Recurrent Neural Network Introduction

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Topics

- Applications
- Recurrent neural network (RNN) model
- Back propagation through time
- Different types of RNN

Applications – Speech recognition

- Input
  - Audio clip – Sequence data
- Output
  - Text transcript – Sequence data
- Example
  - The Quick Brown Fox Jumps Over The Lazy Dog

Audio ack – Wikipedia

Applications – Sentiment classification

- Input
  - Text – Sequence data
- Output
  - Number of stars
- Example
  - Input – This movie is excellent.
  - Output – 5 stars

Applications – Name entity recognition

- Input
  - Text – Sequence data
- Output
  - Numbers 0 or 1
- Example
  - Input – Mumbai is capital of Maharashtra.
  - Output – 1 0 0 0 1

Applications – Machine translation

- Input
  - Sentence in one language – Sequence data
- Output
  - Translation in another language – Sequence data
- Example
  - Input – तू *कसा आहेस?*
  - Output – How are you?

Applications – Music generation

- Input
  - Genre of music (integer)
  - First few notes of music
- Output
  - Music – Sequence data

Applications – Image captioning

- Input
  - Image – Image features – Sequence data
- Output
  - Caption – Sequence data

"man in black shirt is playing guitar."

Image ack – Google

Applications – Action recognition

- Input
  - Video – Sequence data
- Output
  - Caption – Sequence data
- Example
  - Input – Video
  - Output – Reading a book

Video ack – Youtube

Recurrent neural network – Example

- Name entity recognition
- Input – x – Mumbai is capital of Maharashtra.

  $x^{<1>}$ $x^{<2>}$ $x^{<3>}$ $x^{<4>}$ $x^{<5>}$

- Output – y – 1 0 0 0 1

  $y^{<1>}$ $y^{<2>}$ $y^{<3>}$ $y^{<4>}$ $y^{<5>}$

- $x^{<t>}$ and $y^{<t>}$ – t – Temporal sequence

Recurrent neural network – Example

- Length of input sequence – T_x
- Length of output sequence – T_y
- $(x^{<t>}, y^{<t>})$ – t^{th} element of temporal sequence
- $(x^{(i)<t>}, y^{(i)<t>})$– t^{th} element of i^{th} sample
- $(Tx^{(i)}, Ty^{(i)})$– Input and output length of i^{th} sample

Recurrent neural network – Vocabulary

- Word dictionary
- Top common words
- Dictionary size
  - Small – 10000
  - Common – 50000

$$
\begin{bmatrix} \textbf{a} \\ \textbf{...} \\ \textbf{capital} \\ \textbf{...} \\ \textbf{is} \\ \textbf{...} \\ \textbf{Maharashtra} \\ \textbf{...} \\ \textbf{Mumbai} \\ \textbf{...} \\ \textbf{of} \\ \textbf{...} \\ \textbf{Zurich} \end{bmatrix}
\quad
\begin{bmatrix} \textbf{1} \\ \textbf{...} \\ \textbf{300} \\ \textbf{...} \\ \textbf{501} \\ \textbf{...} \\ \textbf{2001} \\ \textbf{...} \\ \textbf{2301} \\ \textbf{...} \\ \textbf{2401} \\ \textbf{...} \\ \textbf{10000} \end{bmatrix}
$$

Recurrent neural network – Vocabulary

- One hot encoding
- Example
  - Word – capital
  - 1 at 300th location
  - 0 everywhere

…	a	1
0	…	…
1	capital	300
0	…	…
…	is	501
…	…	…
…	Maharashtra	2001
…	…	…
…	Mumbai	2301
…	…	…
…	of	2401
…	…	…
…	Zurich	10000

Recurrent neural network – Vocabulary

- One hot encoding
- Example
  - Word – is
  - 1 at 501st location
  - 0 everywhere

...	a	1
...	...	...
...	capital	300
0	...	...
1	is	501
0	...	...
...	Maharashtra	2001
...	...	...
...	Mumbai	2301
...	...	...
...	of	2401
...	...	...
...	Zurich	10000

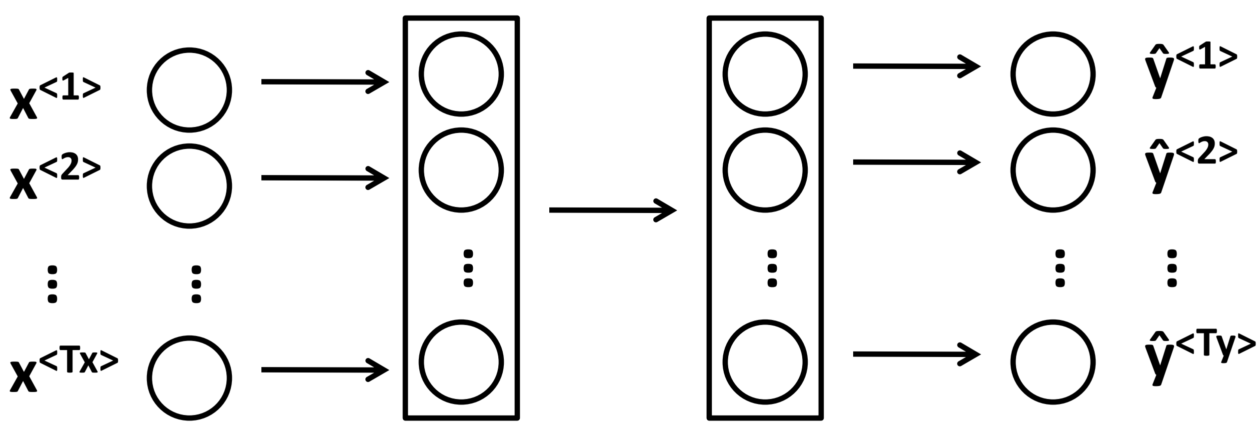
Recurrent neural network – Vocabulary

- One hot encoding
- Example
  - Word – Maharashtra
  - 1 at 2001st location
  - 0 everywhere

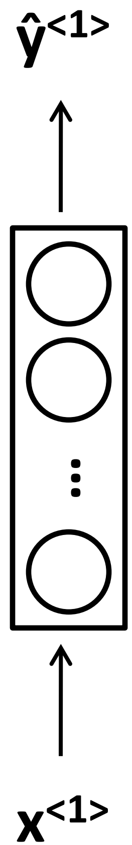
…	a	1
…	…	…
…	capital	300
…	…	…
…	is	501
0	…	…
1	Maharashtra	2001
0	…	…
…	Mumbai	2301
…	…	…
…	of	2401
…	…	…
…	Zurich	10000

Recurrent neural network – Why?

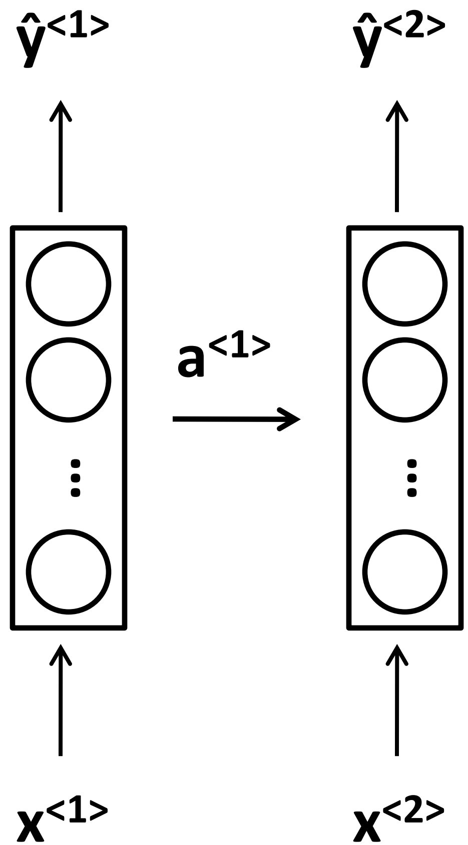
- Standard neural network
  - Different lengths in different samples for input and output sequences
  - No feature sharing across different text positions
  - Large vocabulary – Large number of parameters



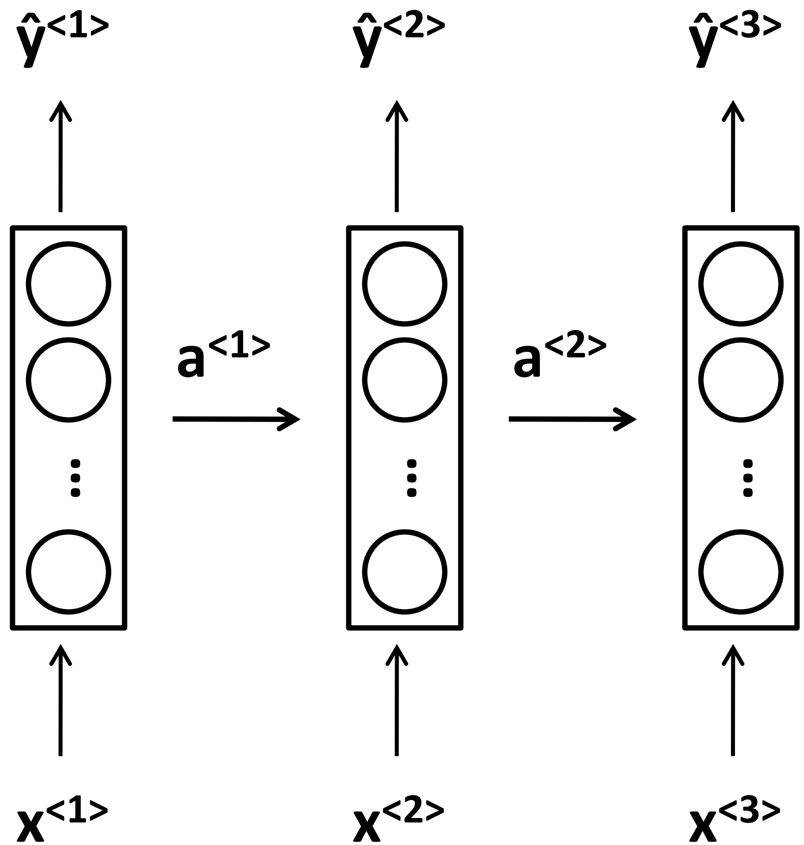
Recurrent neural network



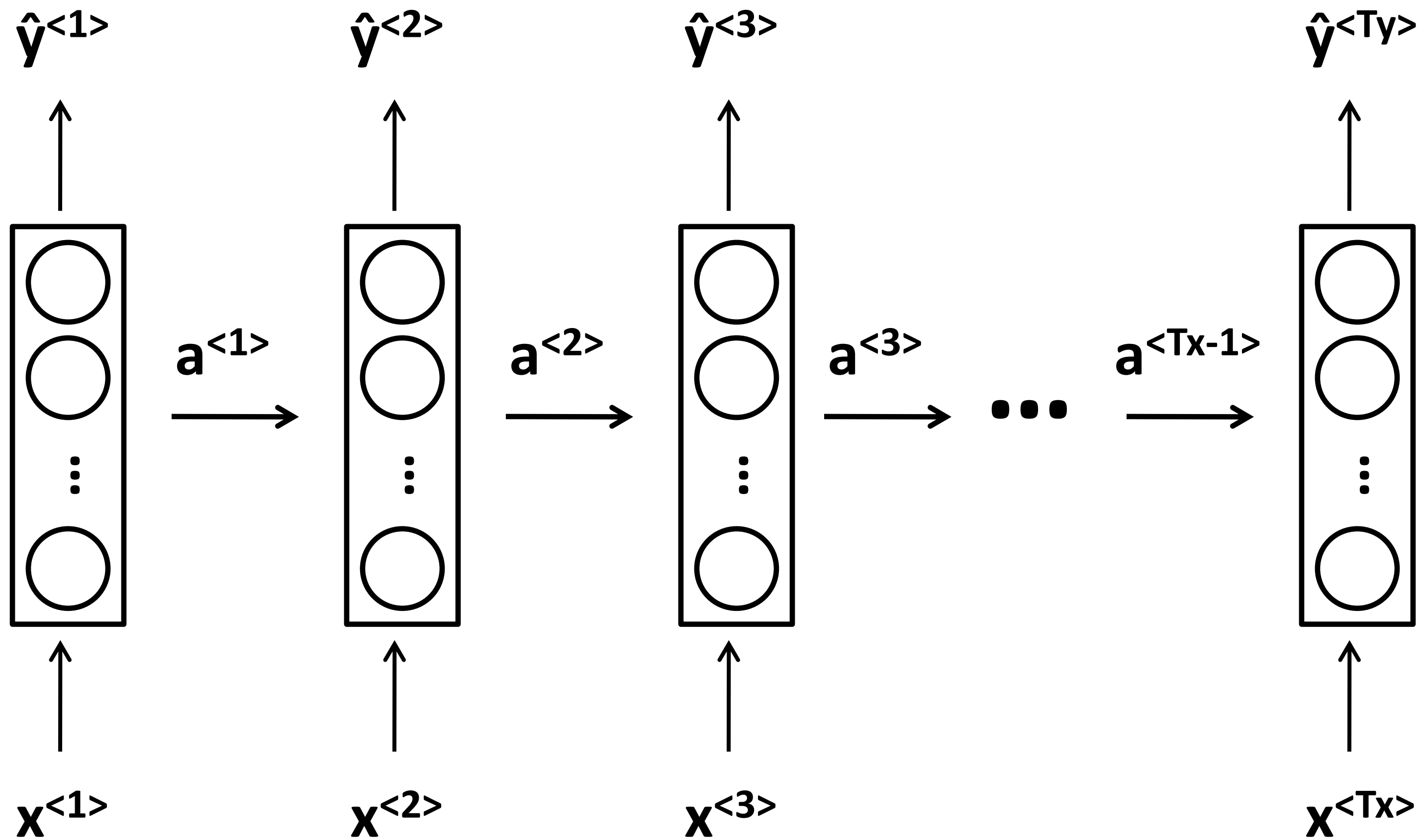
Recurrent neural network



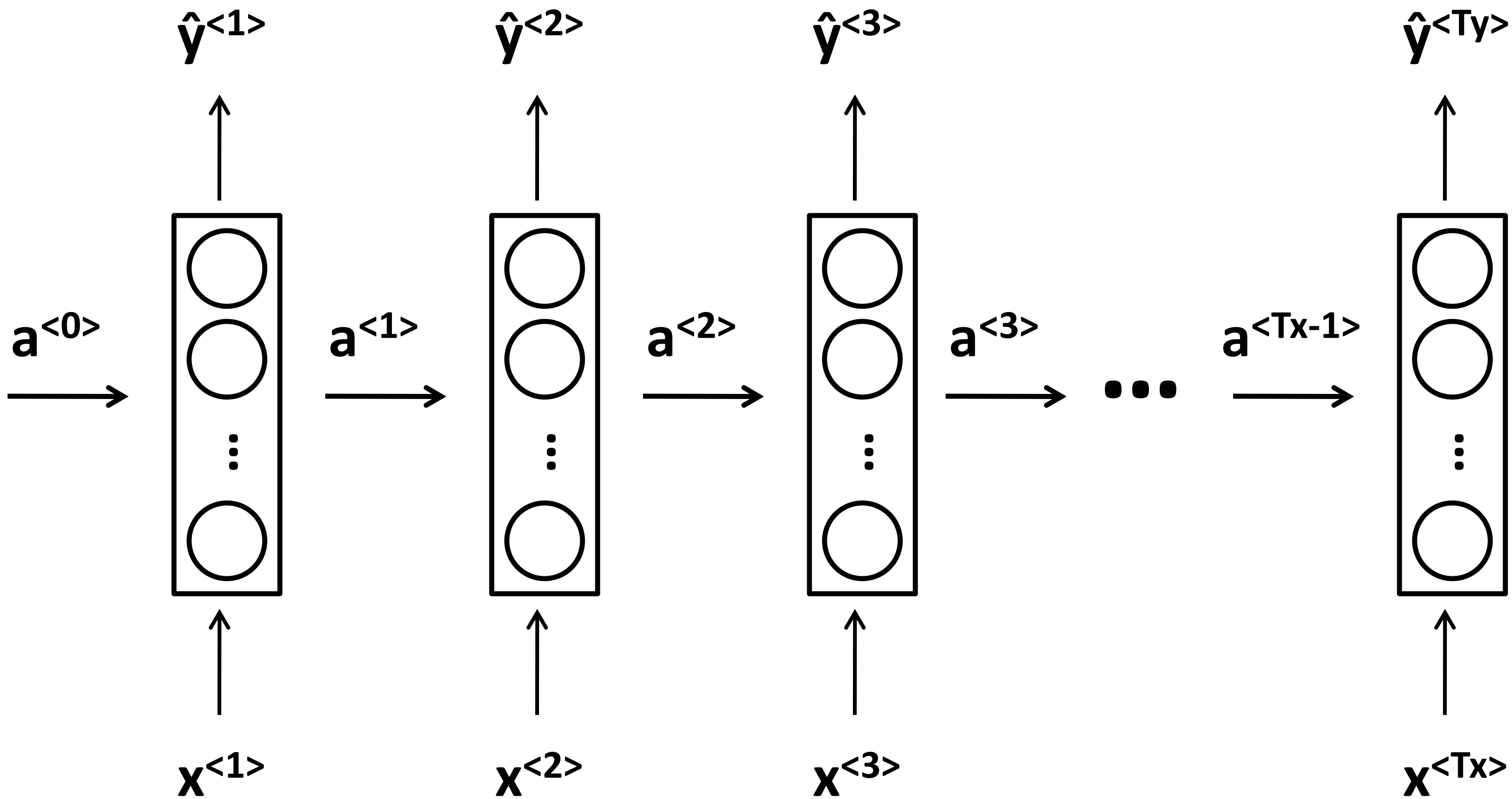
Recurrent neural network



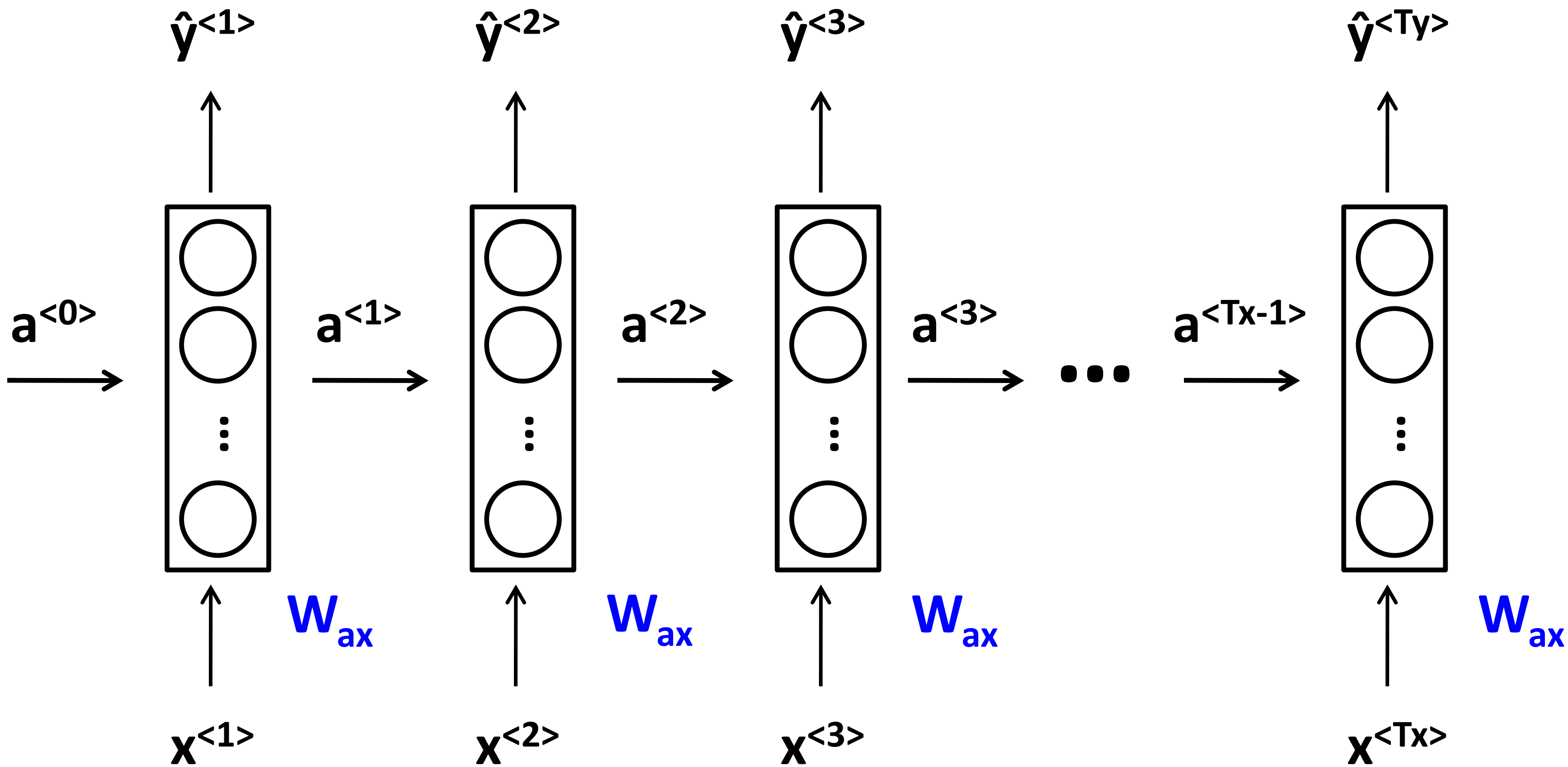
Recurrent neural network



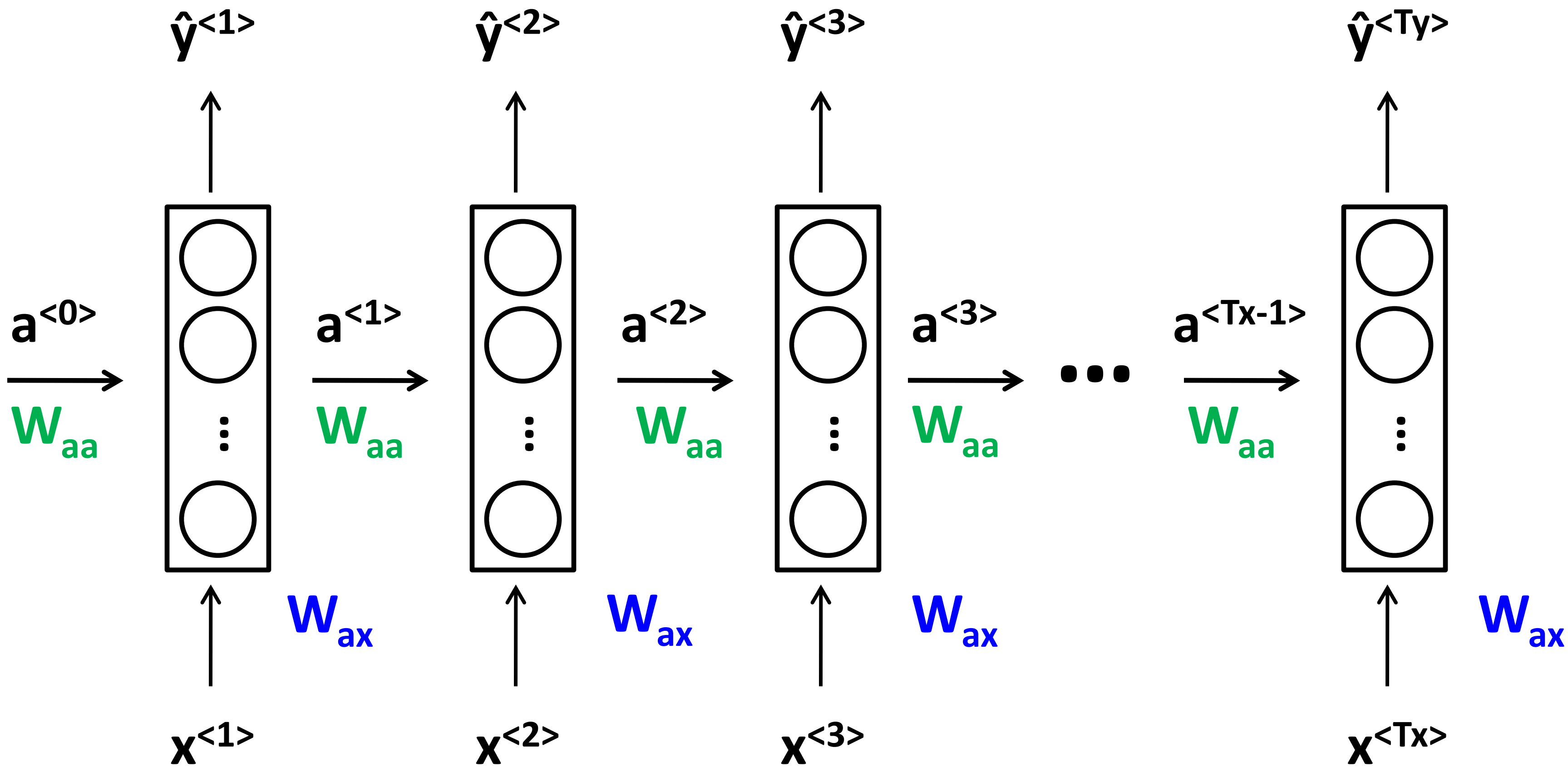
Recurrent neural network



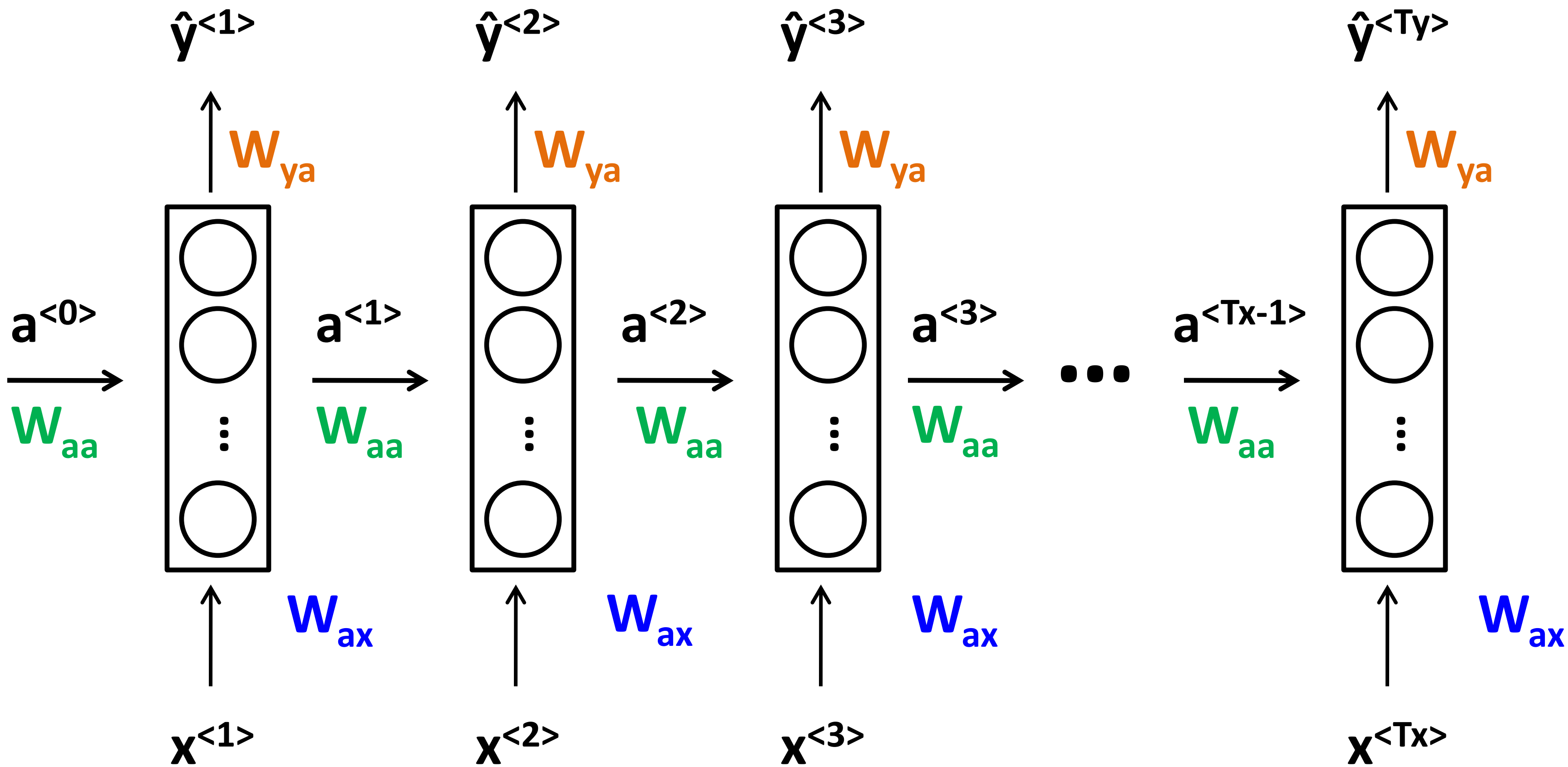
Recurrent neural network



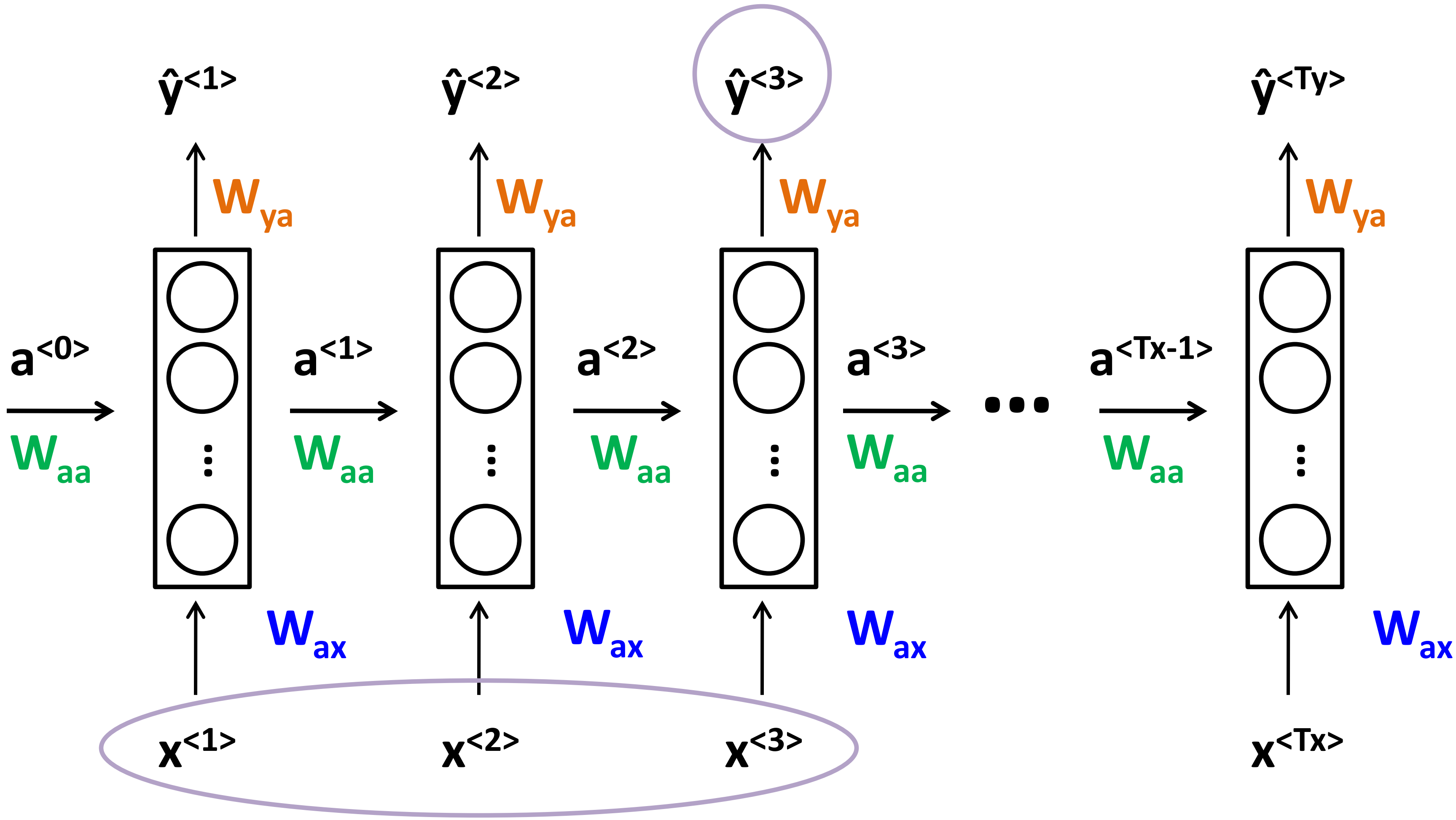
Recurrent neural network



Recurrent neural network



Recurrent neural network

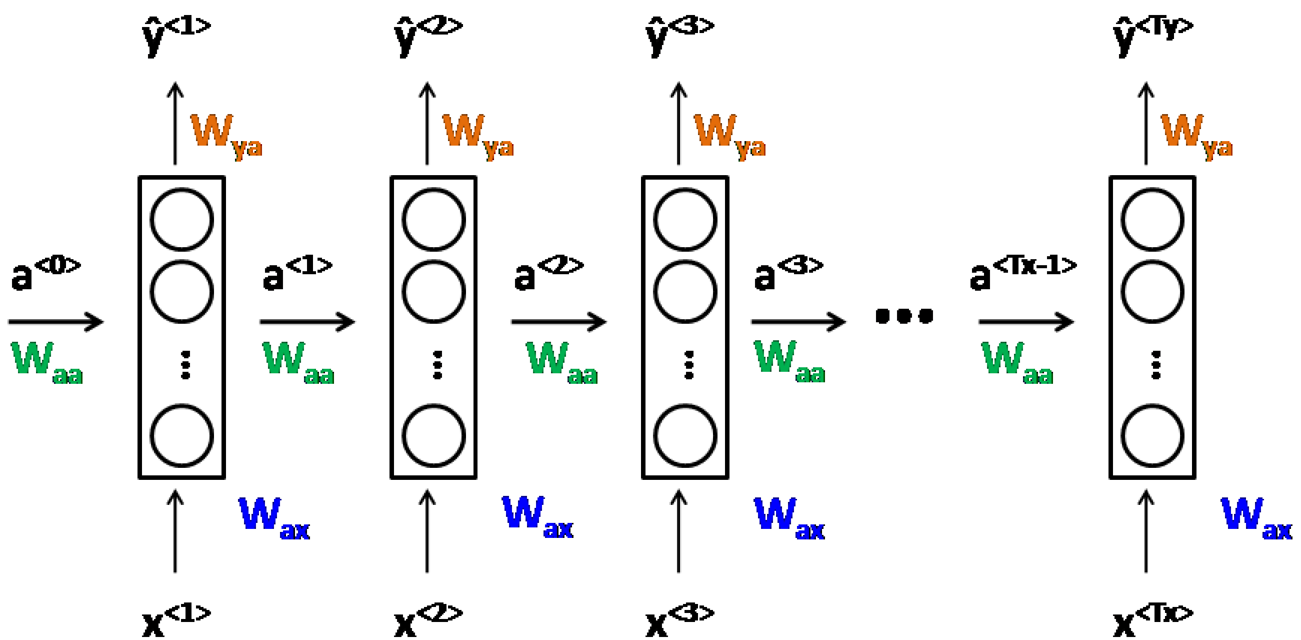


Recurrent neural network

- Use information from previous input
  - Simple Recurrent neural network
- No information from future input
  - Solution – Bi directional neural network

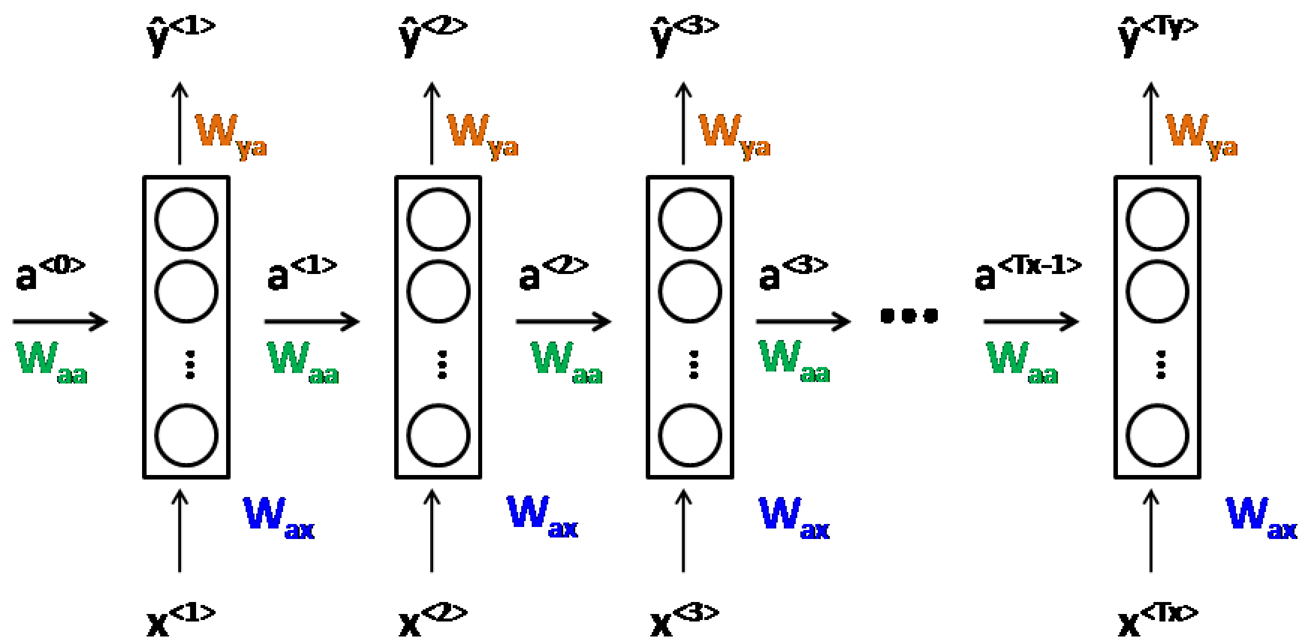
Recurrent neural network

- $a^{<0>} = 0$



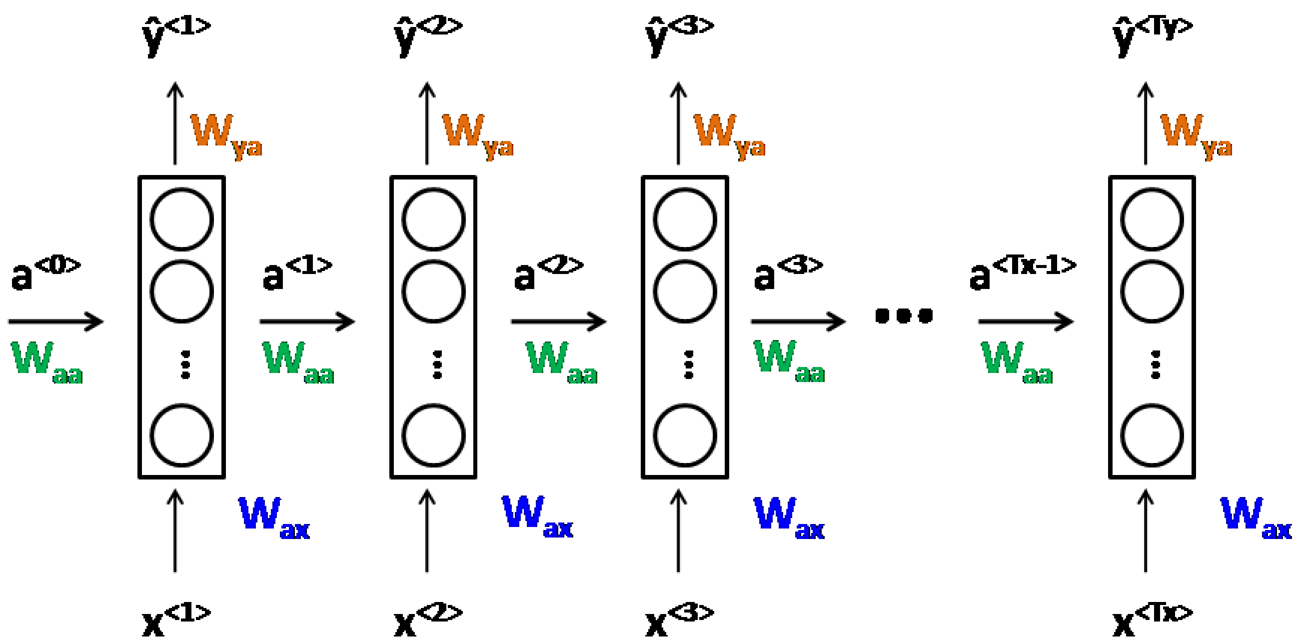
Recurrent neural network

- $a^{<0>} = 0$
- $a^{<1>} = g(W_{aa}\ a^{<0>} + W_{ax}\ x^{<1>} + b_a)$
- $\hat{y}^{<1>} = g(W_{ya}\ a^{<1>} + b_y)$



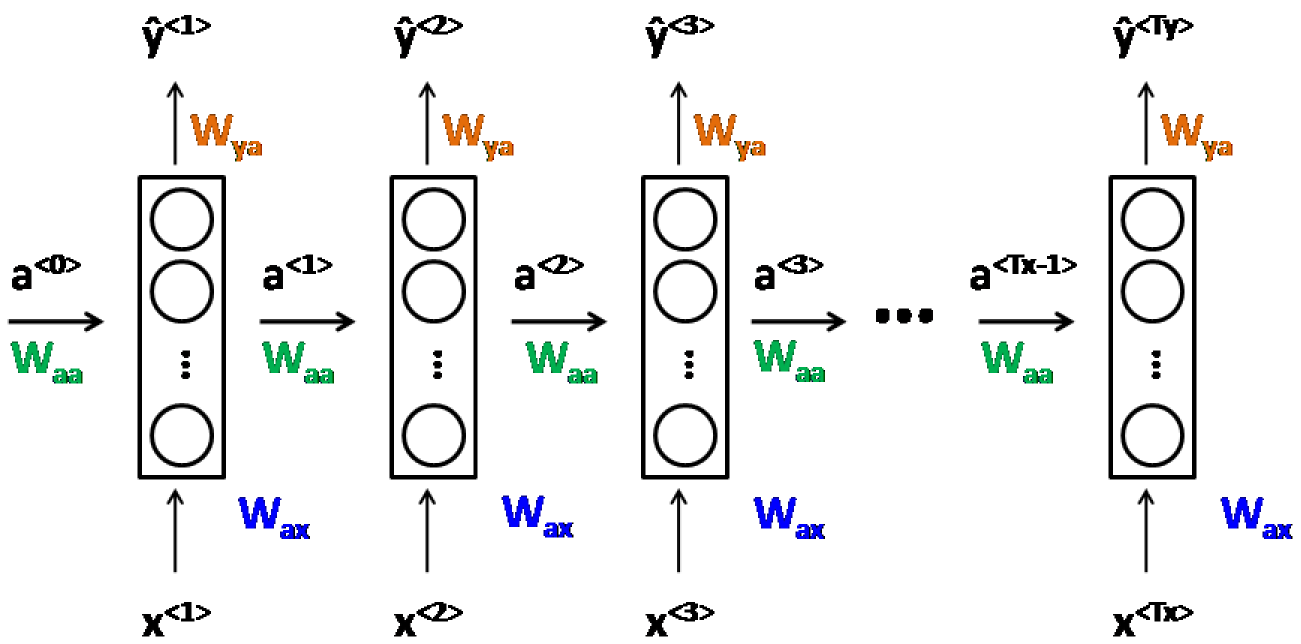
Recurrent neural network

- $a^{<0>} = 0$
- $a^{<1>} = g(W_{aa}\, a^{<0>} + W_{ax}\, x^{<1>} + b_a)$ – tanh or relu
- $\hat{y}^{<1>} = g(W_{ya}\, a^{<1>} + b_y)$ – sigmoid or softmax



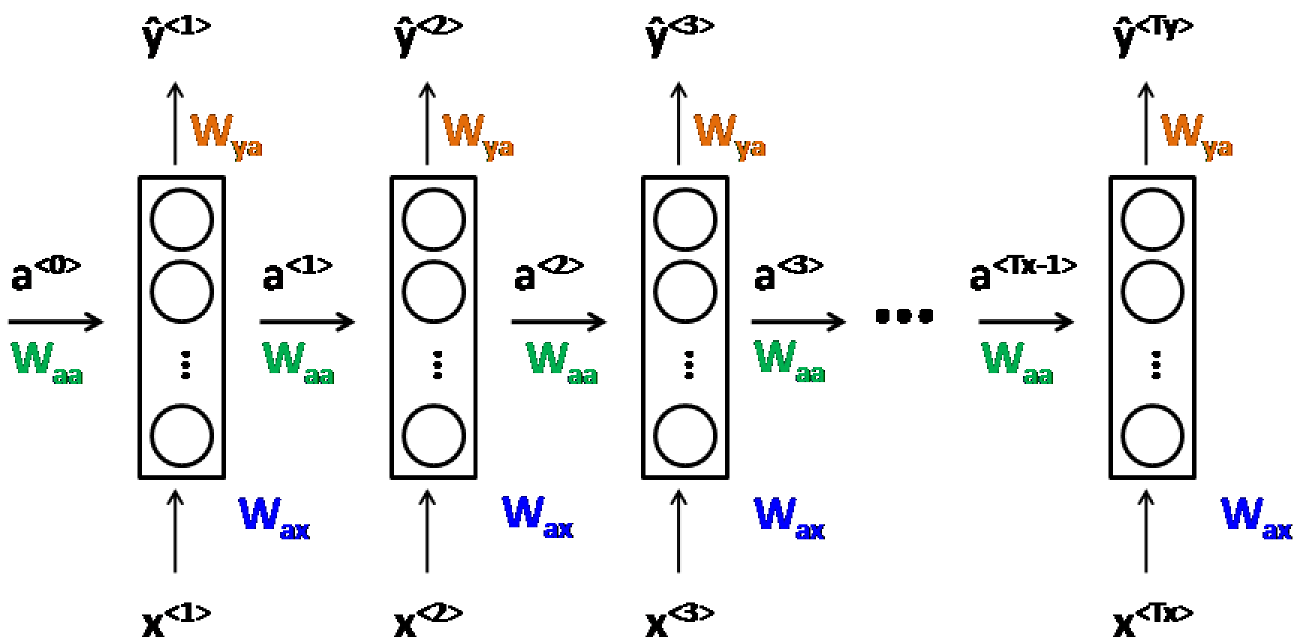
Recurrent neural network

- $a^{<t>} = g(W_{aa}\, a^{<t-1>} + W_{ax}\, x^{<t>} + b_a)$
- $\hat{y}^{<t>} = g(W_{ya}\, a^{<t>} + b_y)$



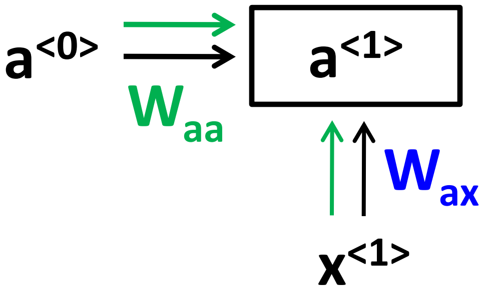
Recurrent neural network

- $a^{<t>} = g(W_{aa}\, a^{<t-1>} + W_{ax}\, x^{<t>} + b_a)$
- $a^{<t>} = g(W_a\, [a^{<t-1>}, x^{<t>}] + b_a)$ – Stack values
- $\hat{y}^{<t>} = g(W_{ya}\, a^{<t>} + b_y)$



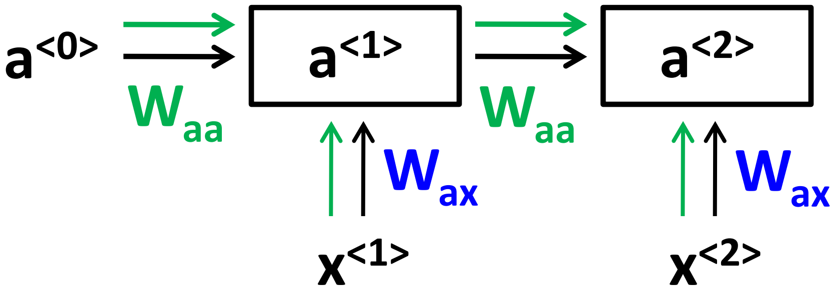
Back propagation through time

- $a^{<1>} = g(W_{aa}\, a^{<0>} + W_{ax}\, x^{<1>} + b_a)$



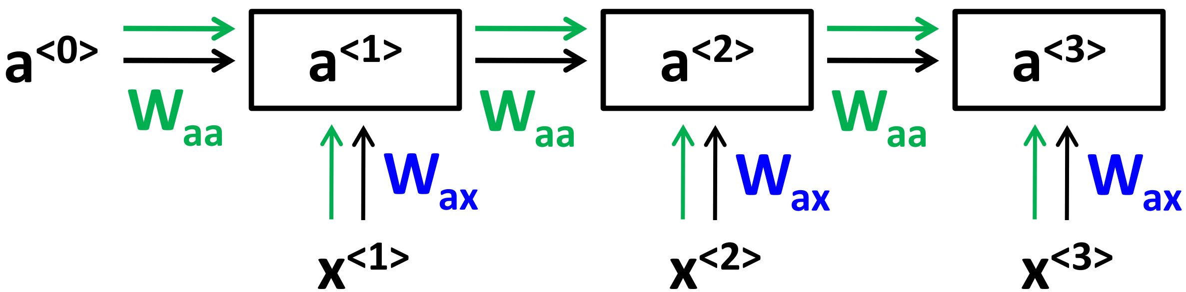
Back propagation through time

- $a^{<2>} = g(W_{aa}\, a^{<1>} + W_{ax}\, x^{<2>} + b_a)$



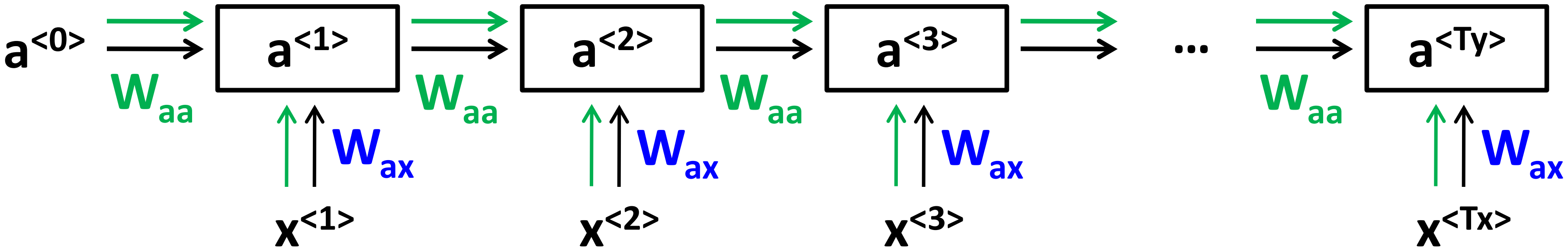
Back propagation through time

- $a^{<3>} = g(W_{aa}\, a^{<2>} + W_{ax}\, x^{<3>} + b_a)$



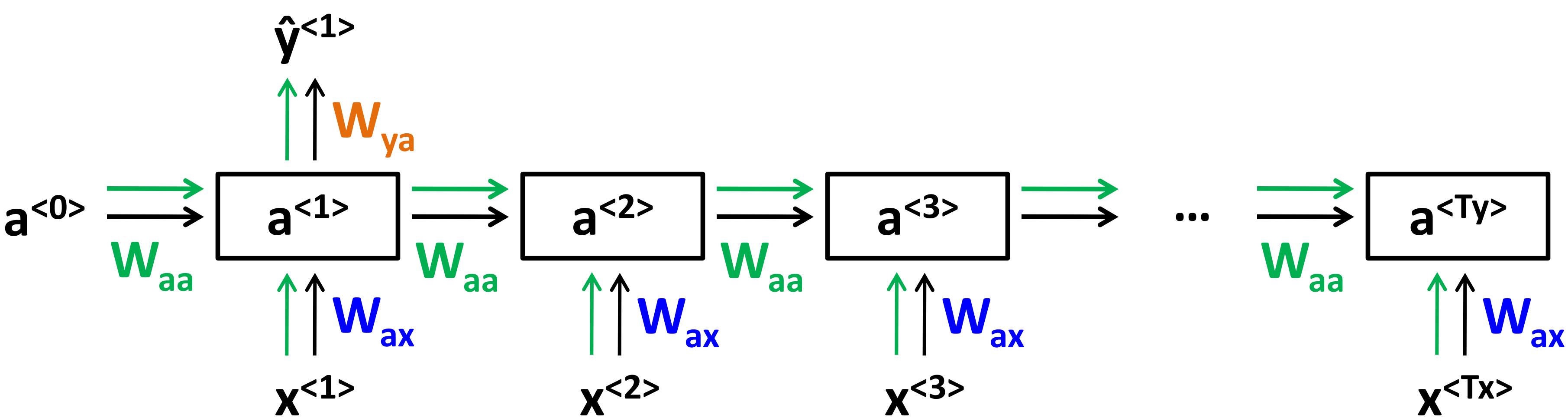
Back propagation through time

- $a^{<t>} = g(W_{aa}\, a^{<t-1>} + W_{ax}\, x^{<t>} + b_a)$



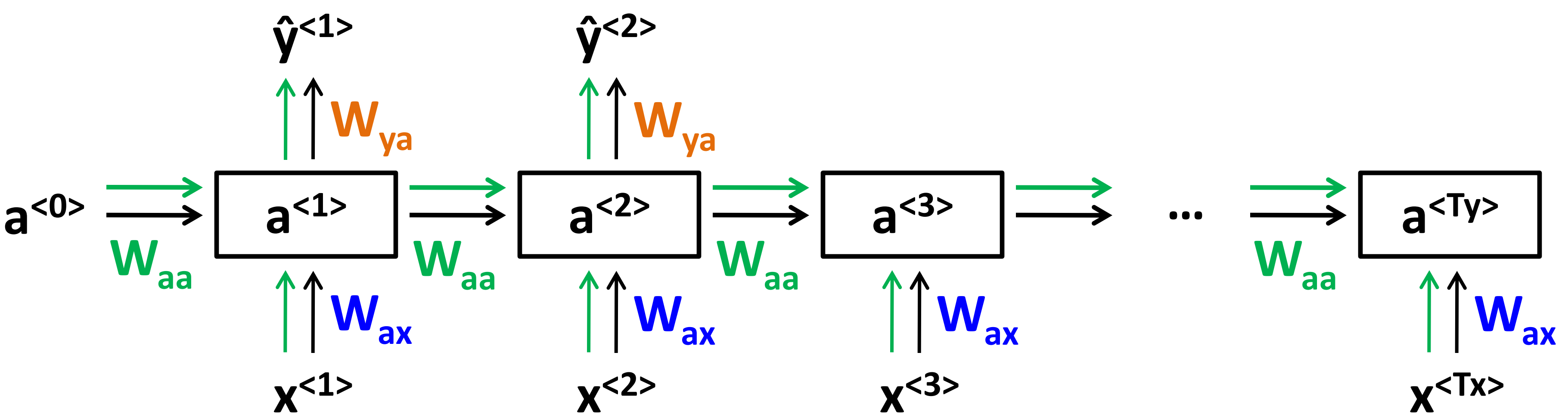
Back propagation through time

- $\hat{y}^{<1>} = g(W_{ya}\, a^{<1>} + b_y)$



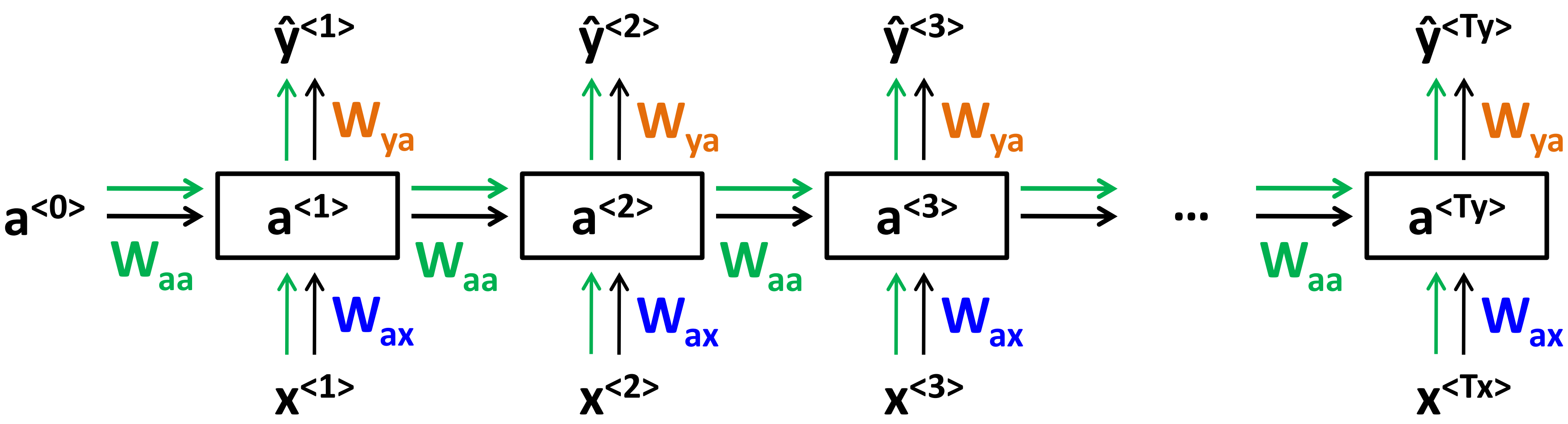
Back propagation through time

- $\hat{y}^{<2>} = g(W_{ya}\, a^{<2>} + b_y)$



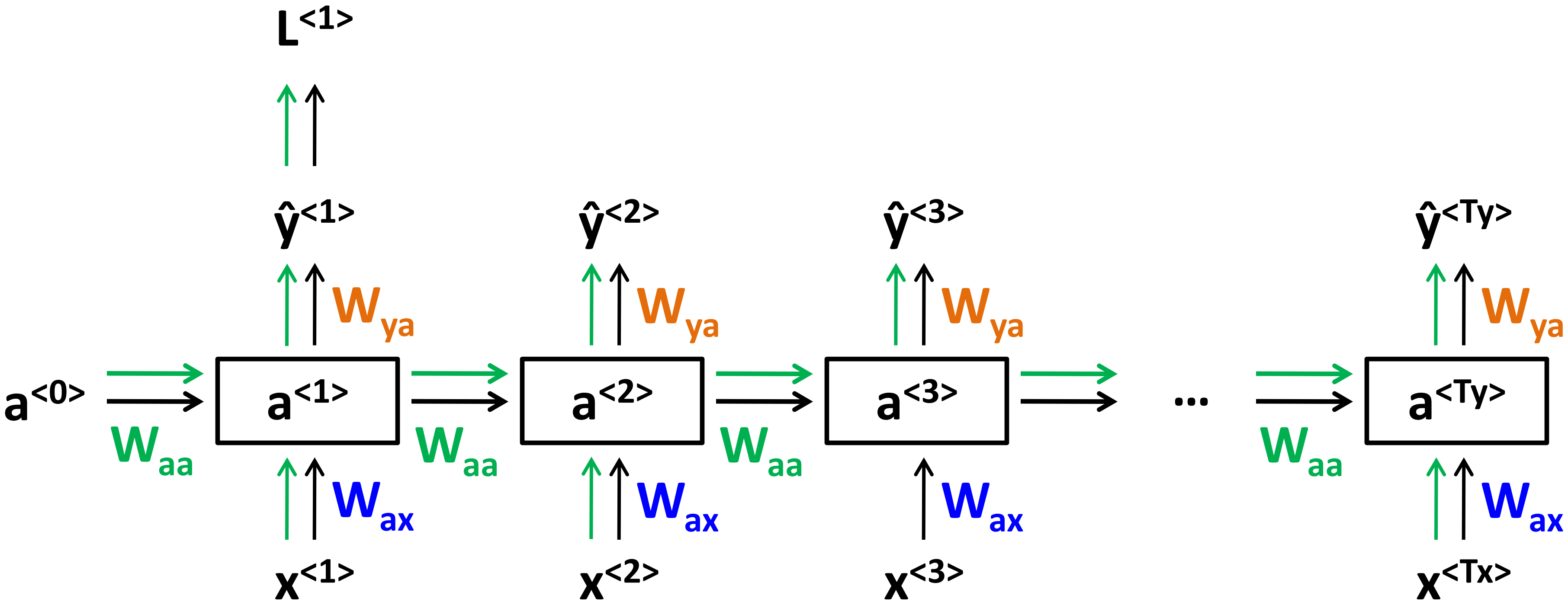
Back propagation through time

- $\hat{y}^{<t>} = g(W_{ya}\, a^{<t>} + b_y)$



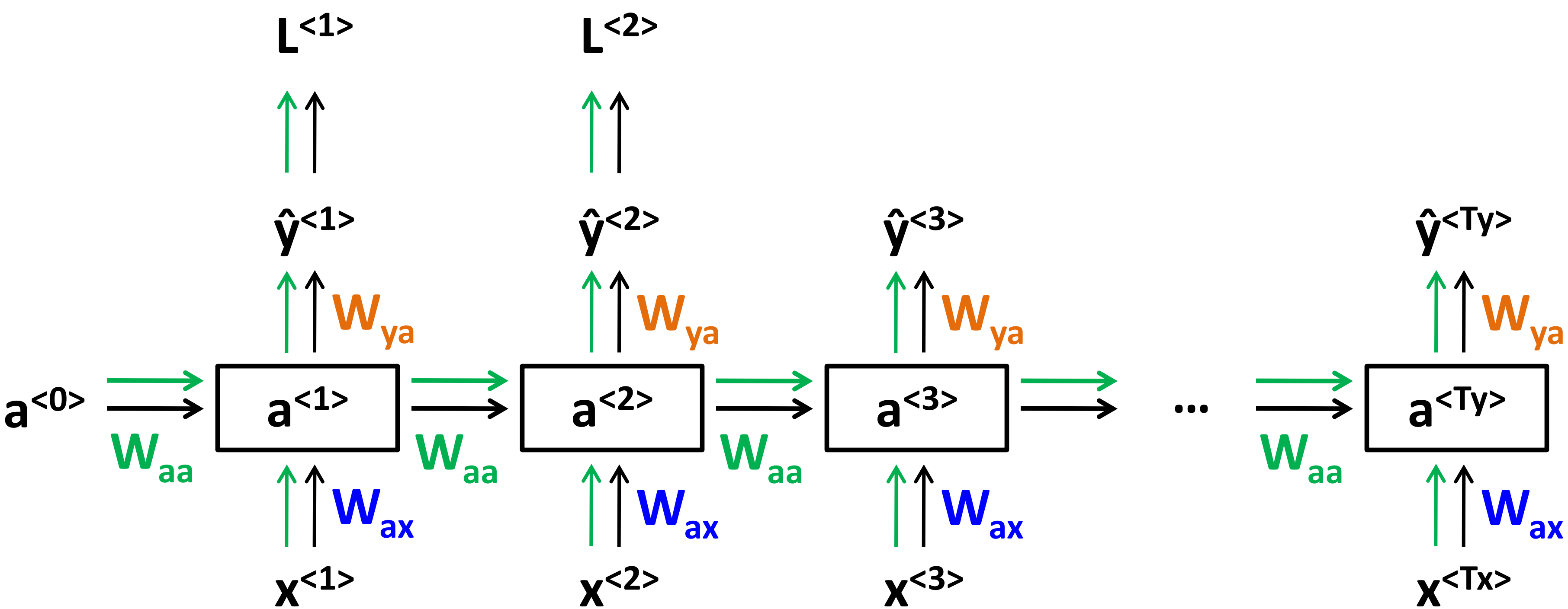
Back propagation through time

- $L^{<1>}(\hat{y}^{<1>}, y^{<1>}) = -y^{<1>} \log(\hat{y}^{<1>}) - (1-y^{<1>}) \log(1-\hat{y}^{<1>})$



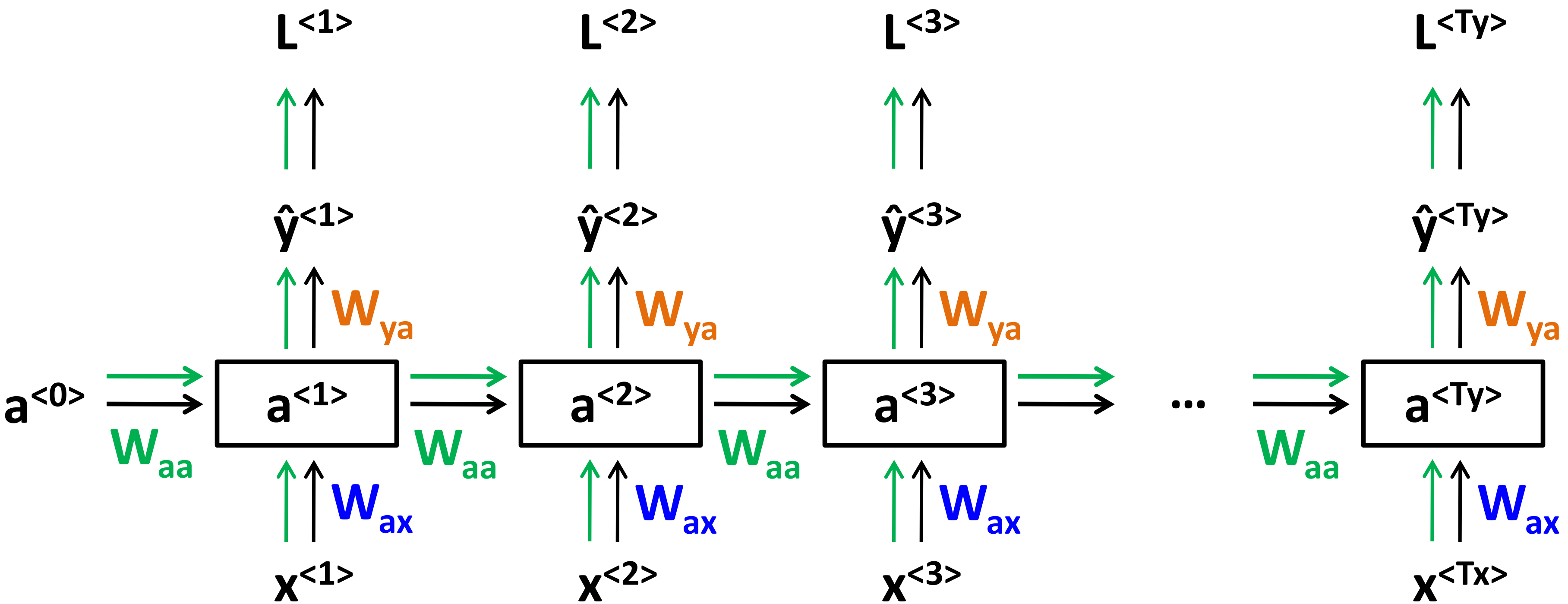
Back propagation through time

- $L^{<2>}(\hat{y}^{<2>}, y^{<2>}) = -y^{<2>}\log(\hat{y}^{<2>}) - (1-y^{<2>})\log(1-\hat{y}^{<2>})$



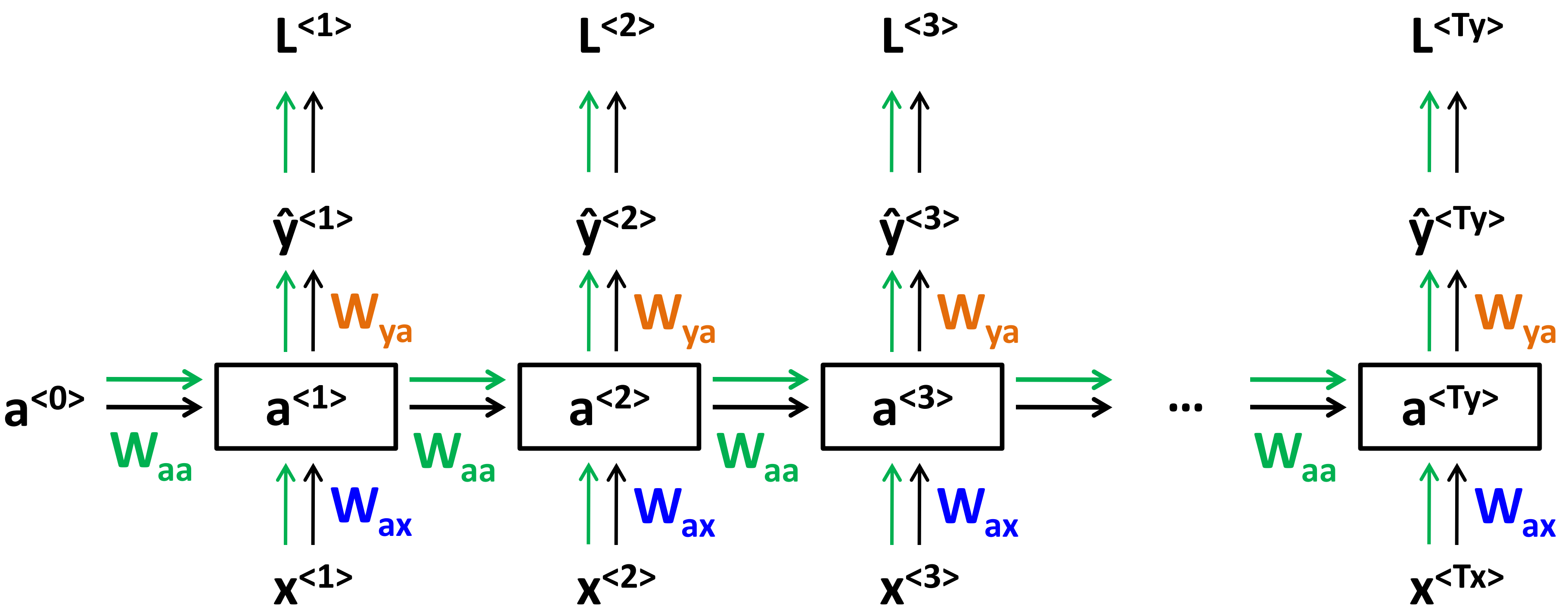
Back propagation through time

- $L^{<t>}(\hat{y}^{<t>}, y^{<t>}) = -y^{<t>}\log(\hat{y}^{<t>}) - (1-y^{<t>})\log(1-\hat{y}^{<t>})$



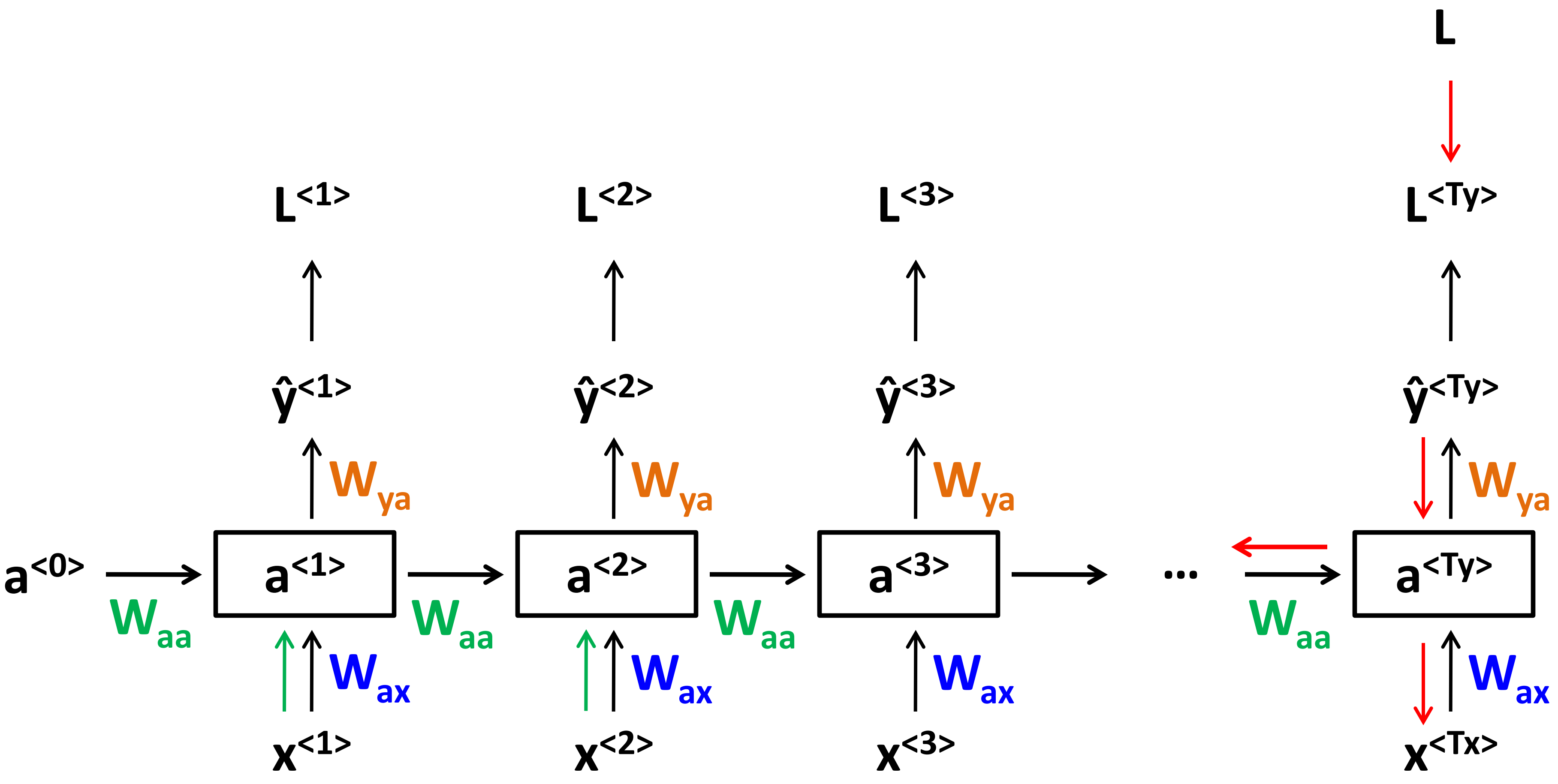
Back propagation through time

- $L(\hat{y}, y) = L^{<1>} + L^{<2>} + L^{<3>} + \ldots + L^{<Ty>}$



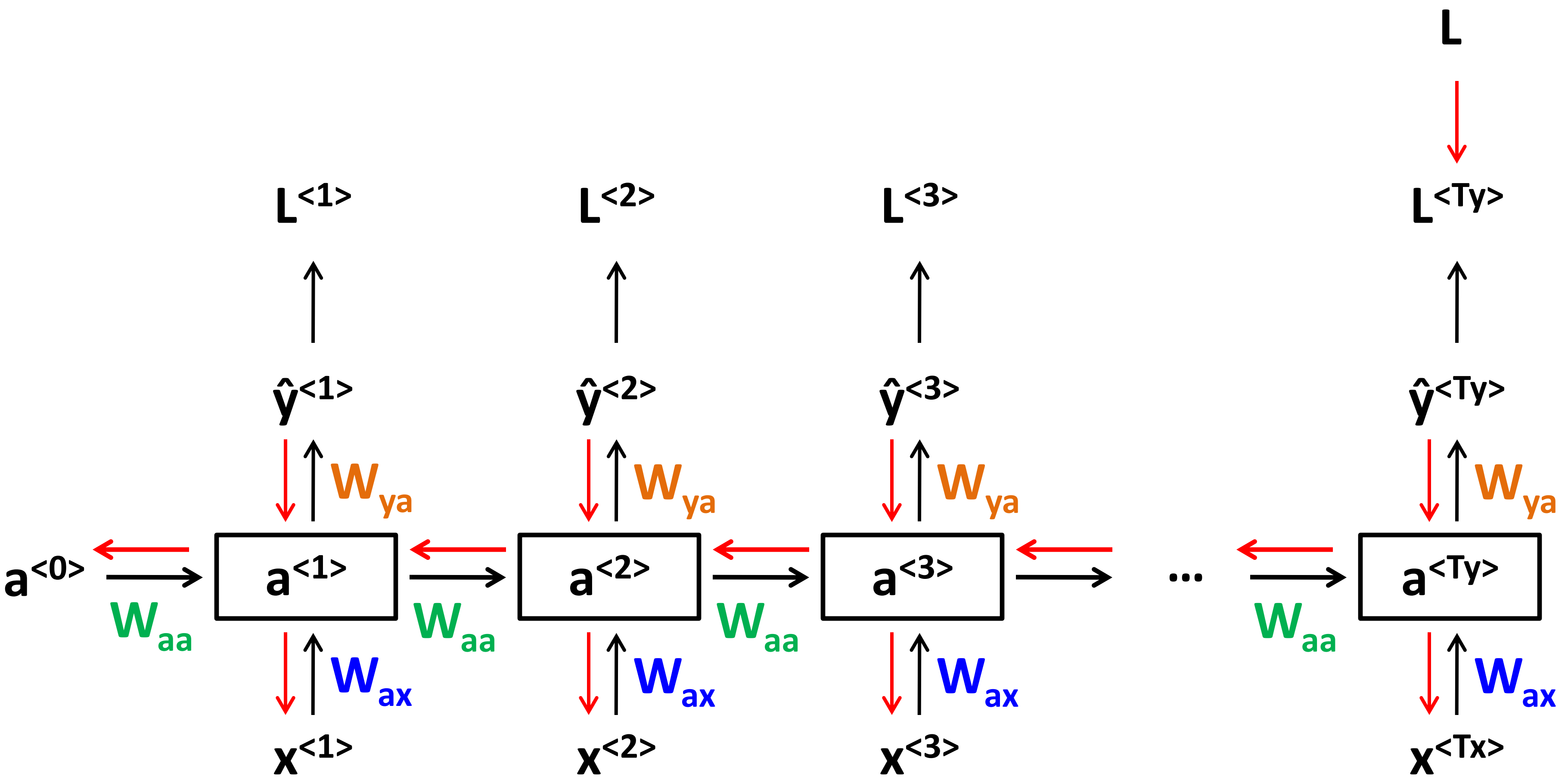
Back propagation through time

- $L(\hat{y}, y) = L^{\langle 1 \rangle} + L^{\langle 2 \rangle} + L^{\langle 3 \rangle} + \ldots + L^{\langle T_y \rangle}$



Back propagation through time

- $L(\hat{y}, y) = L^{<1>} + L^{<2>} + L^{<3>} + \ldots + L^{<T_y>}$

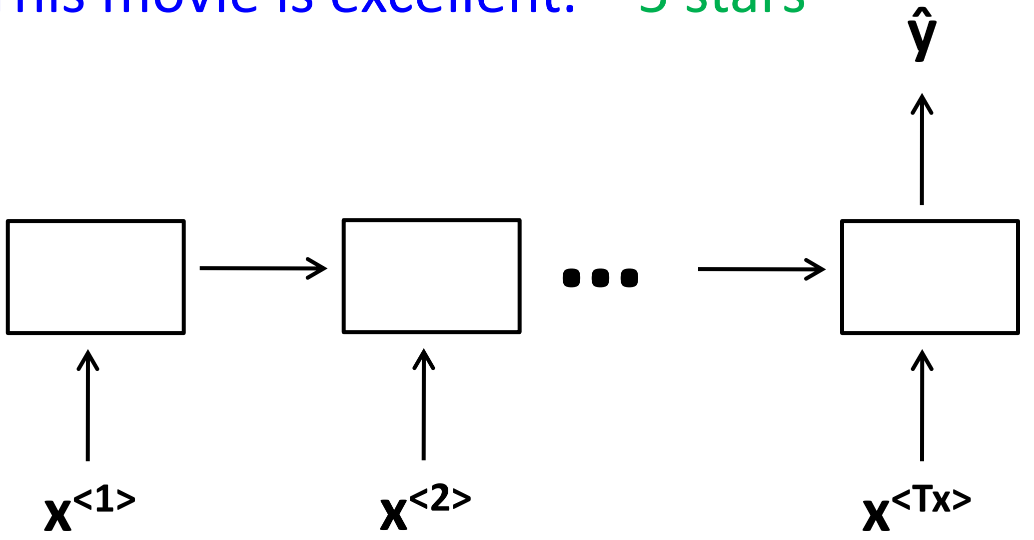


Different types of RNN

- Many to one
- One to many
- Many to many ($T_x = T_y$)
- Many to many (T_x != T_y)

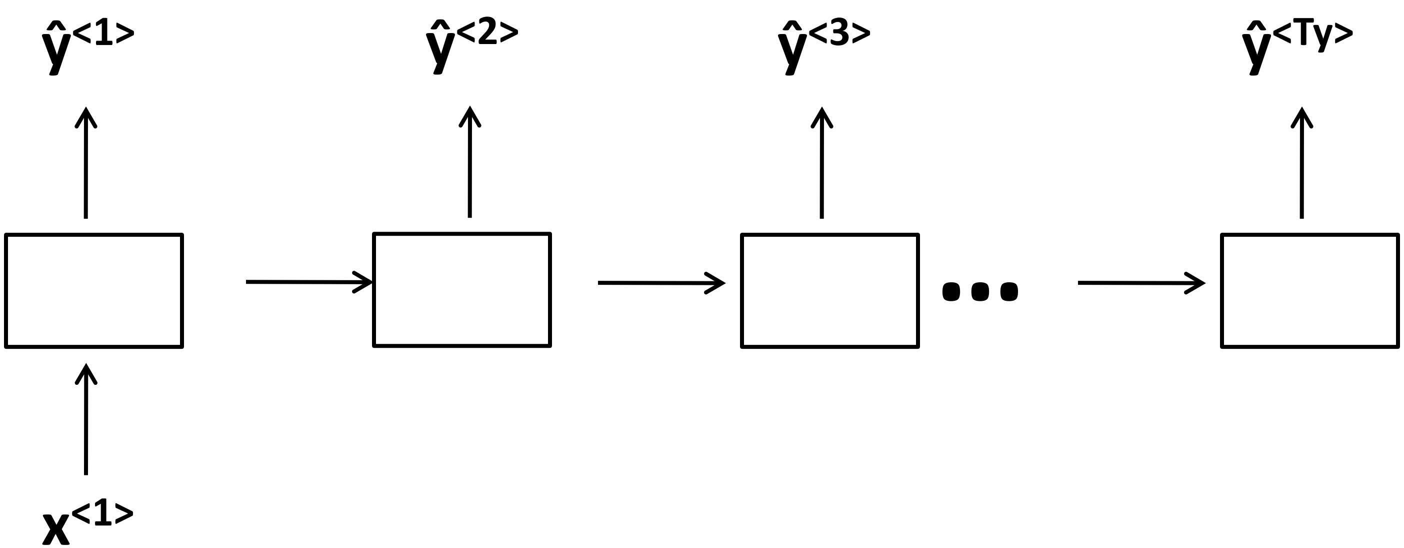
Different types of RNN – Many to one

- Sentiment classification
  - Input – Text – ($x^{<1>}$, $x^{<2>}$, … $x^{<Tx>}$) – Many
  - Output – Integer 1–5 – One
  - Example
    - This movie is excellent. – 5 stars



Different types of RNN – One to many

- Music generation
  - Input – Genre of music (integer) – One
  - Output – Set of notes – Many



Different types of RNN – One to many

- Music generation
  - Input – Genre of music (integer) – One
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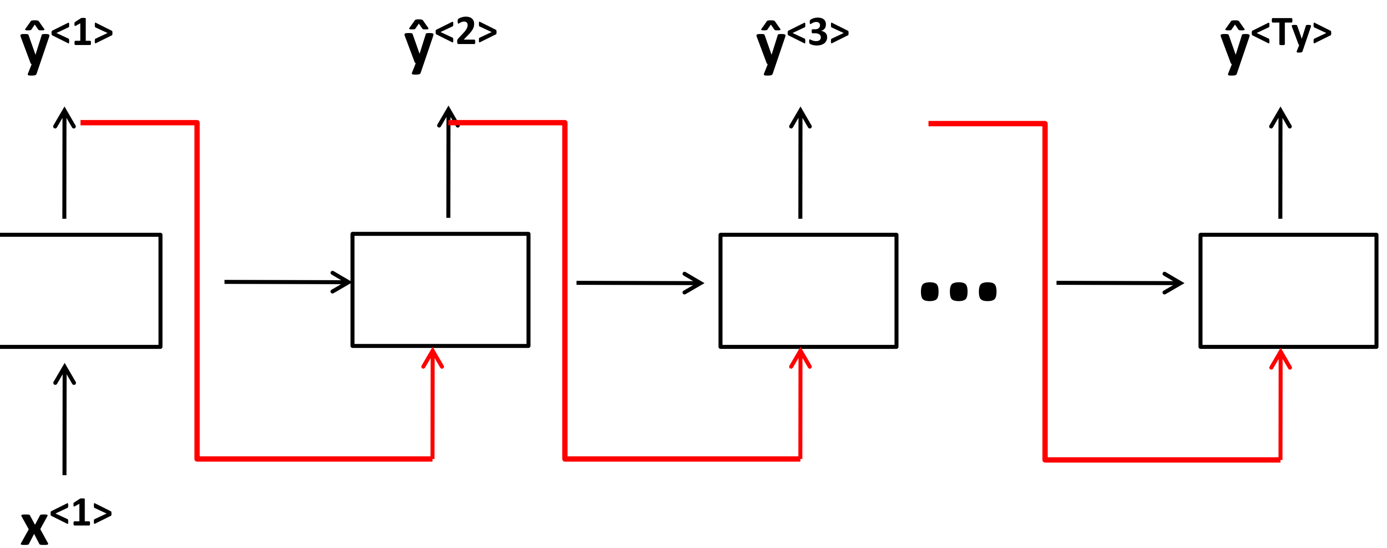
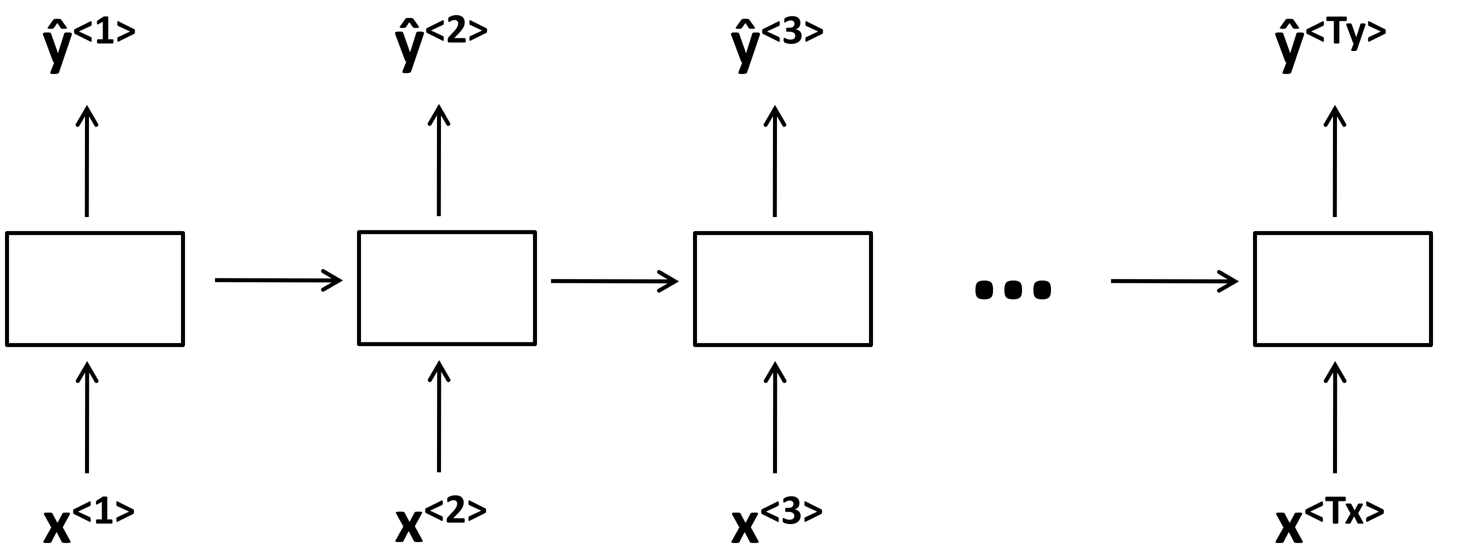


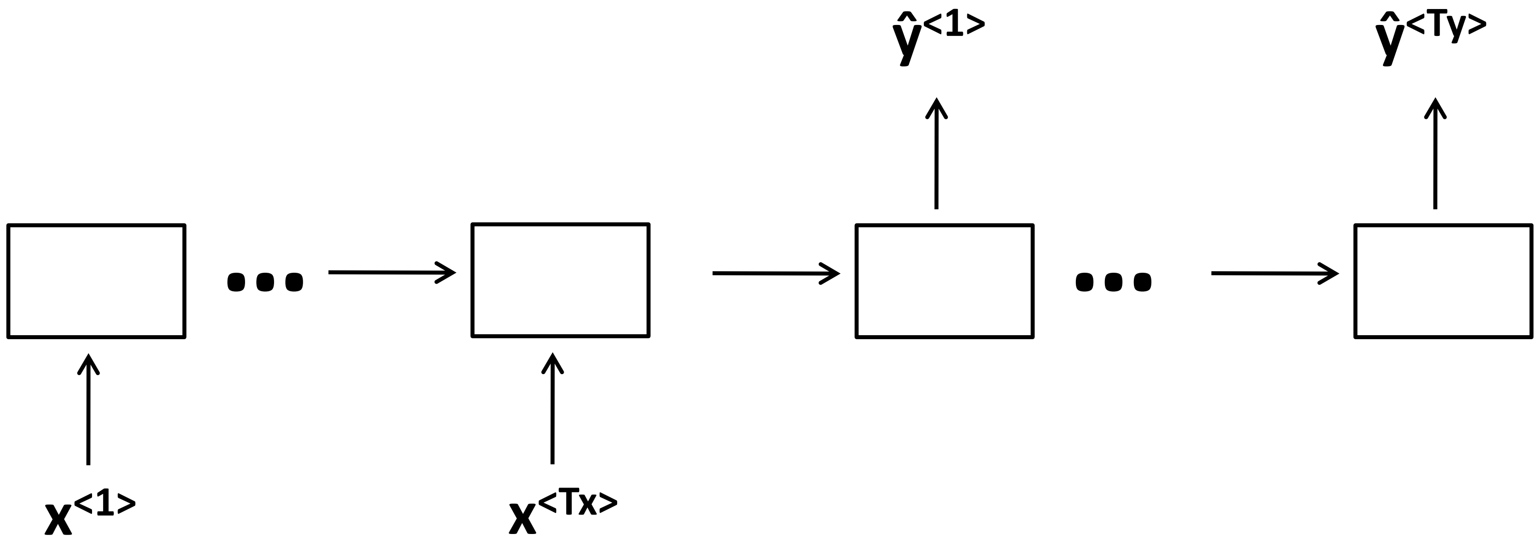
Different types of RNN – Many to many

- Name entity recognition ($T_x = T_y$)
  - Input – Text – ($x^{<1>}$, $x^{<2>}$, … $x^{<Tx>}$) – Many
  - Output – Numbers – ($y^{<1>}$, $y^{<2>}$, … $y^{<Ty>}$) – Many
  - Example
    - Mumbai is capital of Maharashtra. – 1 0 0 0 1



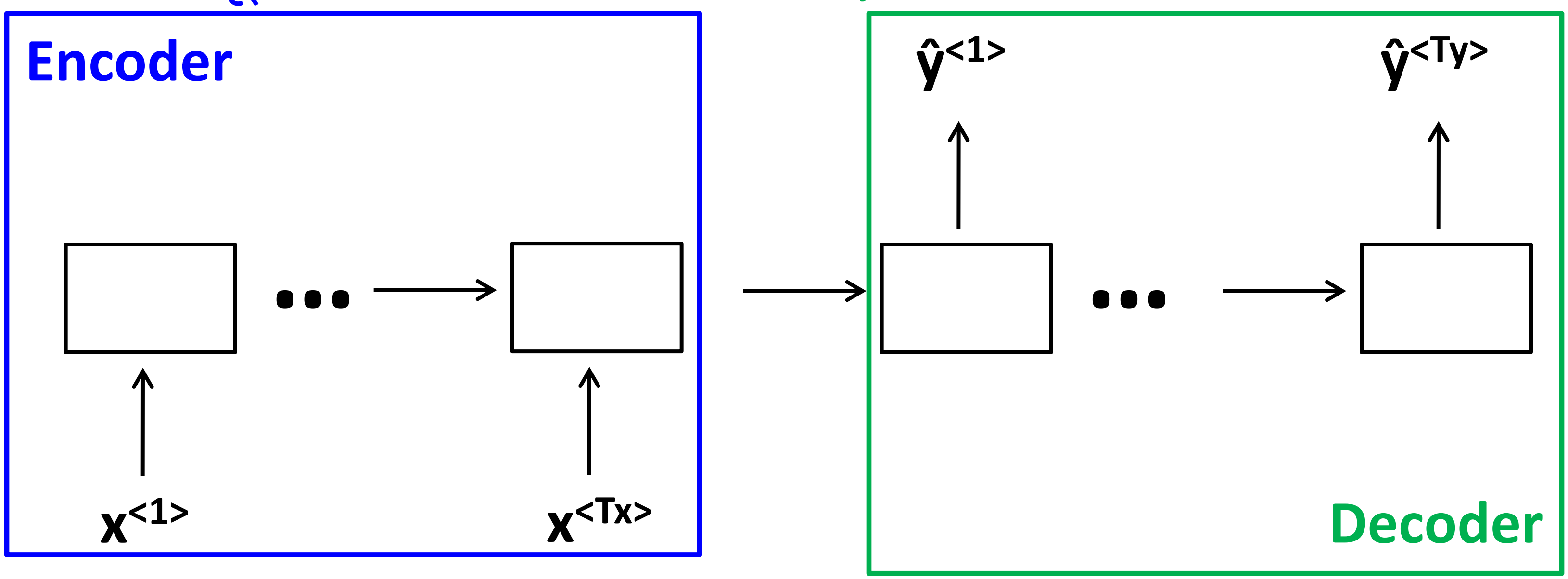
Different types of RNN – Many to many

- Machine translation (T_x != T_y)
  - Input – Text – ($x^{<1>}$, $x^{<2>}$, ... $x^{<Tx>}$) – Many
  - Output – Text – ($y^{<1>}$, $y^{<2>}$, ... $y^{<Ty>}$) – Many
  - Example
    - तू कसा आहेस? – How are you?



Different types of RNN – Many to many

- Machine translation (T_x != T_y)
  - Input – Text – ($x^{<1>}, x^{<2>}, \dots x^{<Tx>}$) – Many
  - Output – Text – ($y^{<1>}, y^{<2>}, \dots y^{<Ty>}$) – Many
  - Example
    - तू कसा आहेस? – How are you?



Questions?

Thank you