NLP Recent History

Text Features

- Natural Language Processing = Machine Learning with Text

- Step 1 – Identify text-based features
- Step 2 – Label data for a task
- Step 3 – Train a classifier

Text Features – Old School

- Lexical Features
  - Part-of-speech tags (Verb/Noun/Adj)
  - Stems / Lemmas
  - Word Frequency
  - Psycholinguistic Features
  - Terminologies
  - Morphology (affixes)

Text Features – Old School

- Sentential Features
  - Sentence Structure
  - Parse Tree Features
  - Sentence Dependencies
  - POS ratios
  - Punctuation frequency
  - Averages of lexical features

Text Features – Old School

- Document Features
  - Bag-of-words
  - TF-IDF Vectors

Text Features – Word Embeddings

- Represent each word as a vector of numbers

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The cat sat on the mat

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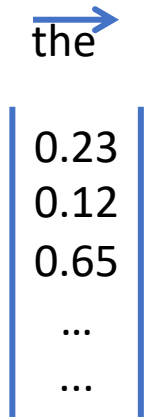

The cat sat on the mat

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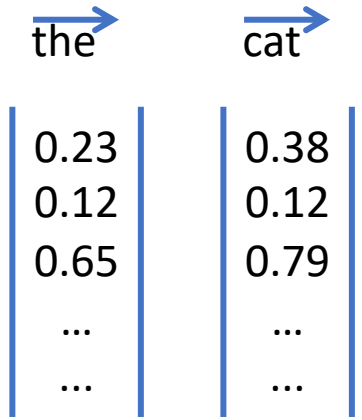

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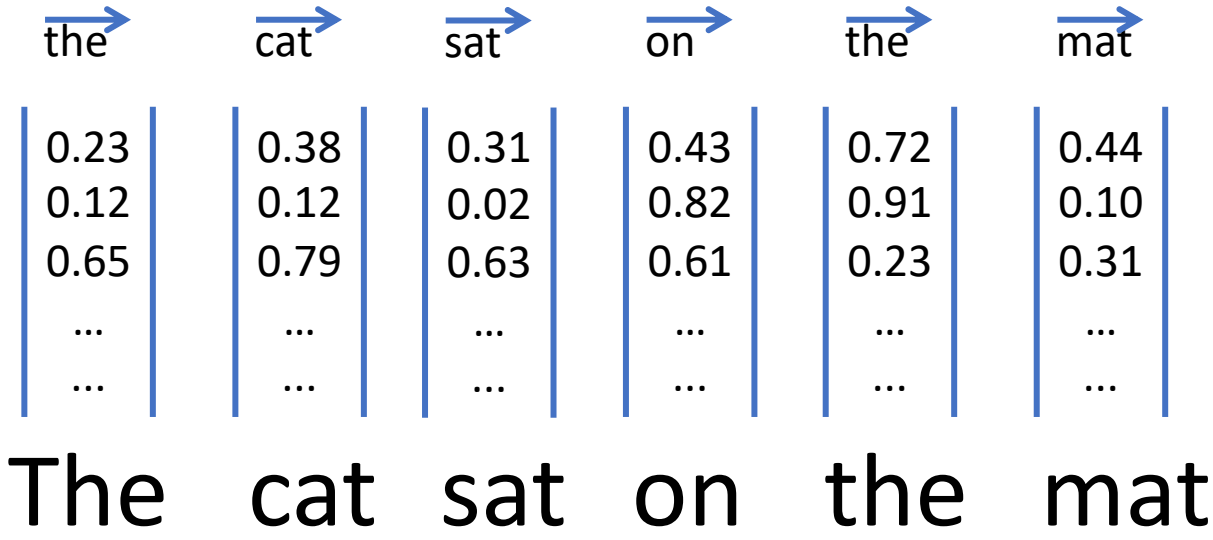

Text Features – Count-based Embeddings

- The cat sat on the mat
- Dogs and cats are animals
- Cats like milk
- The dog chased the stick
- Dogs like bones

	cat	sat	mat	dog	chase	stick	animal	bone	milk
cat									
sat									
mat									
dog									
chase									
stick									
animal									
bone									
milk									

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	cat	sat	mat	dog	chase	stick	animal	bone	milk
cat	3	1	1	1	0	0	1	0	1
sat	1	1	1	0	0	0	0	0	0
mat	1	1	1	0	0	0	0	0	0
dog	1	0	0	3	1	1	1	1	0
chase	0	0	0	1	1	1	0	0	0
stick	0	0	0	1	1	1	0	0	0
animal	1	0	0	1	0	0	1	0	0
bone	0	0	0	1	0	0	0	1	0
milk	1	0	0	1	0	0	0	0	1

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1	1	1	0	0	0	0	0	0
1	0	0	3	1	1	1	1	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
1	0	0	1	0	0	1	0	0
0	0	0	1	0	0	0	1	0
1	0	0	1	0	0	0	0	1

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1	1	1	0	0	0	0	0	0
1	0	0	3	1	1	1	1	0
0	0	0	1	1	1	0	0	0
0	0	0	1	1	1	0	0	0
1	0	0	1	0	0	1	0	0
0	0	0	1	0	0	0	1	0
1	0	0	1	0	0	0	0	1

- Issue
  - Dimensionality = vocab size
- Reduce with PCA..

Text Features – Count-based Embeddings

- Which animal likes milk?

animal
1
0
0
1
0
0
1
0
0

+

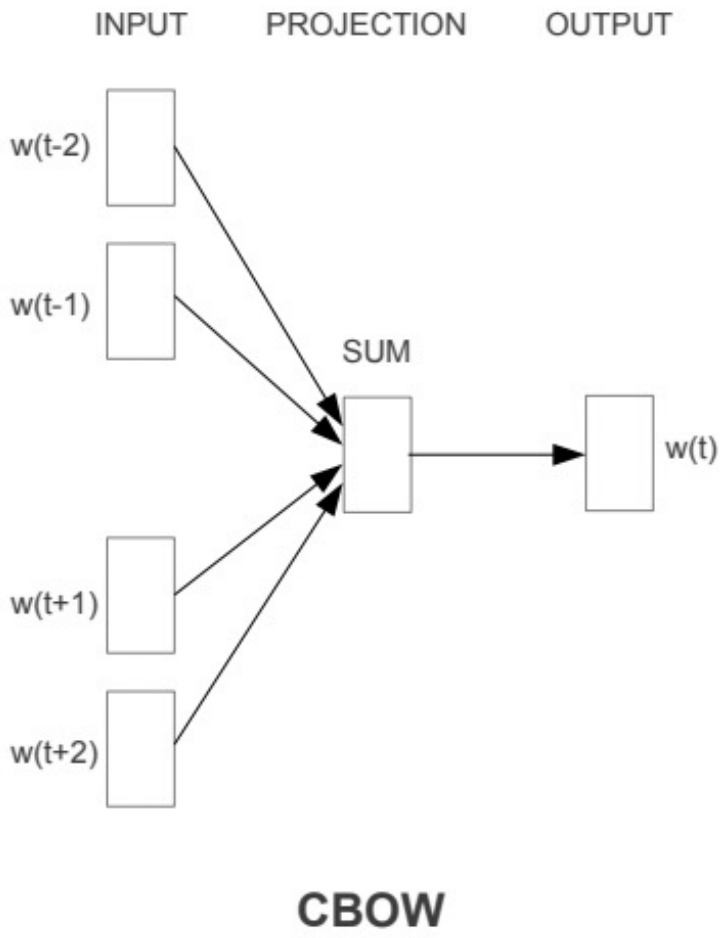
milk
1
0
0
0
0
0
0
0
1

~

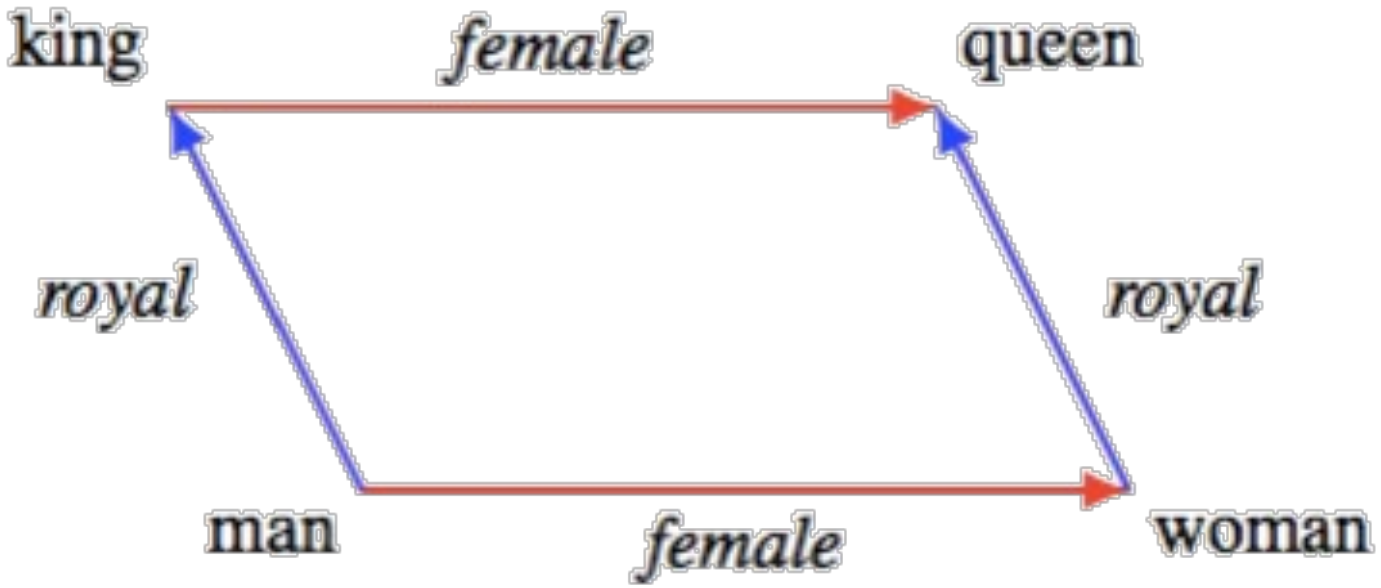
cat
3
1
1
1
0
0
1
0
1

Text Features – Learnt Embeddings (Word2Vec)

- Learn a set of word vectors that can be used to predict surrounding words
- Initialise random vectors and train neural network, updating vector weights with network
- End result is a set of vectors that perform like count-based, but without counting

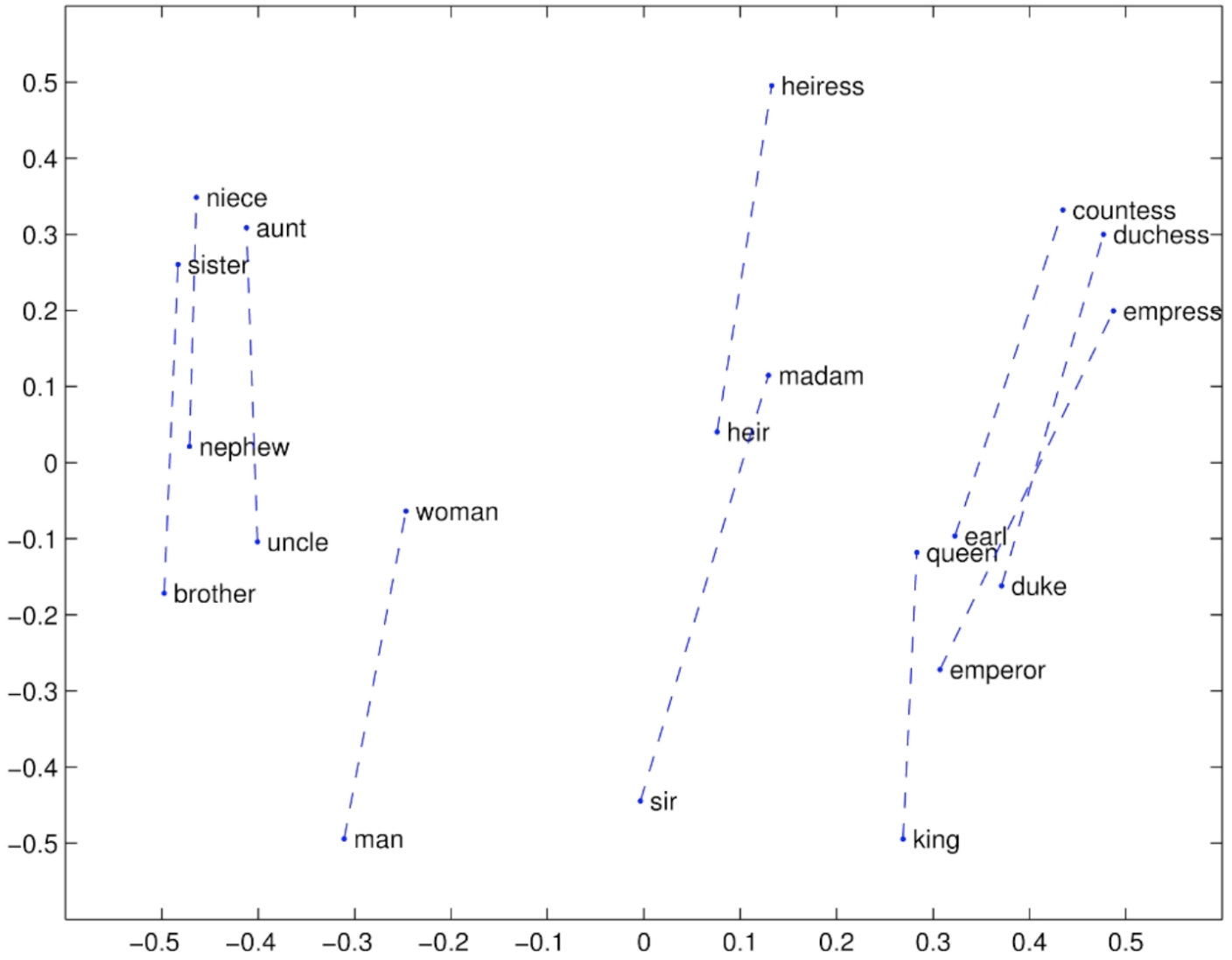


Text Features – Learnt Embeddings (Word2Vec)

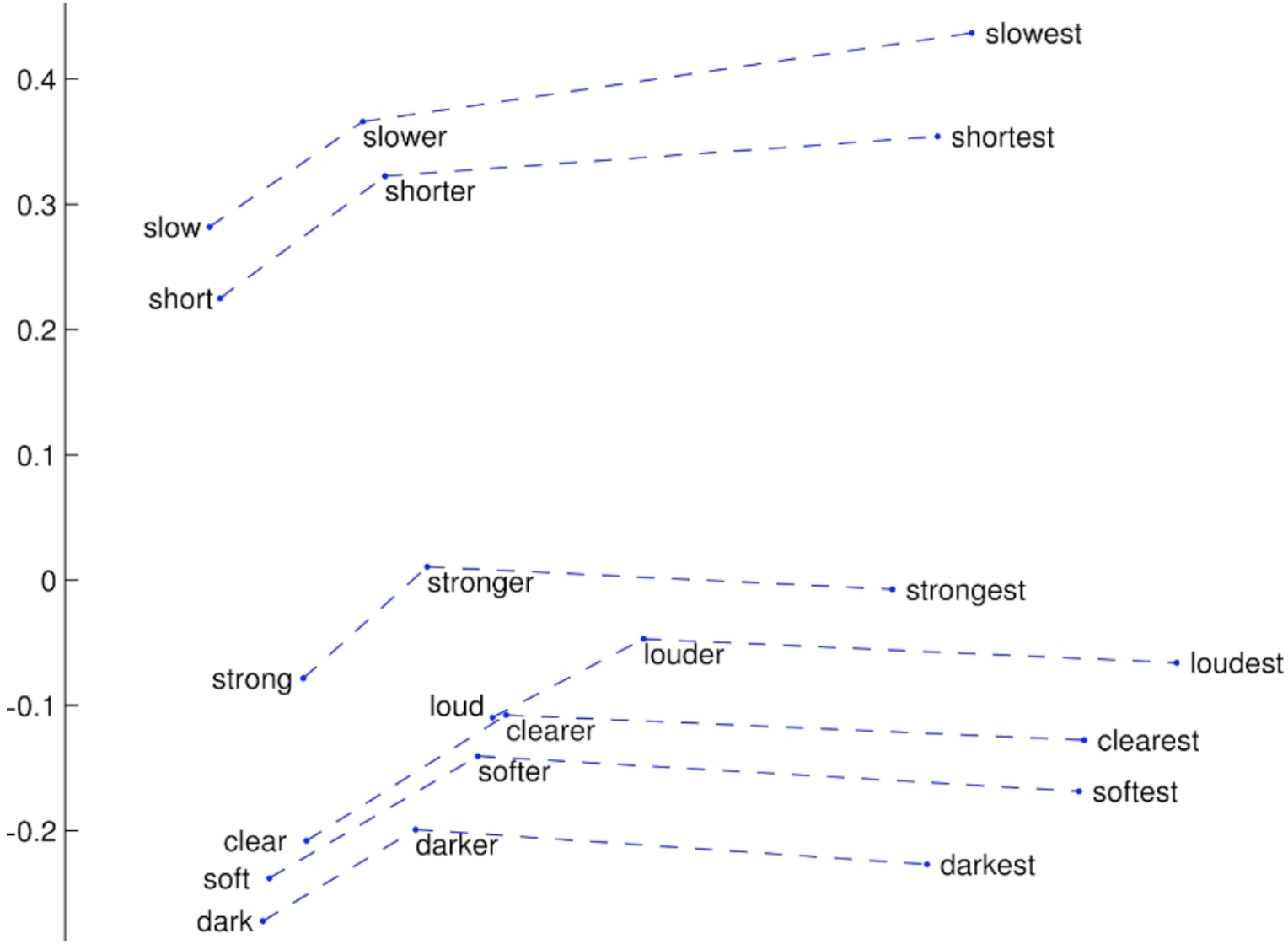


$$\overrightarrow{king} - \overrightarrow{man} + \overrightarrow{woman} \approx \overrightarrow{queen}$$

Text Features – Learnt Embeddings (Word2Vec)



Text Features – Learnt Embeddings (Word2Vec)



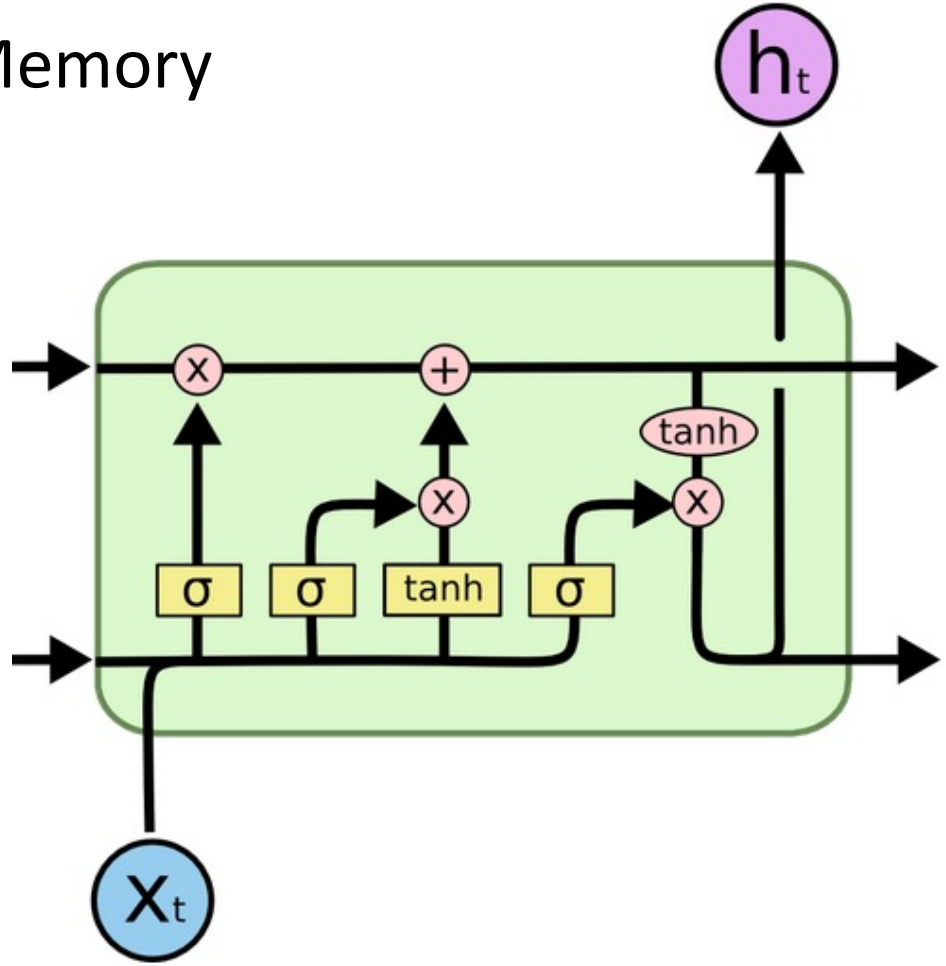
Example Tasks

- Classification
  - Sentiment Analysis
  - Readability
  - Categorisation
- Text Generation
  - Machine Translation
  - Summarisation
  - Data-to-text
- Natural Language Understanding
  - Inference / Reasoning
  - Chatbots / Intelligent Tutoring

http://nlpprogress.com/

Sequence classification

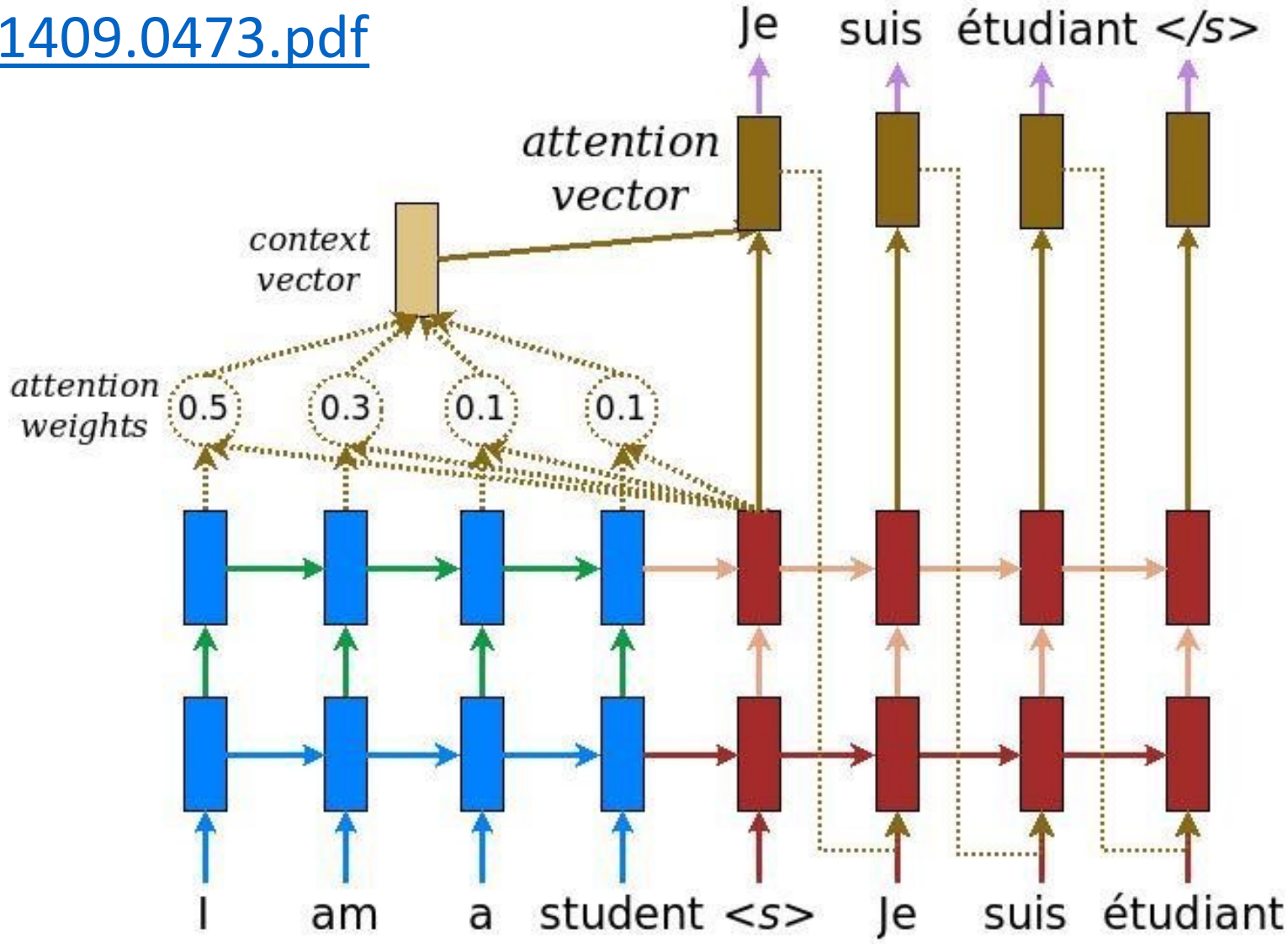
- Long Short Term Memory



Sequence classification

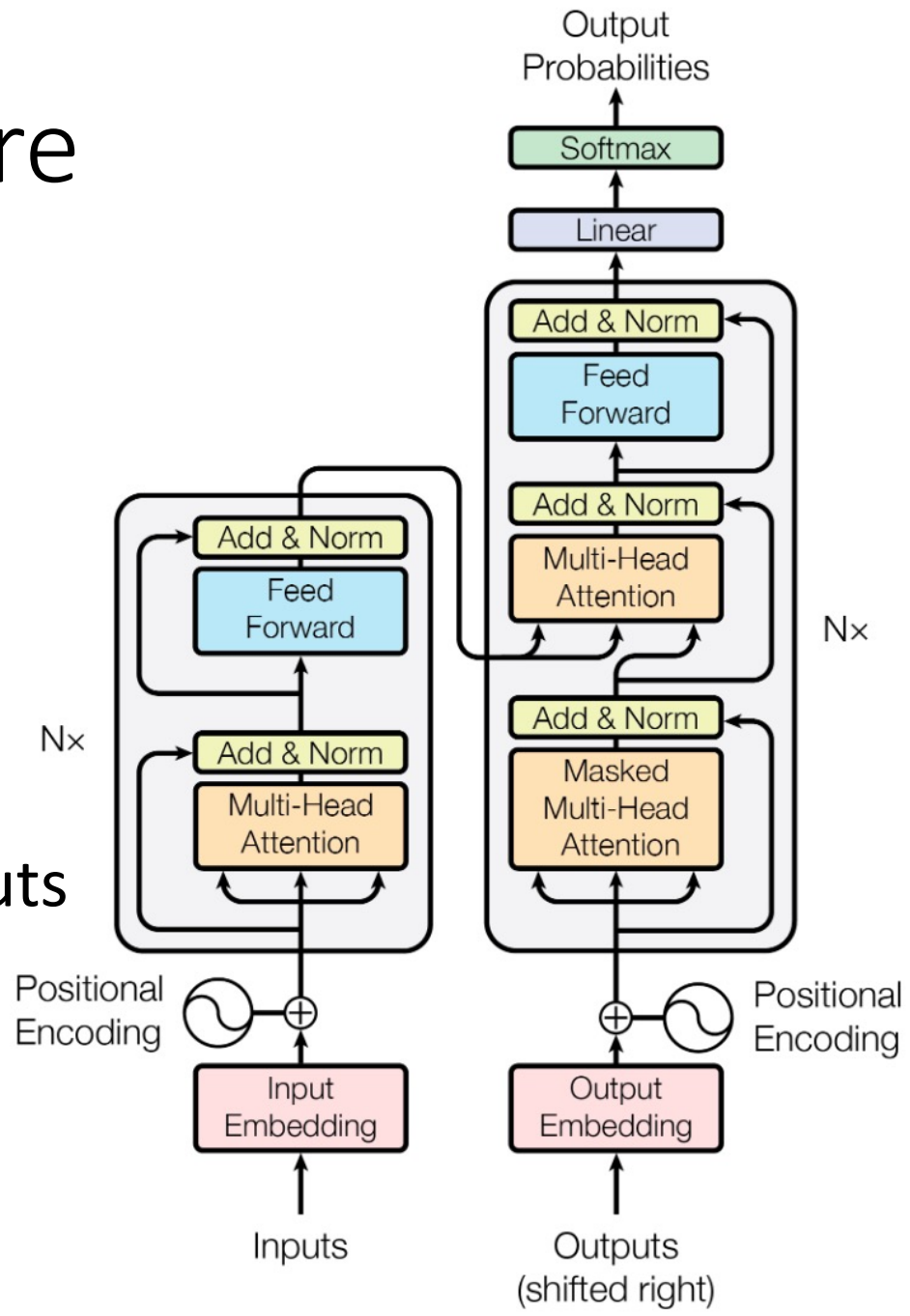
https://arxiv.org/pdf/1409.0473.pdf

- LSTMs + Attention



The Transformer - Architecture

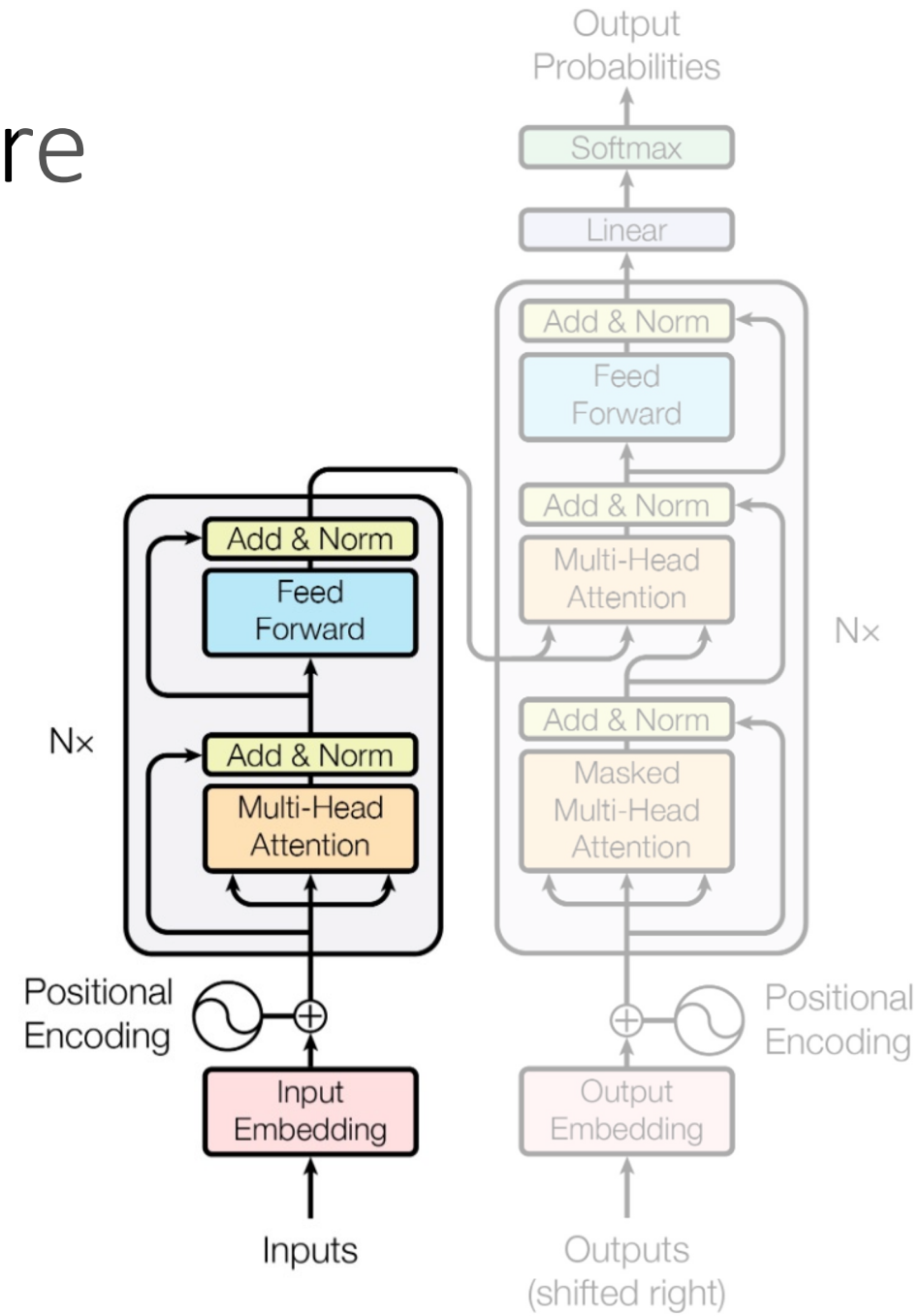
- Encoder-Decoder architecture
  - Feature space acts as an interlingua
- Encoder
  - Inputs (words) are encoded using embeddings
  - Transforms input embeddings to feature space
  - 6 stacked layers attention and feed-forward
- Decoder – transform feature space to outputs
  - Converts output of last encoder layer into a set of probabilities which predict the next word



The Transformer - Architecture

- Encoder Layer

- Creates context vector for input sequence
- N=6 stacked layers

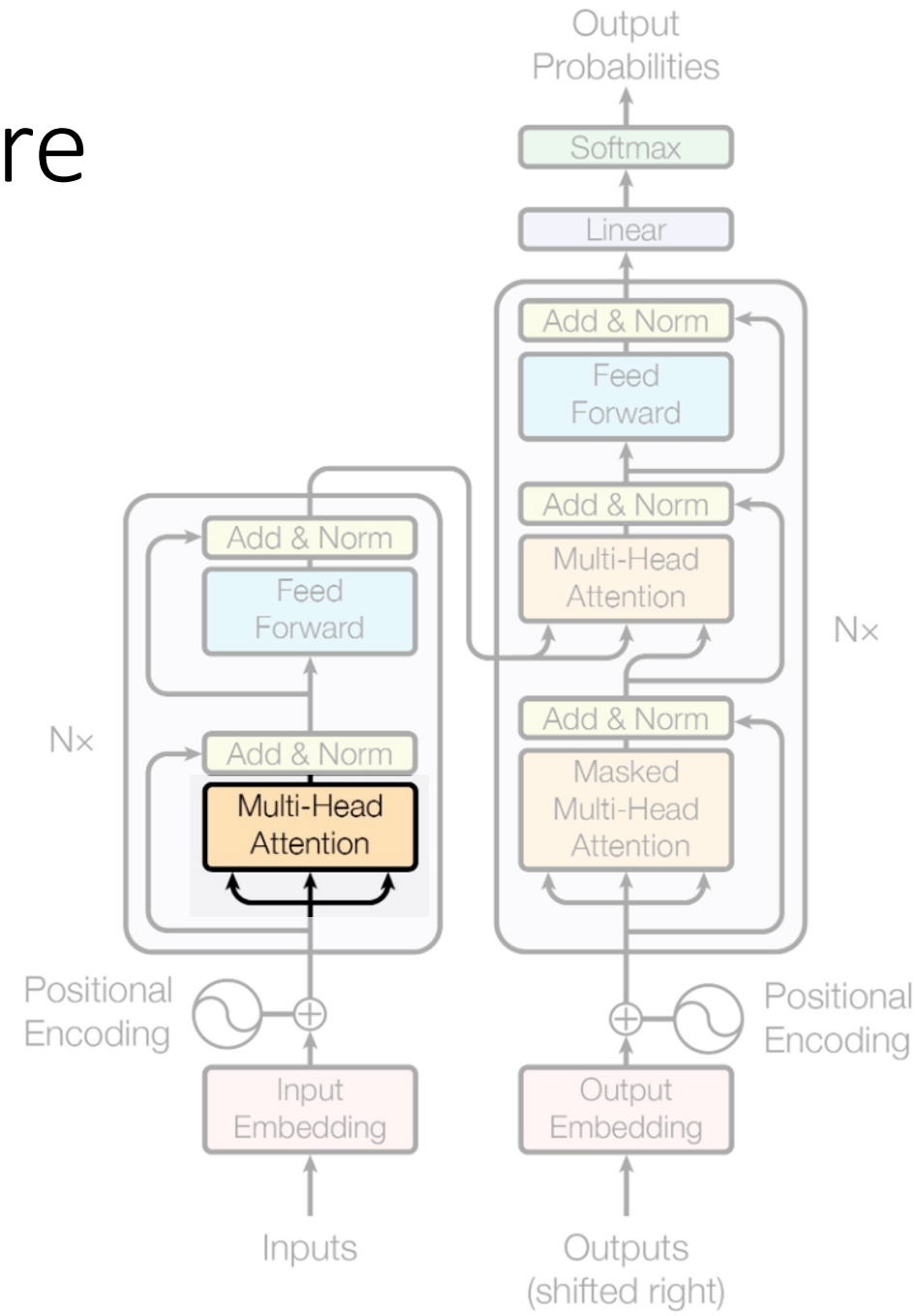


The Transformer - Architecture

- Encoder – multi-headed self attention

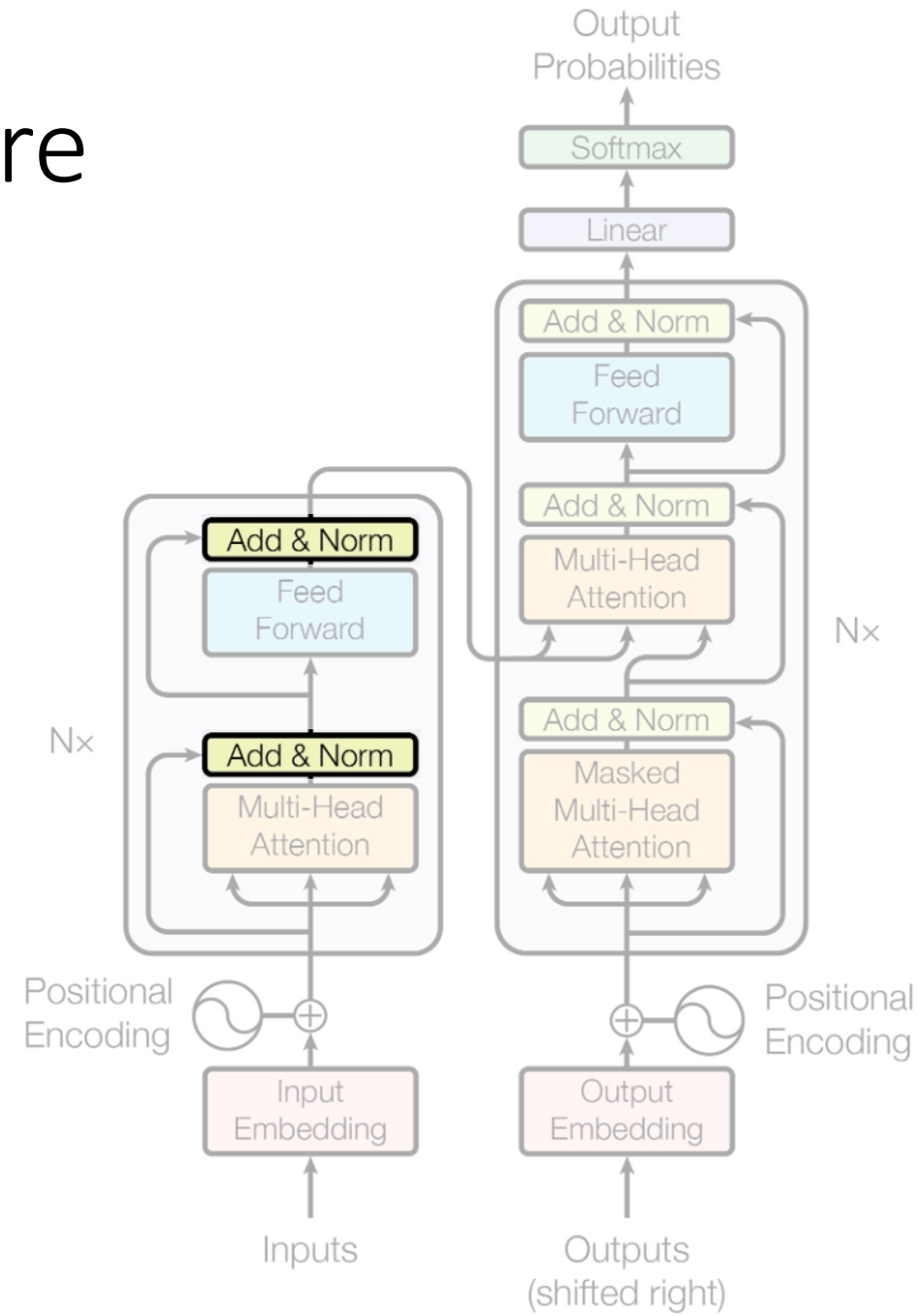
- Self-attention
  - All inputs available to encoder
  - Attention selects relevant parts of input
  - Key, Value, Query (read paper for details)

- Multi-headed
  - Ran in parallel N=8 times
  - Output of each ‘head’ is concatenated



The Transformer - Architecture

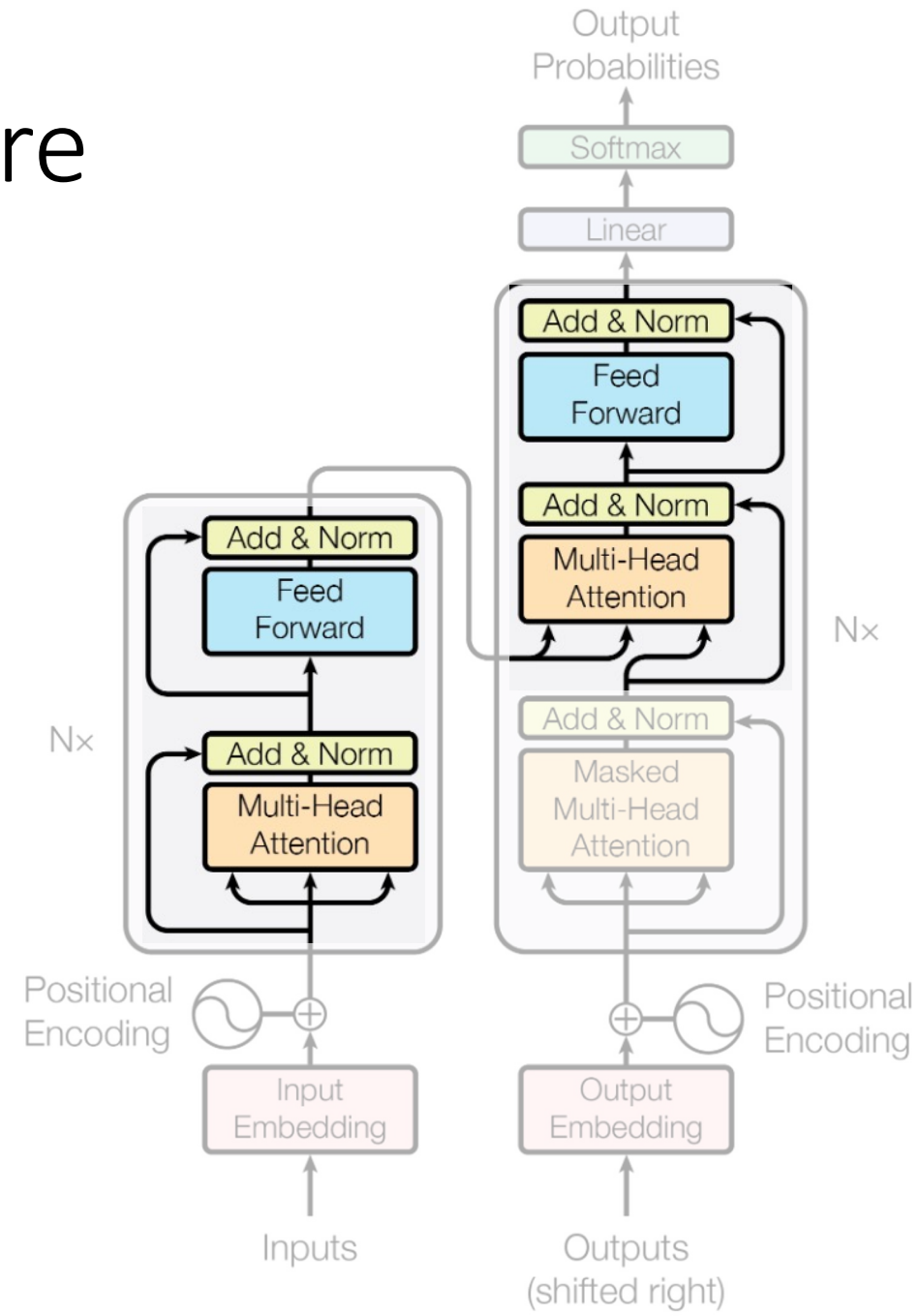
- Encoder - Add and normalize
- Note that the input from before each step is carried through to the next step
- Normalisation prevents exploding gradient



The Transformer - Architecture

- Decoder – Replicates encoder

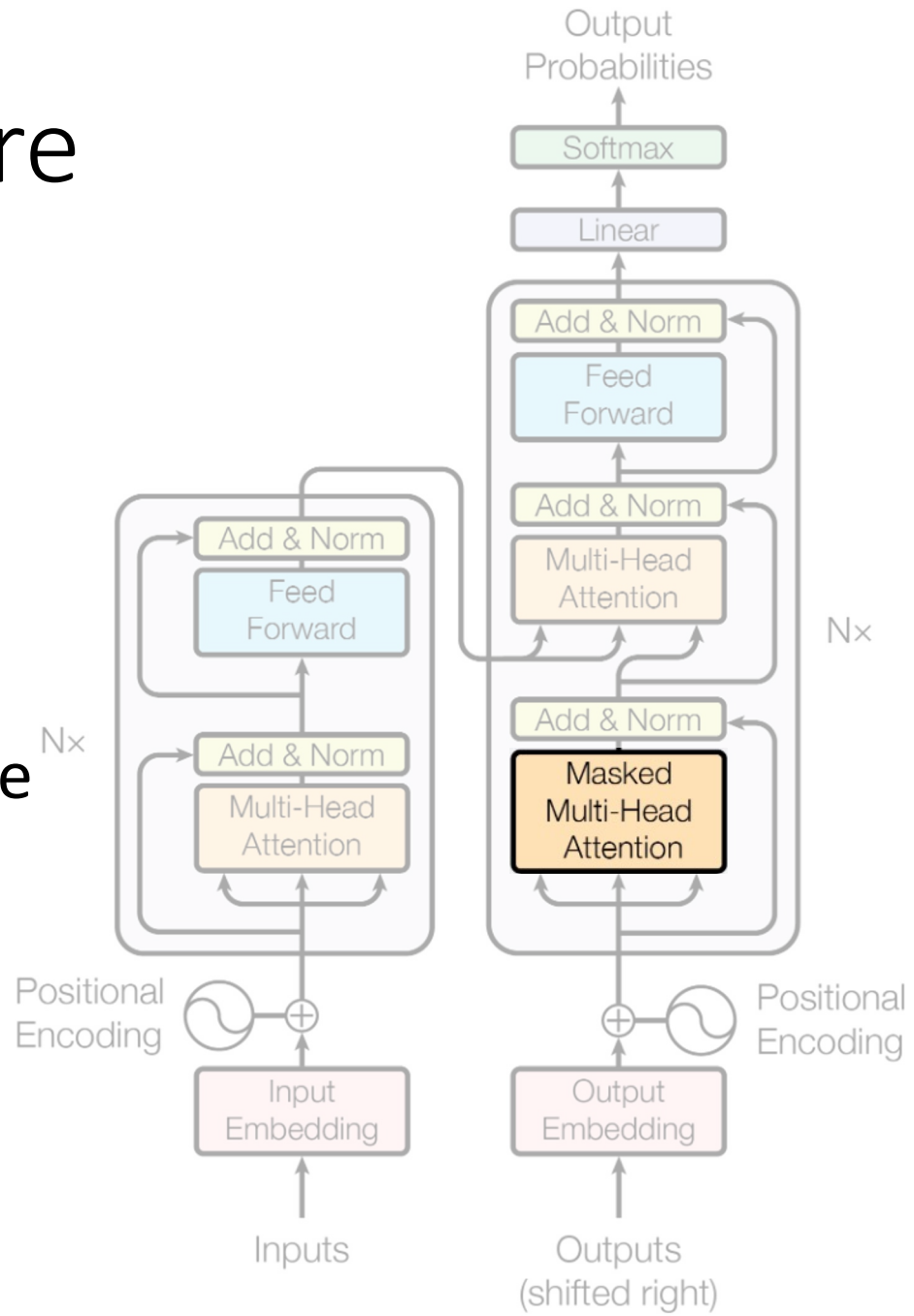
- Multi-head self attention and feed forward network are carried over
  - Applied to the attention weights from encoder
  - Also applied to the last output from decoder



The Transformer - Architecture

- Decoder – Masked Multi-head attention

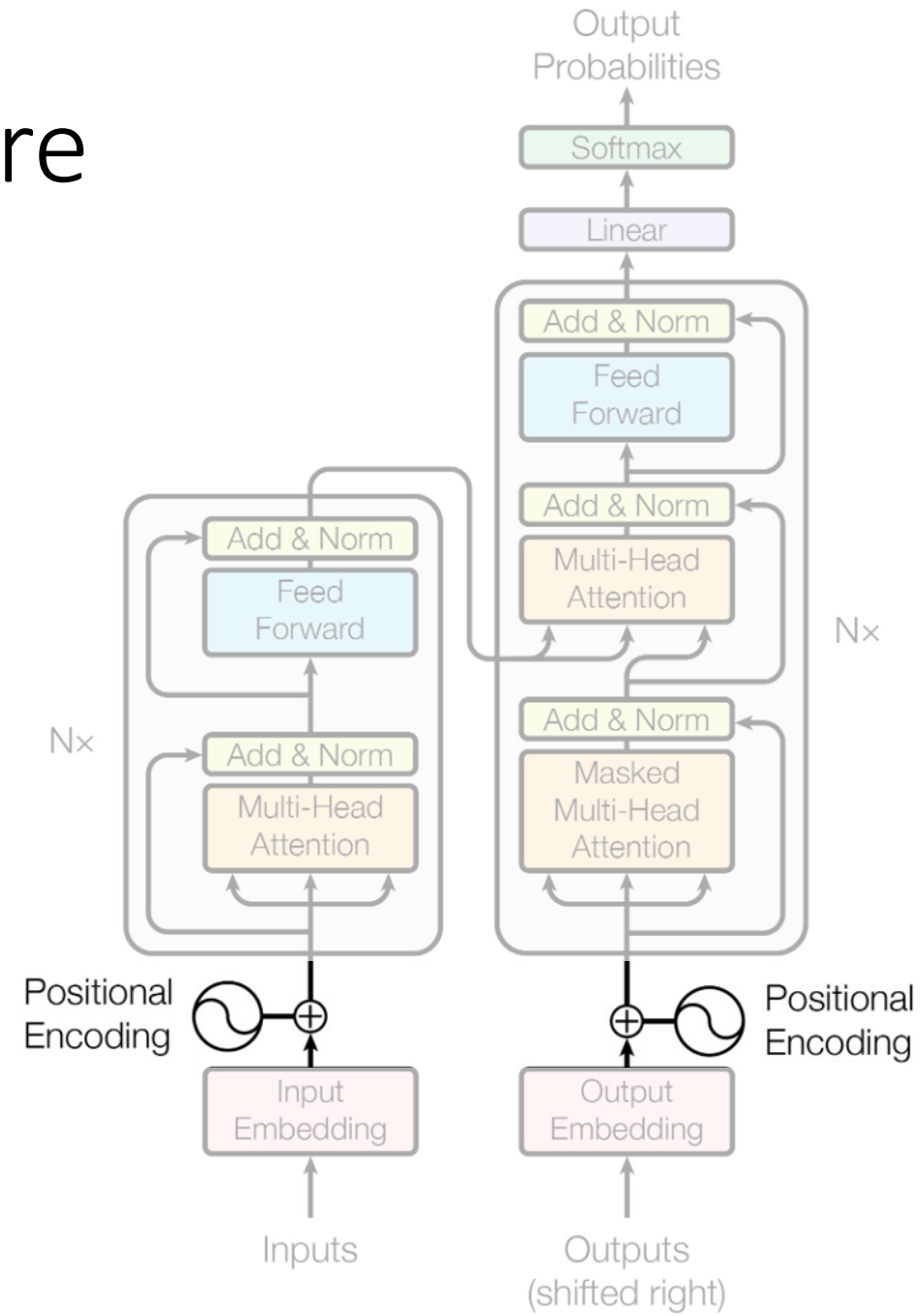
- Masking prevents information from future becoming available at decode time
- Otherwise, self-attention the same as before



The Transformer - Architecture

- Encoder-Decoder – Sinusoidal Positional Encoding

- Encodes whereabout in the sentence the word is likely to have occurred
  - Applies sin/cos function to alternate dimensions of the embedding
  - This is summed with the word embeddings
  - So embedding contains info on meaning + position in sentence

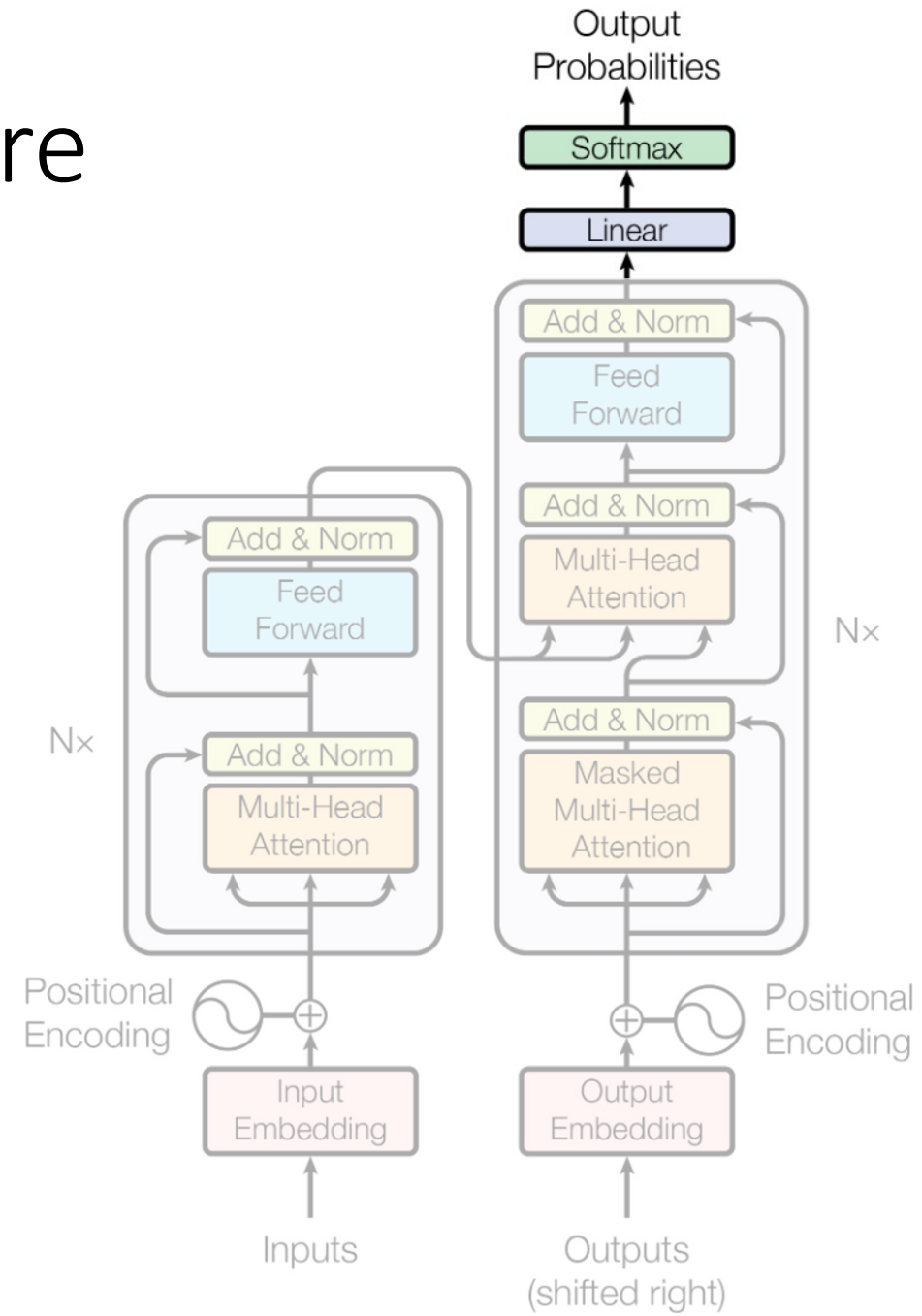


The Transformer - Architecture

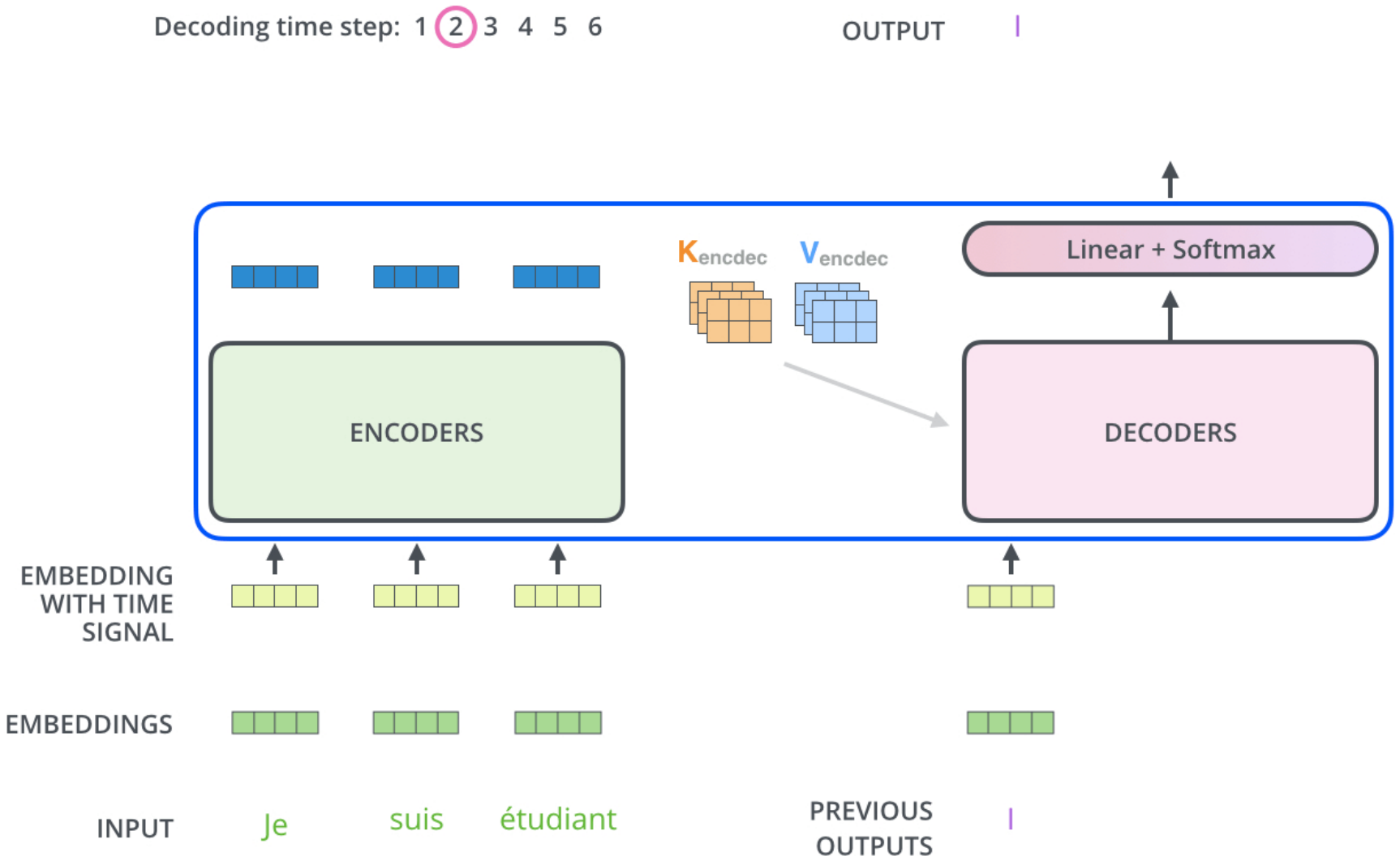
- Output

- Linear layer
  - Fully connected NN
  - Converts k-dim vector to size of output vocab

- Softmax layer
  - Normalises probabilities in 0-1 range.



The Transformer - Visualisation

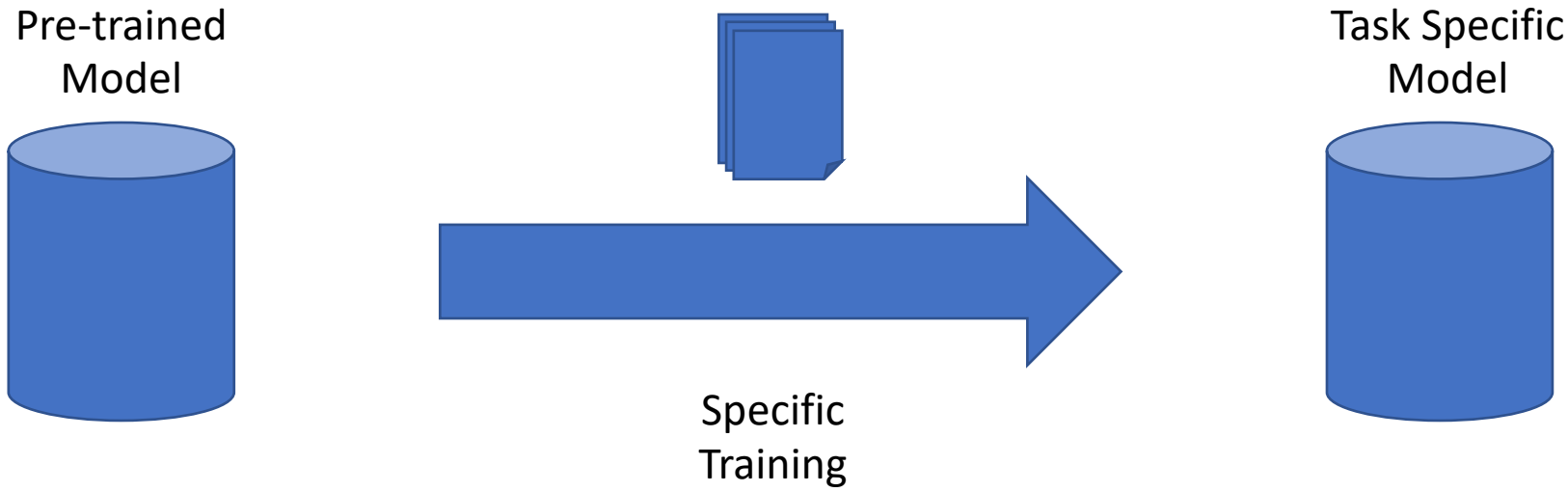


Pre-trained Models

- NLP would be very expensive if we had to retrain models every time
- Fortunately, pre-trained models are available that we can use

Fine-tuning

- Pre-trained models can be adapted to a specific task



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- Image Classification
- Object Detection
- Image Segmentation
- Image-to-Image
- Unconditional Image Generation
- Video Classification
- Zero-Shot Image Classification

Natural Language Processing

- Text Classification
- Token Classification
- Table Question Answering
- Question Answering
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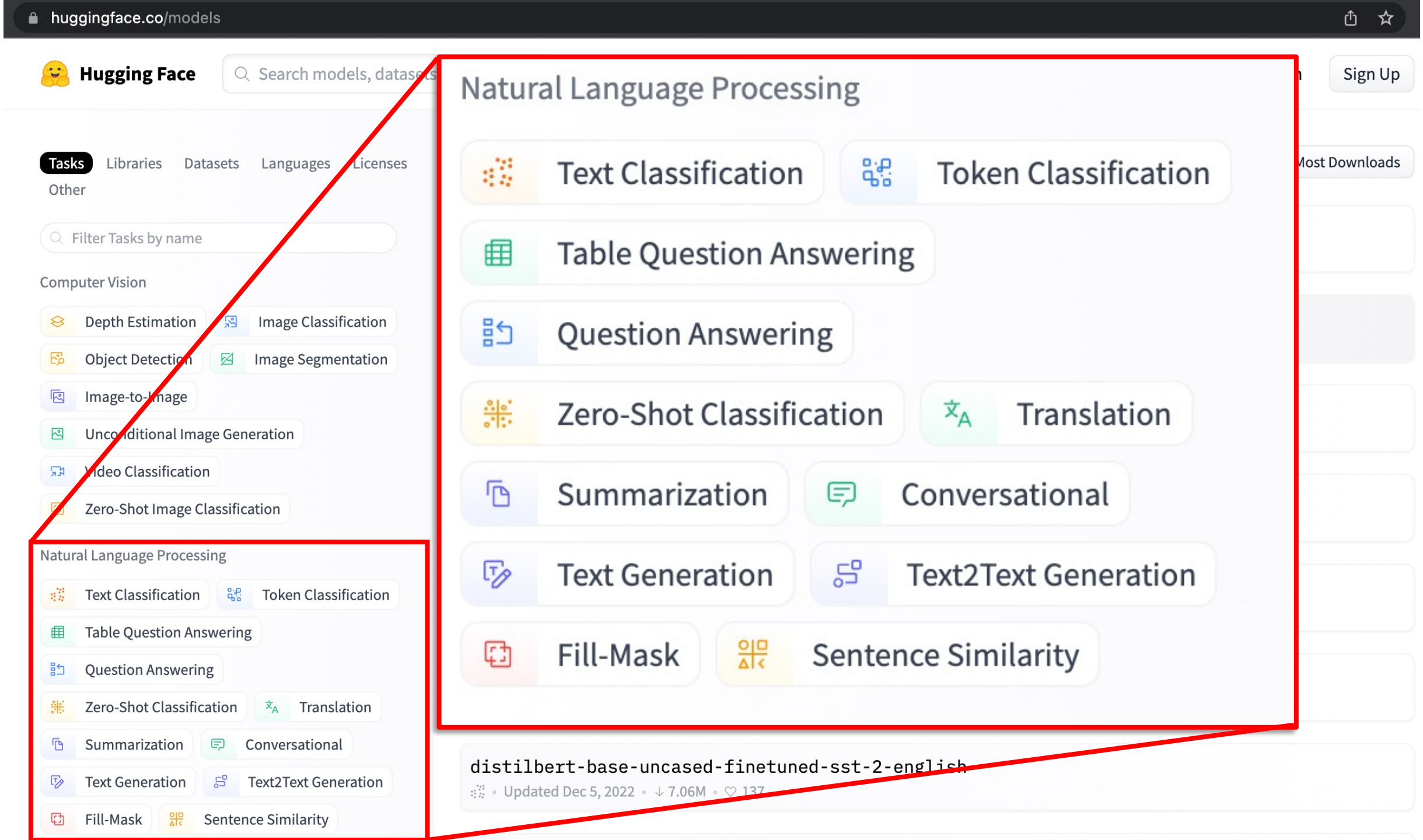
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