Carnegie Mellon University
School of Computer Science

10701: Introduction to Machine Learning

Neural Networks and Deep Learning (2)

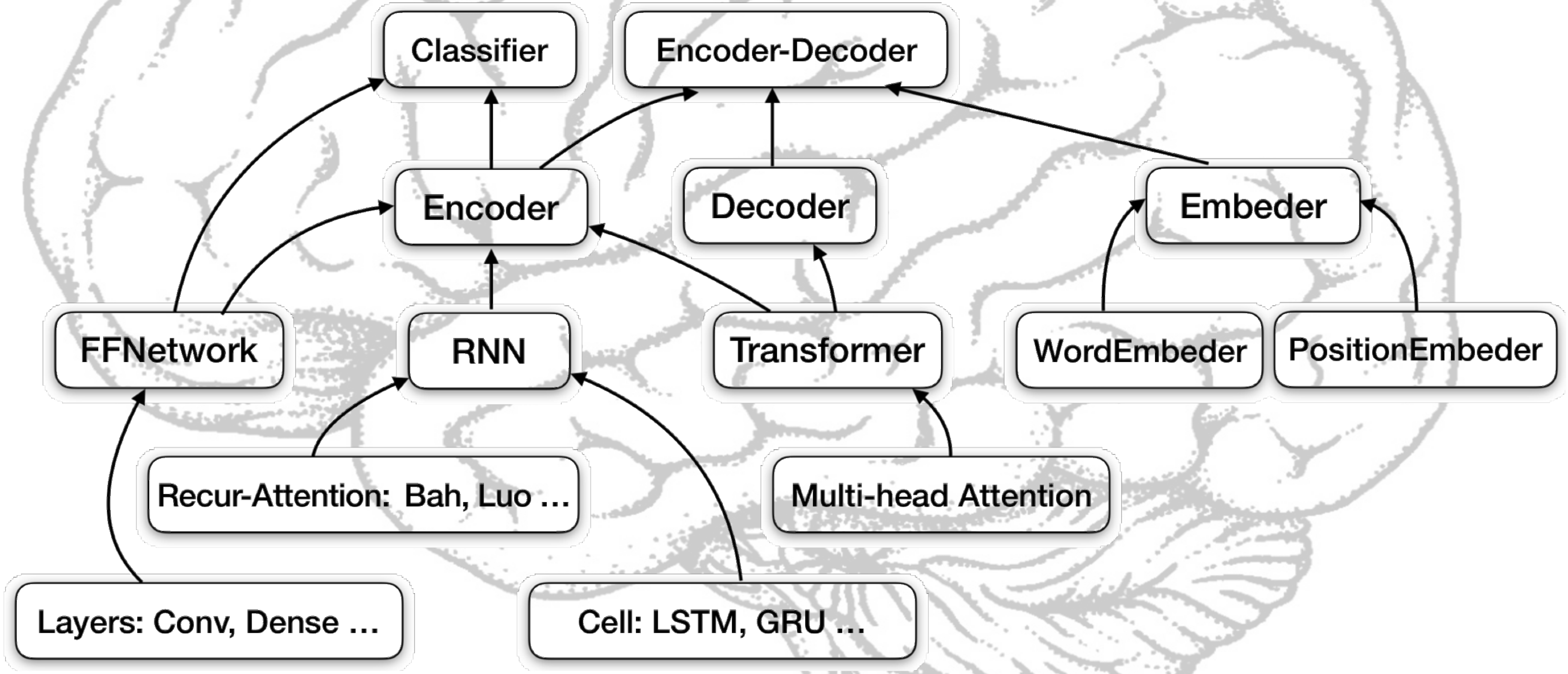
- Building blocks for deep learning

Eric Xing

Lecture 11, October 12, 2020

Reading: see class homepage

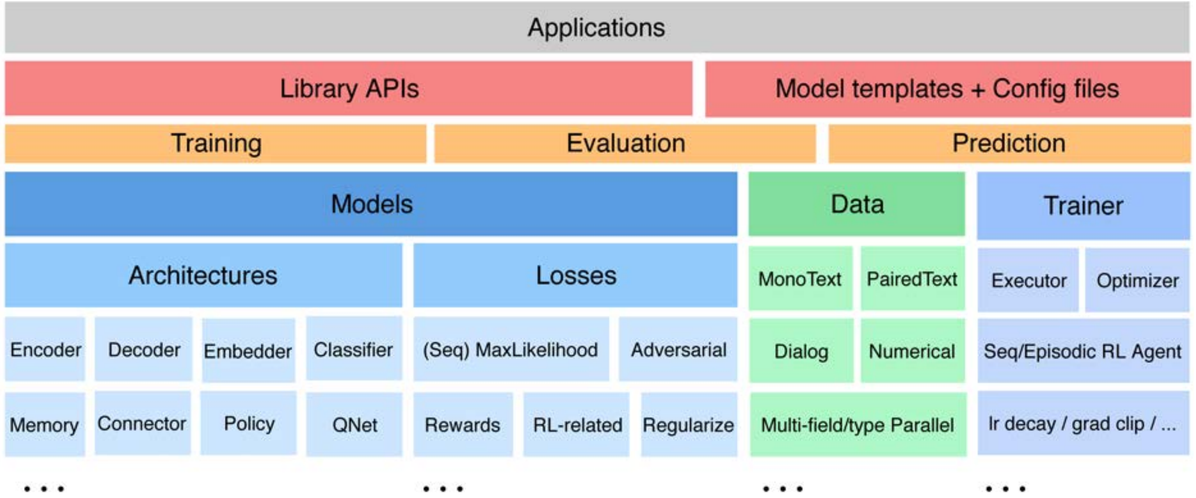
Neural network components



Compositional ML

- A catalog on building blocks
- Highly modularized programming
  - Data, structure, loss, learning, …
  - Intuitive conceptual-level APIs
- Easy switch between algorithms
  - Plug in & out modules
  - No changes to irrelevant parts

```
# Read data
dataset = PairedTextData(data_hparams)
batch = DataIterator(dataset).get_next()
# Encode
embedder = WordEmbedder(dataset.vocab.size, hparams=embedder_hparams)
encoder = TransformerEncoder(hparams=encoder_hparams)
enc_outputs = encoder(embedder(batch['source_text_ids']),
                      batch['source_length'])
# Build decoder
decoder = AttentionRNNDecoder(memory=enc_outputs,
                              hparams=decoder_hparams)
# Maximum Likelihood Estimation
## Teacher-forcing decoding
outputs, length, _ = decoder(decoding_strategy='teacher-forcing',
                             inputs=embedder(batch['target_text_ids']),
                             seq_length=batch['target_length']-1)
## Cross-entropy loss
loss = sequence_sparse_softmax_cross_entropy(
    labels=batch['target_text_ids'][:,1:], logits=outputs.logits, seq_length=length)
```

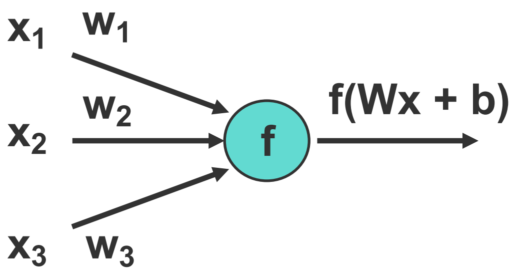


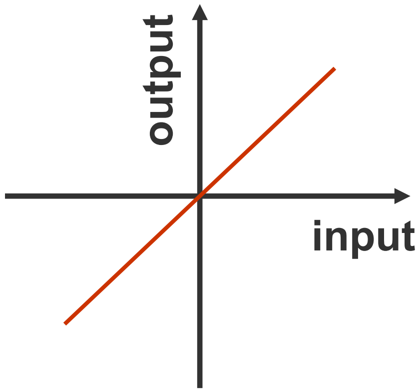
Outline

- Convolutional Networks (ConvNets)
- Recurrent Networks (RNNs)
  - Long-range dependency, vanishing gradients
  - LSTM
  - RNNs in different forms
- Attention Mechanisms
  - (Query, Key, Value)
  - Attention on Text and Images
- Transformers: Multi-head Attention
  - Transformer
  - BERT

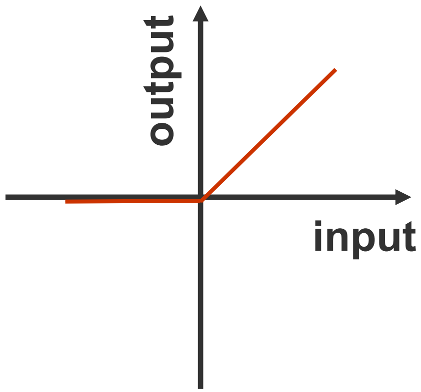
Modern building blocks of deep networks

- Activation functions
  - Linear and ReLU
  - Sigmoid and tanh
  - Etc.





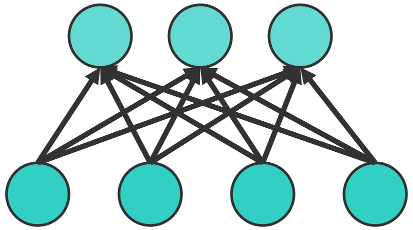
Linear



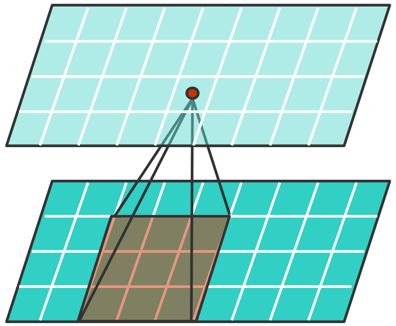
Rectified linear (ReLU)

Modern building blocks of deep networks

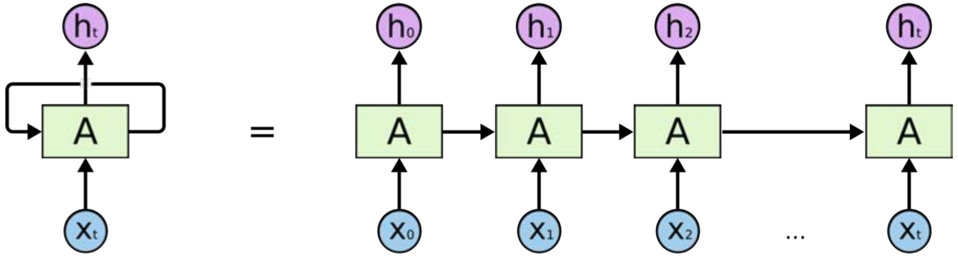
- Activation functions
  - Linear and ReLU
  - Sigmoid and tanh
  - Etc.
- Layers
  - Fully connected
  - Convolutional & pooling
  - Recurrent
  - ResNets
  - Etc.



fully connected

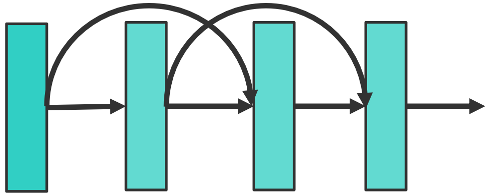


convolutional



recurrent

source: colah.github.io



blocks with residual connections

Modern building blocks of deep networks

- Activation functions
  - Linear and ReLU
  - Sigmoid and tanh
  - Etc.
- Layers
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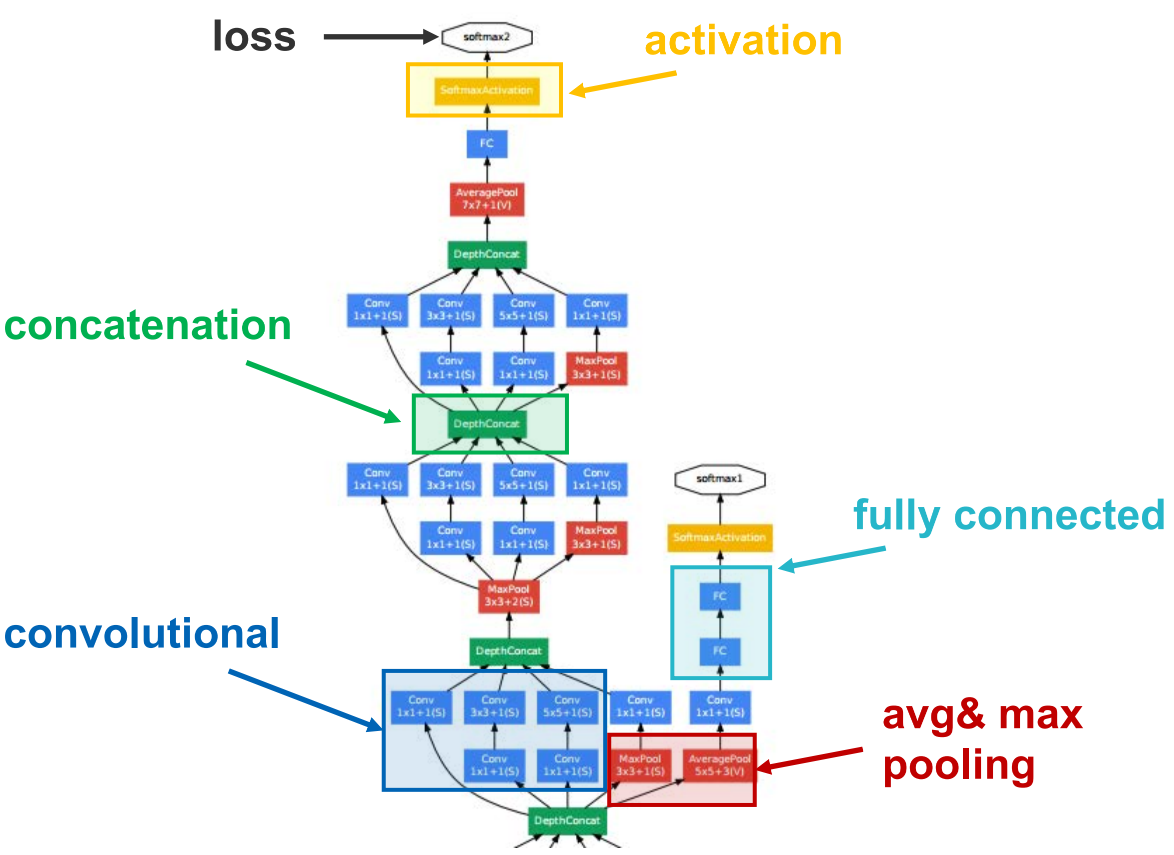
  - Convolutional & pooling
  - Recurrent
  - ResNets
  - Etc.
- Loss functions
  - Cross-entropy loss
  - Mean squared error
  - Etc.

Putting things together:



(a part of GoogleNet)

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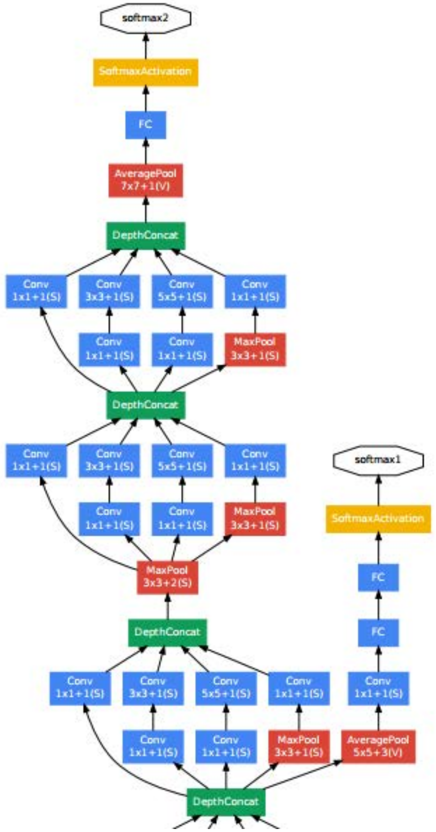

(a part of GoogleNet)

- **Arbitrary combinations of the basic building blocks**
- **Multiple loss functions – multi-target prediction, transfer learning, and more**
- **Given enough data, deeper architectures just keep improving**
- **Representation learning: the networks learn increasingly more abstract representations of the data that are "disentangled," i.e., amenable to linear separation.**

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Convolutional Networks (ConvNets)

- Biologically-inspired variants of MLPs [LeCun et al. NIPS 1989]
  - Receptive field [Hubel & Wiesel 1962; Fukushima 1982]
    - Visual cortex contains a complex arrangement of cells
    - These cells are sensitive to small **sub-regions** of the visual field
  - The sub-regions are **tiled** to cover the entire visual field

Local Filters

Exploit the strong spatially local correlation present in natural images

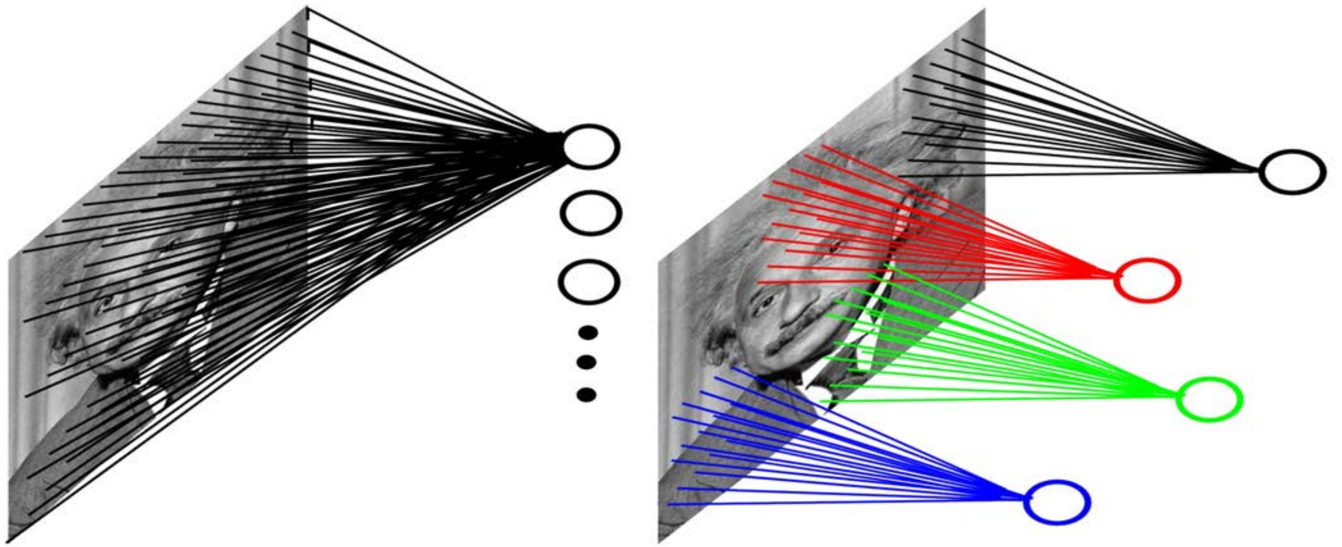
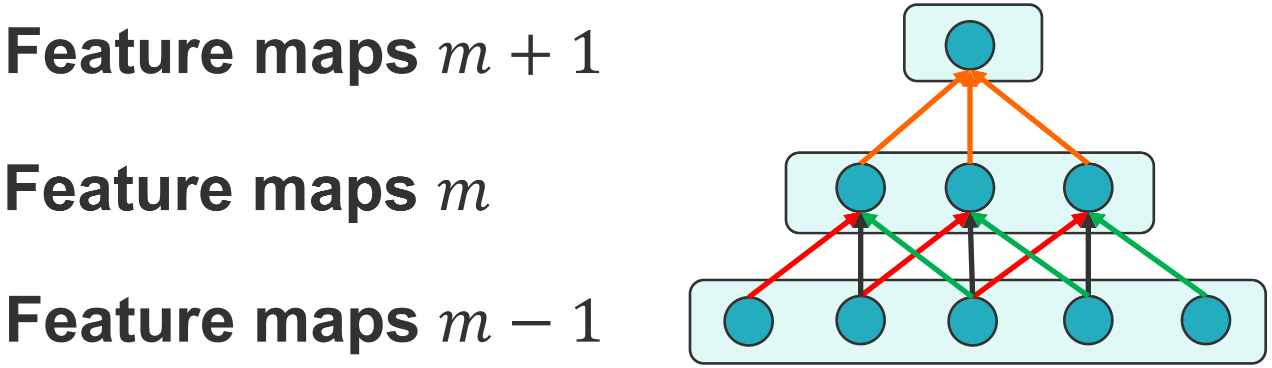


Figure courtesy: Yann LeCun

Convolutional Networks (ConvNets)

- Sparse connectivity
- Shared weights
- Increasingly “global” receptive fields
  - simple cells detect local features
  - complex cells “pool” the outputs of simple cells within a retinotopic neighborhood.



Convolutional Networks (ConvNets)

- Hierarchical Representation Learning [Zeiler & Fergus 2013]

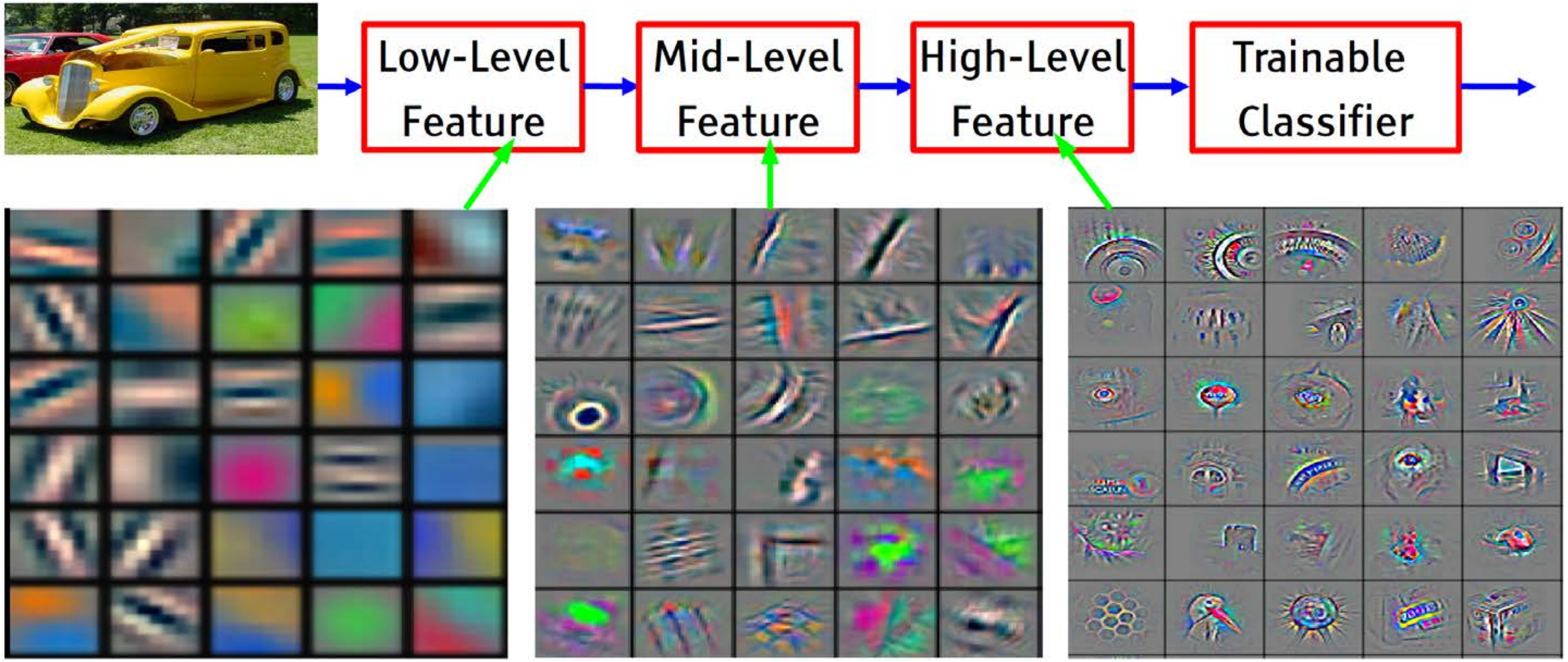
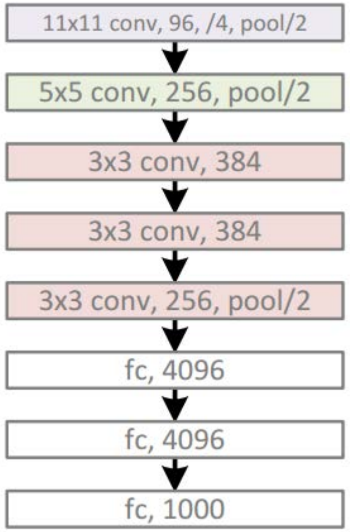


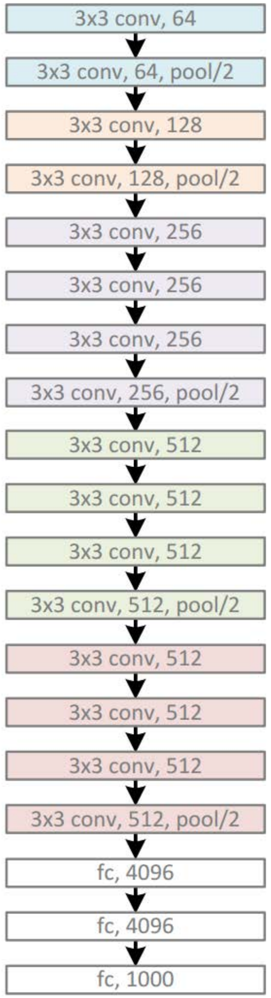
Figure courtesy: Yann LeCun

Evolution of ConvNets

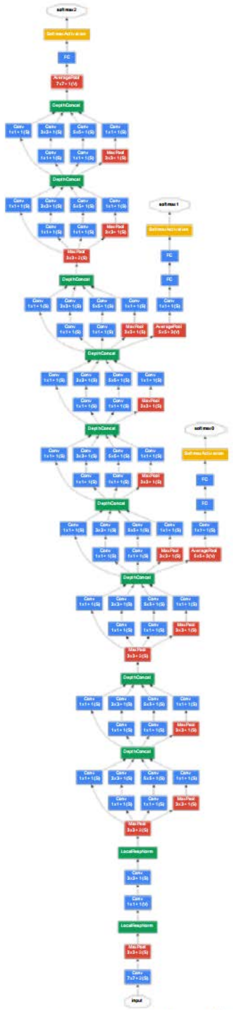
AlexNet, 8 layers



VGG, 19 layers



GoogleNet, 22 layers



ResNet, 152 layers

Figure courtesy: Kaiming He

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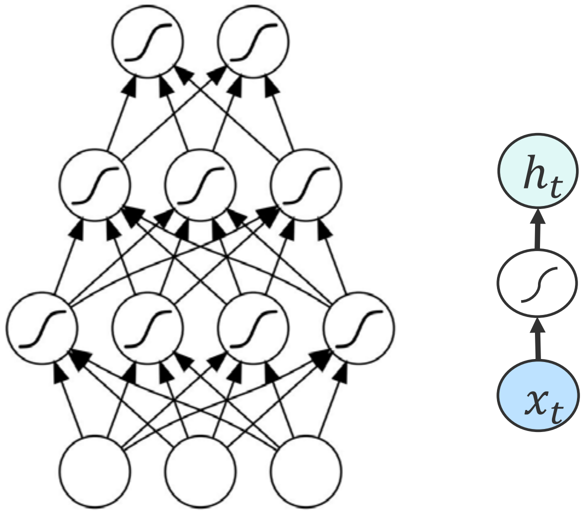
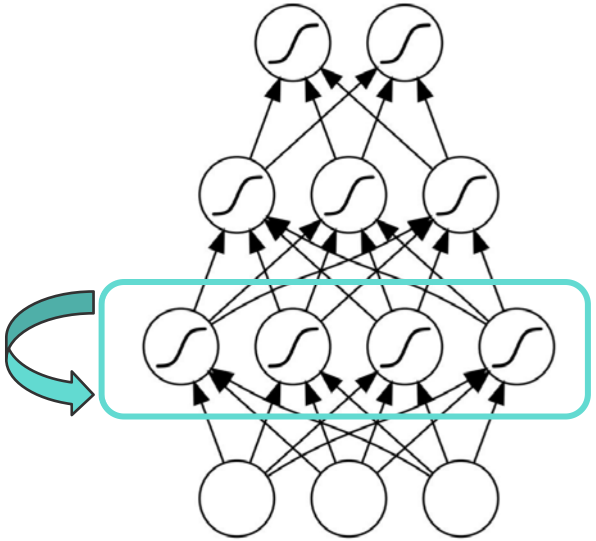
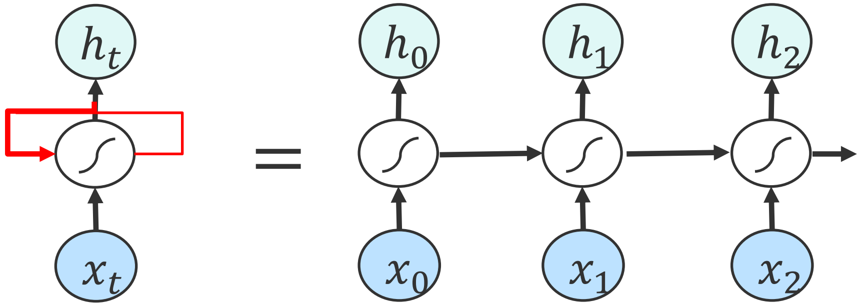
ConvNets → Recurrent Networks (RNNs)

- Spatial Modeling *vs.* Sequential Modeling
- Fixed *vs.* variable number of computation steps.



The output depends ONLY on the current input





The hidden layers and the output additionally depend on previous states of the hidden layers

RNNs in Various Forms

One to One

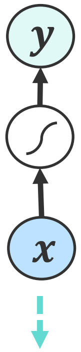


Image classification

One to Many

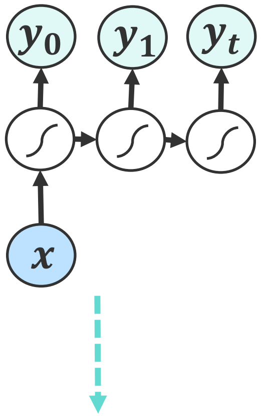
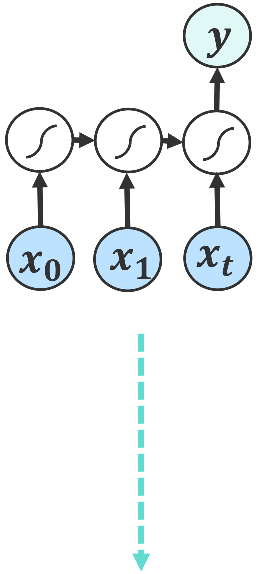


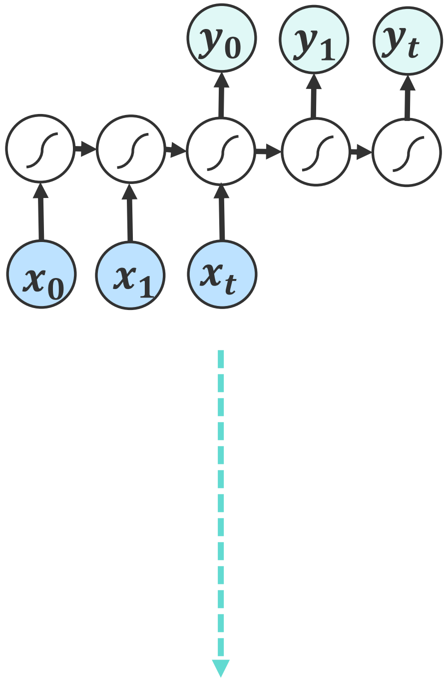
Image captioning

Many to One



Sentence sentiment analysis / Video recognition

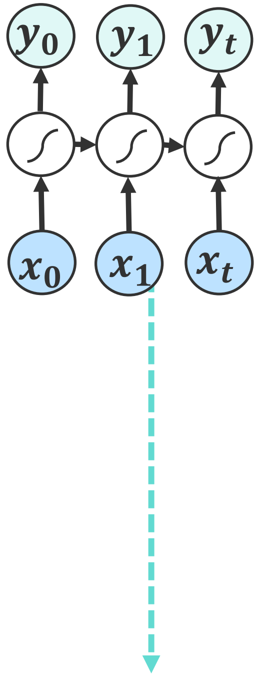
Many to Many



Machine Translation

(Sequence-to-sequence)

Many to Many

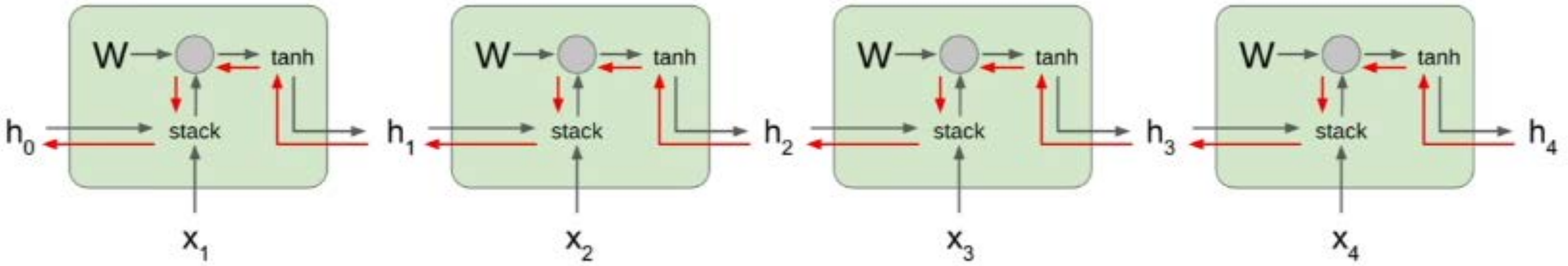


Named Entity Recognition

(Sequence tagging)

Vanishing / Exploding Gradients in RNNs

$$\boldsymbol{h}_t = tanh(W^{hh}\boldsymbol{h}_{t-1} + W^{hx}\boldsymbol{x}_t)$$



Source: CS231N Stanford

Bengio et al., 1994 "Learning long-term dependencies with gradient descent is difficult"
Pascanu et al., 2013 "On the difficulty of training recurrent neural networks"

Vanishing / Exploding Gradients in RNNs

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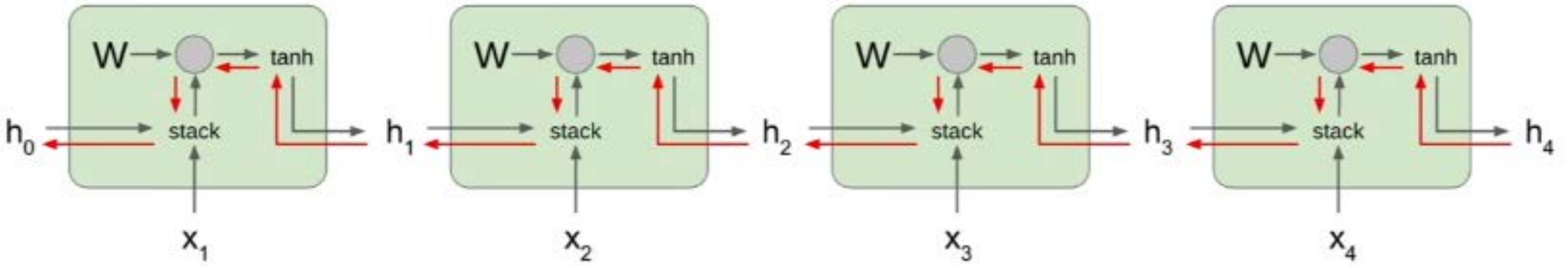

Computing gradient of h_0 involves many factors of W (and repeated tanh)

Source: CS231N Stanford

Bengio et al., 1994 "Learning long-term dependencies with gradient descent is difficult"
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Vanishing / Exploding Gradients in RNNs

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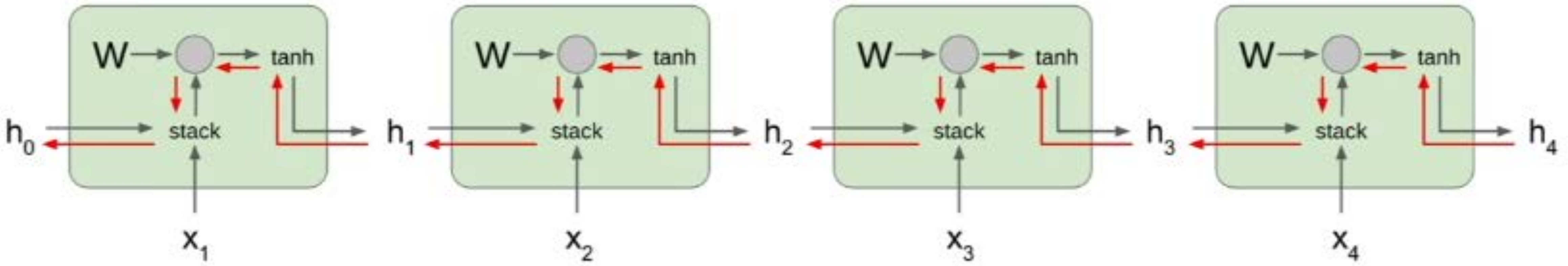

Computing gradient of h_0 involves many factors of W (and repeated tanh)

Largest singular value > 1:
Exploding gradients

→ **Gradient clipping**: Scale gradient if its norm is too big

```
grad_norm = np.sum(grad * grad)
if grad_norm > threshold:
  grad *= (threshold / grad_norm)
```

Largest singular value < 1:
Vanishing gradients

Source: CS231N Stanford

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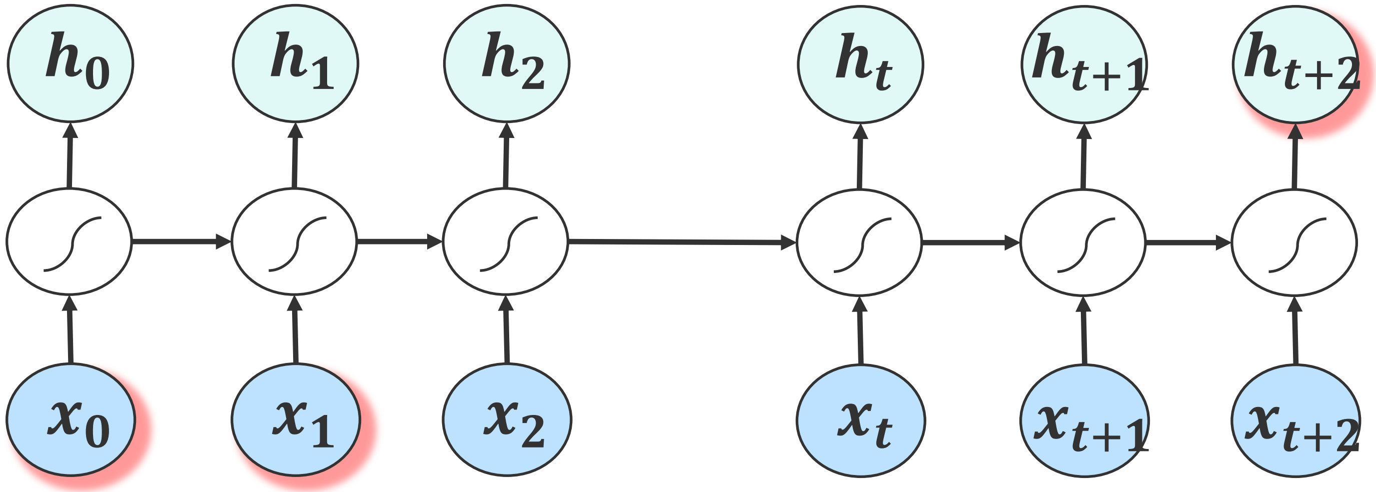
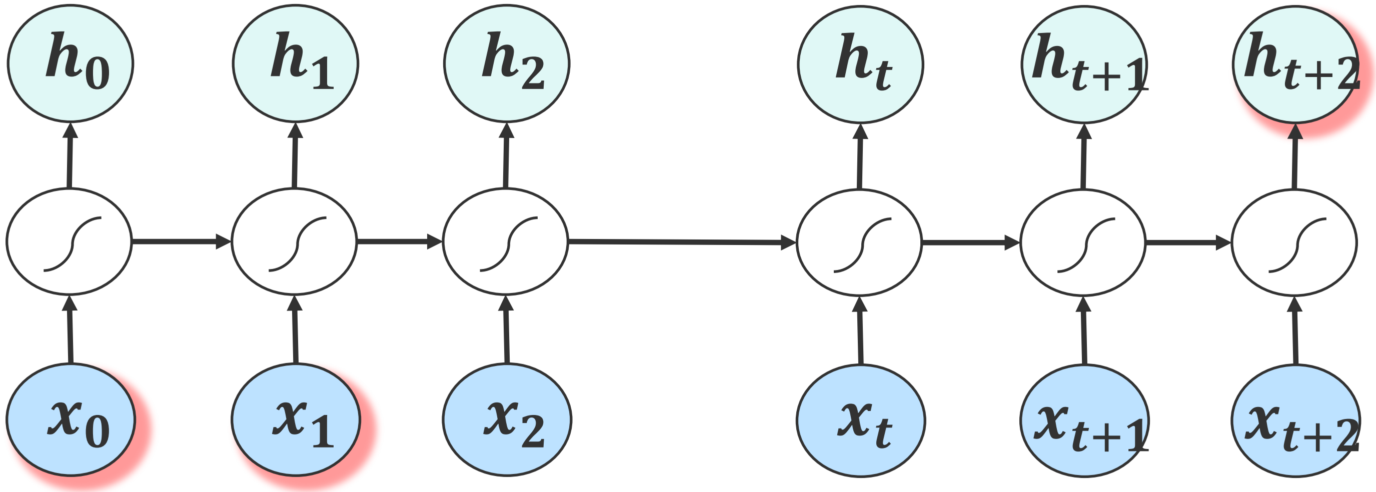
Long-term Dependency Problem



I live in France and I know ___________

Example courtesy: Manik Soni

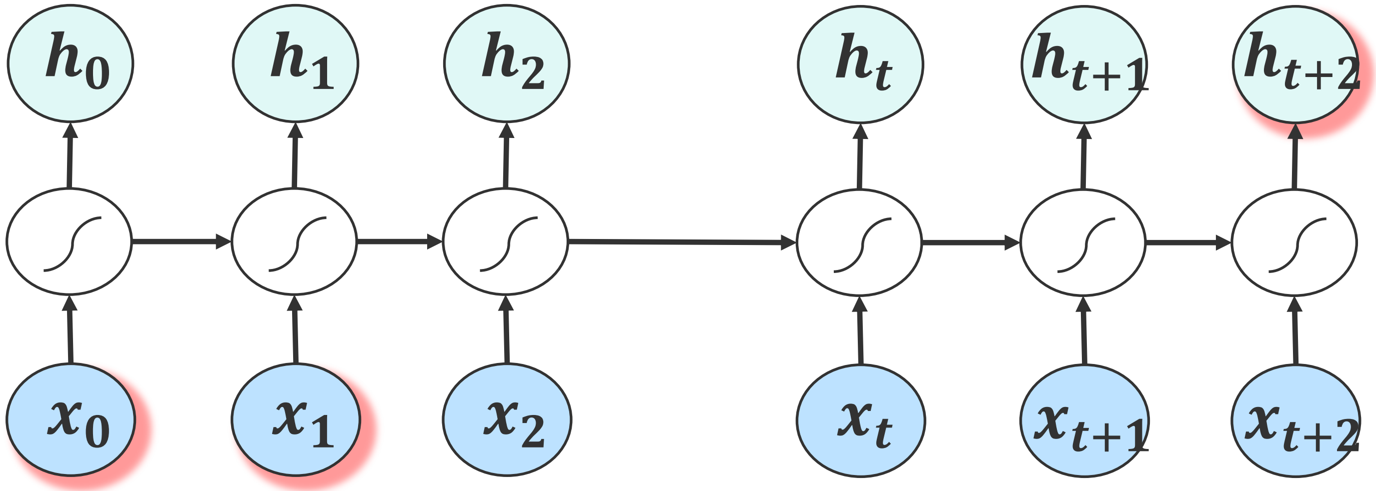
Long-term Dependency Problem



I live in France and I know __*French*__

Example courtesy: Manik Soni

Long-term Dependency Problem



I live in France and I know __French__

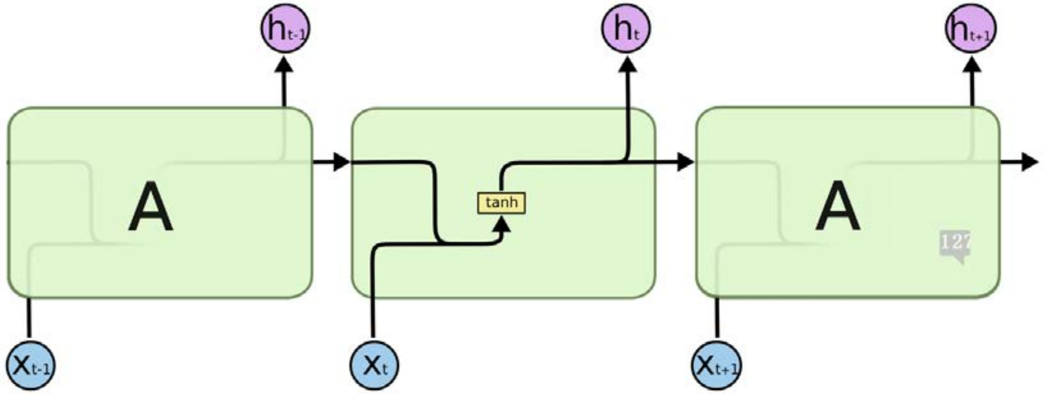
I live in France, a beautiful country, and I know __French__

Example courtesy: Manik Soni

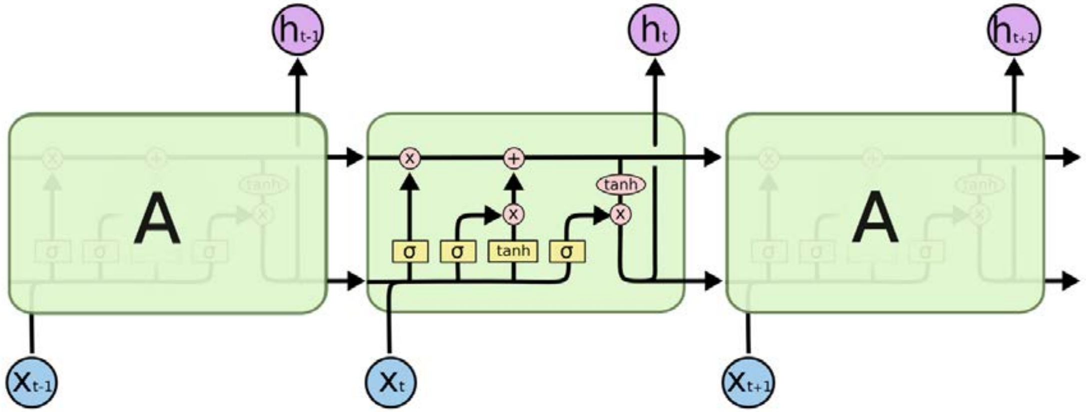
Long Short Term Memory (LSTM)

- LSTMs are designed to explicitly alleviate the long-term dependency problem [Horchreiter & Schmidhuber (1997)]

Standard RNN

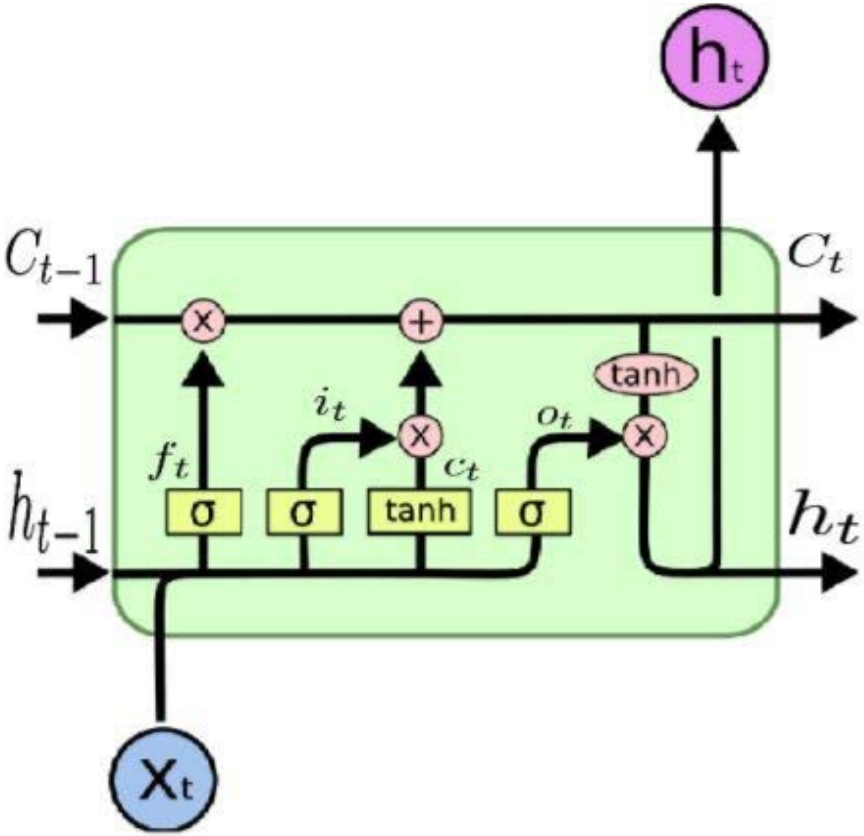


LSTM



Long Short Term Memory (LSTM)

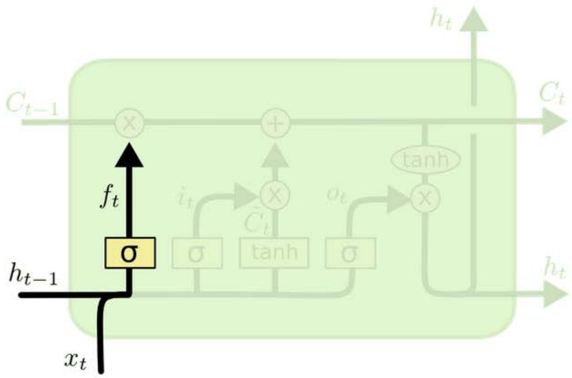
- Gate functions make decisions of reading, writing, and resetting information



- Forget gate: whether to erase cell (reset)
- Input gate: whether to write to cell (write)
- Output gate: how much to reveal cell (read)

Long Short Term Memory (LSTM)

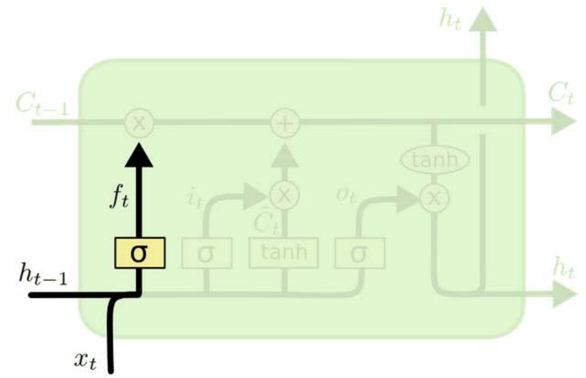
- **Forget gate:** decides what must be removed from $\boldsymbol{h}_{t-1}$



$$\boldsymbol{f_t} = \boldsymbol{\sigma}(\boldsymbol{W_f} \cdot [\boldsymbol{h_{t-1}}, \boldsymbol{x_t}] + \boldsymbol{b_f})$$

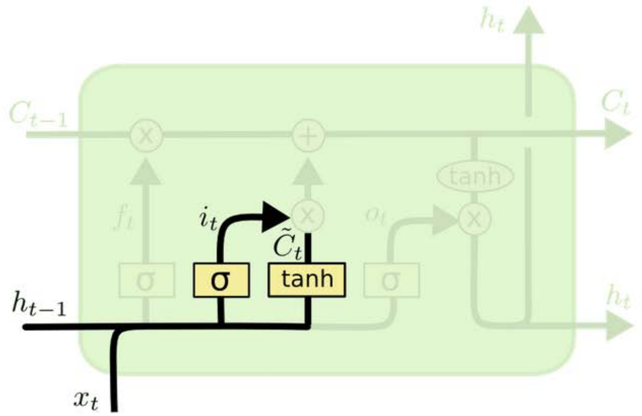
Long Short Term Memory (LSTM)

- **Forget gate:** decides what must be removed from $\boldsymbol{h}_{t-1}$



$$\boldsymbol{f_t} = \boldsymbol{\sigma}(\boldsymbol{W_f} \cdot [\boldsymbol{h_{t-1}}, \boldsymbol{x_t}] + \boldsymbol{b_f})$$

- **Input gate:** decides what new information to store in the cell

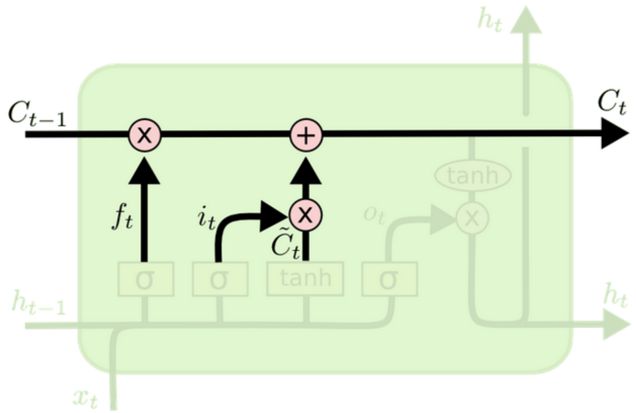


$$\boldsymbol{i_t} = \boldsymbol{\sigma}(\boldsymbol{W_i} \cdot [\boldsymbol{h_{t-1}}, \boldsymbol{x_t}] + \boldsymbol{b_i})$$

$$\widetilde{\boldsymbol{C}}_{\boldsymbol{t}} = \tanh(\boldsymbol{W_C} \cdot [\boldsymbol{h_{t-1}}, \boldsymbol{x_t}] + \boldsymbol{b_C})$$

Long Short Term Memory (LSTM)

- Update cell state:



$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t$$

forgetting unneeded things

scaling the new candidate values by how much we decided to update each state value.

Long Short Term Memory (LSTM)

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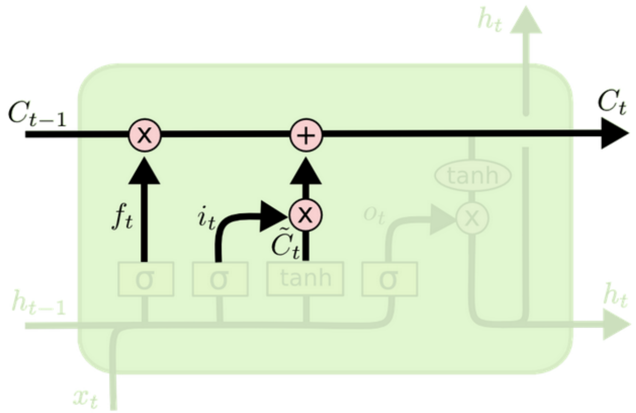
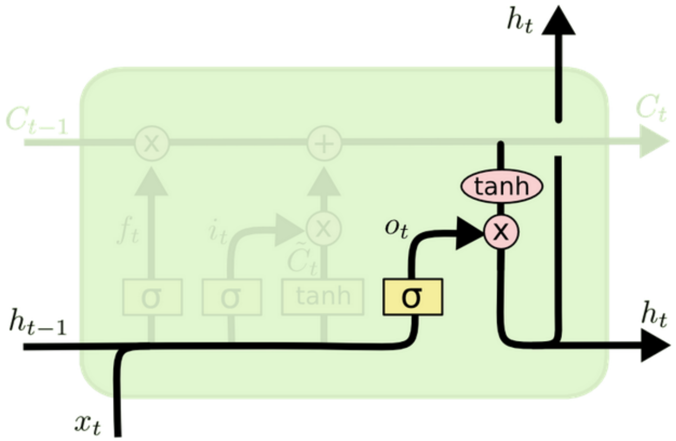


$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t$$

forgetting unneeded things

scaling the new candidate values by how much we decided to update each state value.

- Output gate: decides what to output from our cell state

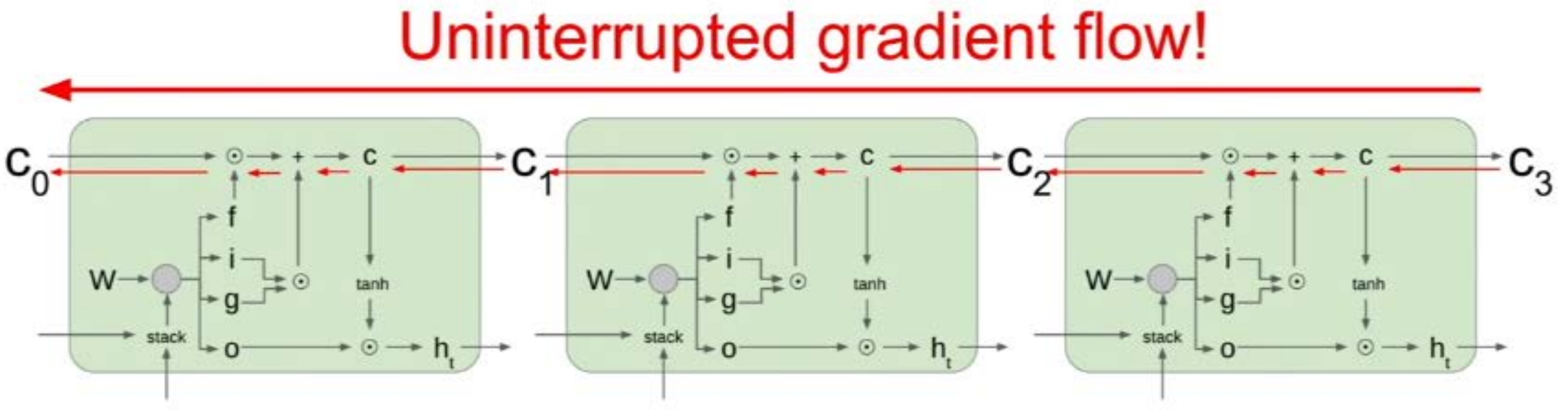


$$o_t = \sigma(W_o \cdot [h_{t-1}, x_t] + b_o)$$

$$h_t = o_t * \tanh(C_t)$$

sigmoid decides what parts of the cell state we're going to output

Backpropagation in LSTM



- No multiplication with matrix W during backprop
- Multiplied by different values of forget gate -> less prone to vanishing/exploding gradient

Source: CS231N Stanford

RNNs in Various Forms

One to One

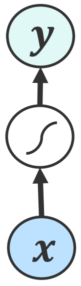


Image classification

One to Many

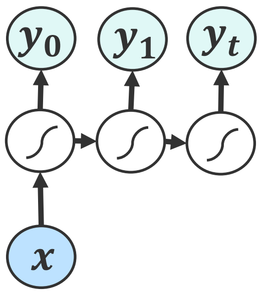
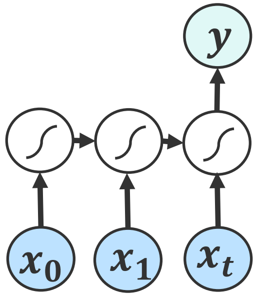


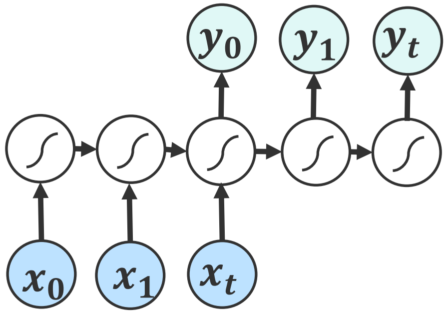
Image captioning

Many to One



Sentence sentiment analysis / Video recognition

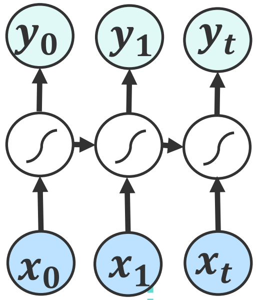
Many to Many



Machine Translation

(Sequence-to-sequence)

Many to Many

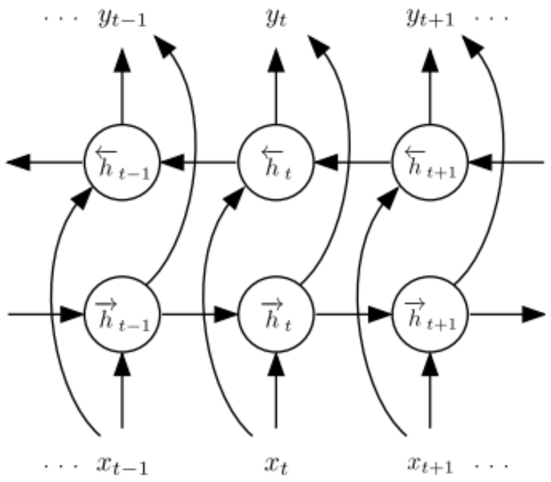


Named Entity Recognition

(Sequence tagging)

RNNs in Various Forms

- Bi-directional RNN
  - Hidden state is the concatenation of both forward and backward hidden states.
  - Allows the hidden state to capture both past and future information.



[Speech Recognition with Deep Recurrent Neural Networks, Alex Graves]

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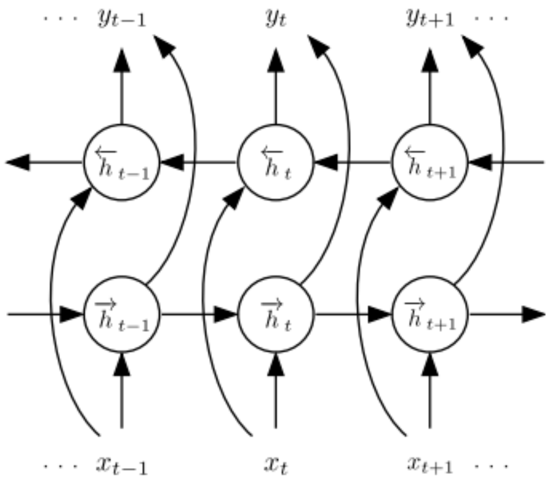
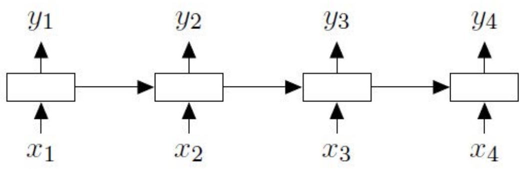


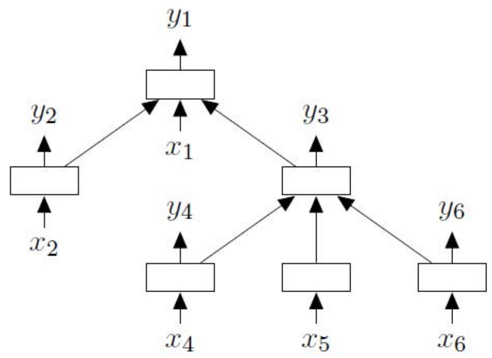
[Speech Recognition with Deep Recurrent Neural Networks, Alex Graves]

- Tree-structured RNN
  - Hidden states condition on both an input vector and the hidden states of arbitrarily many child units.
  - Standard LSTM = a special case of tree-LSTM where each internal node has exactly one child.

Chain-structured LSTM



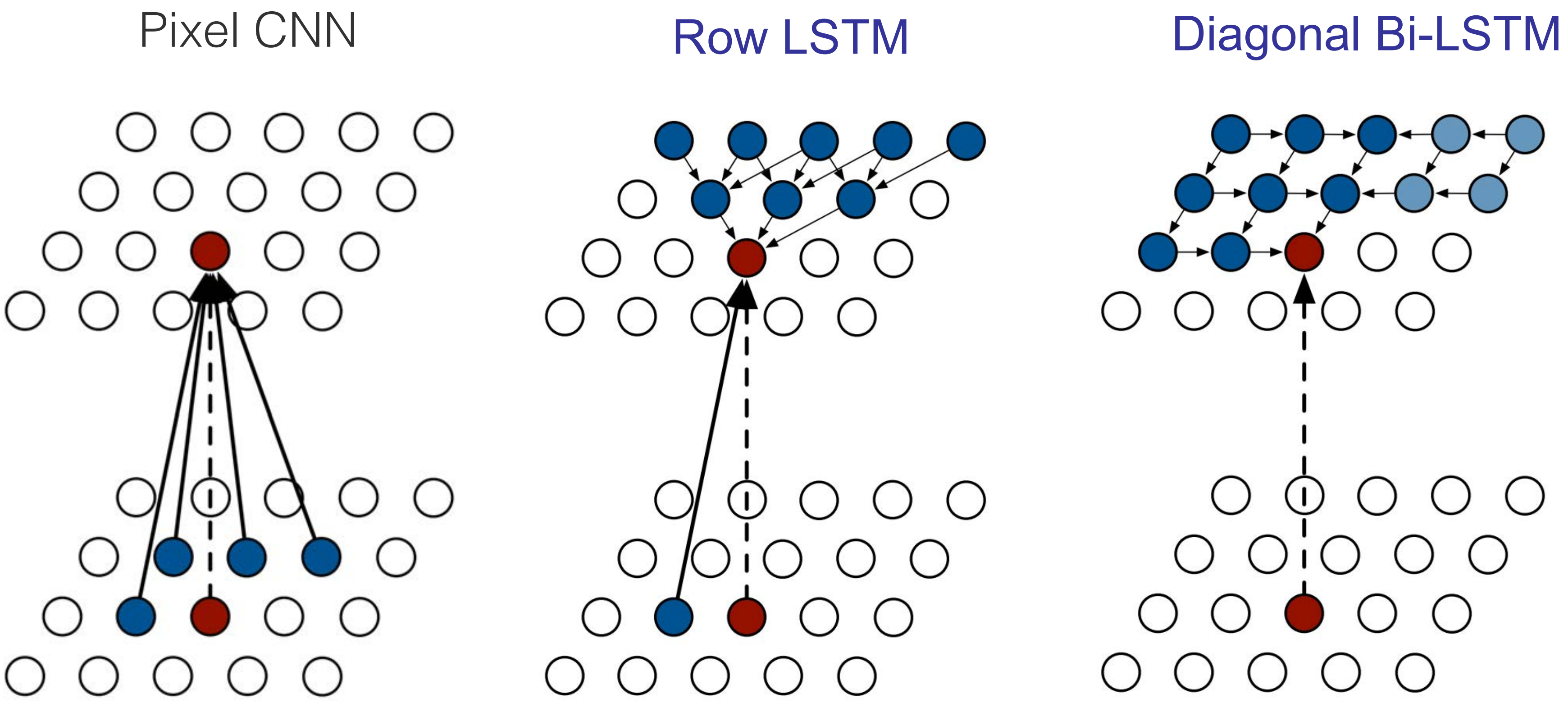
Tree-structured LSTM



Improved Semantic Representations From Tree-Structured Long Short-Term Memory Networks, Tai. et al.

RNNs in Various Forms

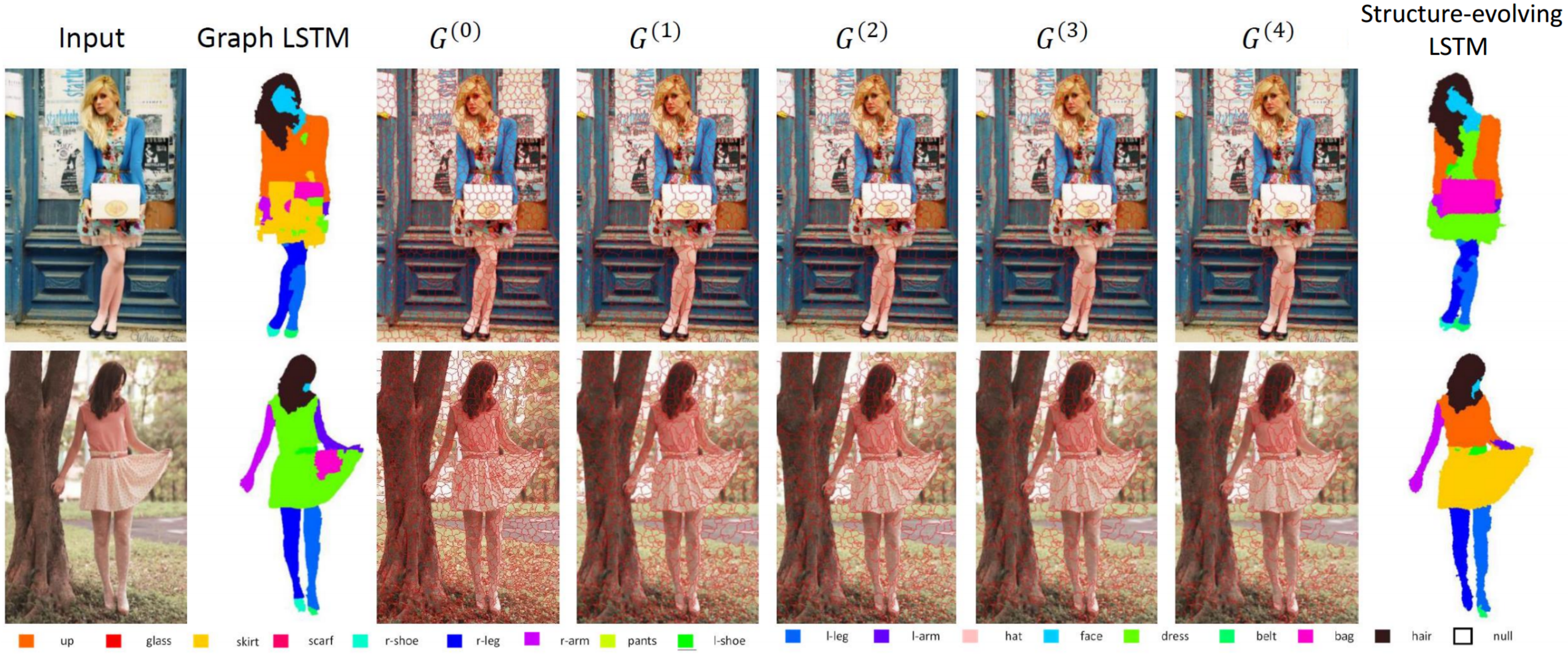
- RNN for 2-D sequences

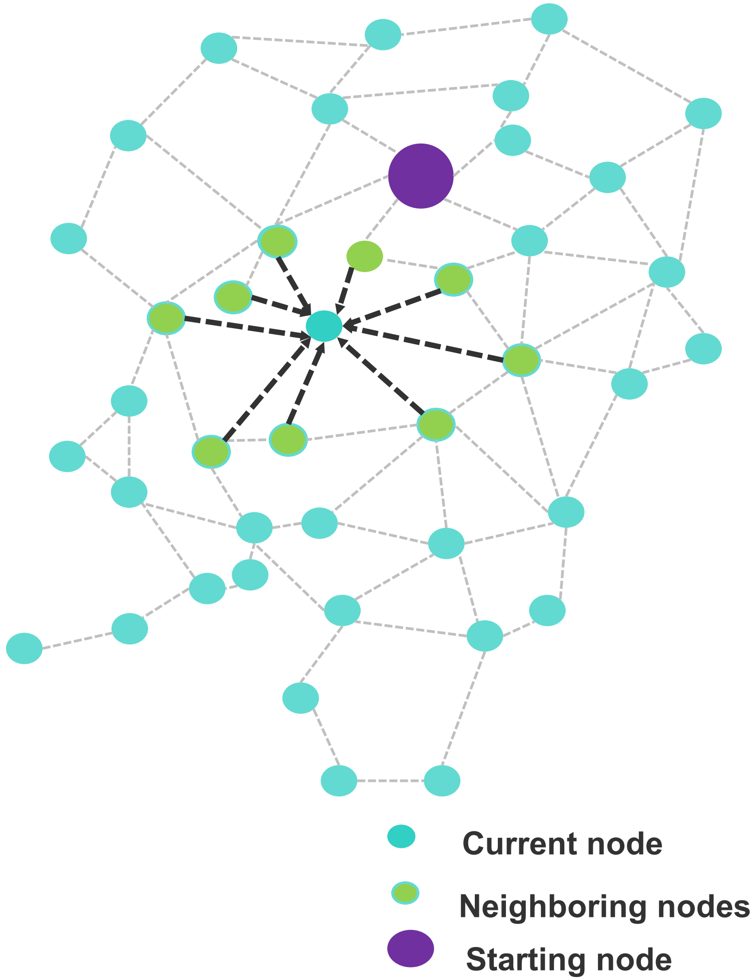


[Pixel Recurrent Neural Networks, van den Oord. et al. 2016]

RNNs in Various Forms

- RNN for Graph Structures
  - Used in, e.g., image segmentation





[Semantic Object Parsing with Graph LSTM. Liang et al. 2016]

Outline

- Convolutional Networks (ConvNets)
- Recurrent Networks (RNNs)
  - Long-range dependency, vanishing
  - LSTM
  - RNNs in different forms
- Attention Mechanisms
  - (Query, Key, Value)
  - Attention on Text and Images
- Transformers: Multi-head Attention
  - Transformer
  - BERT

Attention: Examples

- Chooses which features to pay attention to

A woman is throwing a frisbee in a park.

A dog is standing on a hardwood floor.

A stop sign is on a road with a mountain in the background.

A little girl sitting on a bed with a teddy bear.

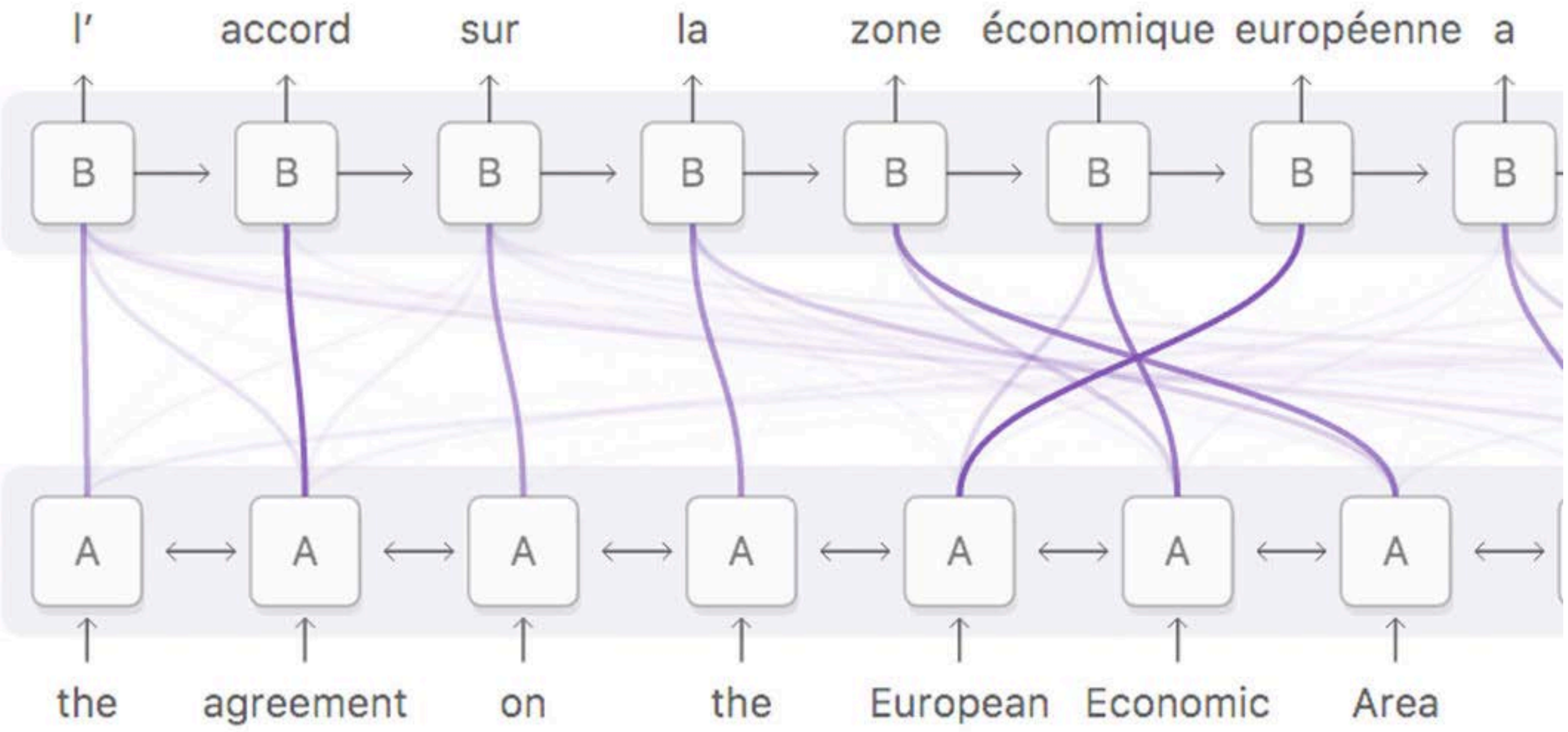
A group of people sitting on a boat in the water.

A giraffe standing in a forest with trees in the background.

Image captioning [Show, attend and tell. Xu et al. 15]

Attention: Examples

- Chooses which features to pay attention to



Machine Translation

Figure courtesy: Olah & Carter, 2016

Why Attention?

Figure courtesy: keitakurita

Why Attention?

- Long-range dependencies
  - Dealing with gradient vanishing problem

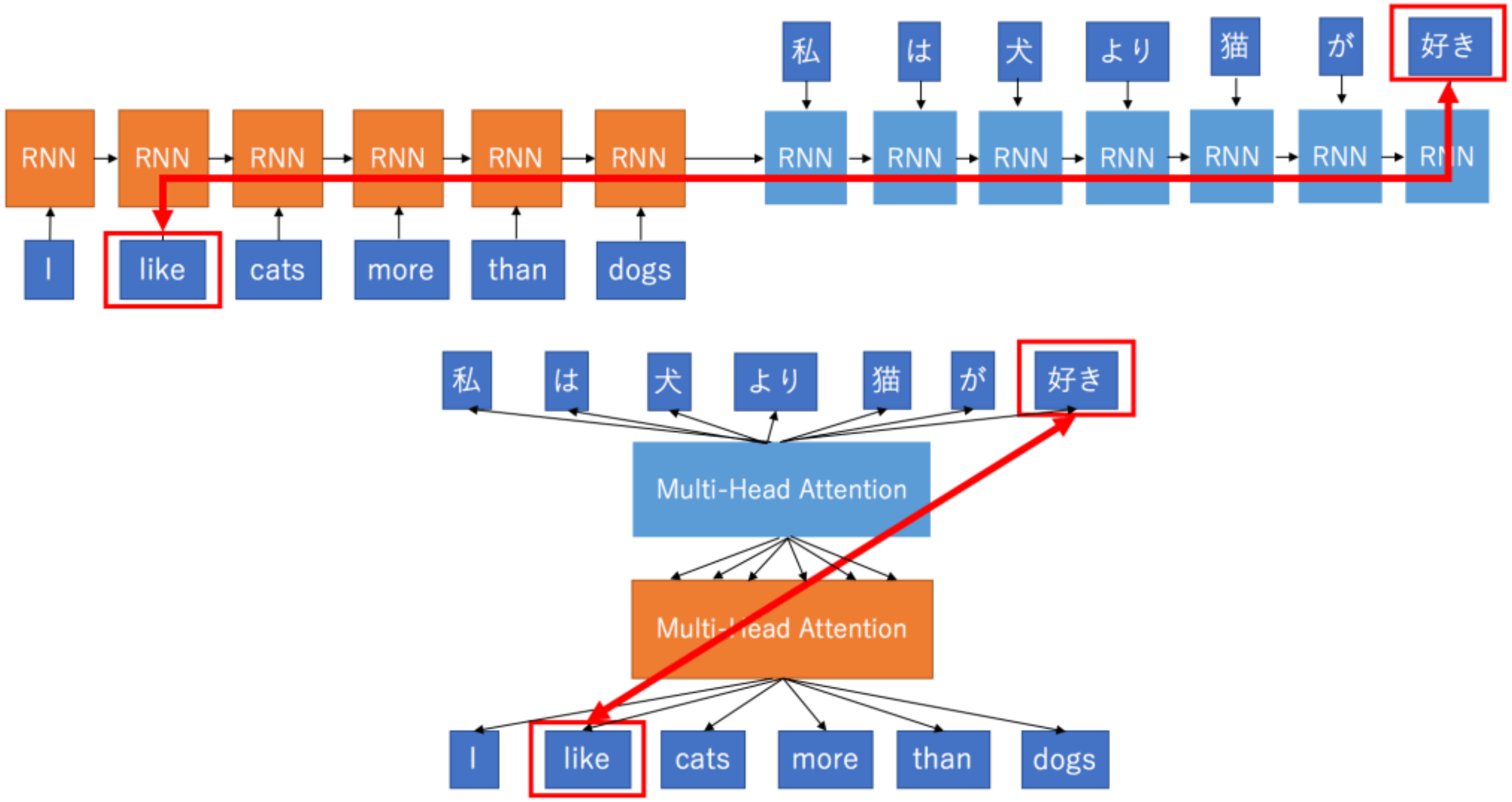


Figure courtesy: keitakurita

Why Attention?

- Long-range dependencies
  - Dealing with gradient vanishing problem
- Fine-grained representation instead of a single global representation
  - Attending to smaller parts of data: patches in images, words in sentences

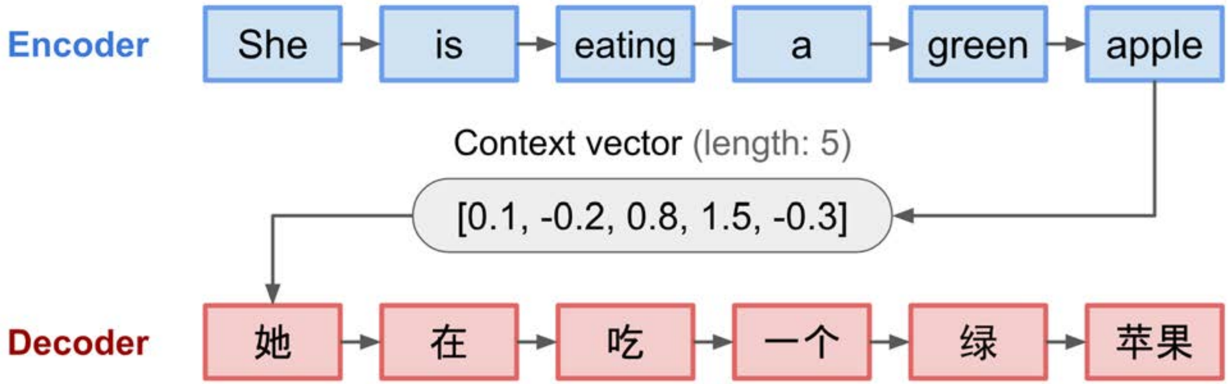


Figure courtesy: Lilian Weng

Why Attention?

- Long-range dependencies
  - Dealing with gradient vanishing problem
- Fine-grained representation instead of a single global representation
  - Attending to smaller parts of data: patches in images, words in sentences
- Improved Interpretability

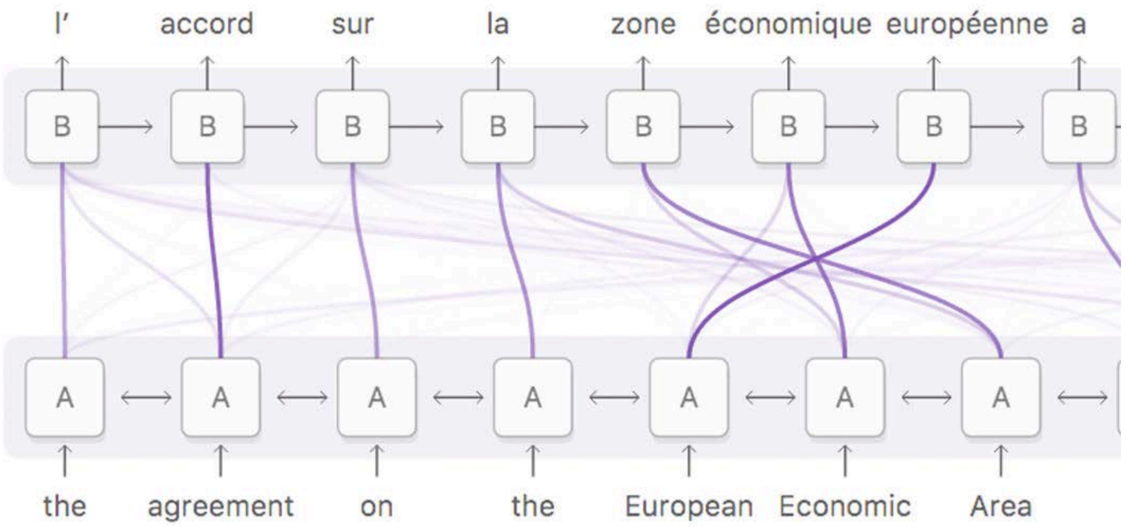


Figure courtesy: Olah & Carter, 2016

Attention Computation

- Encode each token in the input sentence into vectors
- When decoding, perform a linear combination of these vectors, weighted by "attention weights"
  - $\boldsymbol{a} = \mathrm{softmax}(\boldsymbol{alignment\_scores})$

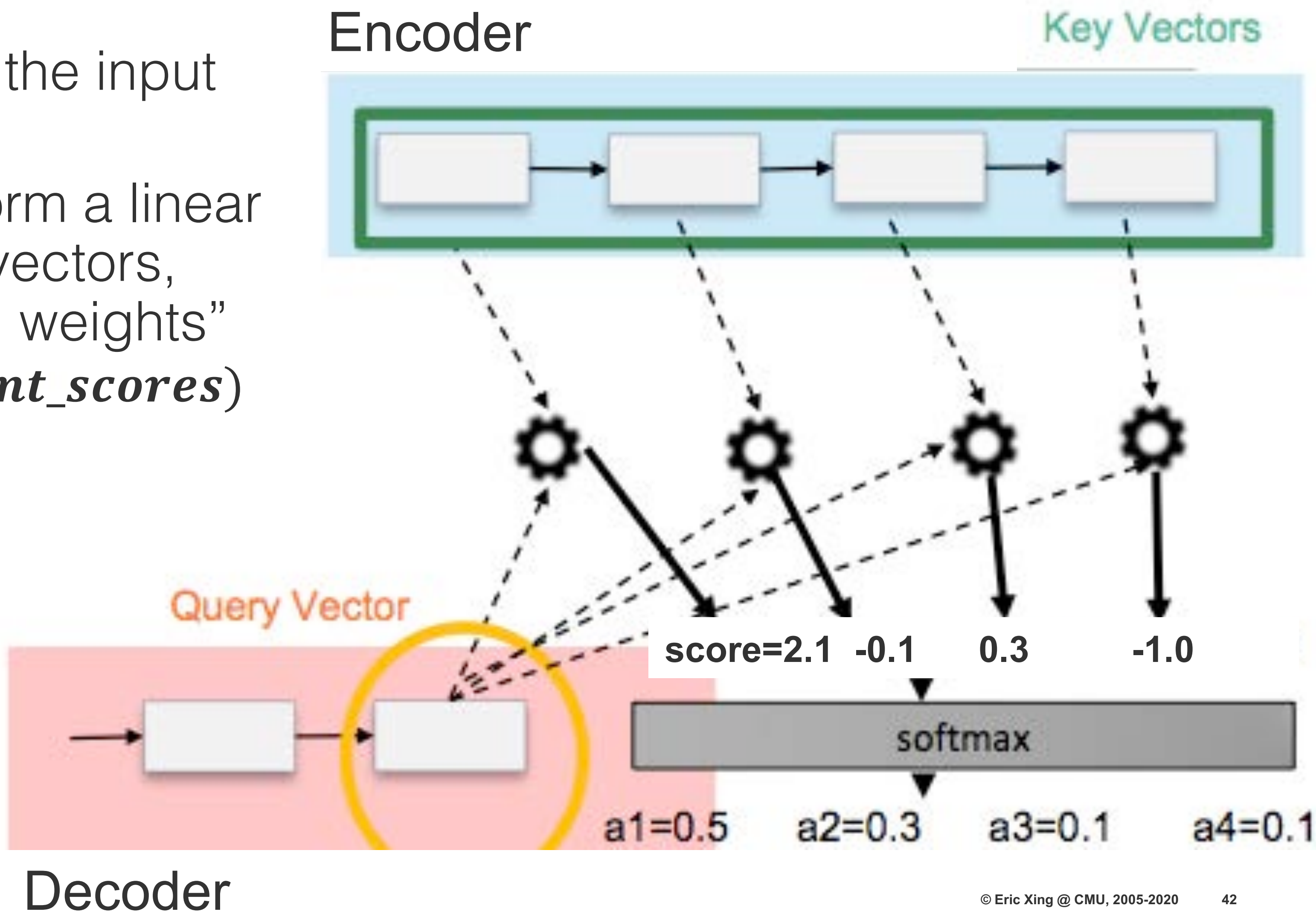
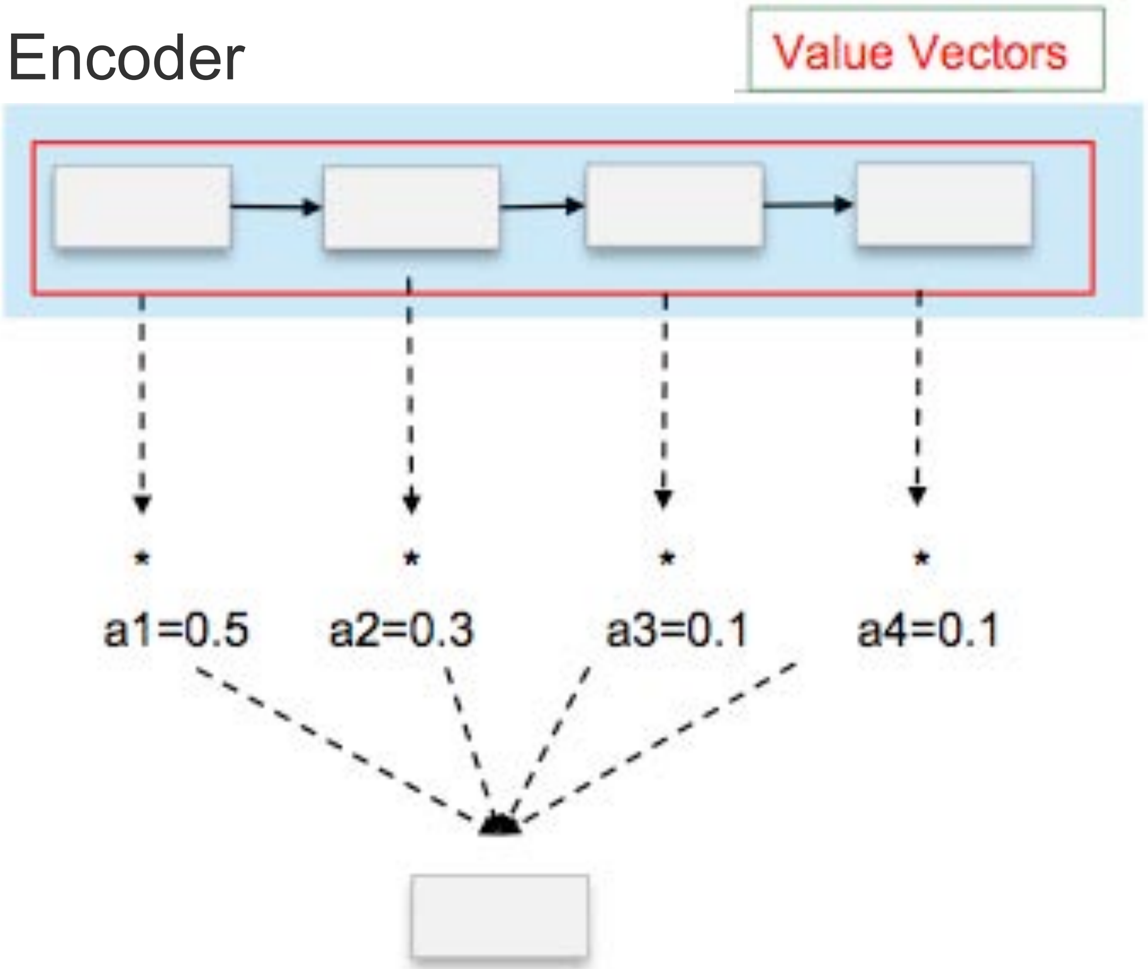


Figure courtesy: MARTA R. COSTA-JUSSÀ

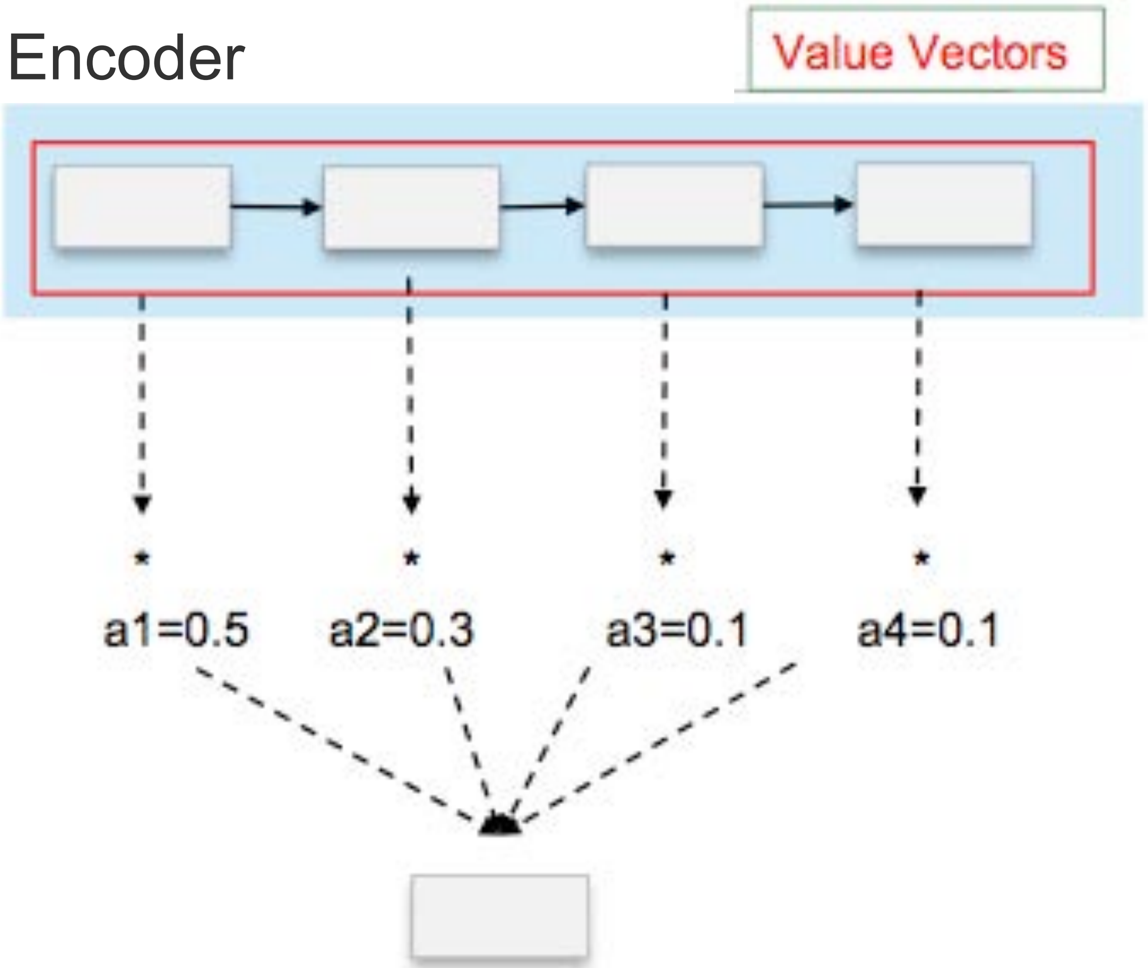
Attention Computation (cont'd)

- Combine together value by taking the weighted sum



Attention Computation (cont'd)

- Combine together value by taking the weighted sum



- **Query**: decoder state
- **Key**: all encoder states
- **Value**: all encoder states

Attention Variants

- Popular attention mechanisms with different alignment score functions

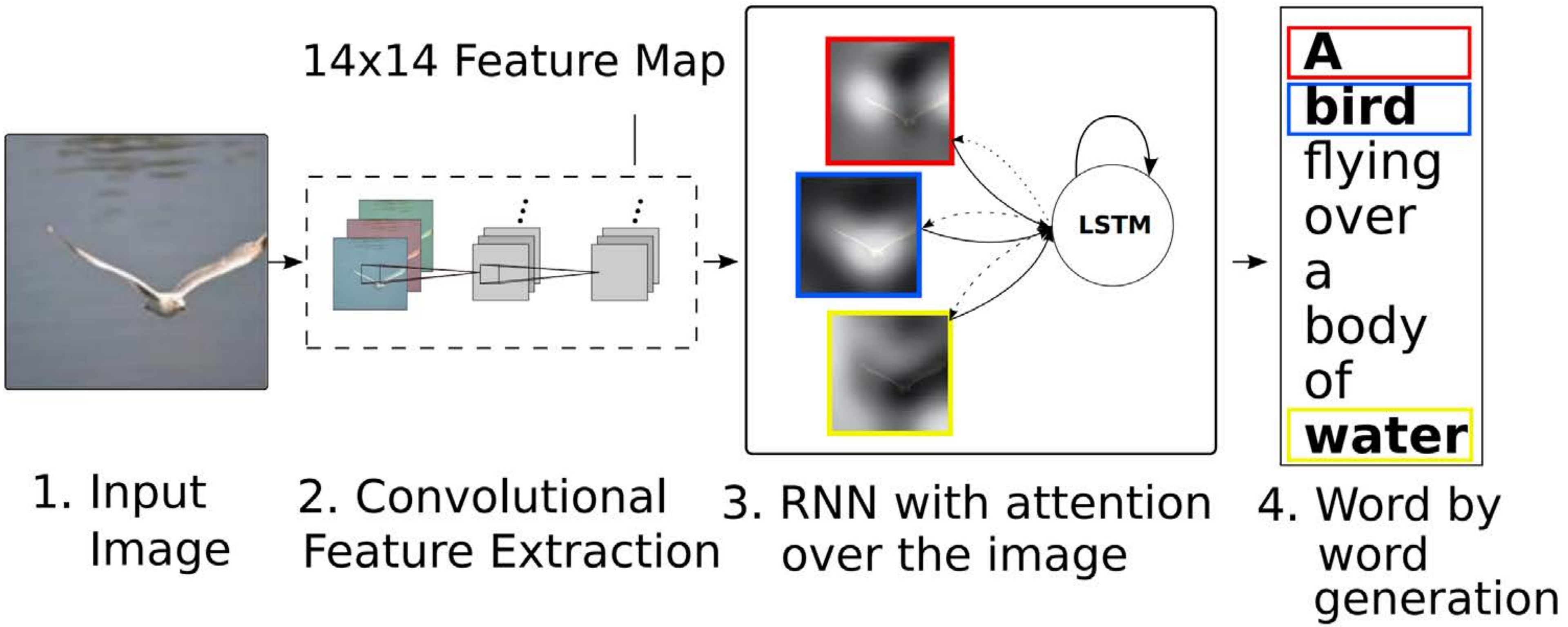
Alignment score = f(Query, Keys)

- **Query**: decoder state s_t
- **Key**: all encoder states h_i
- **Value**: all encoder states h_i

Name	Alignment score function	Citation
Content-base attention	$\text{score}(\boldsymbol{s}_t, \boldsymbol{h}_i) = \text{cosine}[\boldsymbol{s}_t, \boldsymbol{h}_i]$	Graves2014
Additive(*)	$\text{score}(\boldsymbol{s}_t, \boldsymbol{h}_i) = \mathbf{v}_a^\top \tanh(\mathbf{W}_a[\boldsymbol{s}_t; \boldsymbol{h}_i])$	Bahdanau2015
Location-Base	$\alpha_{t,i} = \text{softmax}(\mathbf{W}_a \boldsymbol{s}_t)$ Note: This simplifies the softmax alignment to only depend on the target position.	Luong2015
General	$\text{score}(\boldsymbol{s}_t, \boldsymbol{h}_i) = \mathbf{s}_t^\top \mathbf{W}_a \boldsymbol{h}_i$ where $\mathbf{W}_a$ is a trainable weight matrix in the attention layer.	Luong2015
Dot-Product	$\text{score}(\boldsymbol{s}_t, \boldsymbol{h}_i) = \mathbf{s}_t^\top \boldsymbol{h}_i$	Luong2015
Scaled Dot-Product(^)	$\text{score}(\boldsymbol{s}_t, \boldsymbol{h}_i) = \frac{\mathbf{s}_t^\top \boldsymbol{h}_i}{\sqrt{n}}$ Note: very similar to the dot-product attention except for a scaling factor; where n is the dimension of the source hidden state.	Vaswani2017

Courtesy: Lilian Weng

Attention on Images – Image Captioning



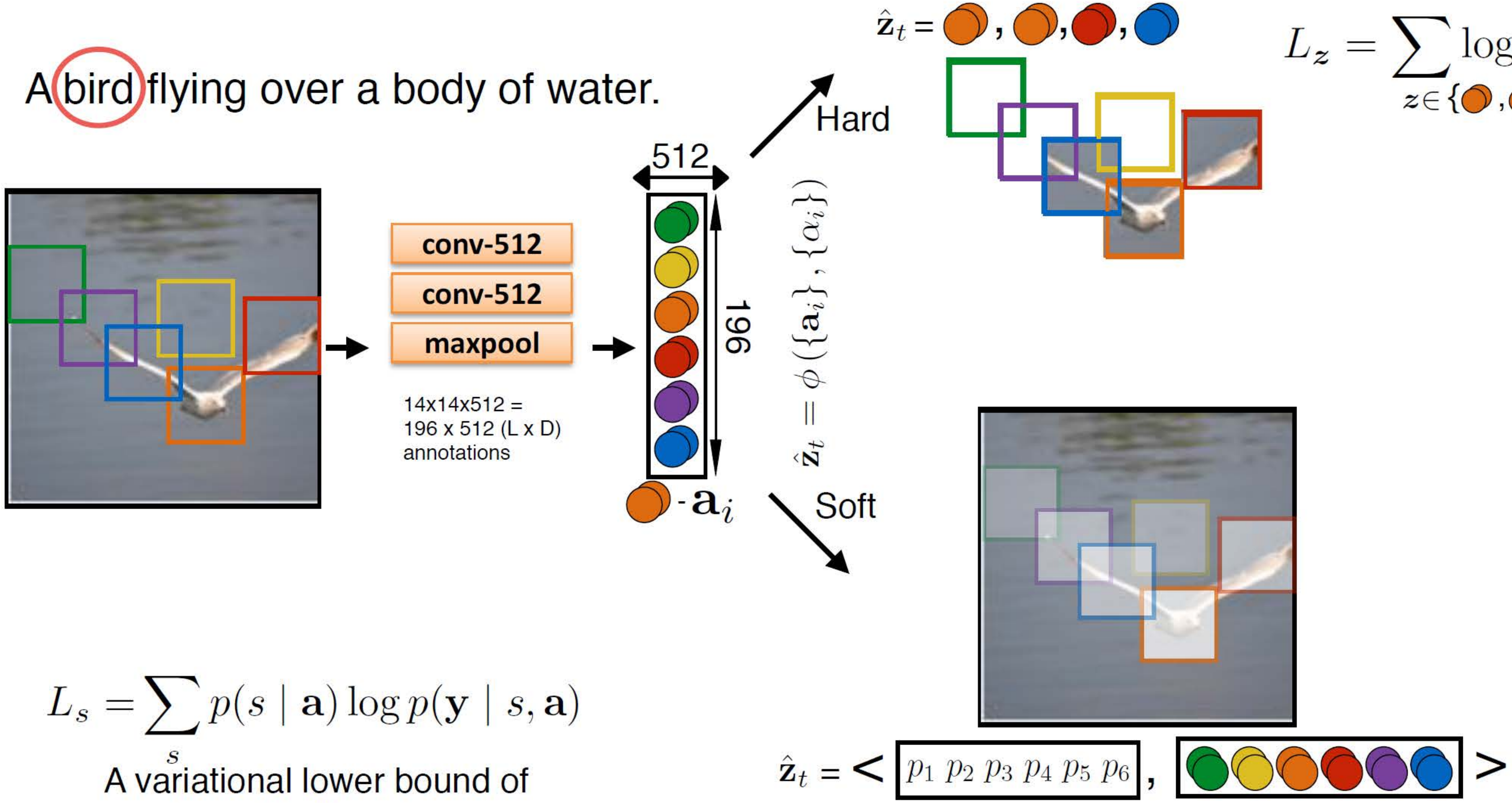
- **Query**: decoder state
- **Key**: visual feature maps
- **Value**: visual feature maps

[Show, attend and tell. Xu et al. 15]

Attention on Images – Image Captioning

Hard attention *vs* Soft attention

Sample regions of attention



$$L_z = \sum_{z \in \{\ldots\}} \log p(\boldsymbol{y} \mid \boldsymbol{z})$$

$$L_s = \sum_s p(s \mid \mathbf{a}) \log p(\mathbf{y} \mid s, \mathbf{a})$$

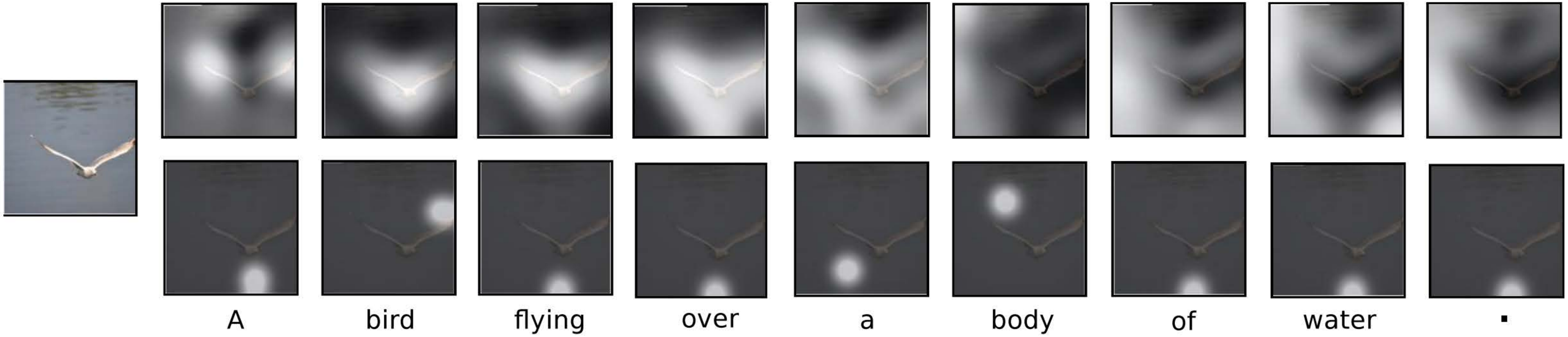
A variational lower bound of maximum likelihood

$\hat{\mathbf{z}}_t = < p_1\ p_2\ p_3\ p_4\ p_5\ p_6, \ldots >$

Computes the expected attention

Attention on Images – Image Captioning

Hard attention *vs* Soft attention



Attention on Images – Image Paragraph Generation

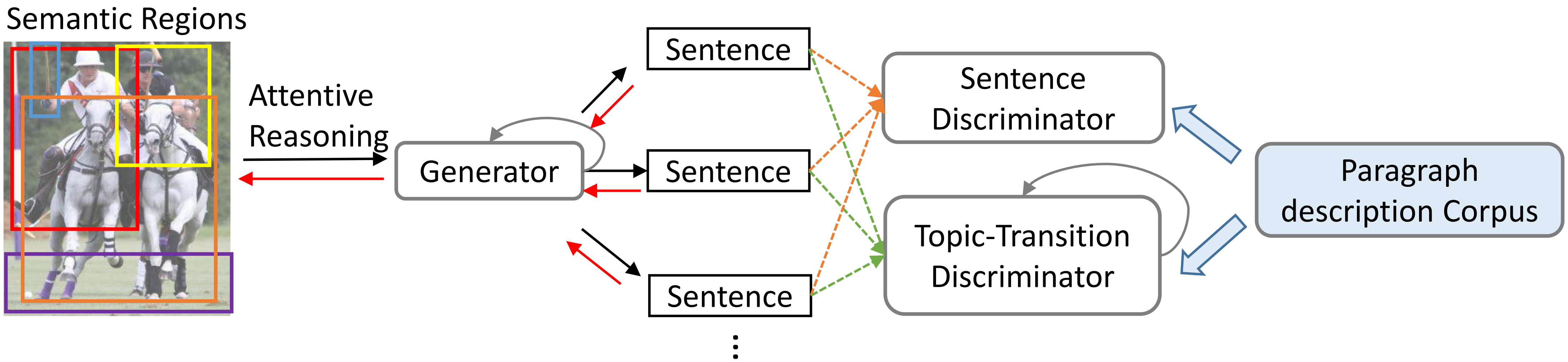
- Generate a long paragraph to describe an image
  - Long-term visual and language reasoning
  - Contentful descriptions -- ground sentences on visual features

This picture is taken for three baseball players on a field. The man on the left is wearing a blue baseball cap. The man has a red shirt and white pants. The man in the middle is in a wheelchair and holding a baseball bat. Two men are bending down behind a fence. There are words band on the fence.

A tennis player is attempting to hit the tennis ball with his left foot hand. He is holding a tennis racket. He is wearing a white shirt and white shorts. He has his right arm extended up. There is a crowd of people watching the game. A man is sitting on the chair.

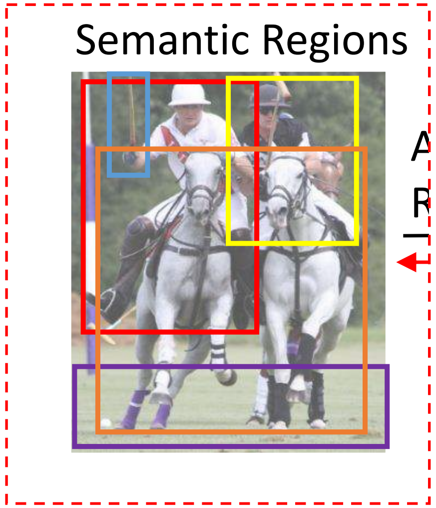
A couple of zebra are standing next to each other on dirt ground near rocks. There are trees behind the zebras. There is a large log on the ground in front of the zebra. There is a large rock formation to the left of the zebra. There is a small hill near a small pond and a wooden log. There are green leaves on the tree.

Attention on Images – Image Paragraph Generation

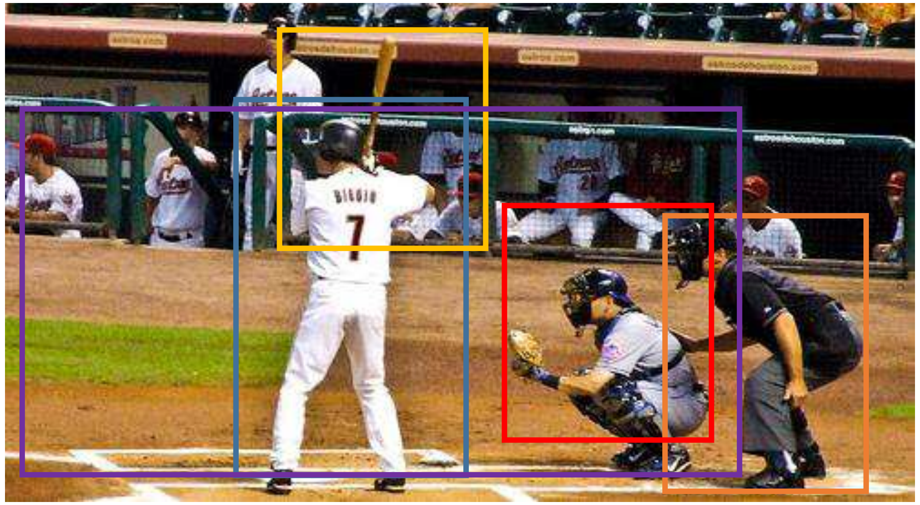


[Recurrent Topic-Transition GAN for Visual Paragraph Generation. Liang et al. 2017]

Attention on Images – Image Paragraph Generation



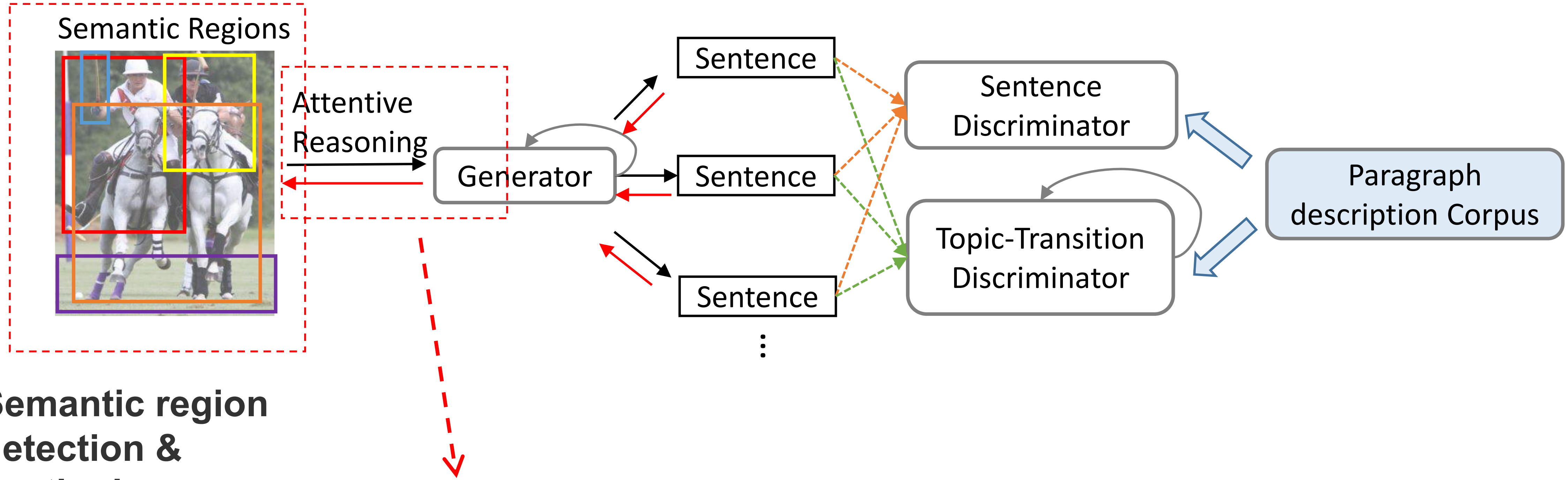
Semantic region detection & captioning



Local Phrases

- people playing baseball
- a man wearing white shirt and pants
- man holding a baseball bat
- person wearing a helmet in the field
- a man bending over

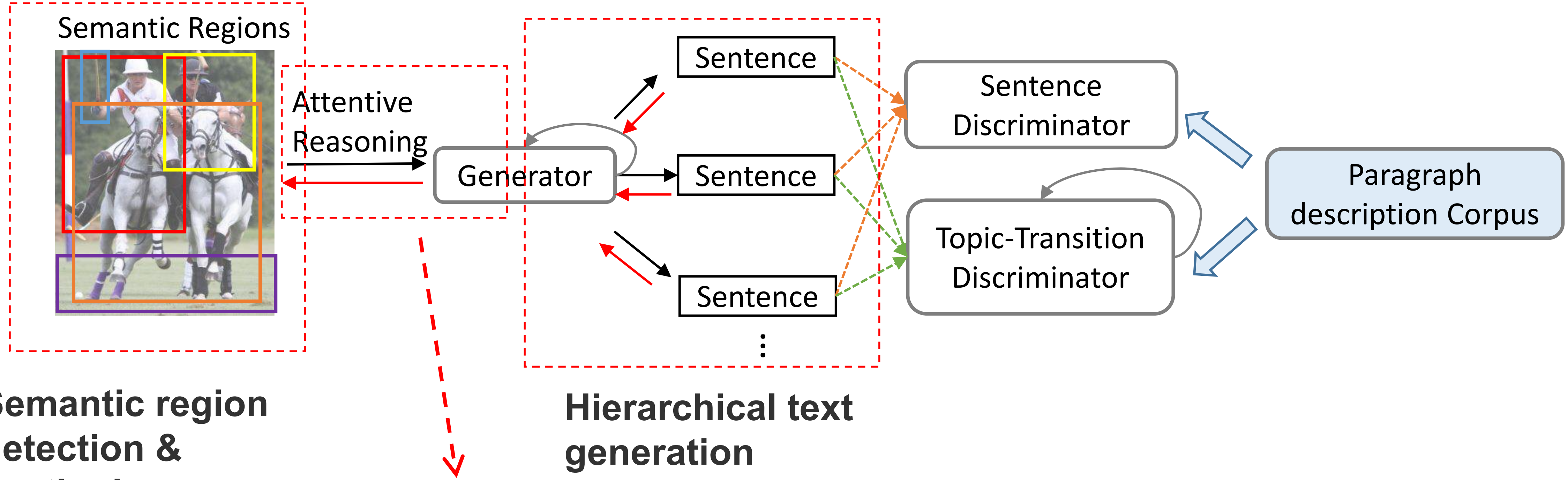
Attention on Images – Image Paragraph Generation



Semantic region detection & captioning

Attention on both visual regions and text phrases

Attention on Images – Image Paragraph Generation

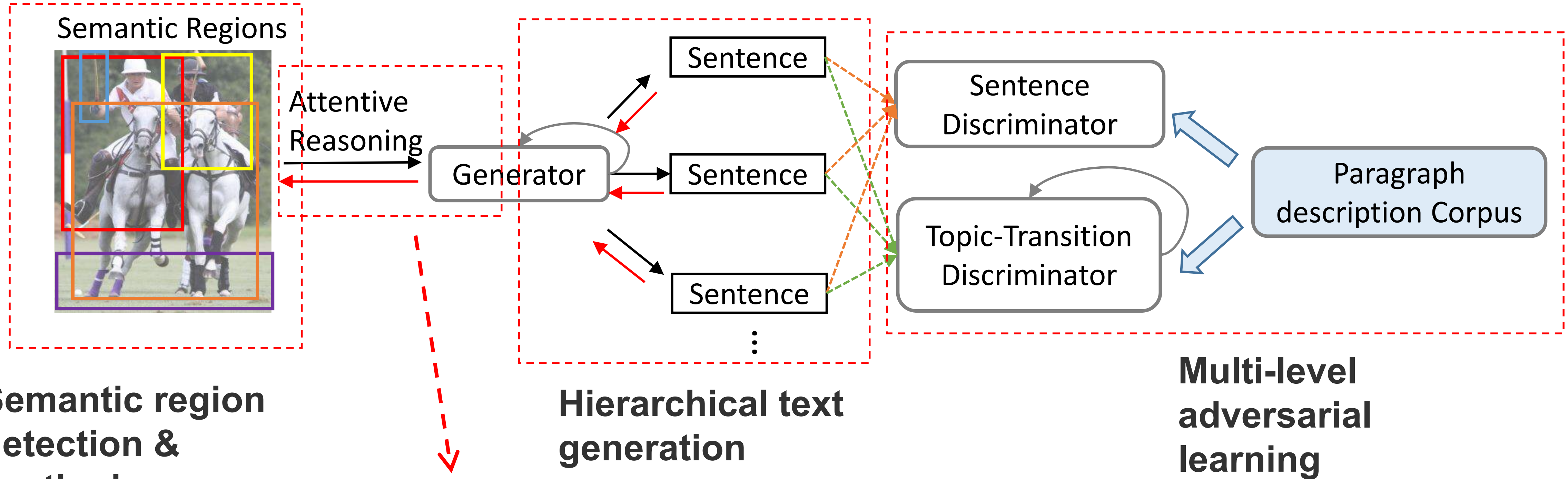


Semantic region detection & captioning

Attention on both visual regions and text phrases

Hierarchical text generation

Attention on Images – Image Paragraph Generation



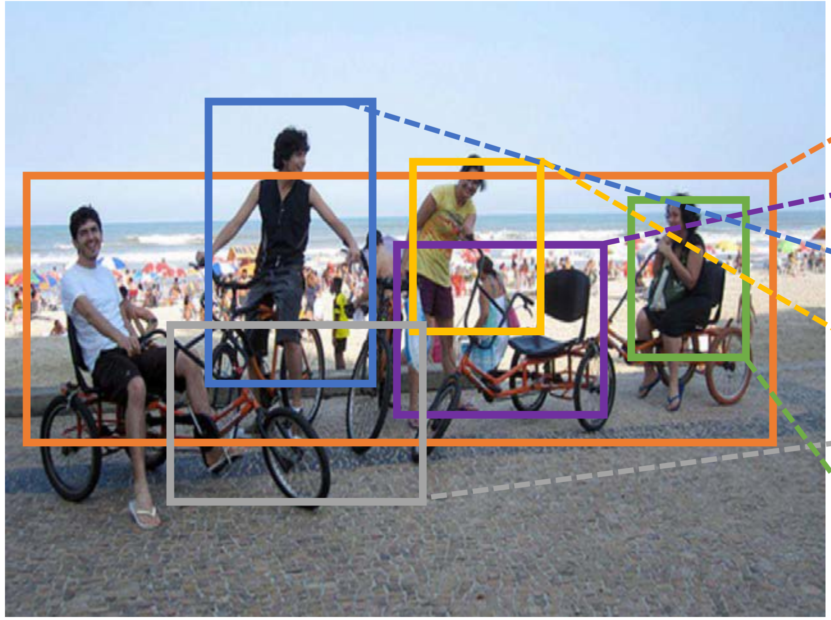
Semantic region detection & captioning

Attention on both visual regions and text phrases

Hierarchical text generation

Multi-level adversarial learning

Attention on Images – Image Paragraph Generation



1) people riding a bike
2) a bicycle parked on the sidewalk
3) man wearing a black shirt
4) a woman wearing a yellow shirt
5) a red and black bike
6) a woman wearing a shirt

Paragraph: *A group of people are riding bikes. There are two people riding bikes parked on the sidewalk. He is wearing a black shirt and jeans. A woman is wearing a short sleeve yellow shirt and shorts. There are many other people on the red and black bikes. A woman wearing a shirt is riding a bicycle.*

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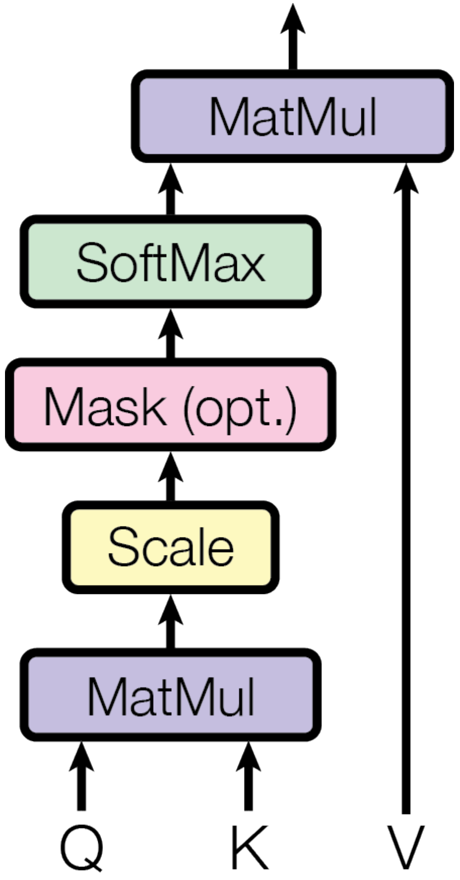
Transformers – Multi-head (Self-)Attention

- State-of-the-art Results by Transformers
  - [Vaswani et al., 2017] Attention Is All You Need
    - Machine Translation
  - [Devlin et al., 2018] BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding
    - Pre-trained Text Representation
  - [Radford et al., 2019] Language Models are Unsupervised Multitask Learners
    - Language Models

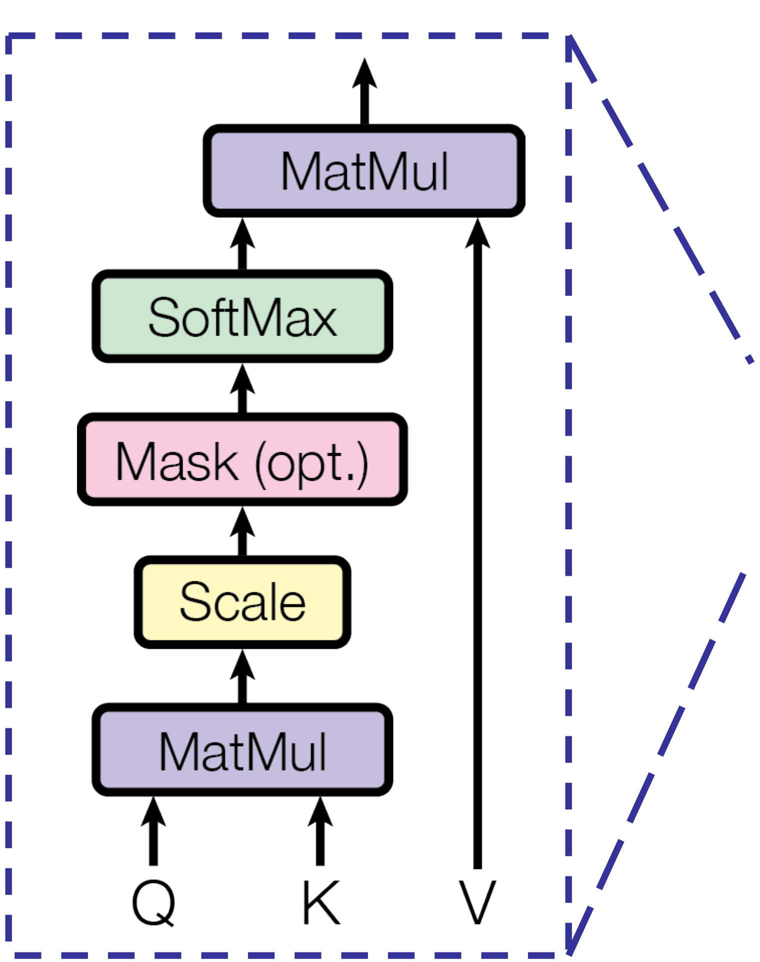
Multi-head Attention



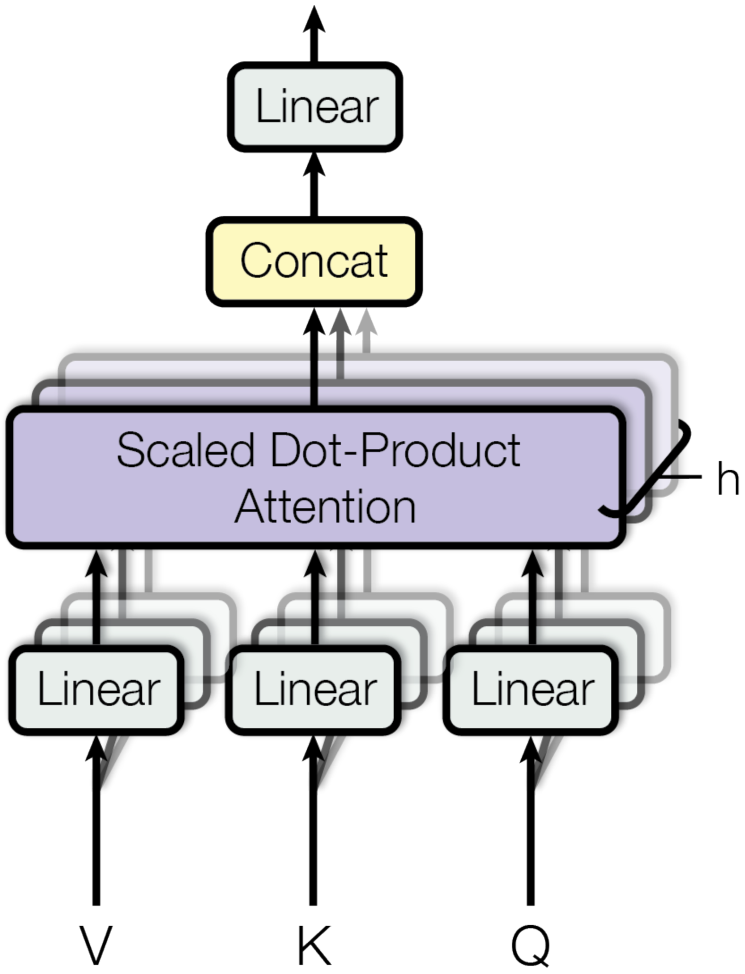
Scaled Dot-Product Attention

Image source: Vaswani, et al., 2017

Multi-head Attention



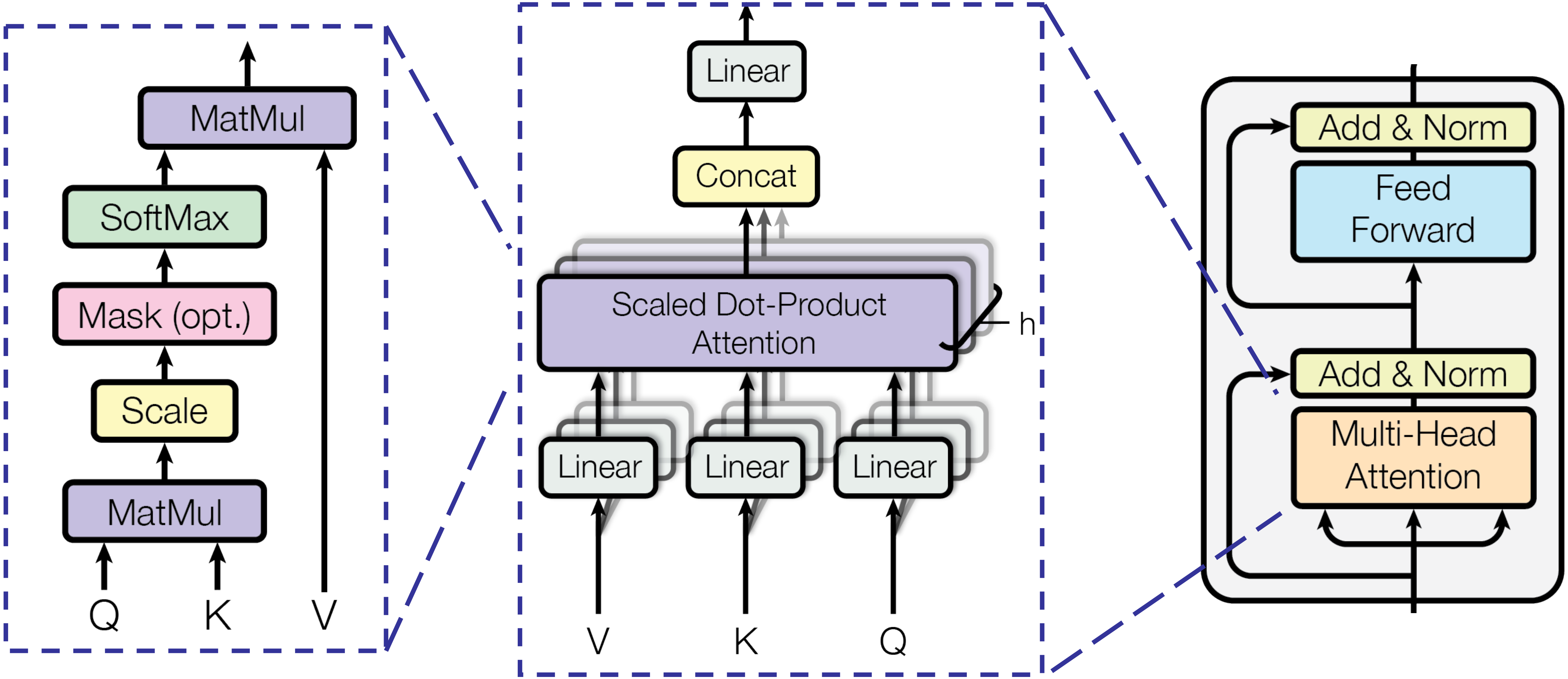
Scaled Dot-Product Attention



Multi-head Attention

Image source: Vaswani, et al., 2017

Multi-head Attention

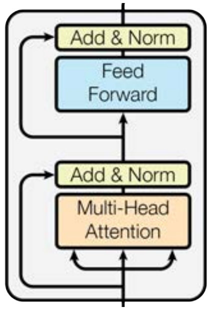


Scaled Dot-Product Attention **Multi-head Attention**

Image source: Vaswani, et al., 2017

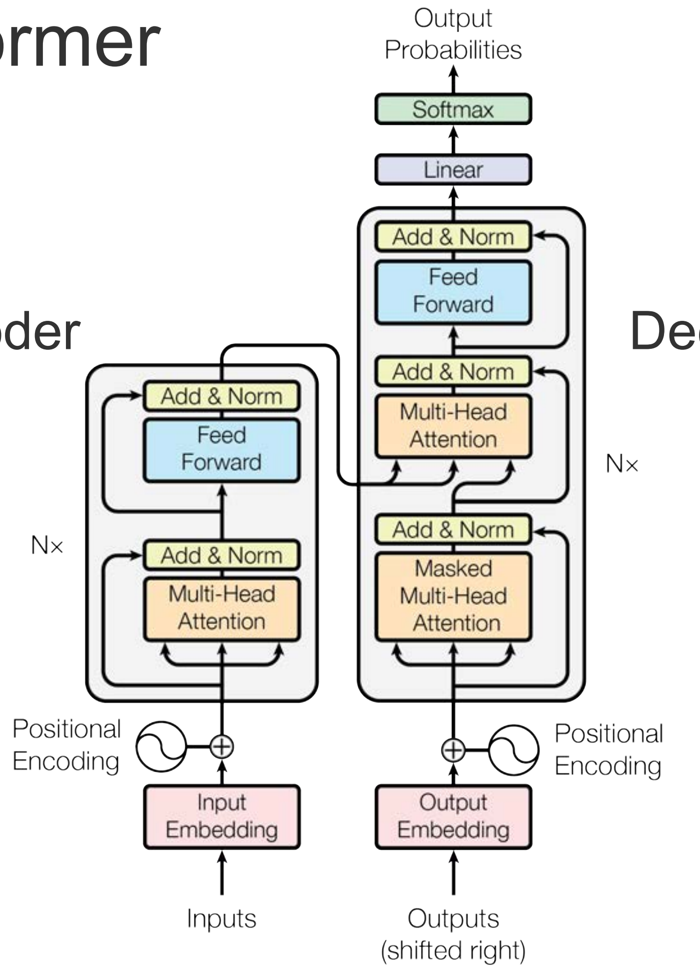
Multi-head Attention in Encoders and Decoders

Transformer



Encoder

Decoder



Multi-head Attention in Encoders and Decoders

Transformer

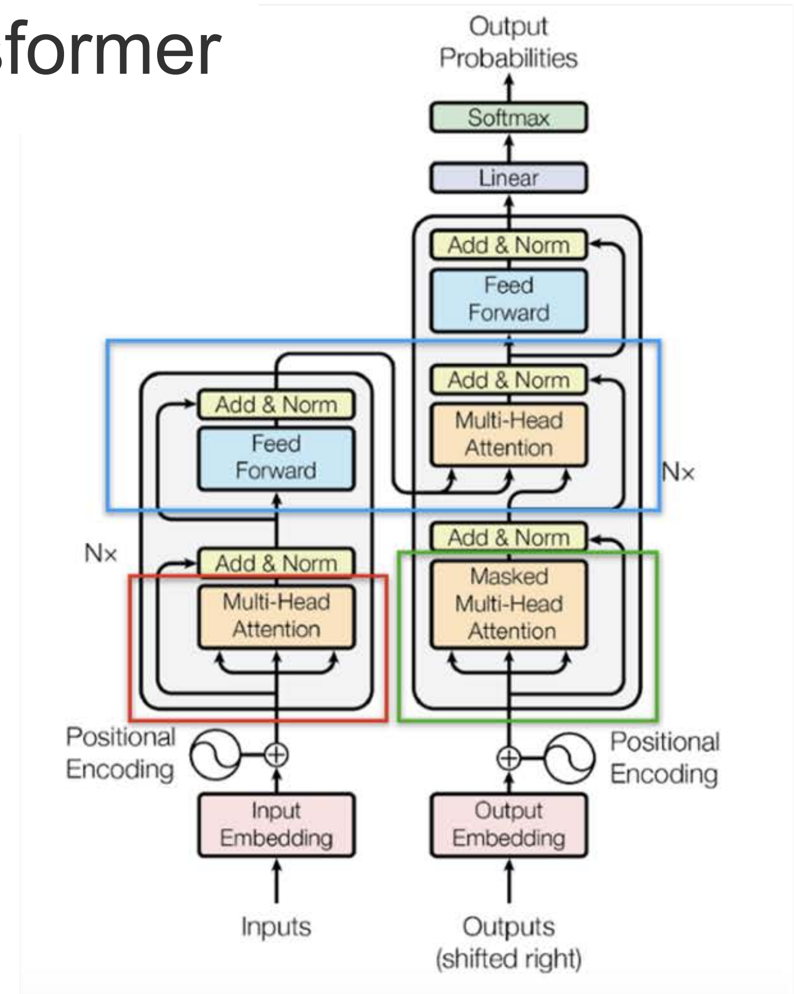


Figure 1: The Transformer - model architecture.

encoder self attention

1. Multi-head Attention
2. Query=Key=Value

decoder self attention

1. Masked Multi-head Attention
2. Query=Key=Value

encoder-decoder attention

1. Multi-head Attention
2. Encoder Self attention=Key=Value
3. Decoder Self attention=Query

Image source: Bgg

BERT: Pre-trained Text Representation Model

Image source: Vaswani, et al., 2017

BERT: Pre-trained Text Representation Model

- Conventional word embedding:
  - Word2vec, Glove
  - A pre-trained matrix, each row is an embedding vector of a word

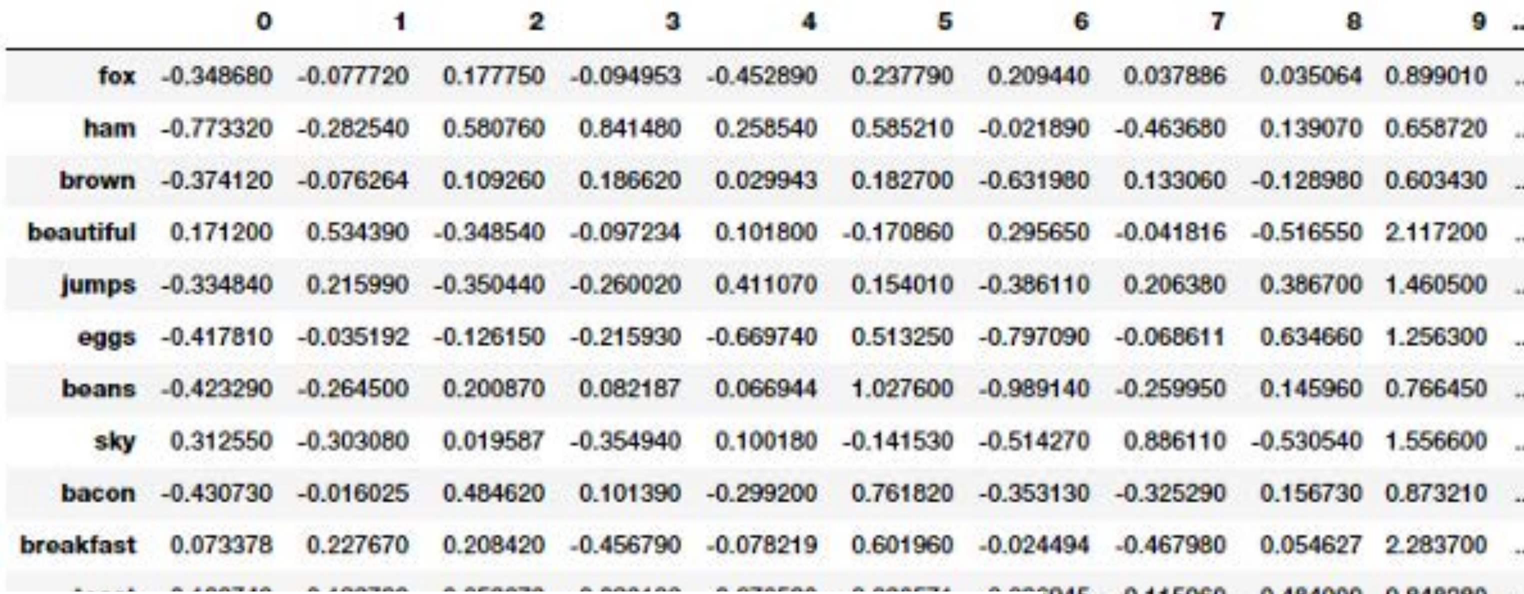
	0	1	2	3	4	5	6	7	8	9	...
fox	-0.348680	-0.077720	0.177750	-0.094953	-0.452890	0.237790	0.209440	0.037886	0.035064	0.899010	...
ham	-0.773320	-0.282540	0.580760	0.841480	0.258540	0.585210	-0.021890	-0.463680	0.139070	0.658720	...
brown	-0.374120	-0.076264	0.109260	0.186620	0.029943	0.182700	-0.631980	0.133060	-0.128980	0.603430	...
beautiful	0.171200	0.534390	-0.348540	-0.097234	0.101800	-0.170860	0.295650	-0.041816	-0.516550	2.117200	...
jumps	-0.334840	0.215990	-0.350440	-0.260020	0.411070	0.154010	-0.386110	0.206380	0.386700	1.460500	...
eggs	-0.417810	-0.035192	-0.126150	-0.215930	-0.669740	0.513250	-0.797090	-0.068611	0.634660	1.256300	...
beans	-0.423290	-0.264500	0.200870	0.082187	0.066944	1.027600	-0.989140	-0.259950	0.145960	0.766450	...
sky	0.312550	-0.303080	0.019587	-0.354940	0.100180	-0.141530	-0.514270	0.886110	-0.530540	1.556600	...
bacon	-0.430730	-0.016025	0.484620	0.101390	-0.299200	0.761820	-0.353130	-0.325290	0.156730	0.873210	...
breakfast	0.073378	0.227670	0.208420	-0.456790	-0.078219	0.601960	-0.024494	-0.467980	0.054627	2.283700	...
toast	0.130740	-0.193730	0.253270	0.090102	-0.272580	-0.030571	0.096945	-0.115060	0.484000	0.848380	...
today	-0.156570	0.594890	-0.031445	-0.077586	0.278630	-0.509210	-0.066350	-0.081890	-0.047986	2.803600	...
blue	0.129450	0.036518	0.032298	-0.060034	0.399840	-0.103020	-0.507880	0.076630	-0.422920	0.815730	...
green	-0.072368	0.233200	0.137260	-0.156630	0.248440	0.349870	-0.241700	-0.091426	-0.530150	1.341300	...
kings	0.259230	-0.854690	0.360010	-0.642000	0.568530	-0.321420	0.173250	0.133030	-0.089720	1.528600	...
dog	-0.057120	0.052685	0.003026	-0.048517	0.007043	0.041856	-0.024704	-0.039783	0.009614	0.308416	...
sausages	-0.174290	-0.064869	-0.046976	0.287420	-0.128150	0.647630	0.056315	-0.240440	-0.025094	0.502220	...
lazy	-0.353320	-0.299710	-0.176230	-0.321940	-0.385640	0.586110	0.411160	-0.418680	0.073093	1.486500	...
love	0.139490	0.534530	-0.252470	-0.125650	0.048748	0.152440	0.199060	-0.065970	0.128830	2.055900	...
quick	-0.445630	0.191510	-0.249210	0.465900	0.161950	0.212780	-0.046480	0.021170	0.417660	1.686900	...

20 rows × 300 columns

Image source: Vaswani, et al., 2017

BERT: Pre-trained Text Representation Model

- Conventional word embedding:
  - Word2vec, Glove
  - A pre-trained **matrix**, each row is an embedding vector of a word



	0	1	2	3	4	5	6	7	8	9	...
fox	-0.348680	-0.077720	0.177750	-0.094953	-0.452890	0.237790	0.209440	0.037886	0.035064	0.899010	...
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bacon	-0.430730	-0.016025	0.484620	0.101390	-0.299200	0.761820	-0.353130	-0.325290	0.156730	0.873210	...
breakfast	0.073378	0.227670	0.208420	-0.456790	-0.078219	0.601960	-0.024494	-0.467980	0.054627	2.283700	...
								-0.115060	0.484000	0.848380	...
								-0.081890	-0.047986	2.803600	...
								0.076630	-0.422920	0.815730	...
								-0.091426	-0.530150	1.341300	...
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								-0.039783	0.009614	0.308416	...
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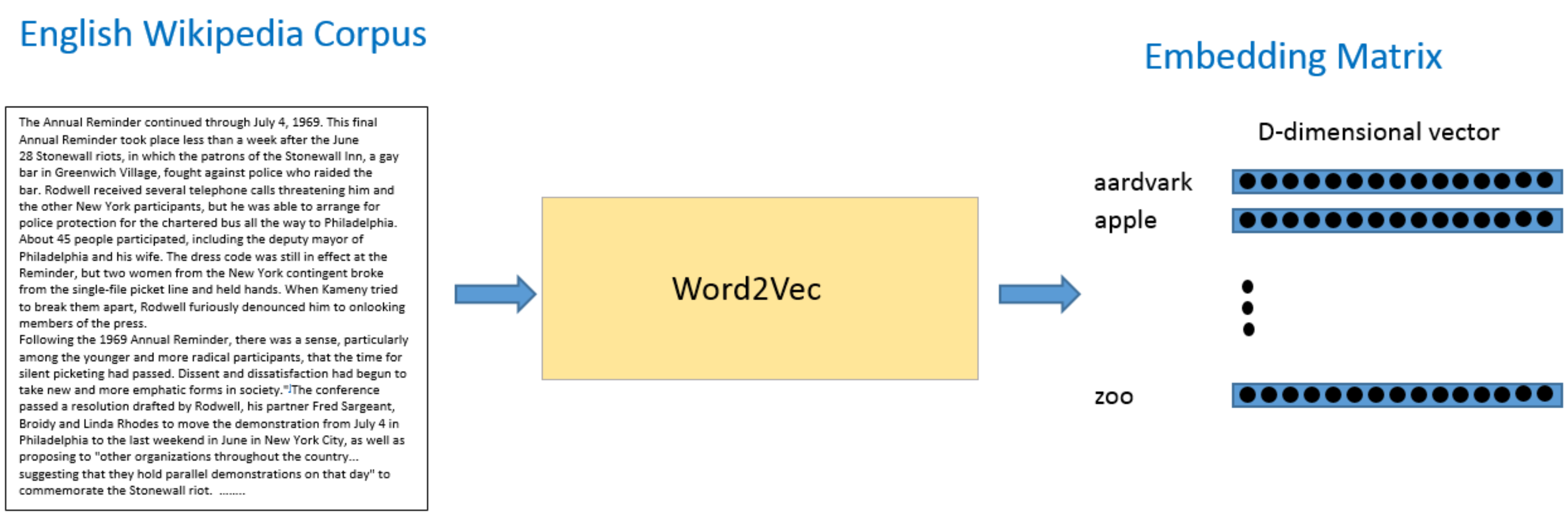
								0.021170	0.417660	1.686900	...

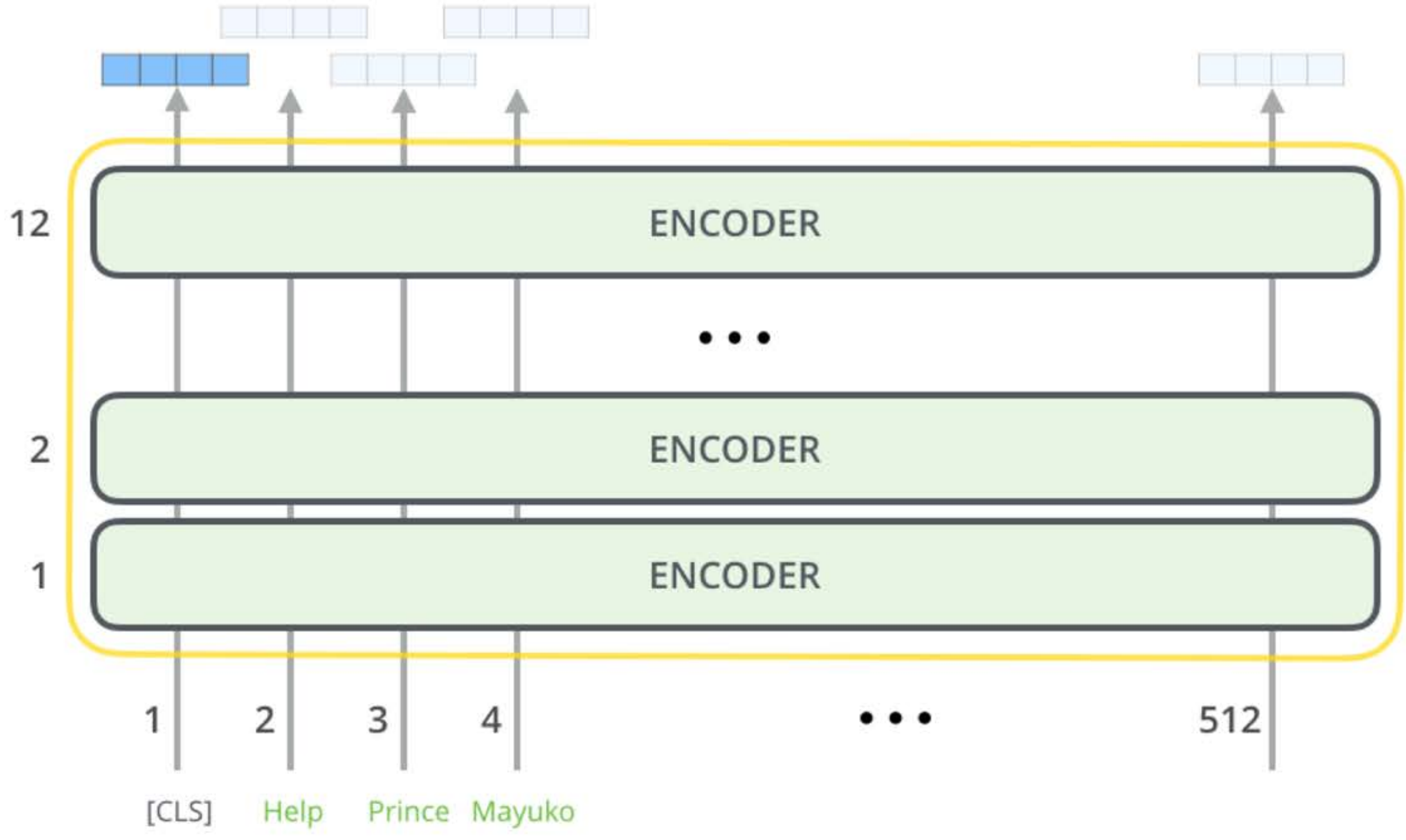


The Annual Reminder continued through July 4, 1969. This final Annual Reminder took place less than a week after the June 28 Stonewall riots, in which the patrons of the Stonewall Inn, a gay bar in Greenwich Village, fought against police who raided the bar. Rodwell received several telephone calls threatening him and the other New York participants, but he was able to arrange for police protection for the chartered bus all the way to Philadelphia. About 45 people participated, including the deputy mayor of Philadelphia and his wife. The dress code was still in effect at the Reminder, but two women from the New York contingent broke from the single-file picket line and held hands. When Kameny tried to break them apart, Rodwell furiously denounced him to onlooking members of the press.
Following the 1969 Annual Reminder, there was a sense, particularly among the younger and more radical participants, that the time for silent picketing had passed. Dissent and dissatisfaction had begun to take new and more emphatic forms in society.[] The conference passed a resolution drafted by Rodwell, his partner Fred Sargeant, Broidy and Linda Rhodes to move the demonstration from July 4 in Philadelphia to the last weekend in June in New York City, as well as proposing to "other organizations throughout the country... suggesting that they hold parallel demonstrations on that day" to commemorate the Stonewall riot. ....

Image source: Vaswa

BERT: Pre-trained Text Representation Model

- BERT: A model to extract *contextualized* word embedding



BERT

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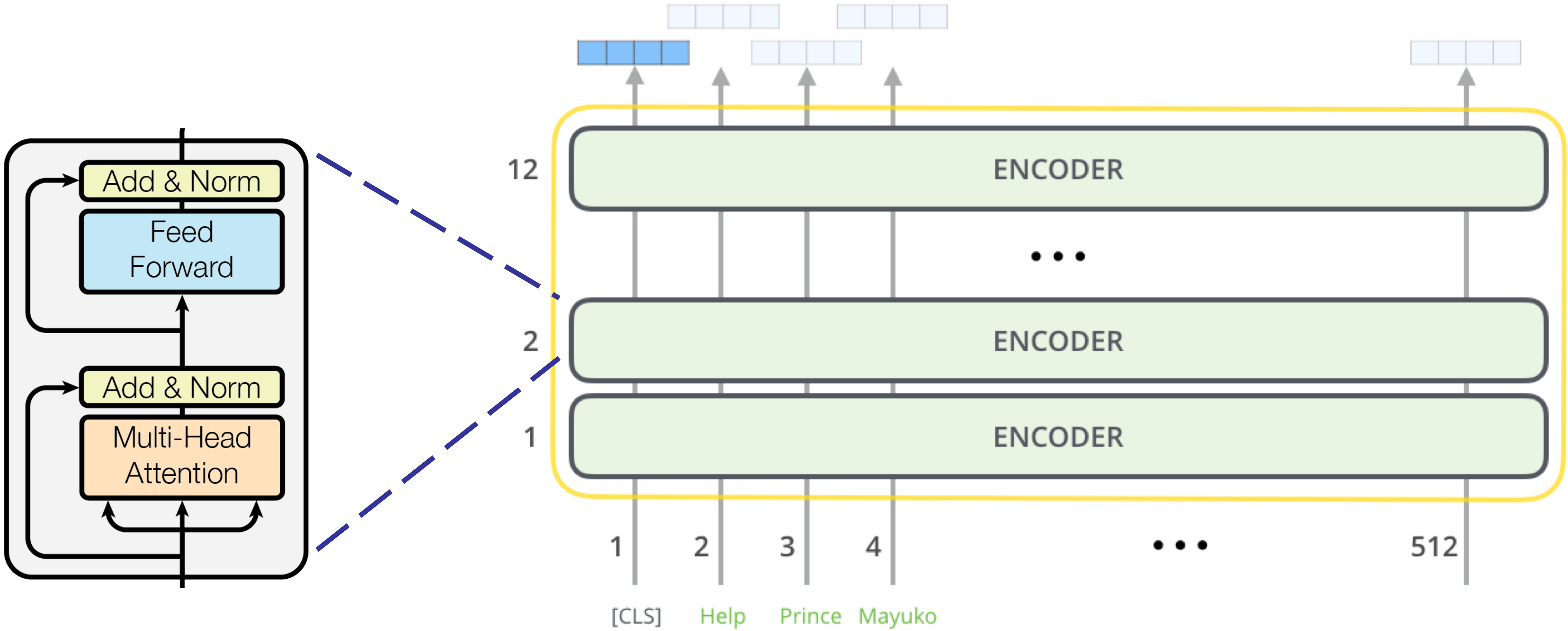

BERT

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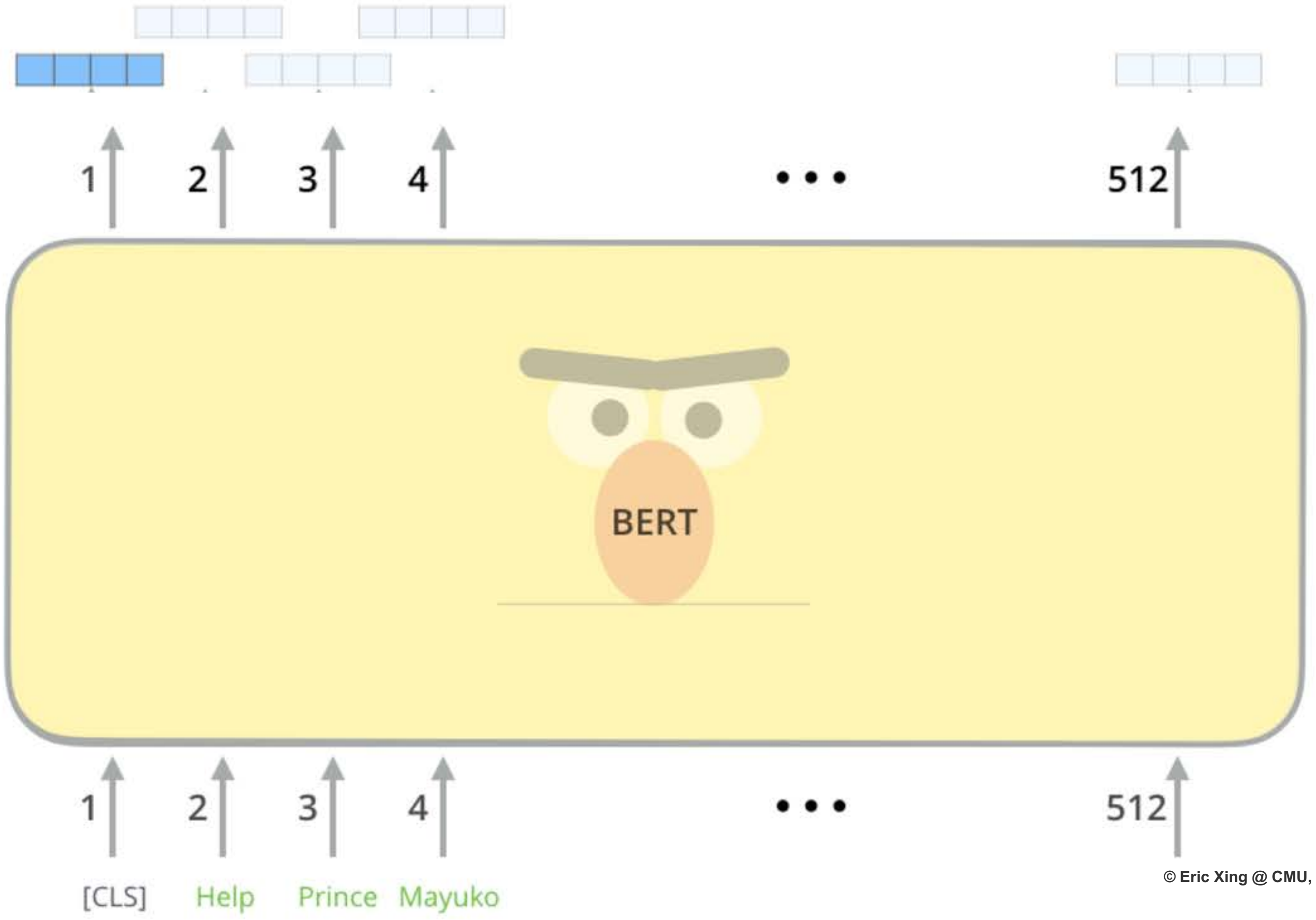
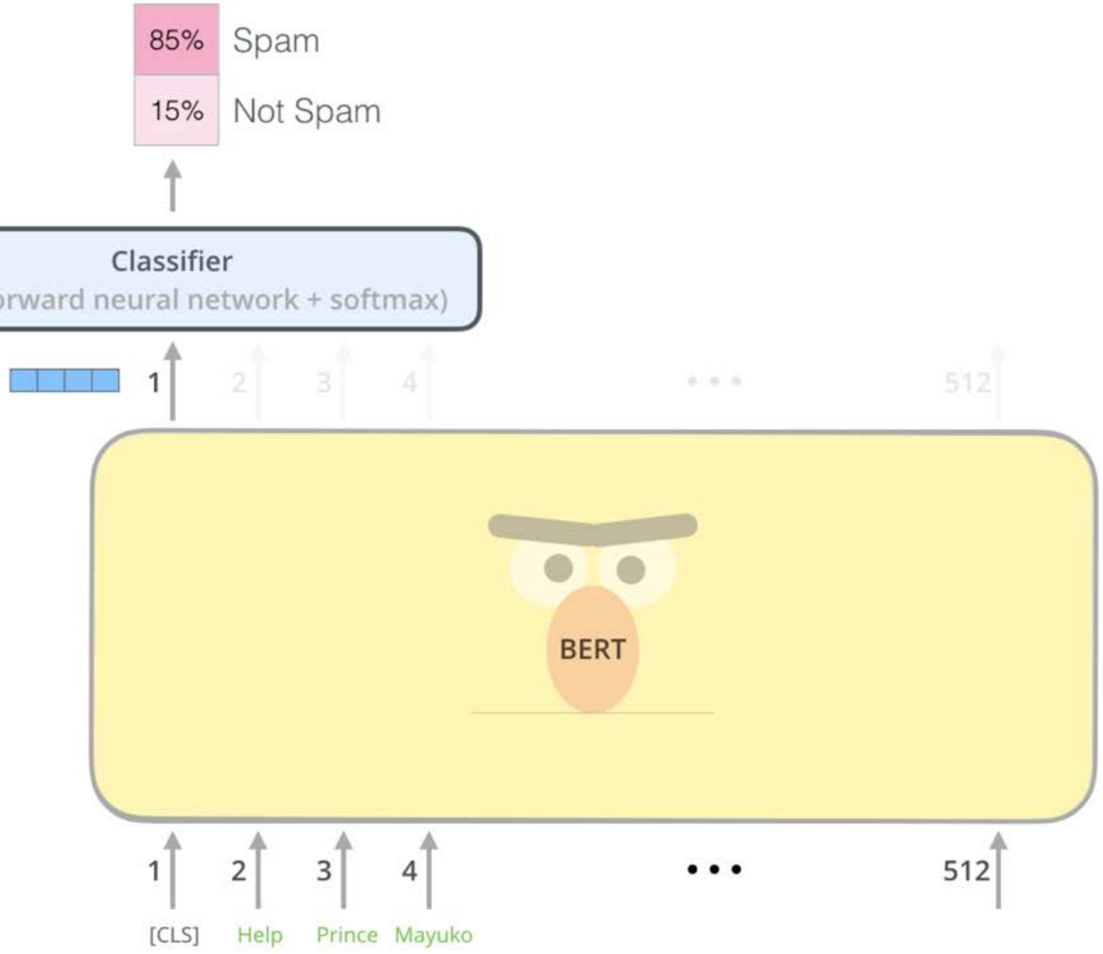


BERT: Pre-trained Text Representation Model

- Use BERT for sentence classification



BERT Results

- **Huge improvements over SOTA on 12 NLP task**

System	MNLI-(m/mm)	QQP	QNLI	SST-2	CoLA	STS-B	MRPC	RTE	**Average**
	392k	363k	108k	67k	8.5k	5.7k	3.5k	2.5k	-
Pre-OpenAI SOTA	80.6/80.1	66.1	82.3	93.2	35.0	81.0	86.0	61.7	74.0
BiLSTM+ELMo+Attn	76.4/76.1	64.8	79.9	90.4	36.0	73.3	84.9	56.8	71.0
OpenAI GPT	82.1/81.4	70.3	88.1	91.3	45.4	80.0	82.3	56.0	75.2
$\text{BERT}_{\text{BASE}}$	84.6/83.4	71.2	90.1	93.5	52.1	85.8	88.9	66.4	79.6
$\text{BERT}_{\text{LARGE}}$	**86.7/85.9**	**72.1**	**91.1**	**94.9**	**60.5**	**86.5**	**89.3**	**70.1**	**81.9**

Table 1: GLUE Test results, scored by the GLUE evaluation server. The number below each task denotes the number of training examples. The "Average" column is slightly different than the official GLUE score, since we exclude the problematic WNLI set. OpenAI GPT = (L=12, H=768, A=12); $\text{BERT}_{\text{BASE}}$ = (L=12, H=768, A=12); $\text{BERT}_{\text{LARGE}}$ = (L=24, H=1024, A=16). BERT and OpenAI GPT are single-model, single task. All results obtained from https://gluebenchmark.com/leaderboard and https://blog.openai.com/language-unsupervised/.

BERT: Pre-training Procedure

- Model architecture:
  - A big Transformer Encoder (240M free parameters)
- Dataset:
  - Wikipedia (2.5B words) + a collection of free ebooks (800M words)

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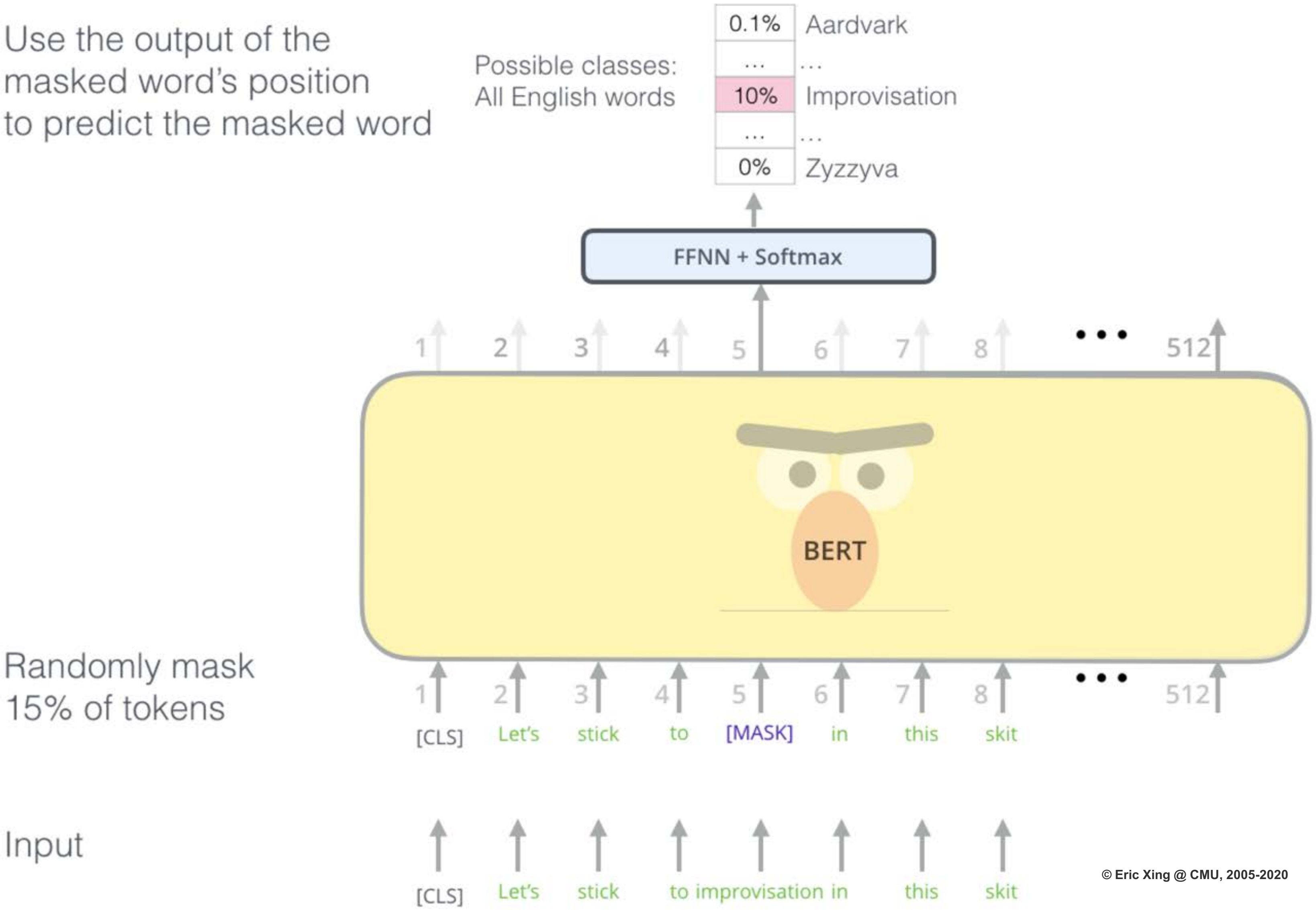
    - Masks some percent of words from the input and has to reconstruct those words from context

BERT: Pre-training Procedure

- Masked LM



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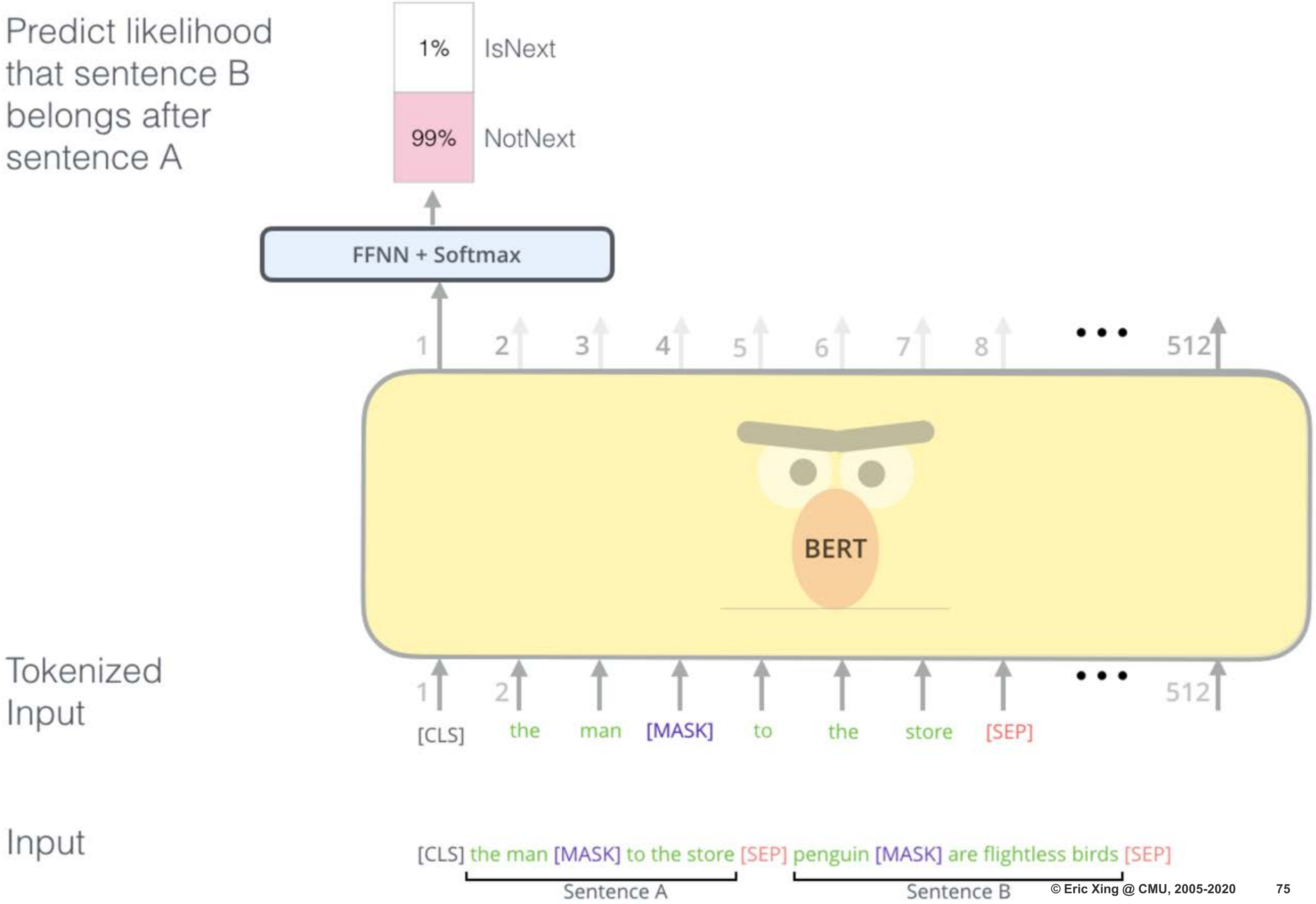
  - masked language model (masked LM)
    - Masks some percent of words from the input and has to reconstruct those words from context
  - Two-sentence task
    - To understand relationships between sentences
    - Concatenate two sentences A and B and predict whether B actually comes after A in the original text

BERT: Pre-training Procedure

- Two sentence task



BERT: Pre-training Procedure

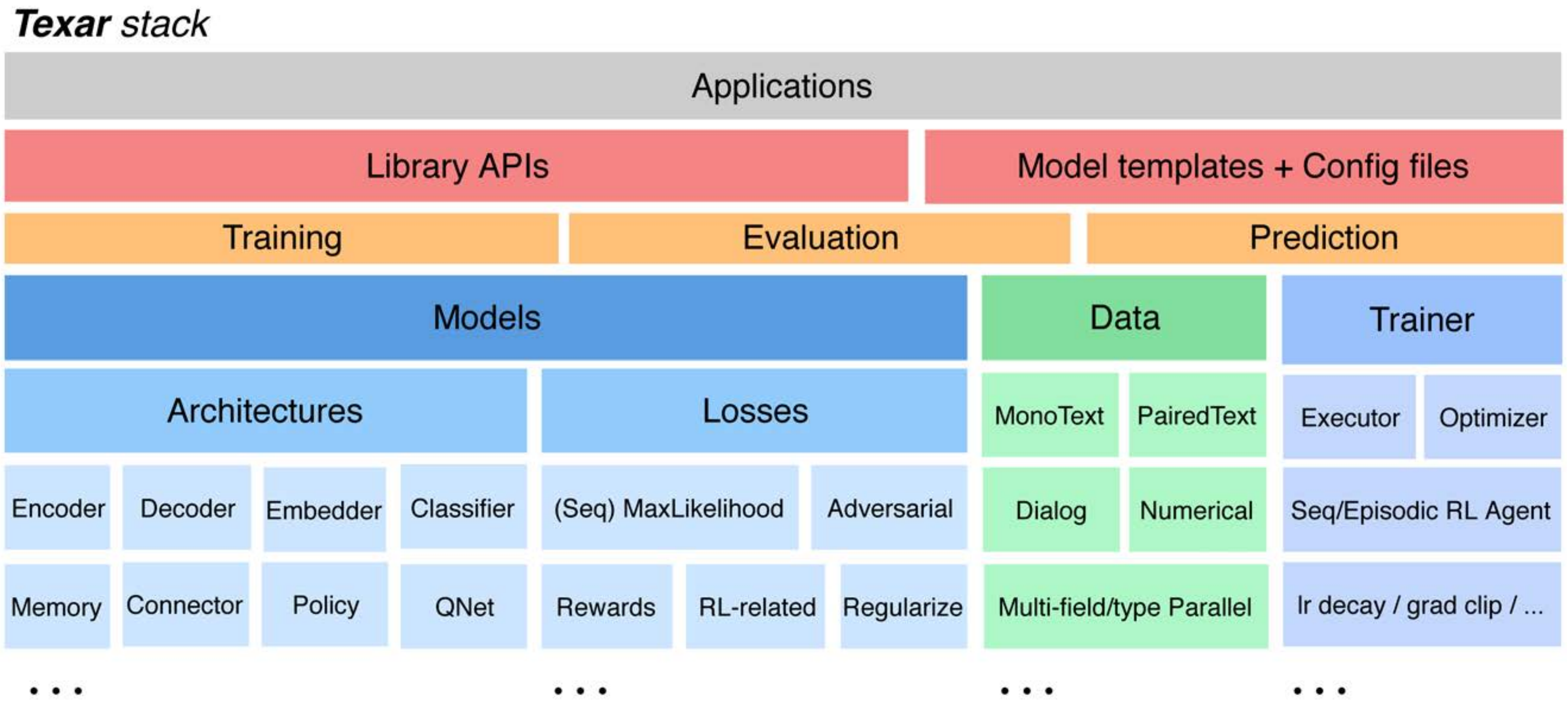
- BERT is trained on 4 TPU pods (=256 TPU chips) in 4 days
  - TPU: a matrix multiplication engine
- = 64 V100 GPUs, Infiniband network, 5.3 days
- = a standard 4 GPU desktop with RTX 2080Ti, 99 days

source: Tim Dettmers

Word Embedding on Texar

Texar

- A general-purpose text generation toolkit on TensorFlow



Word Embedding on Texar

- Word2vec, Glove

```
config.data = {
    "embedding_init": {
        "file": "word2vec.pretrain.dat"
        "read_fn": "load_word2vec" # "load_glove"
    }
}
```

```
import texar as tx

# Load data and pre-trained word embedding matrix
data = tx.data.MonoTextData(hparams=config.data)
iterator = tx.data.DataIterator(data)
data_batch = iterator.get_next()

# Create and initialize word embedder
embedder = texar.modules.WordEmbedder(
    init_value=data.embedding_init_value, hparams=config.emb)

# Embed text into vectors
data_embed = embedder(data_batch)

# Downstream tasks
classifier = tx.modules.Conv1DClassifier(hparams=config.clas)
logits, pred = classifier(input=data_embed)
```

Texar

Word Embedding on Texar

- Word2vec, Glove

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embedder = texar.modules.WordEmbedder(
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data_embed = embedder(data_batch)

# Downstream tasks
classifier = tx.modules.Conv1DClassifier(hparams=config.clas)
logits, pred = classifier(input=data_embed)
```

- BERT

```
# Create BERT embedder
embedder = tx.modules.TransformerEncoder(hparams=bert_config)
# Initialize BERT embedder
texar.init_bert_checkpoint("./bert.ckpt")

# Embed text into vectors
data_embed = embedder(data_batch)
```

Texar

Seq2seq Attention on Texar

```
# Read data
dataset = PairedTextData(data_hparams)
batch = DataIterator(dataset).get_next()

# Encode
embedder = WordEmbedder(dataset.vocab.size, hparams=embedder_hparams)
encoder = TransformerEncoder(hparams=encoder_hparams)
enc_outputs = encoder(embedder(batch['source_text_ids']),
                      batch['source_length'])

# Decode
decoder = AttentionRNNDecoder(memory=enc_outputs,
                              hparams=decoder_hparams)
outputs, length, _ = decoder(inputs=embedder(batch['target_text_ids']),
                             seq_length=batch['target_length']-1)

# Loss
loss = sequence_sparse_softmax_cross_entropy(
    labels=batch['target_text_ids'][:,1:], logits=outputs.logits, seq_length=length)
```

Seq2seq Attention on Texar

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dataset = PairedTextData(data_hparams)
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# Loss
loss = sequence_sparse_softmax_cross_entropy(
    labels=batch['target_text_ids'][:,1:], logits=outputs.logits, seq_length=length)
```

```python
decoder_hparams = {
    'rnn_cell': {
        'type': 'LSTMCell'
    }
    'num_layers': 2,
    'attention': {
        'type': 'LuongAttention',
        'kwargs': {
            'num_units': 256,
        }
    }
}
```

Takeaways

- Convolutional Networks (ConvNets)
- Recurrent Networks (RNNs)
  - LSTM designed for long-range dependency, vanishing gradients
  - RNNs not only for sequence data, but also 2D sequences, Trees, graphs
- Attention Mechanisms
  - Three core elements: (Query, Key, Value)
  - Many variants based on alignment score functions
  - Attention on Text and Images
- Transformers: Multi-head Attention
  - Transformer: encoder-decoder
  - BERT: pre-trained text representation
  - GPT-2: pre-trained language model

Texar