Introduction to Machine Learning (CS419M)

Lecture 14:
- Recurrent Neural Networks
- Use case: Language Modeling

Why Recurrent Neural Networks (RNNs)?

- Fixed-length inputs and outputs may not always be a reasonable choice. E.g. speech recognition, machine translation, sentiment classification, etc.

- Context information is crucial for many sequence prediction problems.

  - Hard to choose a fixed context window.

- RNNs are a family of neural networks that are better suited to handle sequential data
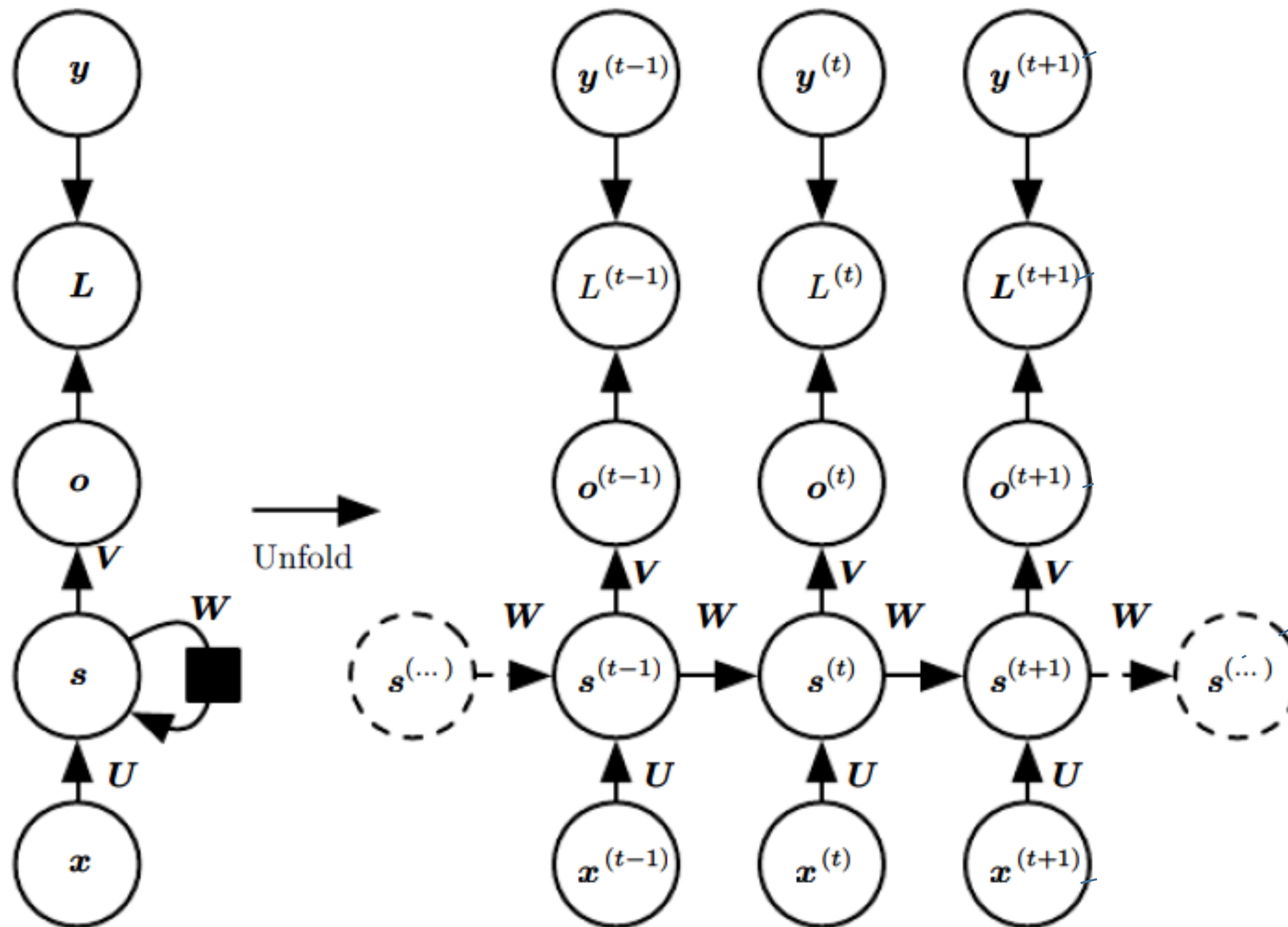
Recurrent Neural Networks (RNNs)

A **hidden state** is associated with each time-step
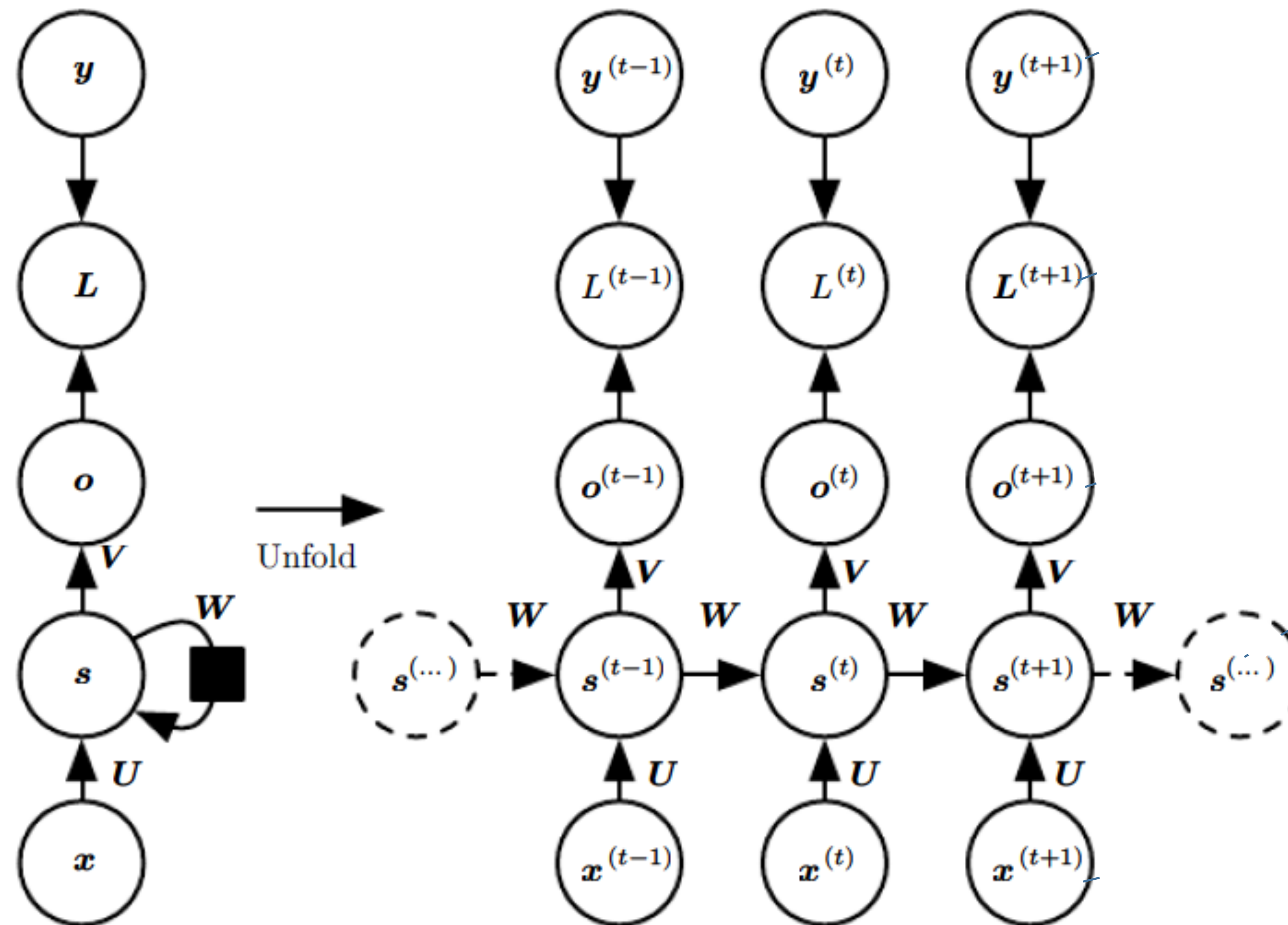
Recurrent Neural Networks (RNNs)

At each time step: Use the input and the **previous hidden state** to compute the output
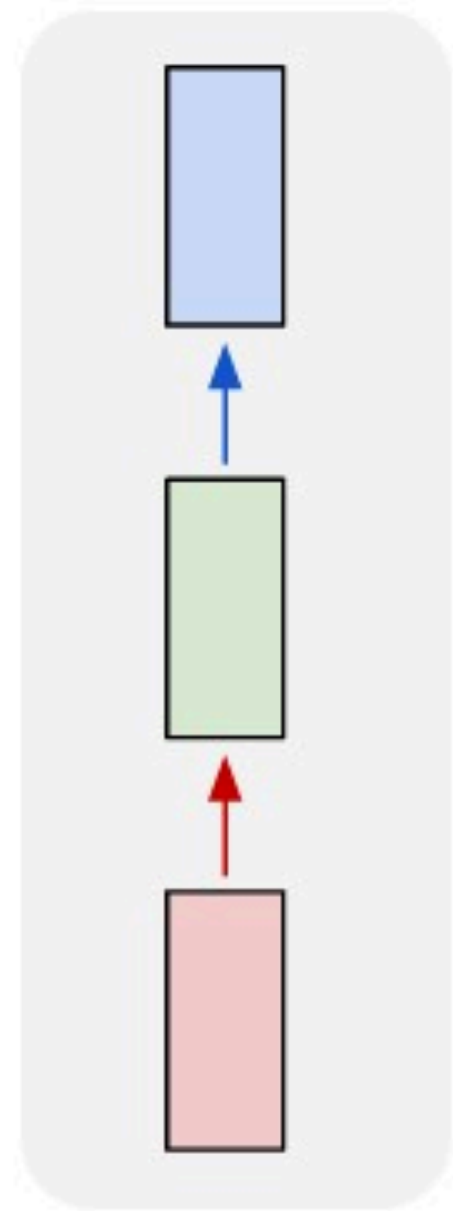

$$\mathbf{s}_t = \tanh(\mathbf{W}\mathbf{s}_{t-1} + \mathbf{U}\mathbf{x}_t + \mathbf{b})$$

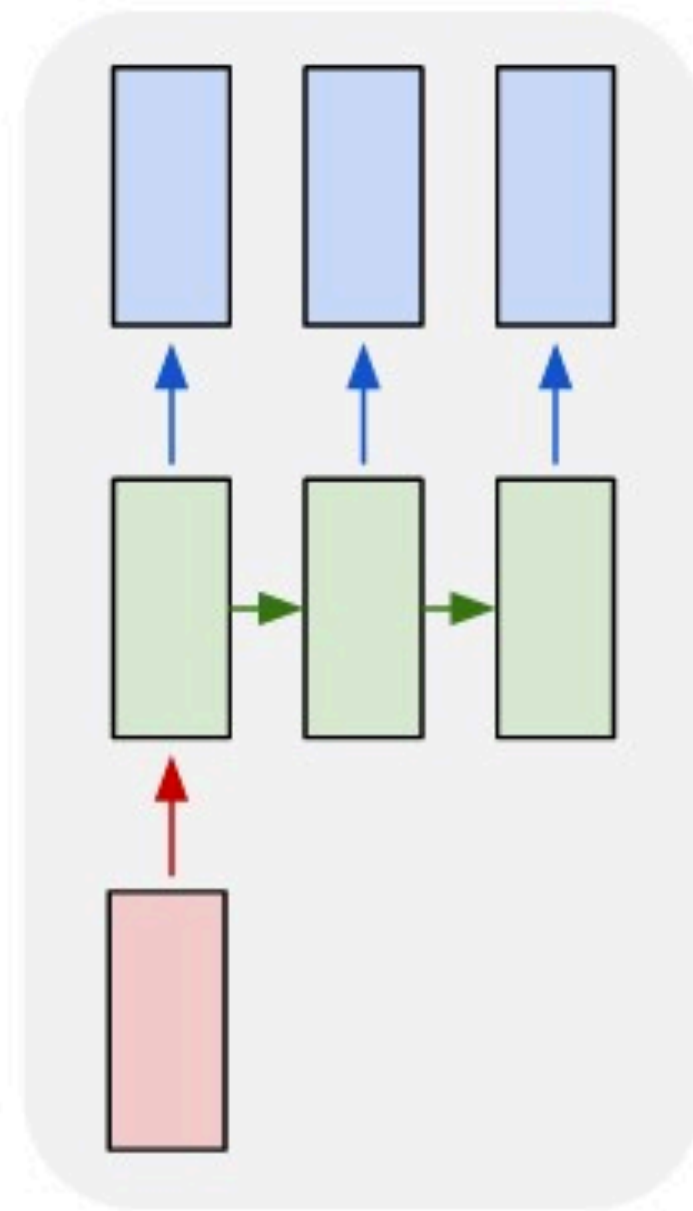$$\mathbf{o}_t = \mathbf{V}\mathbf{s}_t + \mathbf{b}'$$

$$\hat{\mathbf{y}}_t = \mathrm{softmax}(\mathbf{o}_t)$$
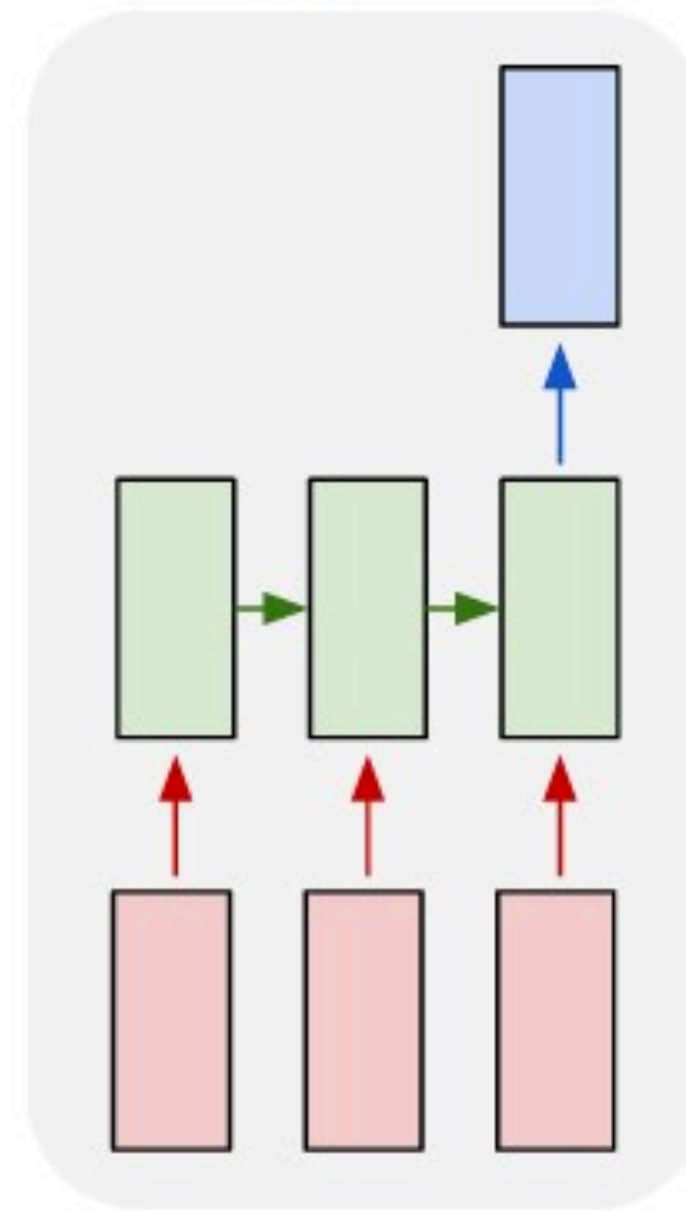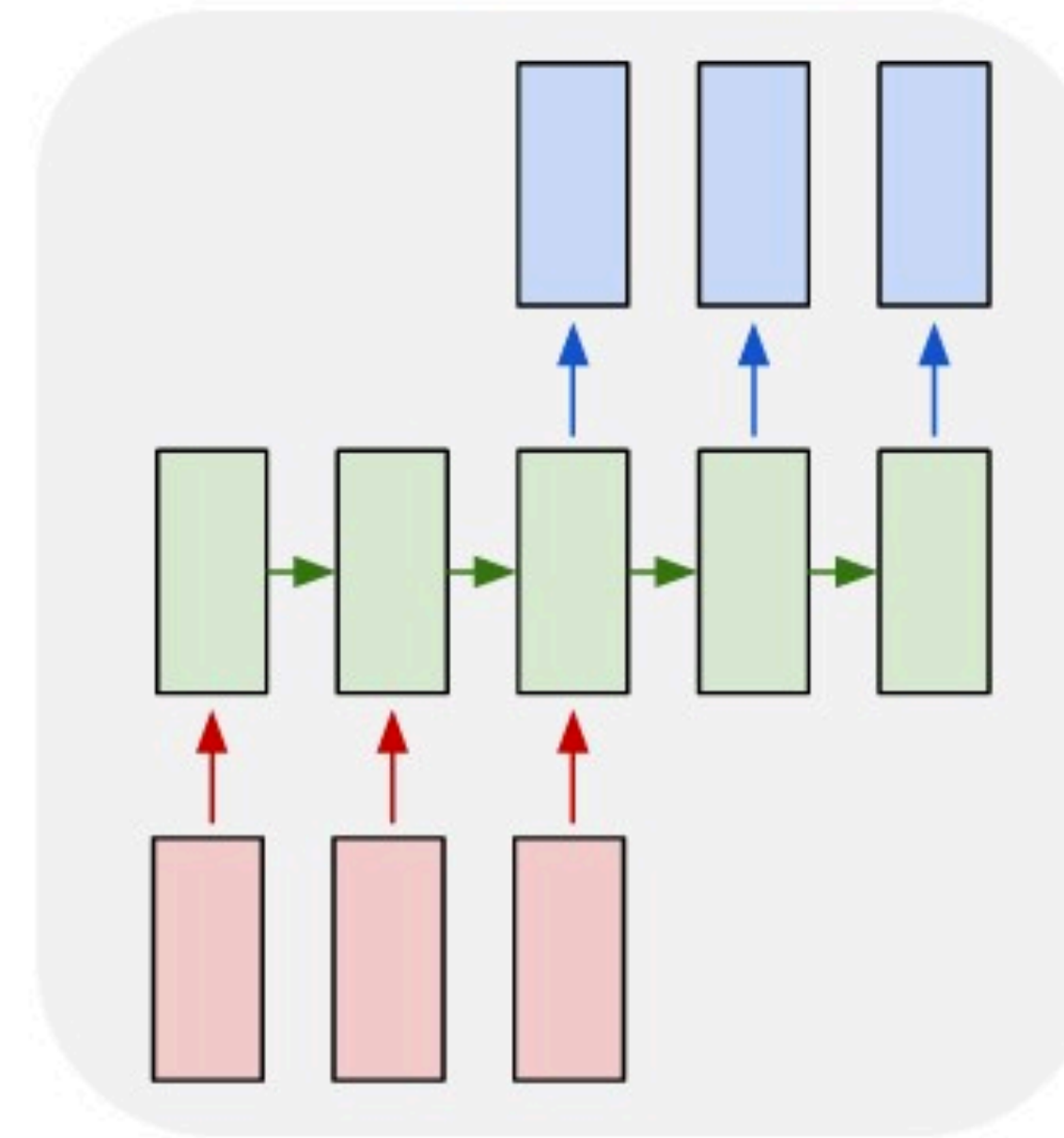
RNNs appear in different forms
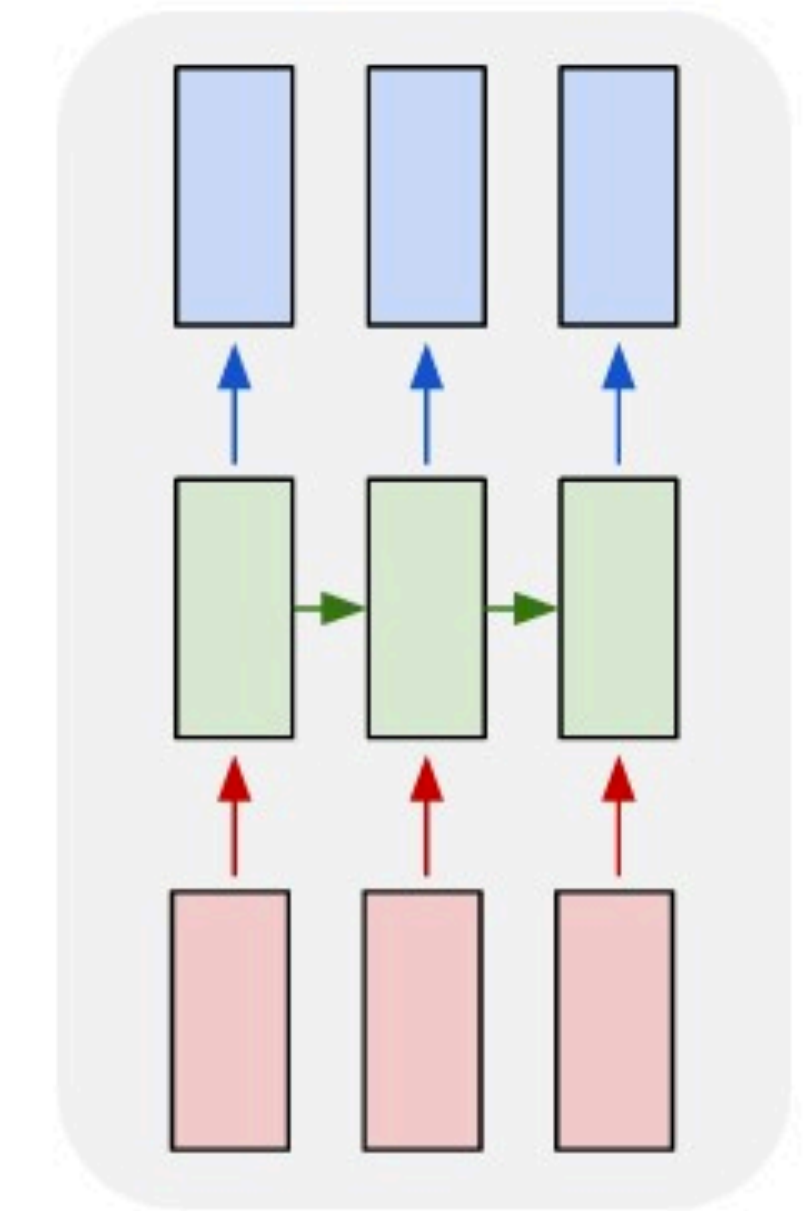
Example:
Language Modeling!
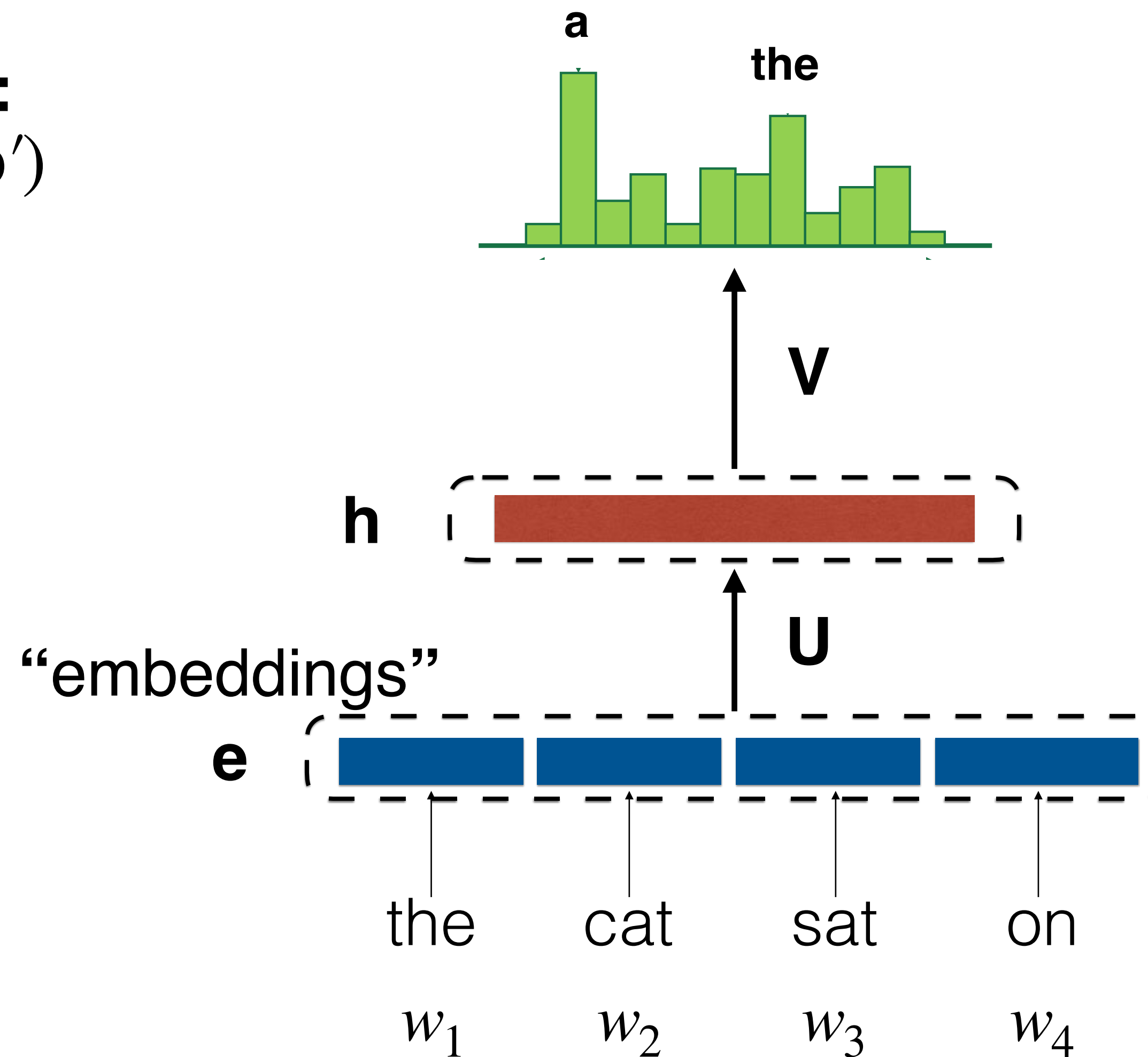
What is language modeling?

- Given a sequence of words or characters, $w_1, \ldots, w_{t-1}$, what is the most likely word at the next timestep w_t?

- Why is this an interesting problem?

  - Useful for a wide range of problems involving natural language. Examples include speech recognition, machine translation, spelling correction, summarization, etc.

Fixed-window NN language model

output probability:
$$\hat{\mathbf{y}} = \text{softmax}(\mathbf{V}\mathbf{h} + \mathbf{b}')$$

a

the

V

hidden layer:
$$\mathbf{h} = \text{tanh}(\mathbf{U}\mathbf{e} + \mathbf{b})$$

h

U

"embeddings"

e

words

the   cat   sat   on

w_1 w_2 w_3 w_4

RNN language model

output probability:
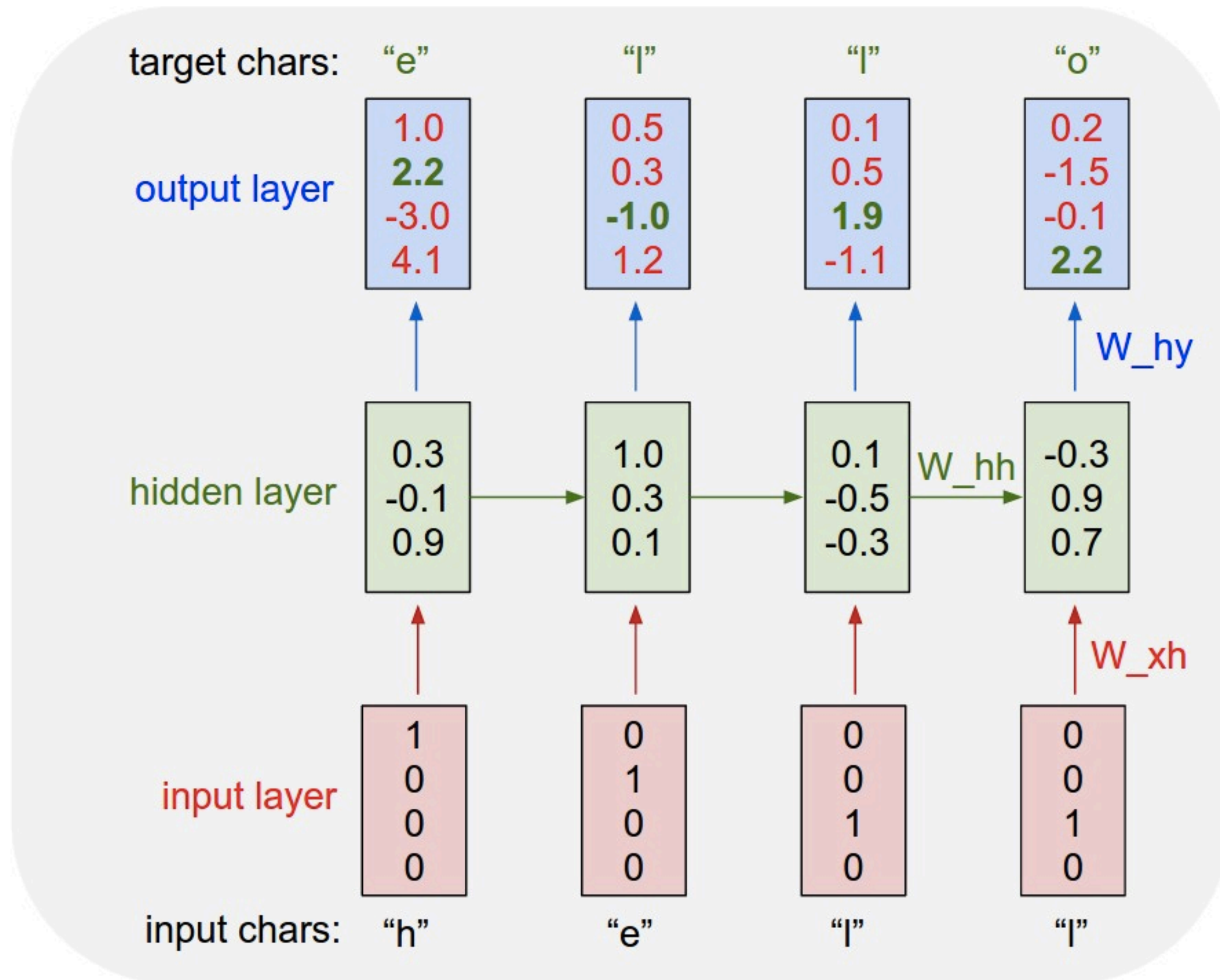$$\hat{\mathbf{y}}_t = \mathrm{softmax}(\mathbf{V}\mathbf{h}_t + \mathbf{b}')$$

hidden layer:
$$\mathbf{h}_t = \tanh(\mathbf{U}\mathbf{e}_t + \mathbf{W}\mathbf{h}_{t-1} + \mathbf{b})$$

words

cat

dog

zebra

sat

ramong

sat

on

a

the

V   **V**   **V**   **V**

W   **W**   **W**

| h_1 | h_2 | h_3 | h_4 |

U   **U**   **U**   **U**

| e_1 | e_2 | e_3 | e_4 |

the   cat   sat   on

w_1 w_2 w_3 w_4
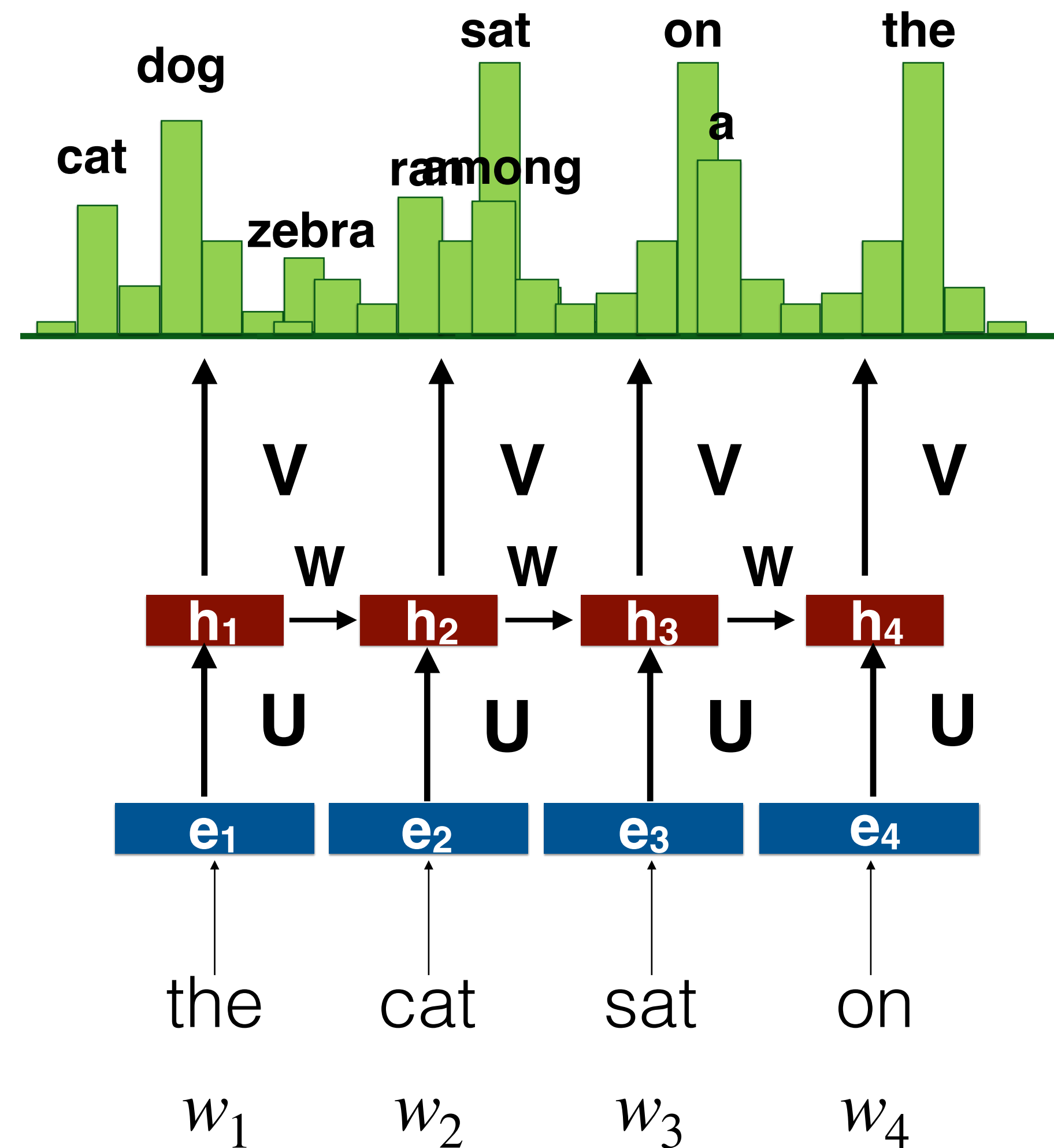
Character-based RNNLMs

Generate text using a trained character-based LM

VIOLA:
Why, Salisbury must find his flesh and thought
That which I am not aps, not a man and in fire,
To show the reining of the raven and the wars
To grace my hand reproach within, and not a fair are hand,
That Caesar and my goodly father's world;
When I was heaven of presence and our fleets,
We spare with hours, but cut thy council I am great,
Murdered and by thy master's ready there
My power to give thee but so much as hell:
Some service in the noble bondman here,
Would show him to her wine.