Natural Language Processing

Lecture 19

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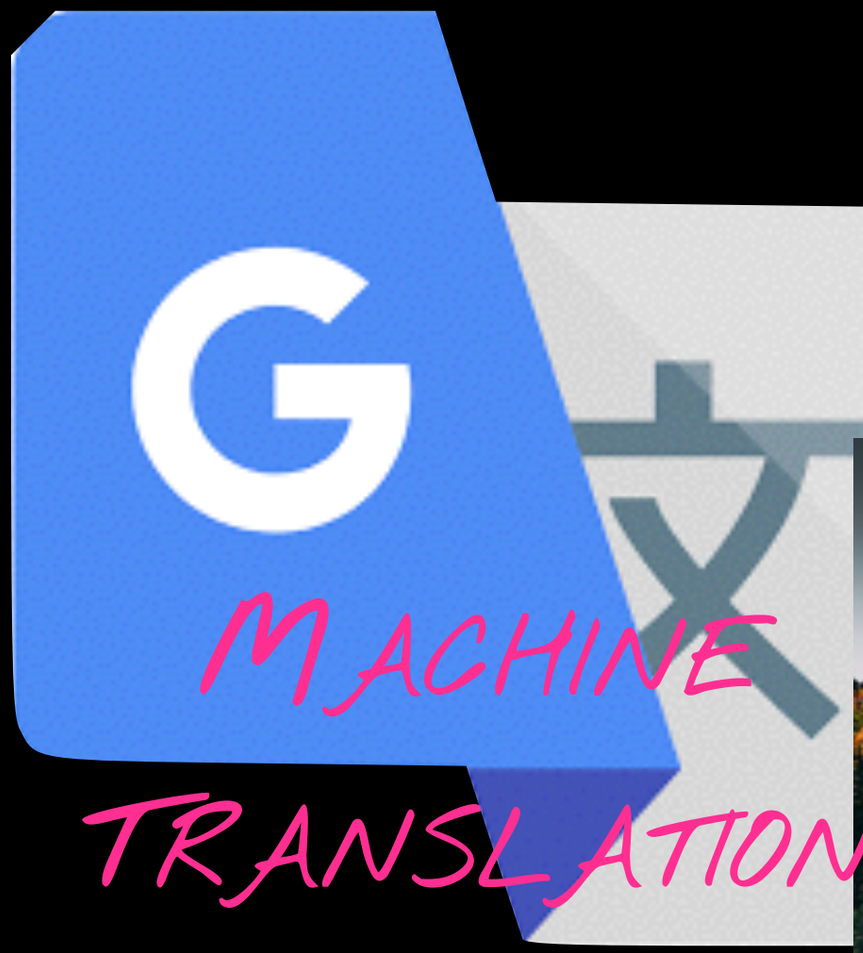
Goals for Today

- Learn about **recurrent neural network architectures**
- Learn about **convolutional neural network architectures**
- Understand the concept of **convolution** and **pooling**
- Understand the **difference between recurrent and convolutional** networks
- Understand the **attention mechanism**

Recurring Matters



MACHINE TRANSLATION

IMAGE CAPTIONS

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Long-Term Trouble

SUBJECT

"Wenn er aber auf der Strasse der in Sammt und Seide gehüllten jetzt sehr ungenirt nach der neusten Mode gekleideten Regierungsräthin begegnet."

VERB

Mark Twain, *The Awful German Language*

Long-Term Trouble

NEGATION

This is not in any sense of the word a funny movie.

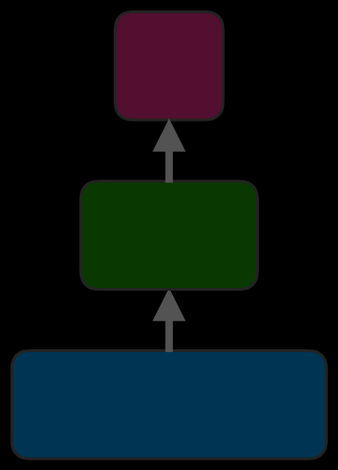
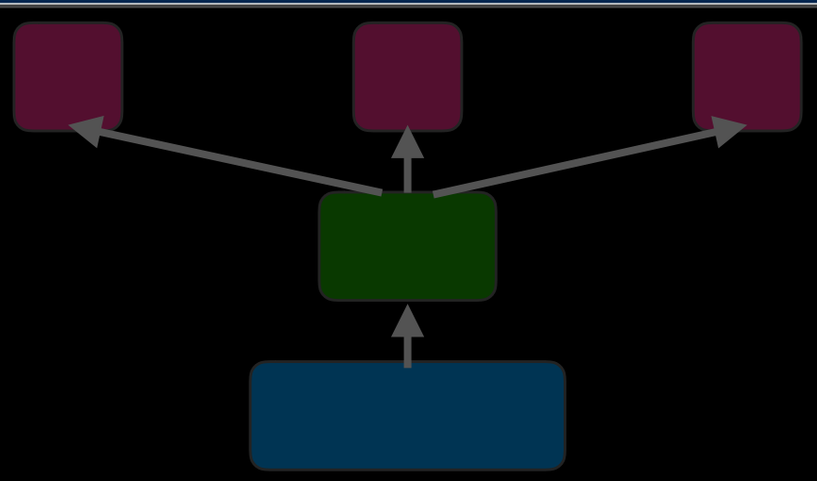
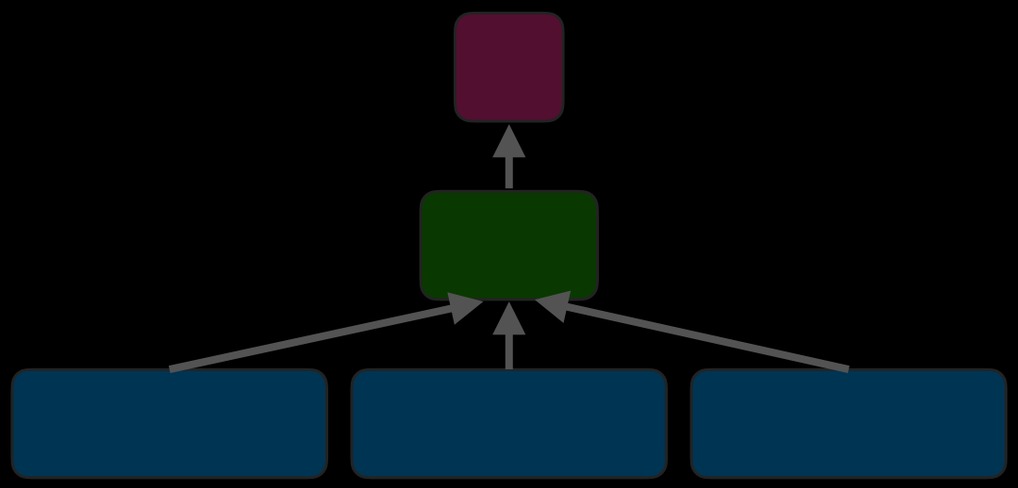
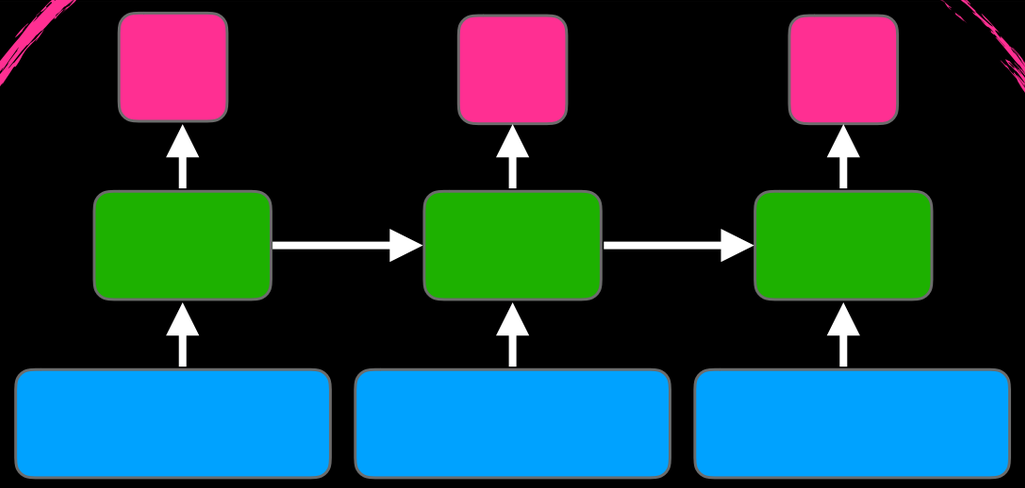
Sequence Tagging

PRON	**VERB**	**ADP**	**DET**	**???**	**PUNCT**
I	went	to	the	show	.

show {VERB, NOUN}

Structured prediction: depends on the POS of a previous word

Types of Text Classification

	Fixed length	Variable length
Fixed length	 Logistic Regression, Perceptron, Feed-Forward Network, Random Forest, Naive Bayes, SVM, …	 Multitask Learning, Decoder
Variable length	 Convolutional Neural Networks (CNN)	 Recurrent Neural Networks (RNN), Hidden Markov Models (HMM), Conditional Random Fields

Recurrent Networks

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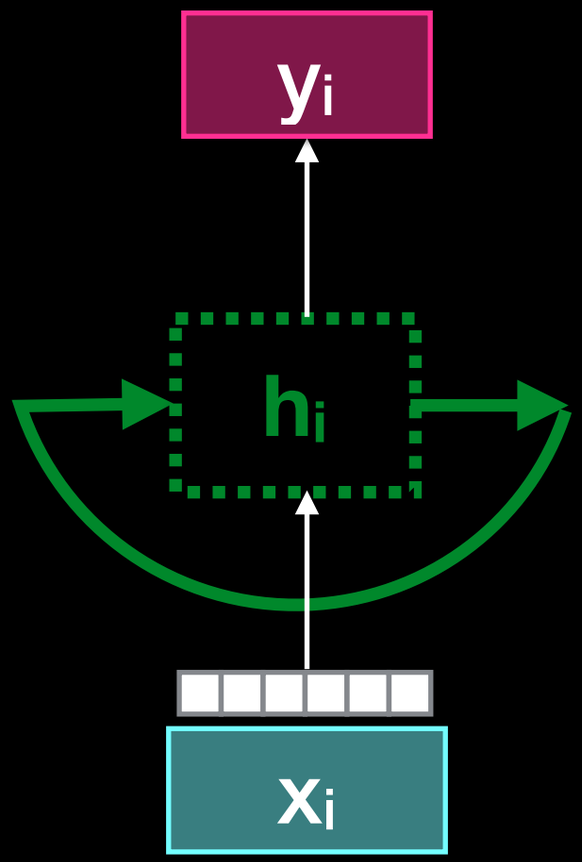
Recurrence

$$y_i = f(h_i)$$

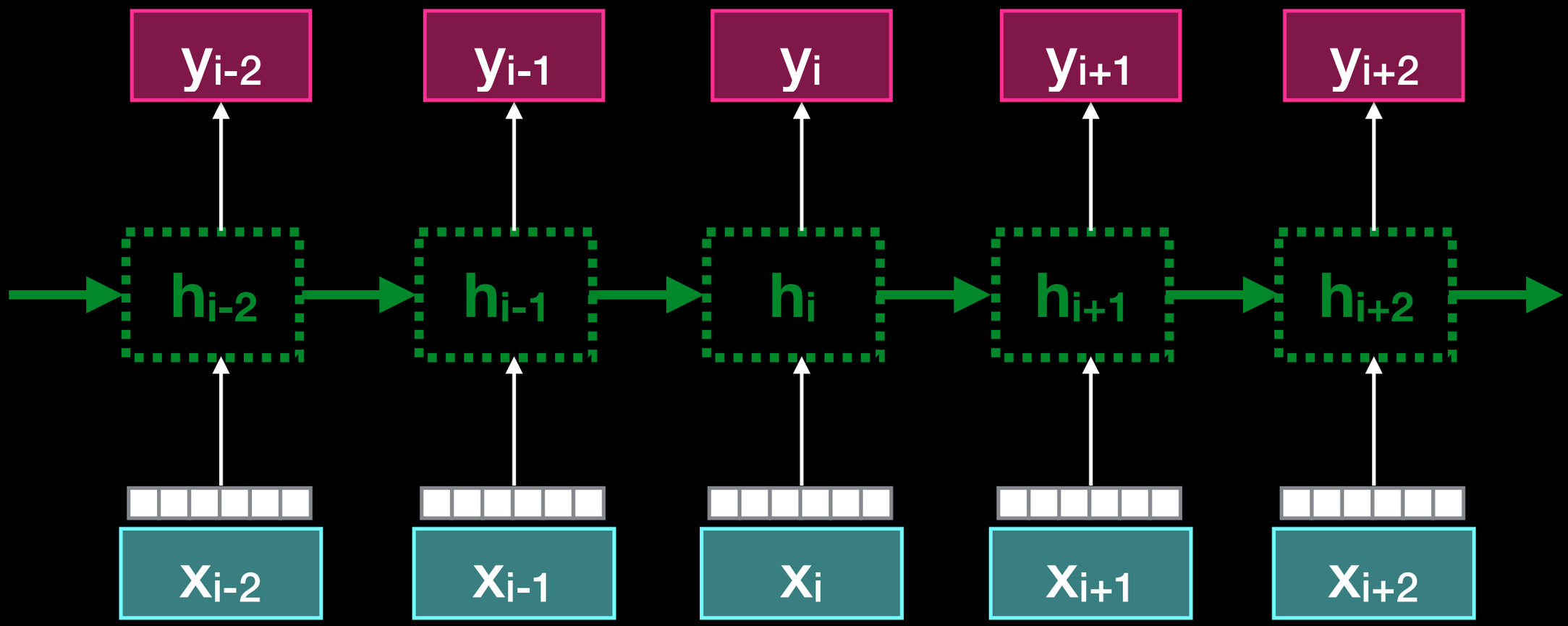
$$h_i = s(h_{i-1}, x_i)$$



…Unrolled

$$y_i = f(h_i)$$

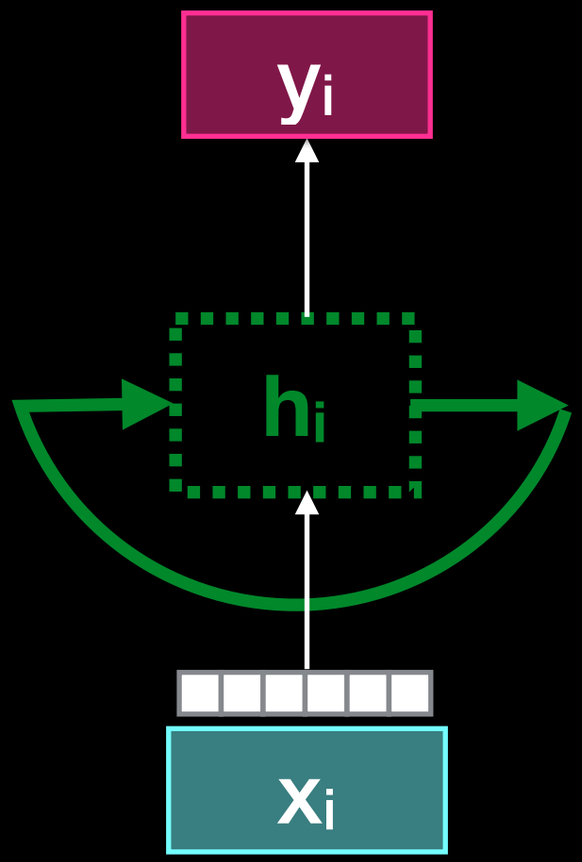
$$h_i = s(h_{i-1}, x_i)$$



Concretely

$$y_i = f(h_i) = h_i$$

$$h_i = s(h_{i-1}, x_i) = \tanh(W_1 h_{i-1} + W_2 x_i + b)$$



SIMPLE RNN

Recap: LMs

TRIGRAM MODEL

$$P(w_1, w_2, \ldots, w_n) \approx \prod_{i=1}^{N} P(w_i | w_{i-2}, w_{i-1})$$

`* * The weather today is fine STOP`

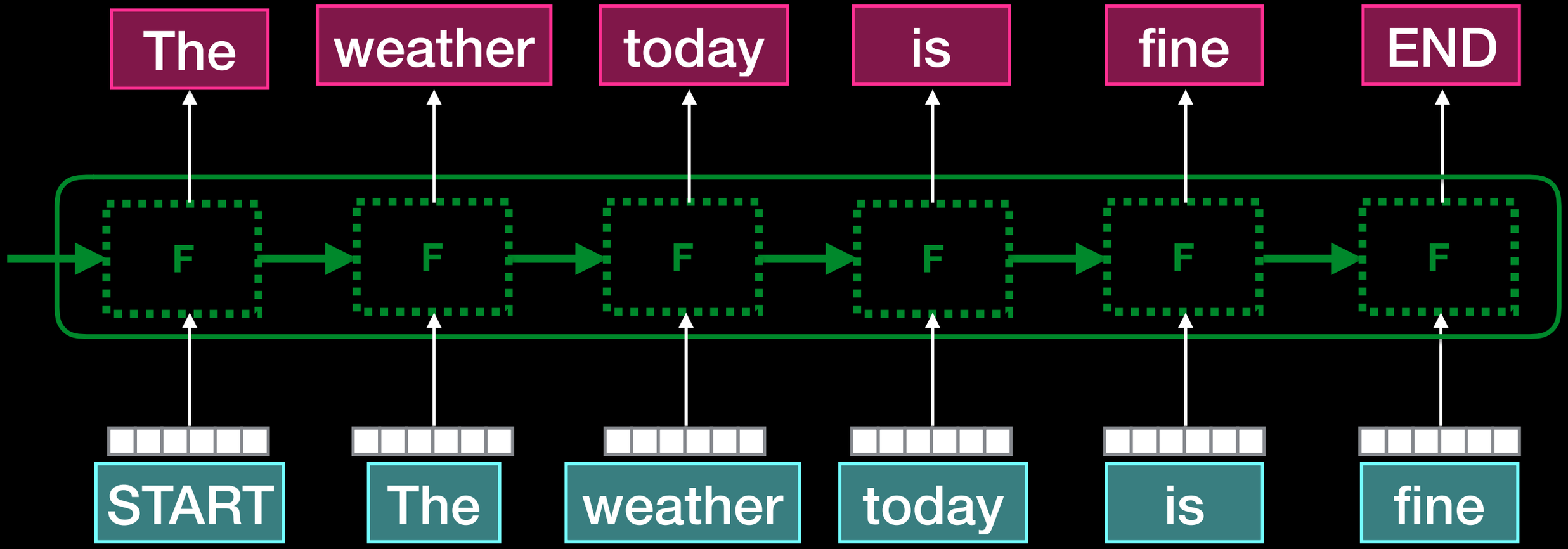
CHAIN RULE

$$P(S) = P(w_1, \ldots, w_n) = P(\texttt{The} \mid \texttt{* *})$$
$$\times P(\texttt{weather} \mid \texttt{* The})$$
$$\times P(\texttt{today} \mid \texttt{The weather})$$
$$\times P(\texttt{is} \mid \texttt{weather today})$$
$$\times P(\texttt{fine} \mid \texttt{today is})$$
$$\times P(\texttt{STOP} \mid \texttt{is fine})$$

Neural LMs

$$P(w_1, w_2, \ldots, w_n) \approx \prod_{i=1}^{N} P(w_i|w_1, w_{i-1})$$

INIFINTE MODEL



PREDICT NEXT WORD GIVEN HISTORY

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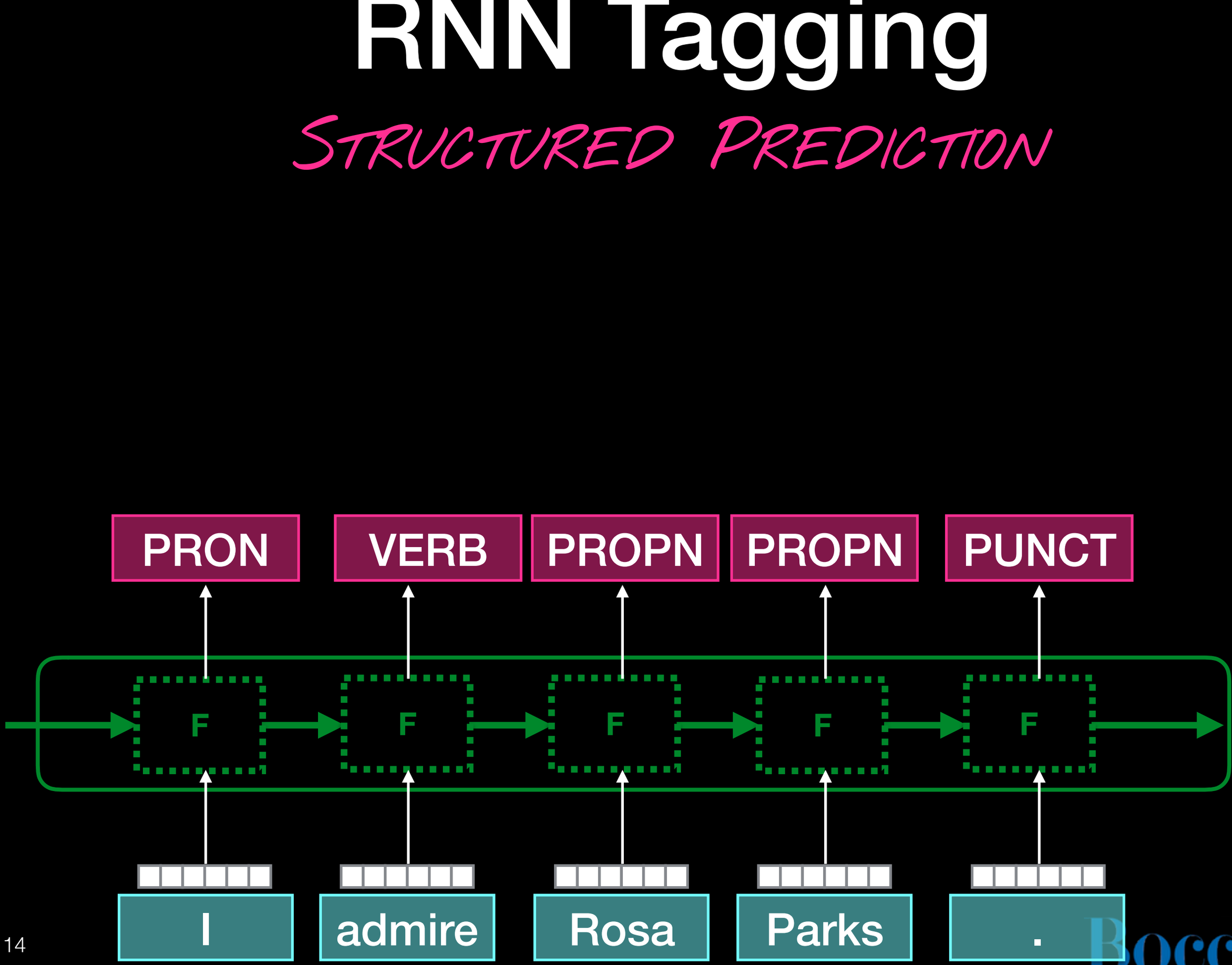
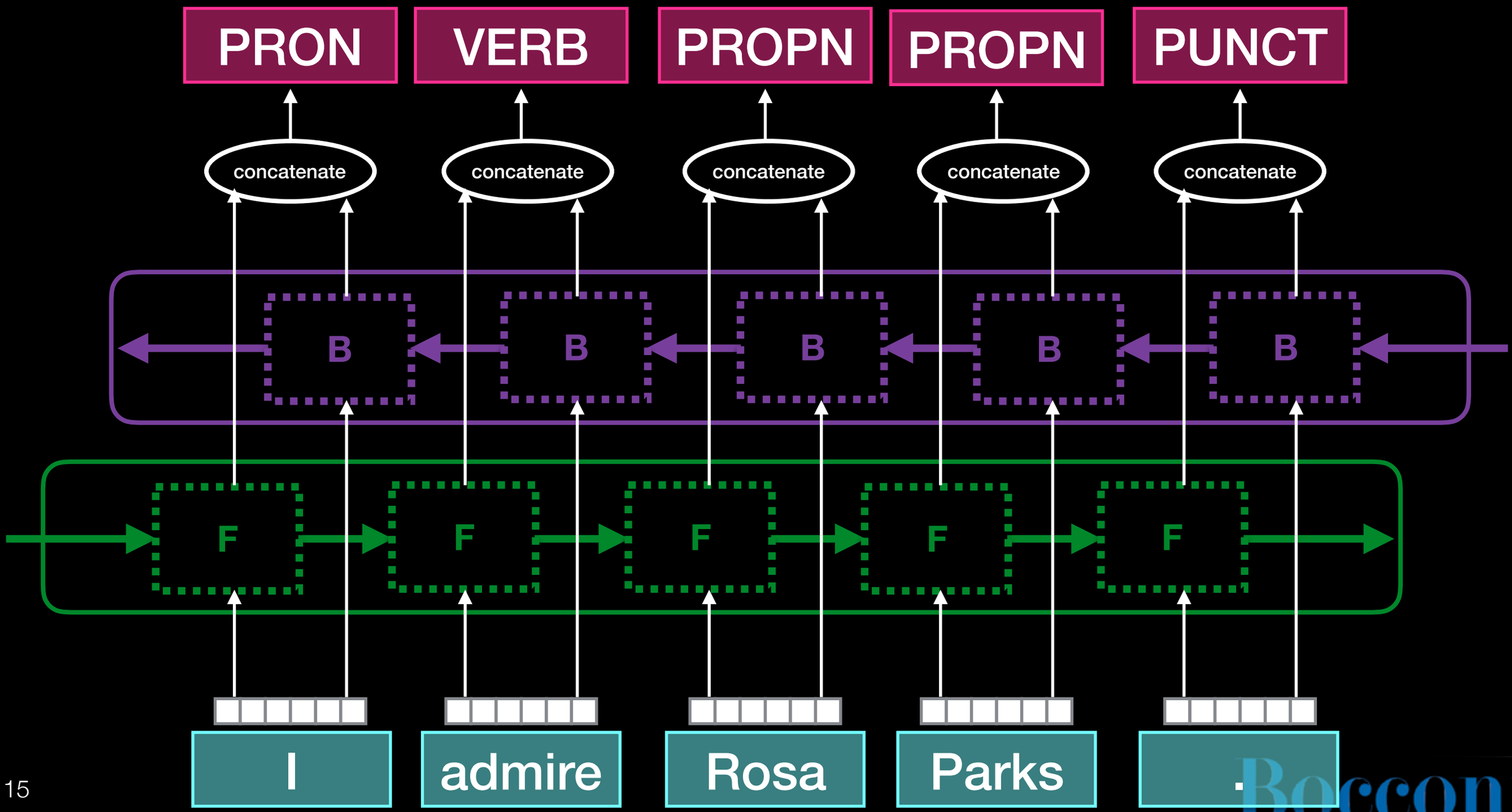
RNN Tagging

Structured Prediction



Bidirectional-RNN

Structured Prediction



Special

Recurrent Networks

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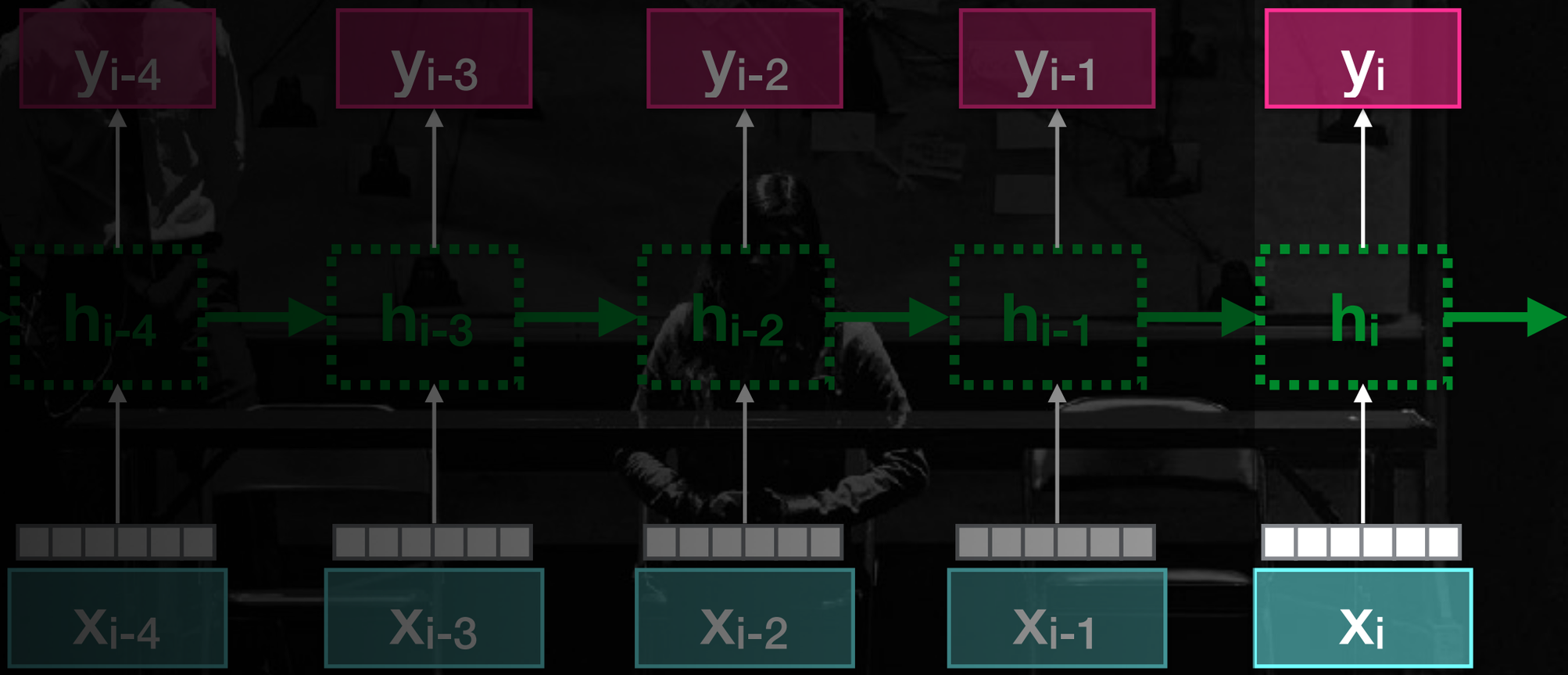
Vanishing Memory

WHERE WERE YOU MARCH 3, 2016?



PROBLEM WITH LONG SEQUENCES

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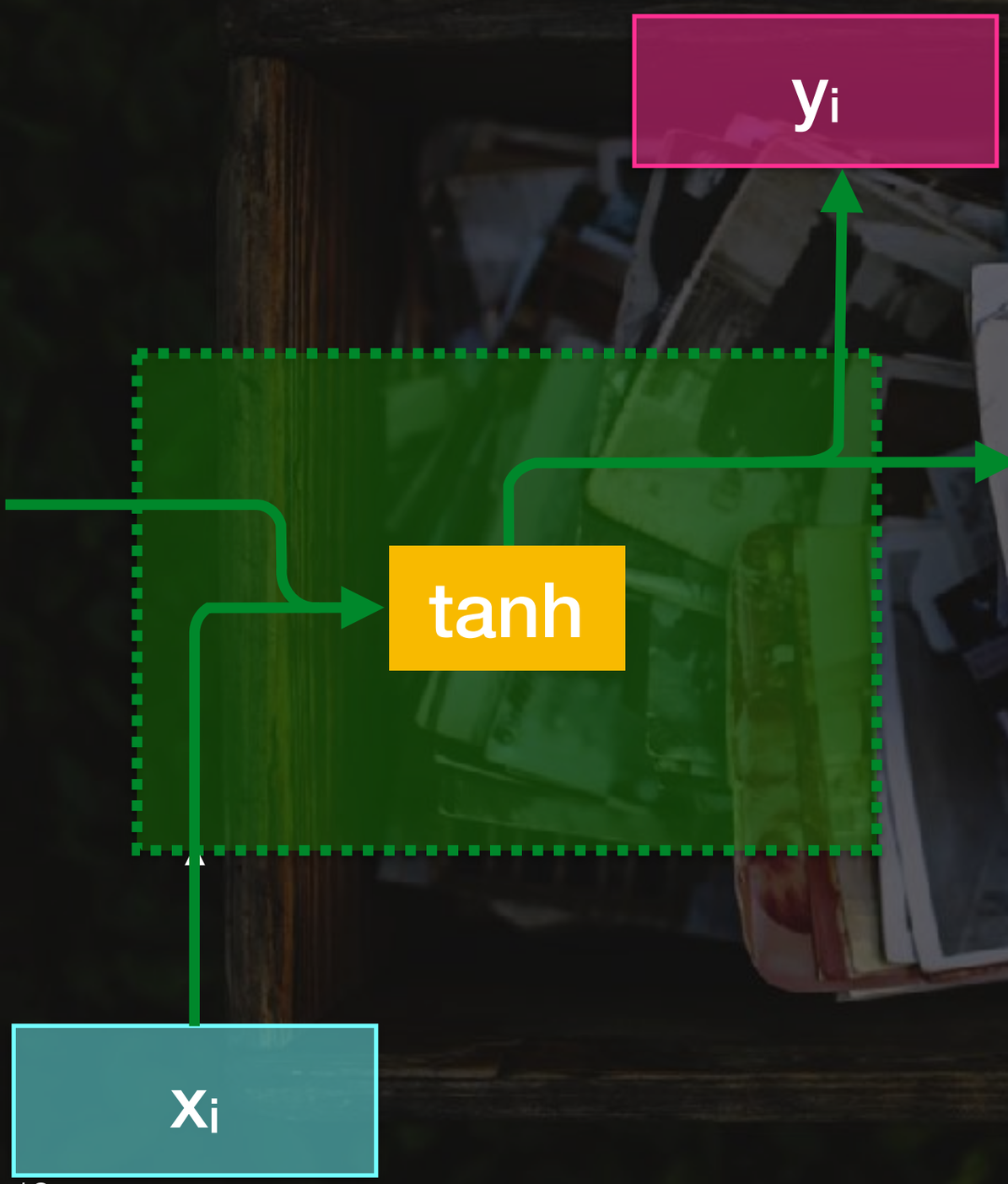
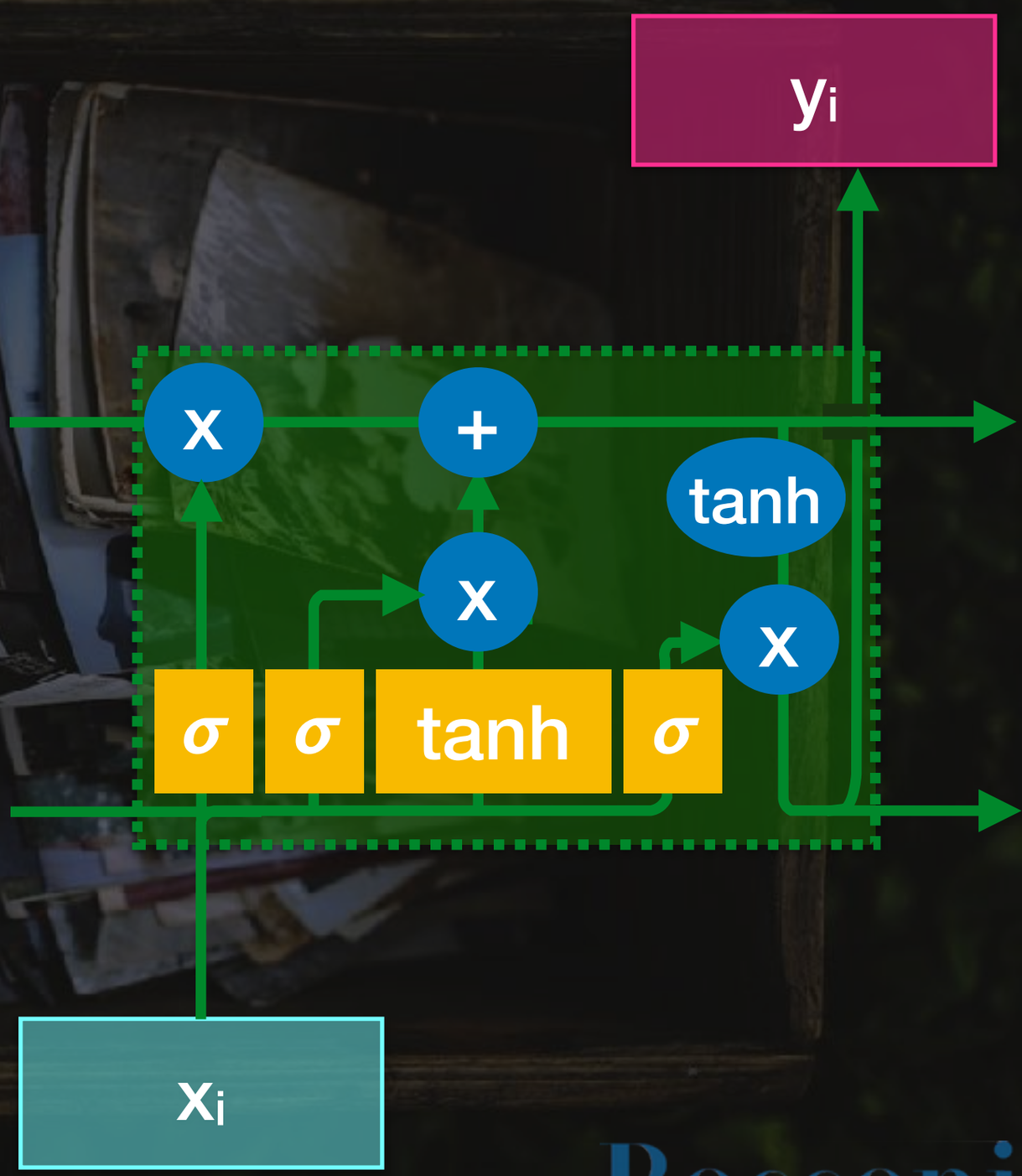
Selective Forgetting

SIMPLE RNN

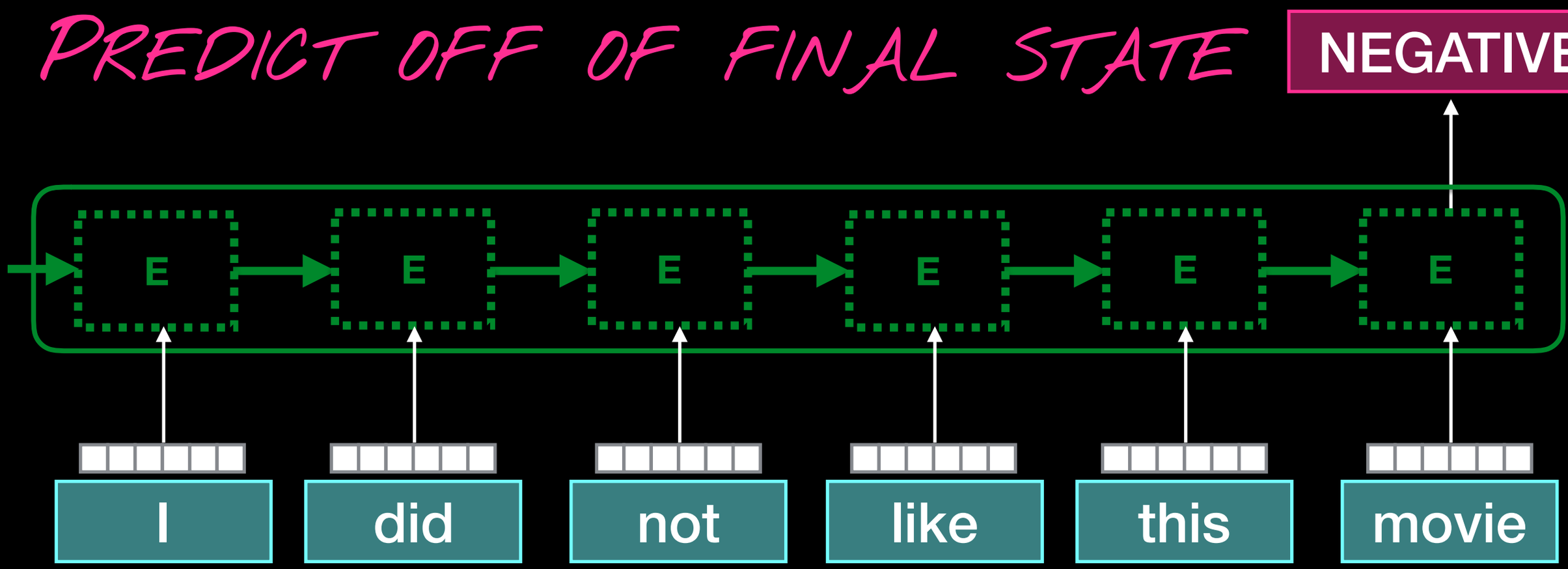


LSTM



Acceptor

PREDICT OFF OF FINAL STATE



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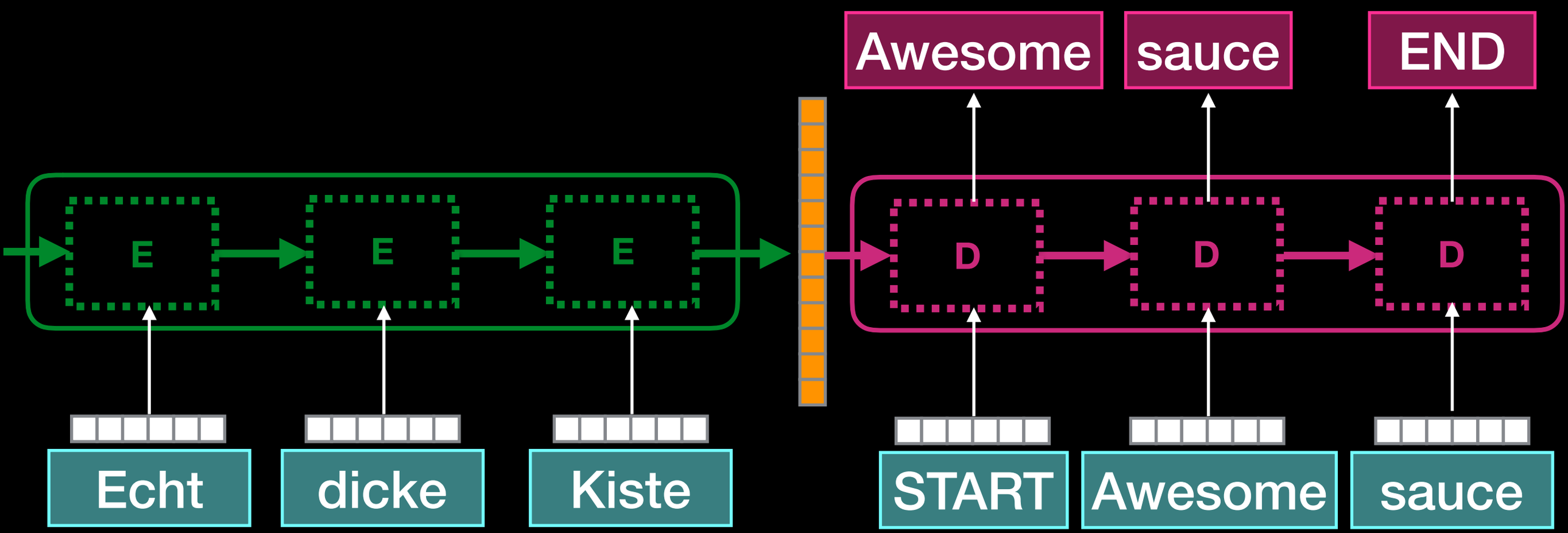
Encoder-Decoder

…And Generate Output from it



Gobble up sequence into a vector…

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Convolution

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Convoluted Matters

Text Sort classification

Retail

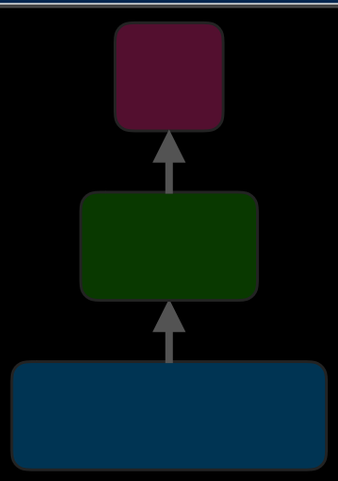
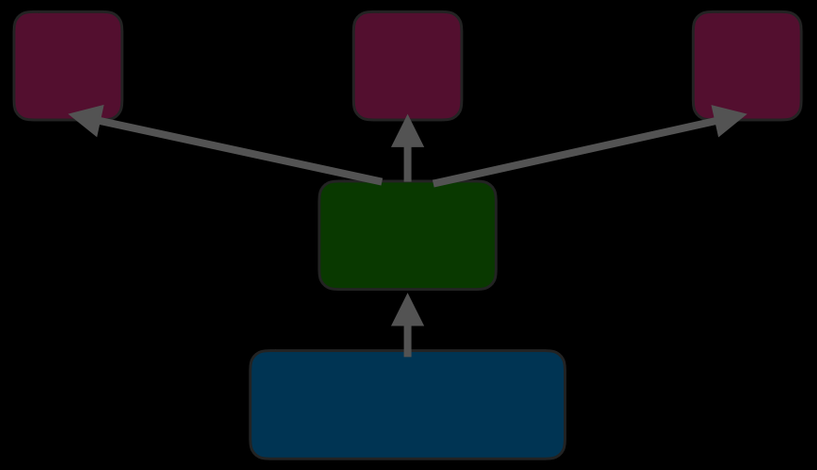
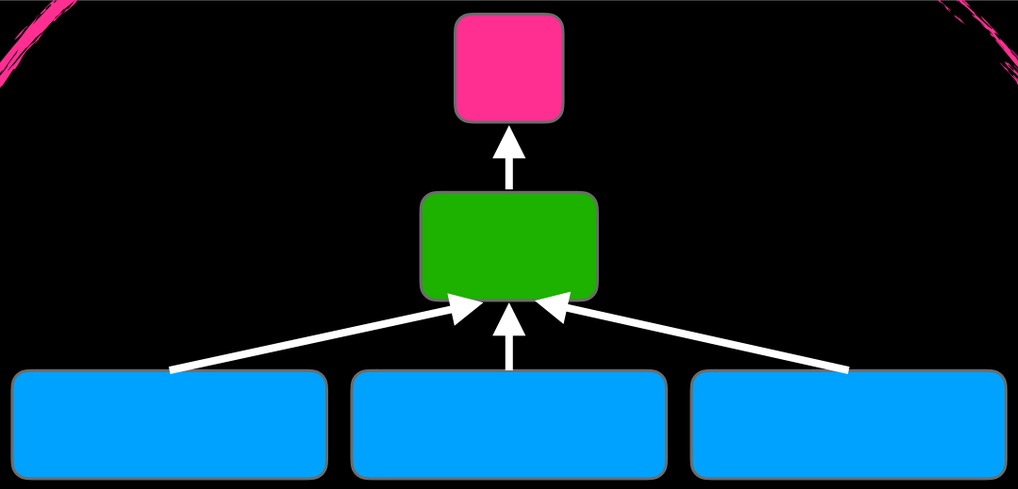
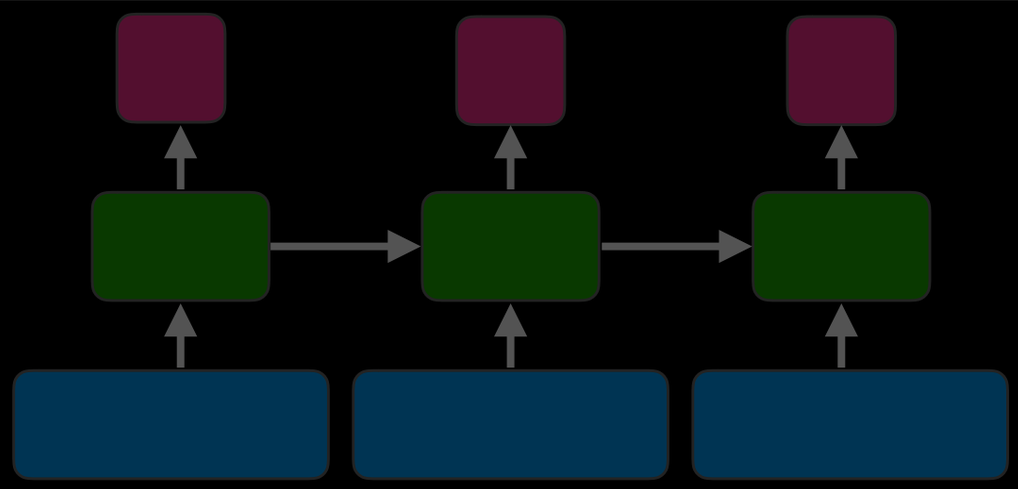
Sentiment Analysis

positive

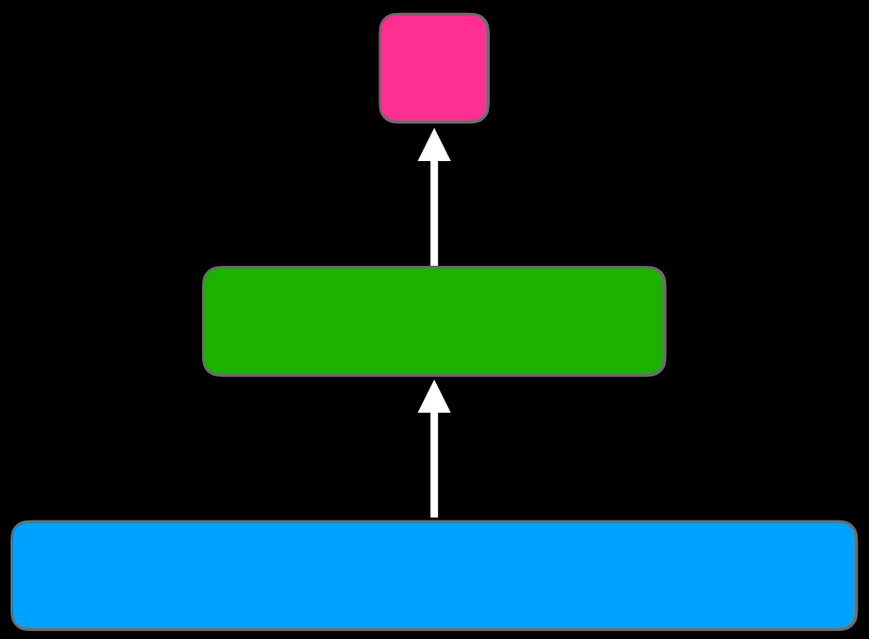
Relation Extraction

founded_by(Amazon, Jeff Bezos)

Types of Text Classification

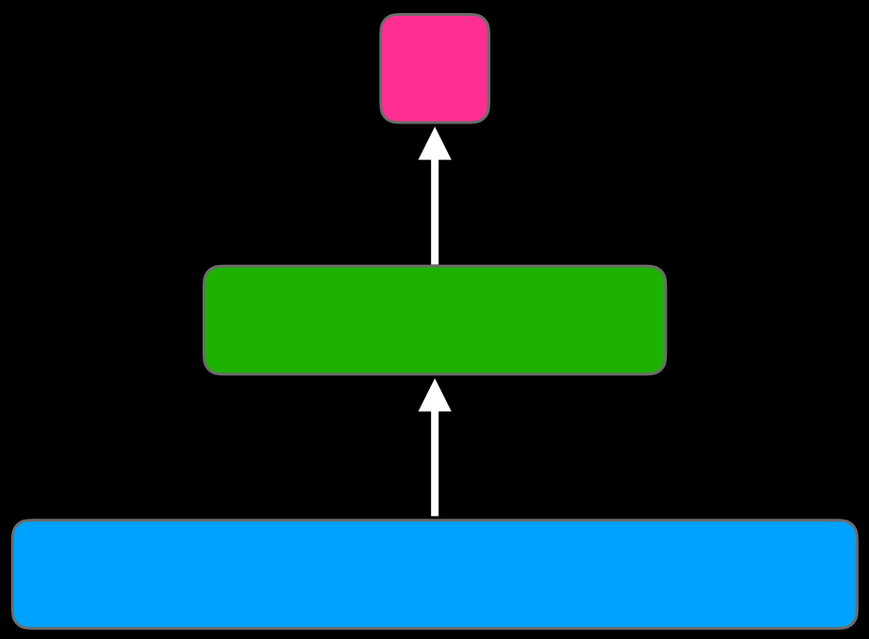
	Fixed length	Variable length
Fixed length	 Logistic Regression, Perceptron, Feed-Forward Network, Random Forest, Naive Bayes, SVM, …	 Multitask Learning, Decoder
Variable length	 Convolutional Neural Networks (CNN)	 Recurrent Neural Networks (RNN), Hidden Markov Models (HMM), Conditional Random Fields

Problems with MLPs



Not bad, actually quite good

$\neq$



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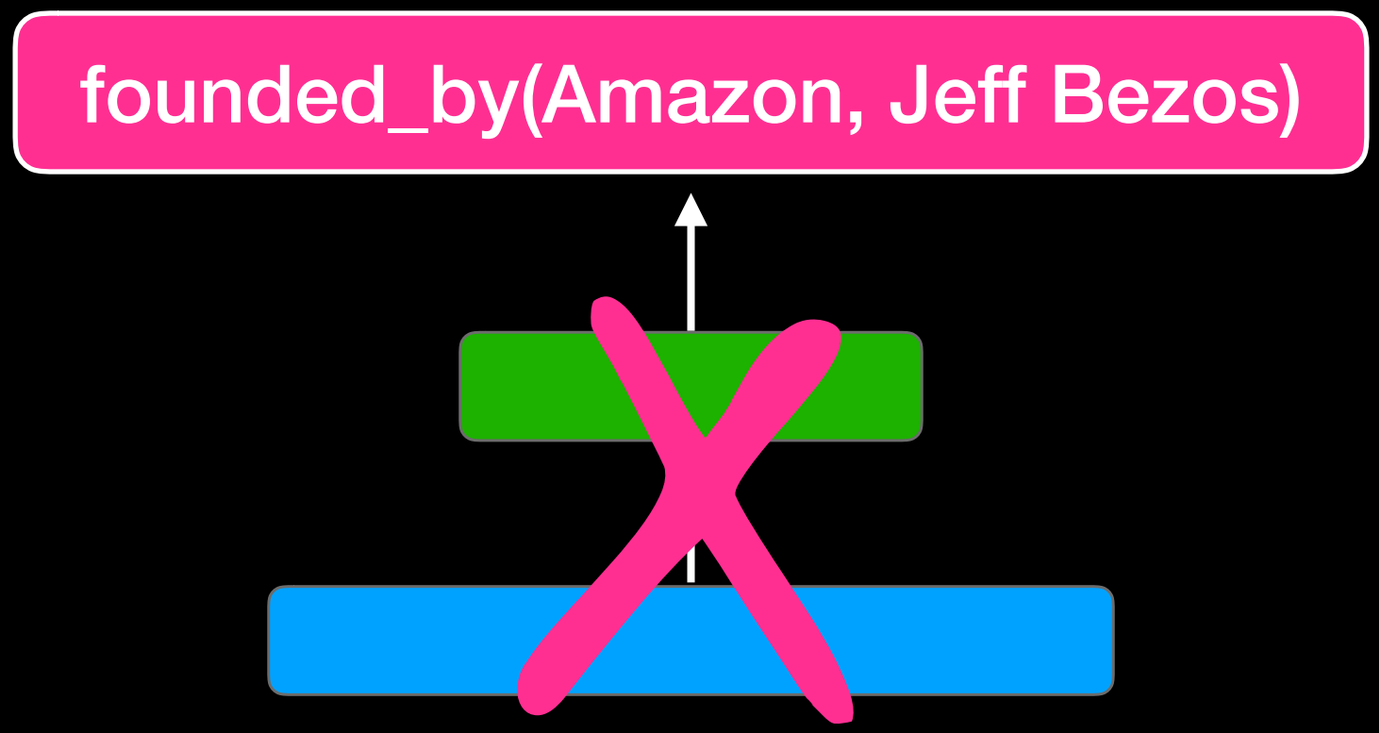
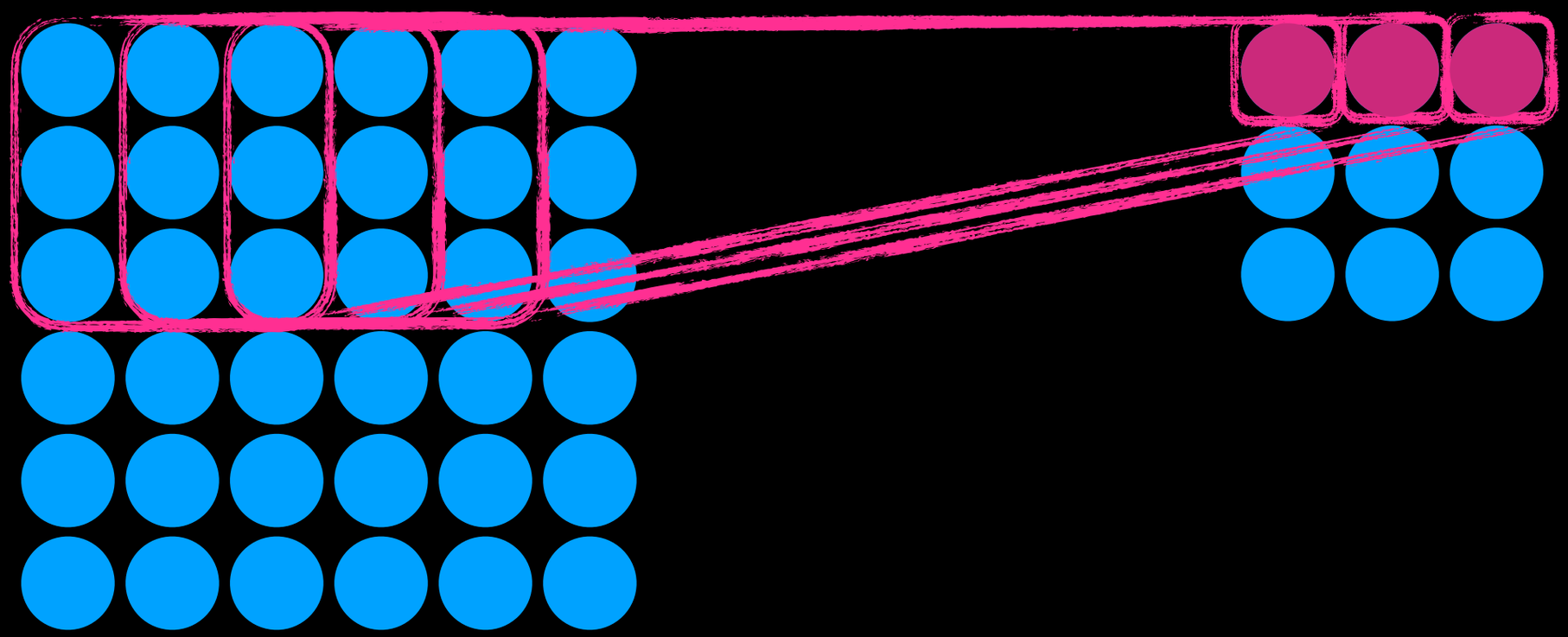
Problems with MLPs

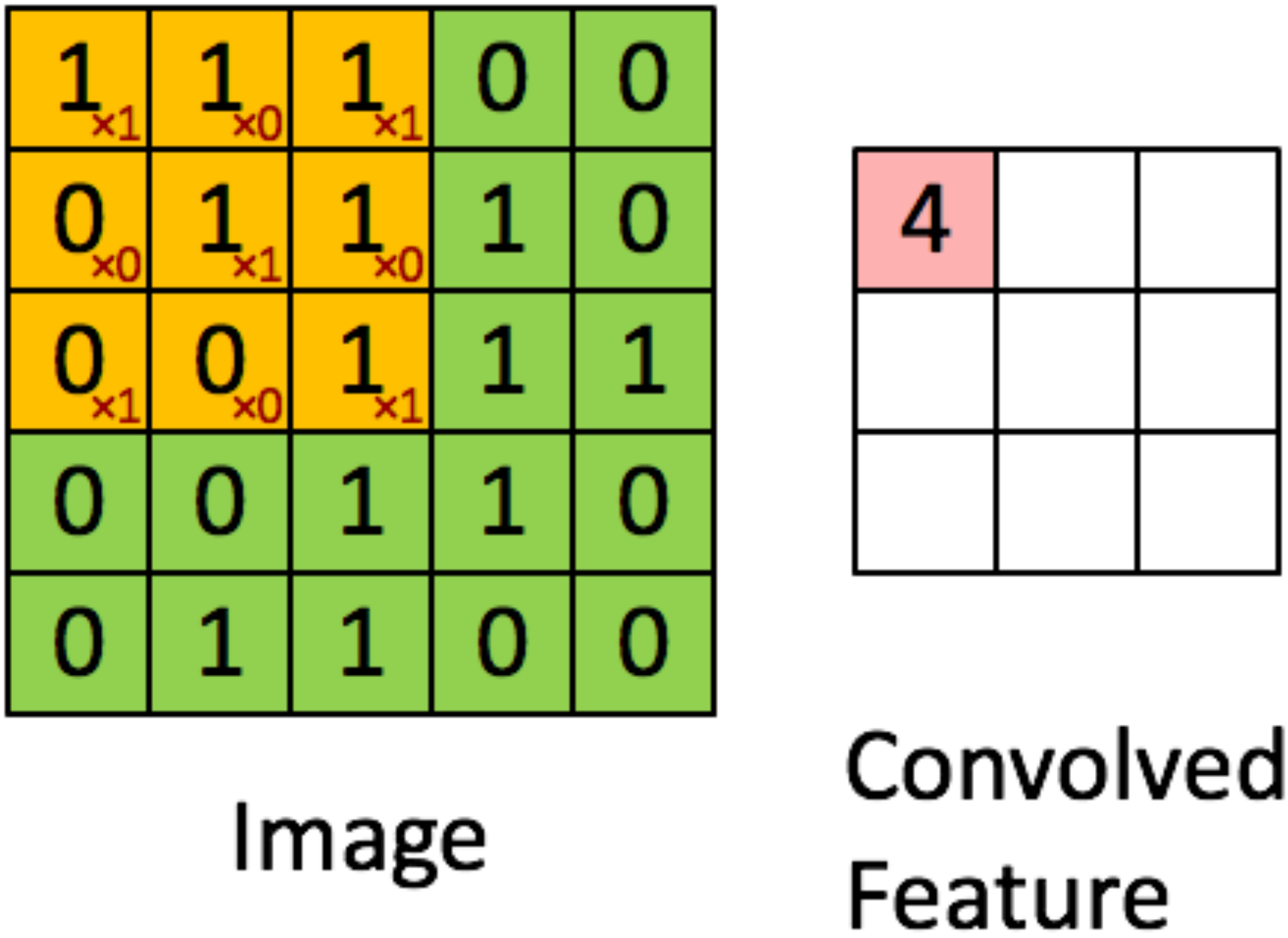


Jeff Bezos, or what Dr. Evil would look like on steroids, went from book seller to billionaire when he founded Amazon in 1994.

Convolution



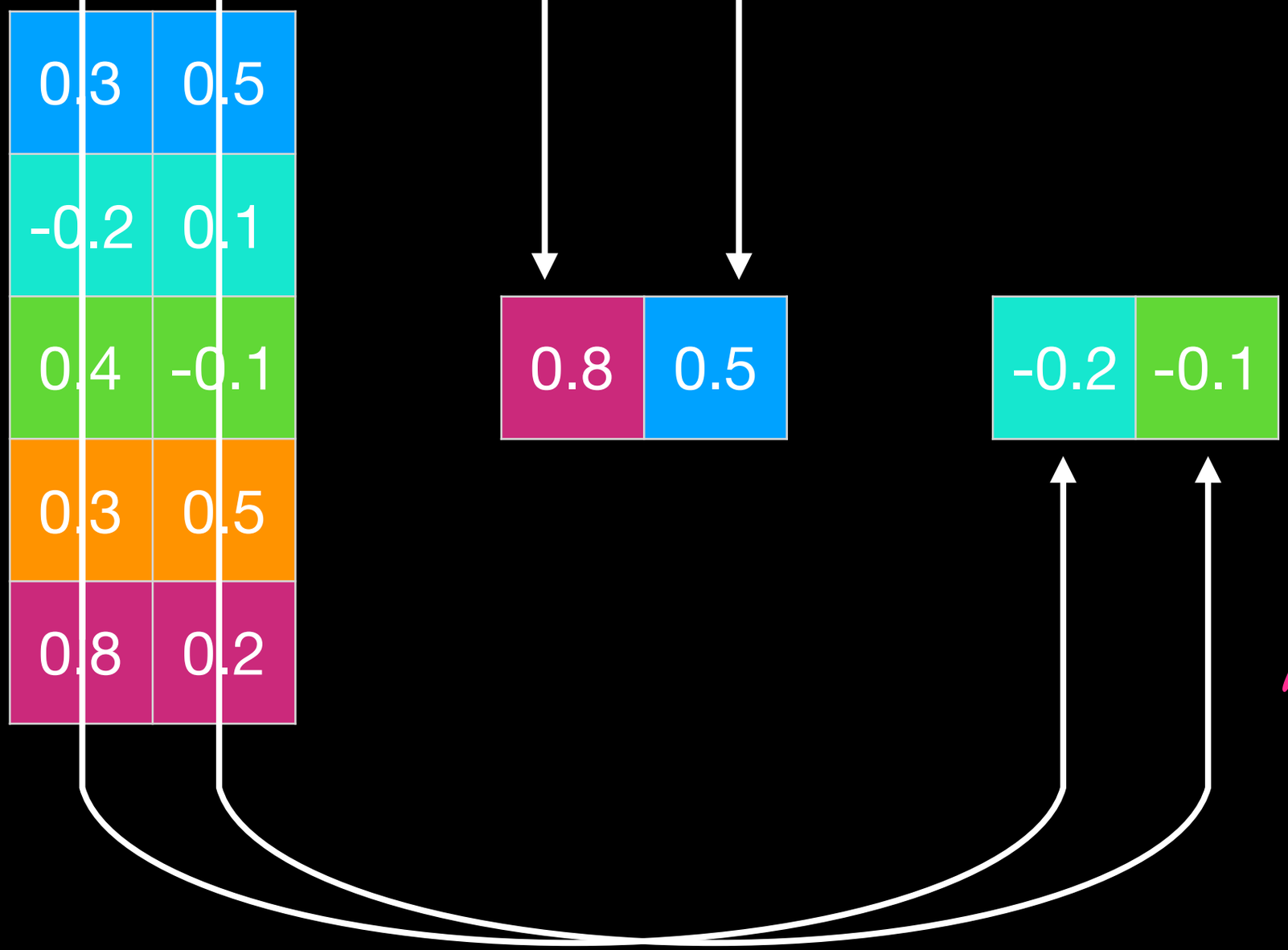
Convolution Extraction



http://deeplearning.stanford.edu/wiki/index.php/Feature_extraction_using_convolution

Pooling

MAX POOLING



MIN POOLING

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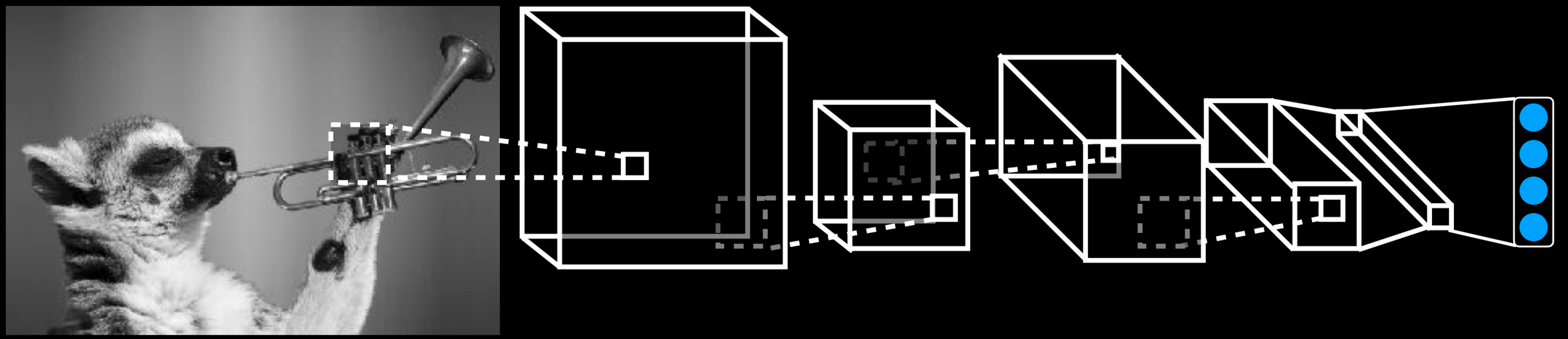
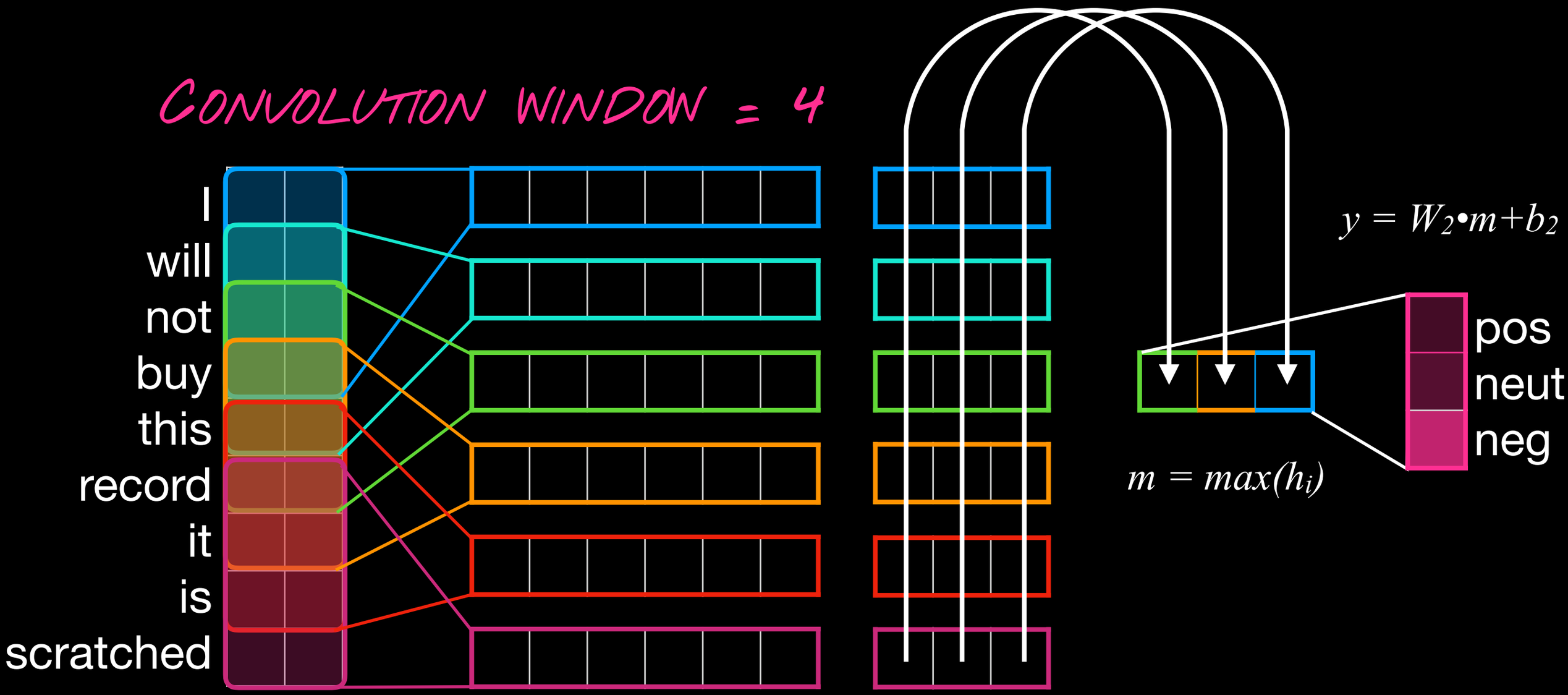
CNNs in Images



CNNs in Text



$c_i = concat(x_{i-i+3})$ $h_i = relu(W_1 \bullet c_i + b_1)$

The Attention Mechanism

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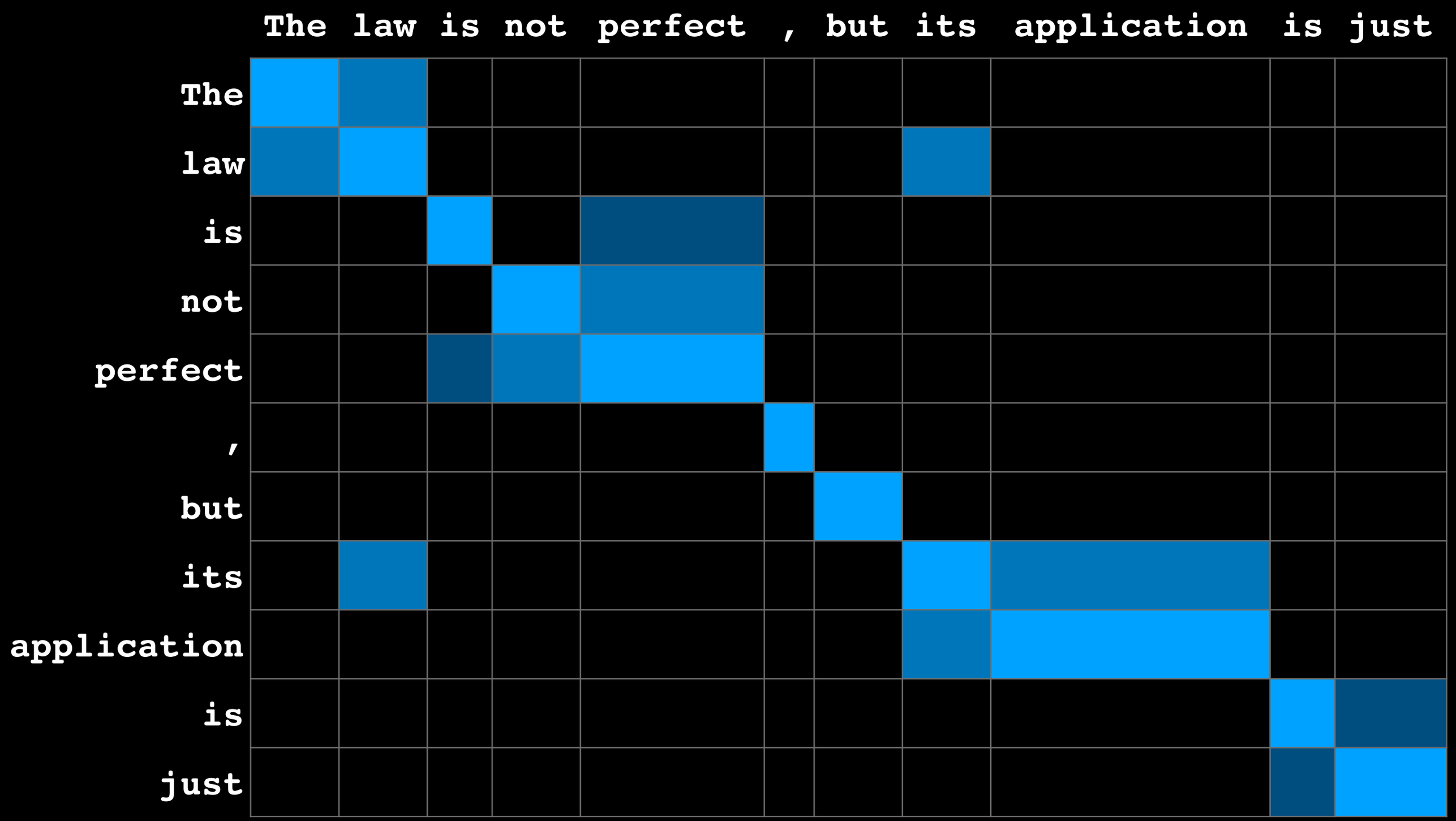
Attention!

- Learn syntactic and semantic relations between words in
  - the input and output (RNNs)
  - only the input (CNNs)
- Good for machine translation (word alignment) and classification (complex expressions)

CNN with Attention



FIND LONG-RANGE DEPENDENCIES

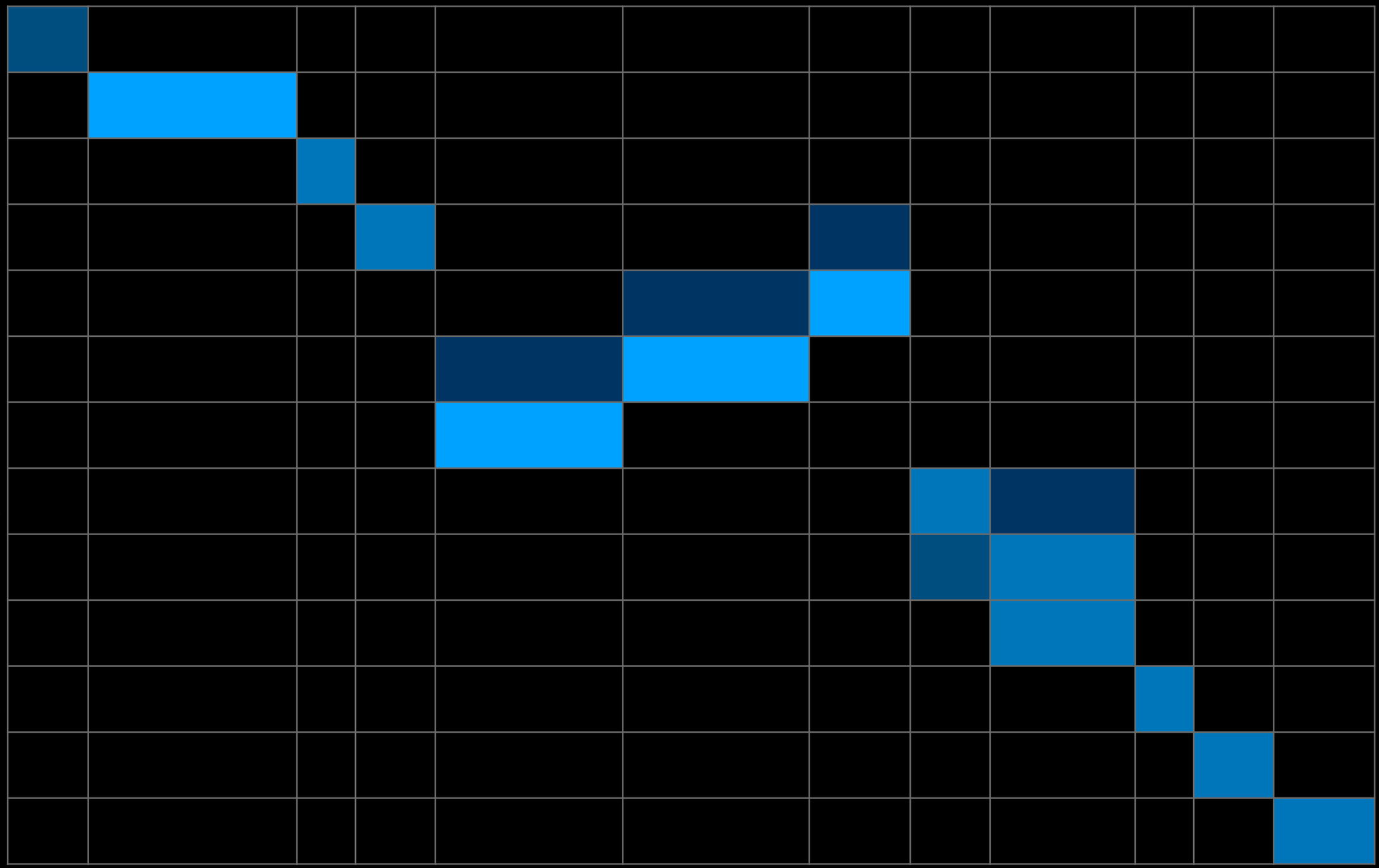
RNN with Attention

OUTPUT

The agreement on the European Economic Area was signed in Aug 1992

INPUT

L'
accord
sur
la
zone
économique
européenne
a
été
signé
on
août
1992



LEARN REORDERING

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RNN with Attention

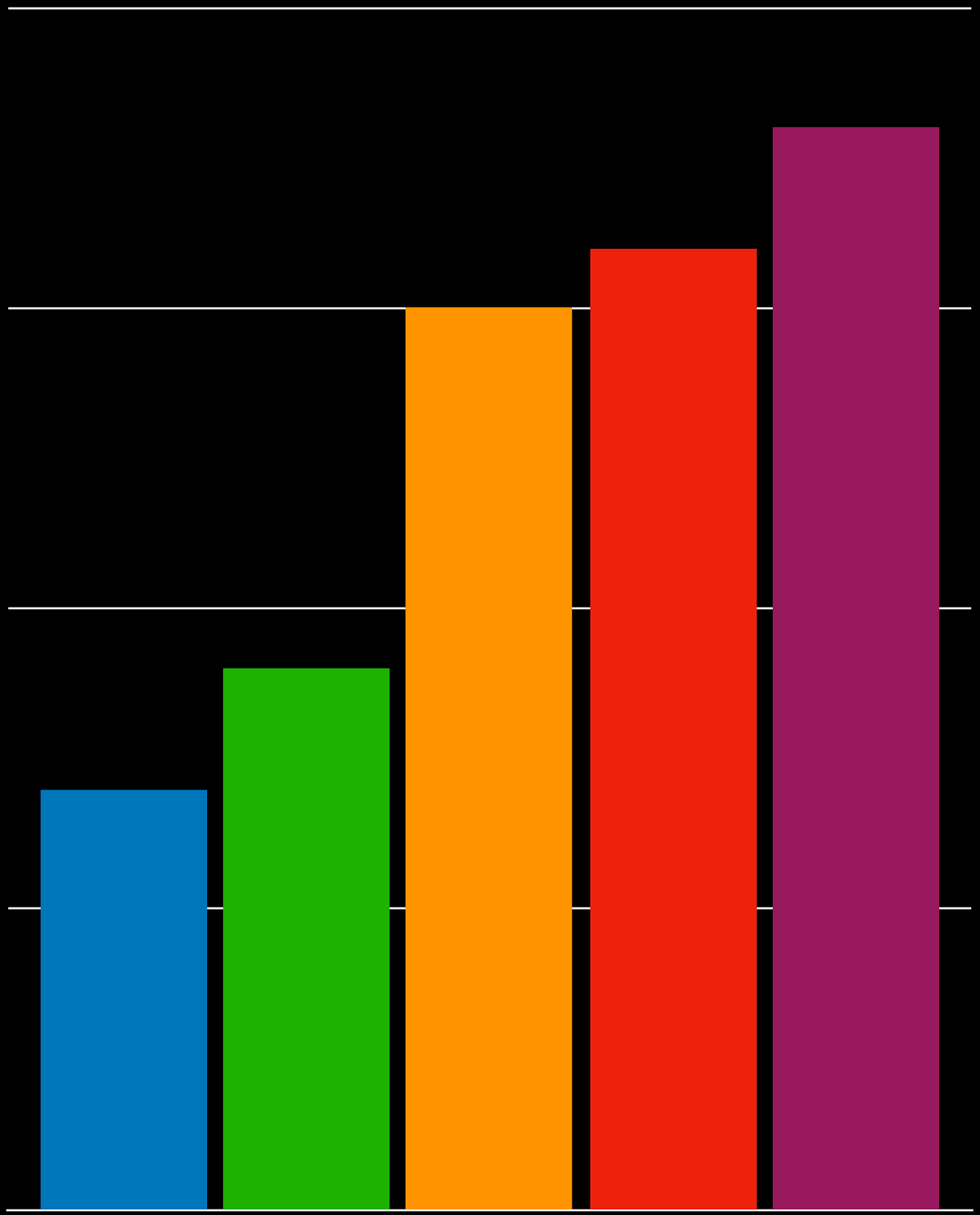
OUTPUT

INPUT	Economic	growth	has	slowed	down	in	recent	years
Das								
Wirtschafts-								
wachstum								
hat								
sich								
in								
den								
letzten								
Jahren								
verlangsamt								

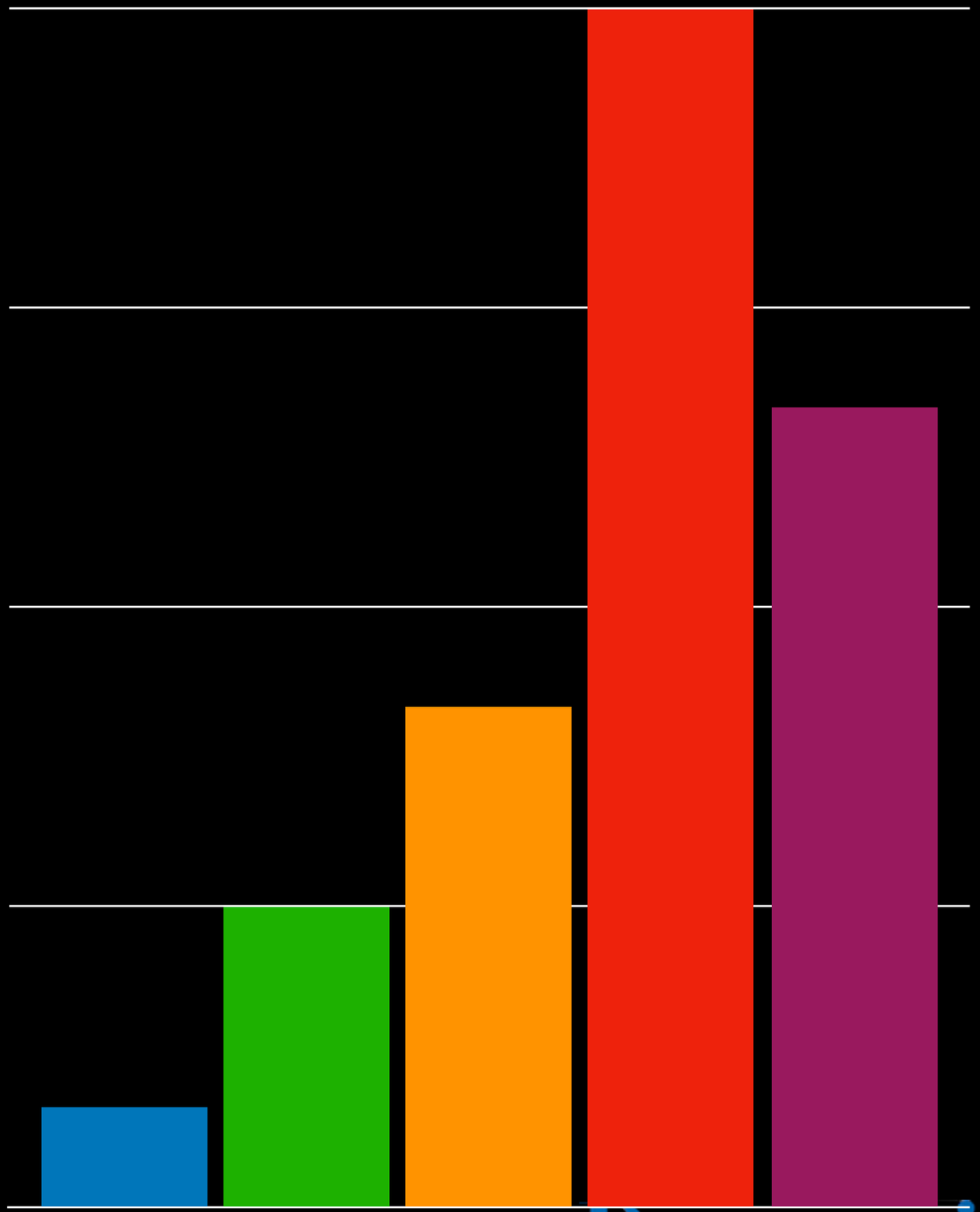
LEARN REORDERING

Performance

Logistic Regression Feed-Forward CNN RNN CNN+Attention



performance



parameters

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Wrapping up

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Take Home Points

- **Recurrent Neural Nets** address long-range dependencies
- Condition each word on all previous ones (better for **LMs** and **sequence labels)**
- **Bidirectional RNNs** condition on following words
- **LSTMs** learn to forget useless input
- **Convolution windows** captures **different views** of input
- **Pooling** reduces dimensionality
- CNNs are often **better for text classification** than feedforward NNs
- **Attention** improves coherence and performance