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TRANSFORMERS AND ATTENTION

LLMs

PRESENTED BY

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THE ENCODER-DECODER FRAMEWORK

- LSTMs and RNNs were state-of-the-art in NLP
- Feedback loop allows information propagation across steps, ideal for sequential data like text.
- Outputs a vector (hidden state) at each step, retaining information from previous steps.

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THE ENCODER-DECODER FRAMEWORK

RNNs in Machine Translation

- **Encoder:** Encodes input sequence into a numerical representation (last hidden state).
- **Decoder**: Generates output sequence from the encoded representation.

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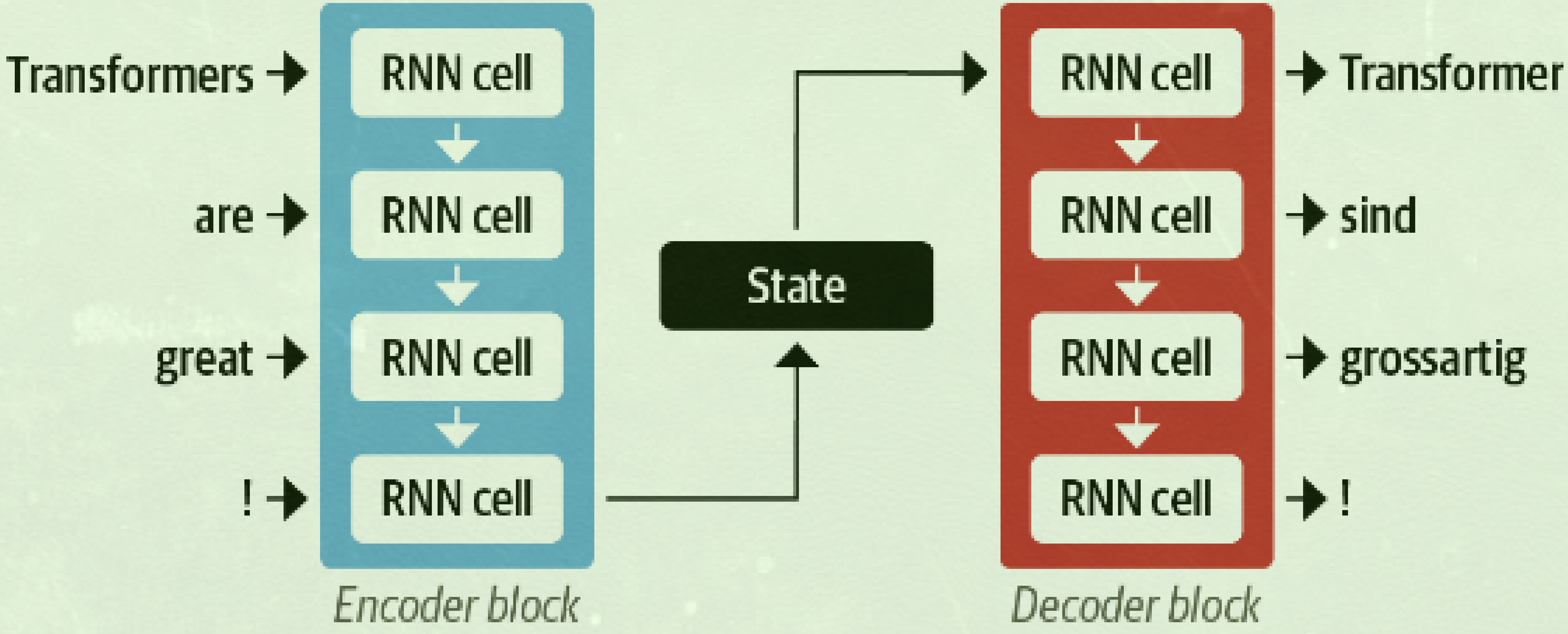
THE ENCODER-DECODER FRAMEWORK



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BUT !!!!

Information Bottleneck:

- Final hidden state must represent the entire input sequence.
- Difficult for long sequences; early information can get lost.

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ATTENTION MECHANISMS

Key Ideas

- Decoder assigns weights to each encoder state at every decoding timestep.

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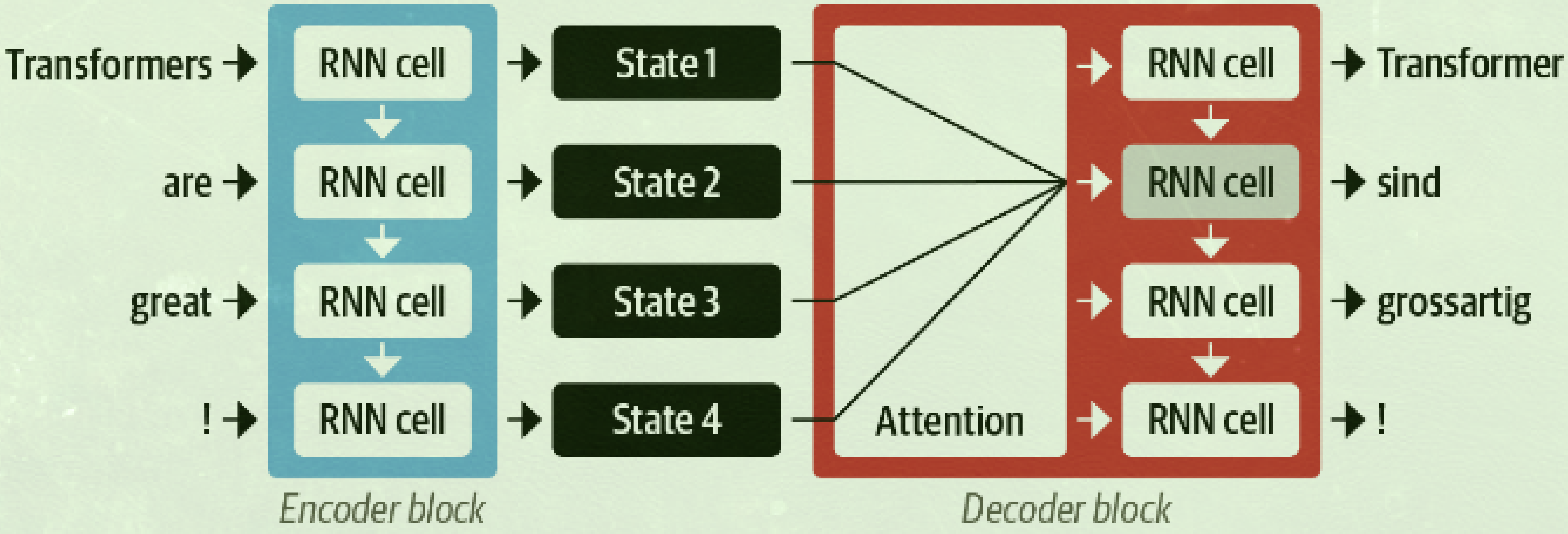
ATTENTION MECHANISMS



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ATTENTION MECHANISMS

Key Ideas

- Focuses on the most relevant input tokens for generating each output token.

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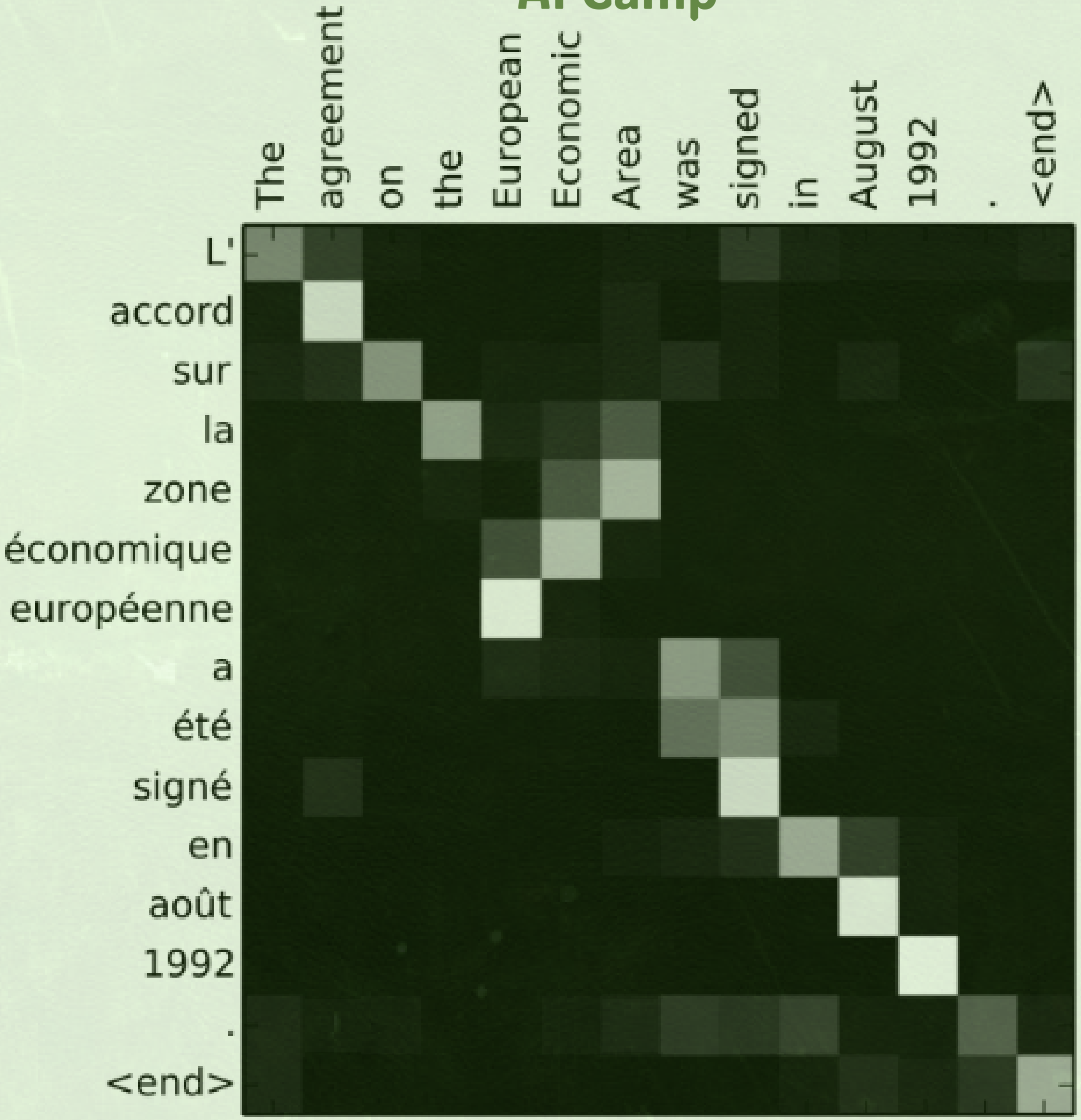

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TRANSFORMER ANATOMY

- The original Transformer is based on the encoder-decoder

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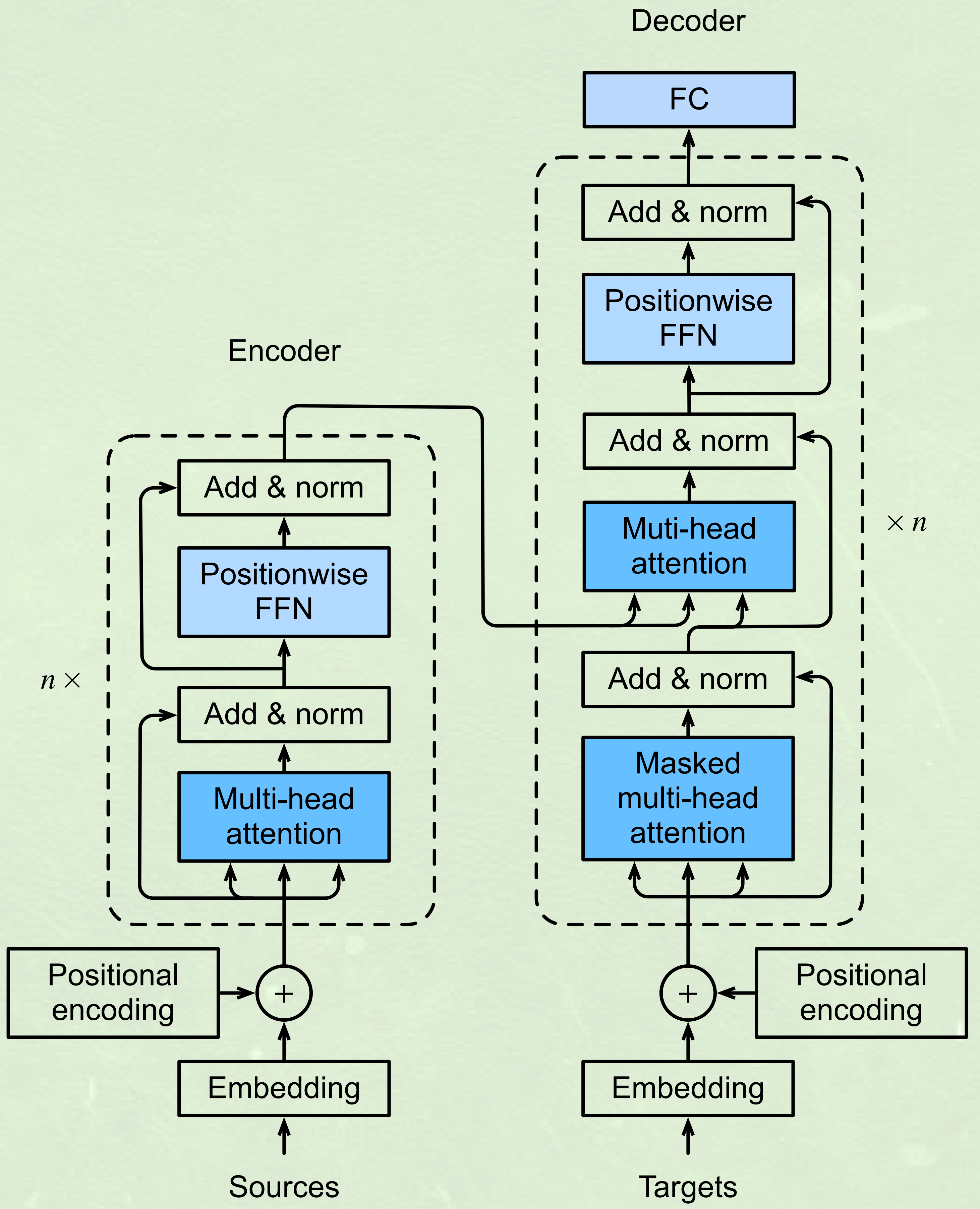

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TRANSFORMER ANATOMY

Transformer architecture types

01
ENCODER-ONLY MODELS

02
ENCODER-DECODER MODELS

03
DECODER-ONLY MODELS

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TRANSFORMER ANATOMY

Encoder

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What is input embedding ?

- An embedding aims to capture the semantic meaning of the token - similar tokens have similar embeddings.

INPUT TOKENS → **EMBEDDINGS**

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What is input embedding ?

Original sentence (tokens)	YOUR	CAT
Input IDs (position in the vocabulary)	105	6587
Embedding (vector of size 512)	952.207	171.411
	5450.840	3276.350
	1853.448	9192.819
	...	...
	1.658	3633.421
	2671.529	8390.473

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Positional embeding

- We want each word to carry some information about its position in the sentence
- We want out model to treat words that appear close to each others as “close”

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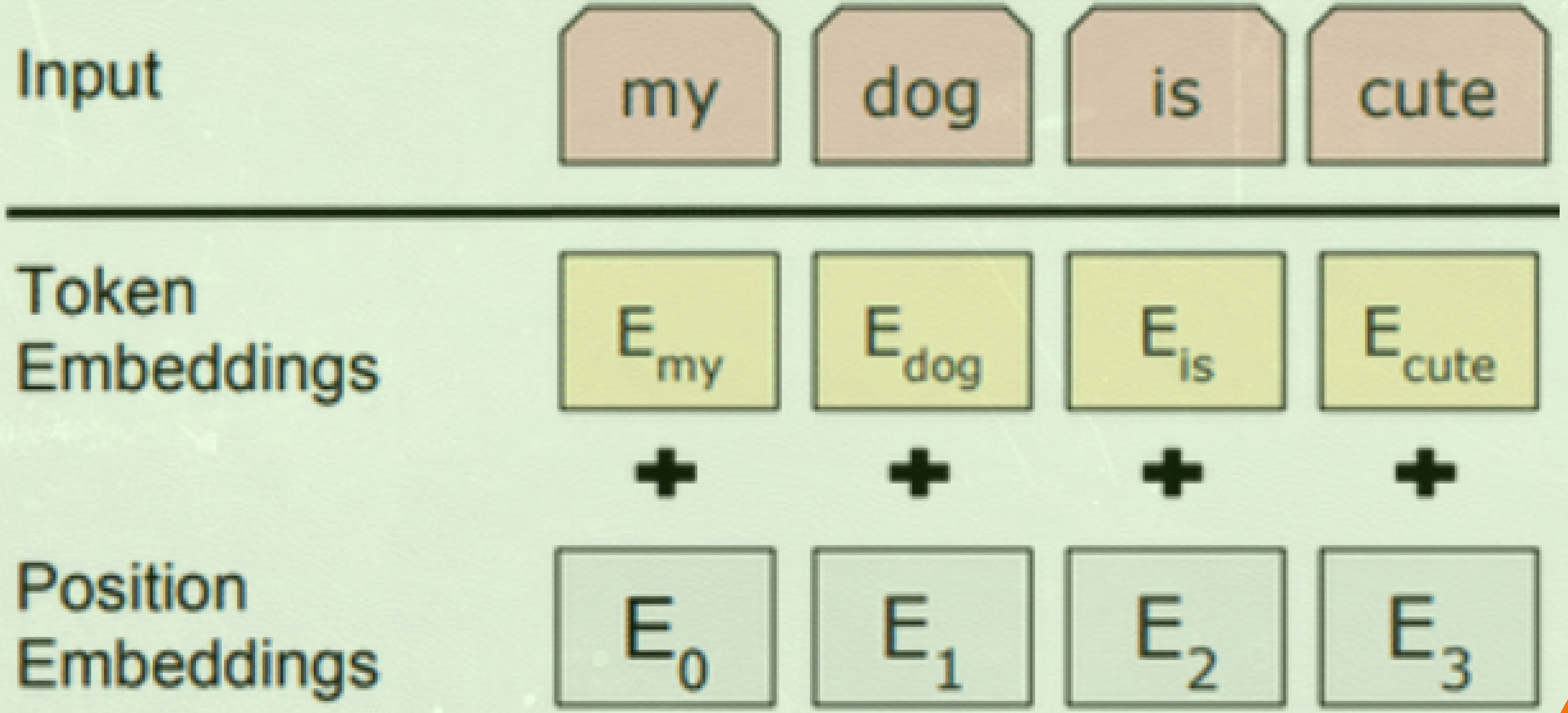

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How positional embeding work ?

Techniques

- Absolute positional representations
  - sinusoidal
  - learned position
- Relative positional representations

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How positional embeding work ?

- One of the techniques they used Cos/Sin :

$$PE_{(pos\ 2i)} = sin\left(\frac{pos}{10000^{\frac{2i}{d_{model}}}}\right)$$

$$PE_{(pos\ 2i+1)} = cos\left(\frac{pos}{10000^{\frac{2i}{d_{model}}}}\right)$$

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TRANSFORMER ANATOMY

How positional embeding work ?

- Why cos/sin ? :

chose this function because we hypothesized it would allow the model to easily learn to attend by relative positions, since for any fixed offset k, PE_{pos+k} can be represented as a linear function of PE_{pos}.

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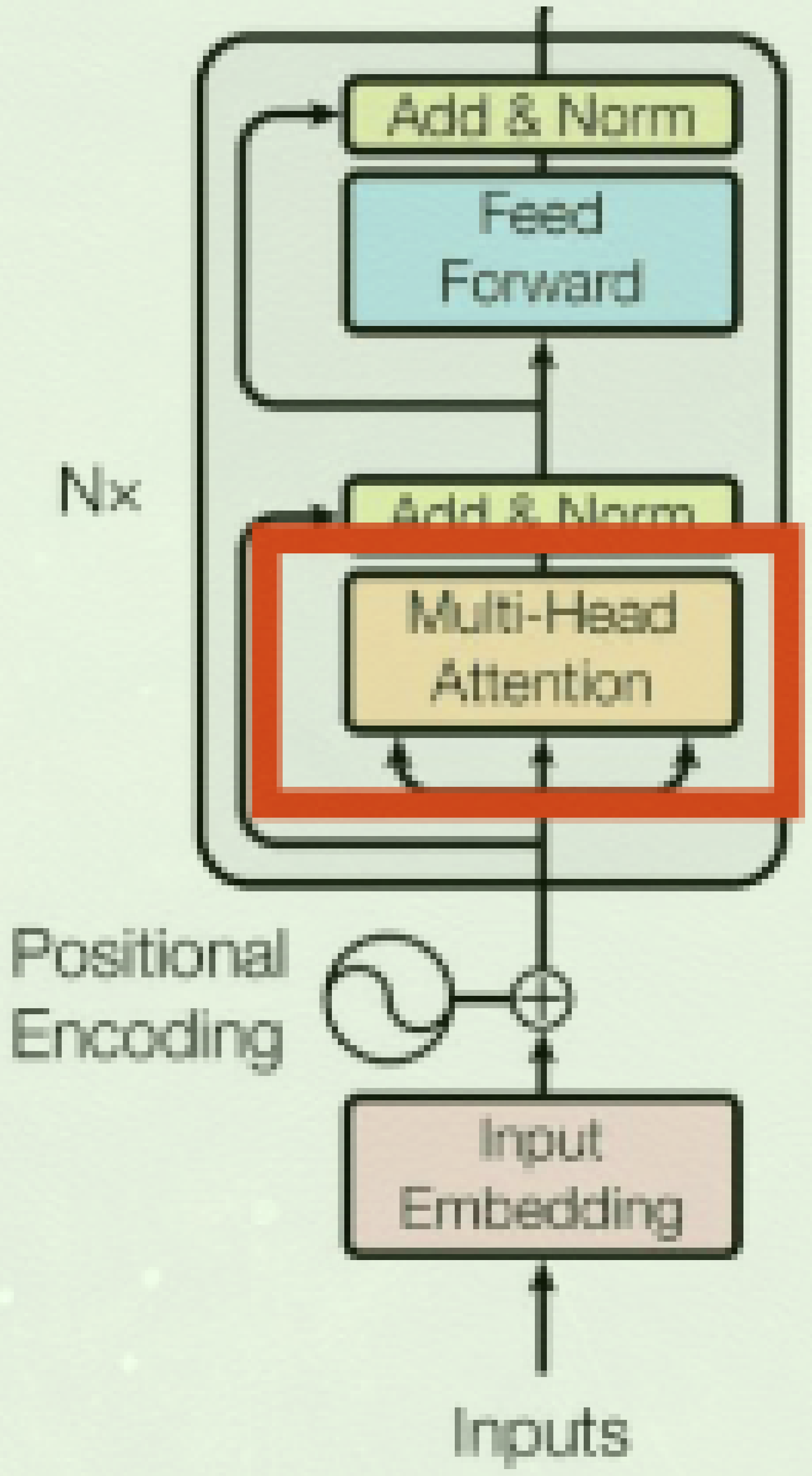

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What is Self-Attention?

- Self-Attention allows the model to relate words to each other
- Instead of using a fixed embedding for each token, the whole sequence is used to compute a weighted average for each token embedding.

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What is Self-Attention?

weighted average

$$x'_i = \sum_{j=1}^{n} w_{ji} x_j$$

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TRANSFORMER ANATOMY

	YOUR	CAT	IS	A	LOVELY	CAT	Σ
YOUR	0.268	0.119	0.134	0.148	0.179	0.152	1
CAT	0.124	0.278	0.201	0.128	0.154	0.115	1
IS	0.147	0.132	0.262	0.097	0.218	0.145	1
A	0.210	0.128	0.206	0.212	0.119	0.125	1
LOVELY	0.146	0.158	0.152	0.143	0.227	0.174	1
CAT	0.195	0.114	0.203	0.103	0.157	0.229	1

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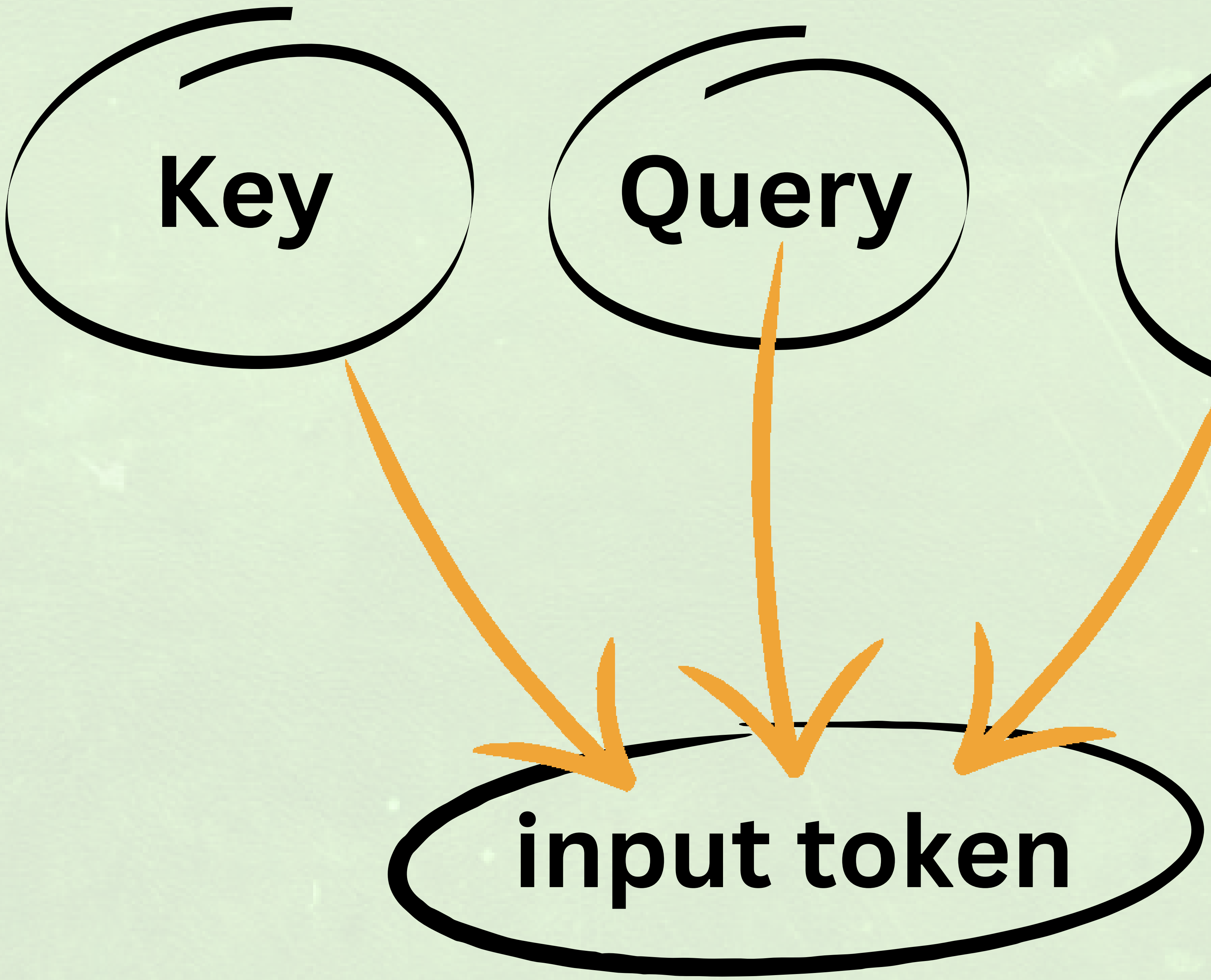
- Step 1: Project Token Embeddings:



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- **Step 2: Compute Attention Scores:**
  - The similarity between the **query** and **key** vectors is computed using **the dot product**

Note :

Queries and keys that are more similar have a larger dot product

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$$\text{softmax}\left(\frac{\underset{(6,\ 512)}{Q} \times \underset{(512,\ 6)}{K^T}}{\sqrt{512}}\right)$$

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- step3 : update Token Embeddings

$$x'_i = \sum_{j=1}^{n} w_{ji} x_j \longrightarrow \text{Attention}(Q,K,V) = \text{softmax}\left(\frac{QK^T}{\sqrt{d_k}}\right)V$$

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	YOUR	CAT	IS	A	LOVELY	CAT
YOUR	0.268	0.119	0.134	0.148	0.179	0.152
CAT	0.124	0.278	0.201	0.128	0.154	0.115
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LOVELY	0.146	0.158	0.152	0.143	0.227	0.174
CAT	0.195	0.114	0.203	0.103	0.157	0.229

(6, 6)

X

V

(6, 512)

=

Attention

(6, 512)

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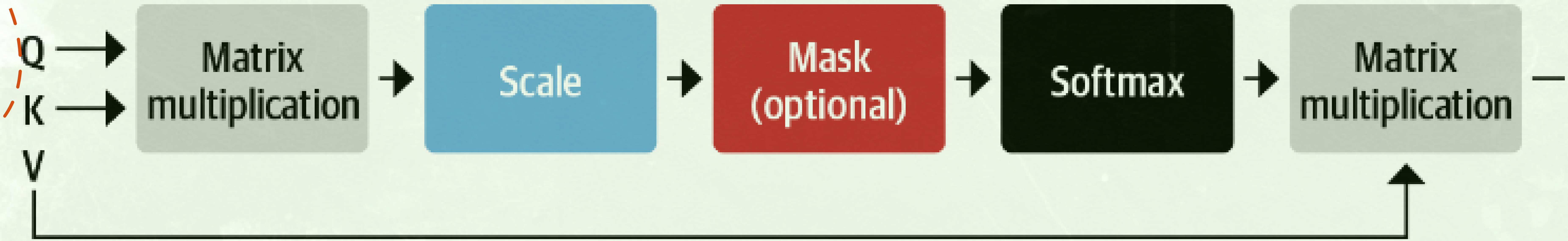
self-attention process



The final dimension of the encoder output is : n*d (original dimension)

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but why Multi-head Attention ?

- Instead of a single set of linear projections, multiple sets (called attention heads) are used.
- Multi-head attention allows the model to capture various semantic relations in parallel.

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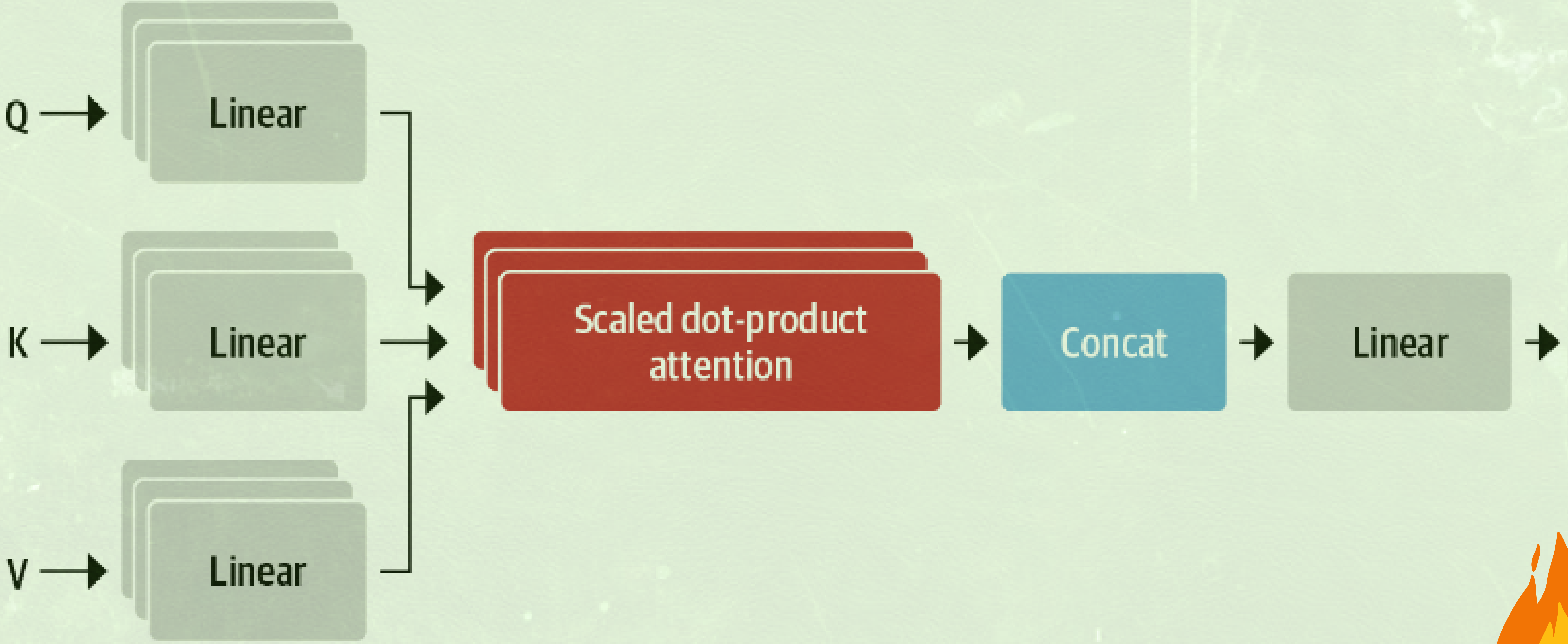

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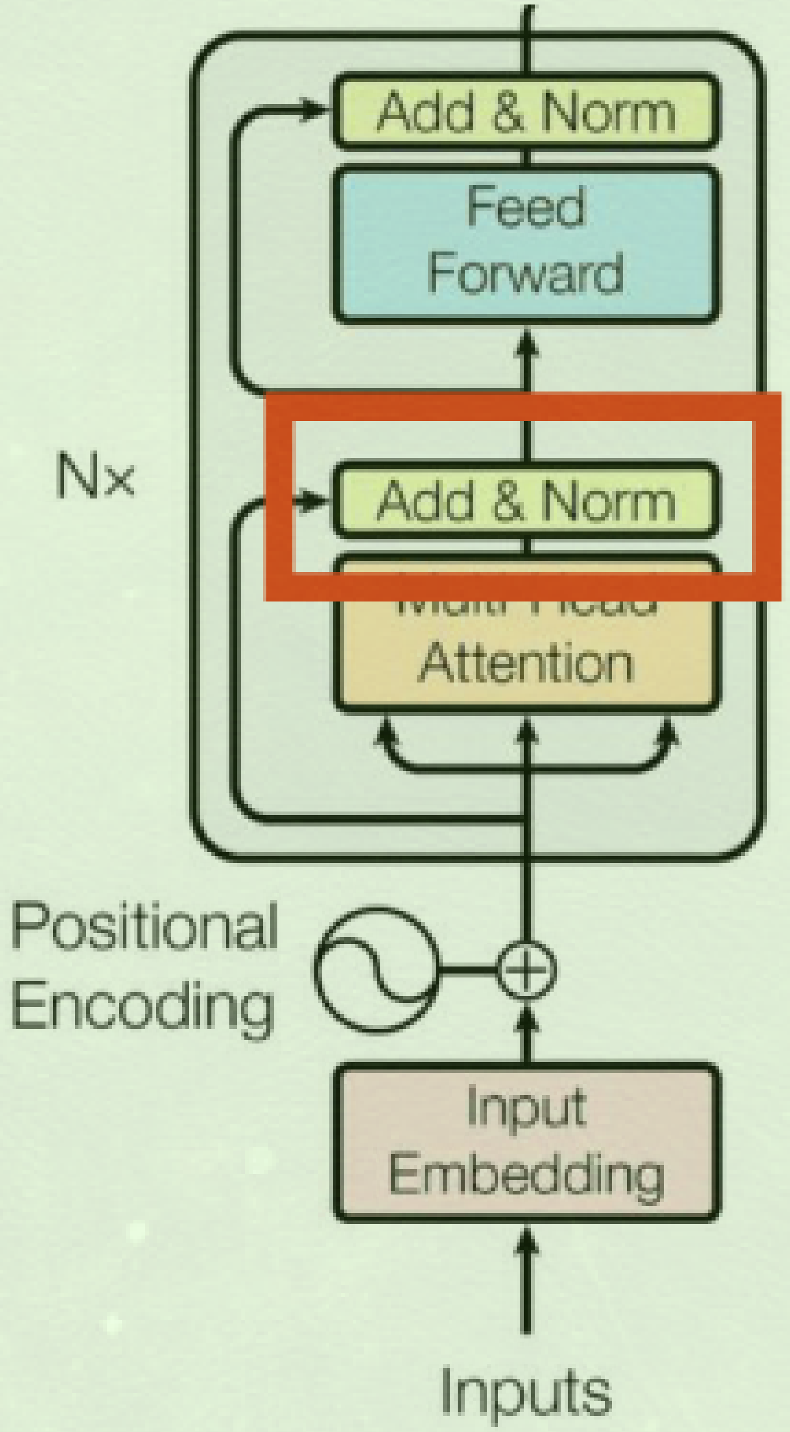

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What is layer normalization?

- Normalizes each input in the batch to have zero mean and unit variance.
- Improves training stability and convergence.

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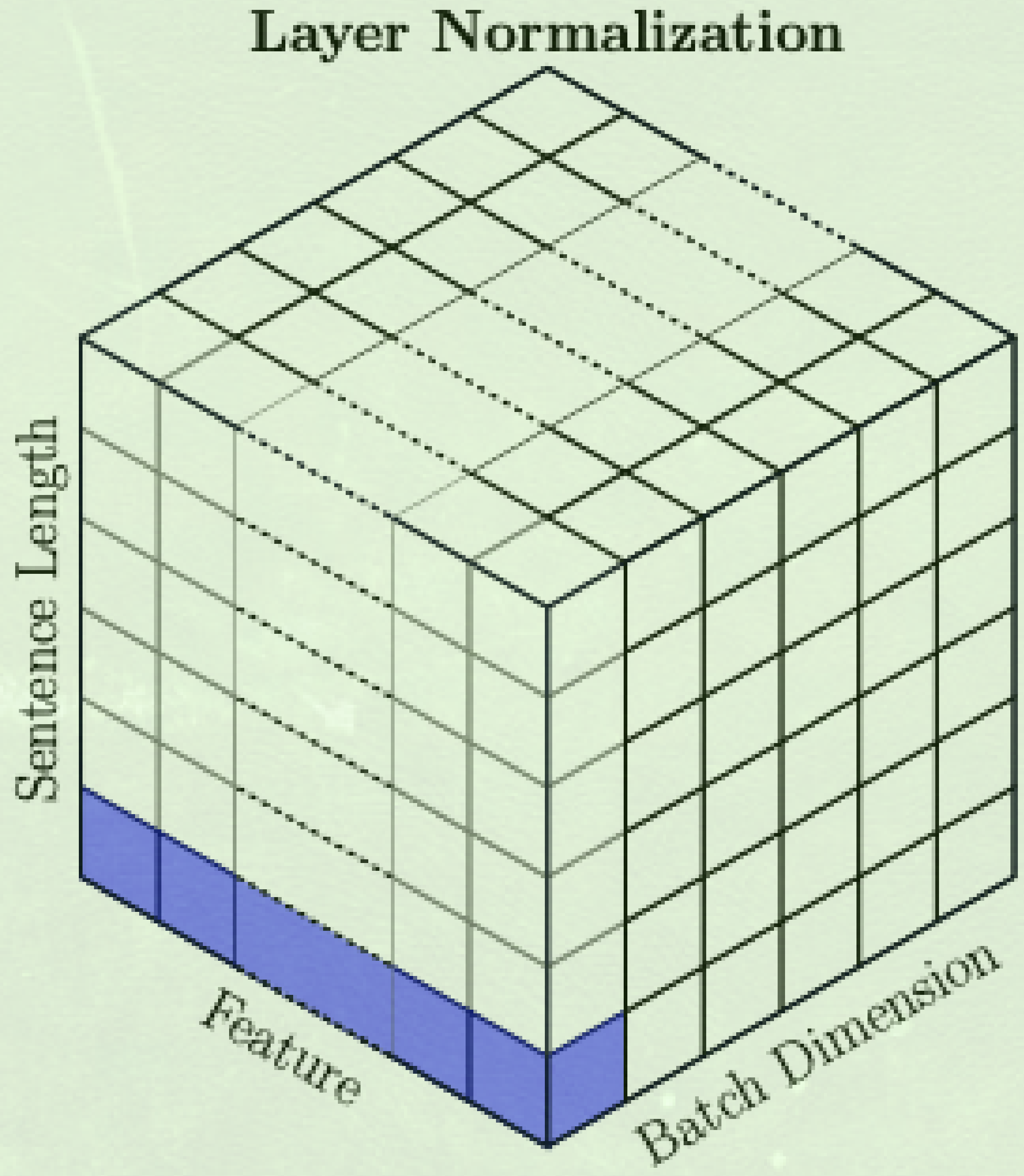

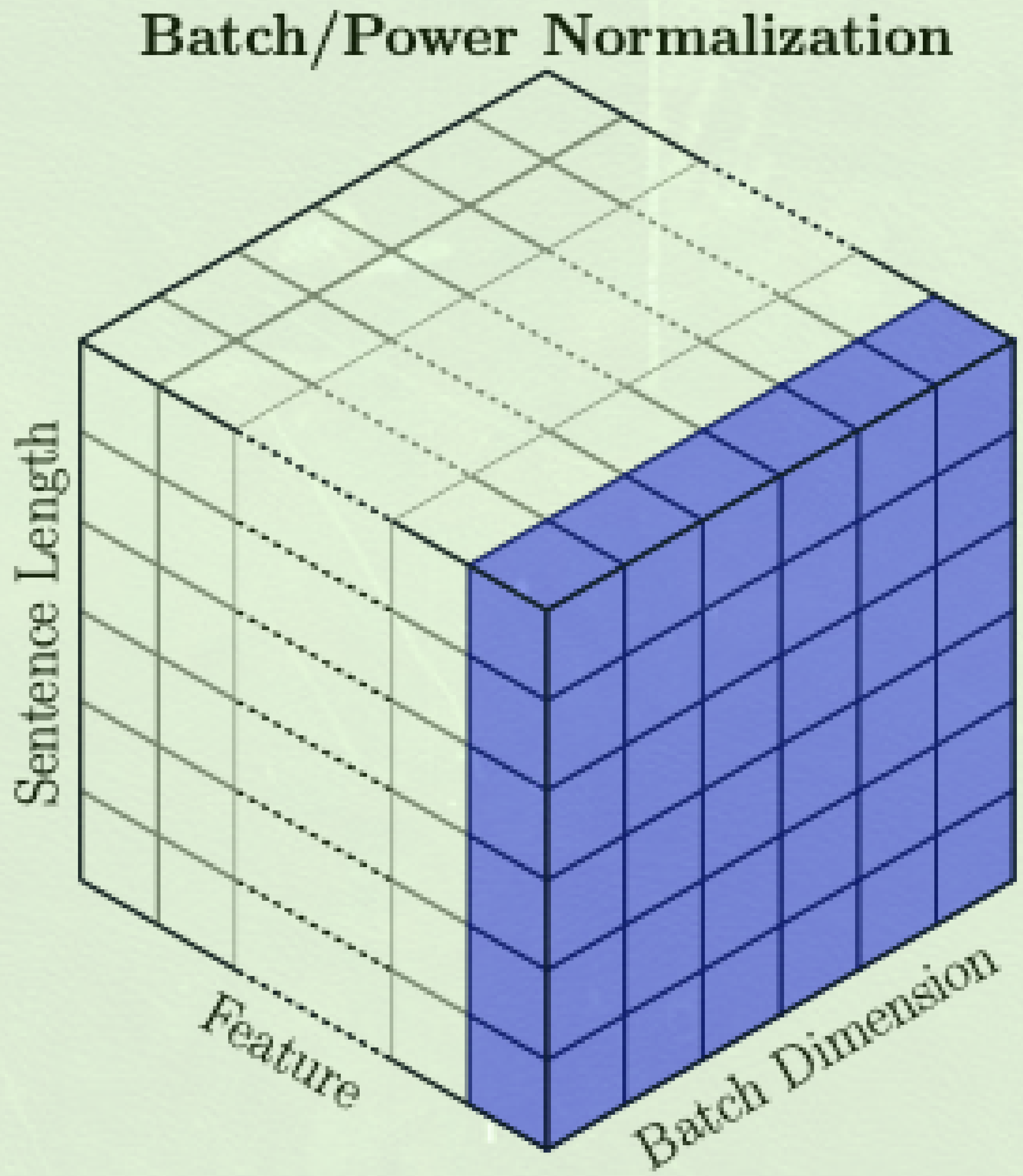

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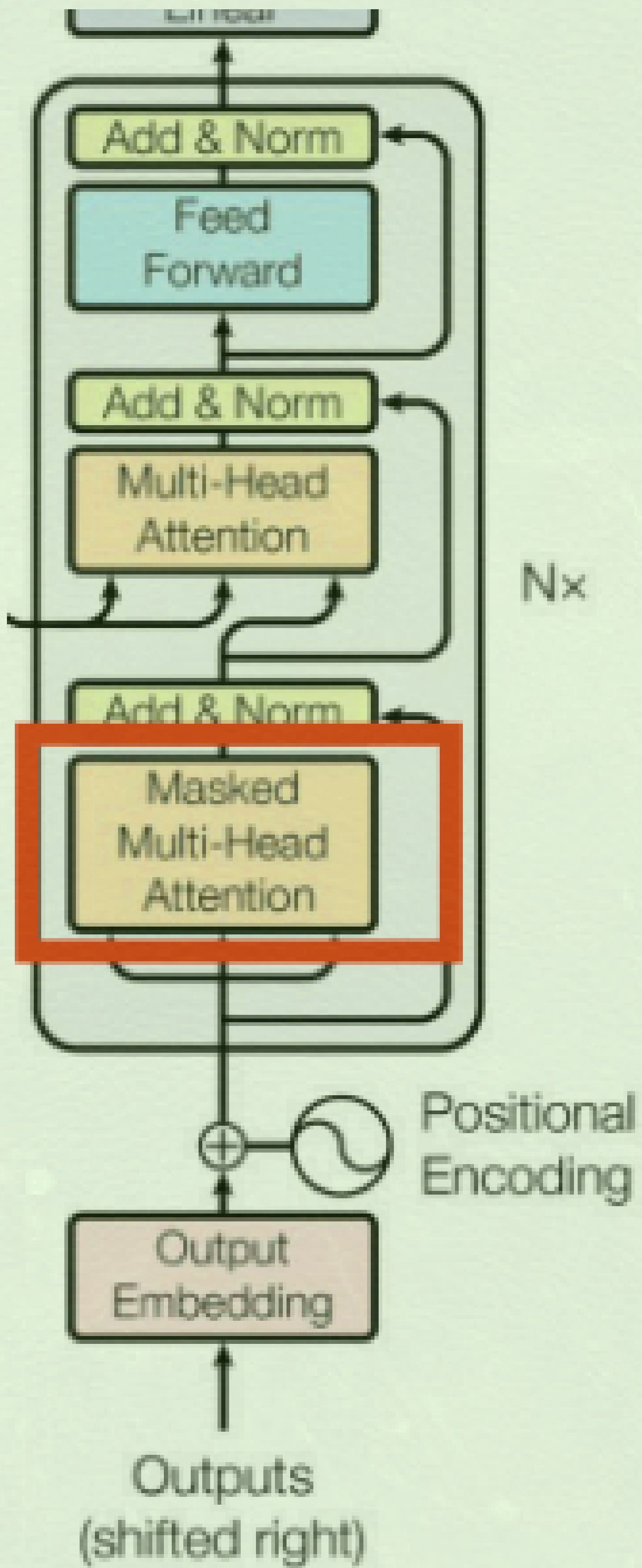

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What is Masked Multi-Head Attention?

- **Our goal is to make the model causal:**

it means the output at a certain position can only depend on the words on the previous positions. The model must not be able to see future words

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TRANSFORMER ANATOMY

Attention weight between the tokens corresponding to “Life” and “short”

	Life	is	short	eat	desert	first
Life	0.17	0.13	0.18	0.16	0.15	0.18
is	0.03	0.68	0.02	0.08	0.14	0.02
short	0.19	0.06	0.25	0.14	0.11	0.23
eat	0.15	0.21	0.14	0.16	0.17	0.14
desert	0.13	0.27	0.11	0.16	0.18	0.12
first	0.19	0.02	0.31	0.11	0.07	0.27

Attention weights calculated in the previous “Self-Attention” section

In the row for corresponding to “Life”, mask out all words that come after “Life”

	Life	is	short	eat	desert	first
Life	0.17	0.13	0.18	0.16	0.15	0.18
is	0.03	0.68	0.02	0.08	0.14	0.02
short	0.19	0.06	0.25	0.14	0.11	0.23
eat	0.15	0.21	0.14	0.16	0.17	0.14
desert	0.13	0.27	0.11	0.16	0.18	0.12
first	0.19	0.02	0.31	0.11	0.07	0.27

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Training a transformers ?

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Inference (Prediction) ?

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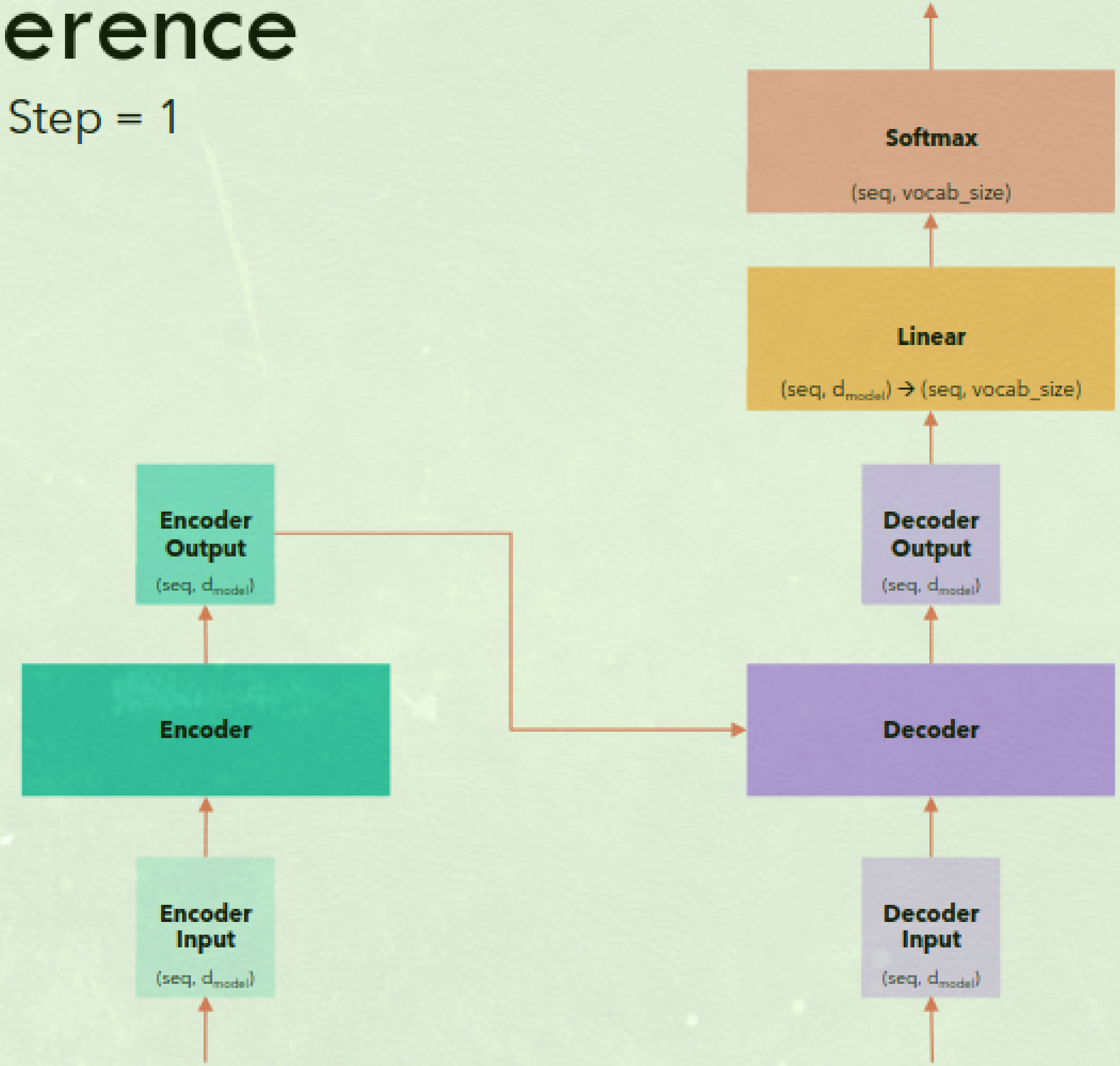
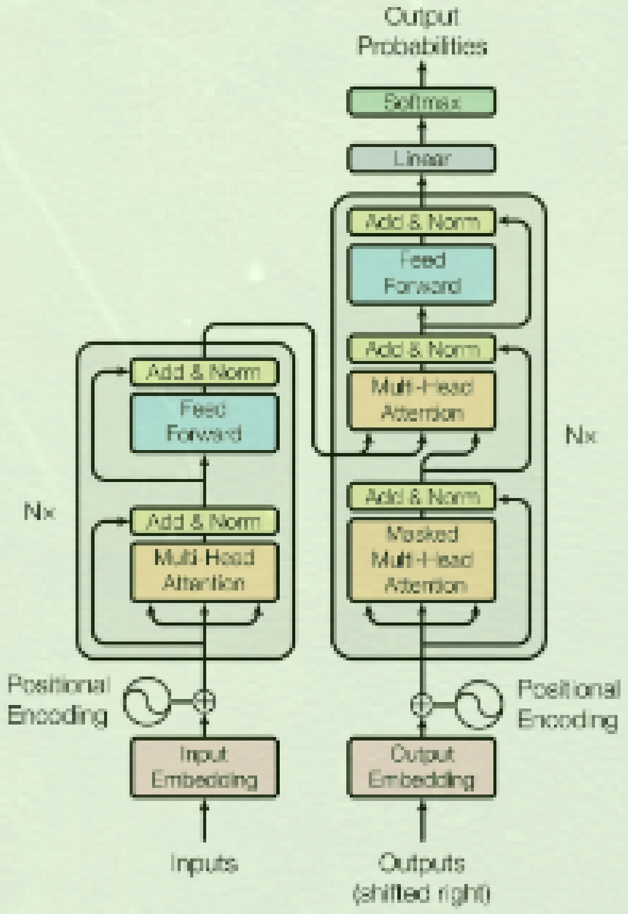
Inference

Time Step = 1



We select a token from the vocabulary corresponding to the position of the token with the maximum value.

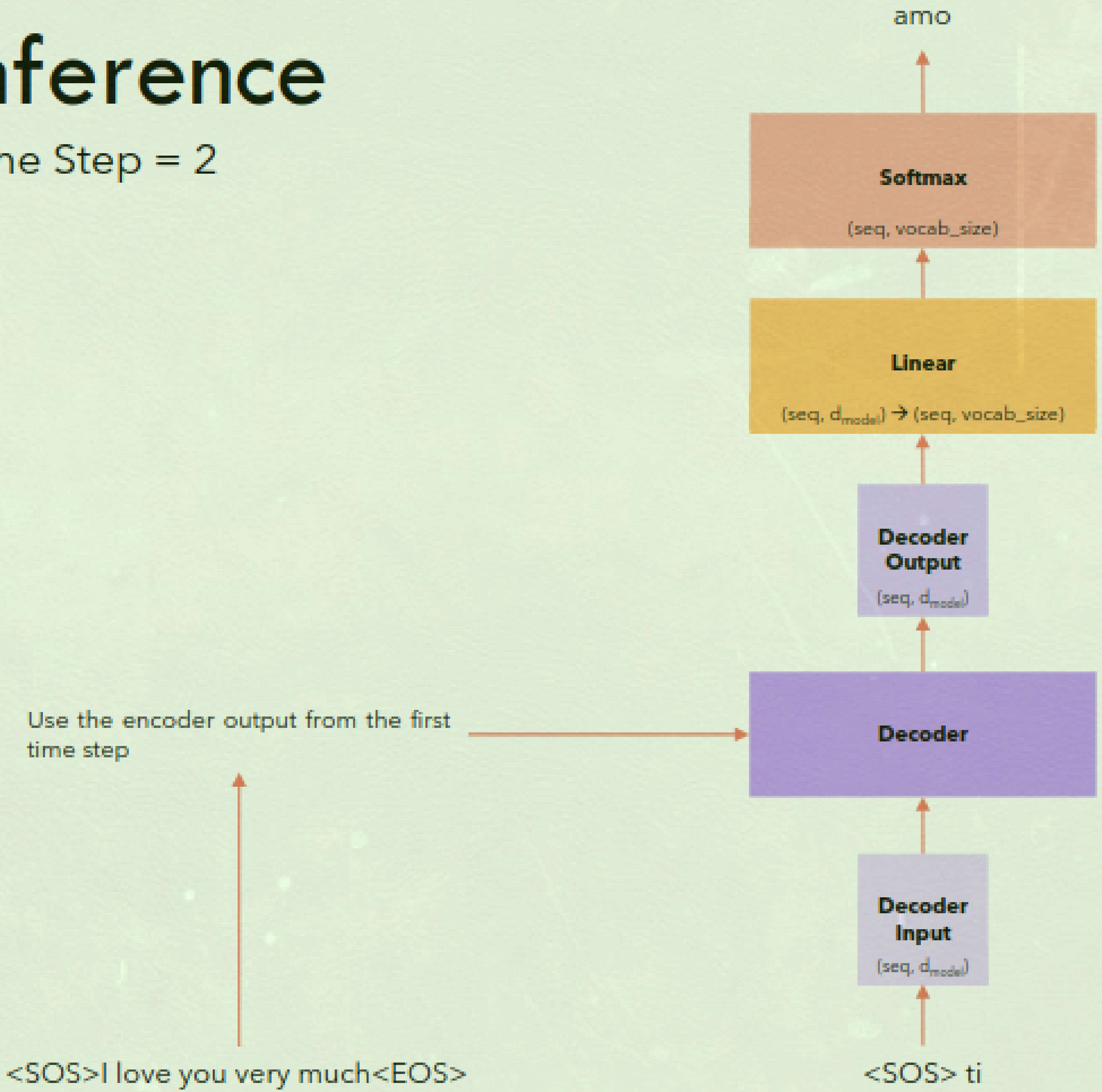
The output of the last layer is commonly known as **logits**



* Both sequences will have same length thanks to padding

Inference

Time Step = 2



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Inference strategy

- Beam-search
- greedy search

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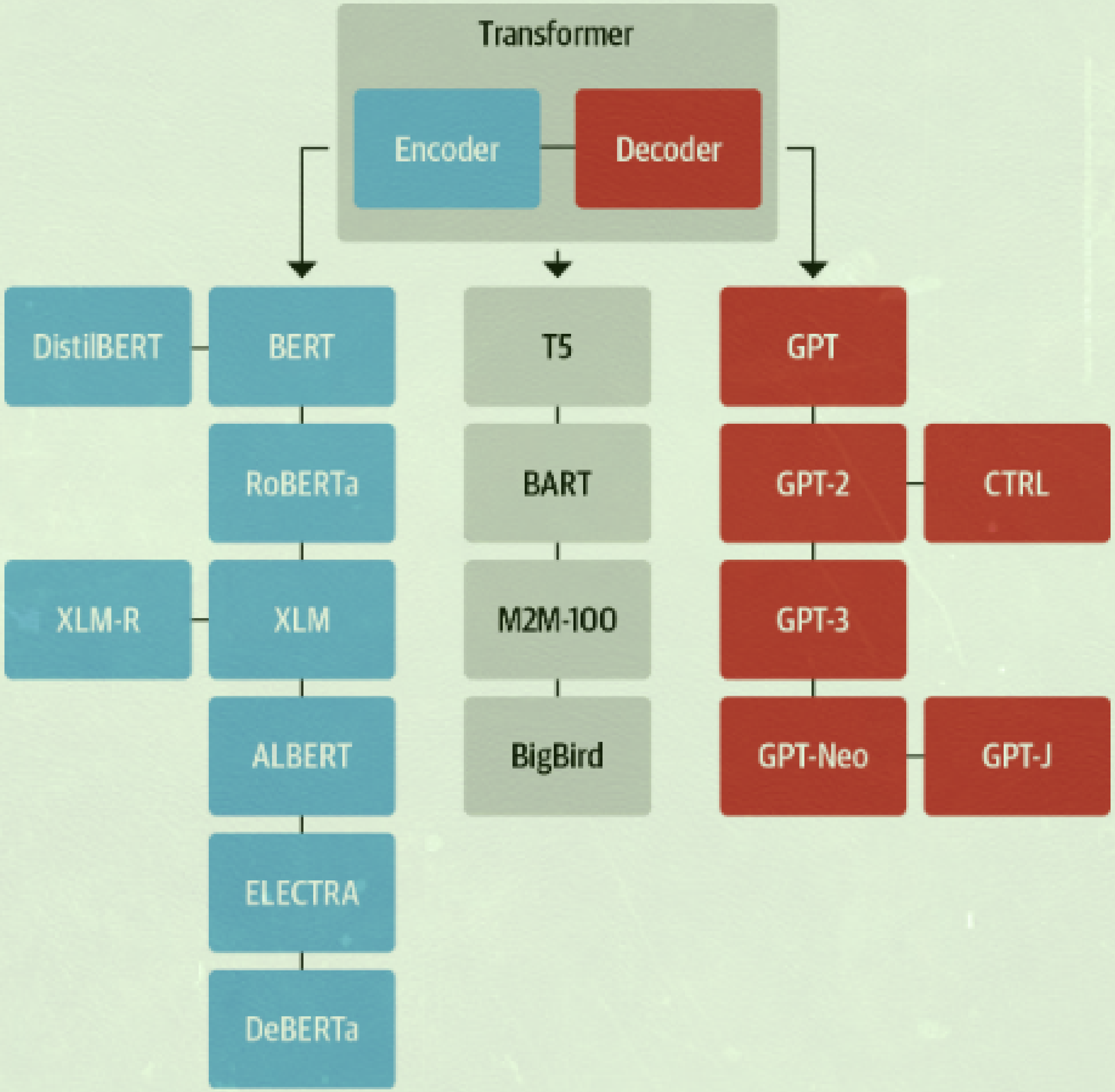

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Bidirectional Encoder Representations from Transformers

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Bert Information

- BERT stands for **Bidirectional Encoder Representations from Transformers**
- Unlike common language models, BERT has been trained using the **left context and the right context**

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Bert Information

- BERT has not been trained on the Next Token Prediction task, but rather, on the **Masked Language Model and Next Sentence Prediction task**

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Pre-Trained BERT

Fine Tune on text classification

Fine Tune on question answering (QA)

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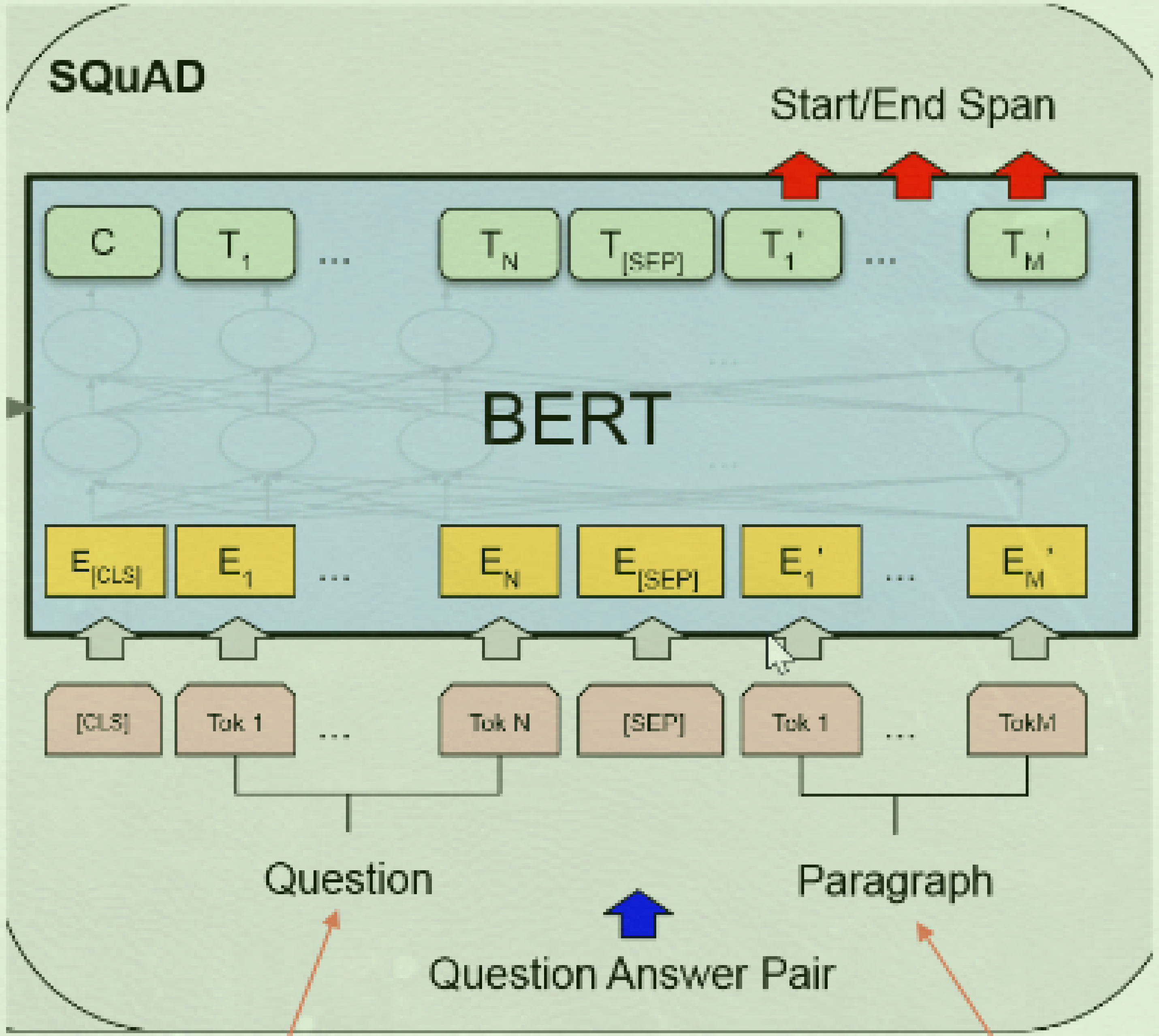

Sentence A

Sentence B

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THANK YOU!

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