DATA ANALYSIS AND VISUALIZATION

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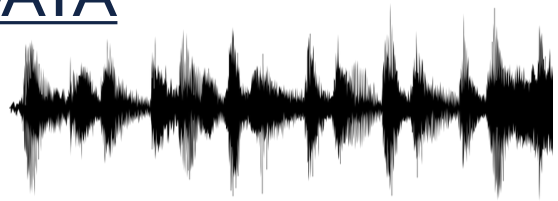
RECURRENT NEURAL NETWORK (RNN)

NOTE

- *Understanding Recurrent Neural Networks requires some effort and a correct perspective. Do not expect them to be as simple as linear regression.*

EXAMPLES OF SEQUENCE DATA

Speech recognition		→	"The quick brown fox jumped over the lazy dog."
Music generation	∅	→	
Sentiment classification	"There is nothing to like in this movie."	→	★☆☆☆☆
DNA sequence analysis	AGCCCCTGTGAGGAACTAG	→	AGCCCCTGTGAGGAACTAG
Machine translation	Voulez-vous chanter avec moi?	→	Do you want to sing with me?
Video activity recognition		→	Running
Name entity recognition	Yesterday, Harry Potter met Hermione Granger.	→	Yesterday, Harry Potter met Hermione Granger.

INPUT TYPES

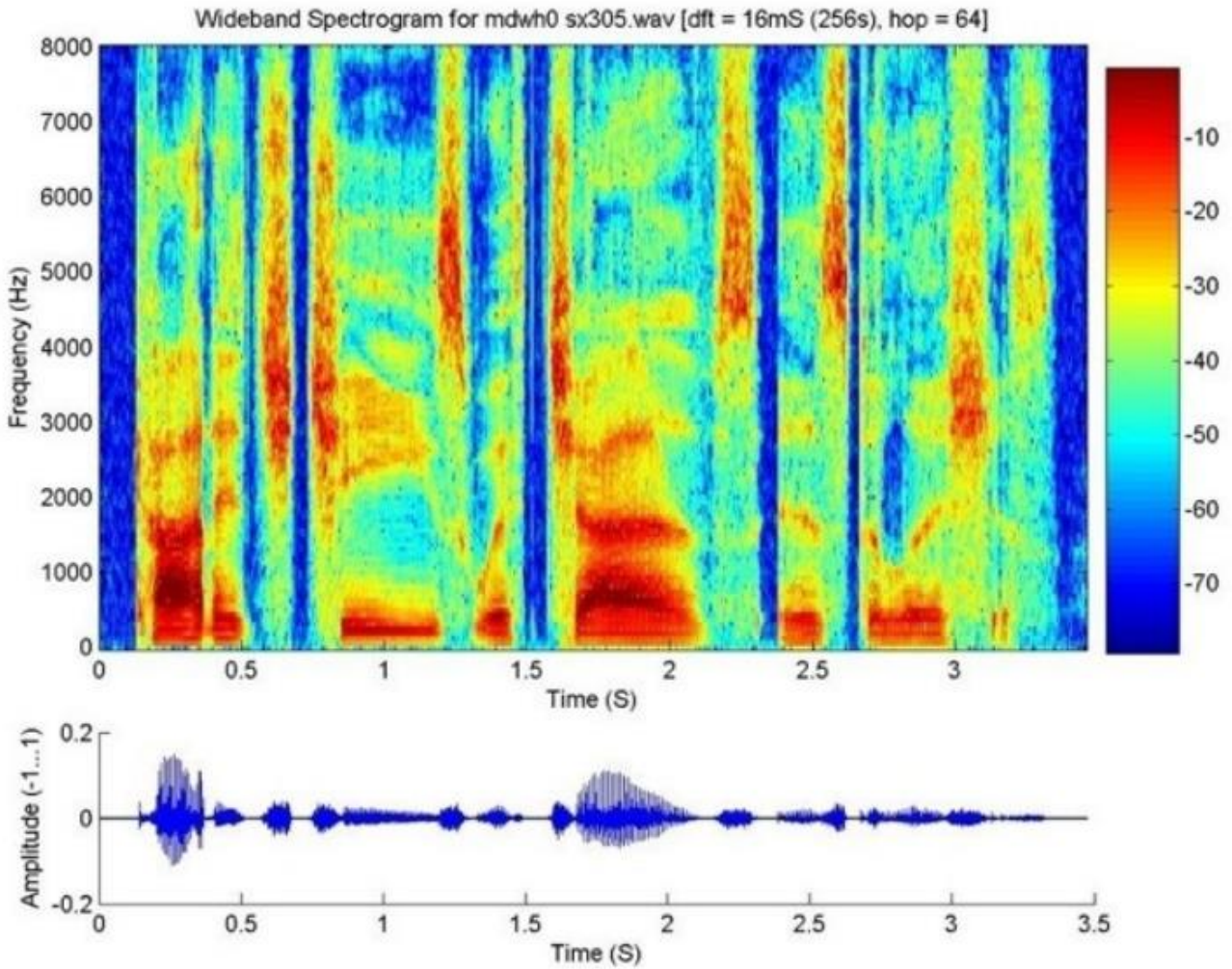
- *Static* signals, such as an image, do not change over time.
  - Ordered with respect to space.
  - Output depends on current input.
- *Dynamic* signals, such as text, audio, video or stock price change over time.
  - Ordered with respect to time.
  - Output depends on current input as well as past (or even future) inputs.
  - Also called *temporal*, *sequential* or *time-series* data.

CONTEXT IN TEXT

The Taj _____ was commissioned by Shah Jahan in 1631, to be built in the memory of ____ wife Mumtaz Mahal, who died on 17 June that year, giving birth to their 14th child, Gauhara Begum. Construction started in 1632, and the mausoleum was completed ____ 1643.

CONTEXT IN VIDEO

CONTEXT IN AUDIO



EXAMPLE

x: Harry Potter and Hermione Granger invented a new spell.

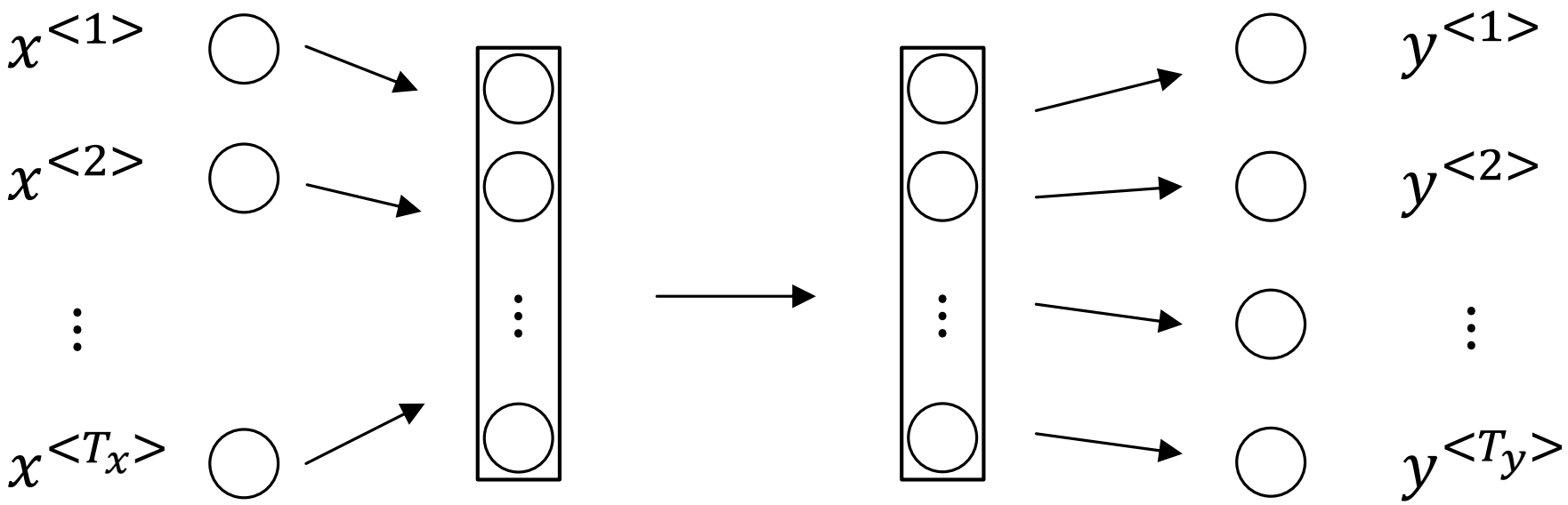
REPRESENTING WORDS

x: Harry Potter and Hermione Granger invented a new spell.

$x^{<1>}$ $x^{<2>}$ $x^{<3>}$ … $x^{<9>}$

And = 367
Invented = 4700
A = 1
New = 5976
Spell = 8376
Harry = 4075
Potter = 6830
Hermione = 4200
Gran… = 4000

WHY NOT A STANDARD NETWORK?

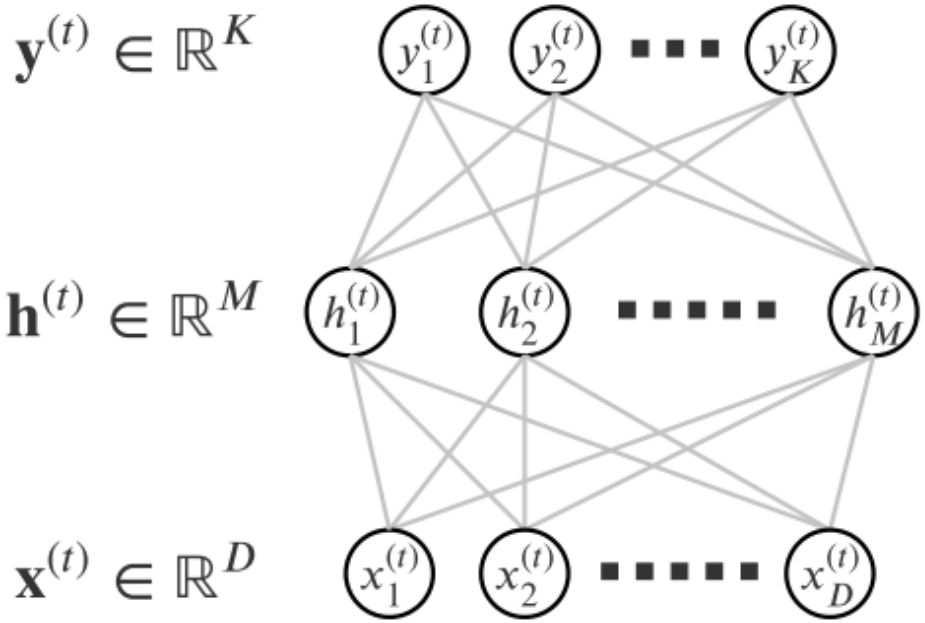


Problems:

- Inputs, outputs can be different lengths in different examples.
- Doesn't share features learned across different positions of text.

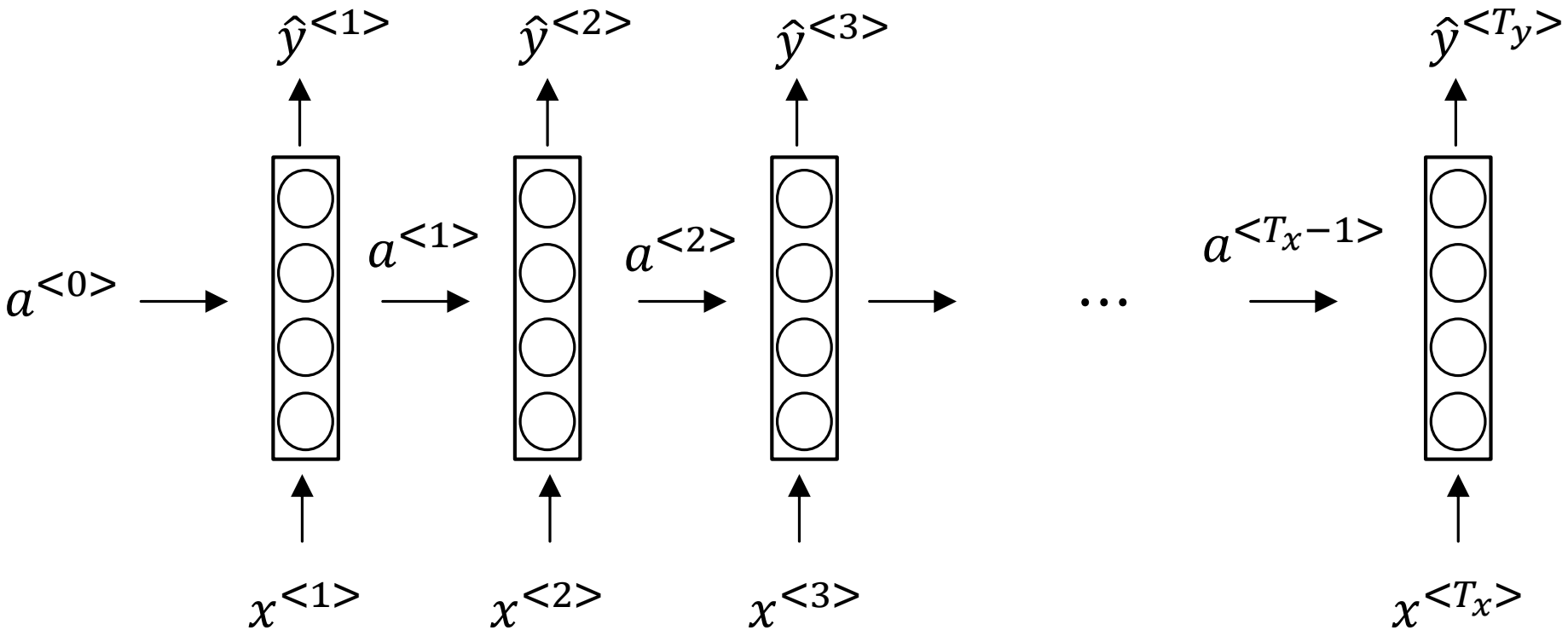
TIME SERIES DATA

- A *single* input will be a *series of vectors* $\mathbf{x}^1, \mathbf{x}^2, \ldots, \mathbf{x}^T$.

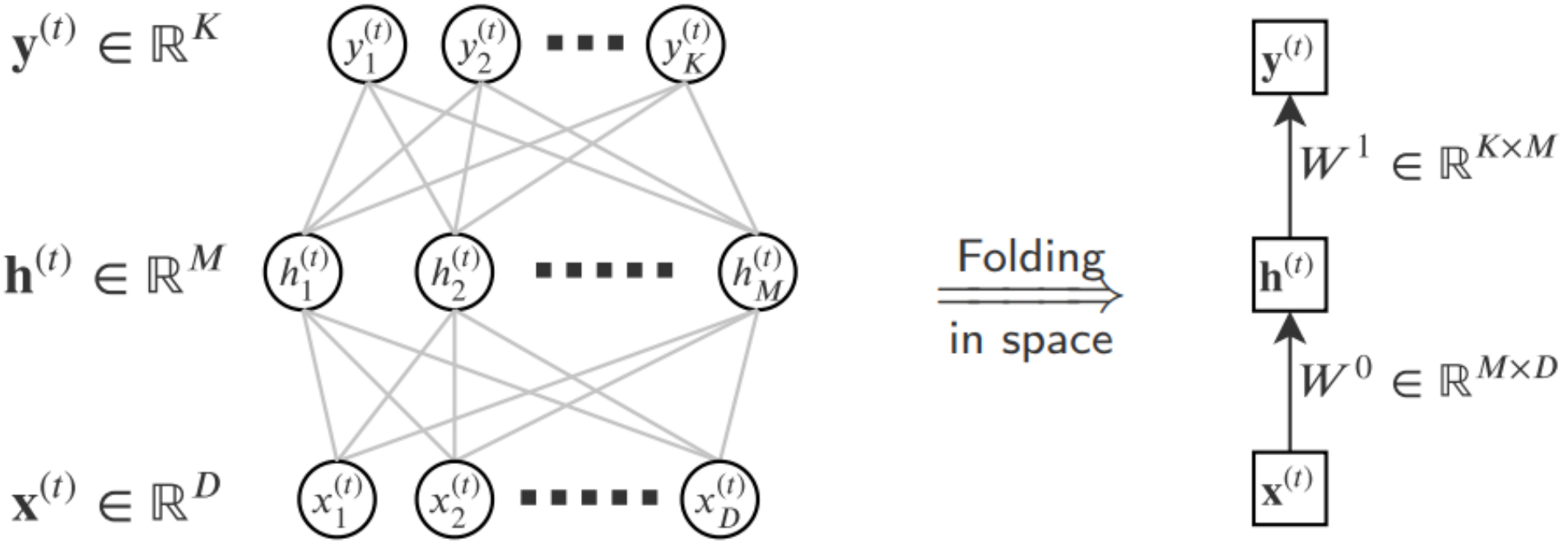


Input component at time t forward propagated through a network.

FORWARD PROPAGATION

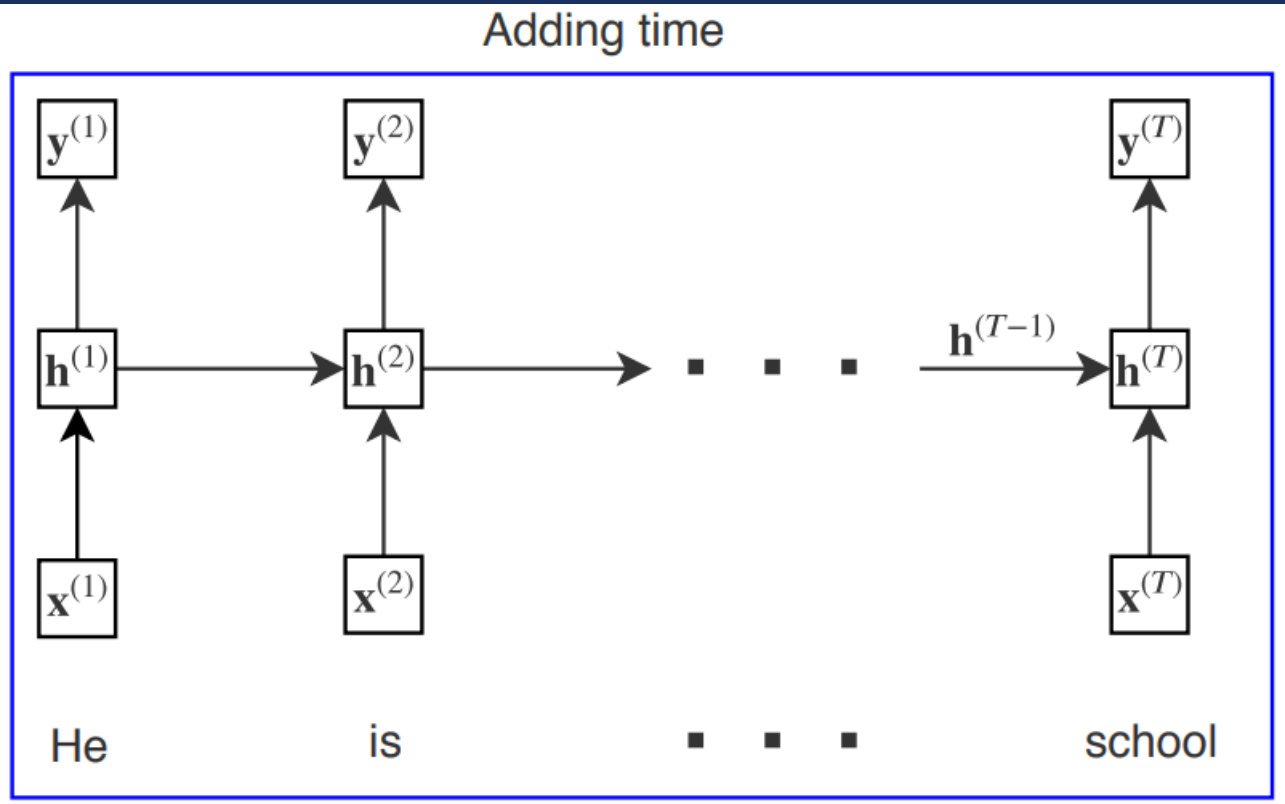


REPRESENTATIONAL SHORTCUT – FOLDING IN SPACE



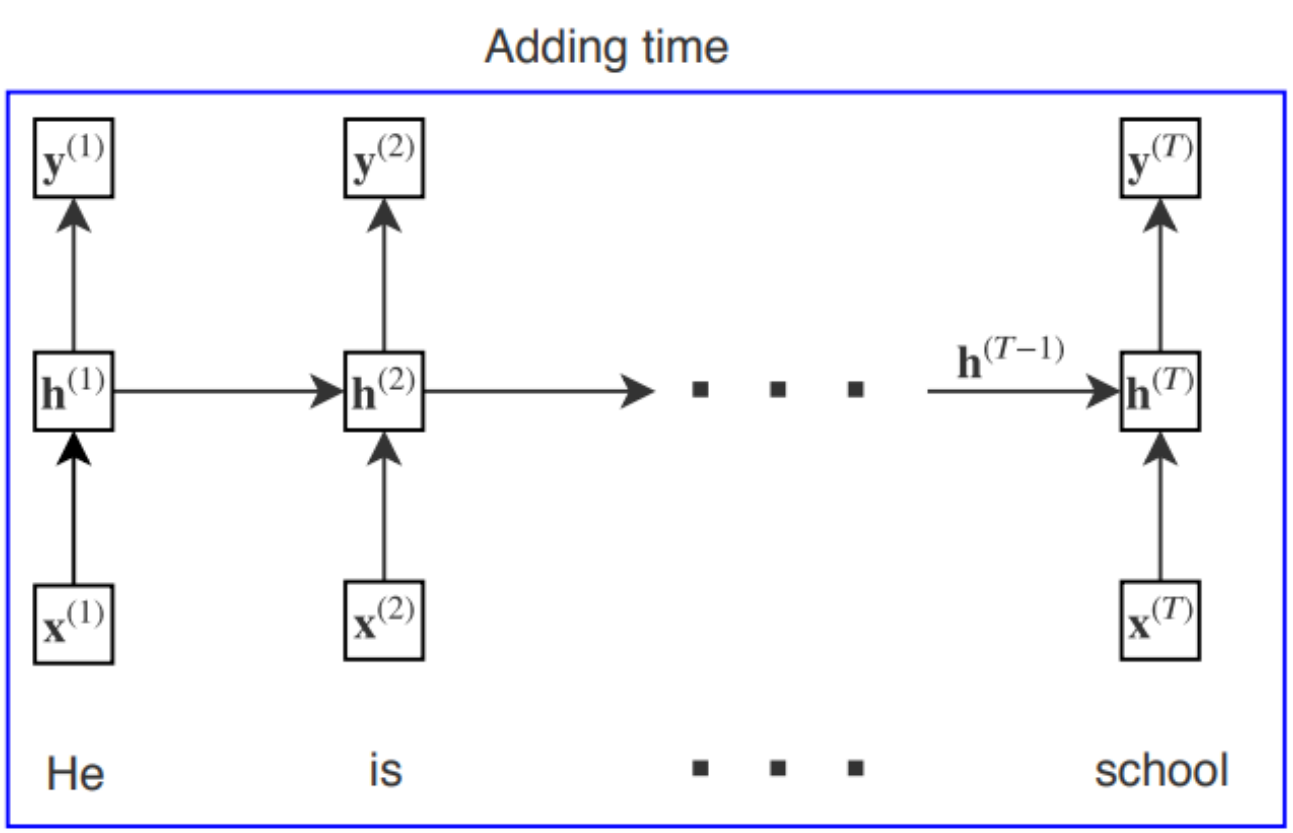
Each box represents a layer of neurons.

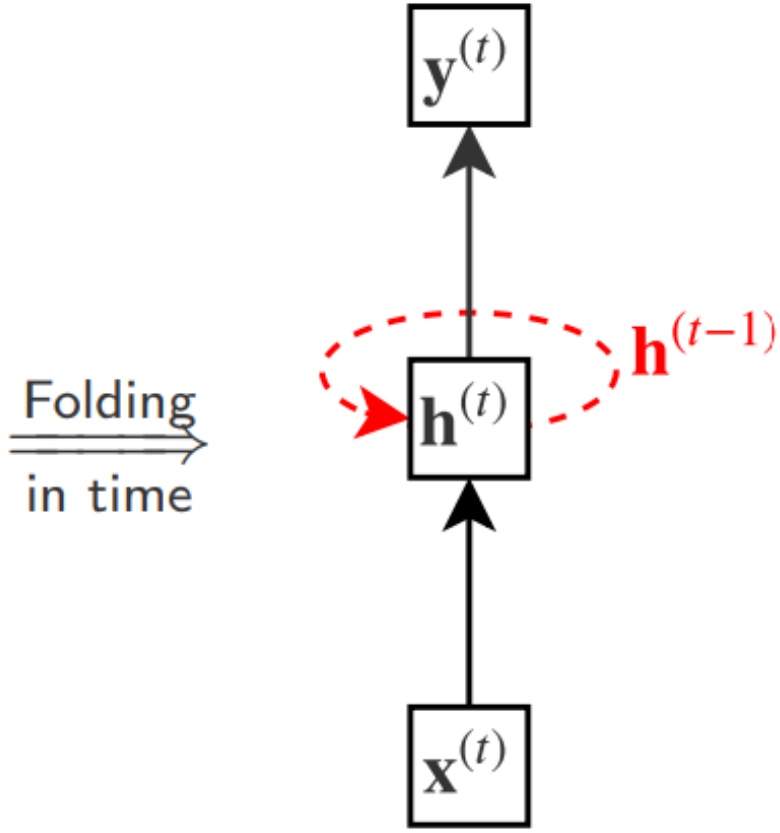
RECURRENT NEURAL NETWORK



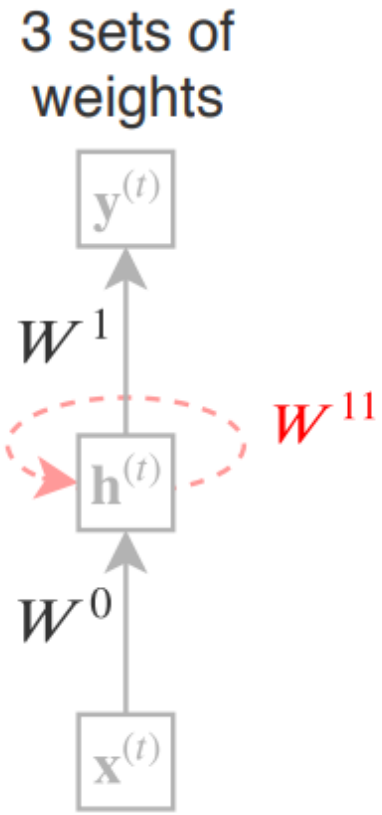
- A recurrent neural network (RNN) makes hidden state at time t directly dependent on the hidden state at time t-1 and therefore indirectly on all previous times.
- Output y^t depends on all that the network has already seen so far

REPRESENTATIONAL SHORTCUT – FOLDING IN TIME





RECURRENT NEURAL NETWORK

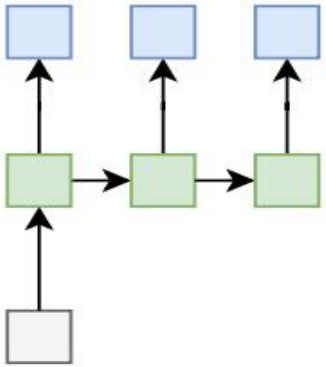


$$\mathbf{y}^{(t)} = f(\overbrace{W^1\mathbf{h}^{(t)} + \mathbf{b}_1}^{\mathbf{a}^{1(t)}})$$

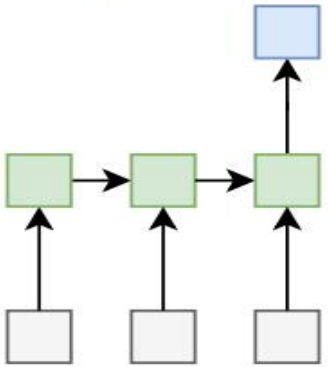
$$\mathbf{h}^{(t)} = \tanh(\underbrace{W^0\mathbf{x}^{(t)} + W^{11}\mathbf{h}^{(t-1)} + \mathbf{b}_0}_{\mathbf{a}^{0(t)}})$$

SEQUENCE MAPPINGS

One-to-many



Many-to-one



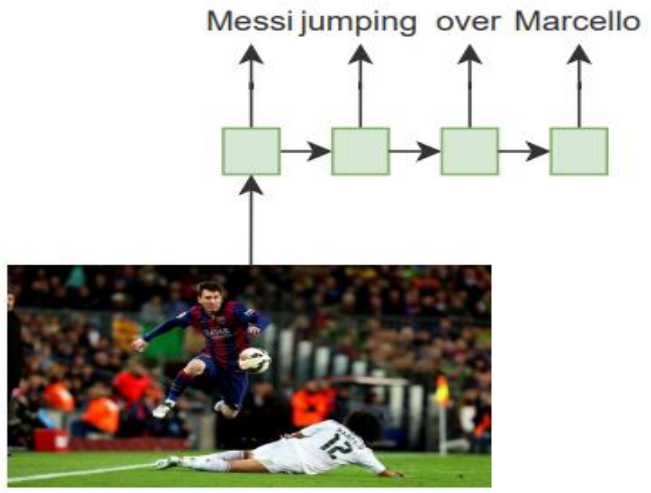
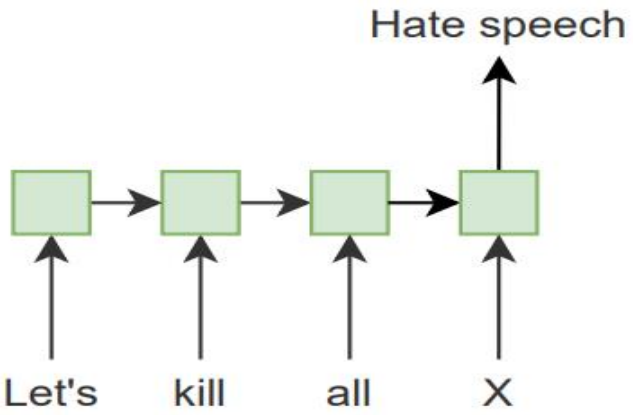


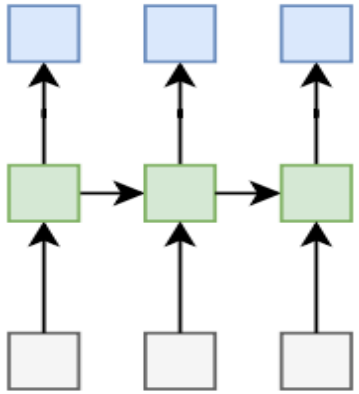
Image caption generation



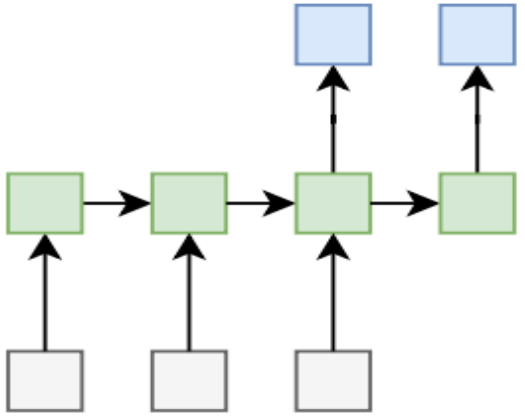
Sentiment classification

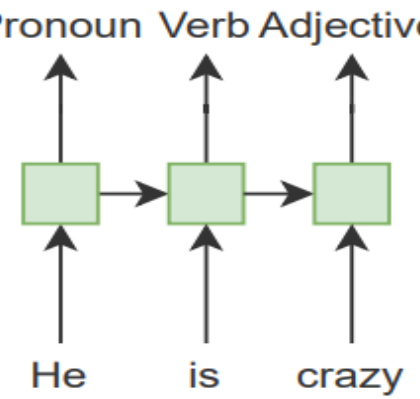
SEQUENCE MAPPINGS

Many-to-many

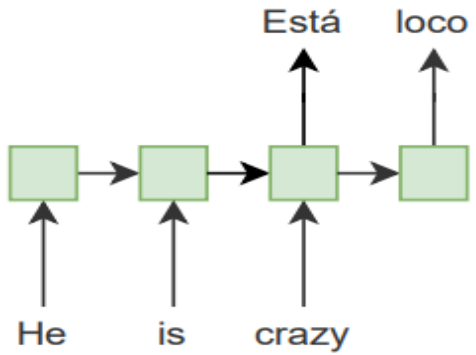


Many-to-many delayed



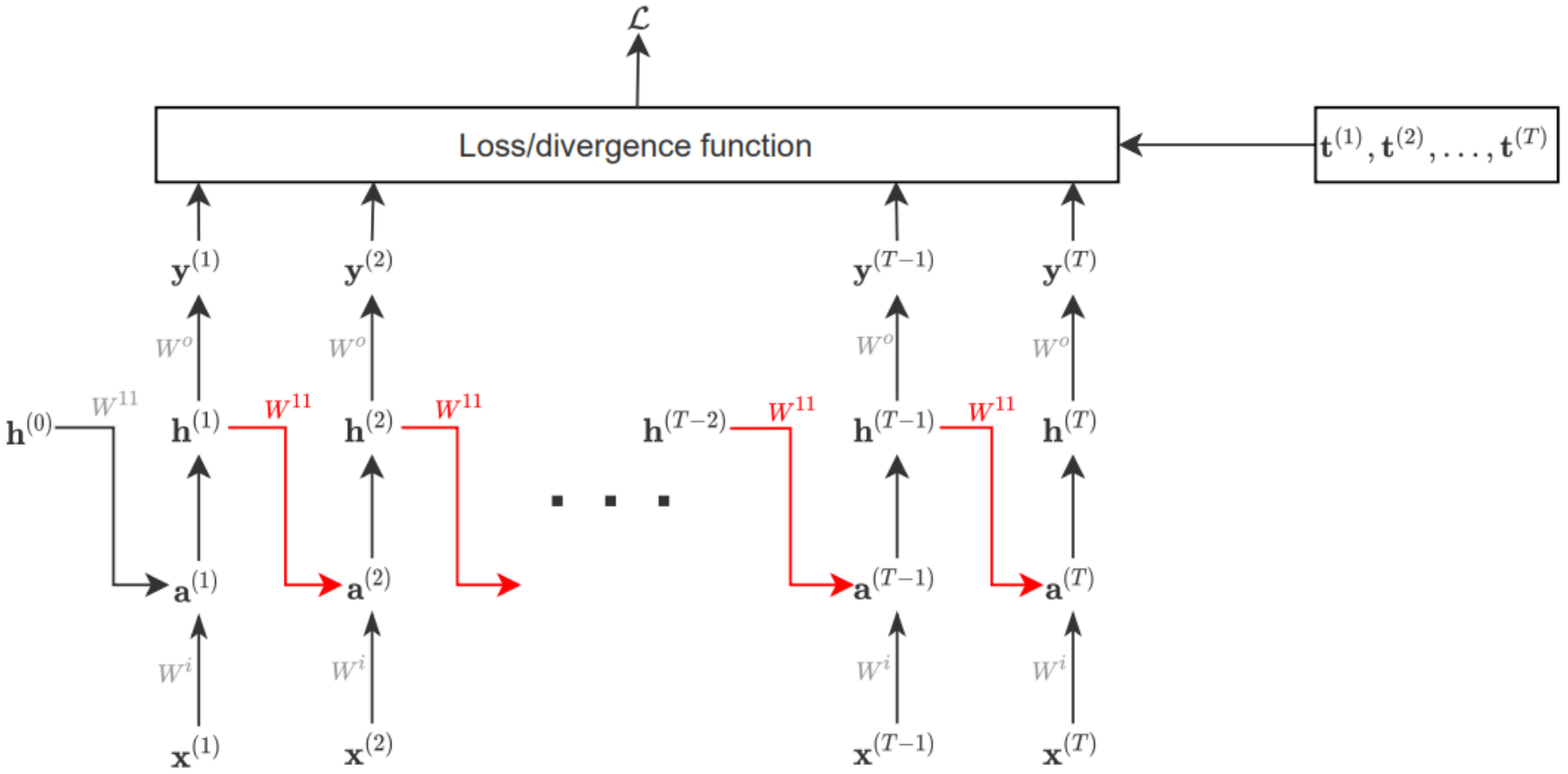


POS tagging



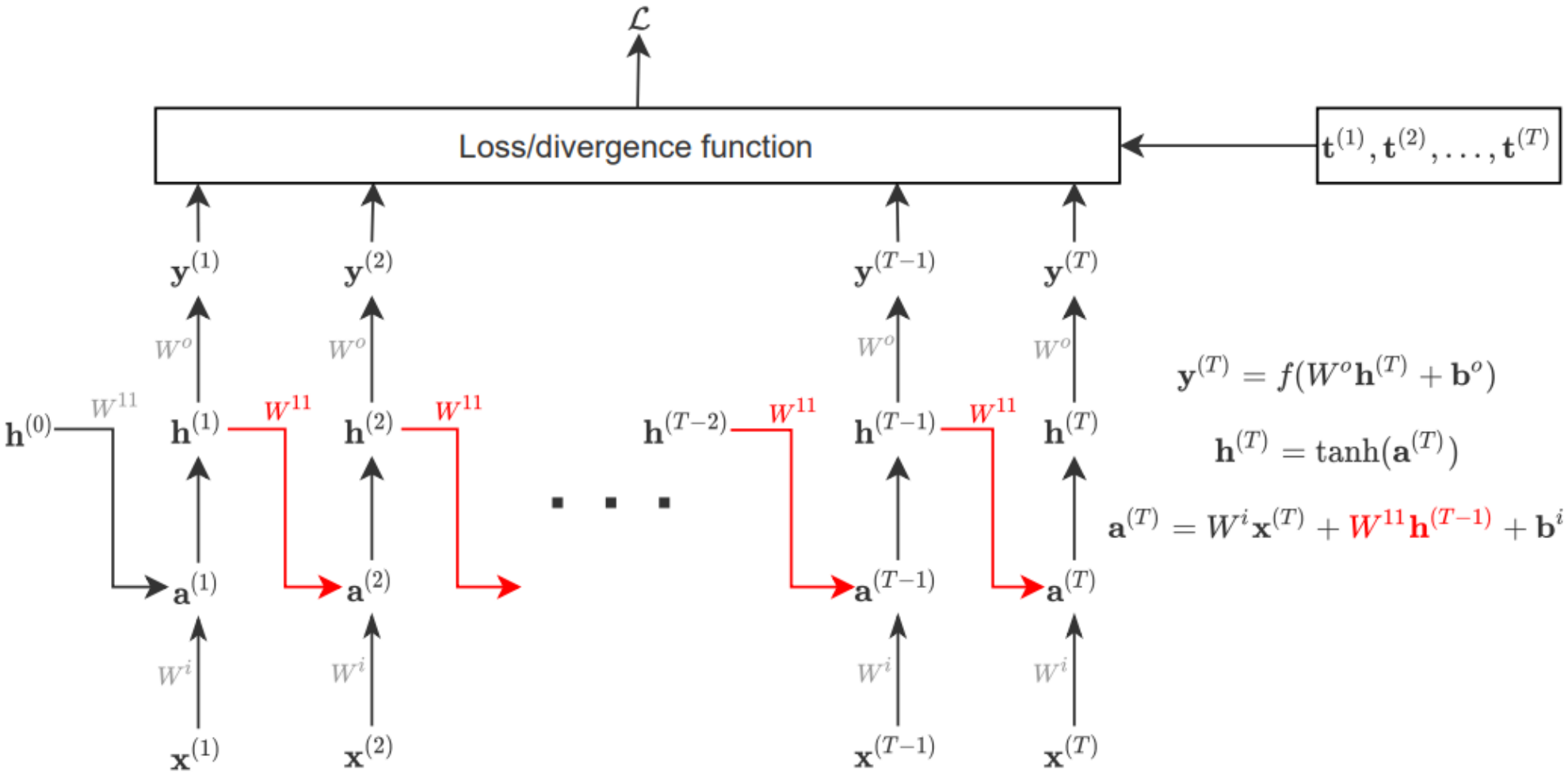
Language translation

FORWARD PROPAGATION THROUGH TIME

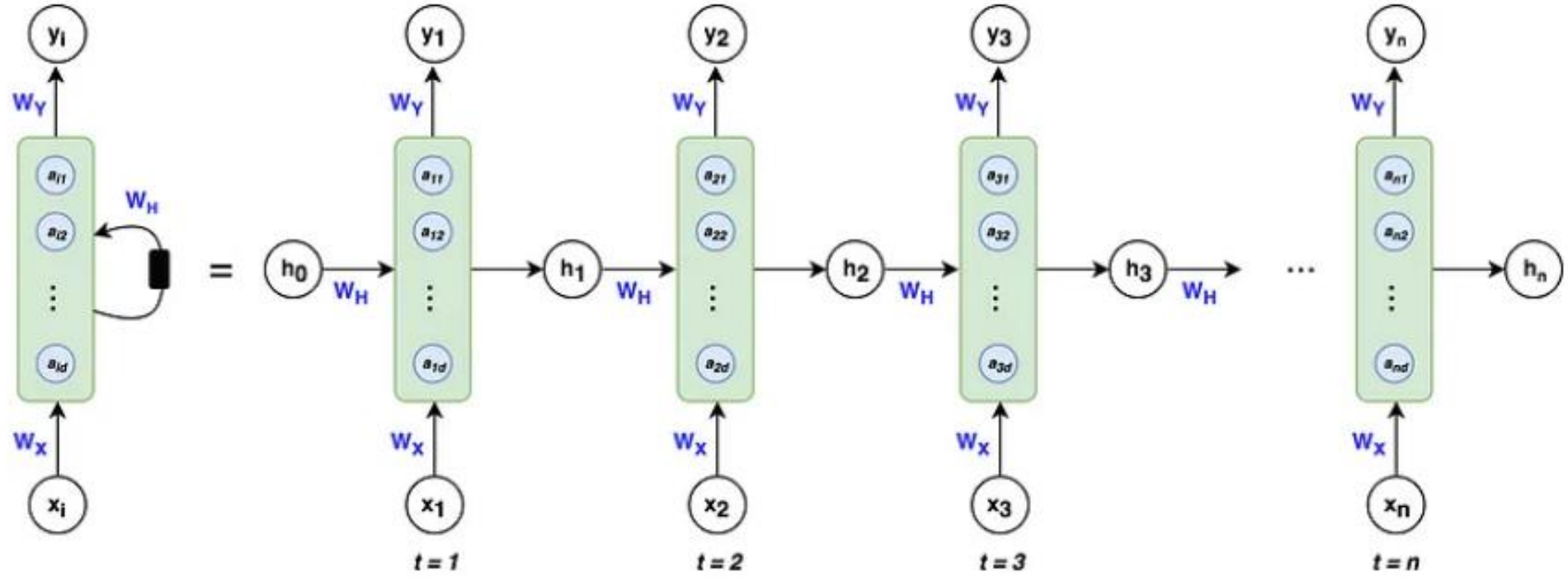


Forward propagation in an RNN unfolded in time. Recurrence between hidden states through pre-activation $\mathbf{a}^{(t)}$ is shown in red.

FORWARD PROPAGATION THROUGH TIME



SIMILAR OTHER NOTATIONS



VECTOR DIMENSIONS