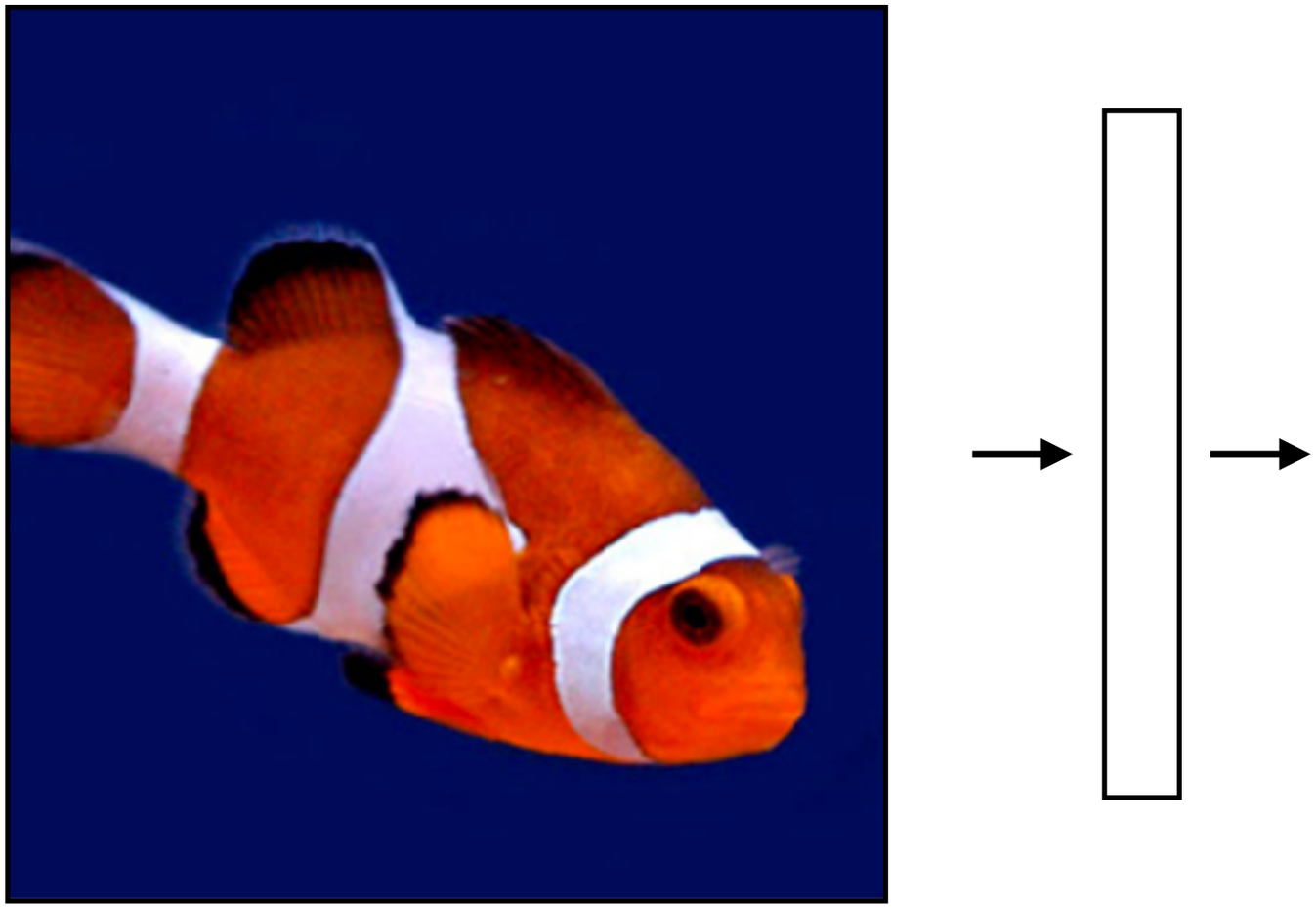
Carnegie Mellon University
Heinz College

94-775/95-865 Lecture 12: Time Series Analysis With Recurrent Neural Nets

George Chen

RNNs

What we've seen so far are "feedforward" NNs



RNNs

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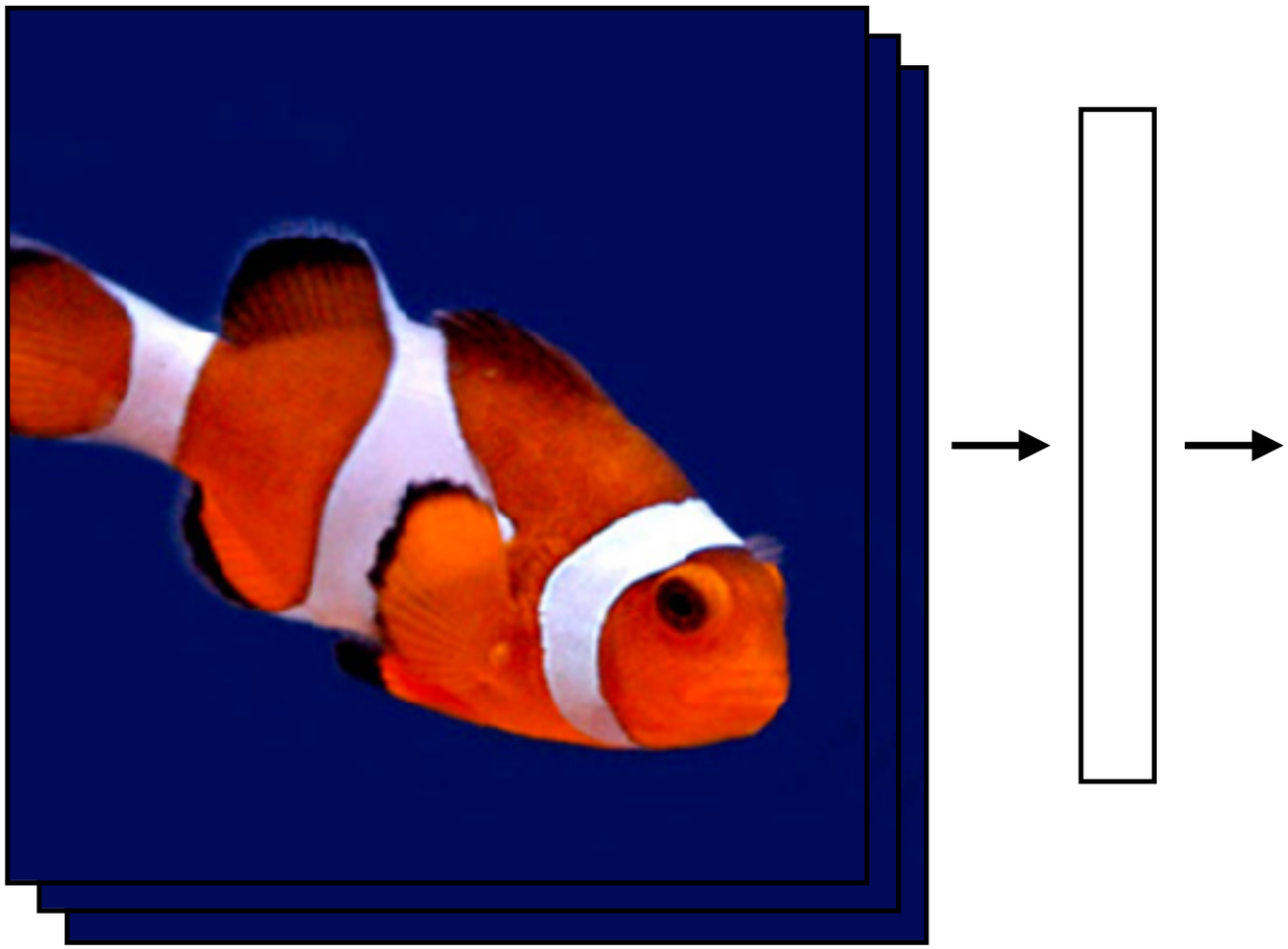


What if we had a video?

RNNs

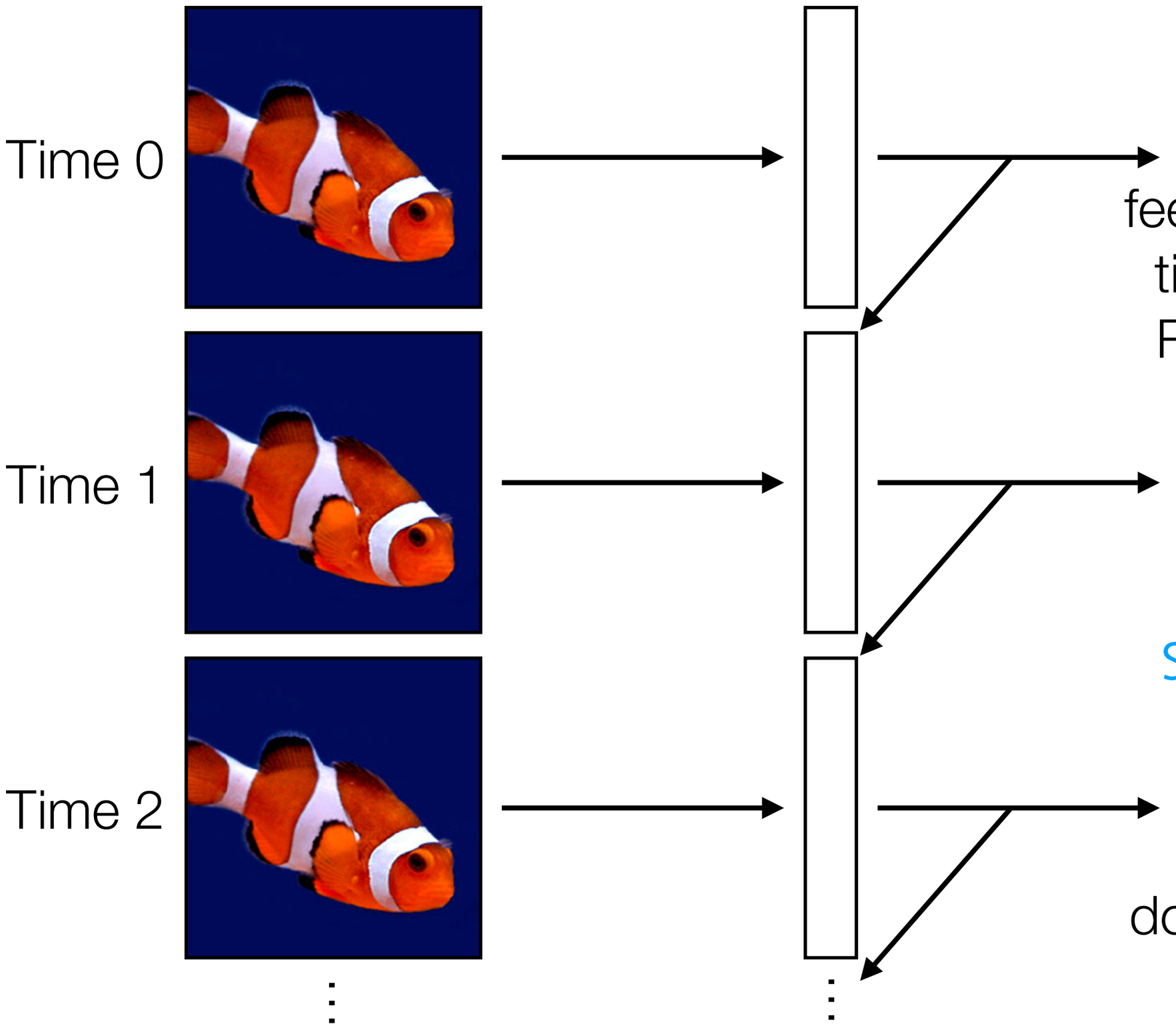
Feedforward NN's: treat each video frame separately

Time 0

Time 1

Time 2

RNNs



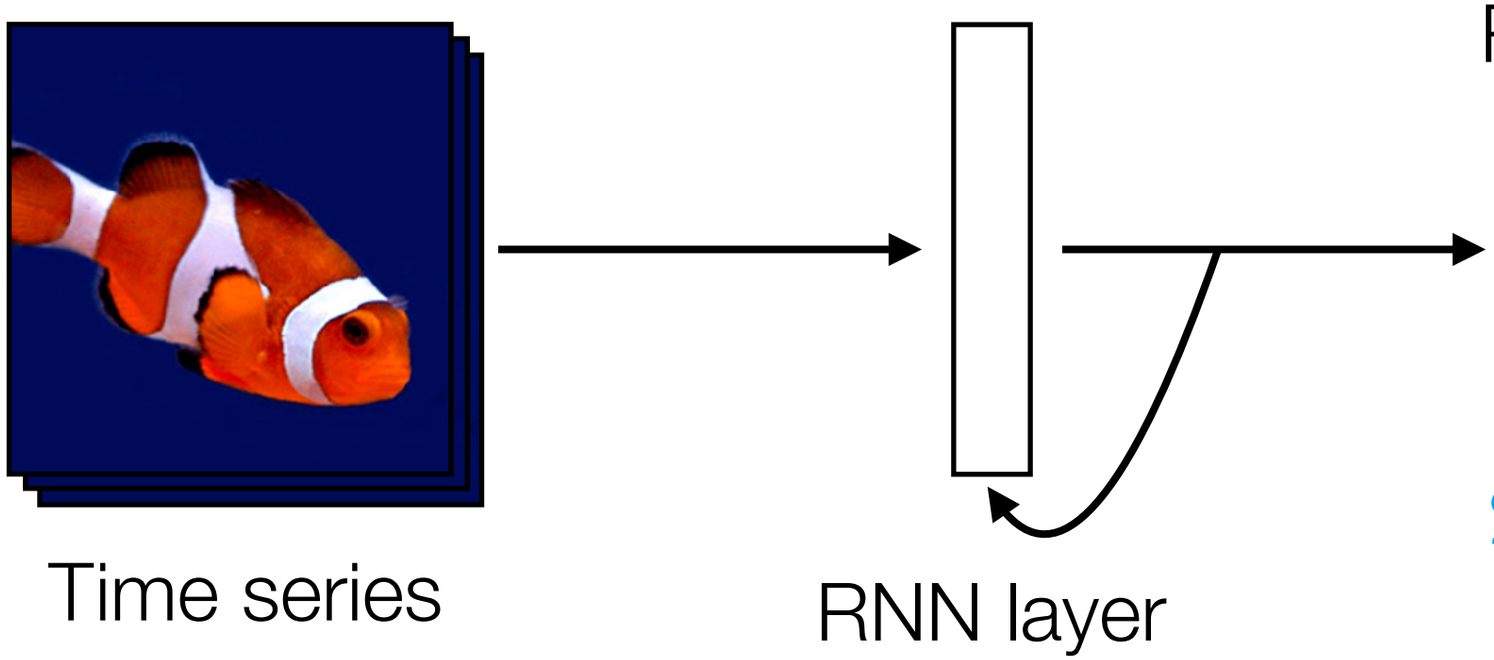
Feedforward NN's: treat each video frame separately

RNN's: feed output at previous time step as input to RNN layer at current time step

In `keras`, different RNN options: `SimpleRNN`, `LSTM`, `GRU`

Recommendation: don't use `SimpleRNN`

RNNs



Time series

RNN layer

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treat each video frame separately

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feed output at previous time step as input to RNN layer at current time step

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`SimpleRNN`, `LSTM`, `GRU`

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Example: SimpleRNN

memory stored in `current_state` variable!

```
current_state = 0

for input in input_sequence:

    output = activation(np.dot(input, W)
                        + np.dot(current_state, U)
                        + b)

    current_state = output
```

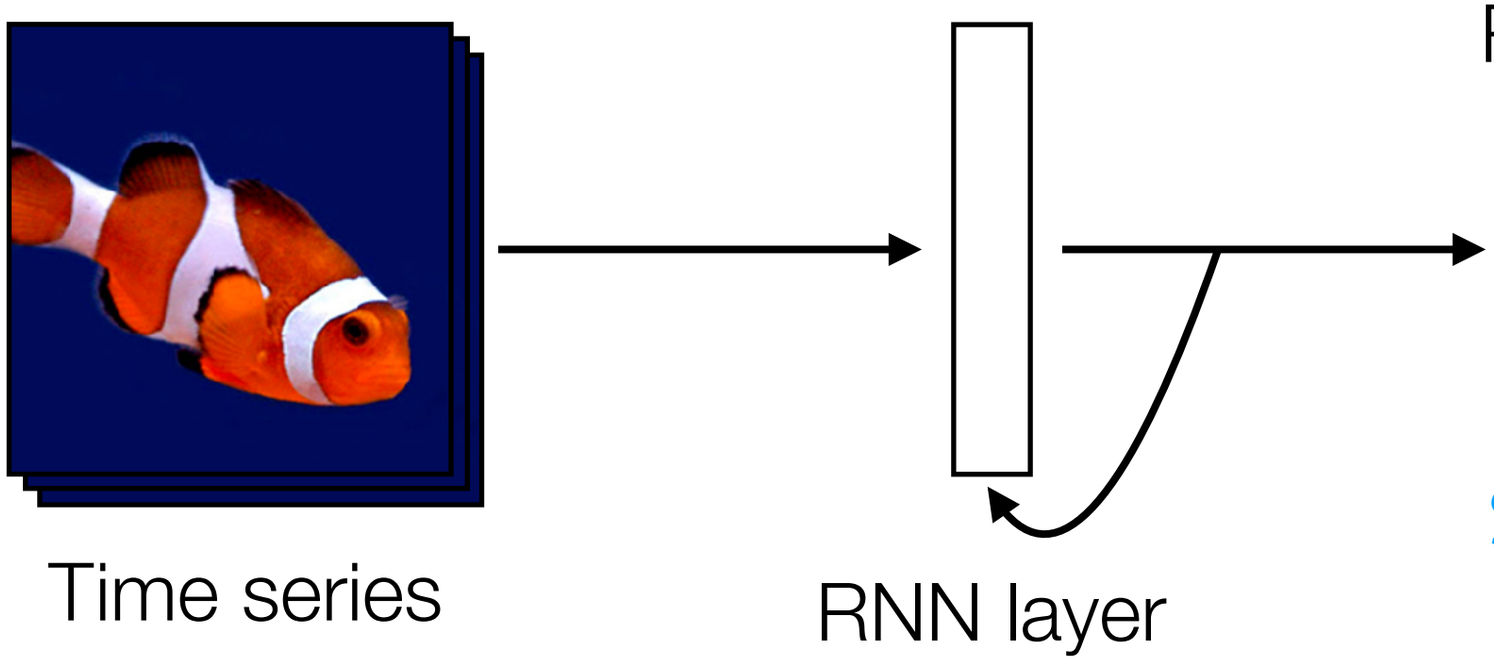
Activation function could, for instance, be ReLU

Parameters: weight matrices `W` & `U`, and bias vector `b`

Key idea: **it's like a dense layer in a `for` loop with some memory!**

RNNs

readily chains together with other neural net layers



Time series

RNN layer

like a dense layer that has memory

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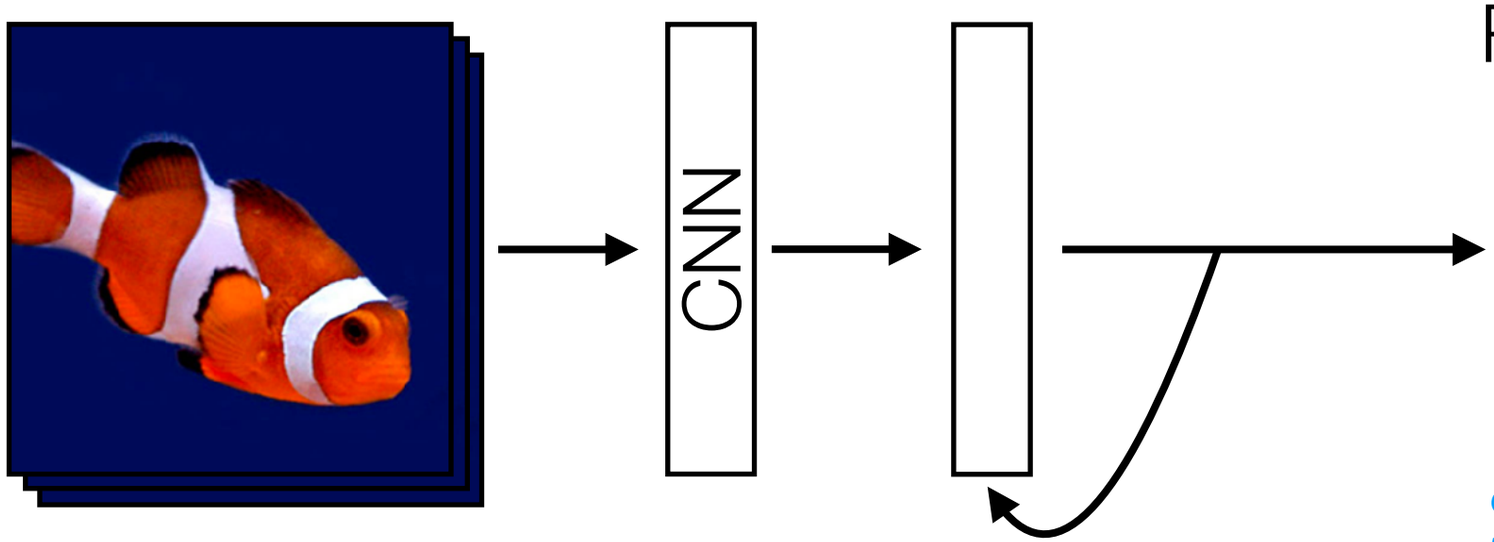

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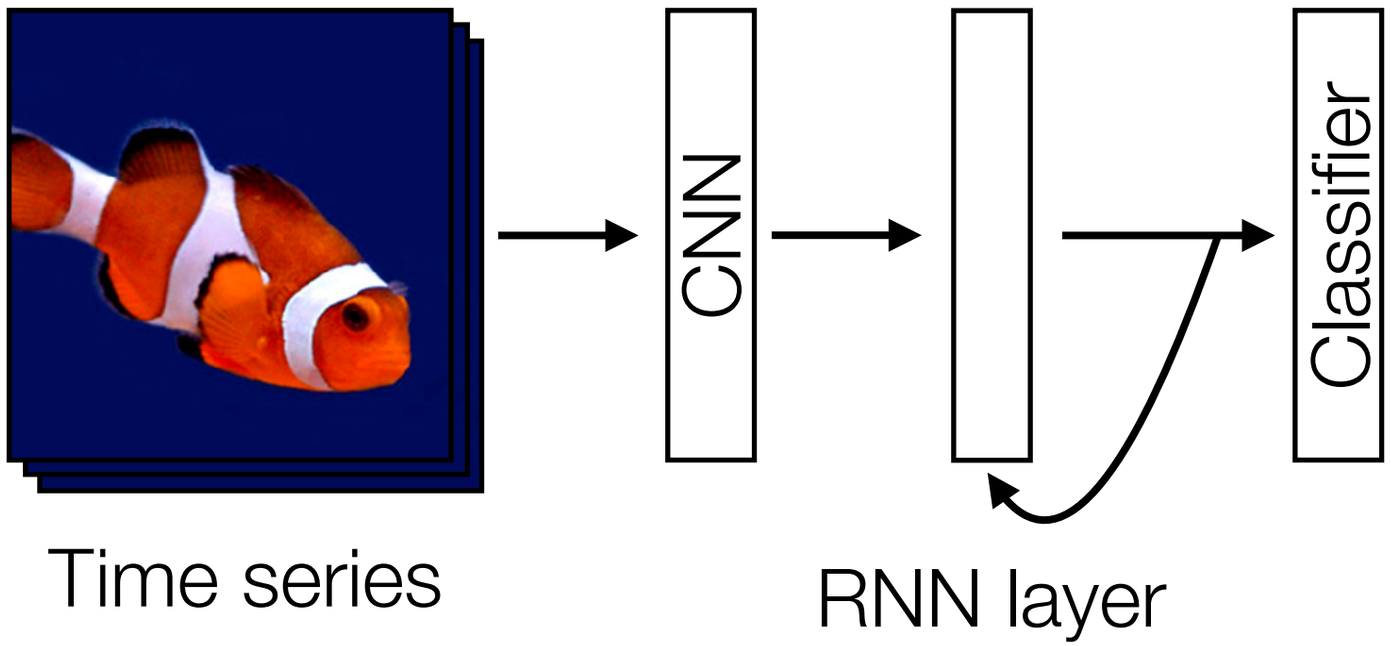

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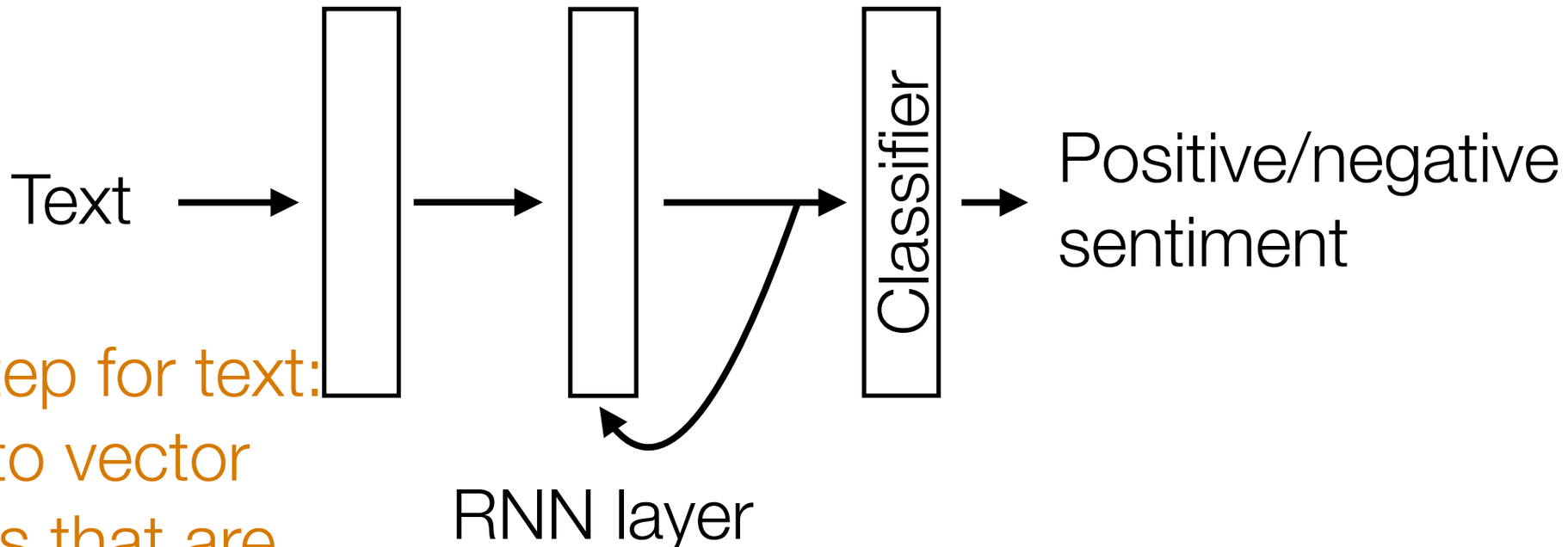
RNNs

Example: Given text (e.g., movie review, Tweet), figure out whether it has positive or negative sentiment (binary classification)



Common first step for text: turn words into vector representations that are semantically meaningful

(Flashback) Do Data Actually Live on Manifolds?

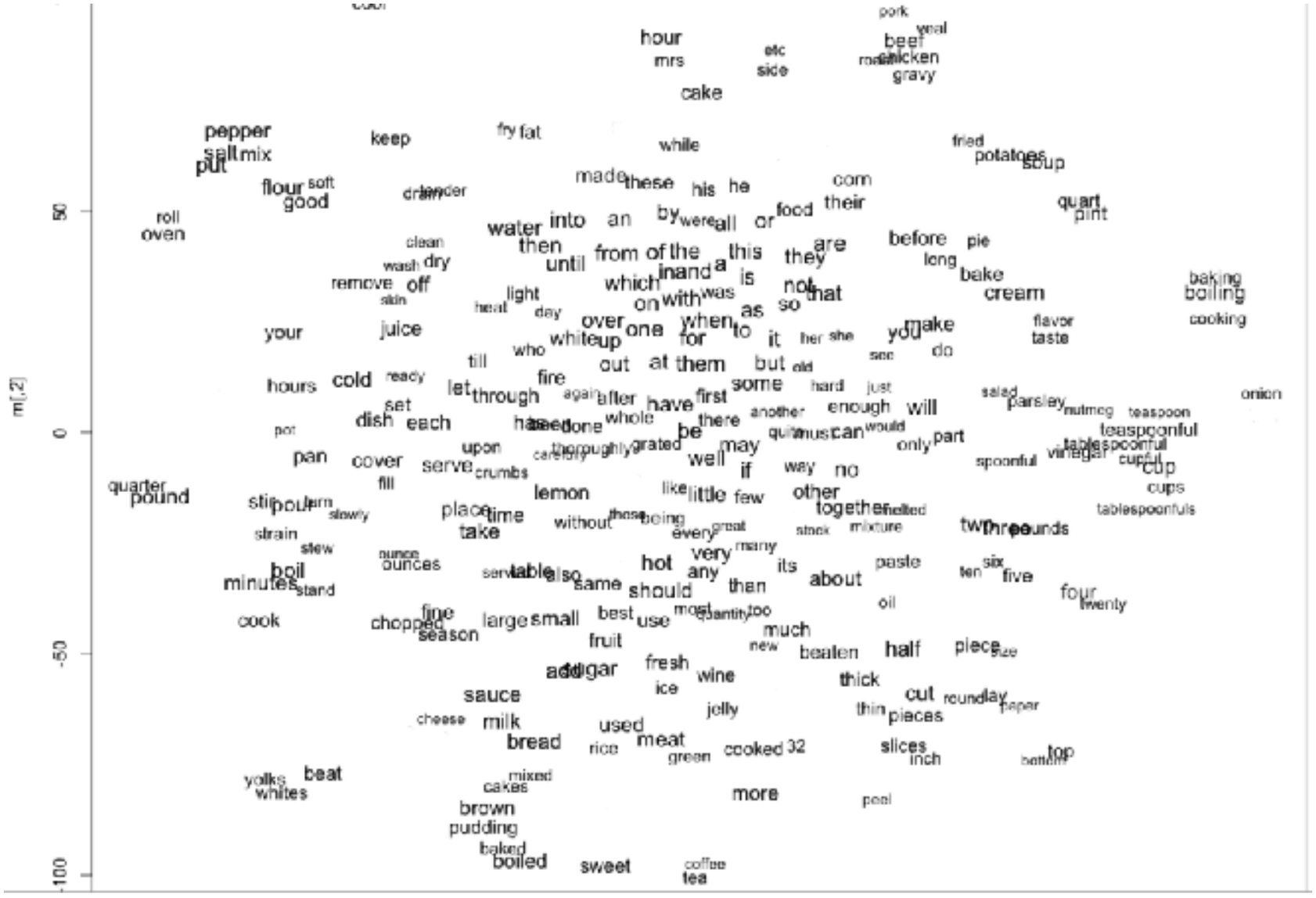
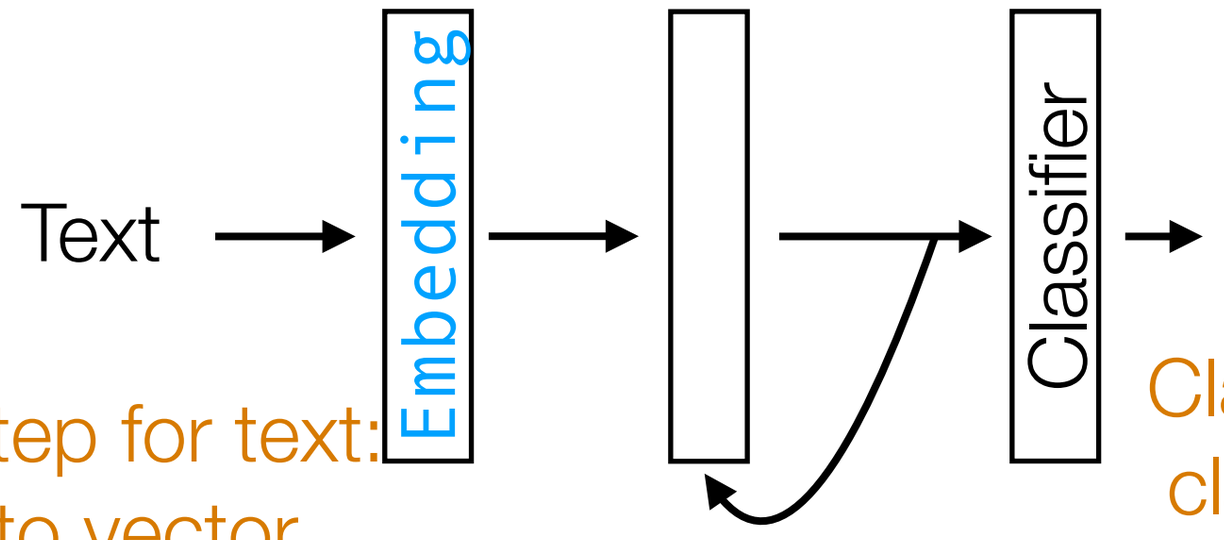


Image source: http://www.adityathakker.com/wp-content/uploads/2017/06/word-embeddings-994x675.png

RNNs

for loss function, replace *category cross entropy* with *binary cross entropy*

Example: Given text (e.g., movie review, Tweet), figure out whether it has positive or negative sentiment (binary classification)



Common first step for text: turn words into vector representations that are semantically meaningful

In `keras`, use the `Embedding` layer

Classification with > 2 classes: dense layer, softmax activation

Classification with 2 classes: dense layer with 2 neurons & softmax equivalent to dense layer with 1 neuron & sigmoid activation (called **logistic regression**)

Word Embeddings

Example of **self-supervised learning**

Even without labels, we can set up a prediction task!

Hide part of training data and try to predict what you've hid!

I'll talk more about self-supervised learning next lecture
(it's a clever application of predictive data analytics concepts)

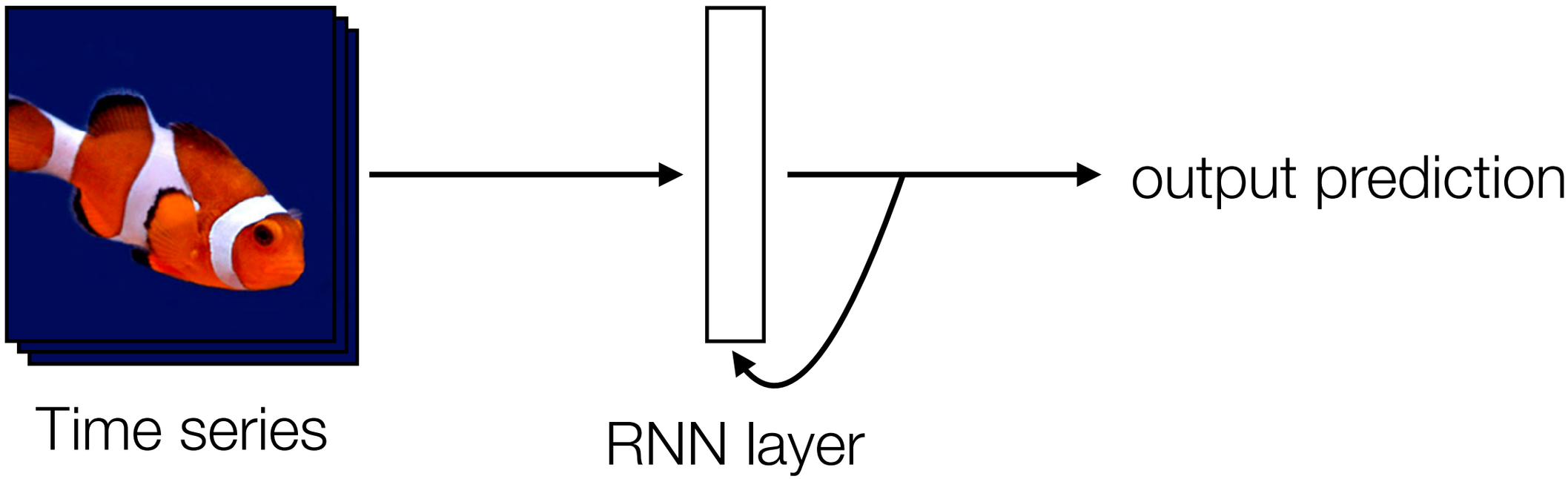
RNNs

Demo

RNNs

- Neatly handles time series in which there is some sort of global structure, so memory helps
  - If time series doesn't have global structure, RNN performance might not be much better than 1D CNN
- An RNN layer by itself doesn't take advantage of image/text structure!
  - For images: combine with convolution layer(s)
  - For text: combine with embedding layer

A Little Bit More Detail

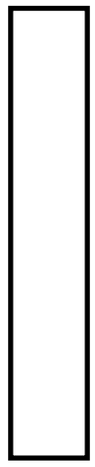


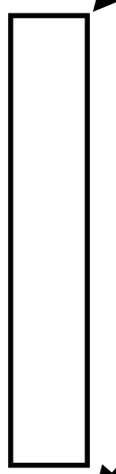
Time 0

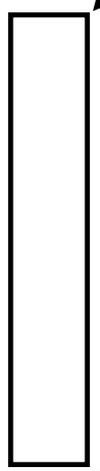
Time 1

Time 2

⋮





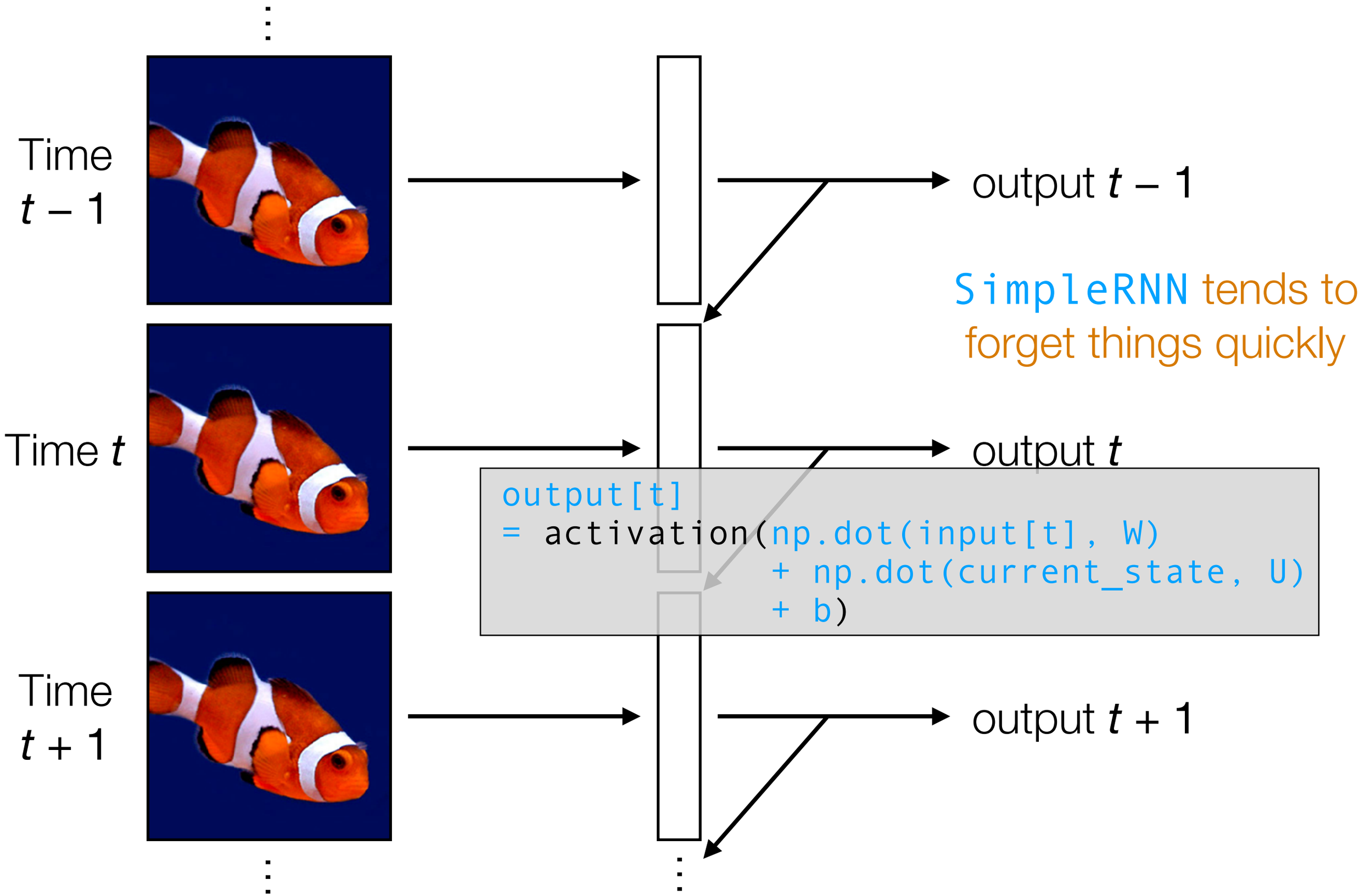


⋮

output prediction 0

output prediction 1

output prediction 2


Time
t – 1
Time t
Time
t + 1
output t – 1
output t
output t + 1
SimpleRNN tends to
forget things quickly
output[t]
= activation(np.dot(input[t], W)
+ np.dot(current_state, U)
+ b)

Long-term memory

Add explicit long-term memory!

Time $t - 1$

output $t - 1$

But need some way to update long-term memory!

Time t

output t

Time $t + 1$

output $t + 1$

Long-term memory

Add explicit long-term memory!

Time $t - 1$

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Time t

output t

Long-term memory

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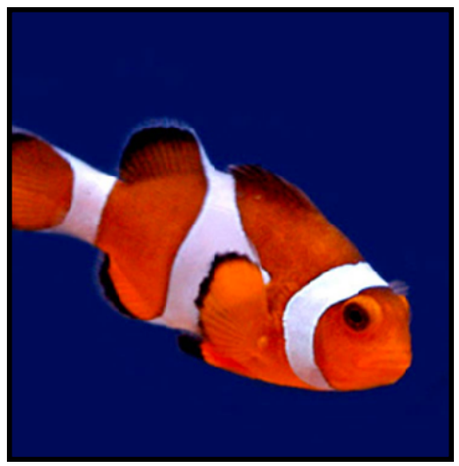
Time t



output t

Long-term memory

Add explicit long-term memory!

Time $t-1$

output $t-1$

But need some way to update long-term memory!

Long-term memory updater

Called a "long short-term memory" (LSTM) RNN

Remembers things longer than `SimpleRNN`

Time t

output t