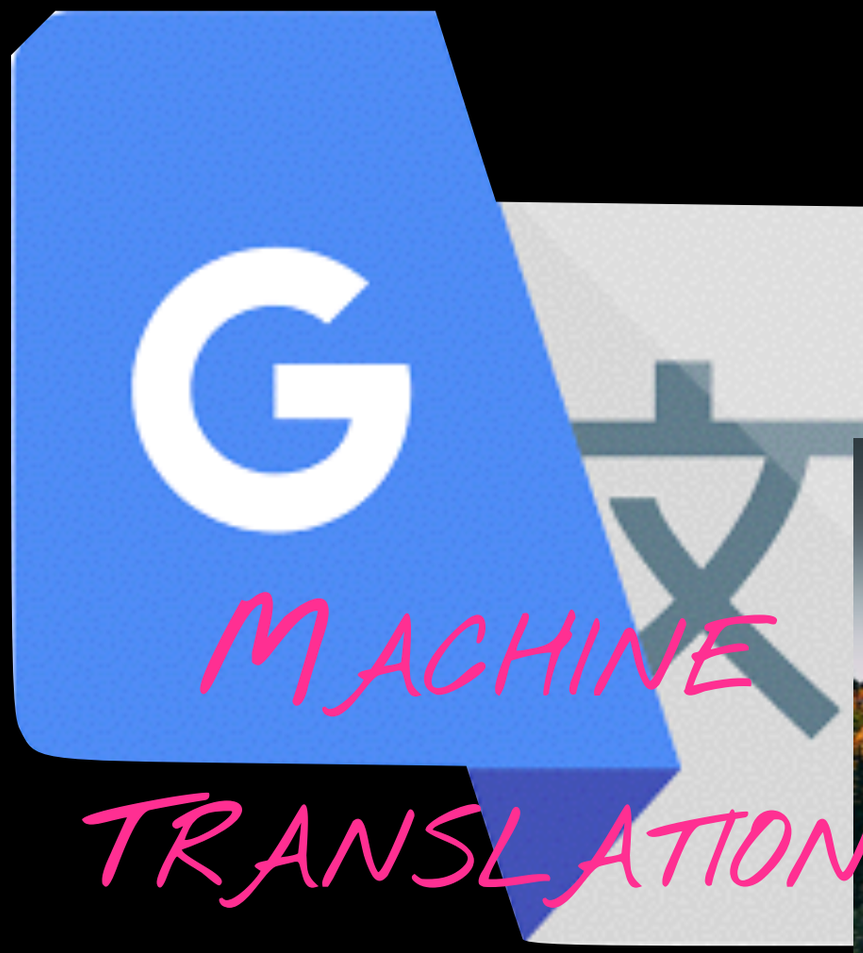
Goals for Today

- 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

Bocconi

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.

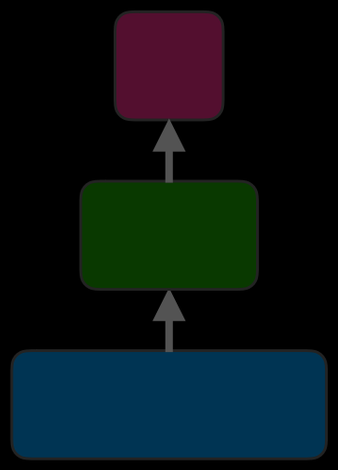
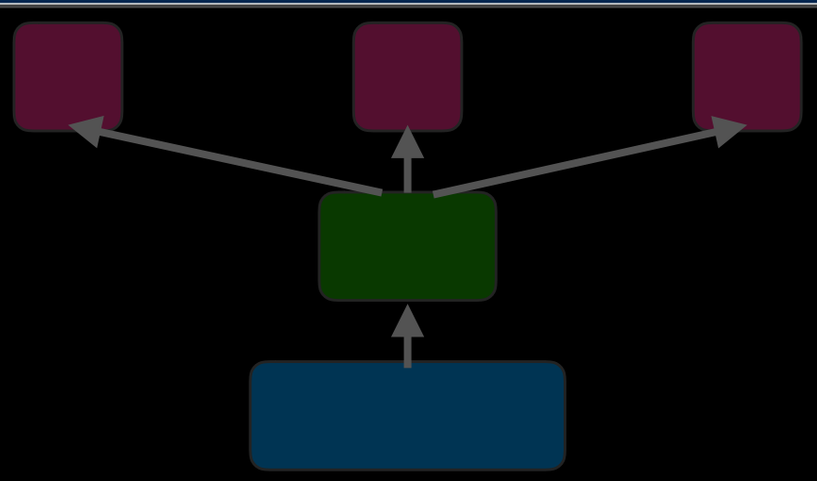
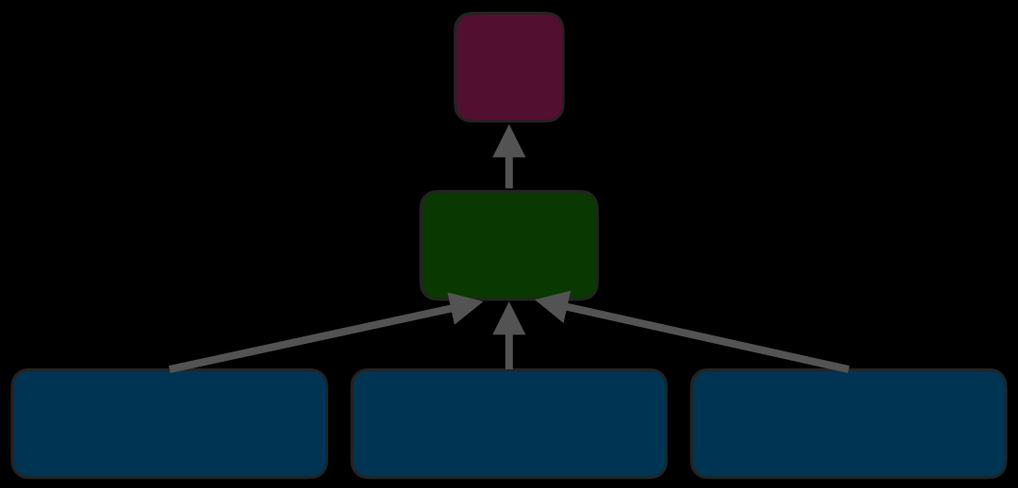
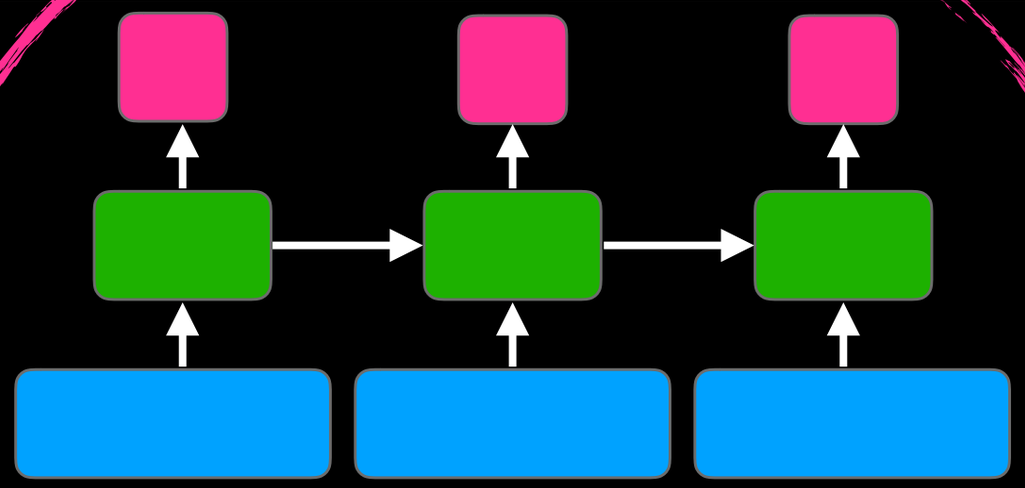
Sequence Tagging

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

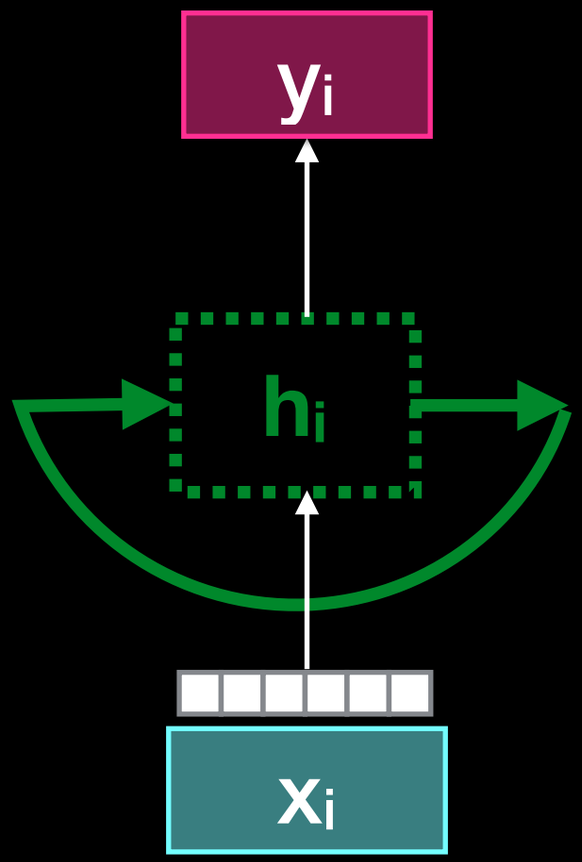
Recurrent Networks

Bocconi

Recurrence

$$y_i = f(h_i)$$

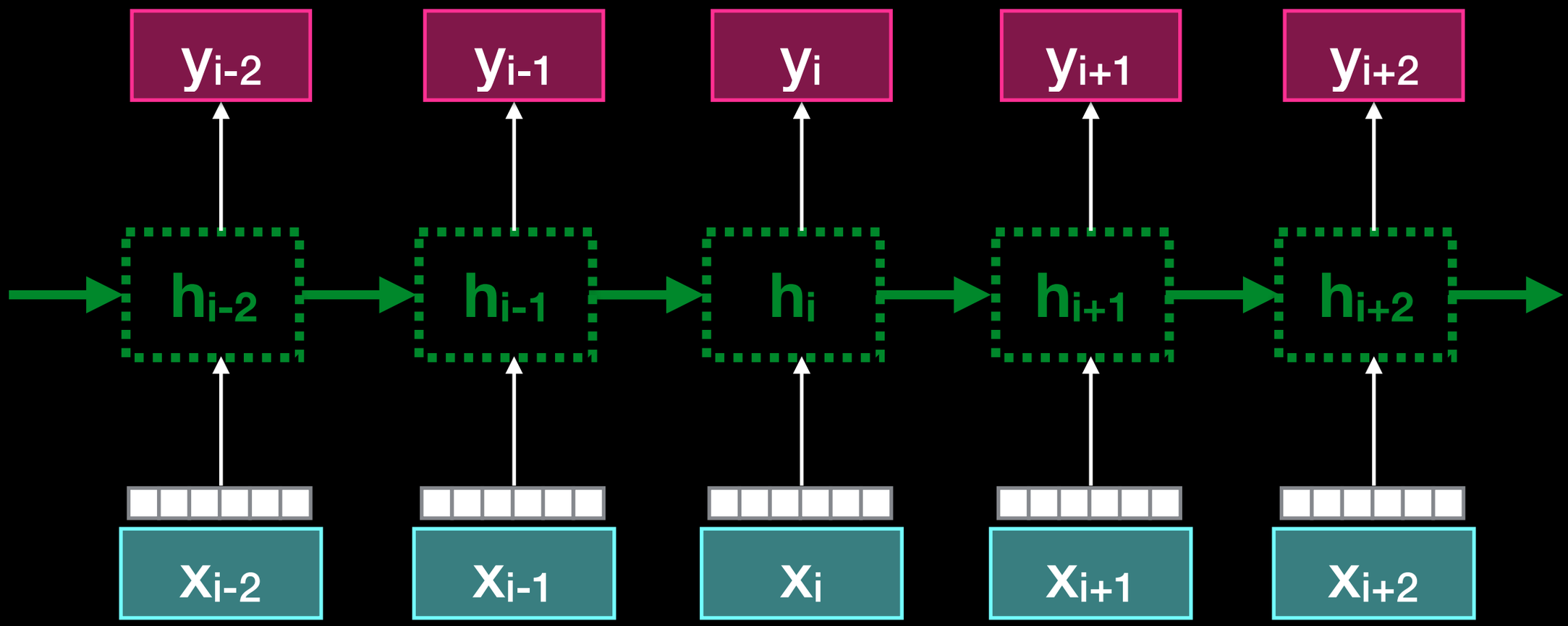
$$h_i = s(h_{i-1}, x_i)$$



…Unrolled

$$y_i = f(h_i)$$

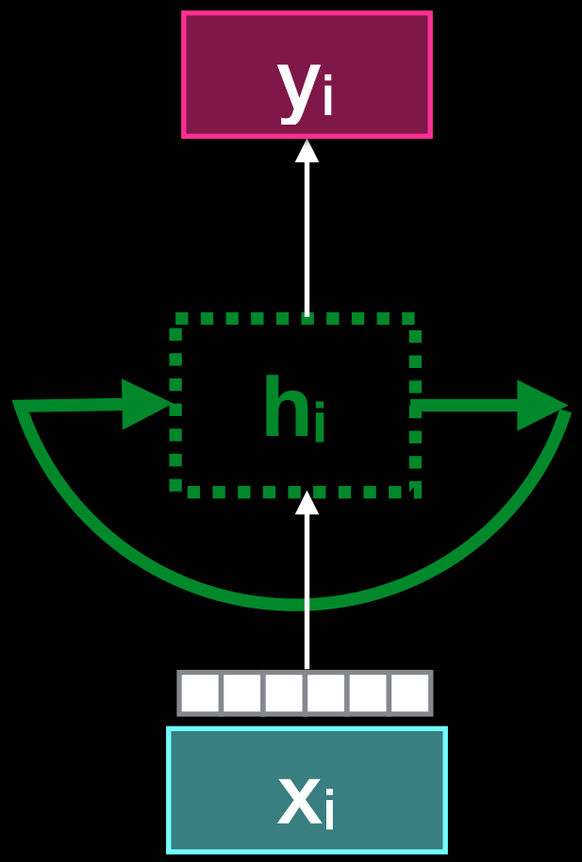
$$h_i = s(h_{i-1}, x_i)$$



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`

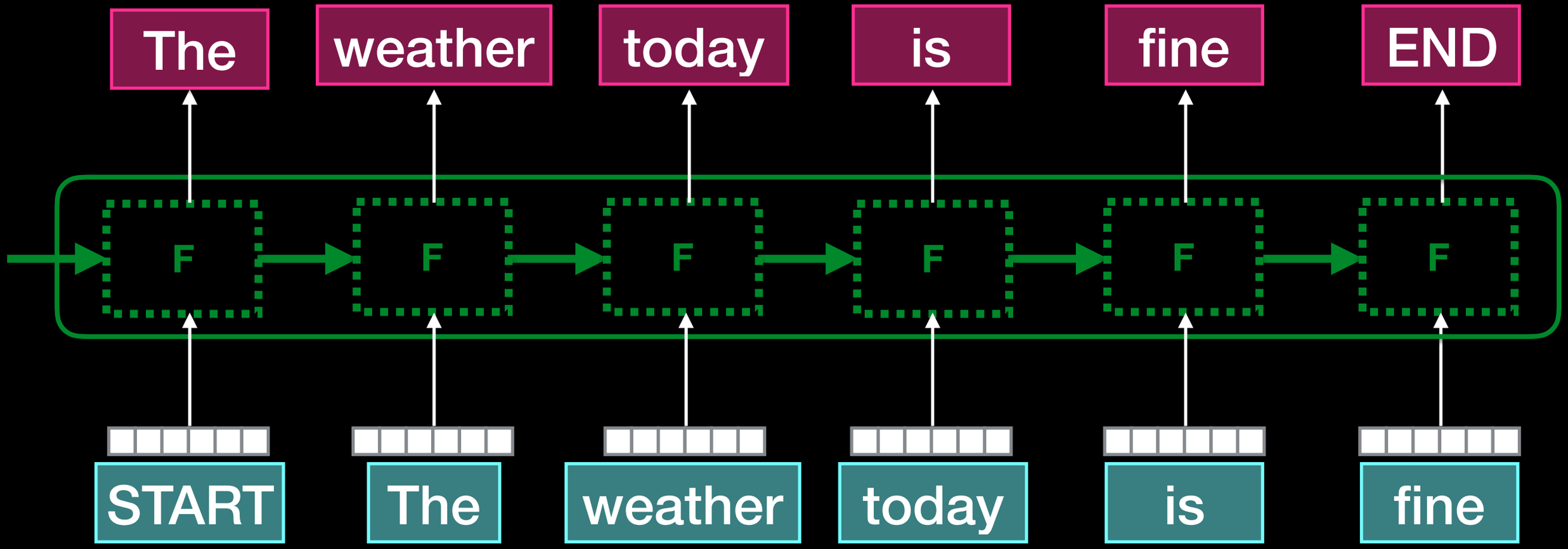
CHAIN RULE

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

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

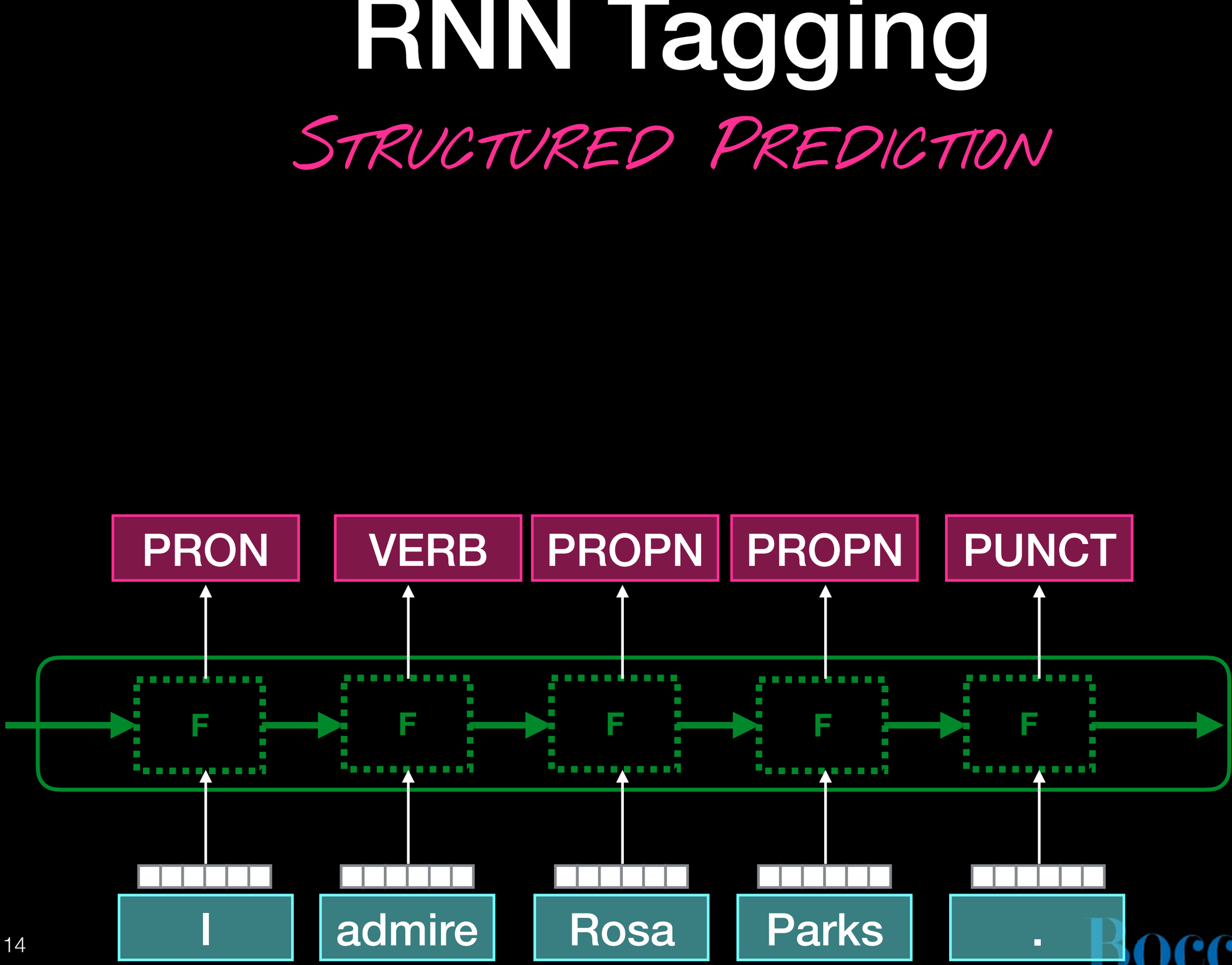


PREDICT NEXT WORD GIVEN HISTORY

Bocconi

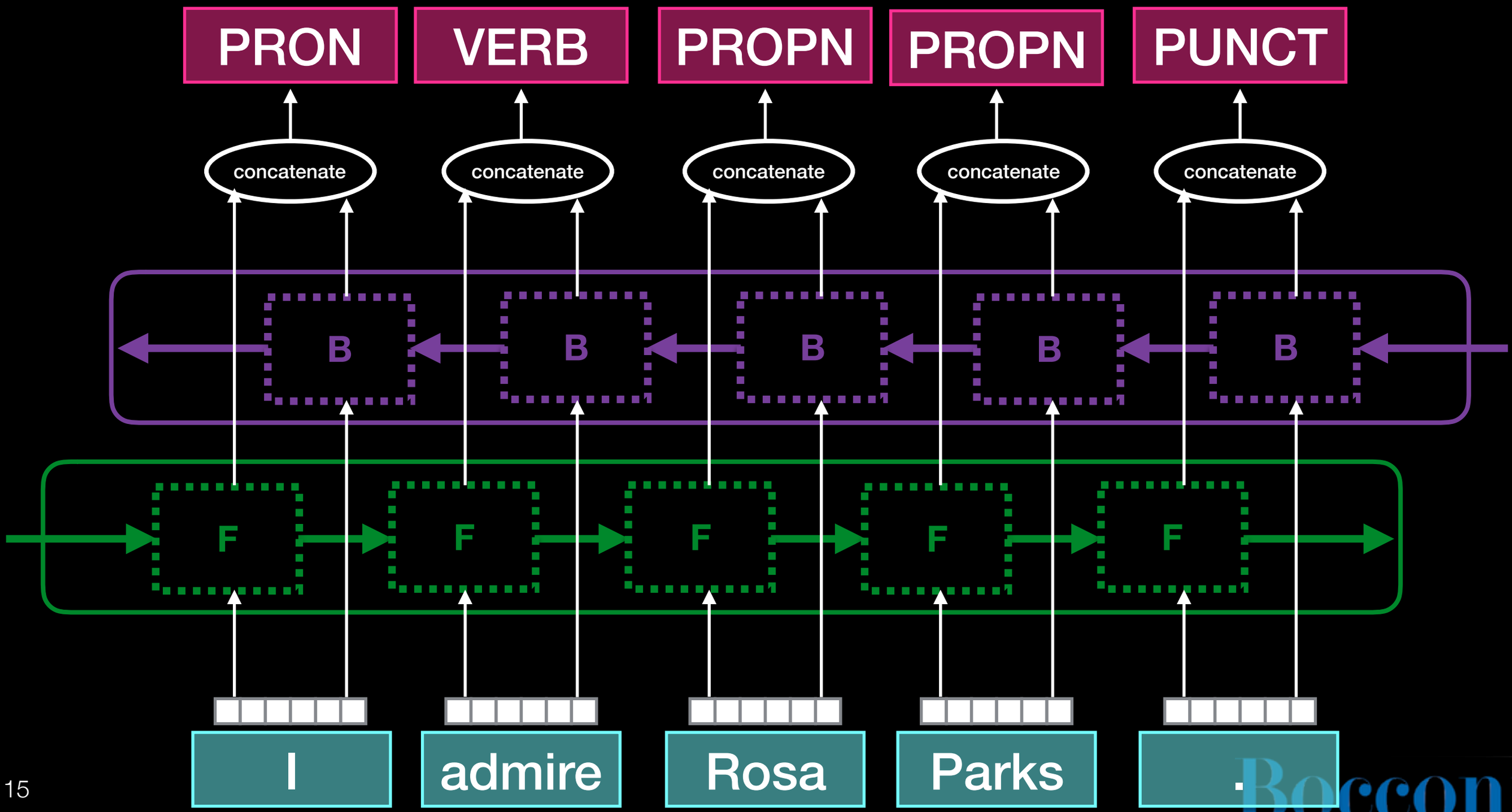
RNN Tagging

Structured Prediction



Bidirectional-RNN

Structured Prediction



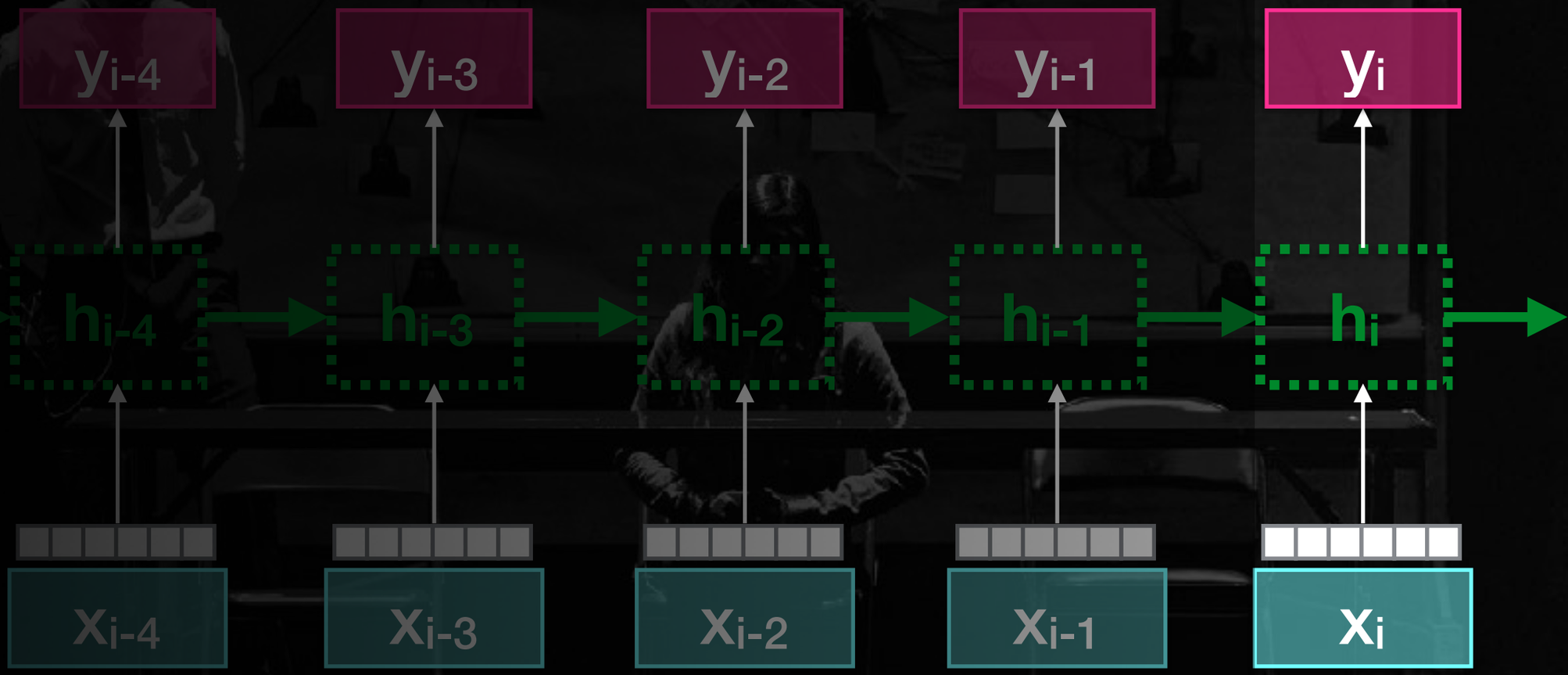
Special

Recurrent Networks

Bocconi

Vanishing Memory

WHERE WERE YOU MARCH 3, 2016?

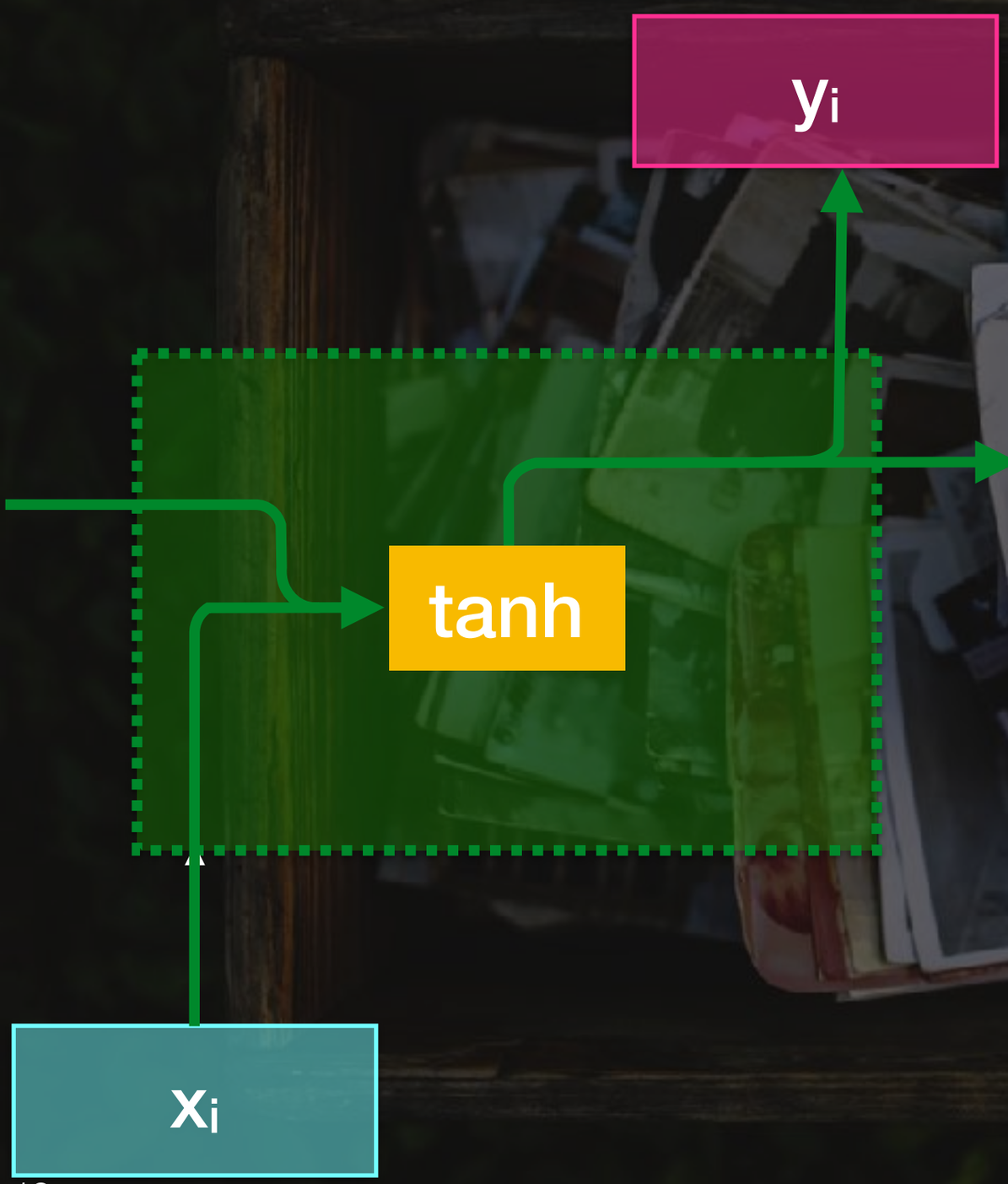


PROBLEM WITH LONG SEQUENCES

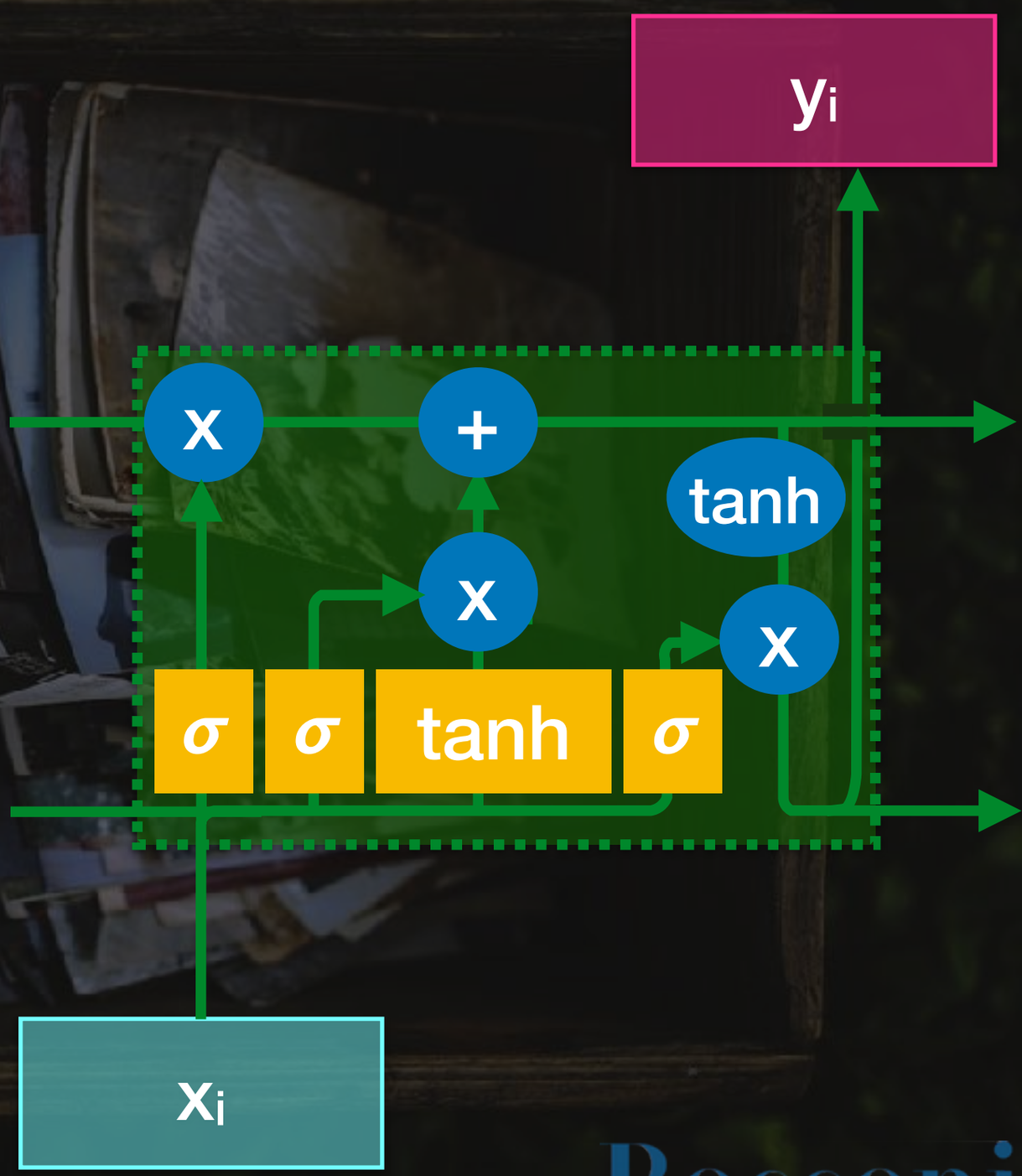
Bocconi

Selective Forgetting

SIMPLE RNN

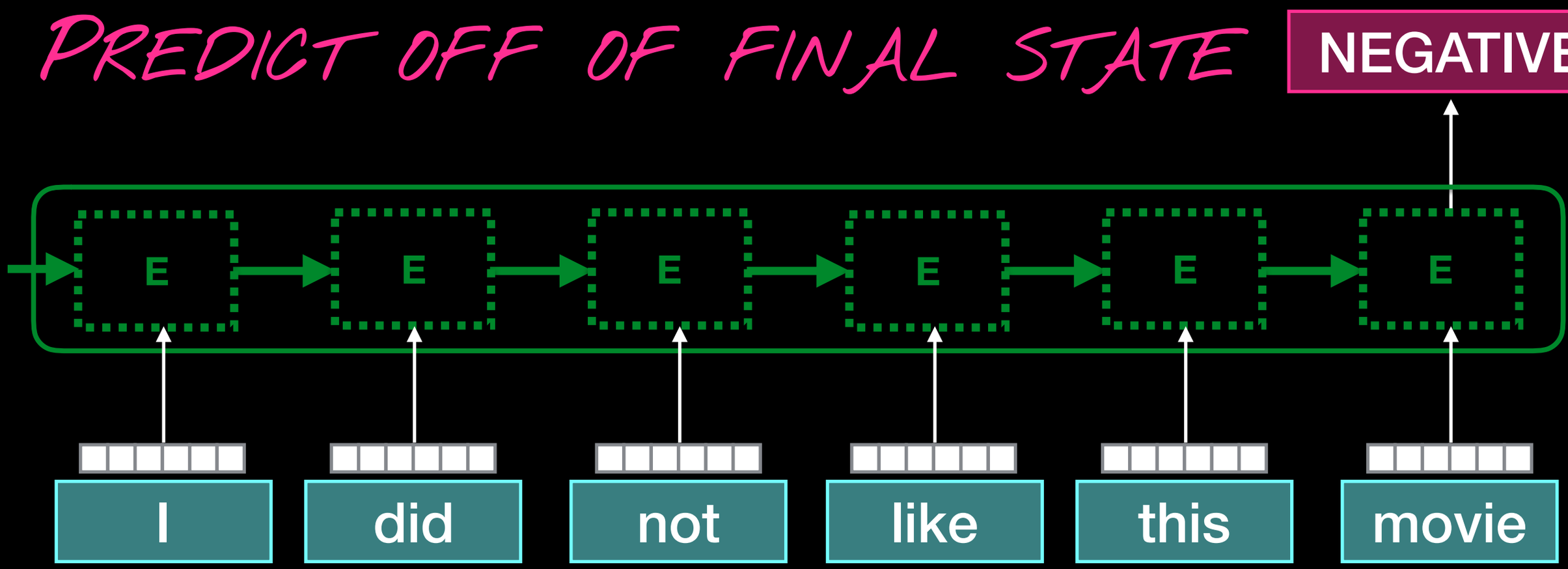


LSTM



Acceptor

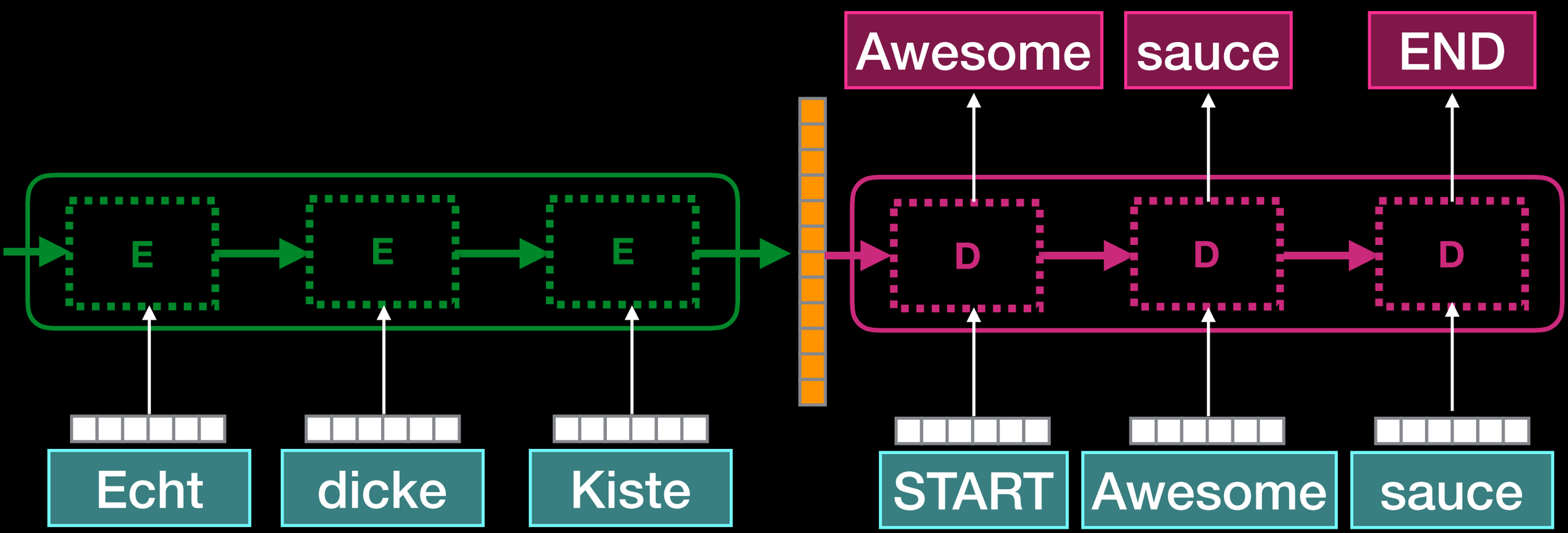
PREDICT OFF OF FINAL STATE



Bocconi

Encoder-Decoder

…And Generate Output from it



Gobble up sequence into a vector…

Bocconi

Convolution

Bocconi

Convoluted Matters

Text Sort classification

Retail

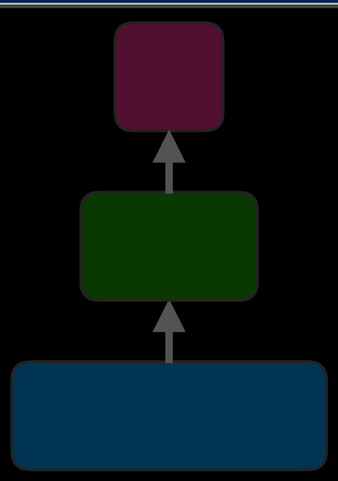
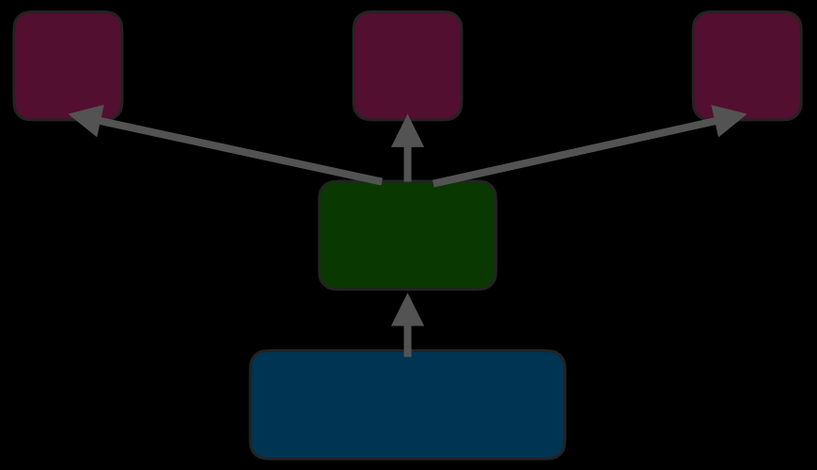
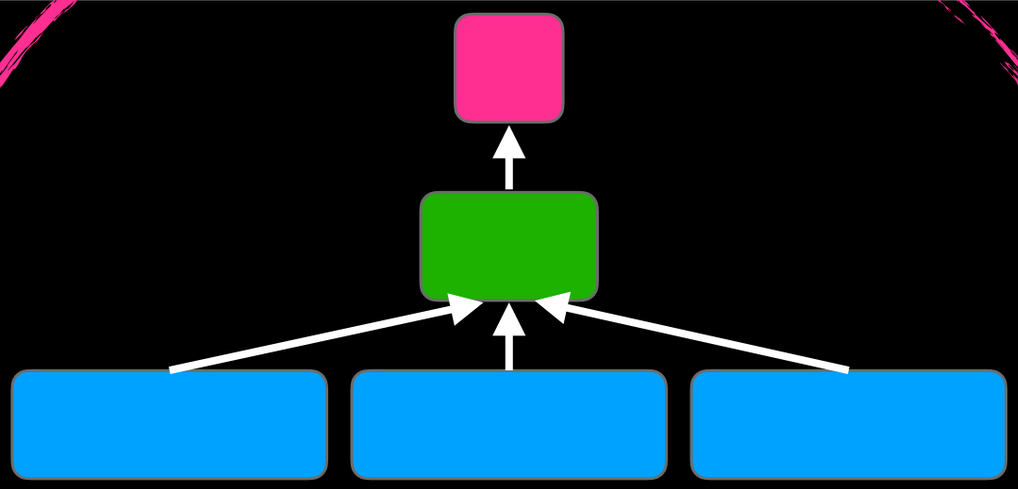
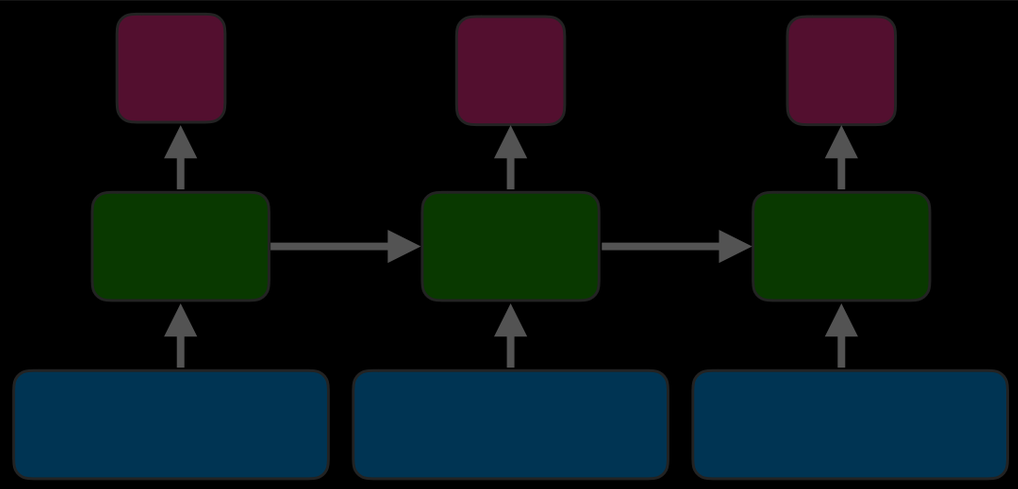
Sentiment Analysis

positive

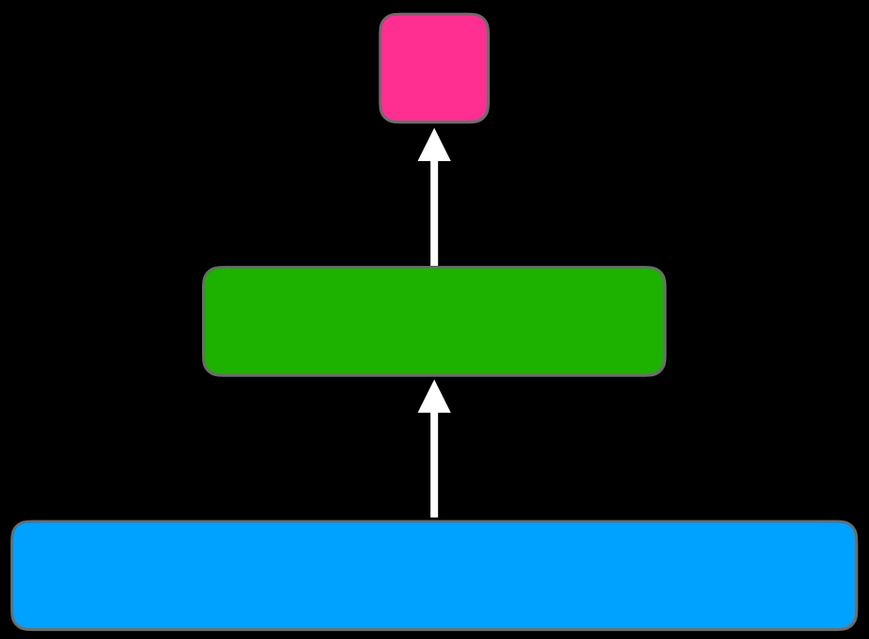
Relation Extraction

founded_by(Amazon, Jeff Bezos)

Types of Text Classification

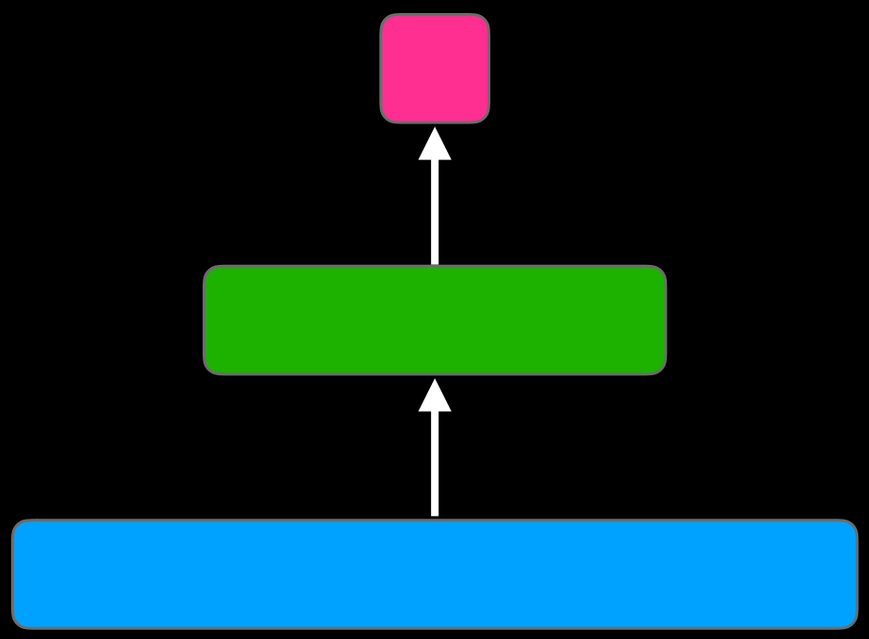
	Fixed length	Variable length
Fixed length	 Logistic Regression, Perceptron, Feed-Forward Network, Random Forest, Naive Bayes, SVM, …	 Multitask Learning, Decoder
Variable length	 Convolutional Neural Networks (CNN)	 Recurrent Neural Networks (RNN), Hidden Markov Models (HMM), Conditional Random Fields

Problems with MLPs



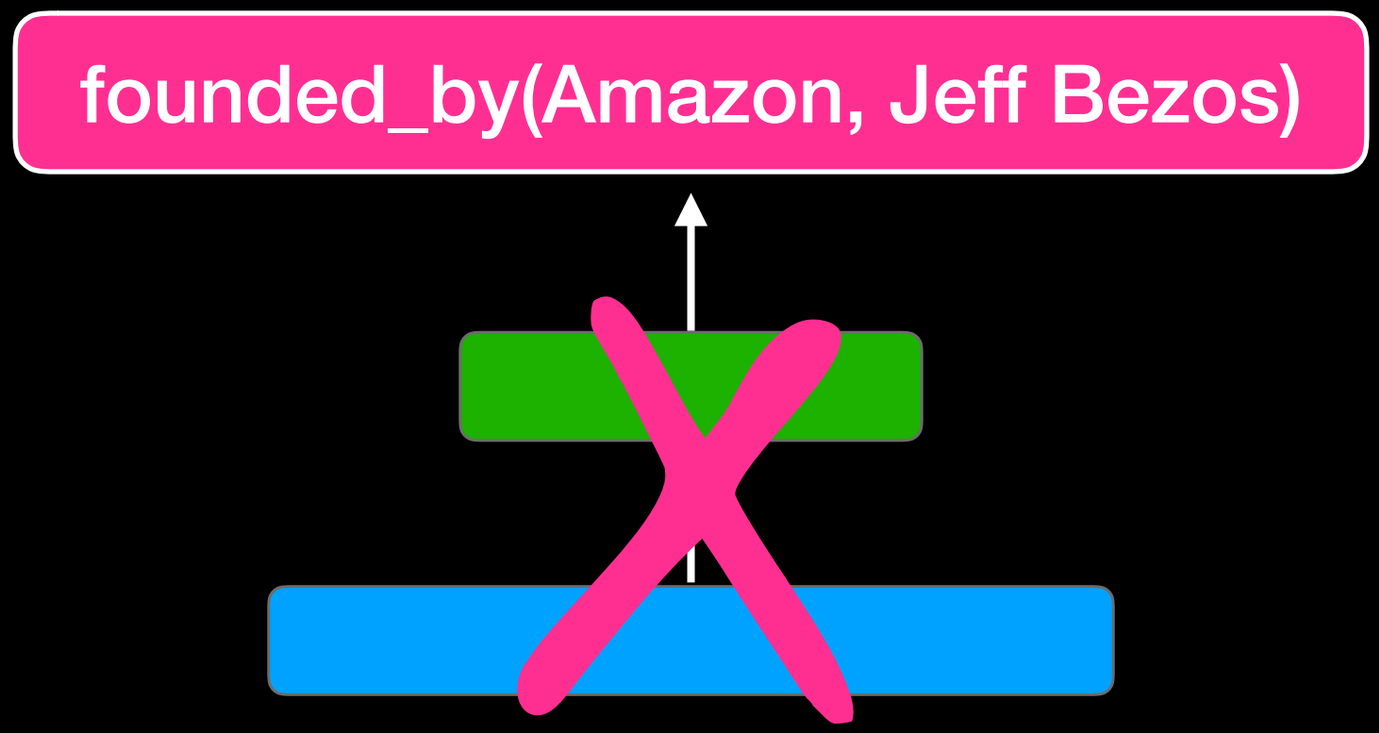
Not bad, actually quite good

$\neq$



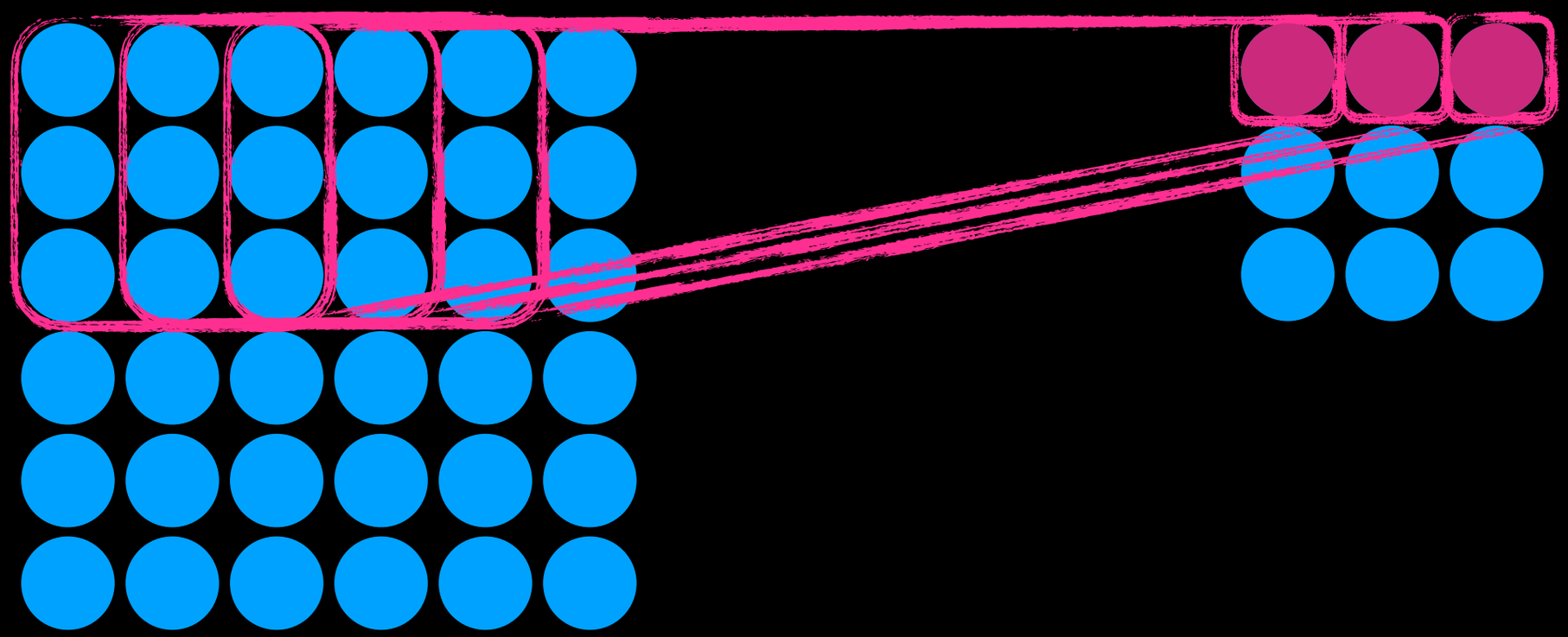
Not good, actually quite bad

Problems with MLPs

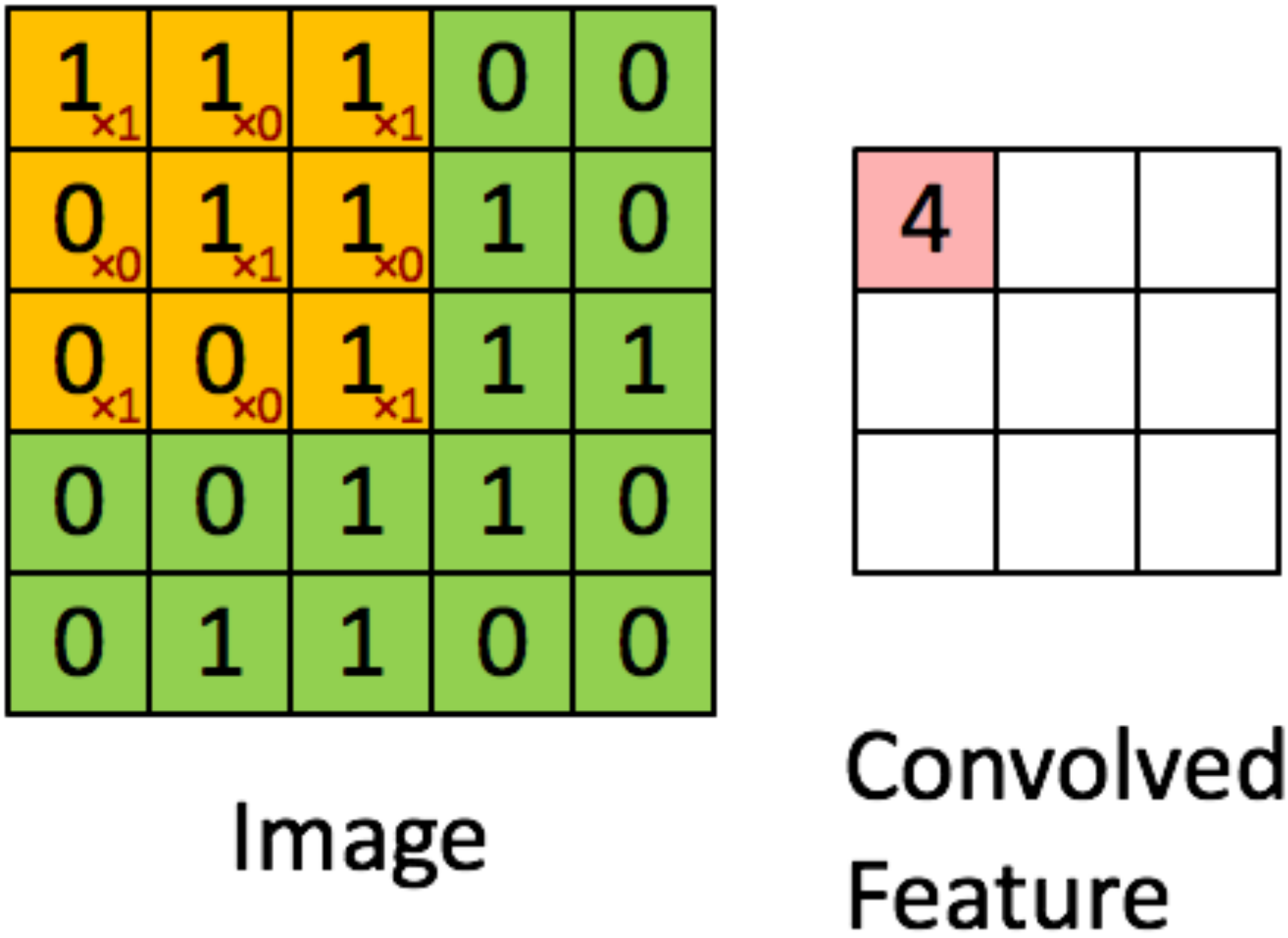


Jeff Bezos, or what Dr. Evil would look like on steroids, went from book seller to billionaire when he founded Amazon in 1994.

Convolution



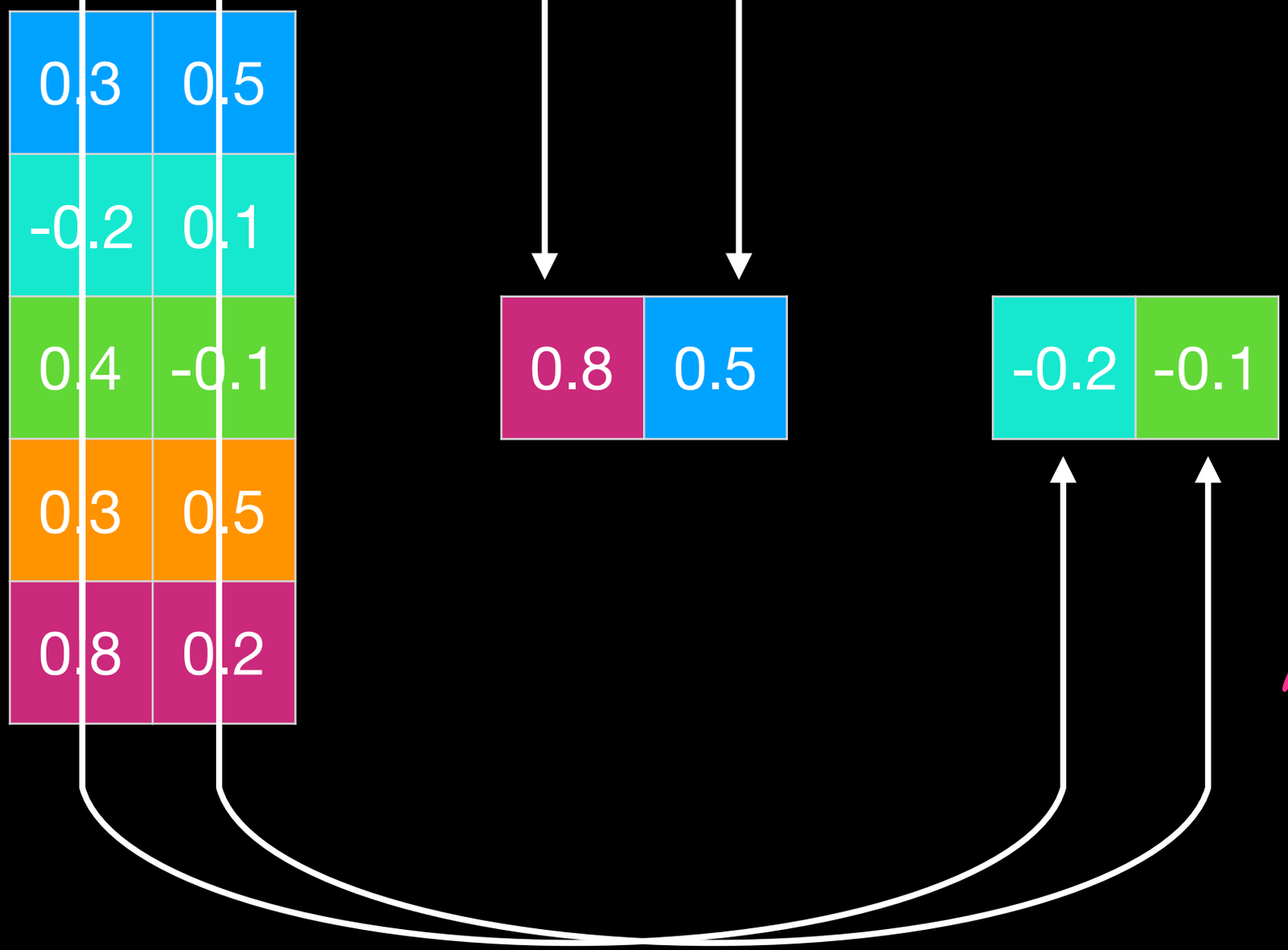
Convolution Extraction



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

Pooling

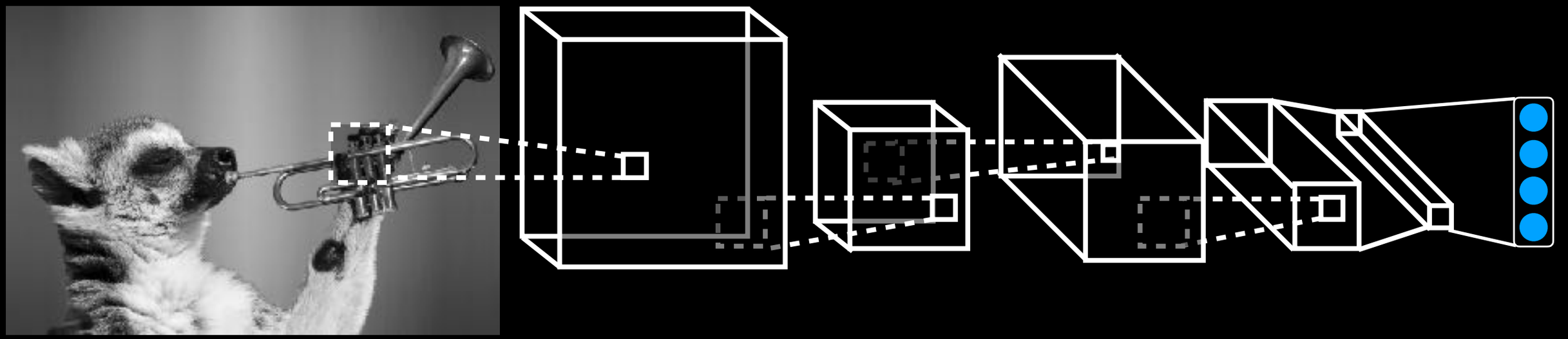
MAX POOLING



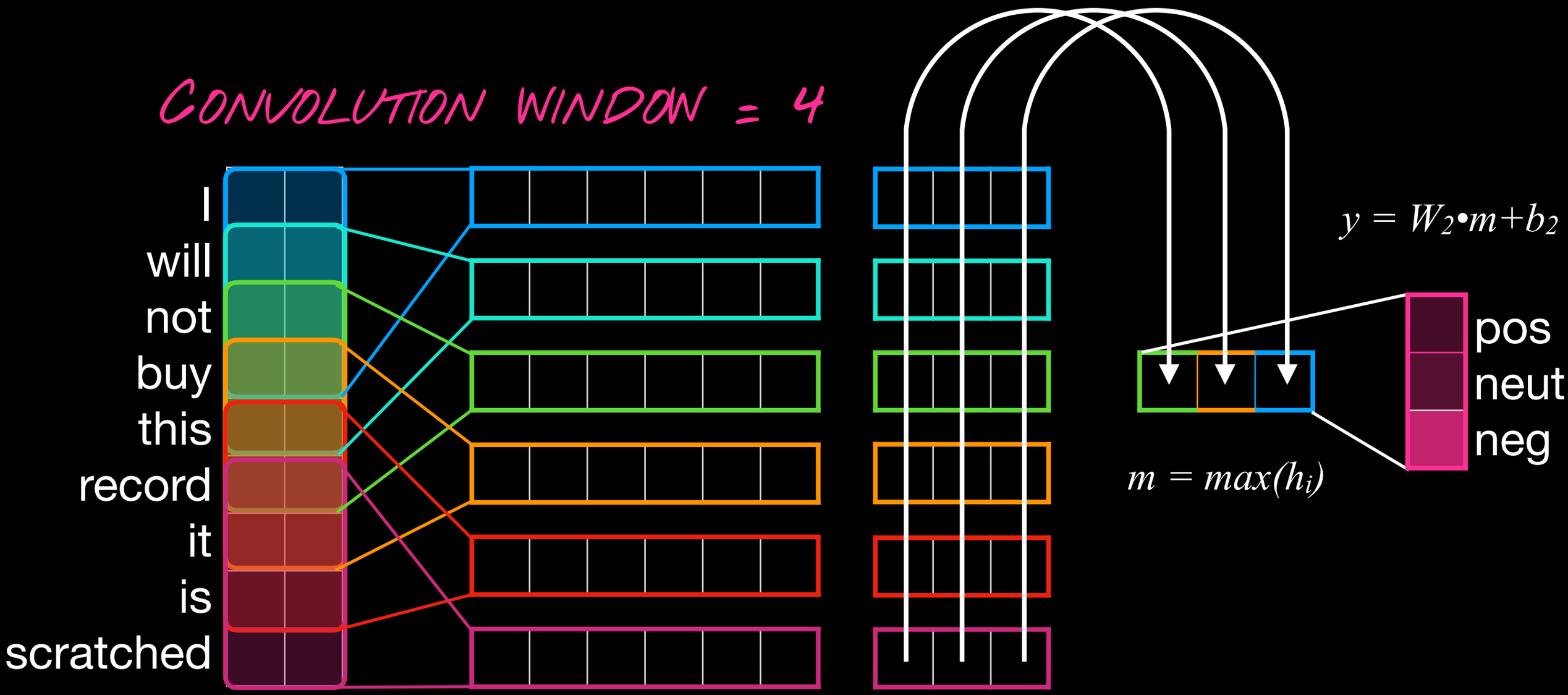
MIN POOLING

Bocconi

CNNs in Images



CNNs in Text



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

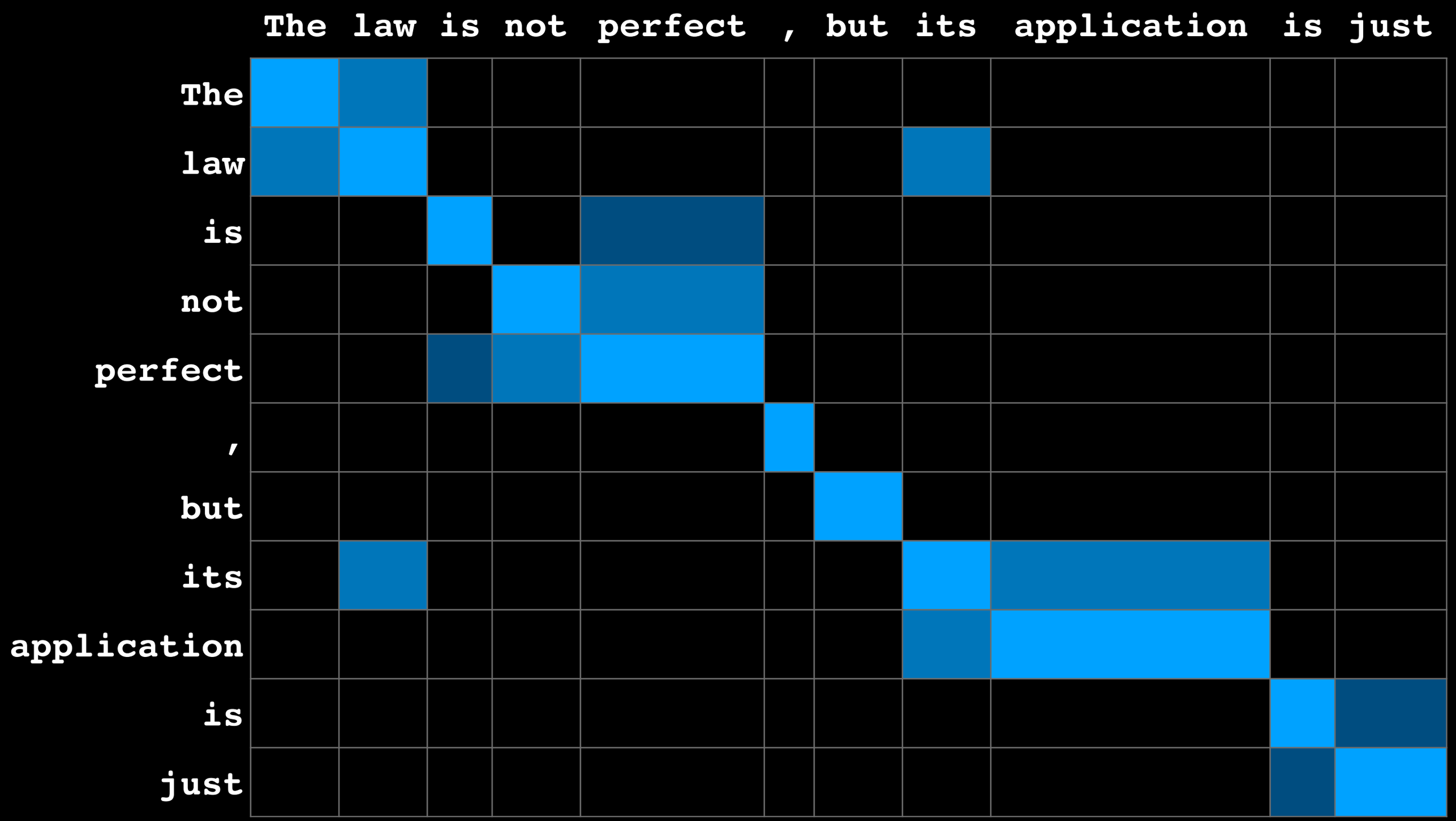
The Attention Mechanism

Bocconi

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

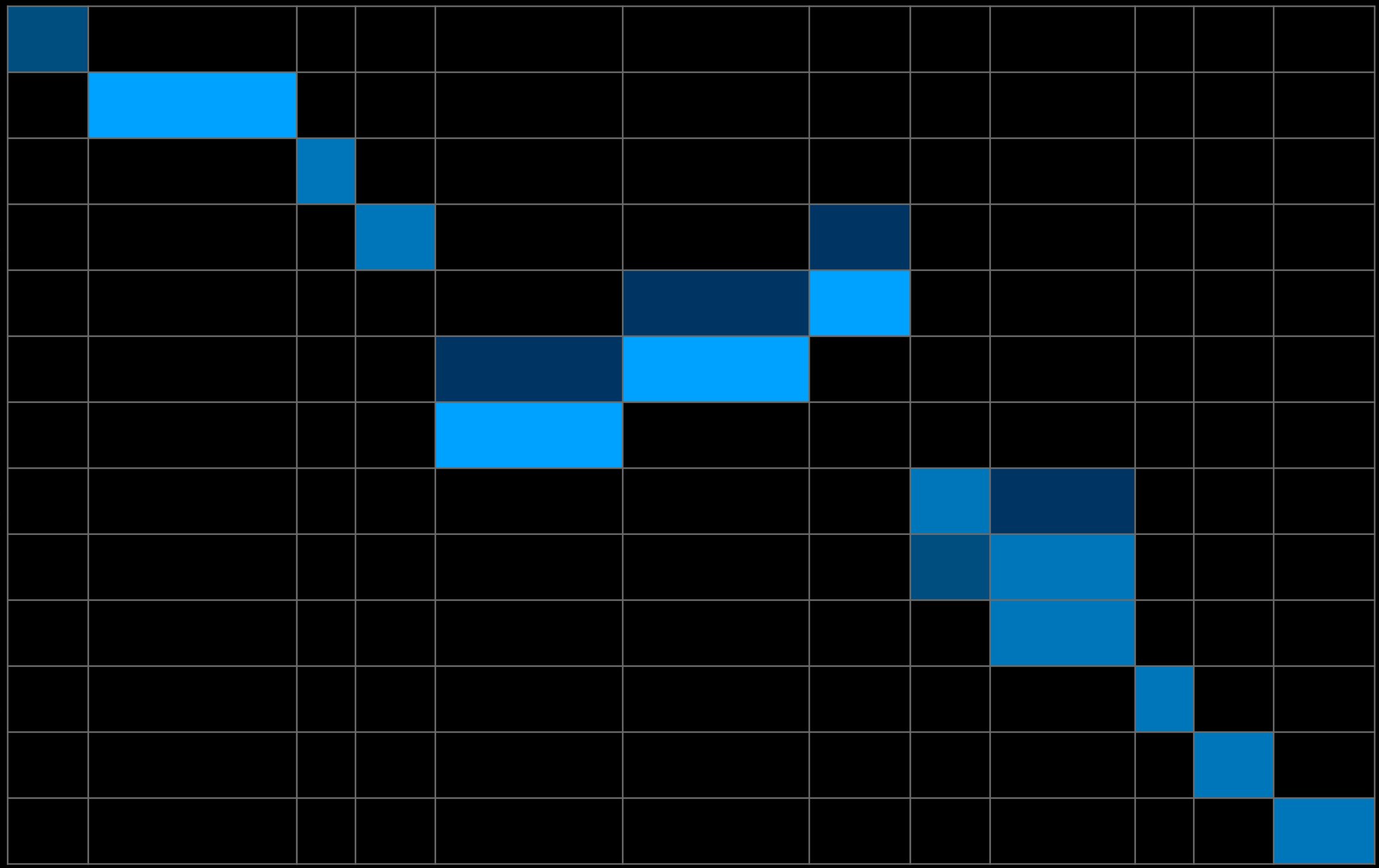
RNN with Attention

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

Bocconi

RNN with Attention

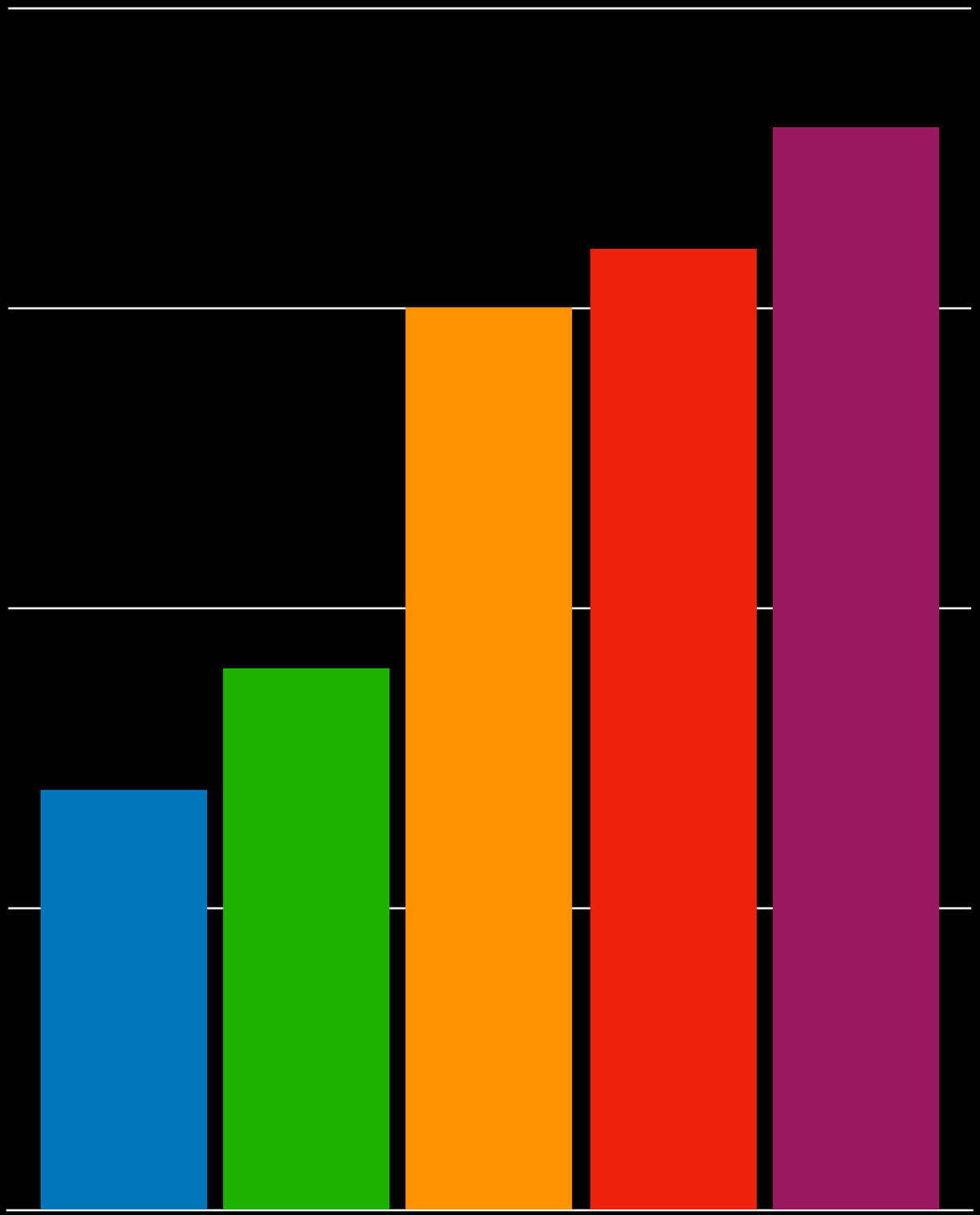
OUTPUT

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

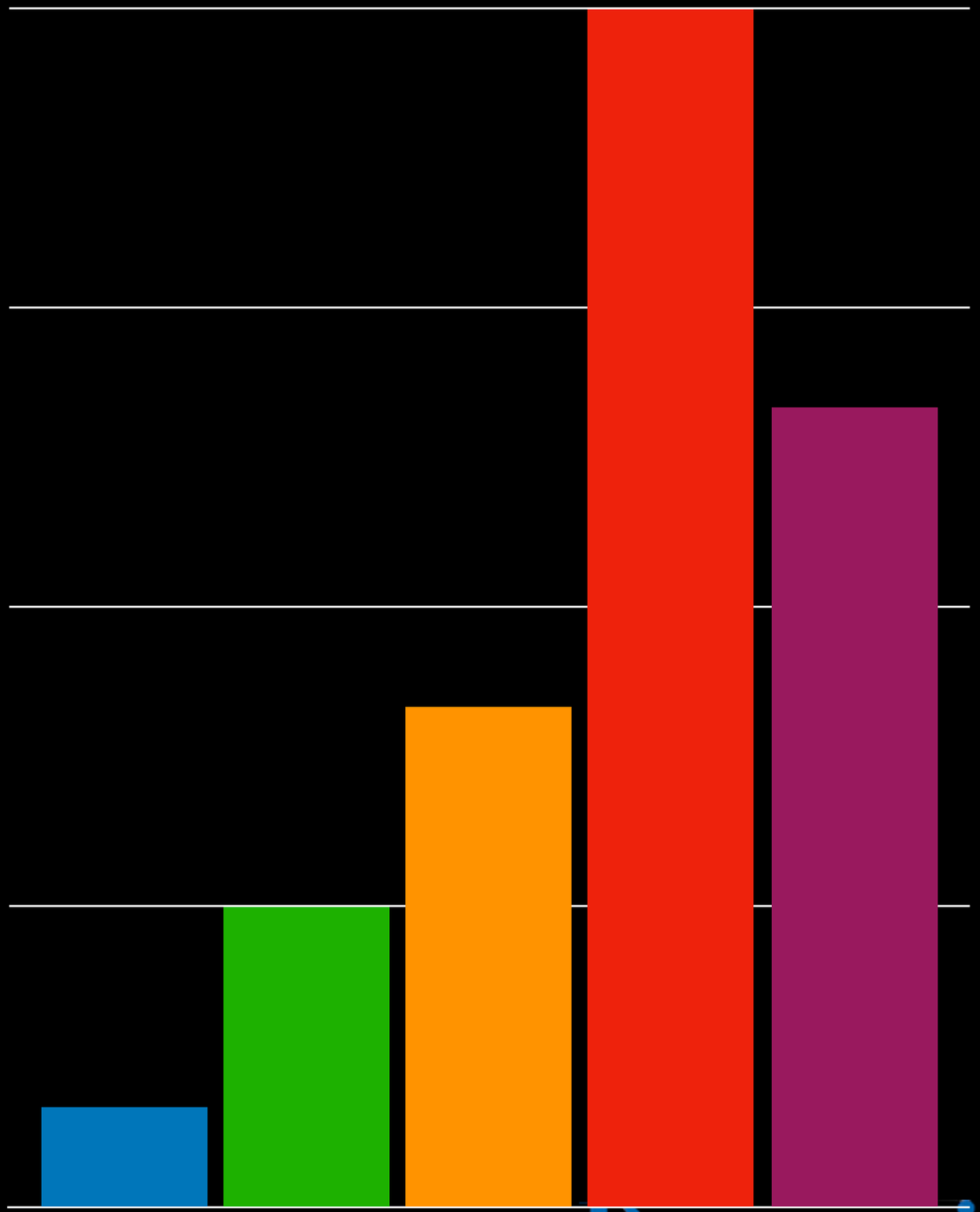
LEARN REORDERING

Performance

Logistic Regression Feed-Forward CNN RNN CNN+Attention



performance



parameters

Bocconi

Wrapping up

Bocconi

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