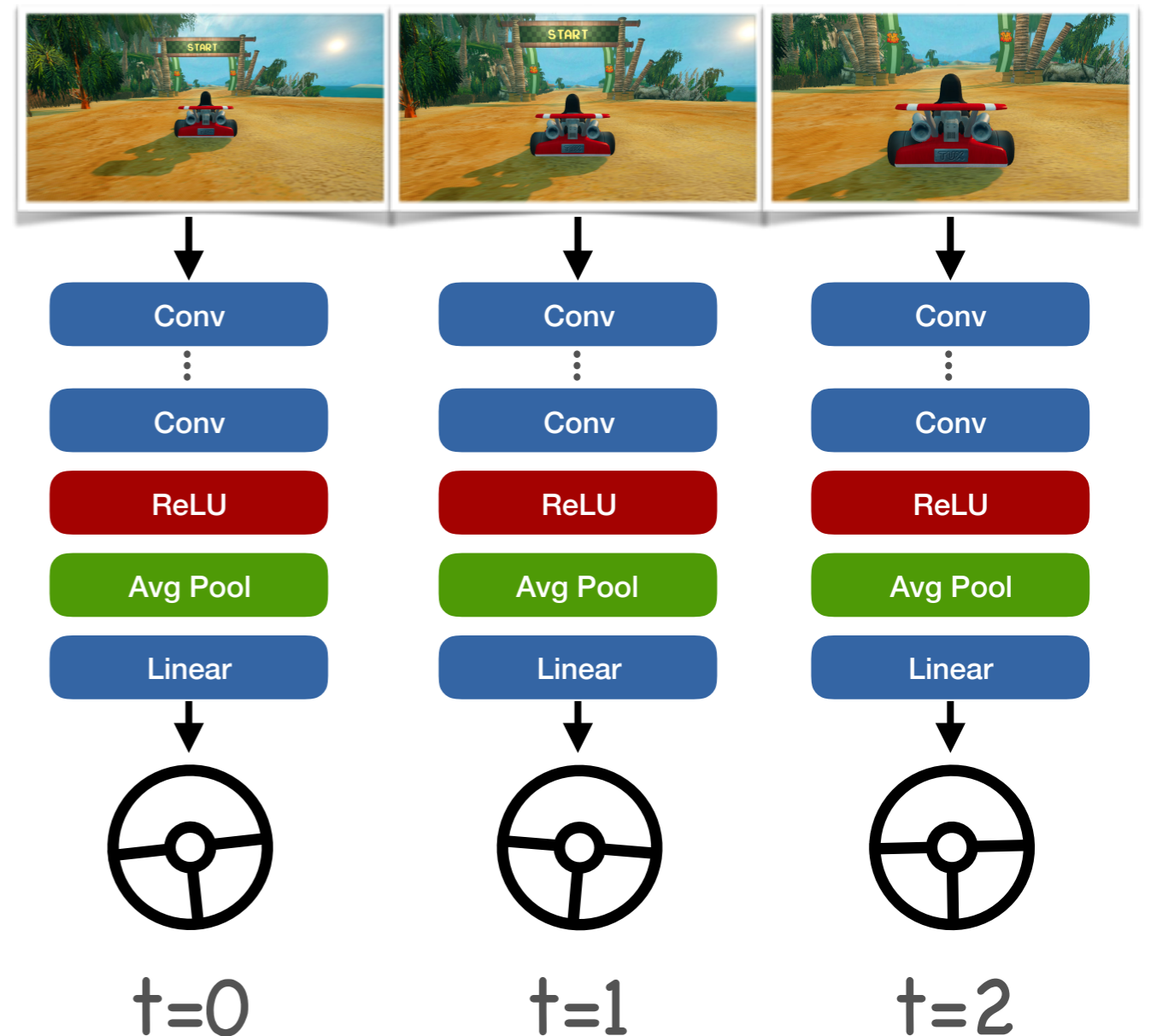


Recurrent neural networks

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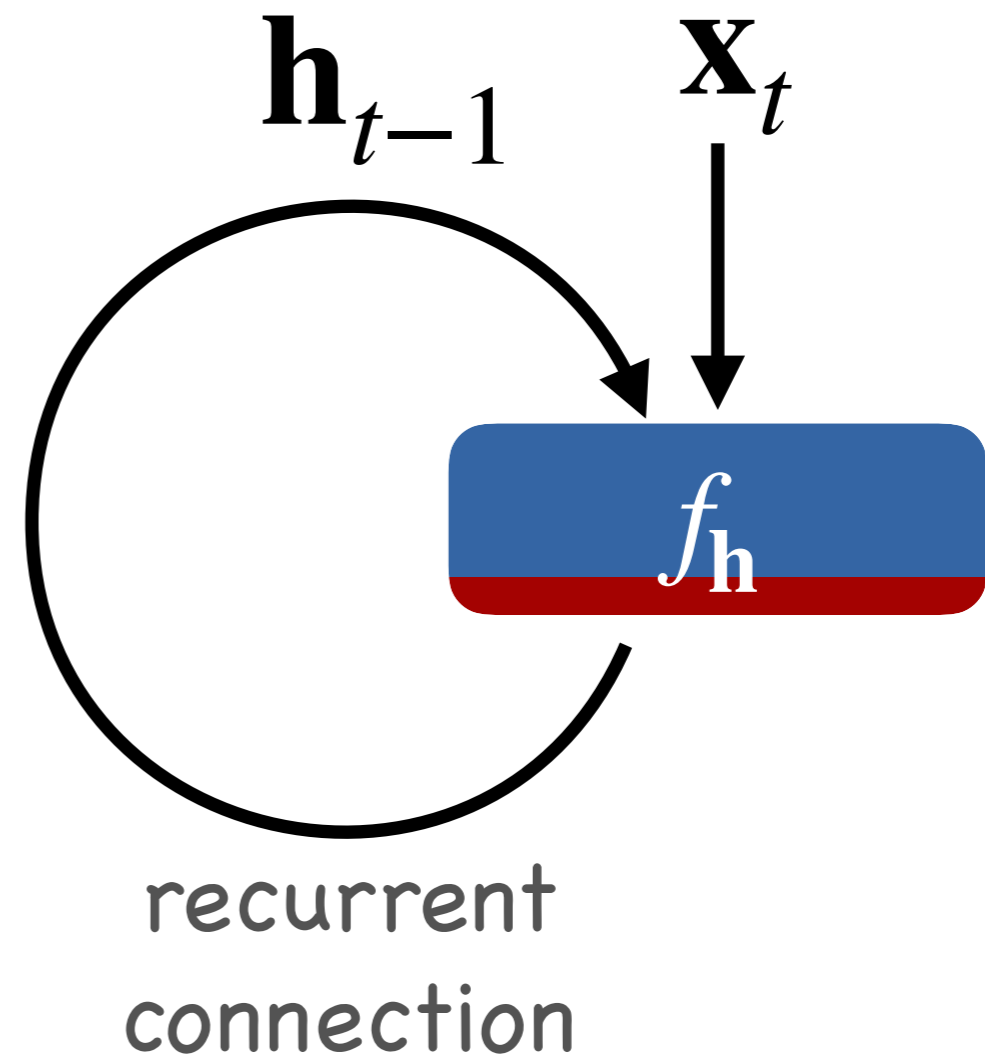
Recurrent neural networks (RNN)

- A network that
- applies same computation multiple times
- keeps some state around



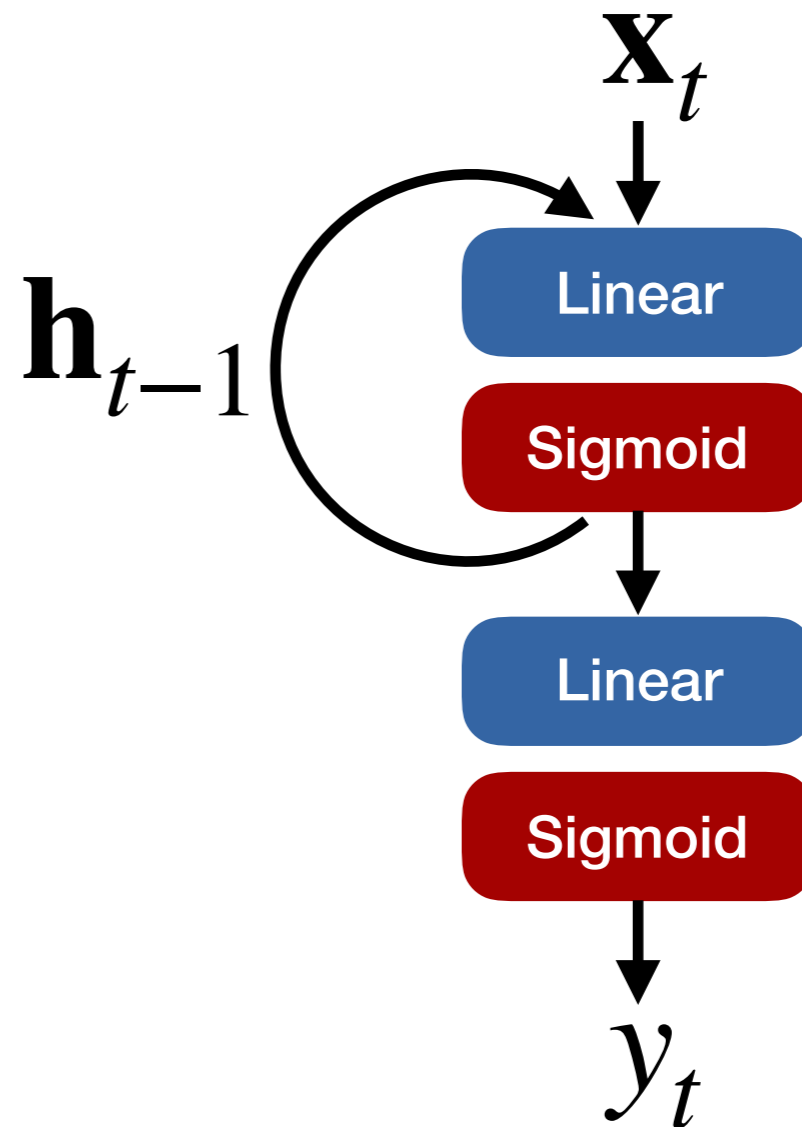
Formal definition

- Basic recurrent unit
 - $\mathbf{h}_t = f_{\mathbf{h}}(\mathbf{x}_t, \mathbf{h}_{t-1}, \theta_{\mathbf{h}})$
- Initial state \mathbf{h}_0
 - Learned
 - Zero



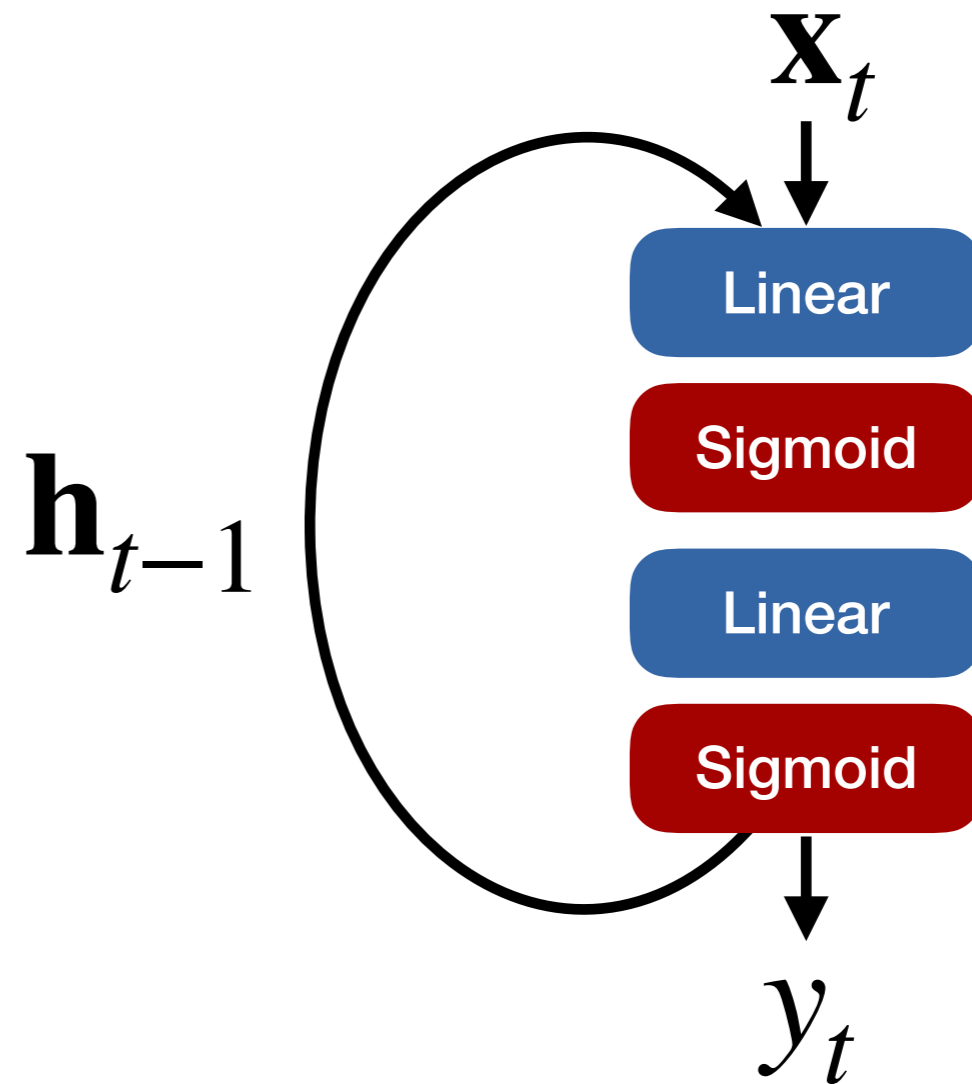
Elman networks

- Recurrent connection within layer



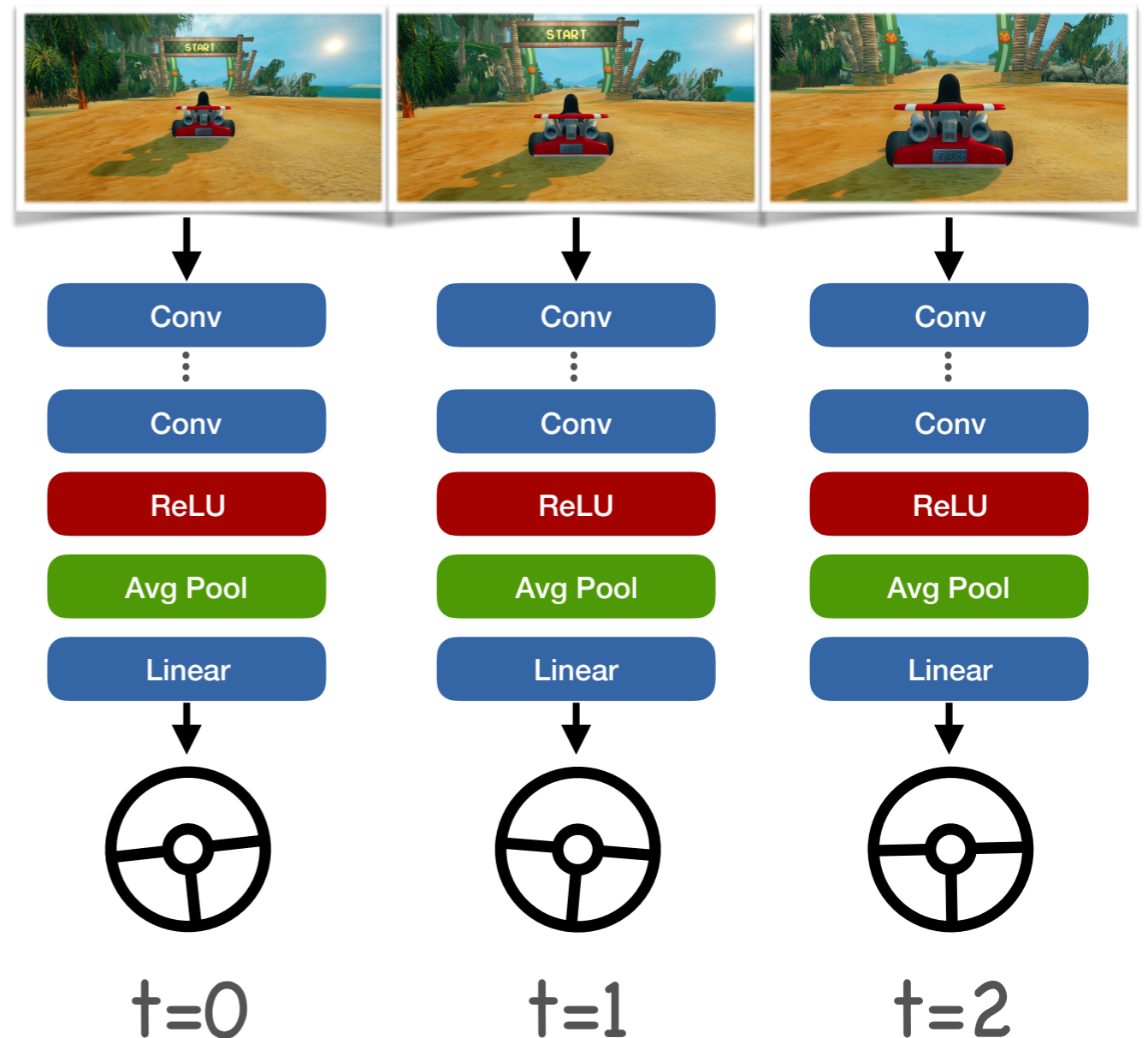
Jordan networks

- Recurrent connection from output to input



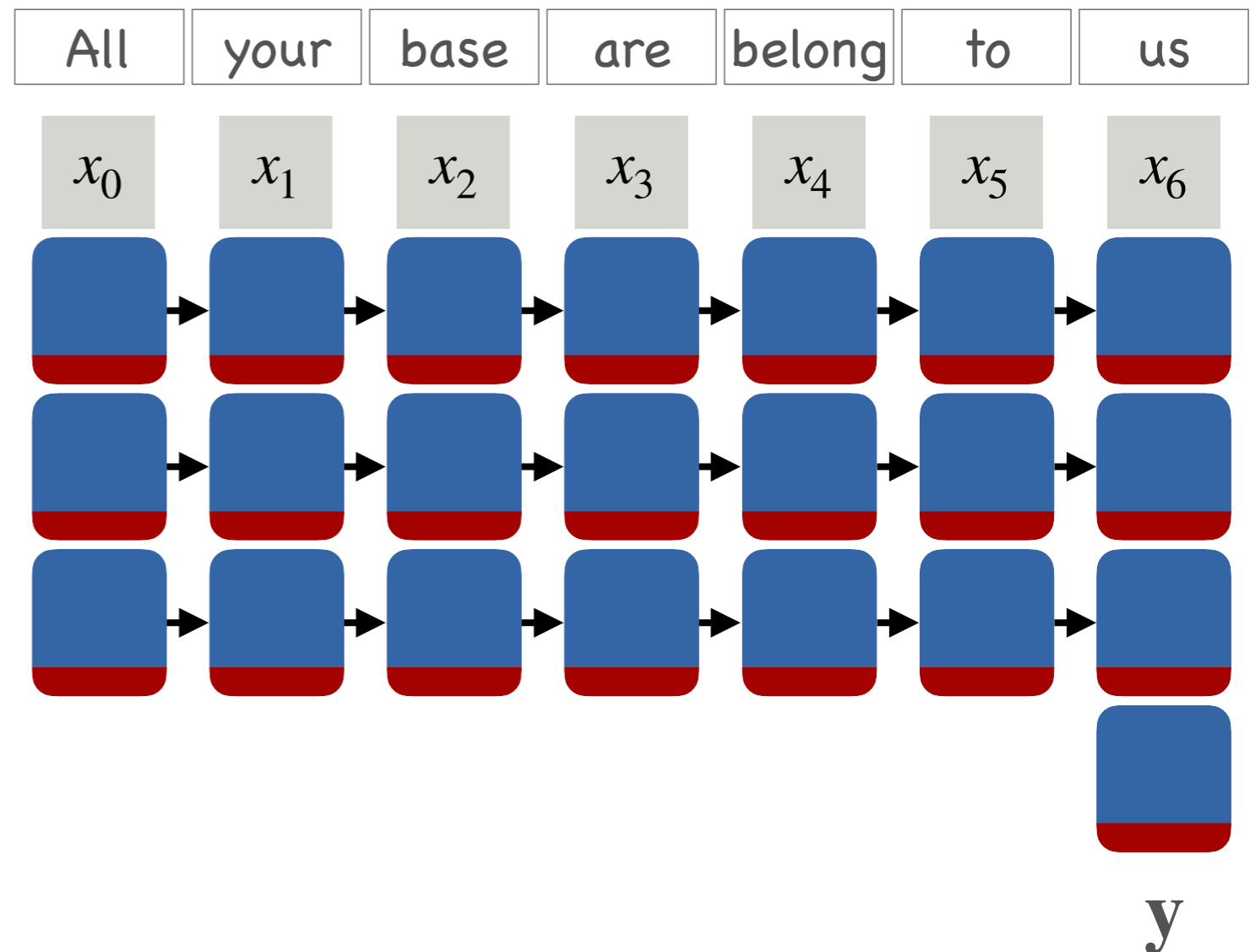
General RNNs

- Feed forward network
- With feedback connections



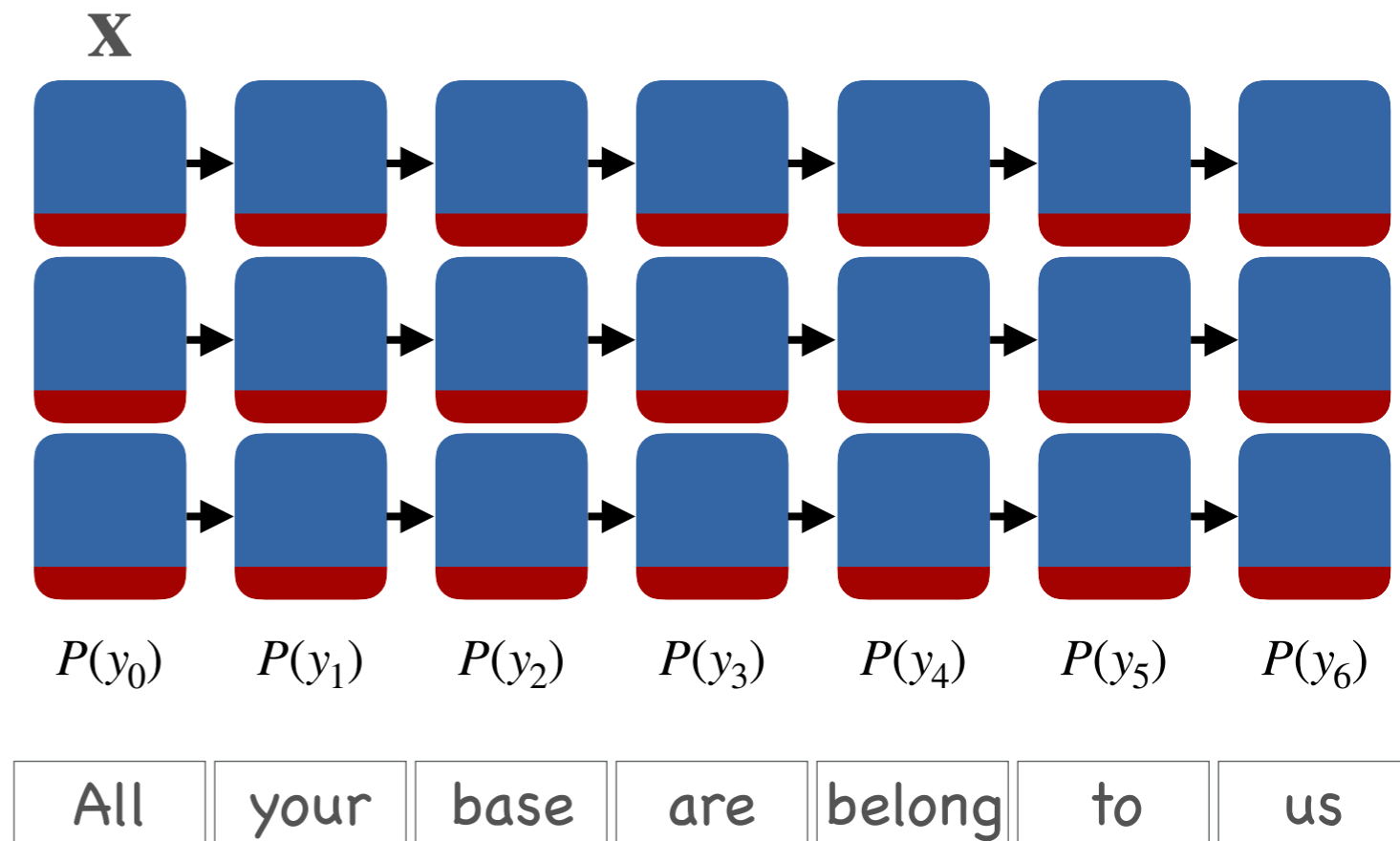
Example: Language understanding

- Reading comprehension
- Sequence in
- Vector out



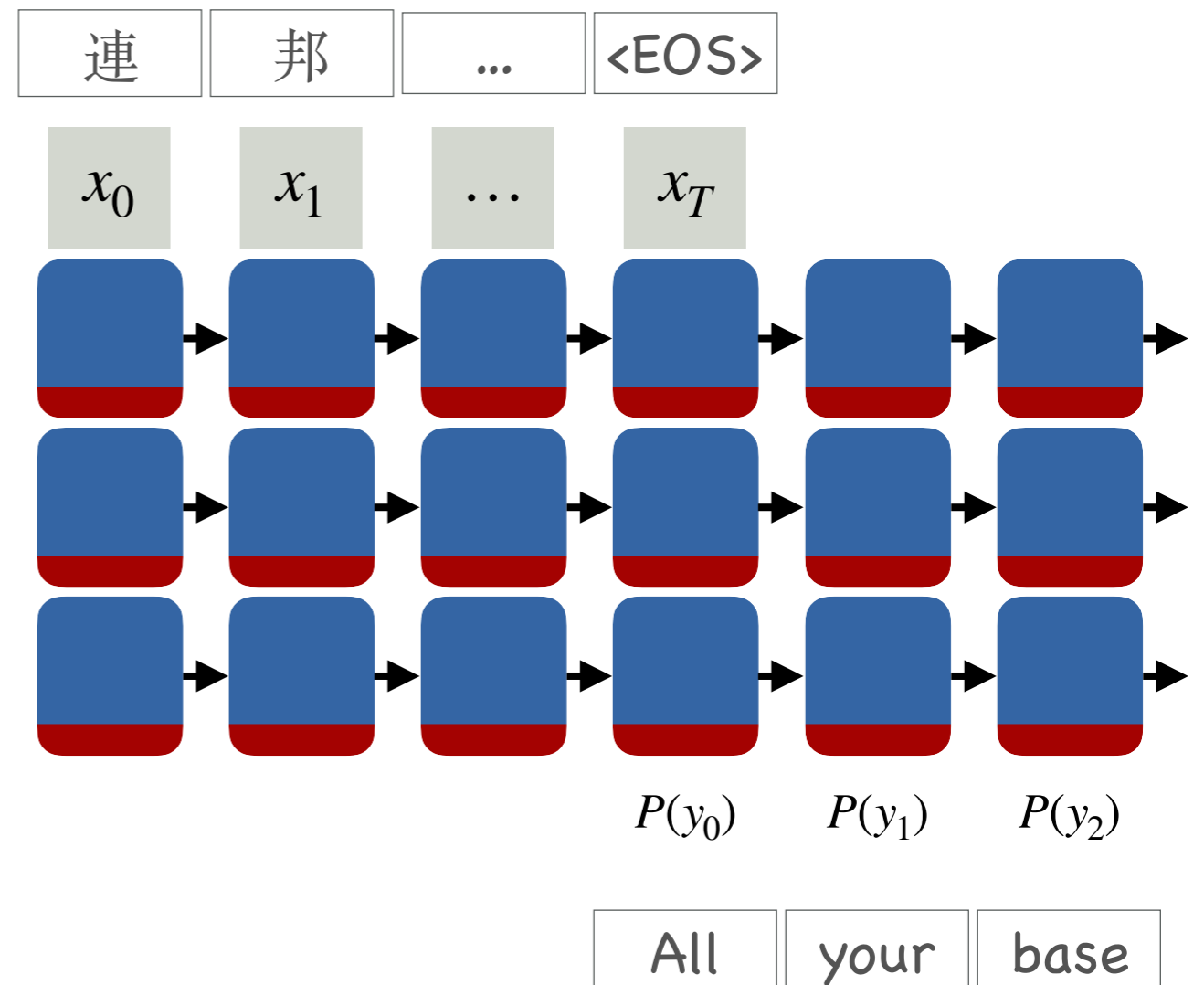
Example: Language generation

- Generate a sentence
- Vector in
- Sequence out



Example: Translation

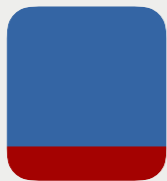
- Translate sentence from one language to another
- Sequence in
- Sequence out



The many RNNs

1-to-1

x



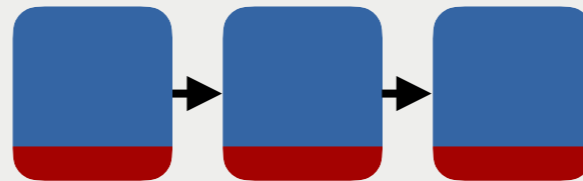
y

many-to-1

x_0

x_1

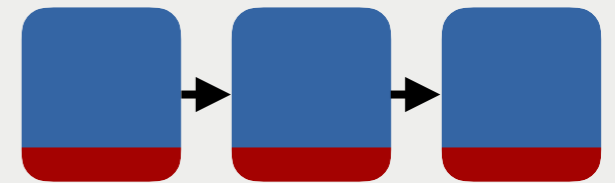
x_2



y

1-to-many

x



$P(y_0)$

$P(y_1)$

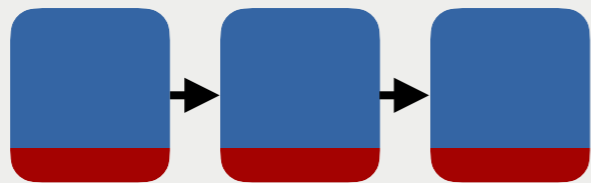
$P(y_2)$

many-to-many

x_0

x_1

x_2



$P(y_0)$

$P(y_1)$

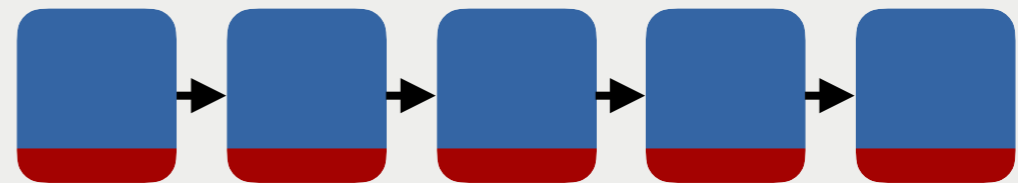
$P(y_2)$

many-to-many

x_0

x_1

x_2



$P(y_0)$

$P(y_1)$

$P(y_2)$