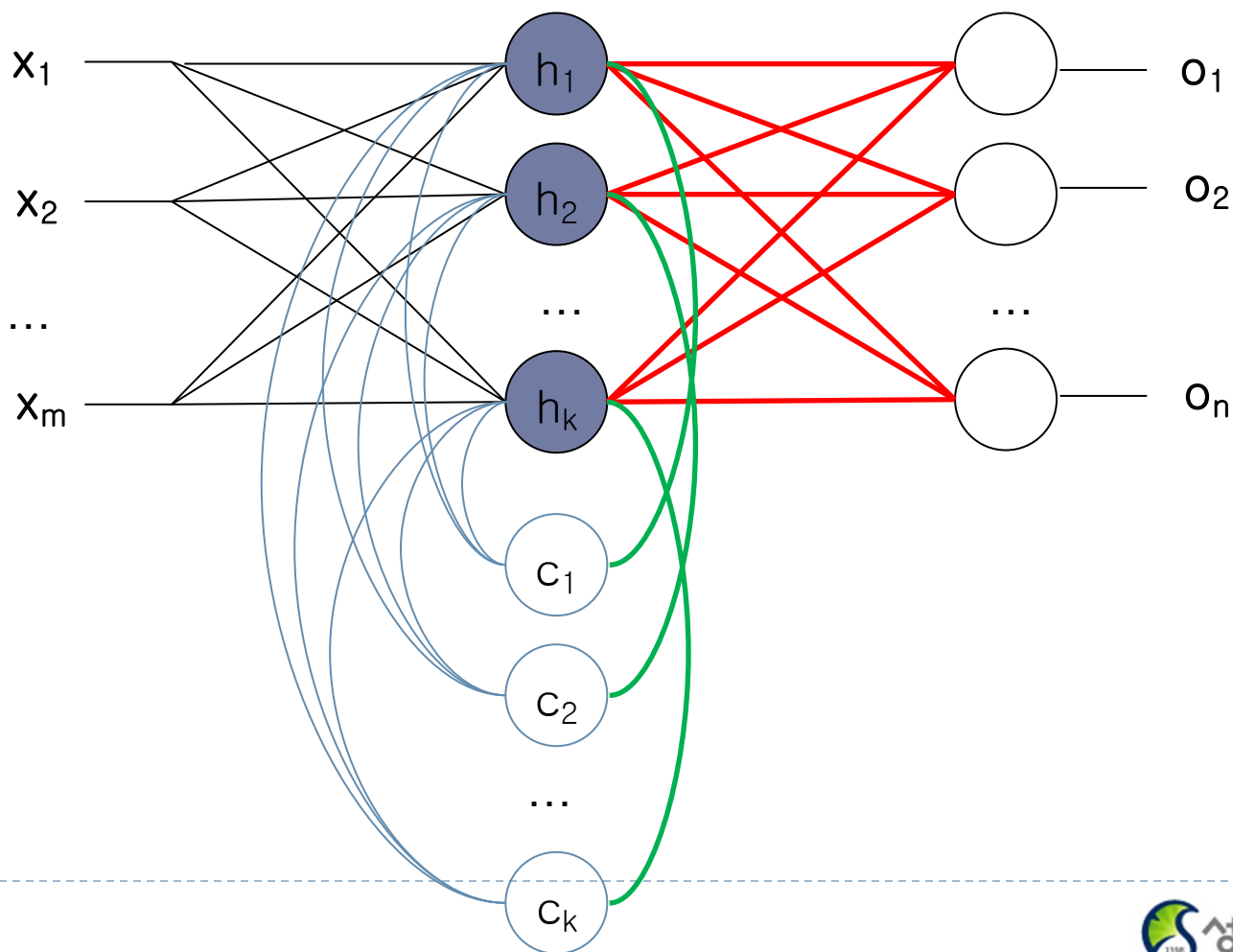
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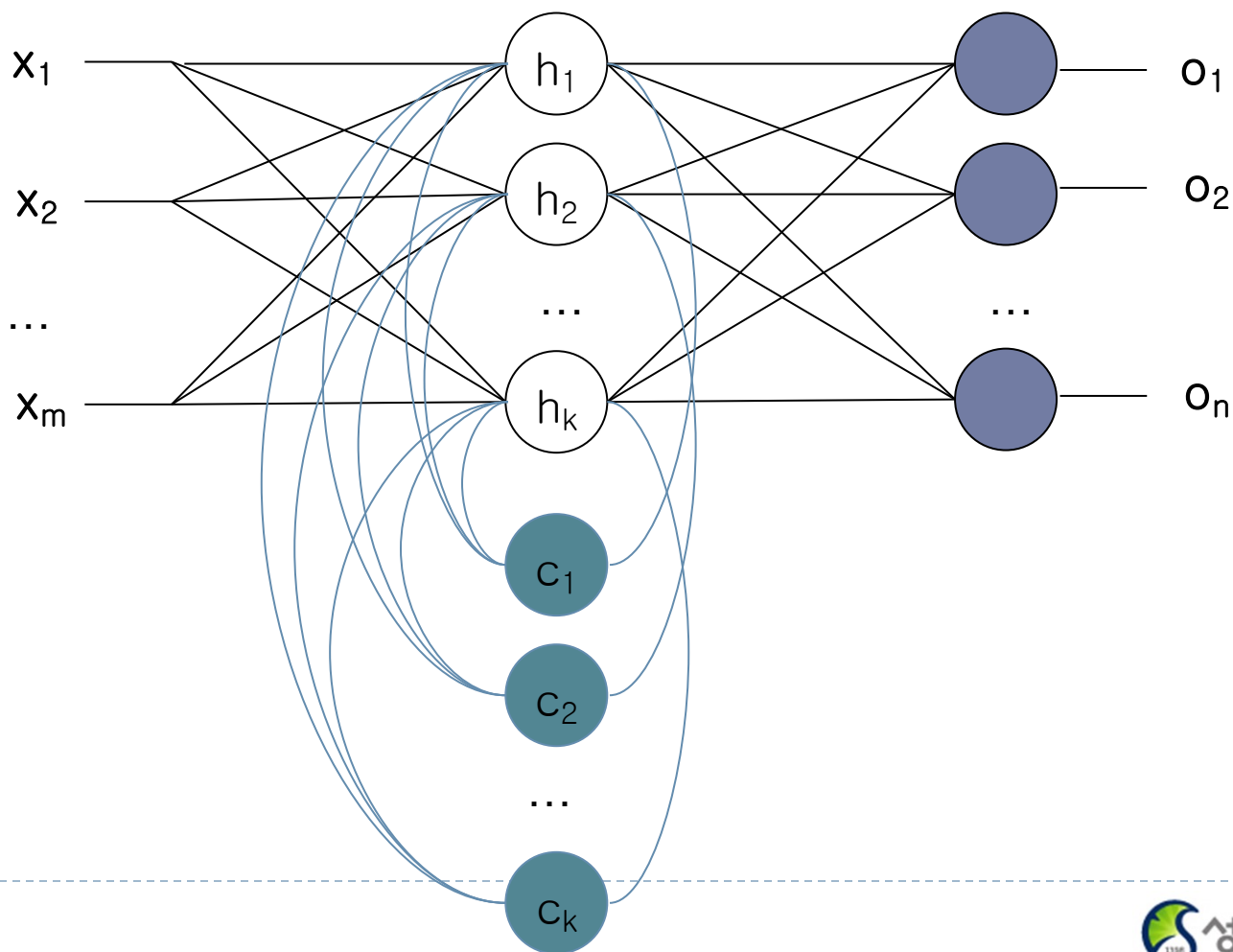
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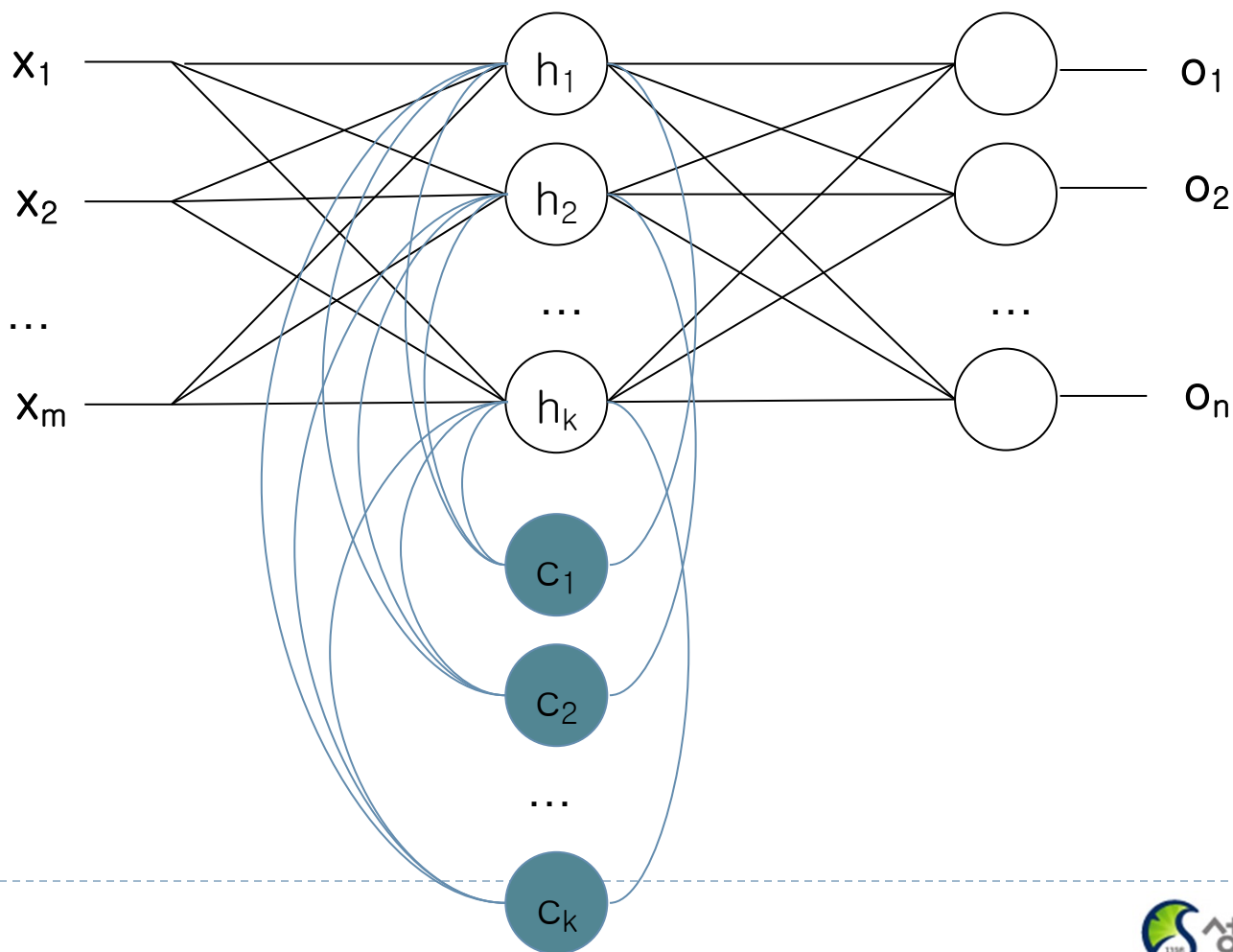
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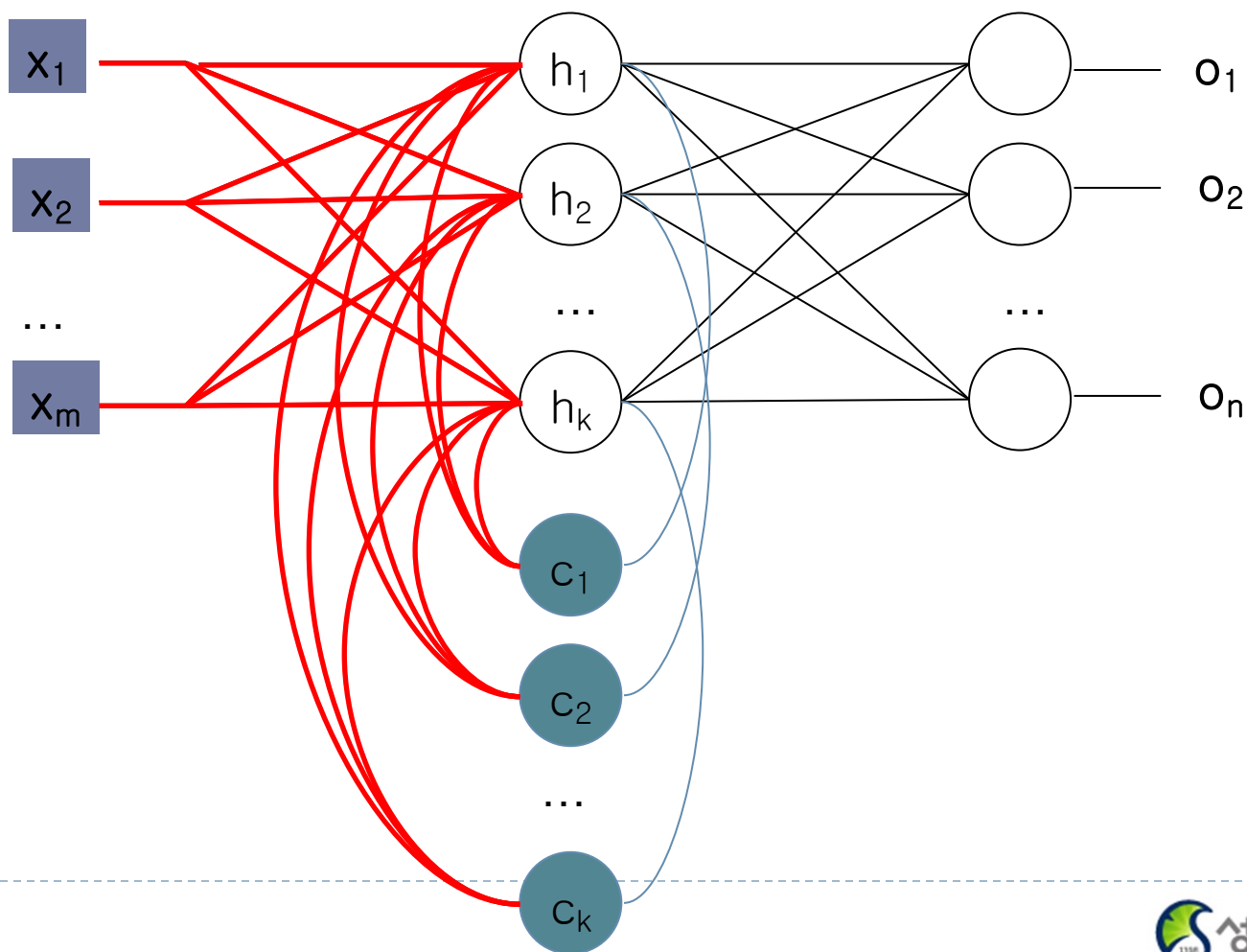
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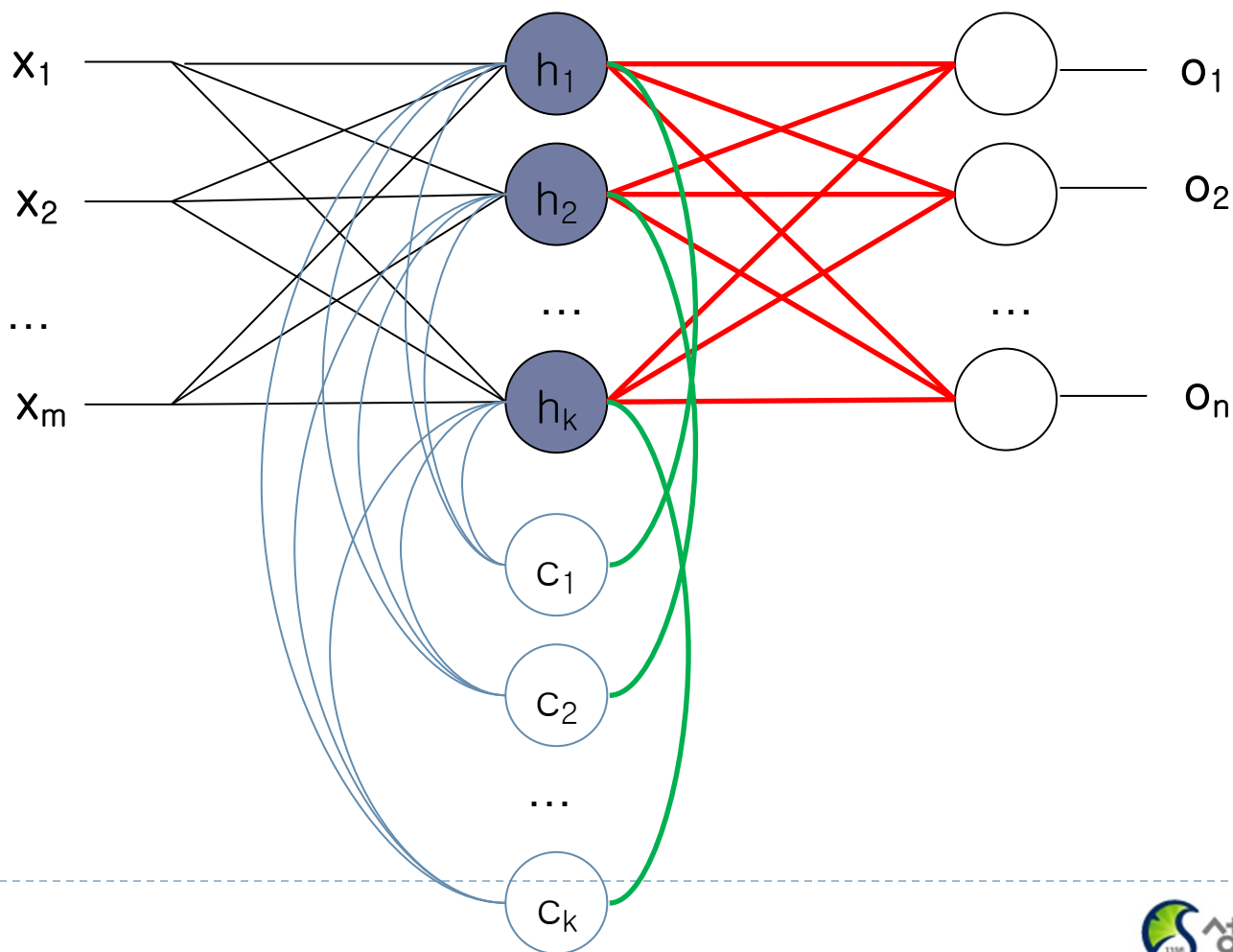
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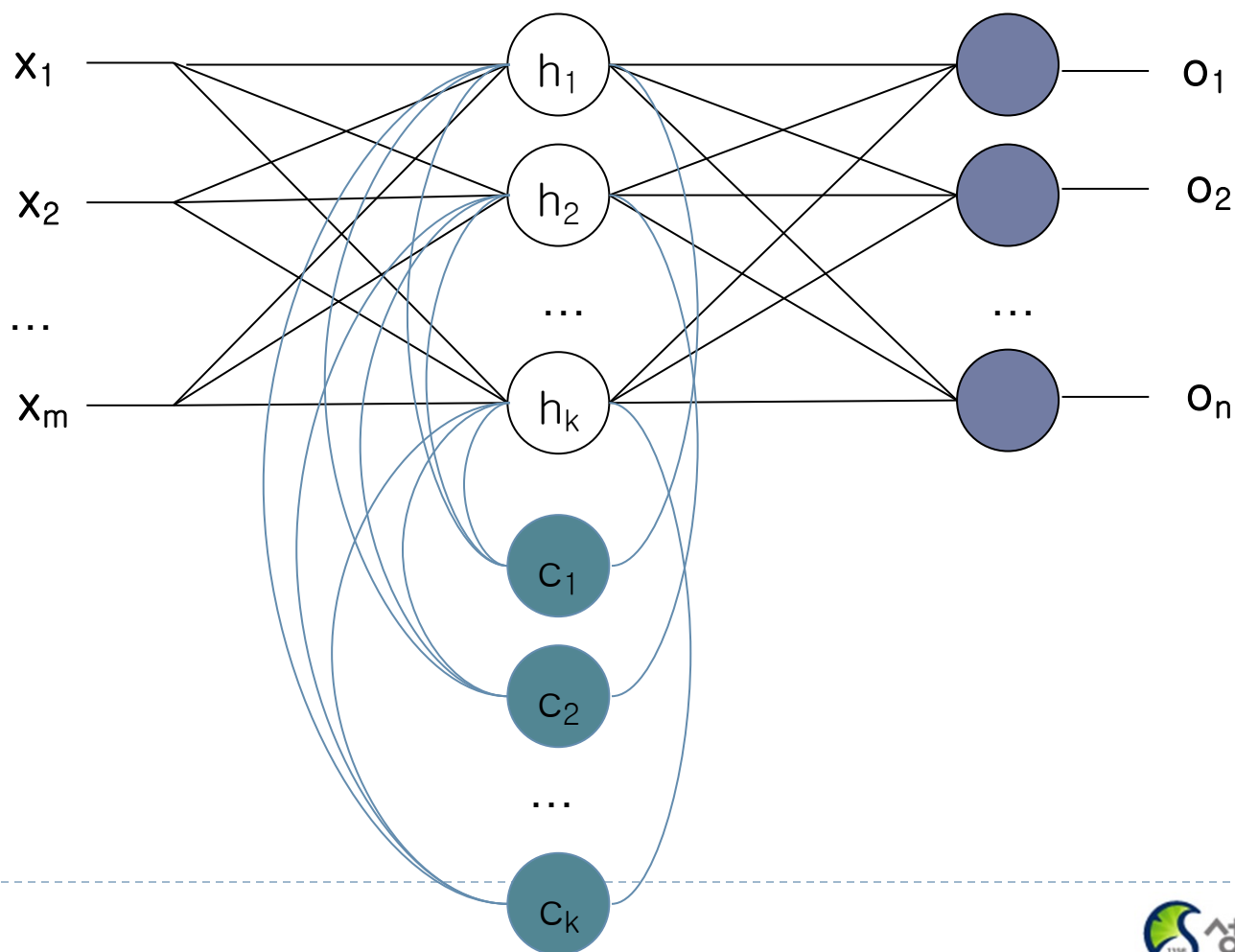
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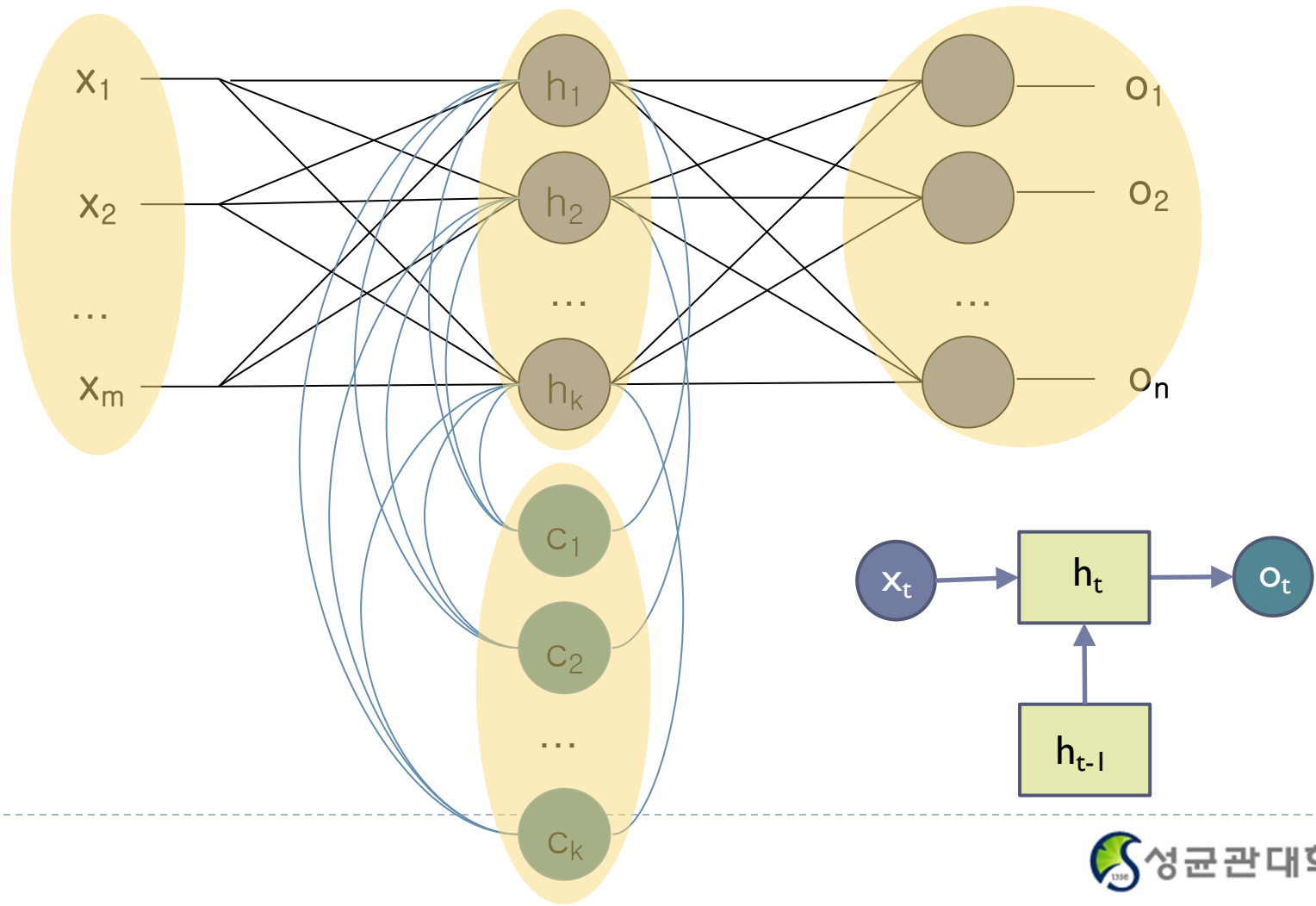
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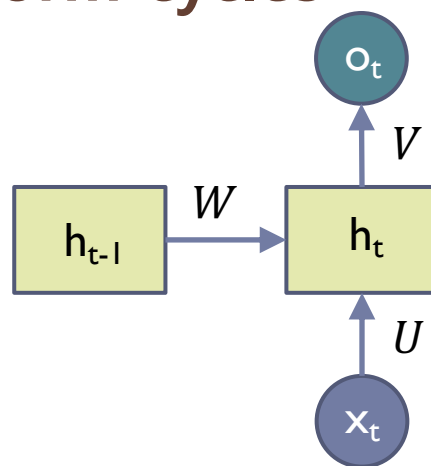
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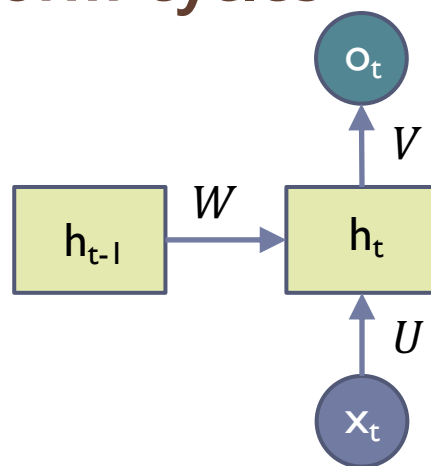
$$h_t = f(Ux_t + Wh_{t-1})$$

$$o_t = g(Vh_t)$$

- $x_t$ : 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

## ► Connections form cycles



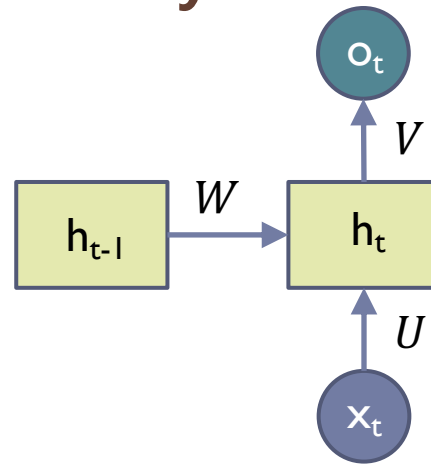
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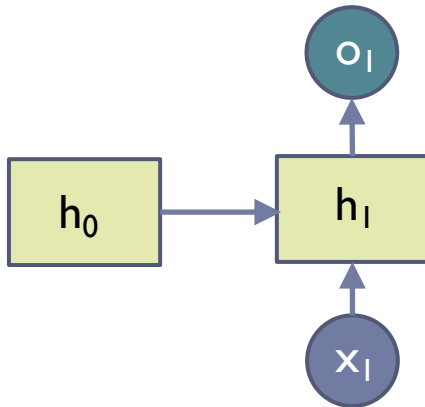
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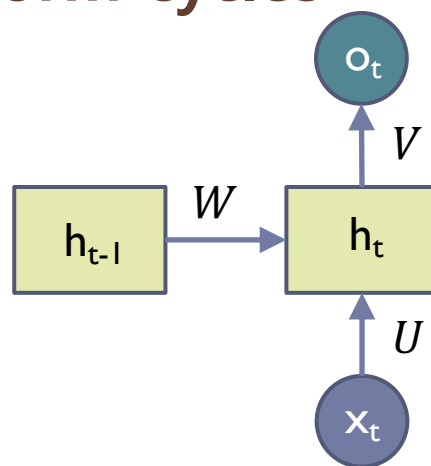
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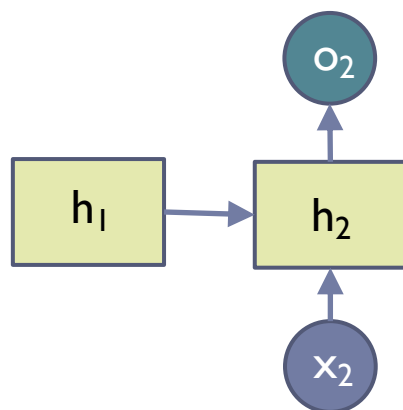
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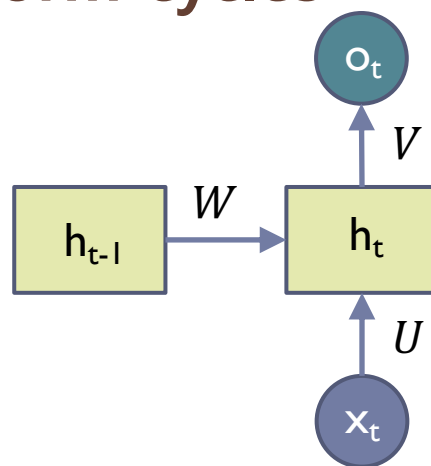
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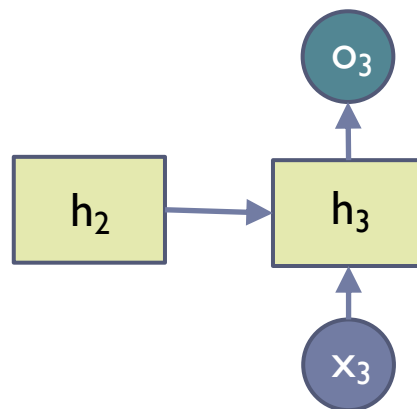
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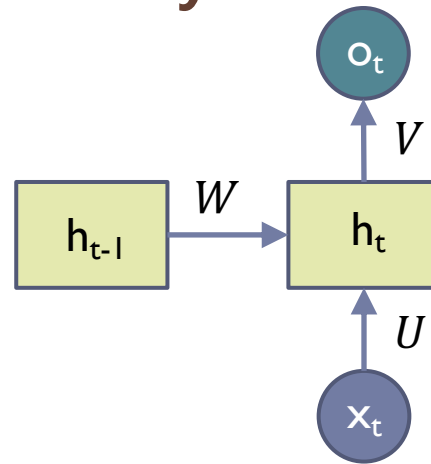
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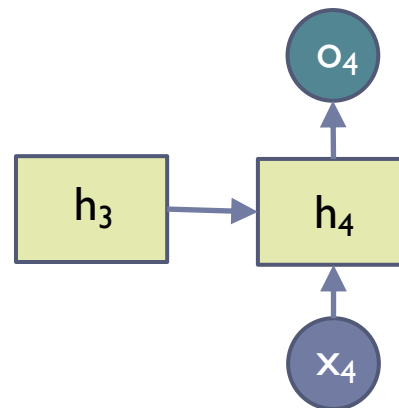


# Recurrent Neural Networks

## ► Connections form cycles

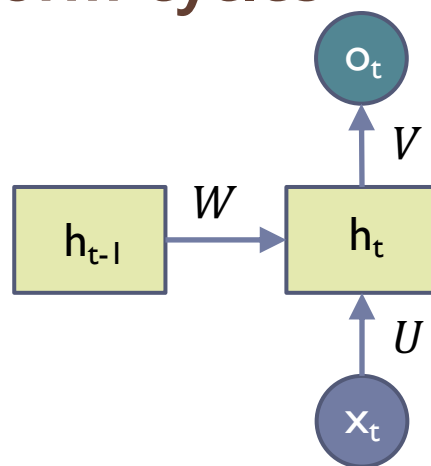


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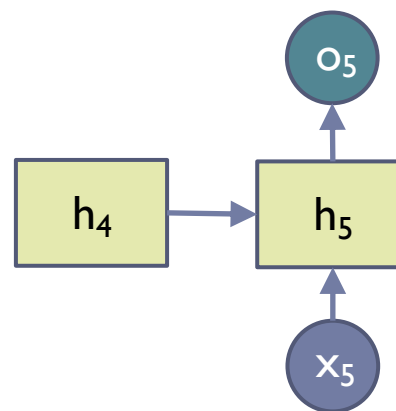
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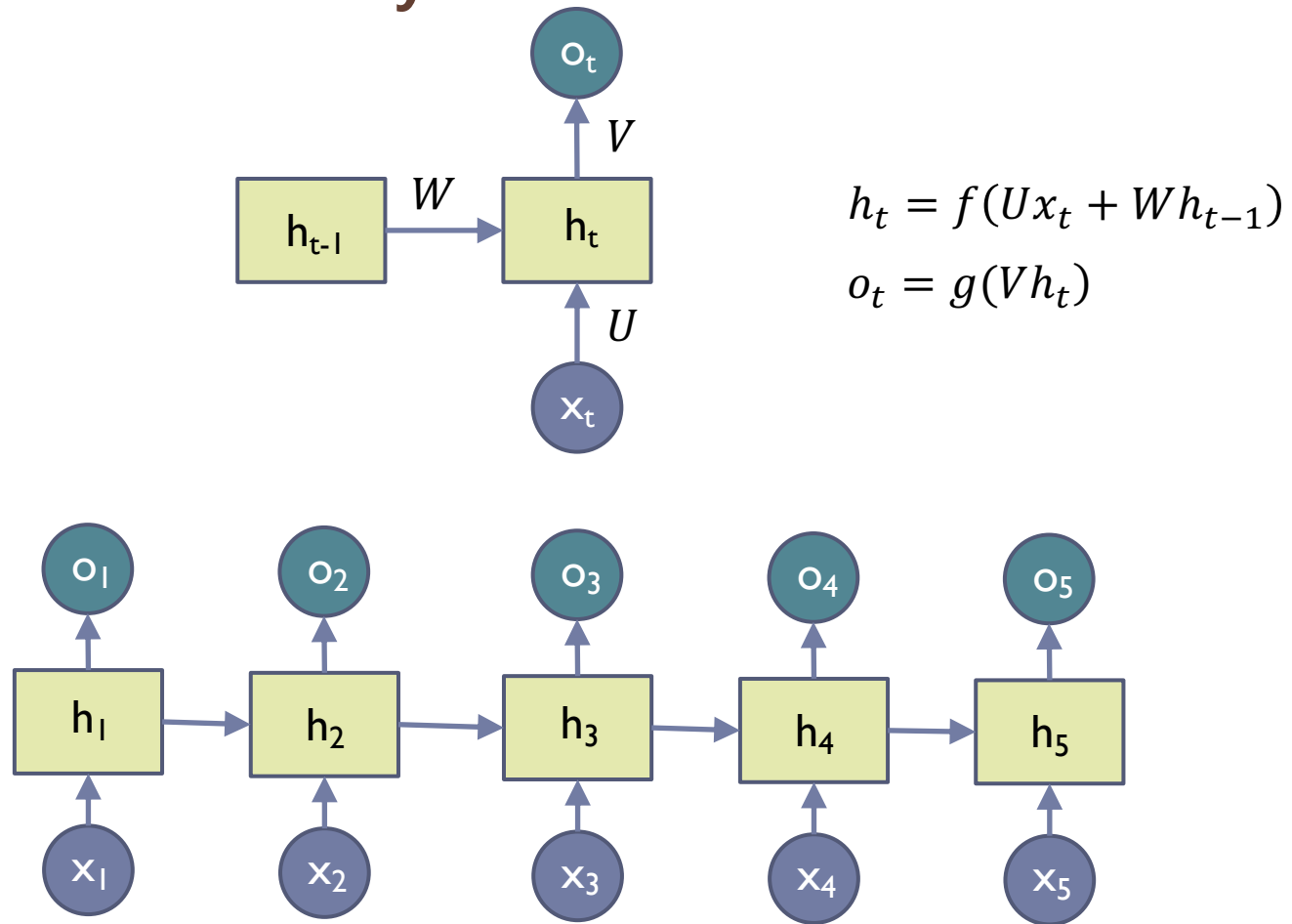
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# Recurrent Neural Networks

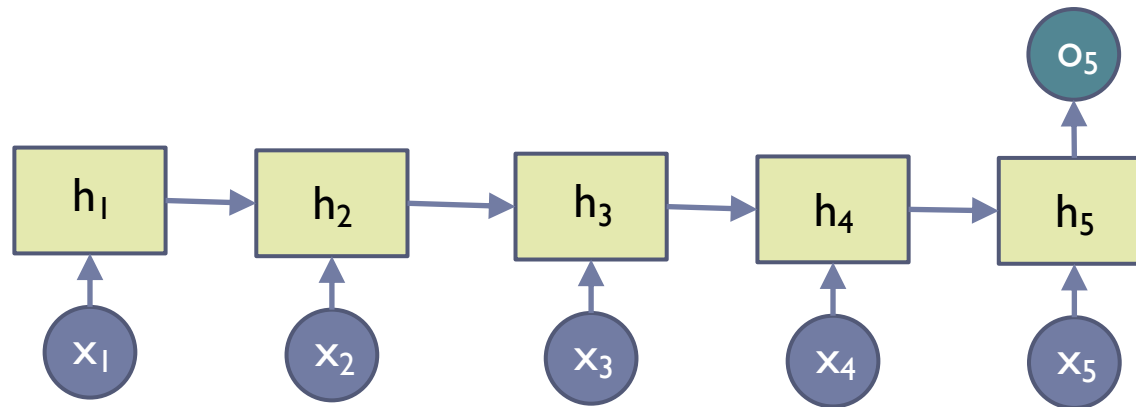
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# Recurrent Neural Networks

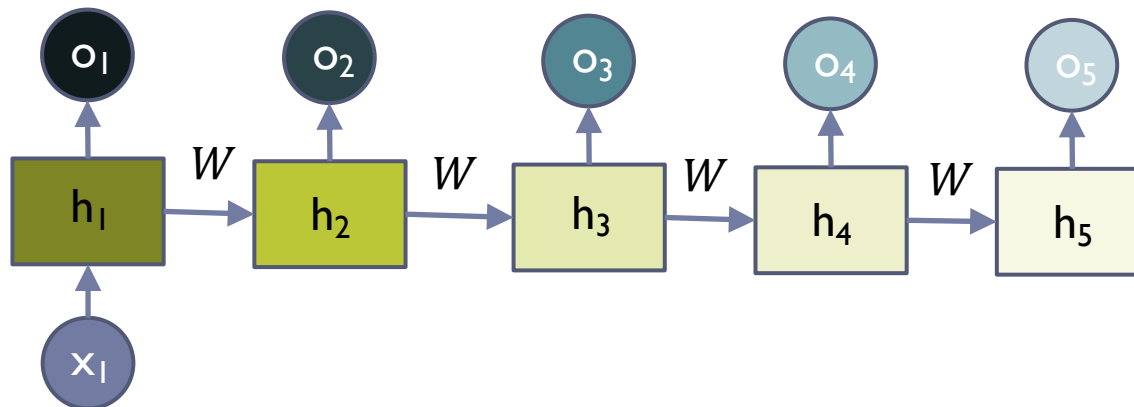
## ▶ Long Term Dependency

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



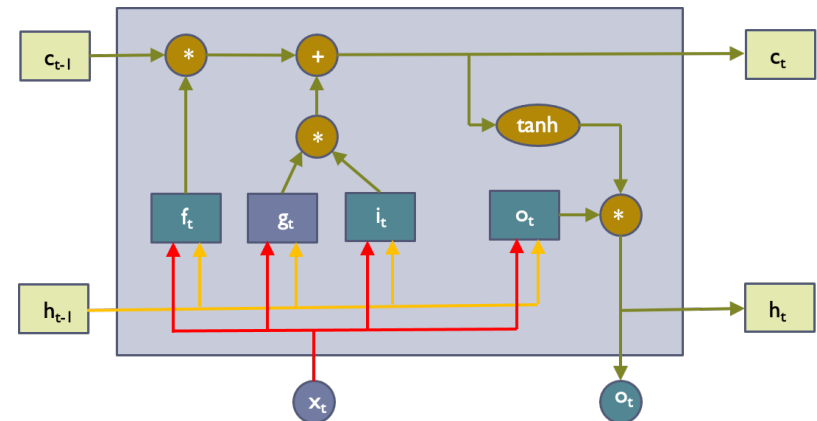
# Recurrent Neural Networks

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



# Long Short-Term Memory (LSTM)

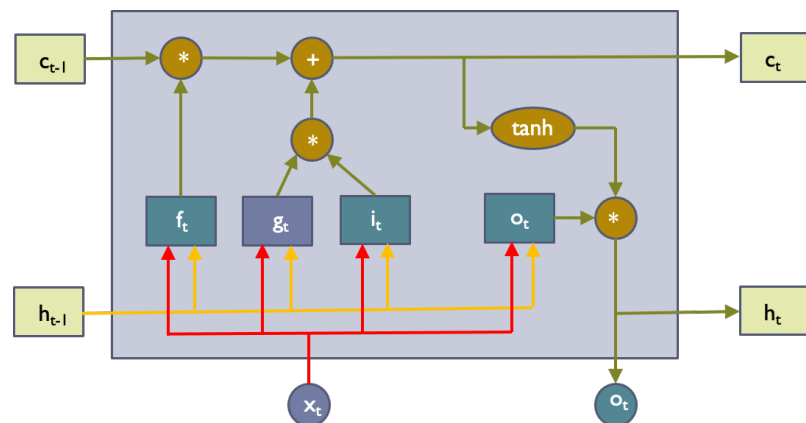
- ▶ **Capable of learning long-term dependencies.**
  - ▶ LSTM networks introduce a new structure called a memory cell
    - ▶ An LSTM can learn to bridge time intervals in excess of 1000 steps
  - ▶ **Gate units that learn to open and close access to the past**
    - ▶ Input gate
    - ▶ Forget gate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

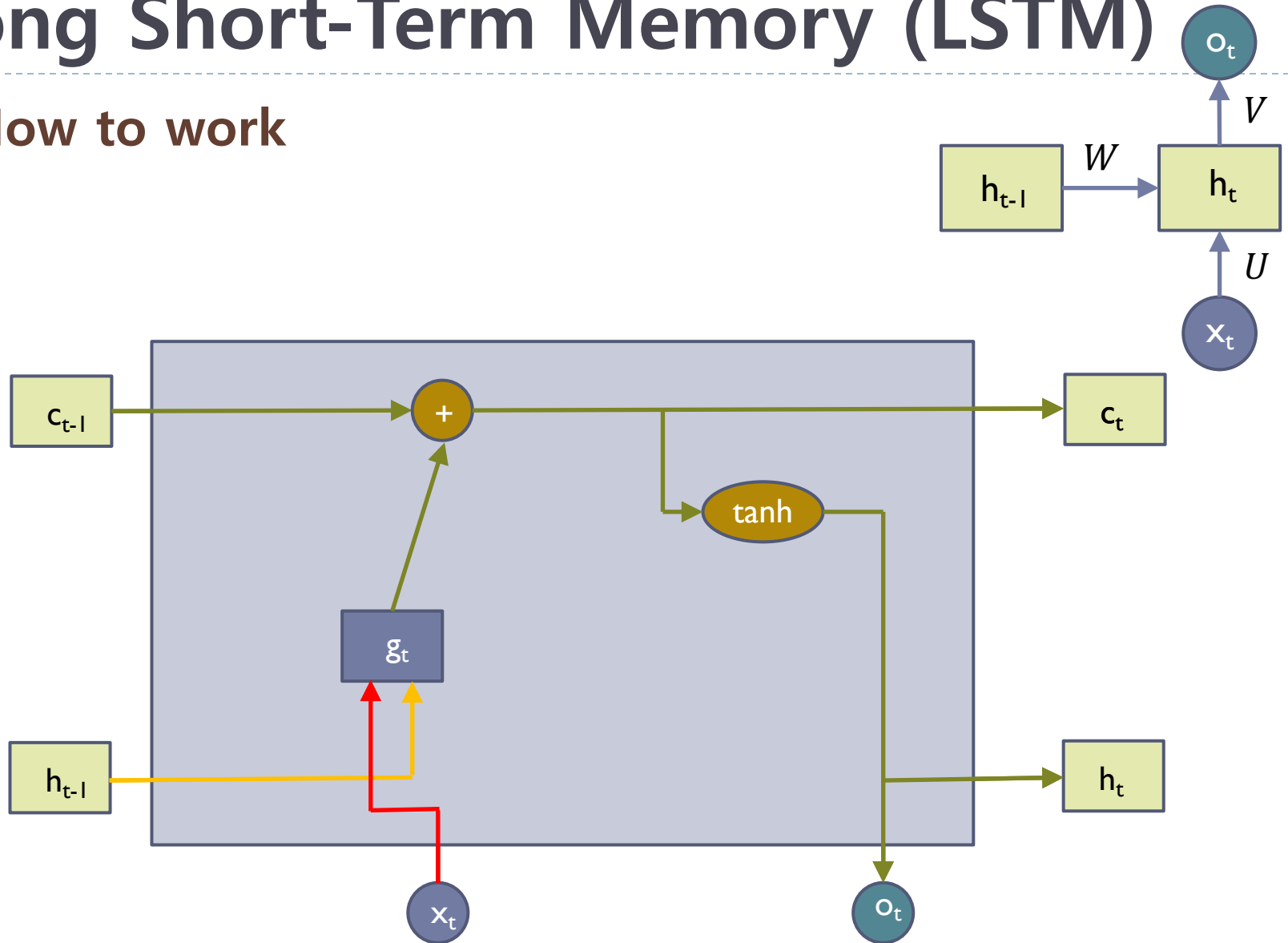


$$\begin{aligned}i &= \sigma(x_t U^i + h_{t-1} W^i) \\f &= \sigma(x_t U^f + h_{t-1} W^f) \\o &= \sigma(x_t U^o + h_{t-1} W^o) \\g &= \tanh(x_t U^g + h_{t-1} W^g) \\c_t &= c_{t-1} \circ f + g \circ i \\h_t &= \tanh(c_t) \circ o \\y &= \text{softmax}(V h_t)\end{aligned}$$



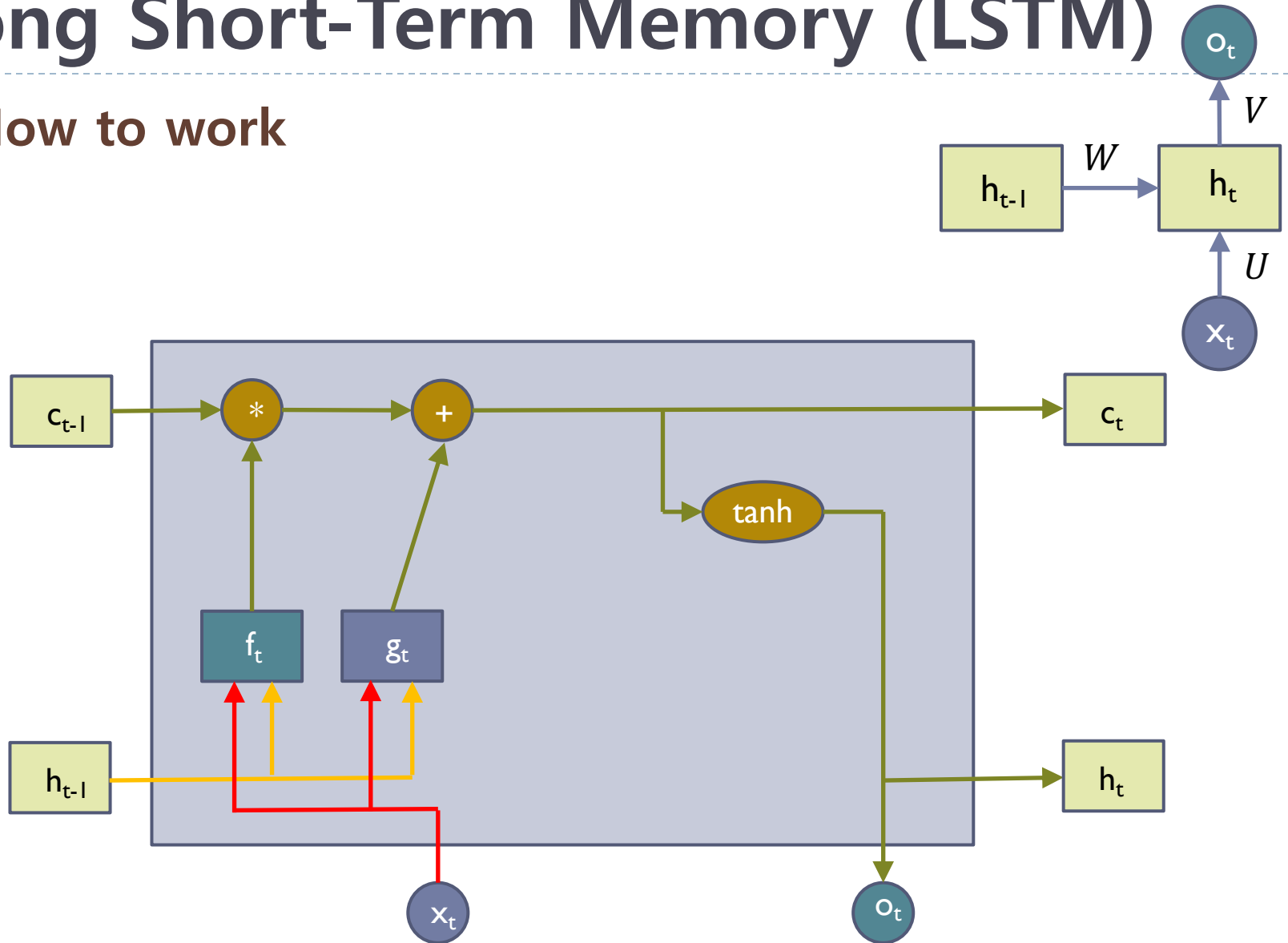
# Long Short-Term Memory (LSTM)

## ► How to work



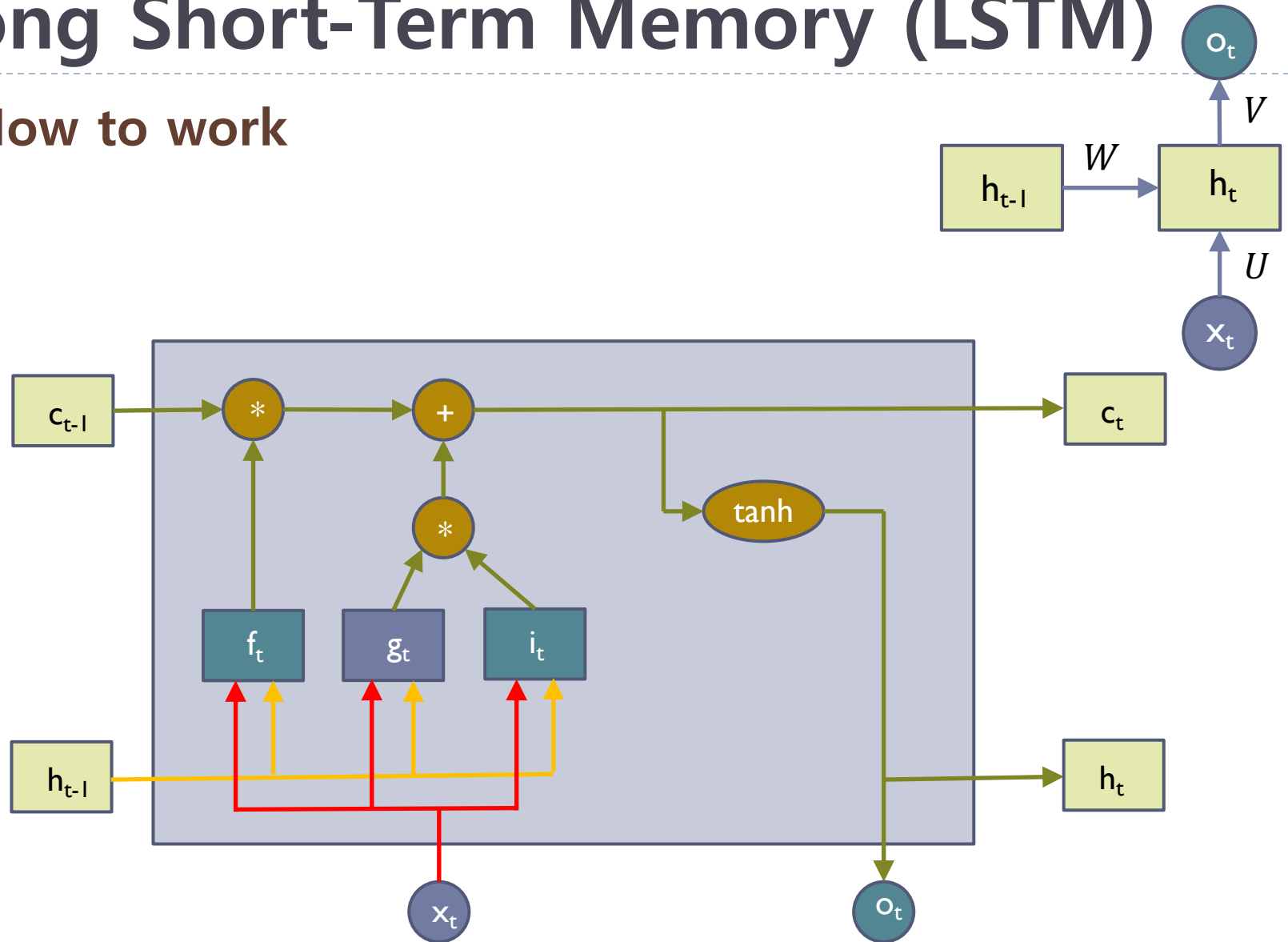
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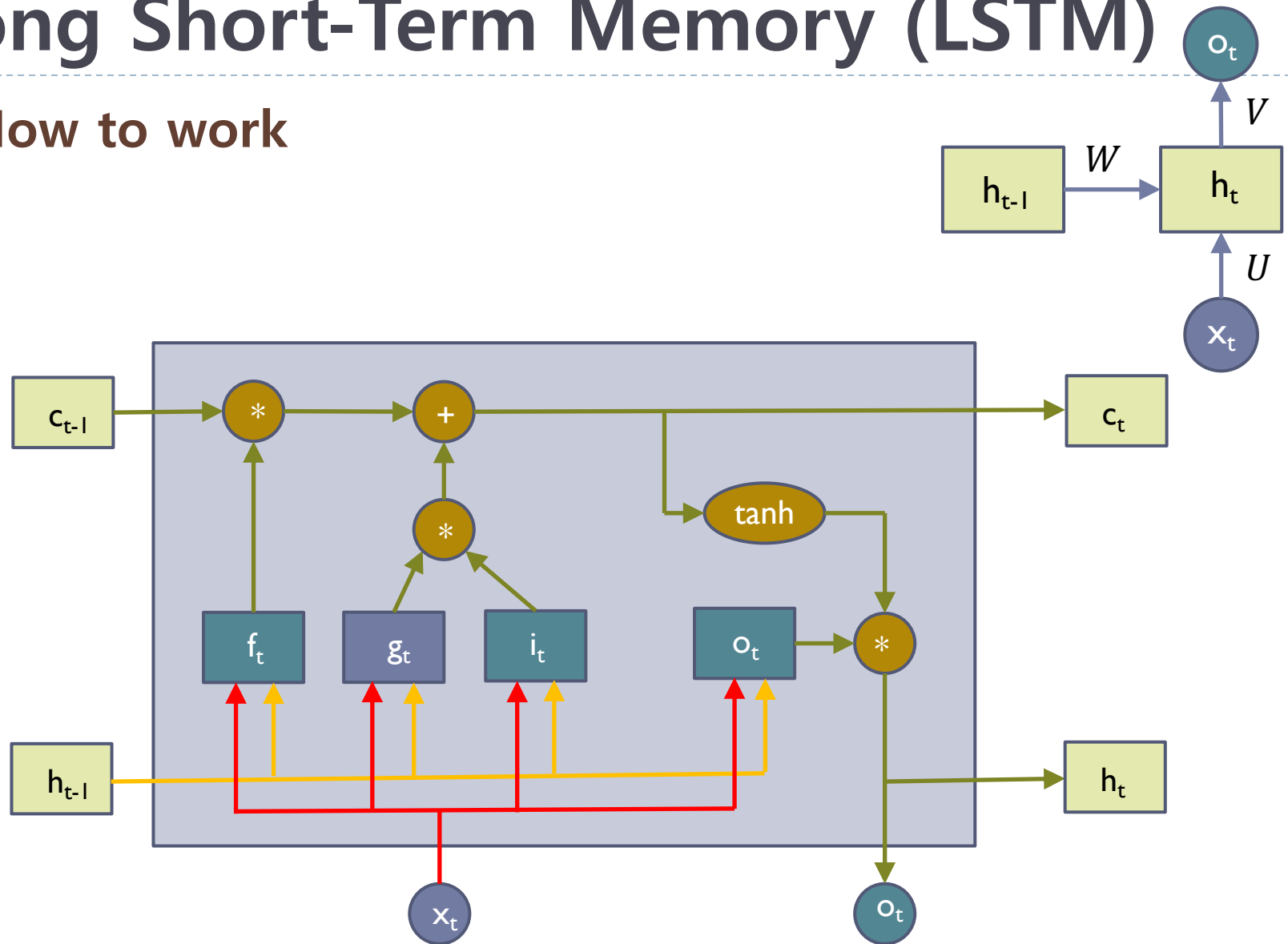
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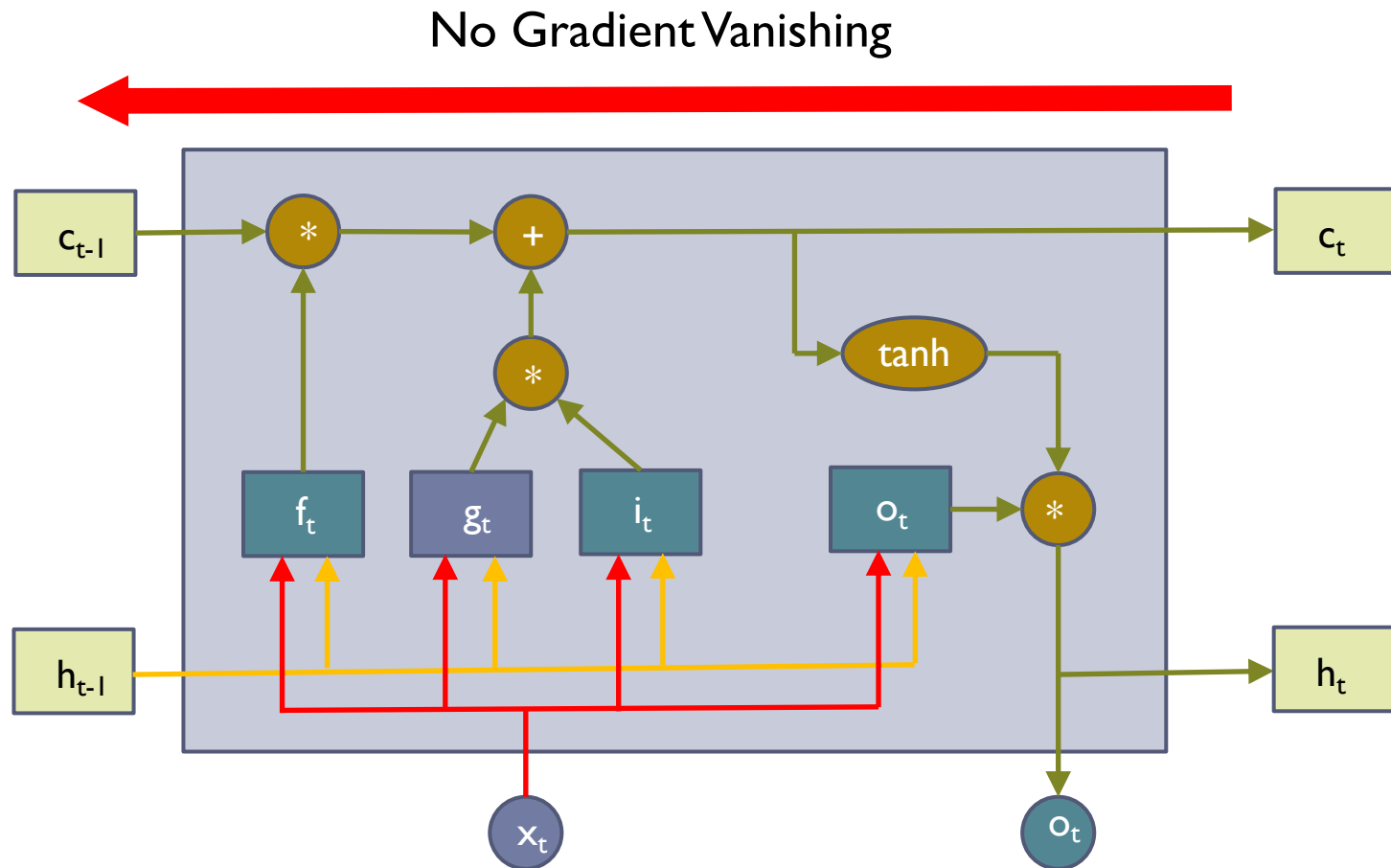
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# Long Short-Term Memory (LSTM)

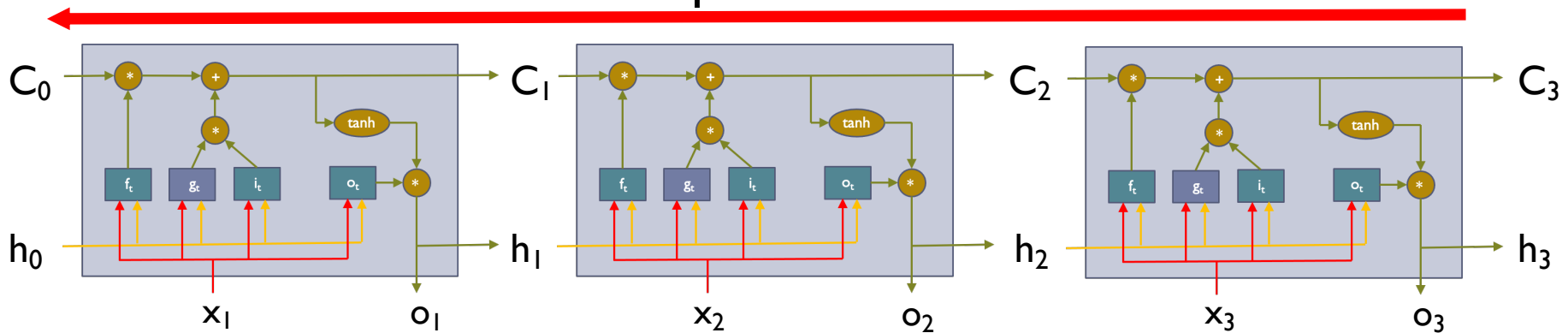
## ▶ Gradient Flow



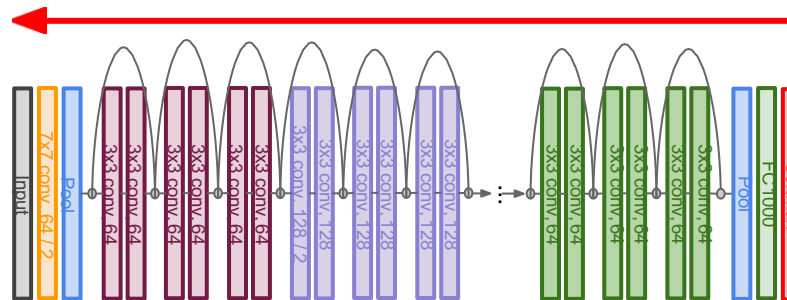
# Long Short-Term Memory (LSTM)

## ► Gradient Flow

### Uninterrupted Gradient Flow



Similar to ResNet!



# Gated Recurrent Units

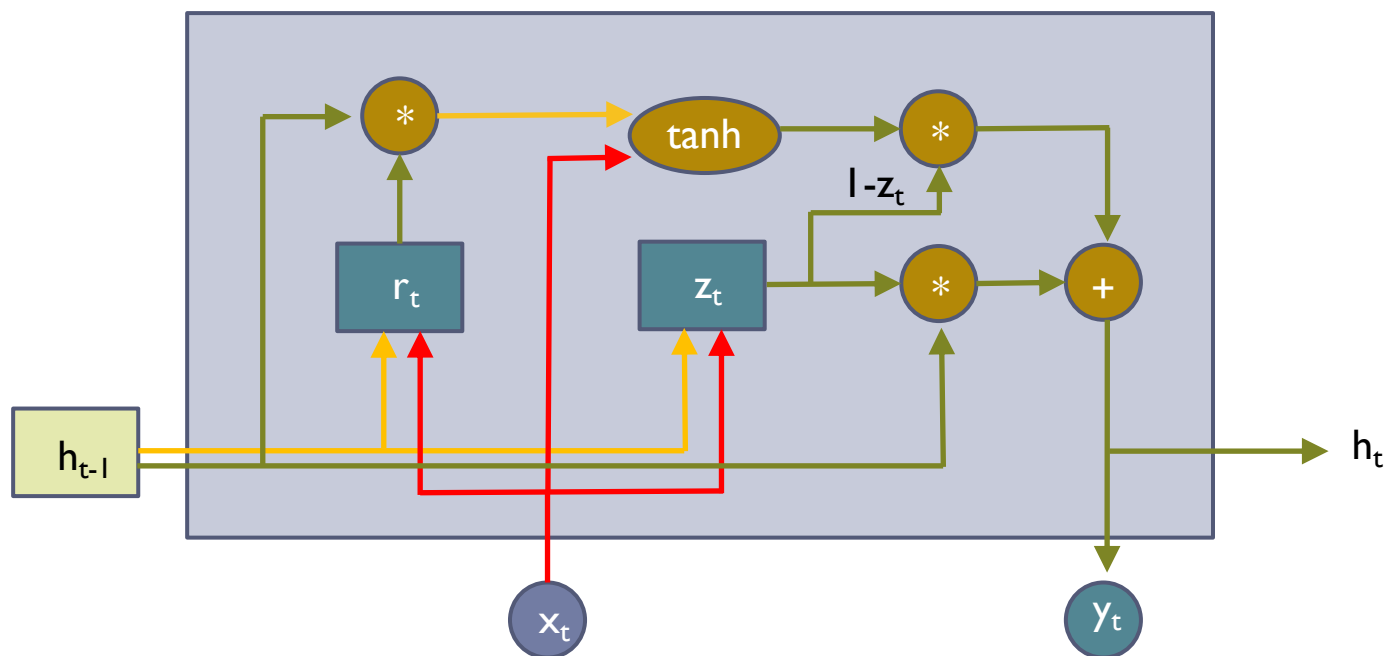
## ► Structure

$$r_t = \sigma(W_{xr}x_t + W_{hr}h_{t-1} + b_r)$$

$$z_t = \sigma(W_{xz}x_t + W_{hz}h_{t-1} + b_z)$$

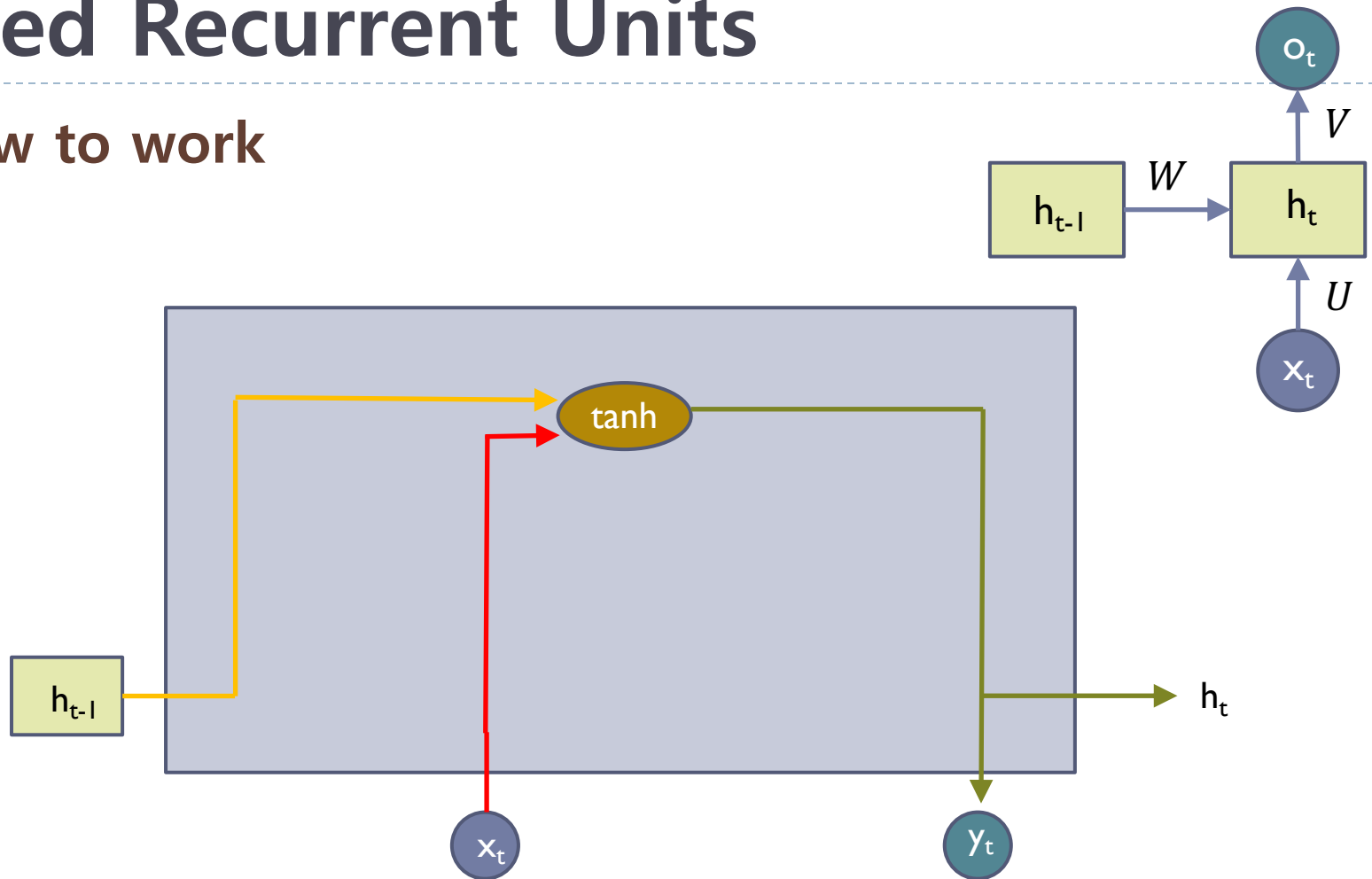
$$\tilde{h}_t = \tanh(W_{xh}x_t + W_{hh}(r_t \odot h_{t-1}) + b_h)$$

$$h_t = z_t \odot h_{t-1} + (1 - z_t) \odot \tilde{h}_t$$



# Gated Recurrent Units

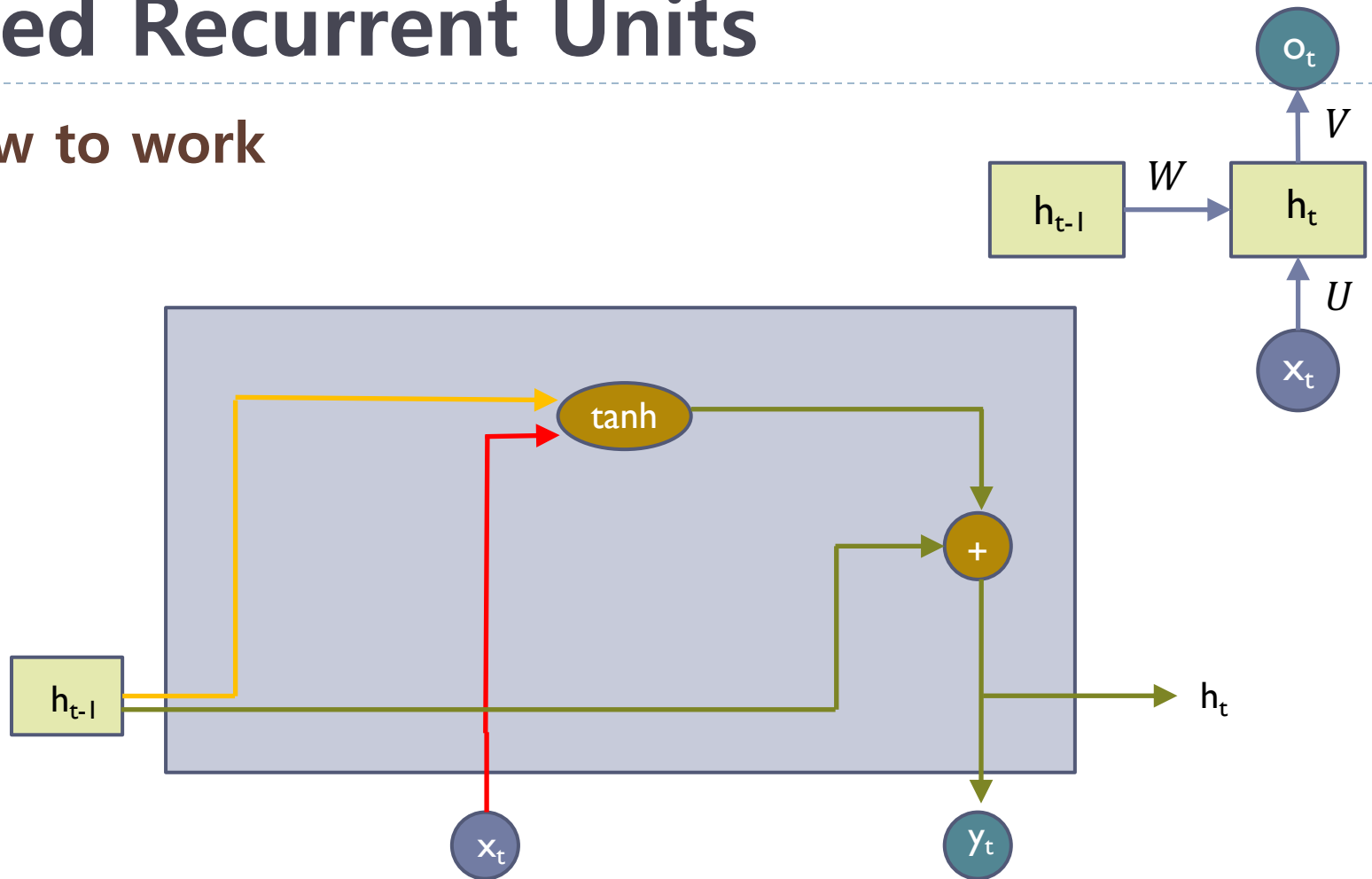
## ▶ How to work





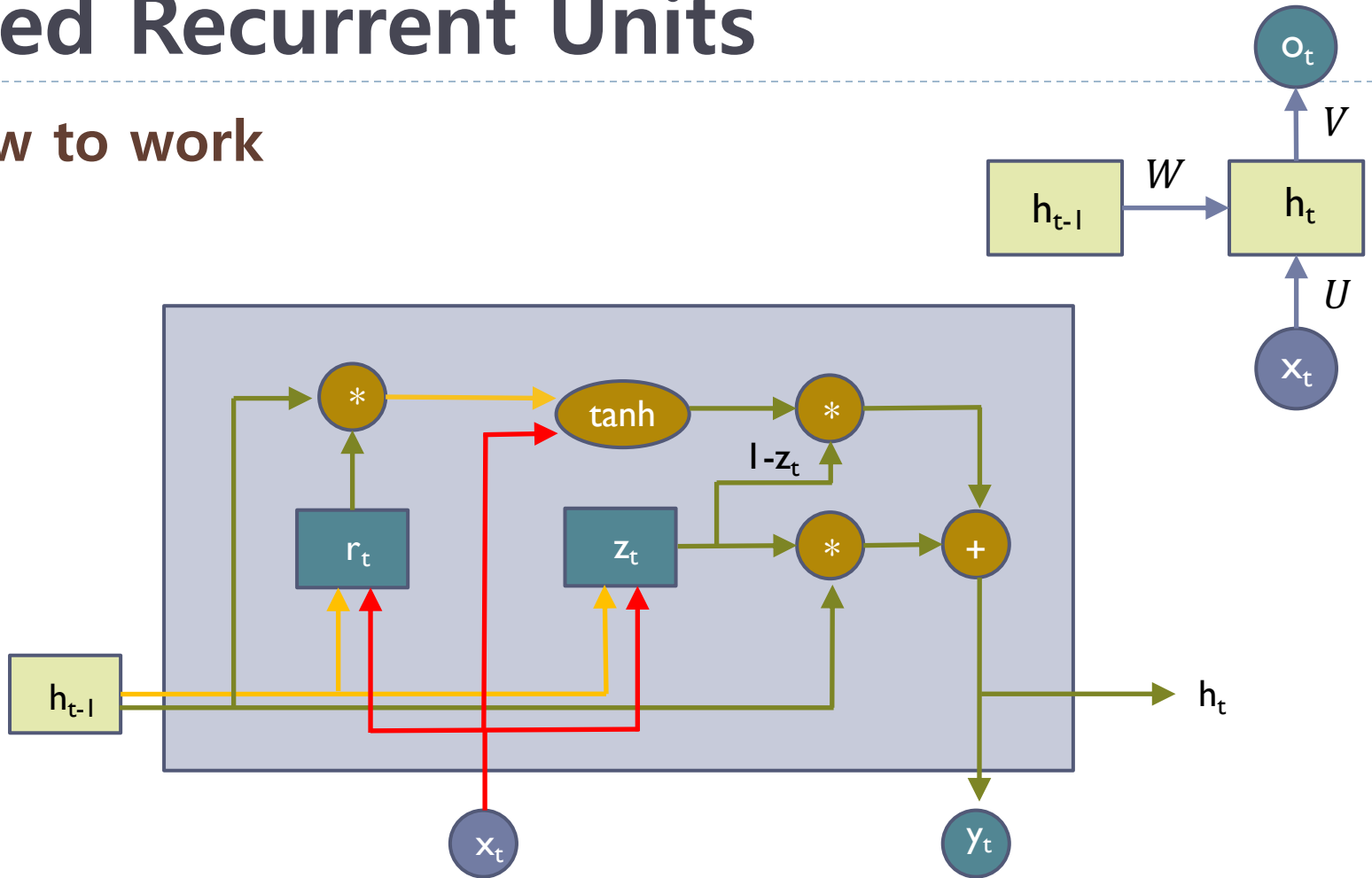
# Gated Recurrent Units

## ▶ How to work



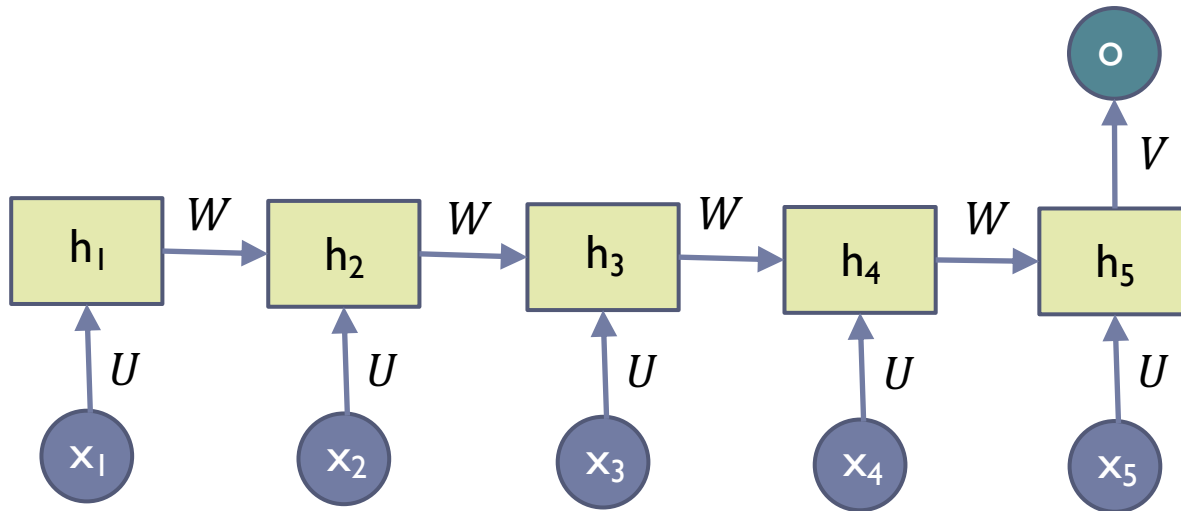
# Gated Recurrent Units

## ► How to work



# Sequence Prediction

$$x_1 x_2 x_3 \cdots x_n \rightarrow y$$



# Question and Answer