Deep Learning: Theory and Practice

Recurrent Neural Networks

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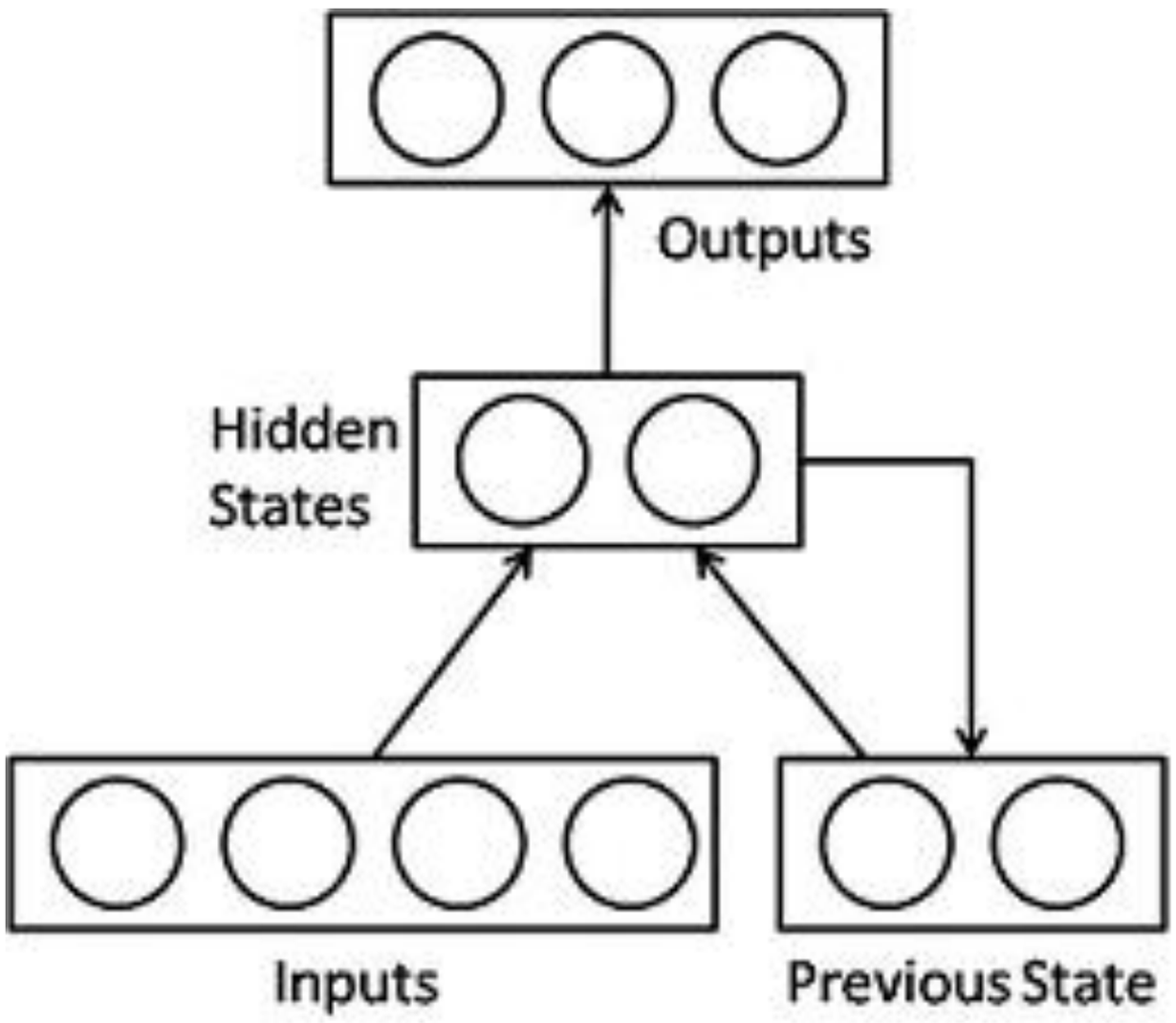
deeplearning.cce2018@gmail.com

Recurrent Operations



Feedback

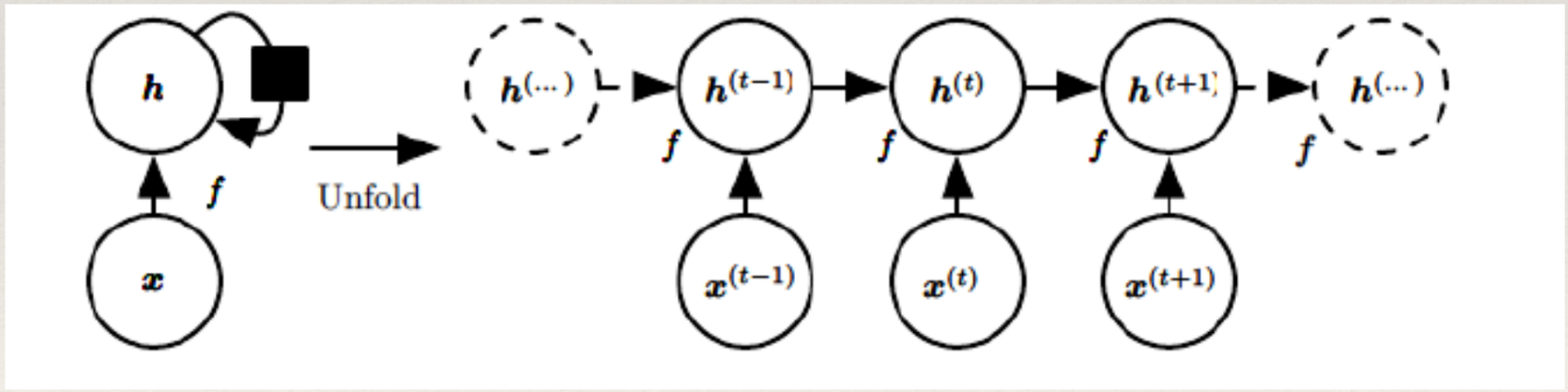
Recurrent Networks

$$\boldsymbol{s}^{(t)} = f(\boldsymbol{s}^{(t-1)}; \boldsymbol{\theta}),$$

$$\begin{aligned} \boldsymbol{s}^{(3)} &= f(\boldsymbol{s}^{(2)}; \boldsymbol{\theta}) \\ &= f(f(\boldsymbol{s}^{(1)}; \boldsymbol{\theta}); \boldsymbol{\theta}) \end{aligned}$$

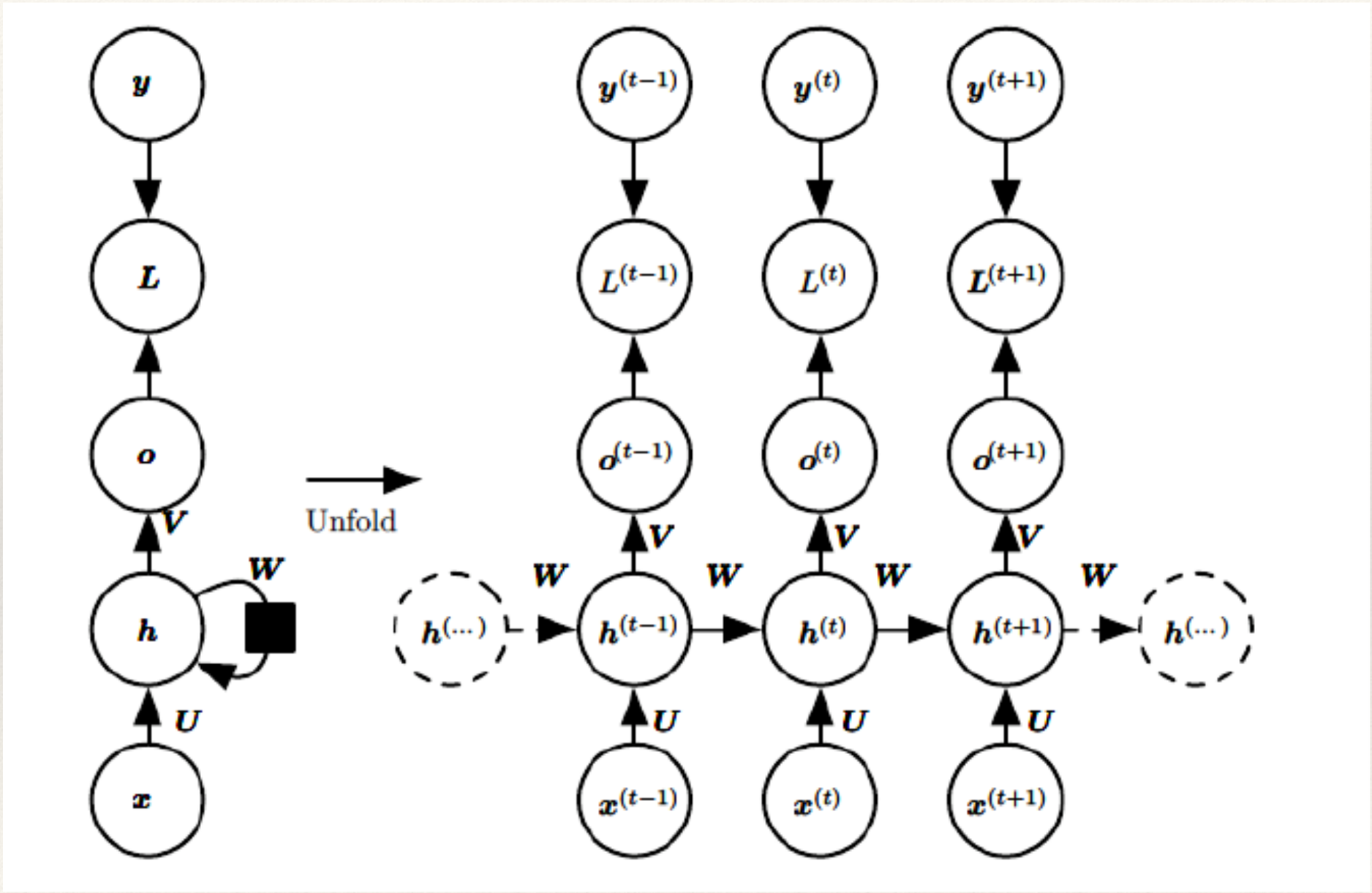
$$\boldsymbol{s}^{(t)} = f(\boldsymbol{s}^{(t-1)}, \boldsymbol{x}^{(t)}; \boldsymbol{\theta}),$$

$$\boldsymbol{h}^{(t)} = f(\boldsymbol{h}^{(t-1)}, \boldsymbol{x}^{(t)}; \boldsymbol{\theta}),$$



"Deep Learning", Ian Goodfellow, Yoshua Bengio, Aaron Courville

Recurrent Networks



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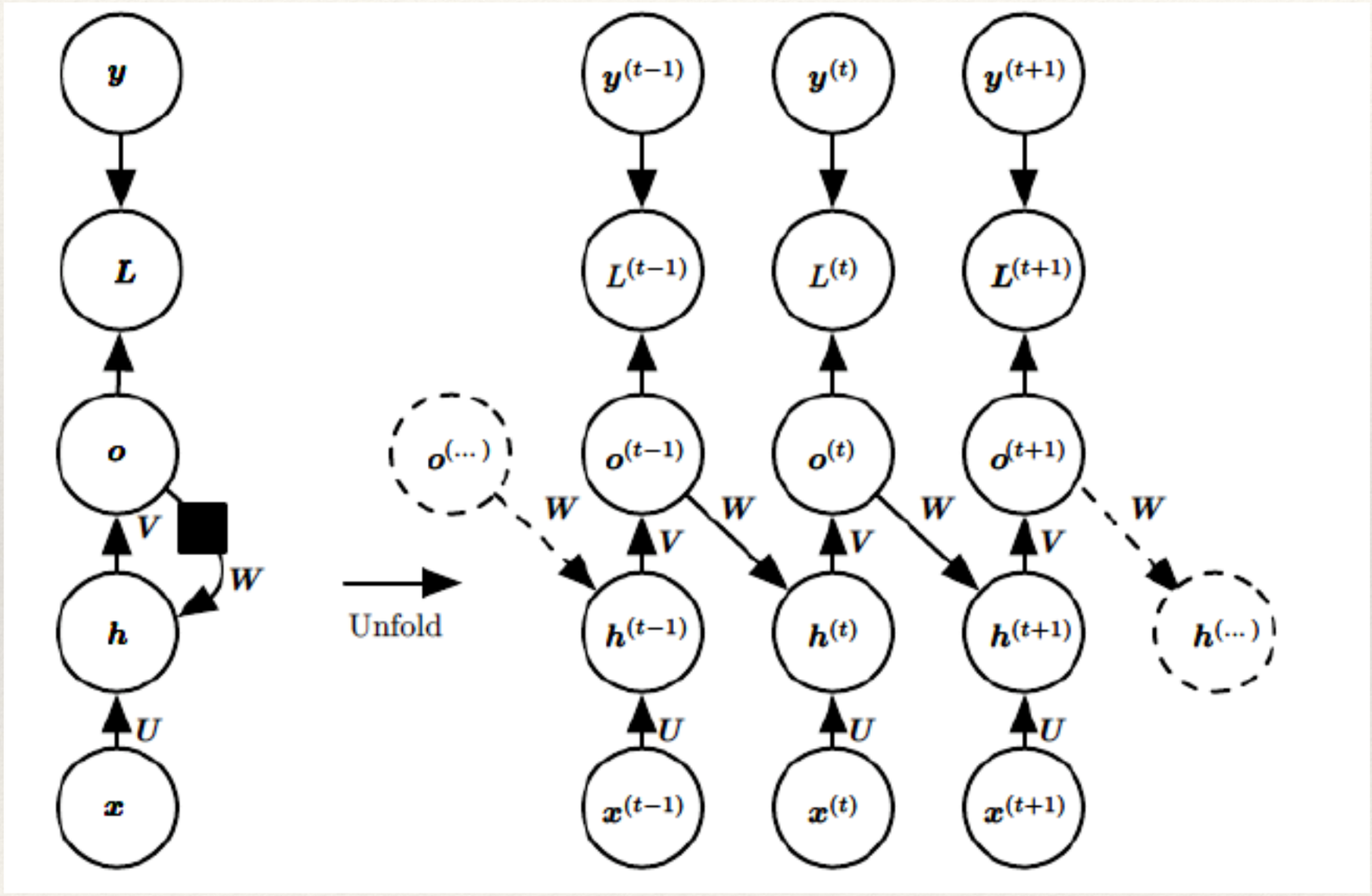
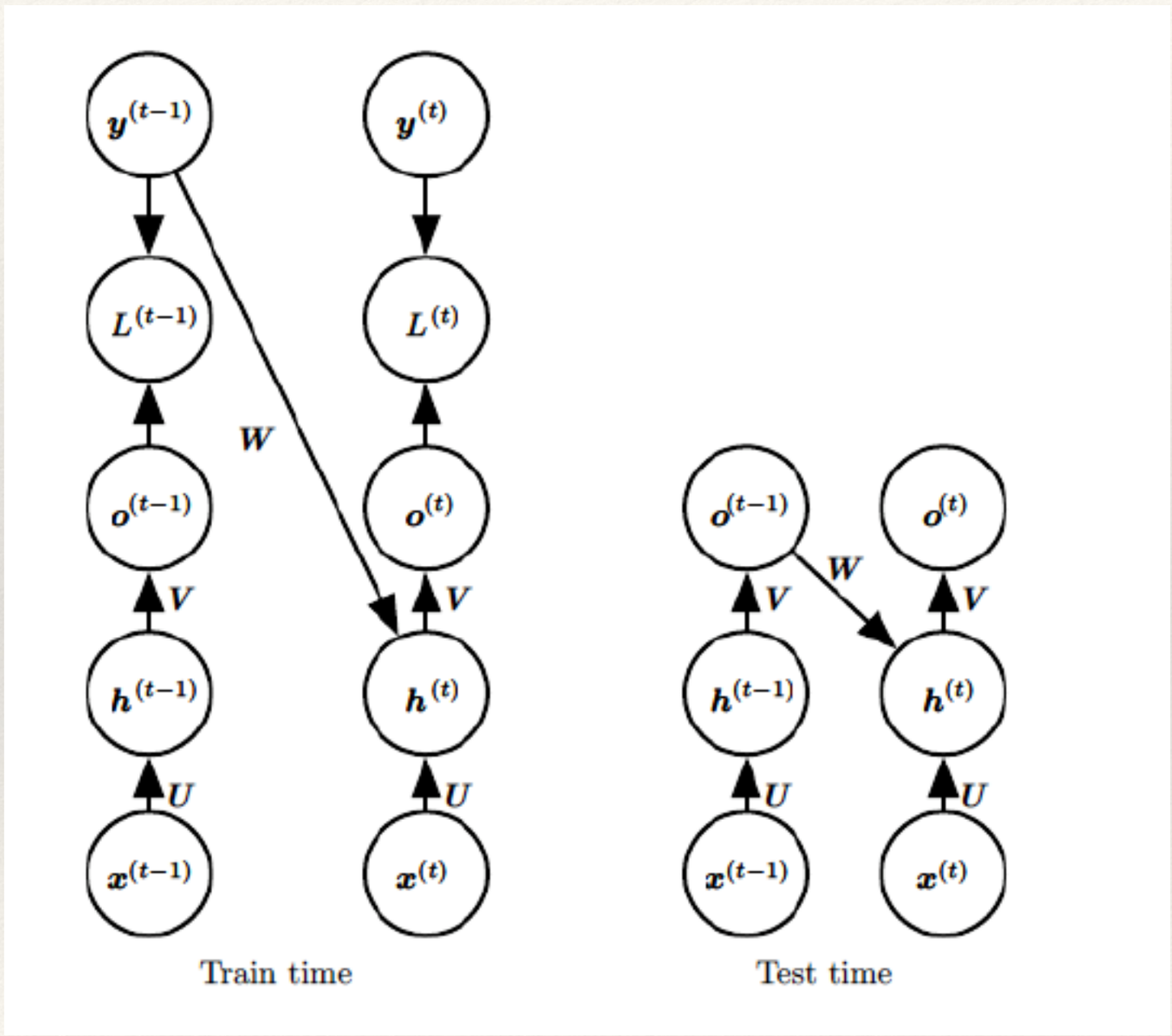
Recurrent Networks



Teacher Forcing Networks

"Deep Learning", Ian Goodfellow, Yoshua Bengio, Aaron Courville

Recurrent Networks



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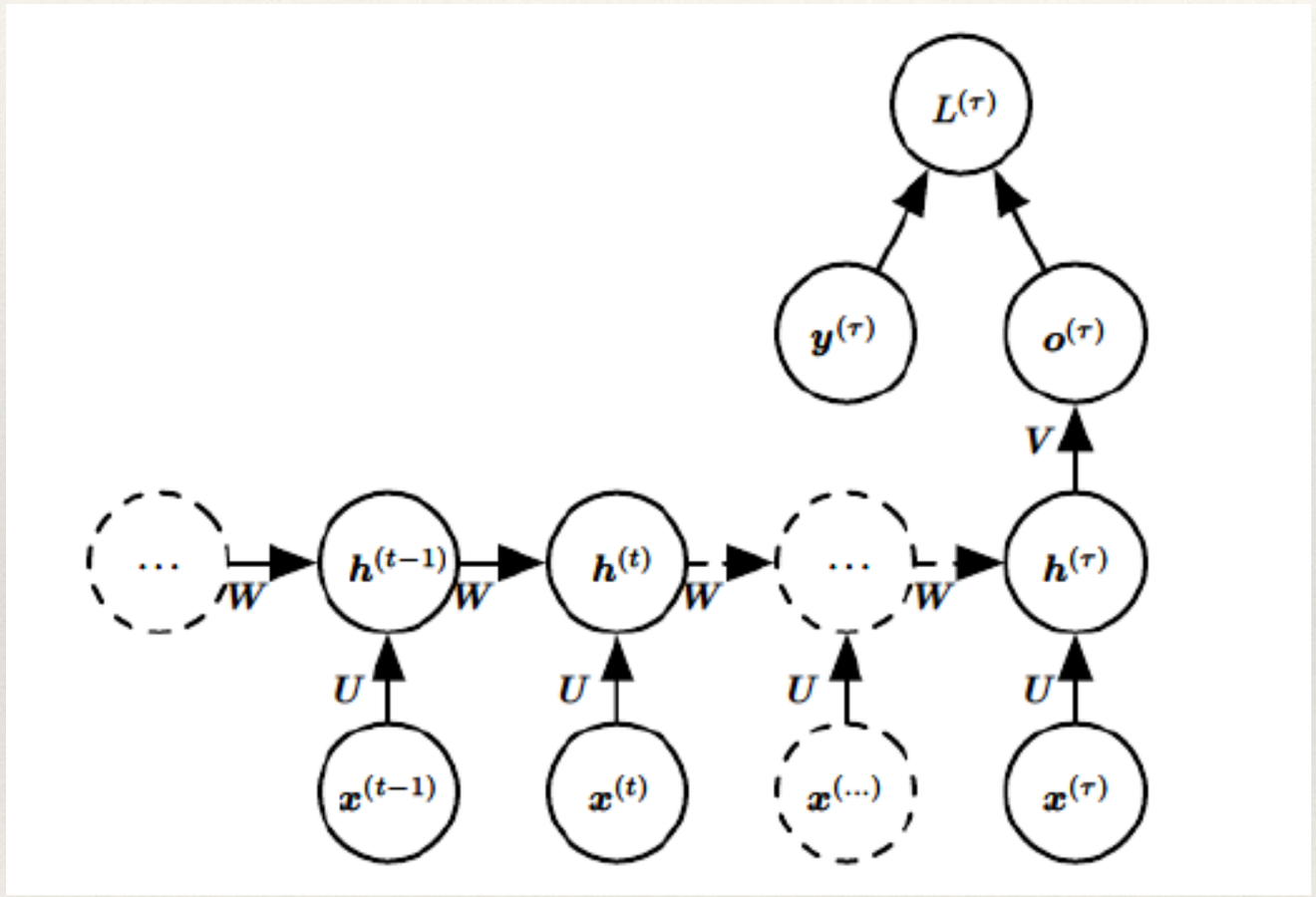
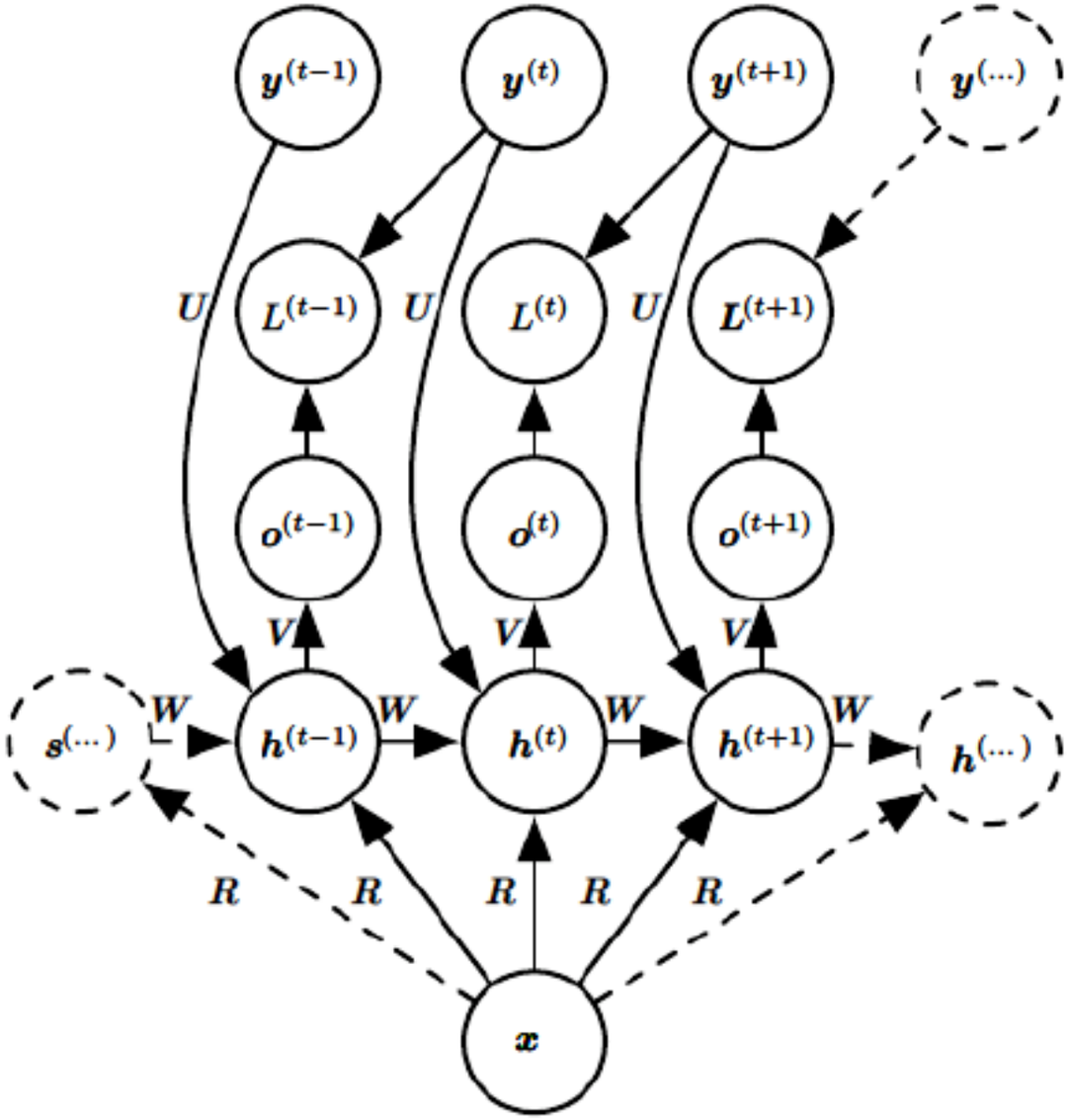
Recurrent Networks



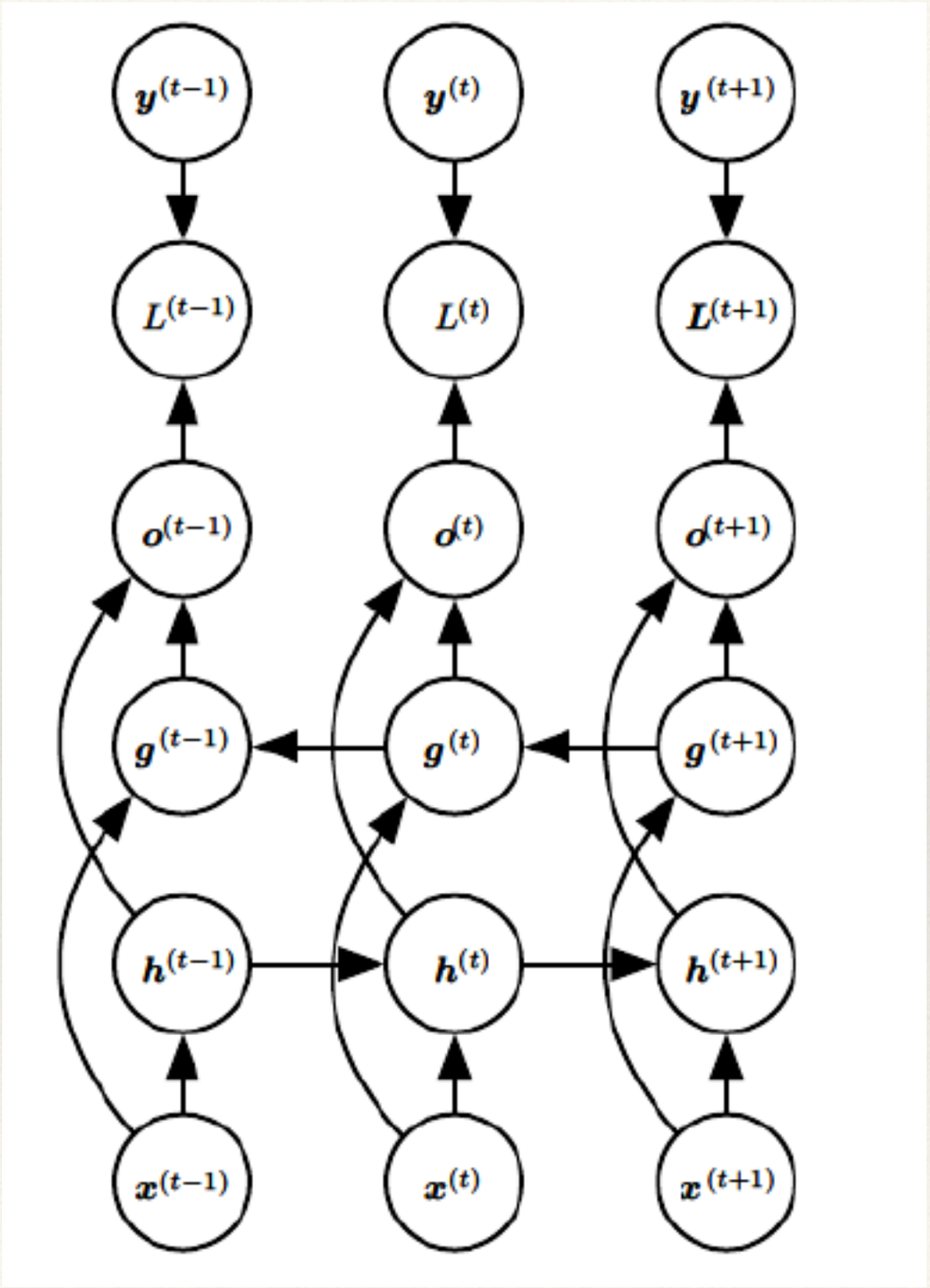
Multiple Input
Single Output

Recurrent Networks



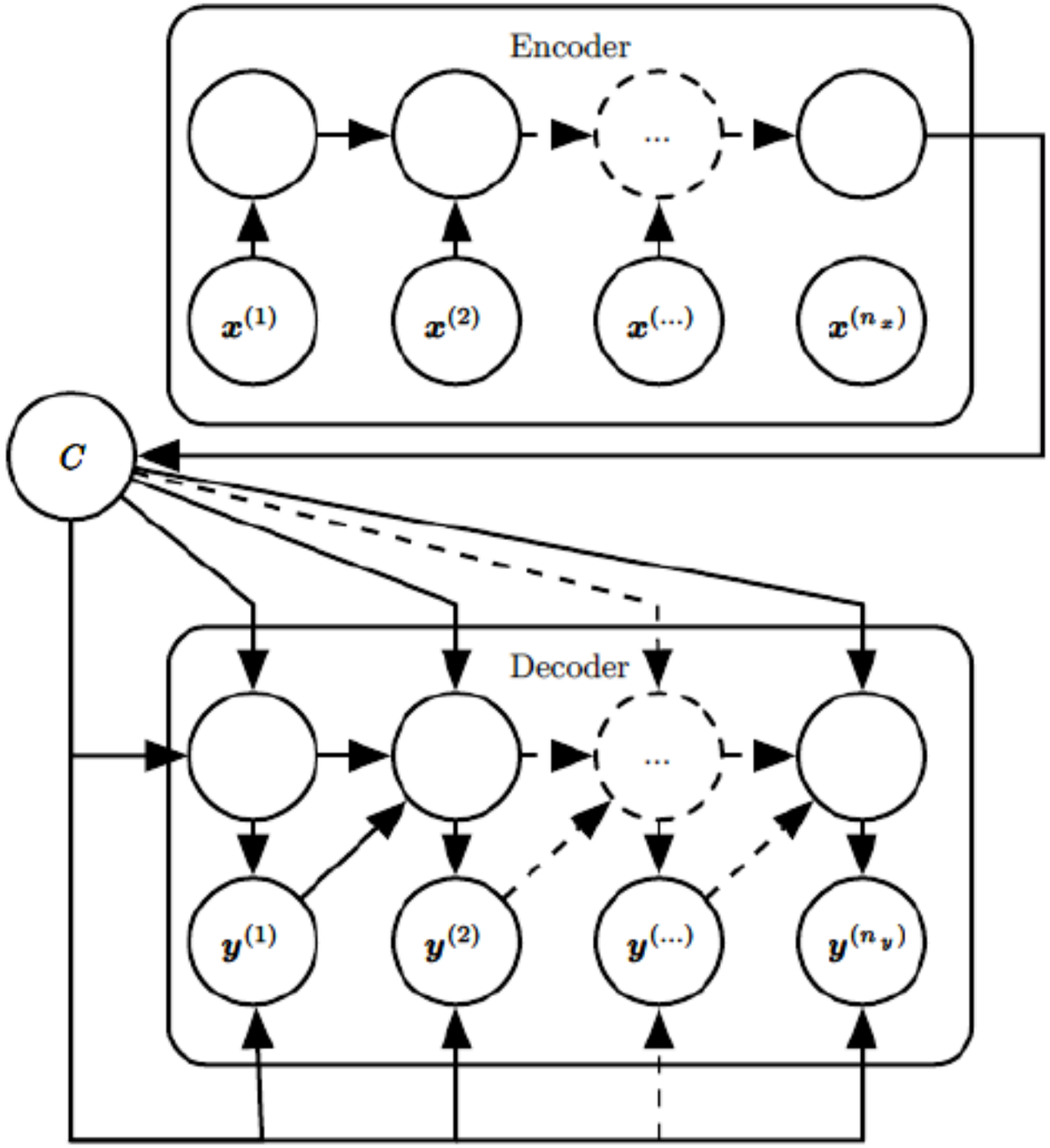
Single Input
Multiple Output

Recurrent Networks



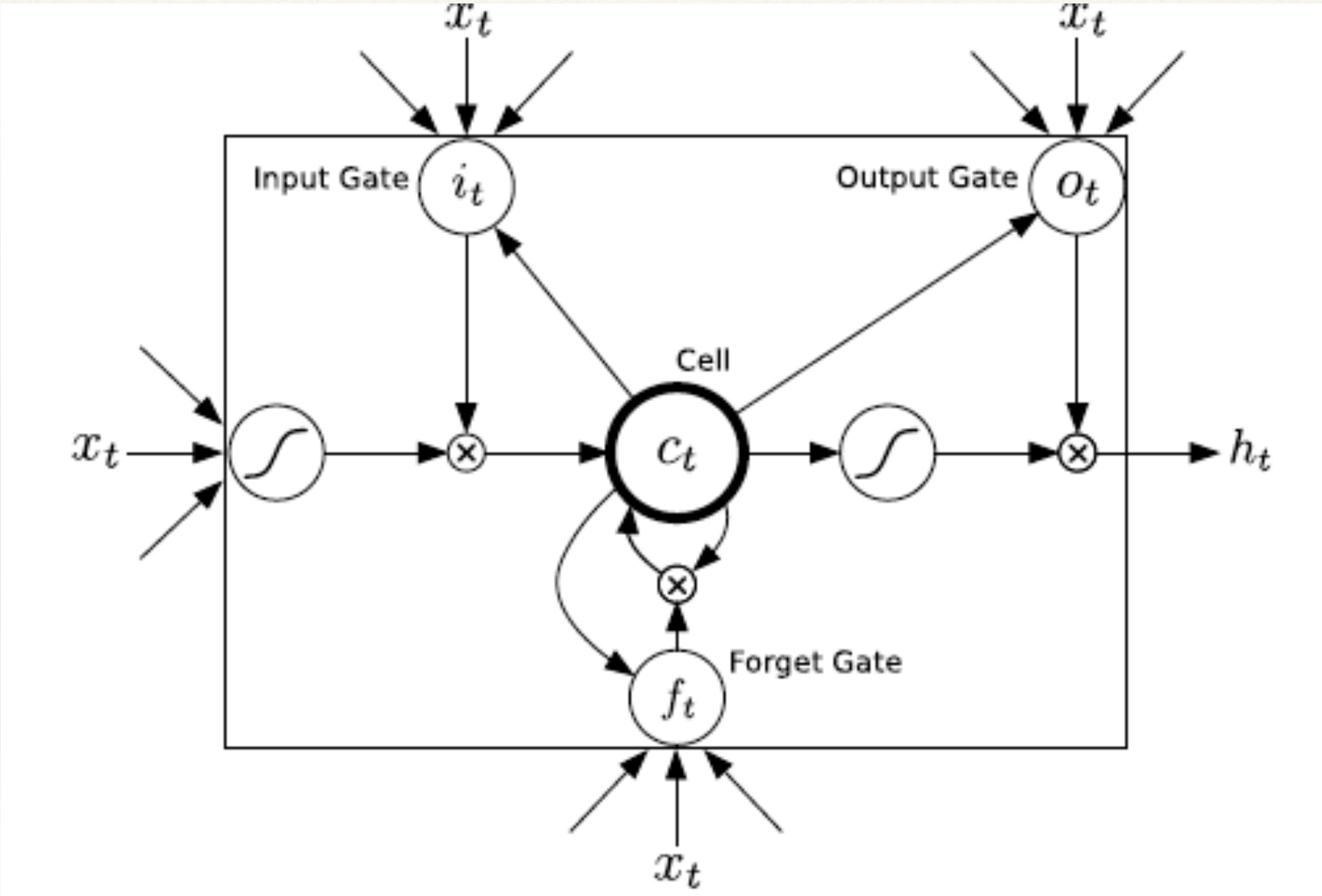
Bi-directional Networks

Recurrent Networks



Sequence to Sequence Mapping Networks

LSTM


x_t
x_t
Input Gate
i_t
Output Gate
o_t
Cell
x_t
c_t
h_t
Forget Gate
f_t
x_t

LSTM

$$
\begin{aligned}
i_t &= \sigma\left(W_{xi}x_t + W_{hi}h_{t-1} + W_{ci}c_{t-1} + b_i\right) \\
f_t &= \sigma\left(W_{xf}x_t + W_{hf}h_{t-1} + W_{cf}c_{t-1} + b_f\right) \\
c_t &= f_t c_{t-1} + i_t \tanh\left(W_{xc}x_t + W_{hc}h_{t-1} + b_c\right) \\
o_t &= \sigma\left(W_{xo}x_t + W_{ho}h_{t-1} + W_{co}c_t + b_o\right) \\
h_t &= o_t \tanh(c_t)
\end{aligned}
$$

Bidirectional LSTMs