AI Deep Learning: Recurrent Neural Networks

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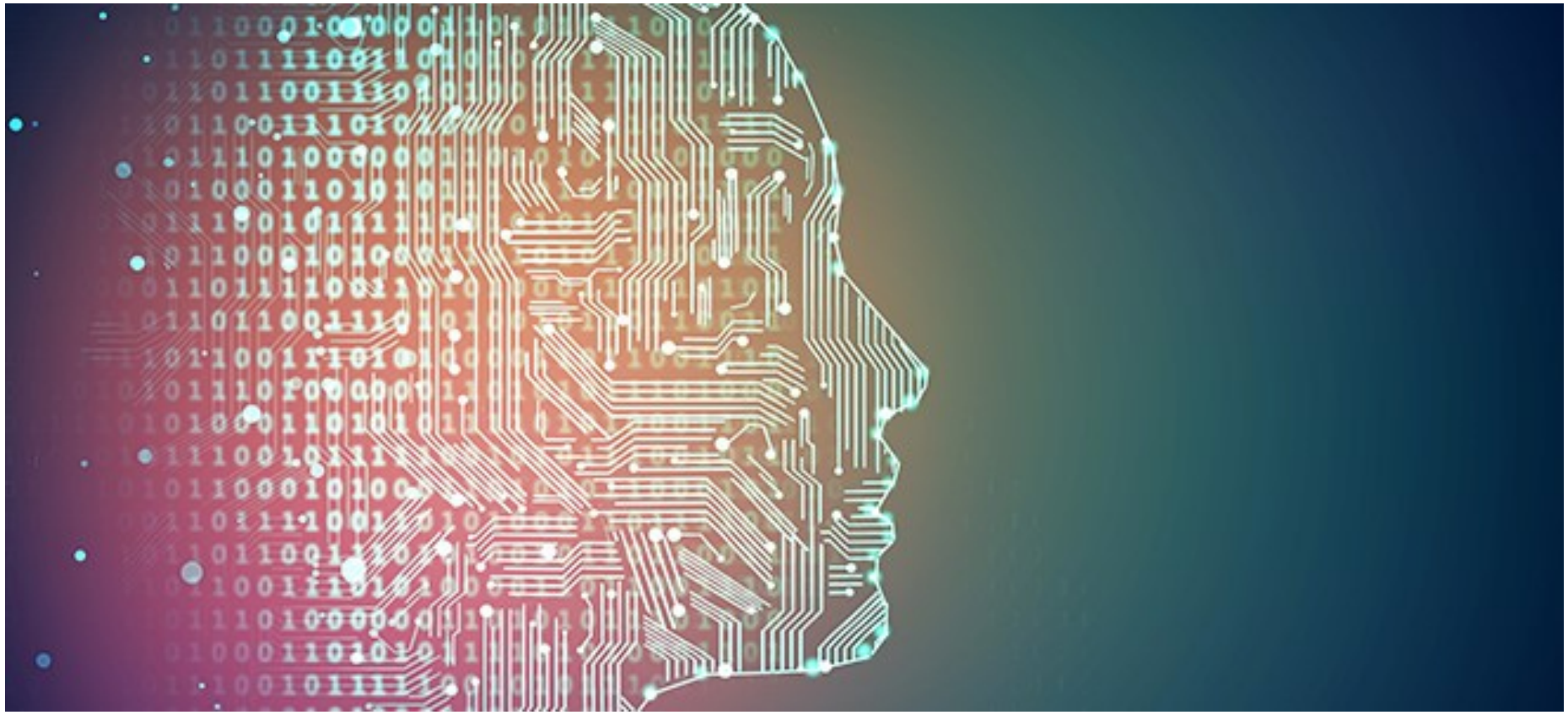
AI Deep Learning: Convolutional Neural Networks (CNN)



AI Deep Learning: Recurrent Neural Networks (RNN)

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2. Recurrent Neural Networks : Overview: Sequence Data: Properties
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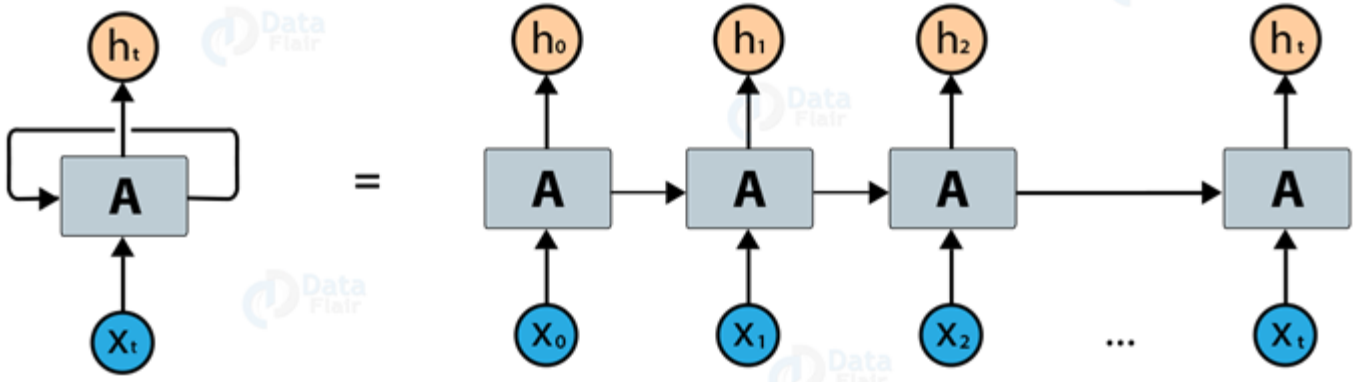
AI Deep Learning: Recurrent Neural Networks (RNN)

RNN: Overview: Sequence Data

- Persistence is a quality that makes humans different from machines.
  - Persistence in the sense that people never start thinking from scratch.
  - A person uses his/her previous **memory** to understand the current learning and makes decisions accordingly.

- For example:
  - Language is an instance of persistence.
  - When a person is talking or writing, the choice of one word is determined both by the words coming before it and those coming after it.



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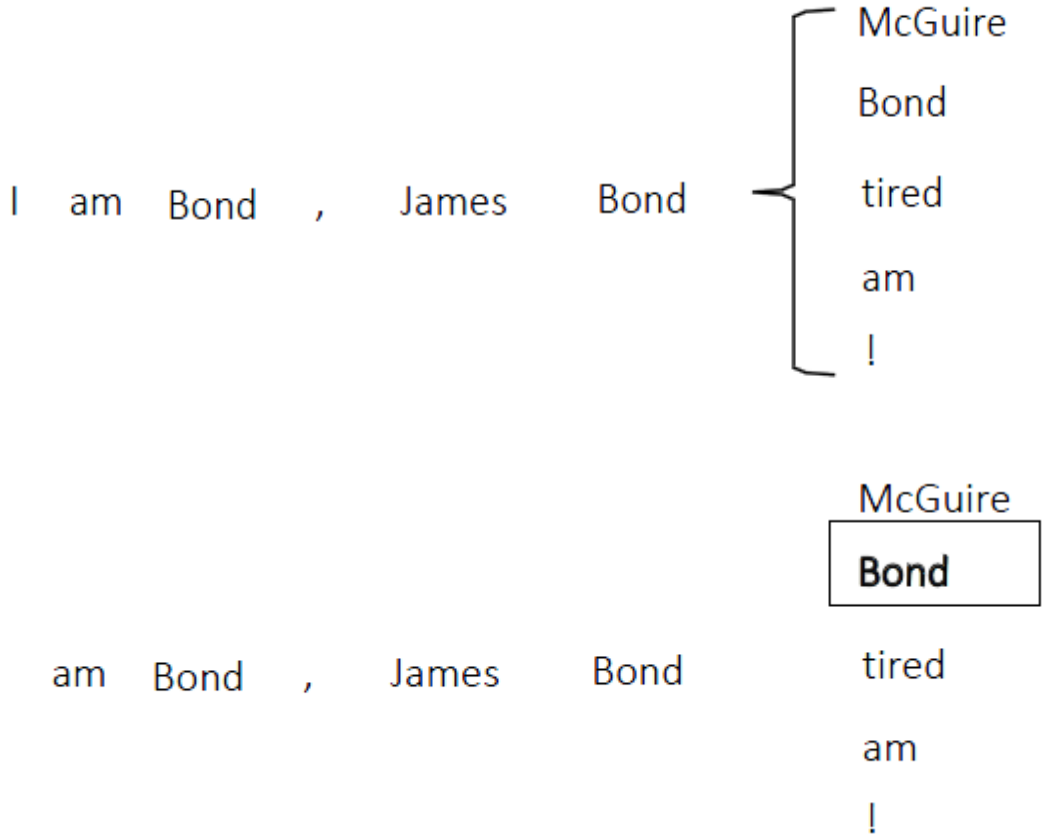
RNN: Sequence Data: Properties

- Data inside a sequence are non identically, independently distributed (IID)
  - The next "word" depends on the previous "words"
  - Ideally on all of them
- We need context, and we need memory!
- Big question: How to model context and memory ?



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RNN: Sequence Data: One-Hot Vectors

- Data A vector with all zeros except for the active dimension
  - For example: 12 words in a sequence → 12 One-hot vectors

Vocabulary	One-hot vectors							
I	I	1	I	0	I	0	I	0
am	am	0	am	1	am	0	am	0
Bond	Bond	0	Bond	0	Bond	1	Bond	0
James	James	0	James	0	James	0	James	1
tired	tired	0	tired	0	tired	0	tired	0
,	,	0	,	0	,	0	,	0
McGuire	McGuire	0	McGuire	0	McGuire	0	McGuire	0
!	!	0	!	0	!	0	!	0

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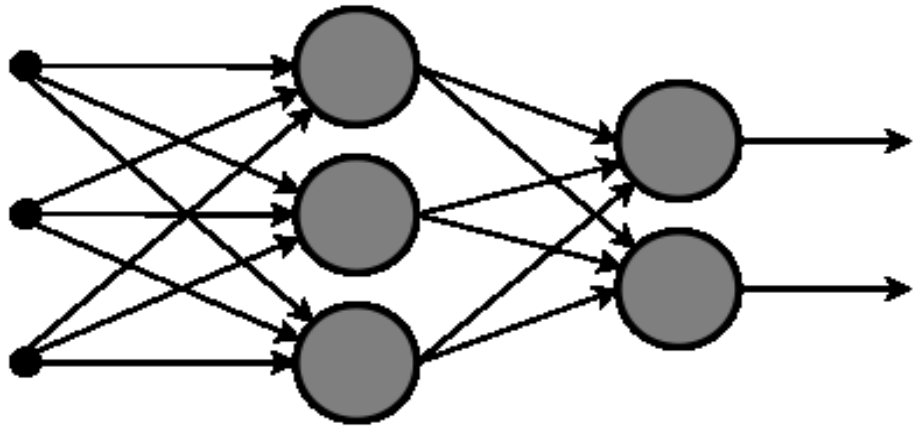
RNN: Overview: Sequence Data

- Feed-forward neural networks:
  - The output is a function between the inputs and a set of weights.
  - The information moves in only one direction, forward, from the input nodes, through the hidden nodes (if any) and to the output nodes.
  - There are no cycles or loops in the network.

- These networks are primarily used for pattern recognition:
  - It is not efficient to use them for handling sequence data



Feed-Forward Neural Network

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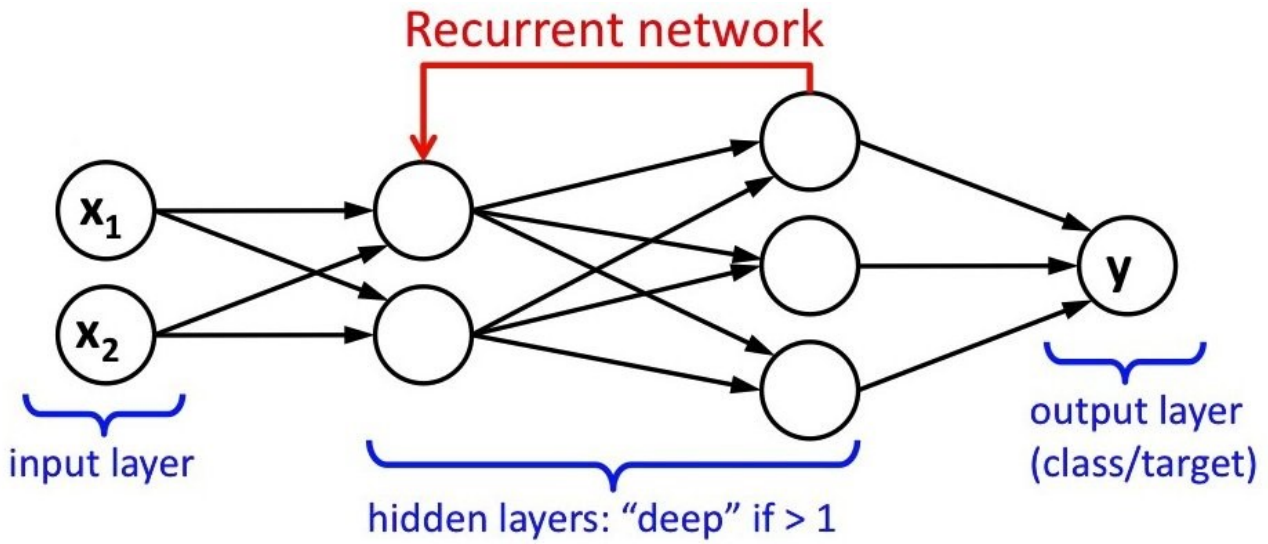
RNN: Overview

- Recurrent neural network (RNN) can handle sequential data successfully.
  - Previous network state also influences the output
    - The network has a "**notion of time**".
    - This effect by a **loop** on the layer output to it's input.
  - It is able to '**memorize**' parts of the inputs and use them to make accurate predictions.
  - RNN's are at the heart of speech recognition, translation and more.



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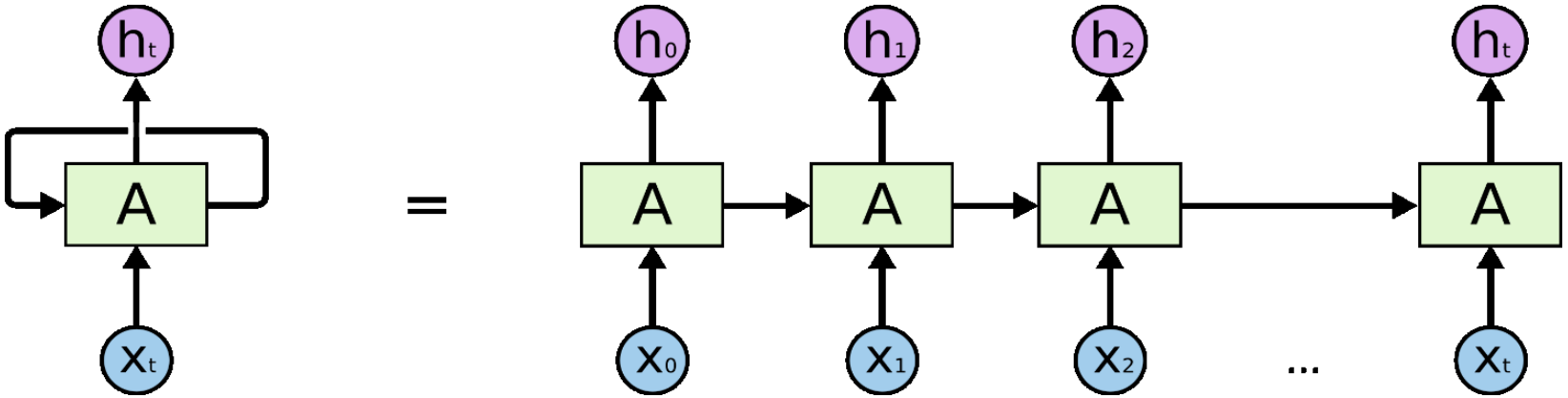
RNN: Overview



- The chain-like nature of the recurrent neural network:
  - Reveals that recurrent neural networks are intimately related to sequences and lists.
  - They're the natural architecture of neural network to use for such data.

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RNN: Overview: Memory

- Memory is a mechanism that learns a representation of the past
- At timestep t project all previous information $1, \ldots, t$ onto a latent space c_t
  - Memory controlled by a neural network h_θ with shared parameters θ
- Then, at timestep $t+1$ re-use the parameters θ and the previous c_t

$$c_{t+1} = h_\theta(x_{t+1}, c_t)$$

$$\ldots$$

$$c_{t+1} = h_\theta(x_{t+1}, h_\theta(x_t, h_\theta(x_{t-1}, \ldots h_\theta(x_1, c_0))))$$

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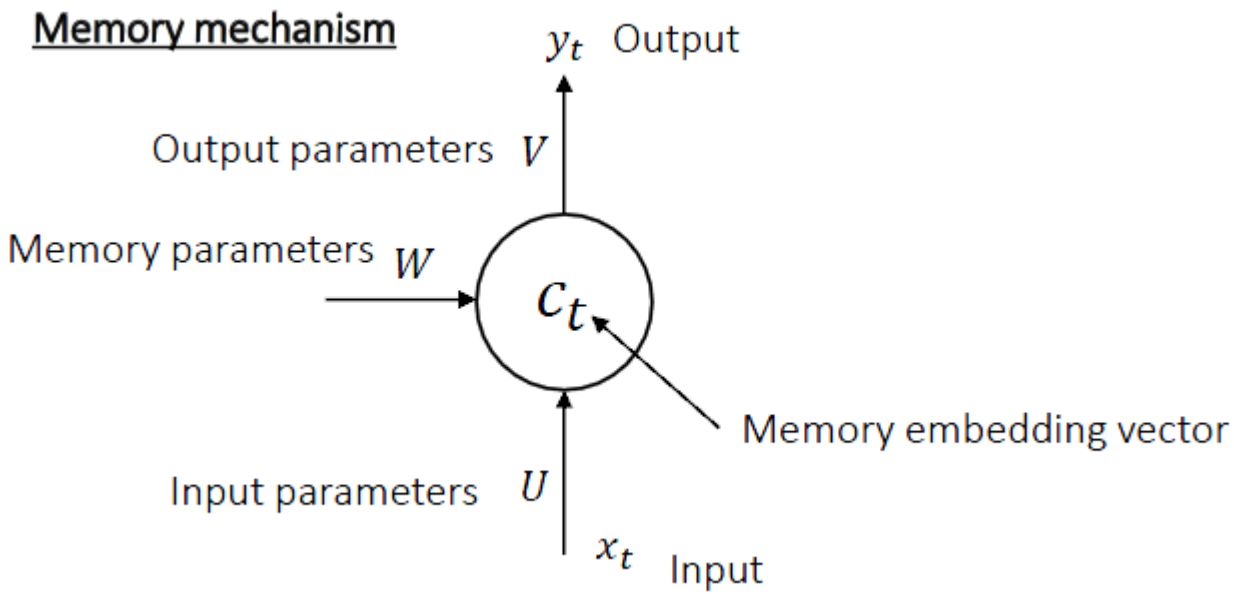
RNN: Overview: Memory: A Graphical Representation

- Data In the simplest case, what are the Inputs/Outputs of our system
- Sequence inputs → we model them with parameters U
- Sequence outputs → we model them with parameters V
- Memory I/O → we model it with parameters W



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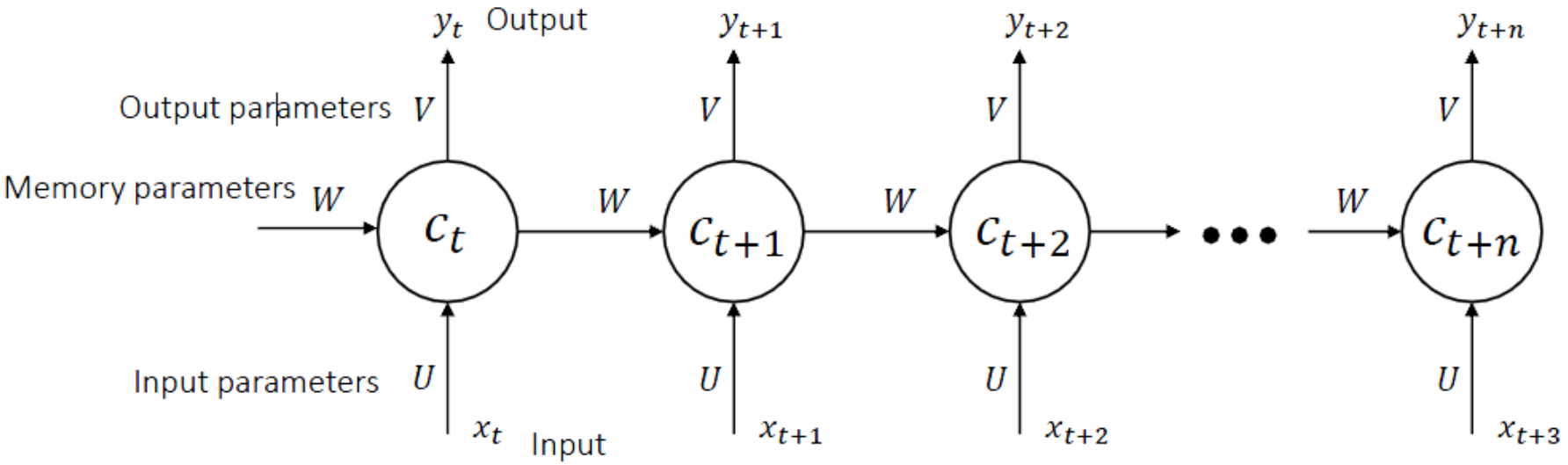

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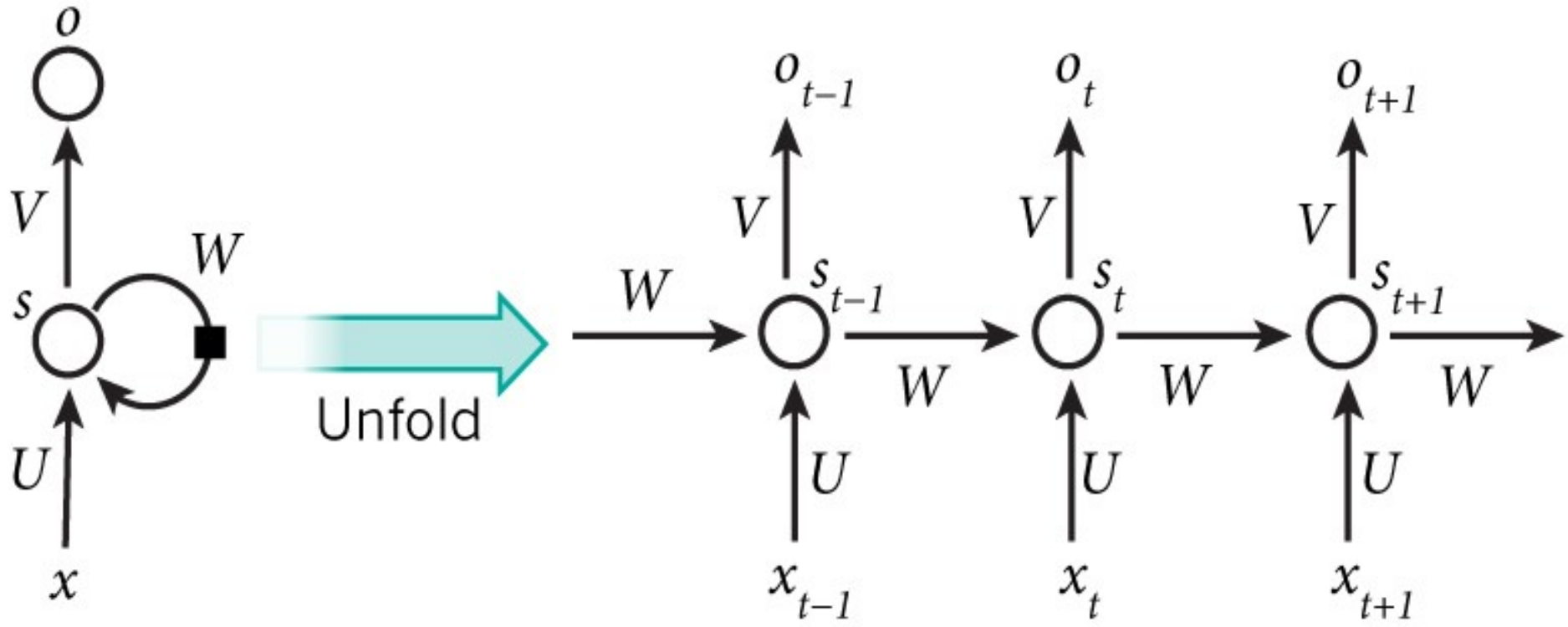
RNN: Overview: Memory: Folding Memory & Unfolding Memory



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RNN: Overview

- The fundamental feature of a Recurrent Neural Network (RNN):
  - The network contains at least one feed-back connection,
    - So the activations can flow round in a loop.
    - That enables the networks to do temporal processing and learn sequences,
    - For example, perform sequence recognition/reproduction or temporal association or prediction.

- Recurrent neural network architectures can have many different forms.
  - One common type consists of a standard Multi-Layer Perceptron (MLP) plus added loops.
    - These can exploit the powerful non-linear mapping capabilities of the MLP, and also have some form of memory.
  - Others have more uniform structures:
    - Potentially with every neuron connected to all the others
    - And may also have stochastic activation functions.

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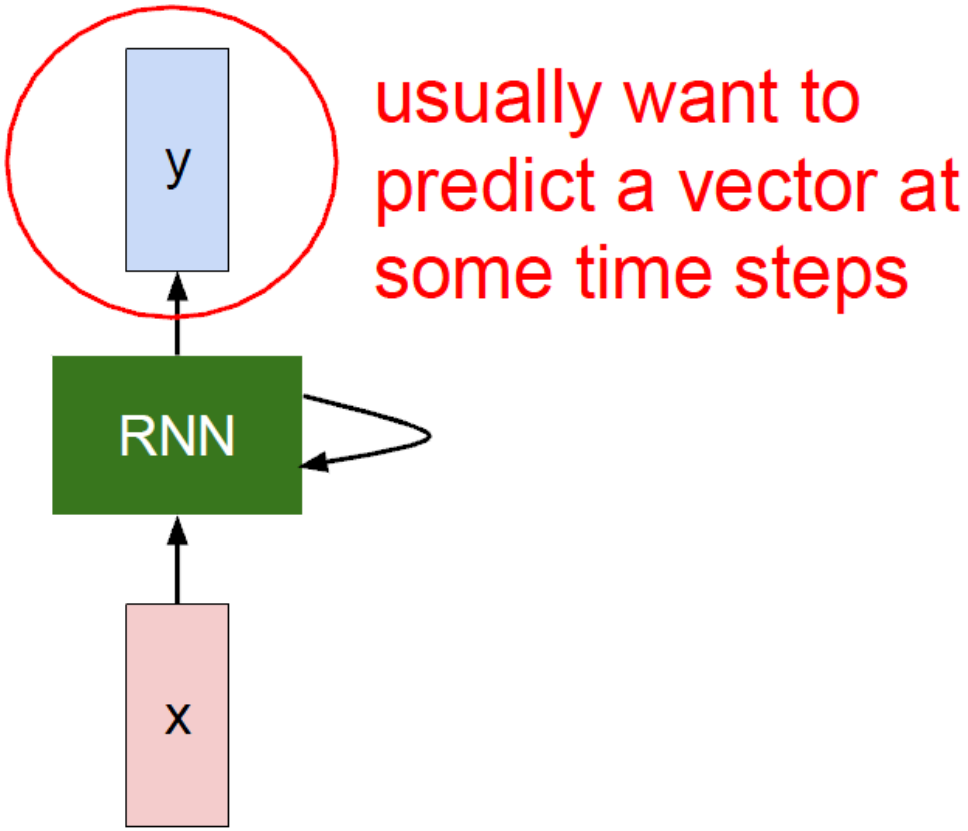
RNN: Overview

- For simple architectures and deterministic activation functions:
  - Learning can be achieved using similar gradient descent procedures to those leading to the back-propagation algorithm for feed-forward networks.
  - When the activations are stochastic, simulated annealing approaches may be more appropriate.
  - The following will look at a few of the most important types and features of recurrent networks.



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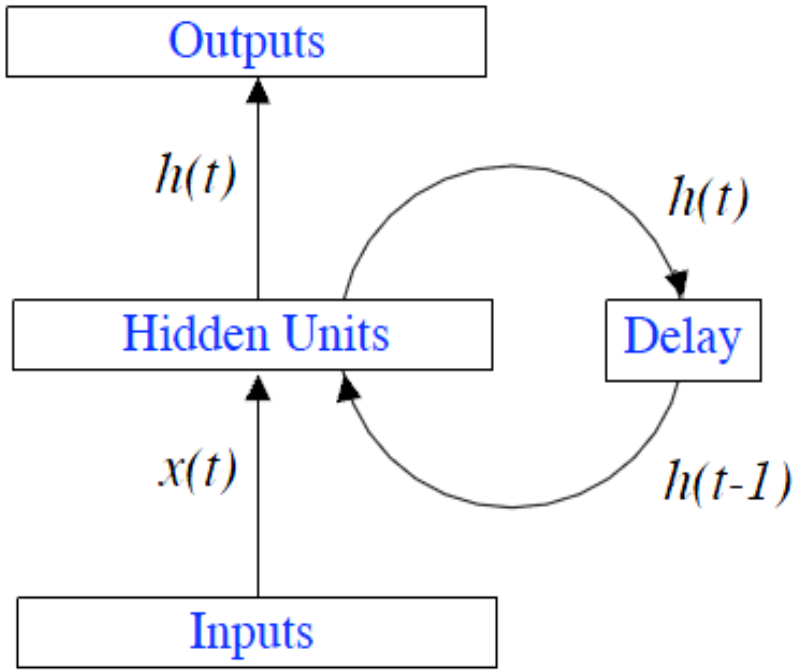
RNN: Fully Recurrent Neural Networks

- The simplest form of fully recurrent neural network:
  - An MLP with the previous set of hidden unit activations feeding back into the network along with the inputs as shown in the figure to the right.

- **NOTES**:
  - The time t has to be discretized, with the activations updated at each time step.

- The time scale might correspond to the operation of real neurons, or for artificial systems any time step size appropriate for the given problem can be used.
  - A delay unit needs to be introduced to hold activations until they are processed at the next time step.



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RNN: Some Examples and Applications

Examples:

- Videos
- Time series data
- Stock exchange
- Biological measurements
- Climate measurements
- Market analysis
- Speech/Music
- User behavior in websites

Applications:

- Machine translation
- Image captioning
- Question answering
- Video generation
- Speech synthesis
- Speech recognition