Natural Language Processing

Introduction to Data Science
Spring 1404

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Agenda

- What is NLP?
- Why NLP is important?
- NLP applications (translation, sentiment analysis, summarization)
- Word embedding (word2vec)
- RNN (sequence processing)
- Attention mechanism, Transformers
- Language modeling (task definition)
- From LMs to general-purpose chatbots

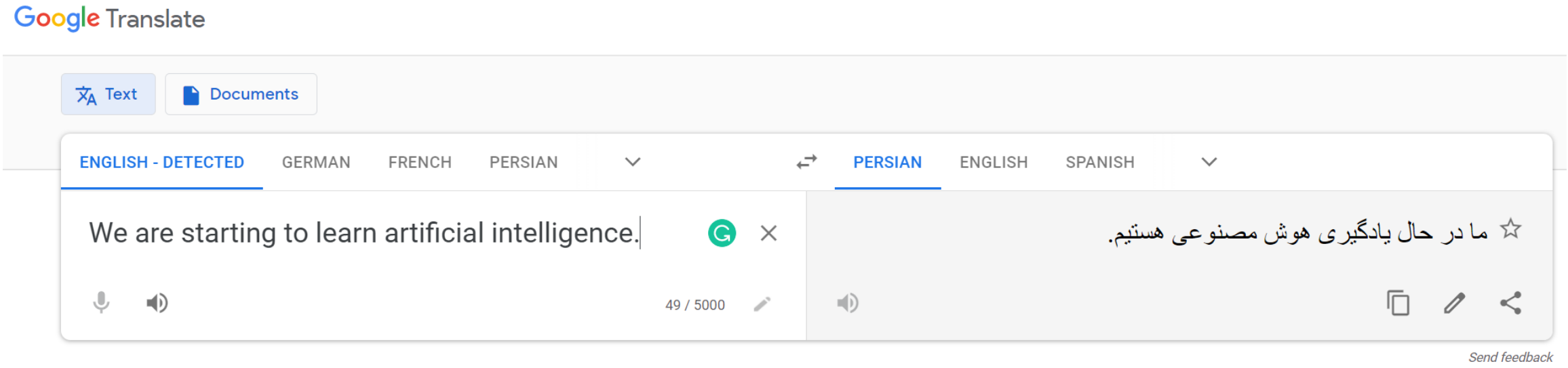
Goal

Comprehension and generation of **natural language**

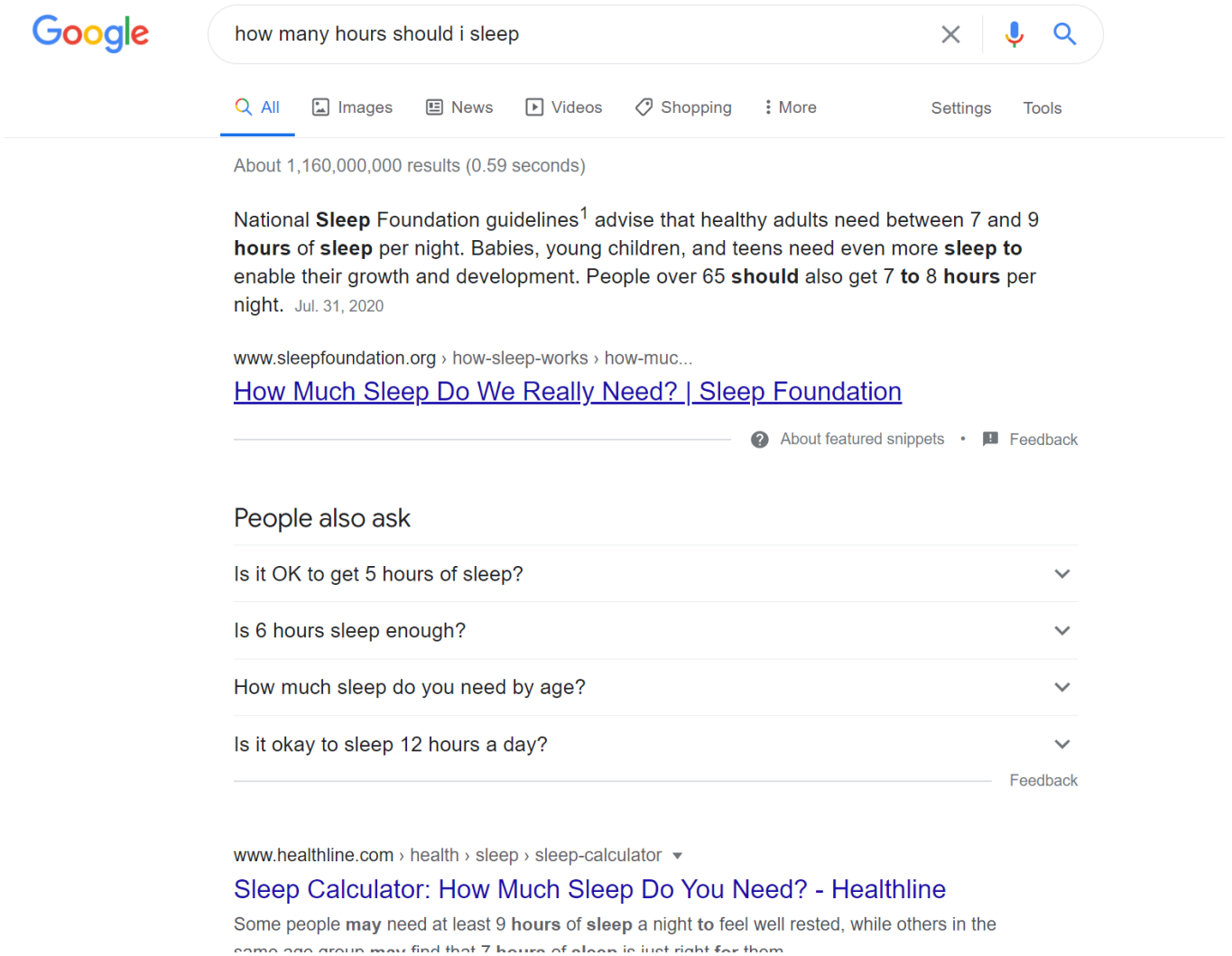
Natural language

- Languages that evolved naturally through human use
  - e.g., Spanish, English, Arabic, Hindi, etc.

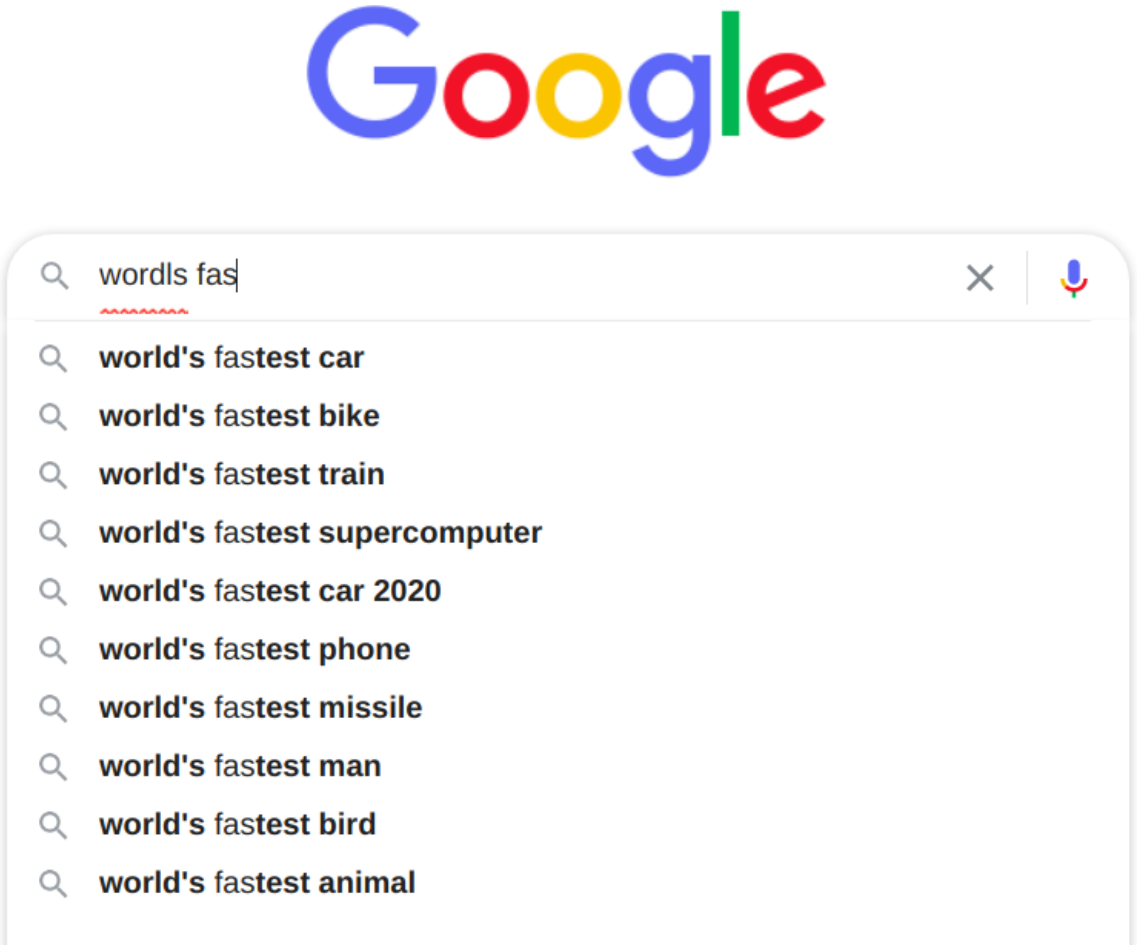
Machine translation



Search & QA


Google
how many hours should i sleep
All
Images
News
Videos
Shopping
More
Settings
Tools
About 1,160,000,000 results (0.59 seconds)
National Sleep Foundation guidelines[1] advise that healthy adults need between 7 and 9 hours of sleep per night. Babies, young children, and teens need even more sleep to enable their growth and development. People over 65 should also get 7 to 8 hours per night. Jul. 31, 2020
www.sleepfoundation.org › how-sleep-works › how-muc...
How Much Sleep Do We Really Need? | Sleep Foundation
About featured snippets
Feedback
People also ask
Is it OK to get 5 hours of sleep?
Is 6 hours sleep enough?
How much sleep do you need by age?
Is it okay to sleep 12 hours a day?
Feedback
www.healthline.com › health › sleep › sleep-calculator
Sleep Calculator: How Much Sleep Do You Need? - Healthline
Some people may need at least 9 hours of sleep a night to feel well rested, while others in the

Search autocorrect and autocomplete



Social media analysis

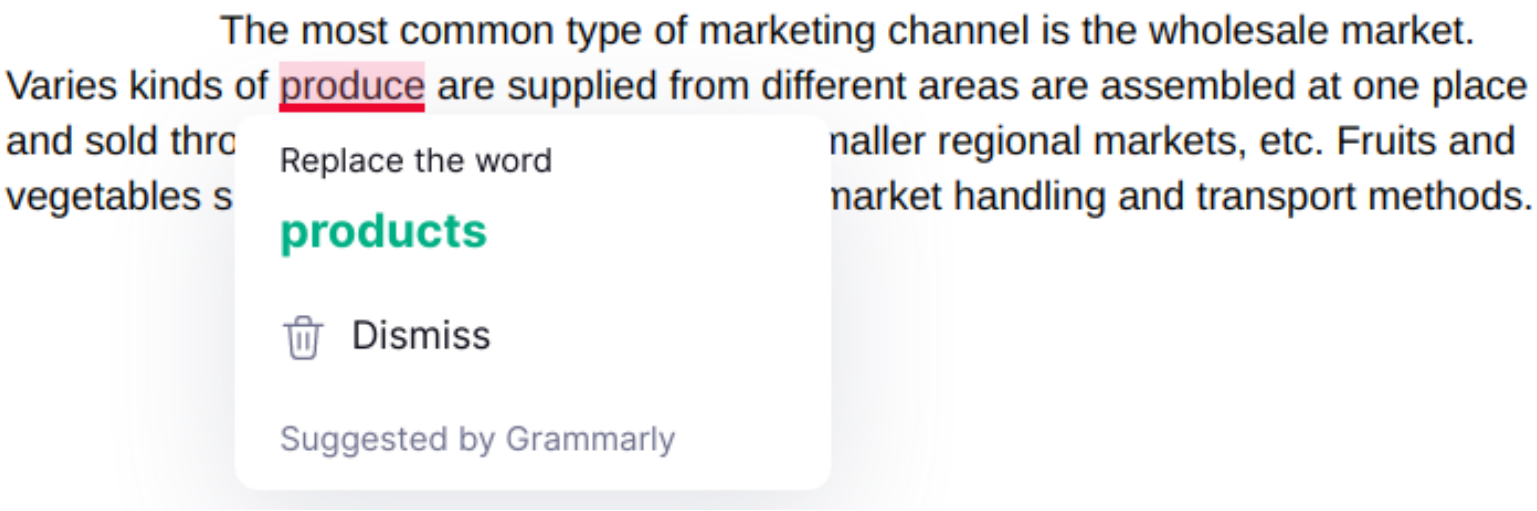
Chatbots


10:05
Hello
Hi, what can we do for you?
Event Feedback
Thanks for coming along today - we'd love to hear what you think about today's event and the presentations. Let's get started.
So, what do you think? Give me you gut feeling!

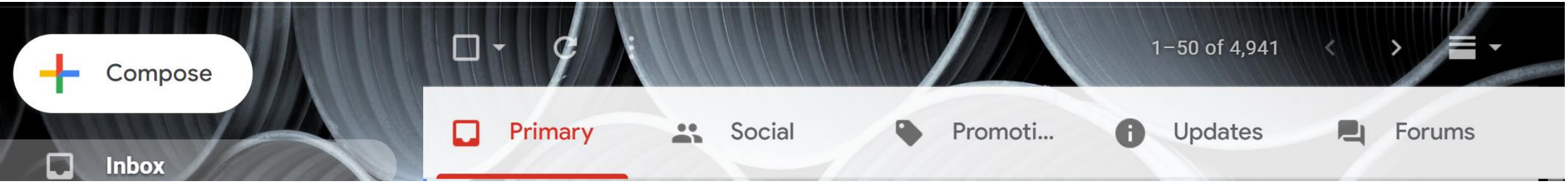
Hiring and recuiretment

Voice assistants

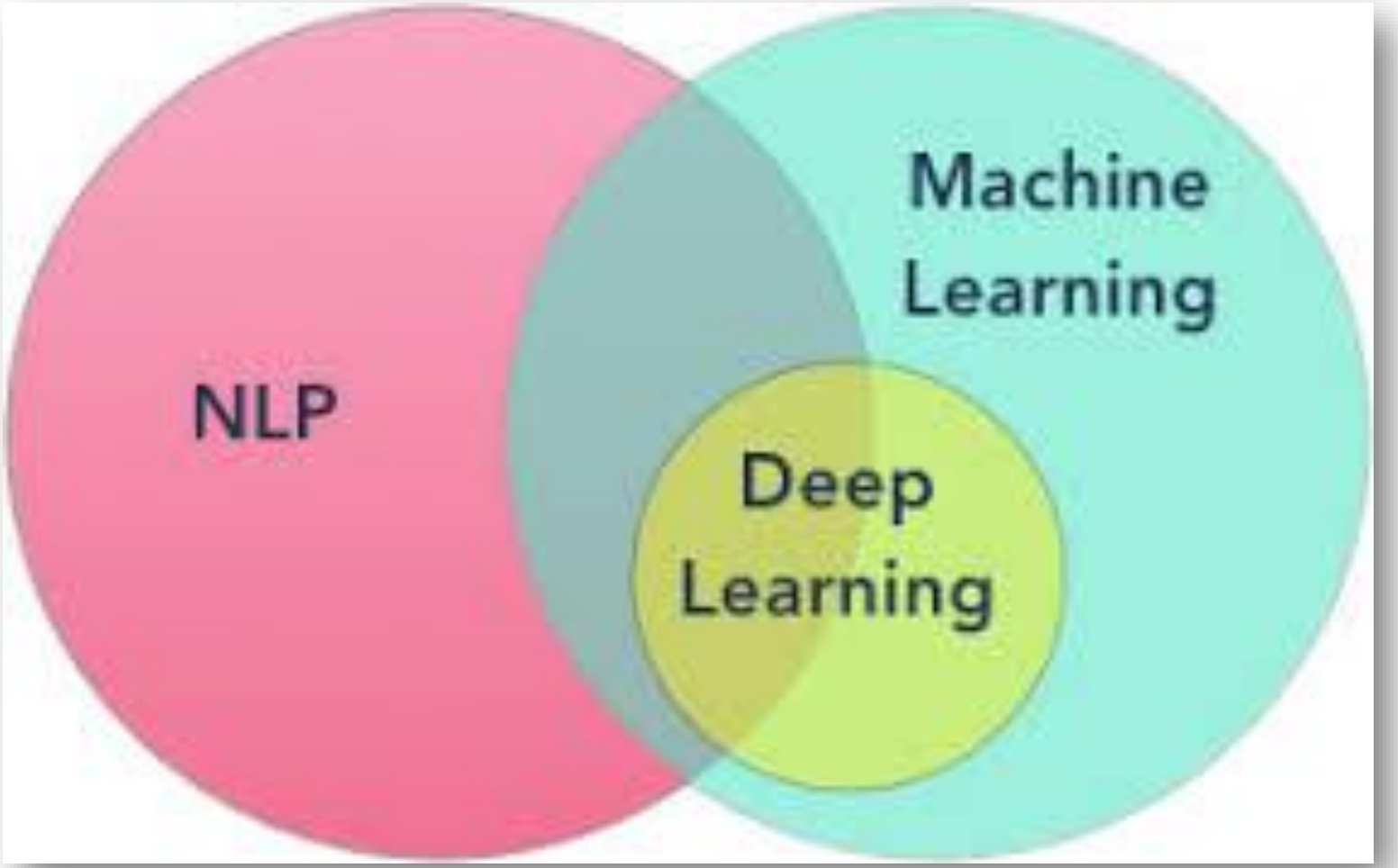
Grammar checkers



Email classification



NLP is not just machine learning



Levels of linguistic structure

Discourse

Semantics

Syntax: Constituents

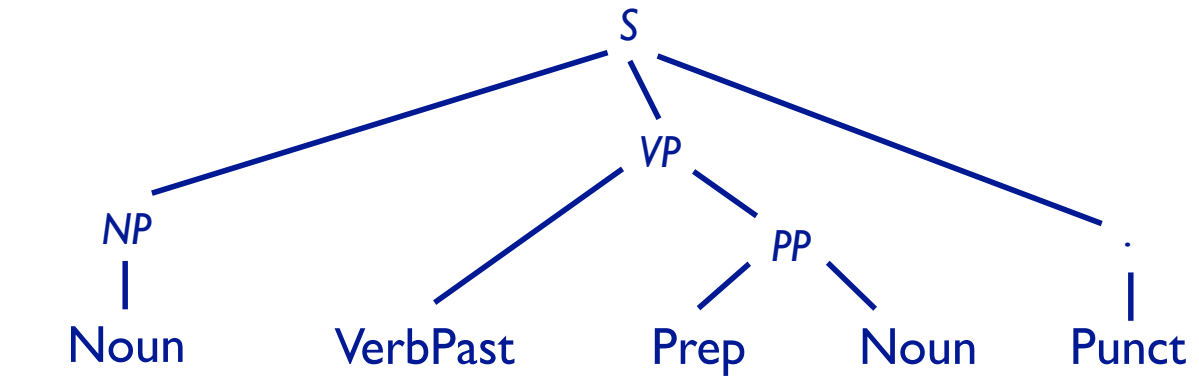
Syntax: Part of Speech

Words

Morphology

Characters

CommunicationEvent(e)
Agent(e, Alice)
Recipient(e, Bob)
SpeakerContext(s)
TemporalBefore(e, s)



Alice talked to Bob .

talk -ed [VerbPast]

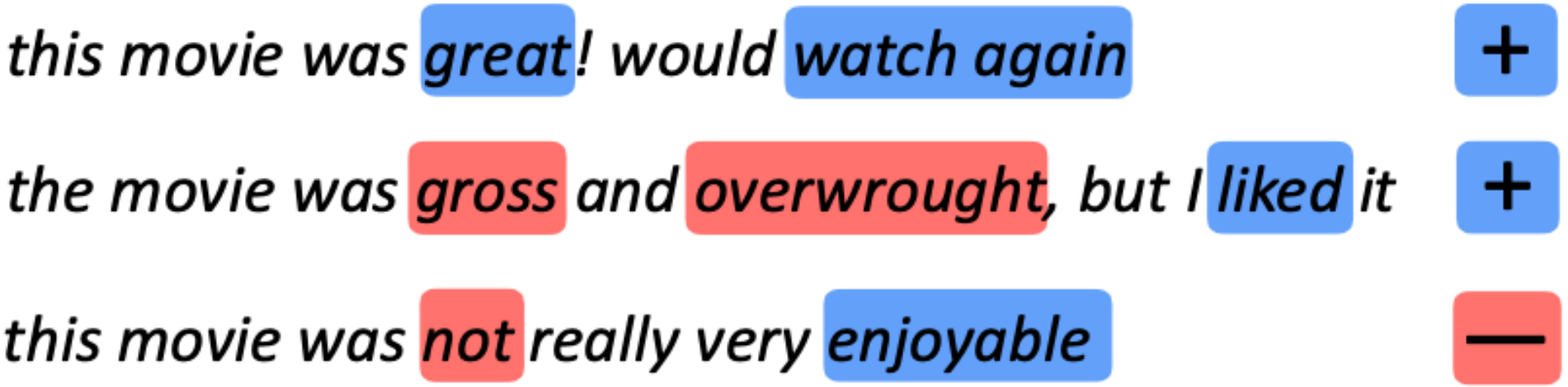
Alice talked to Bob.

Deep Learning for Text Classification

Classification

- Output a choice from a fixed set of labels
- For sentiment:
  - Positive/negative
  - Star rating
  - …

Some examples of binary sentiment classification



https://www.cs.utexas.edu/~gdurrett/courses/online-course/materials.html

Building a classifier

- Let’s say we have 10k labeled sentences
- We want to learn a function f that
  - maps an unseen sentence to one of the labels

From strings to words

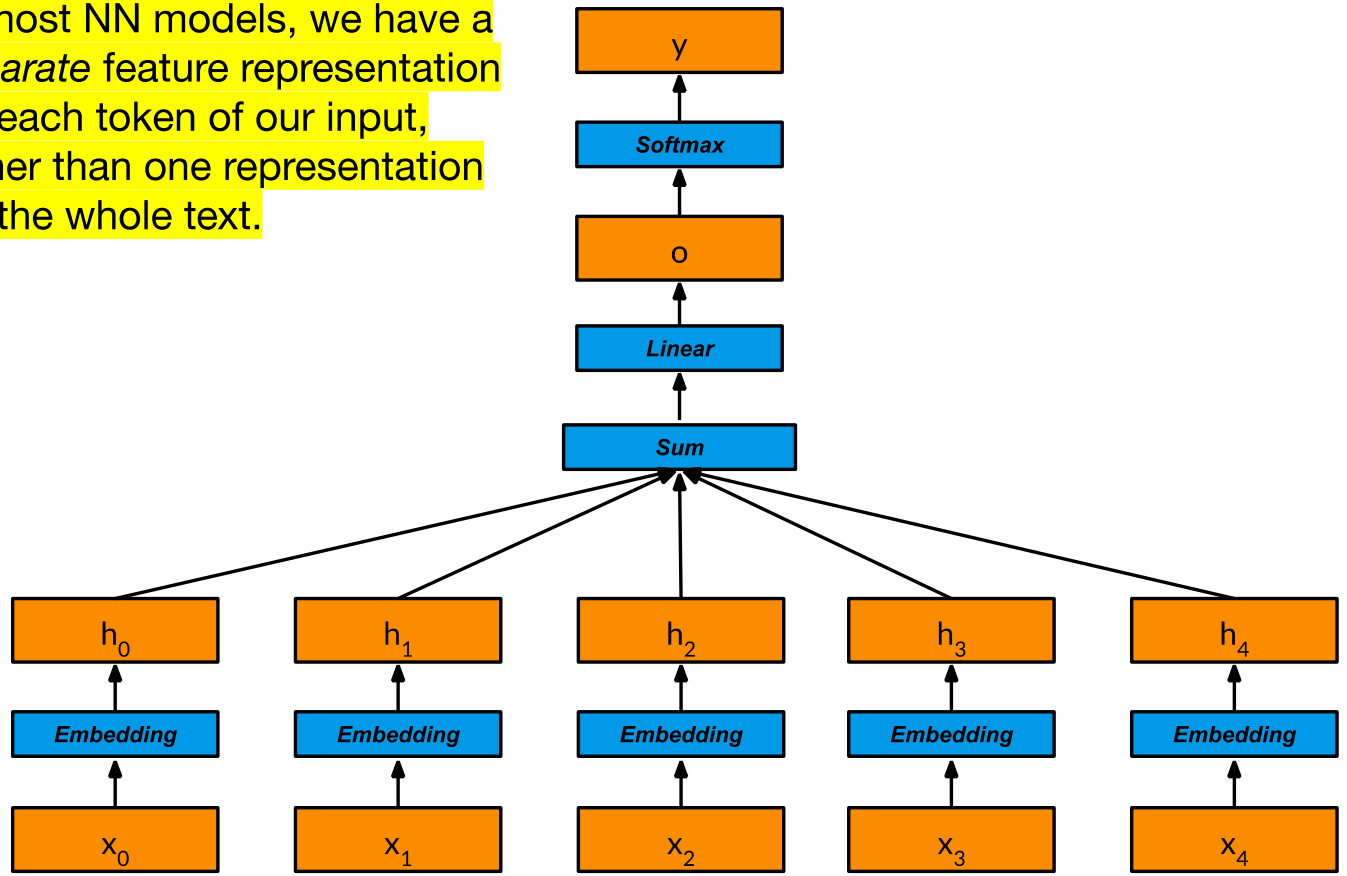
- I don’t like any of Ford’s trucks.

- I do n’t like any of Ford ‘s trucks .

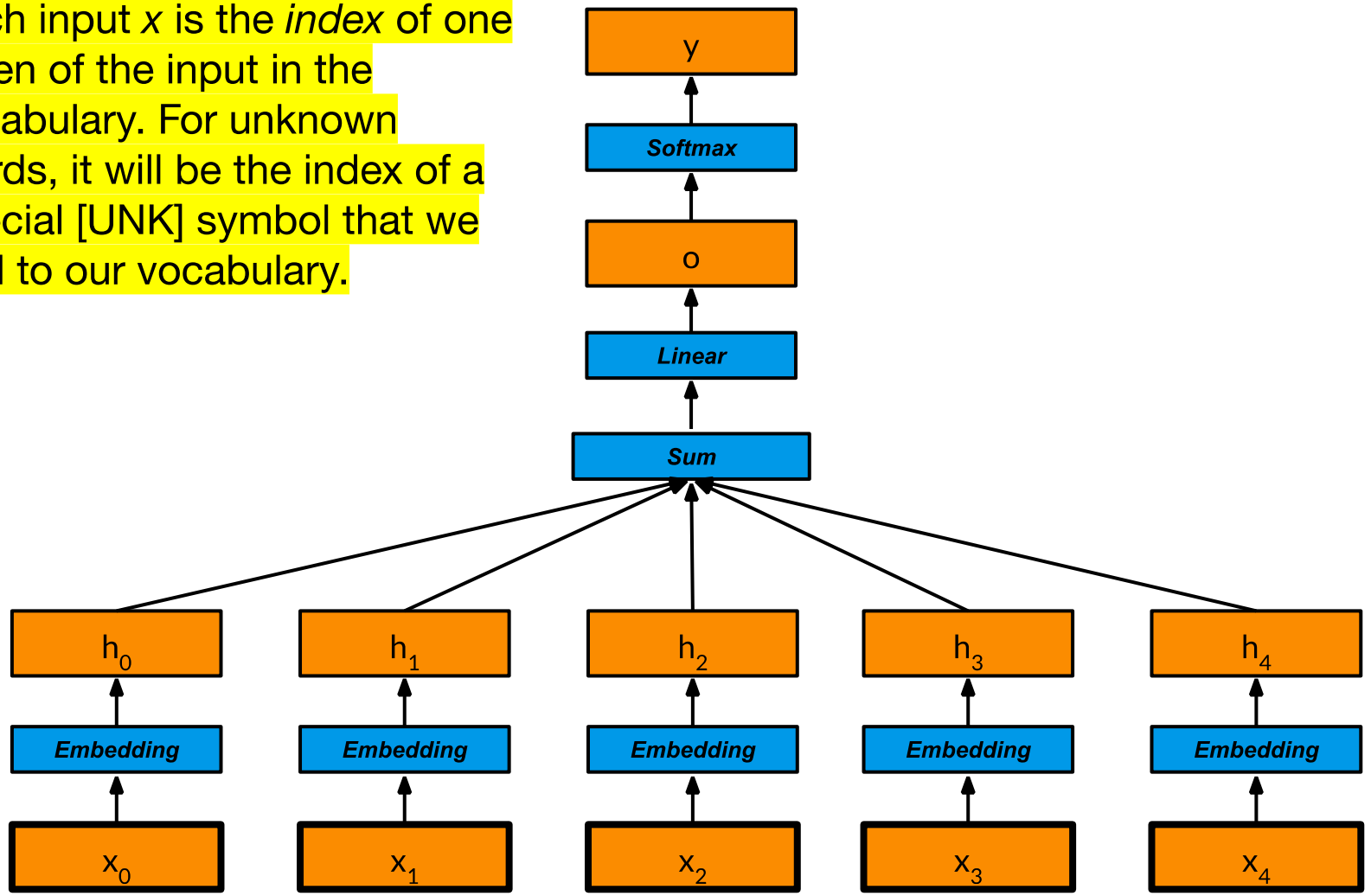
Tokenization: Turning strings into a sequence of symbols (e.g., words, subwords, characters, etc)

NN sentiment classifier

In most NN models, we have a *separate* feature representation for each token of our input, rather than one representation for the whole text.

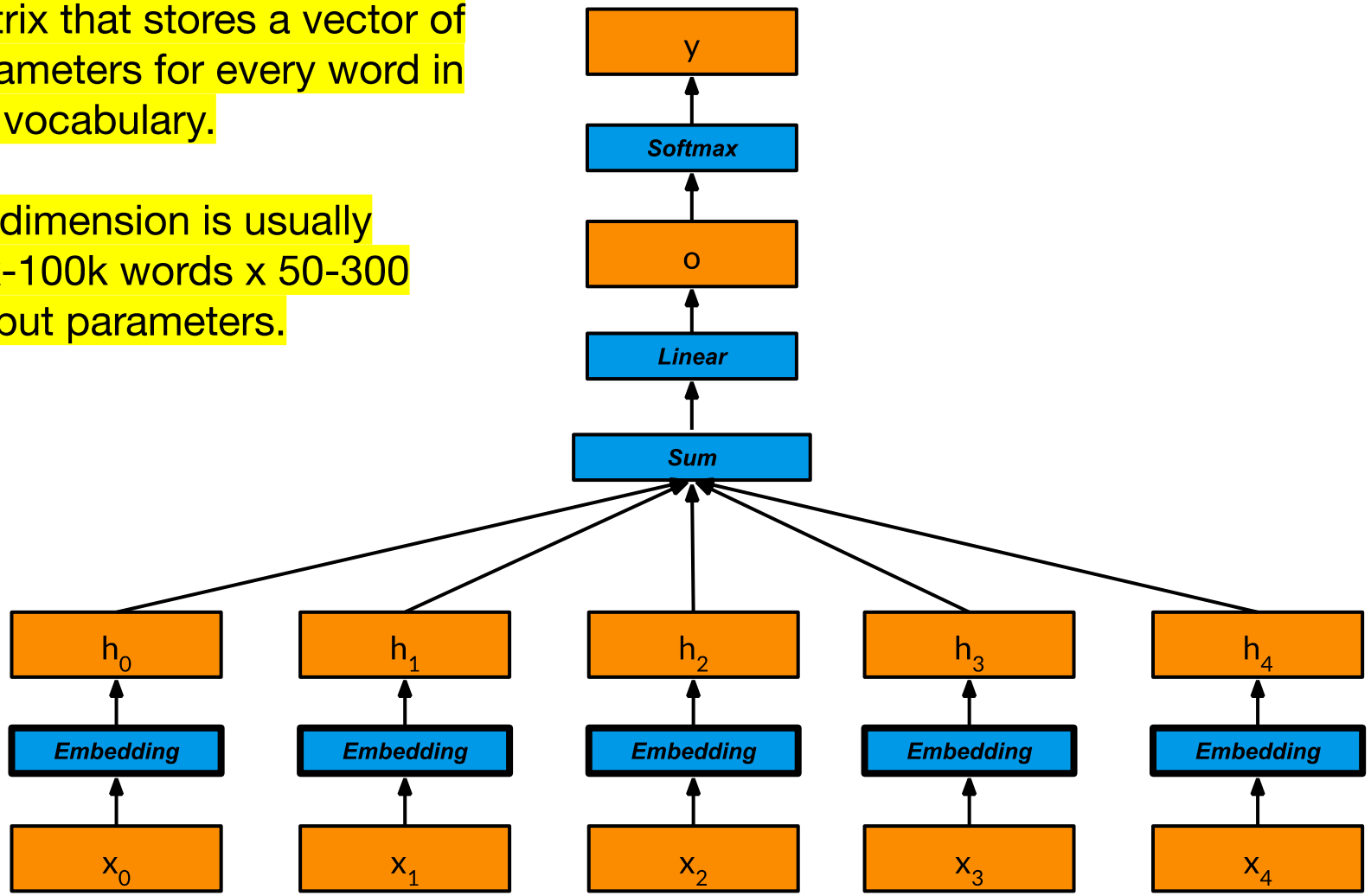


Each input *x* is the *index* of one token of the input in the vocabulary. For unknown words, it will be the index of a special [UNK] symbol that we add to our vocabulary.

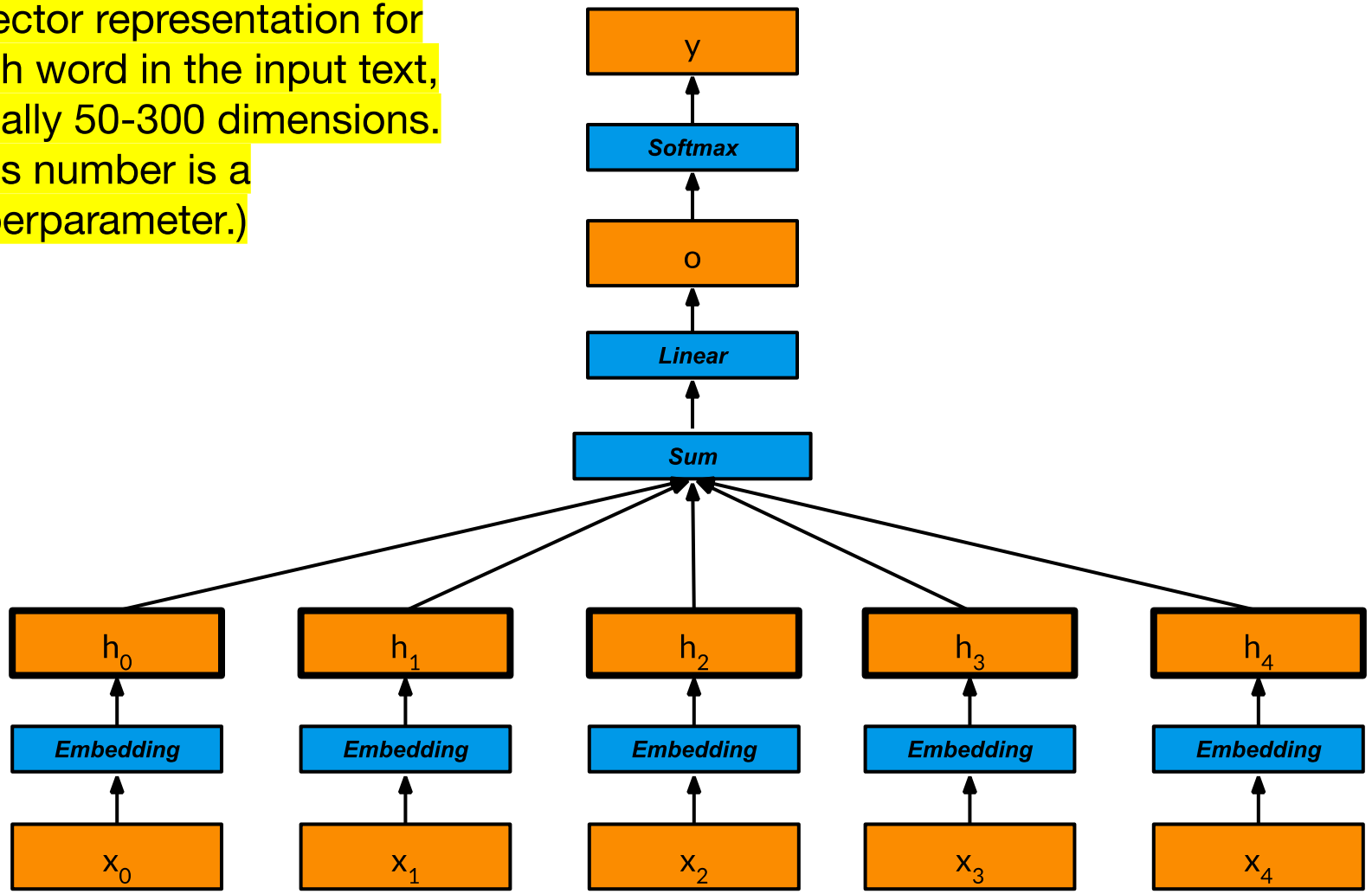


The *embedding layer* is a matrix that stores a vector of parameters for every word in the vocabulary.

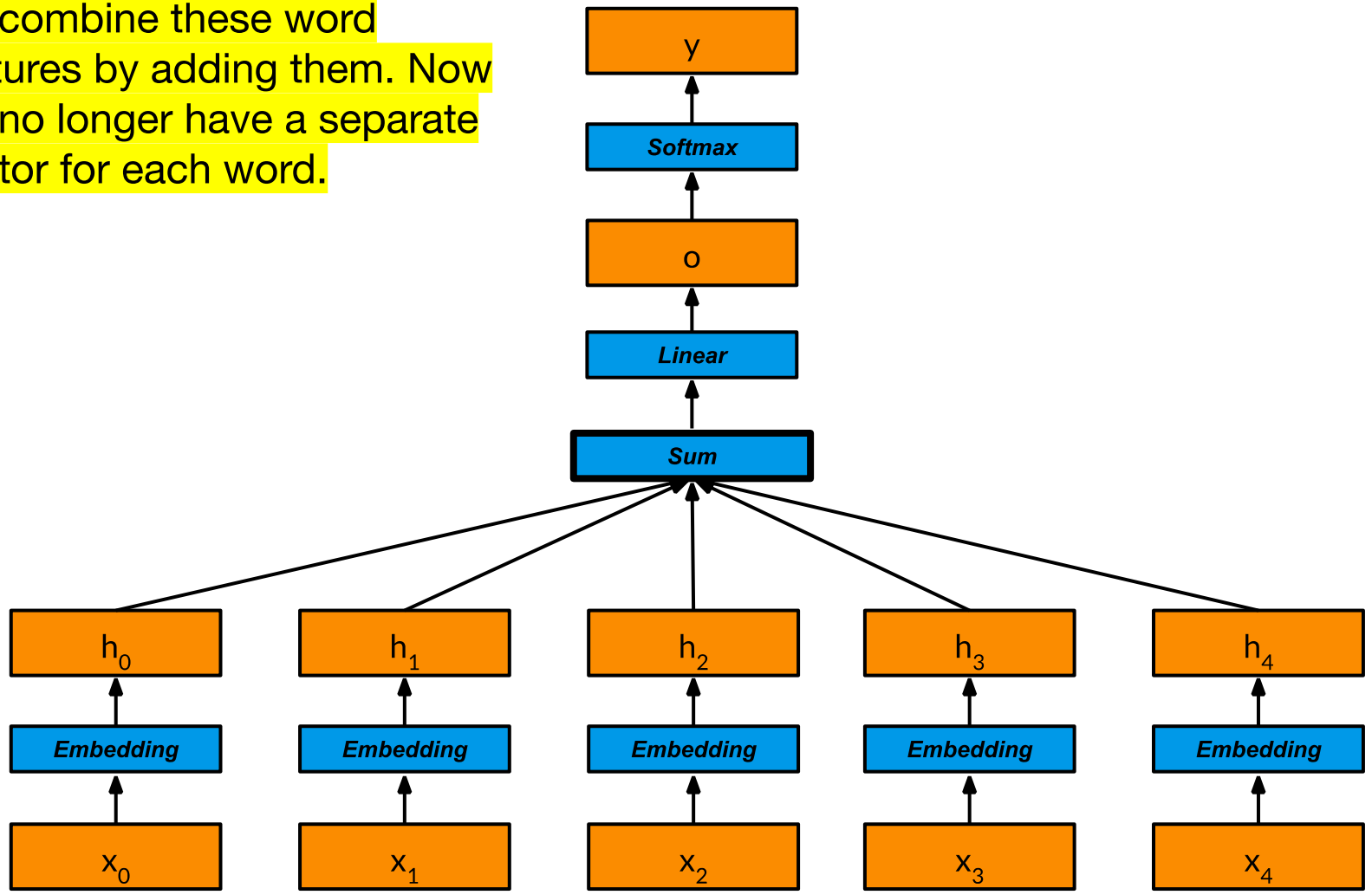
It's dimension is usually 10k-100k words x 50-300 output parameters.



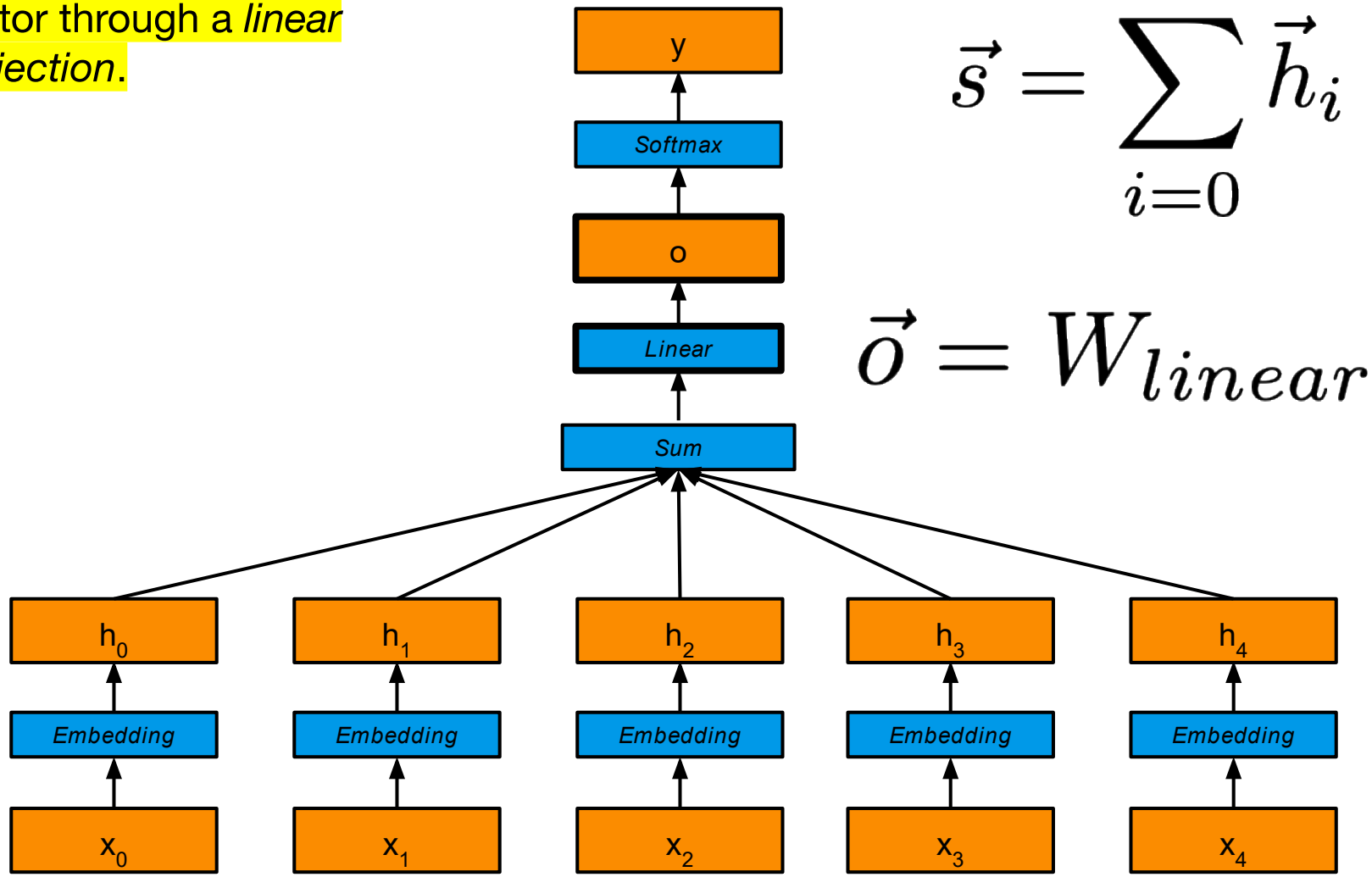
The embedding layer produces a vector representation for each word in the input text, usually 50-300 dimensions. (This number is a hyperparameter.)



In this simple neural network, we combine these word features by adding them. Now we no longer have a separate vector for each word.



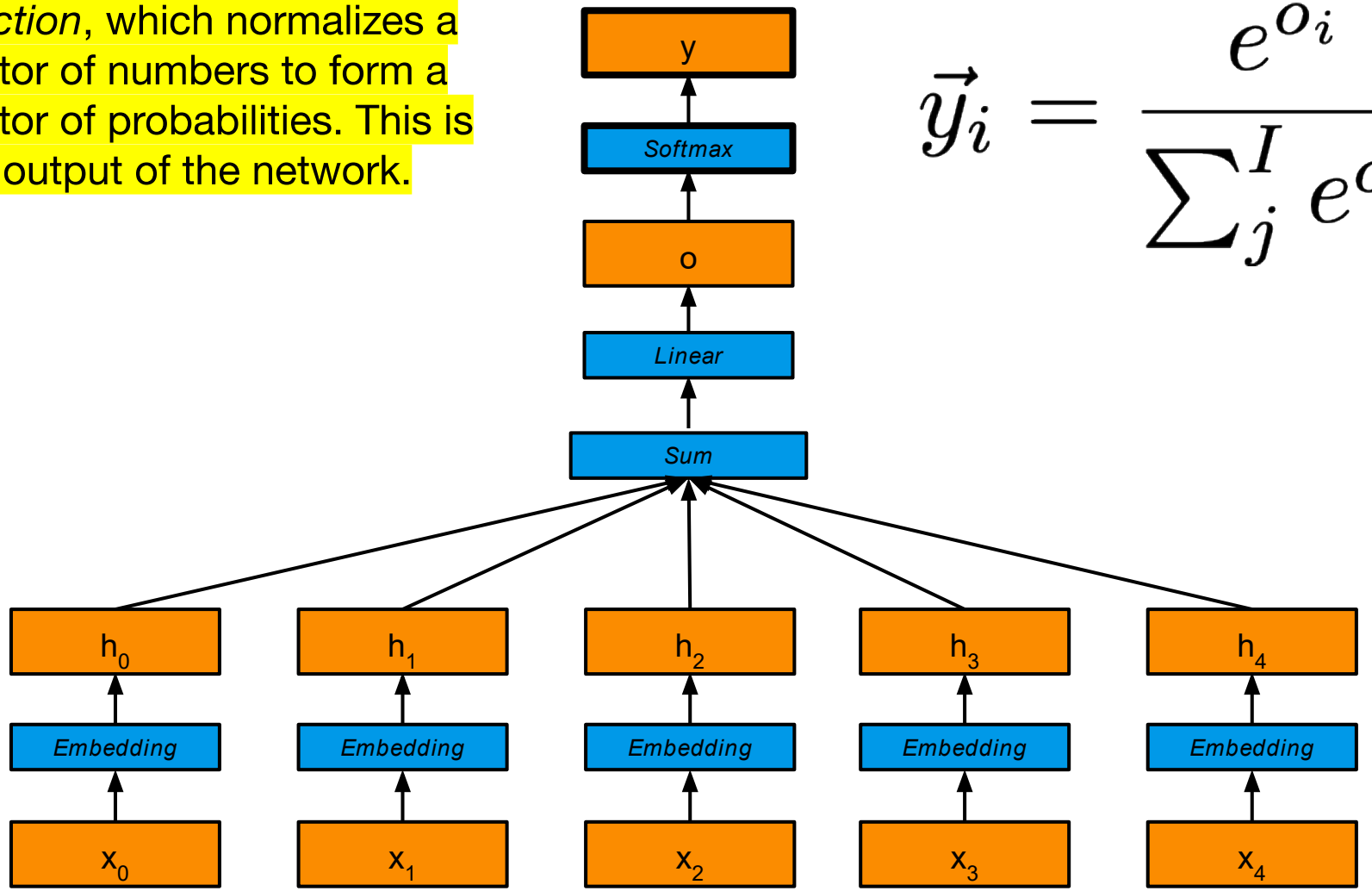
Next, we pass the resulting vector through a *linear projection*.



$$\vec{s} = \sum_{i=0}^{I} \vec{h}_i$$

$$\vec{o} = W_{linear}\vec{s}$$

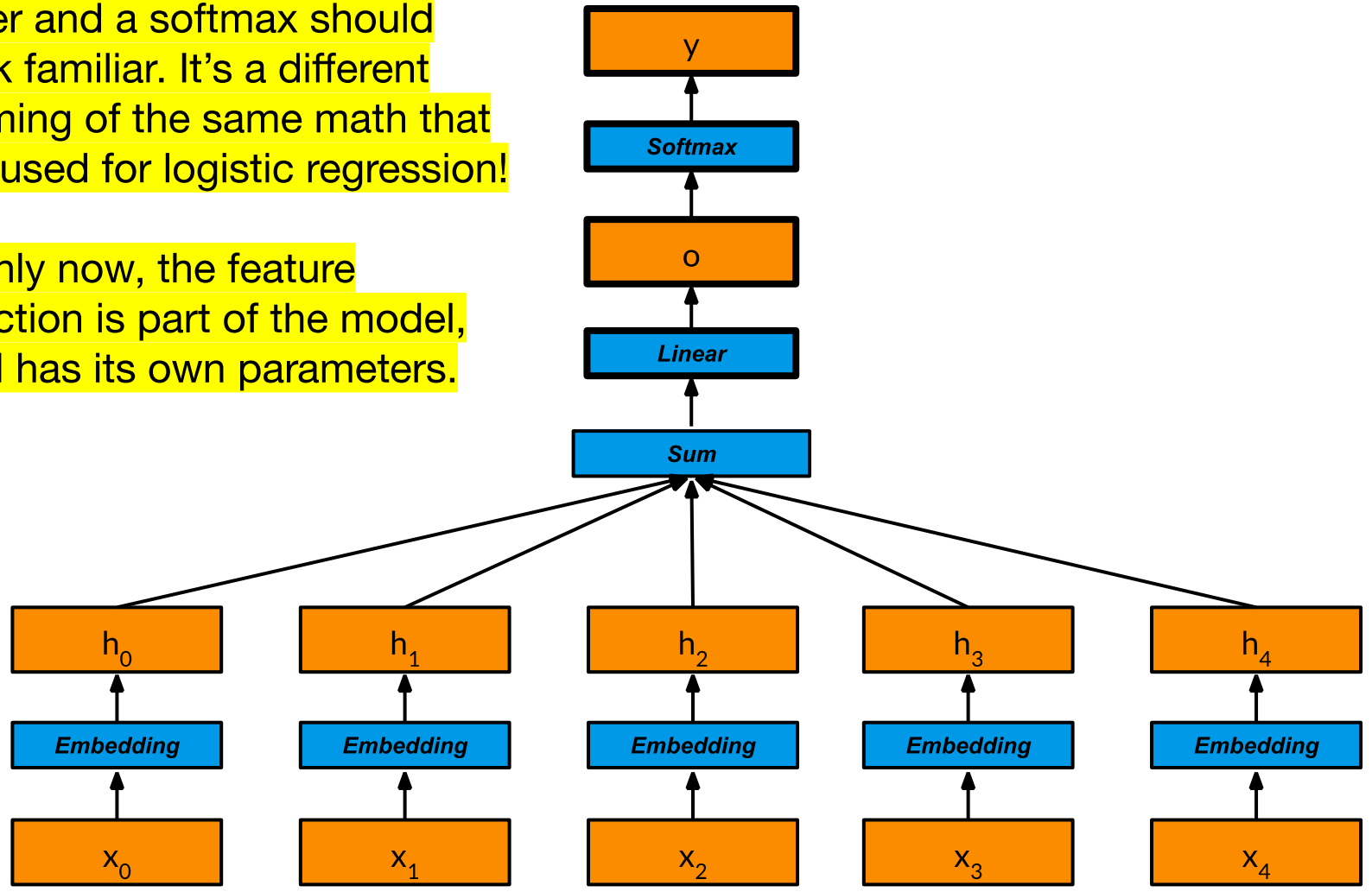
After that, we use the *softmax function*, which normalizes a vector of numbers to form a vector of probabilities. This is the output of the network.



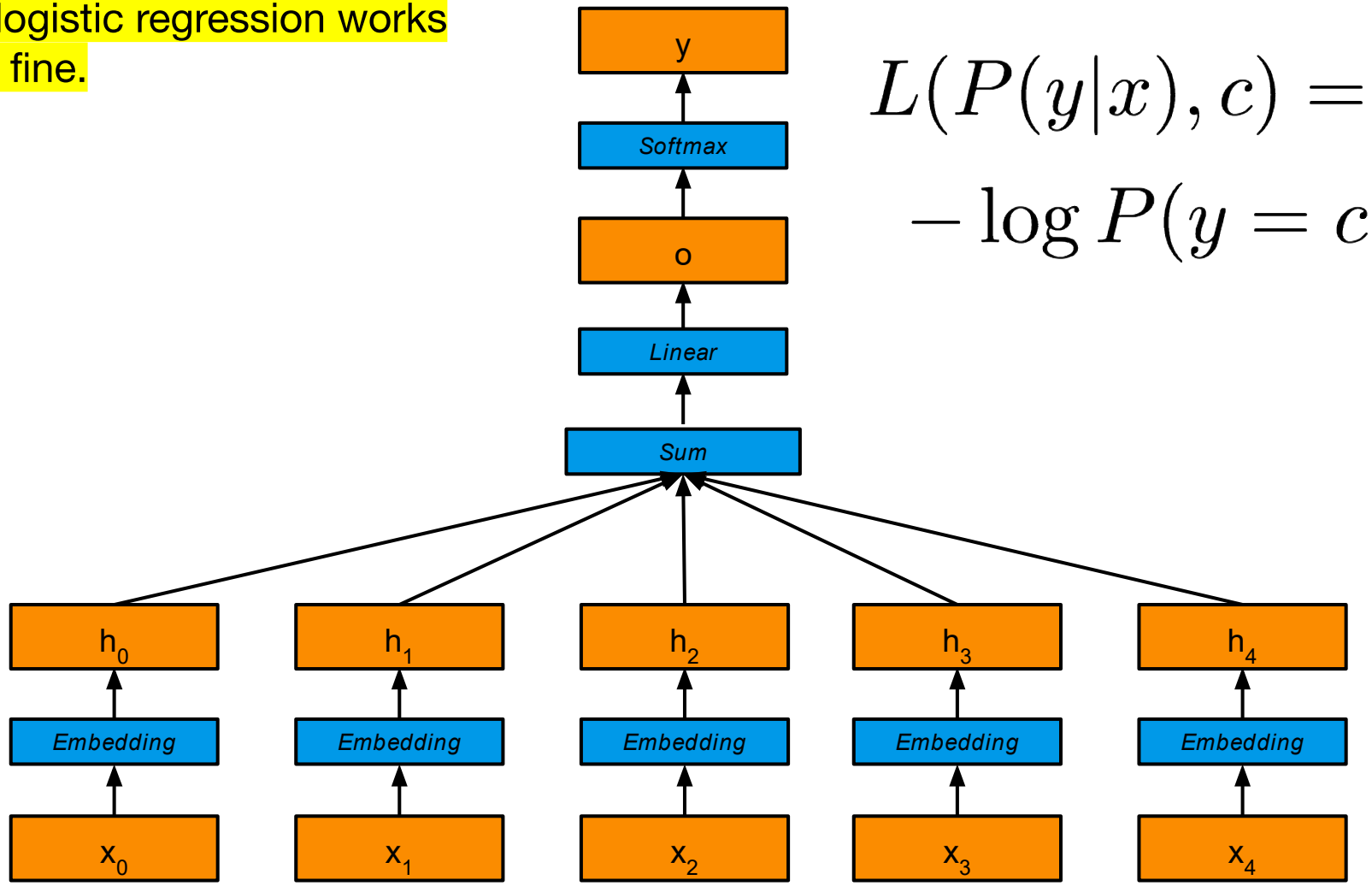
$$\vec{y}_i = \frac{e^{o_i}}{\sum_j^I e^{o_j}}$$

This combination of a linear layer and a softmax should look familiar. It's a different framing of the same math that we used for logistic regression!

...only now, the feature function is part of the model, and has its own parameters.



The *loss function* that we used for logistic regression works just fine.



$$L(P(y|x), c) = -\log P(y = c|x)$$

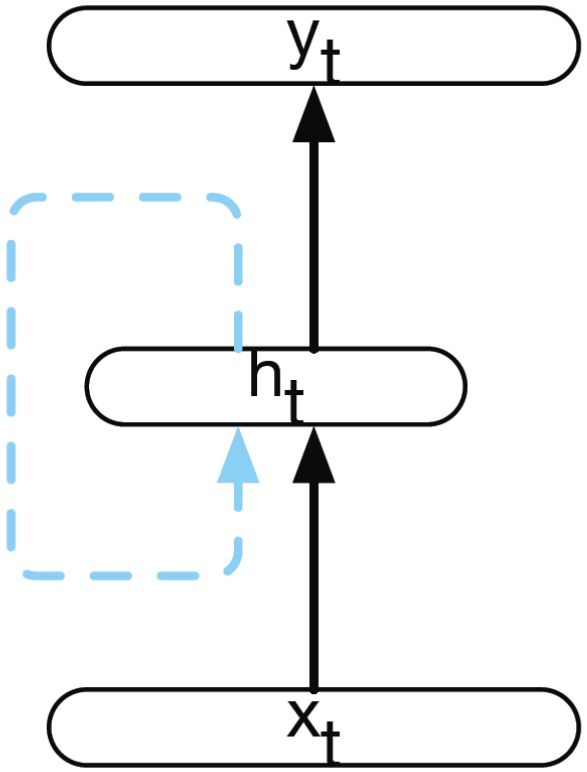
Word embedding

Word embedding

- Each word = a vector
- Similar words are "nearby in space"

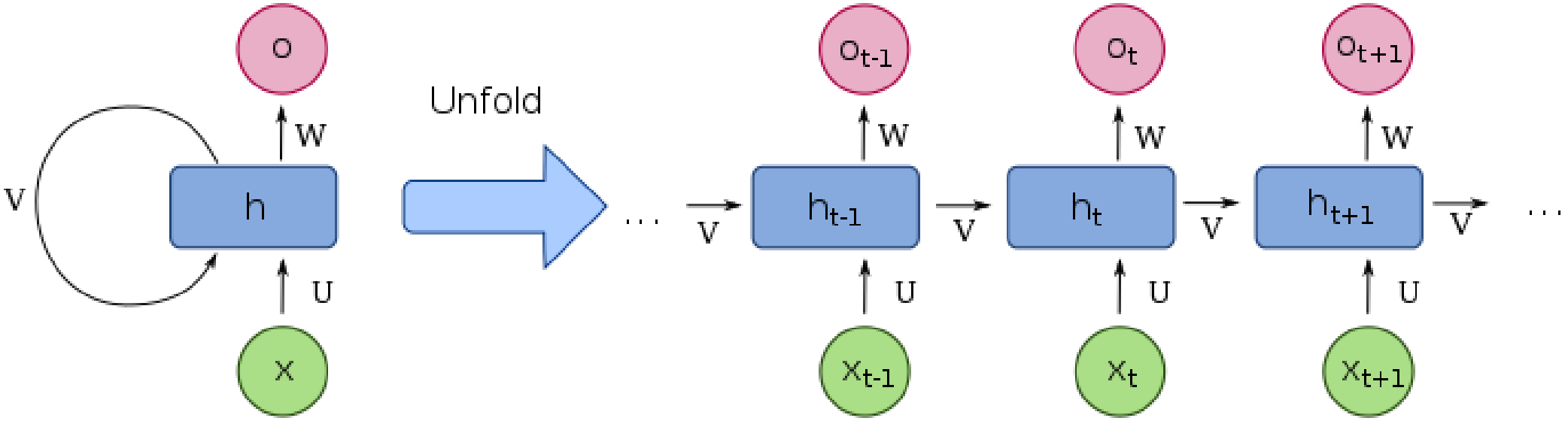
RNNs, attention, transformers

Recurrent Neural Networks (RNNs)

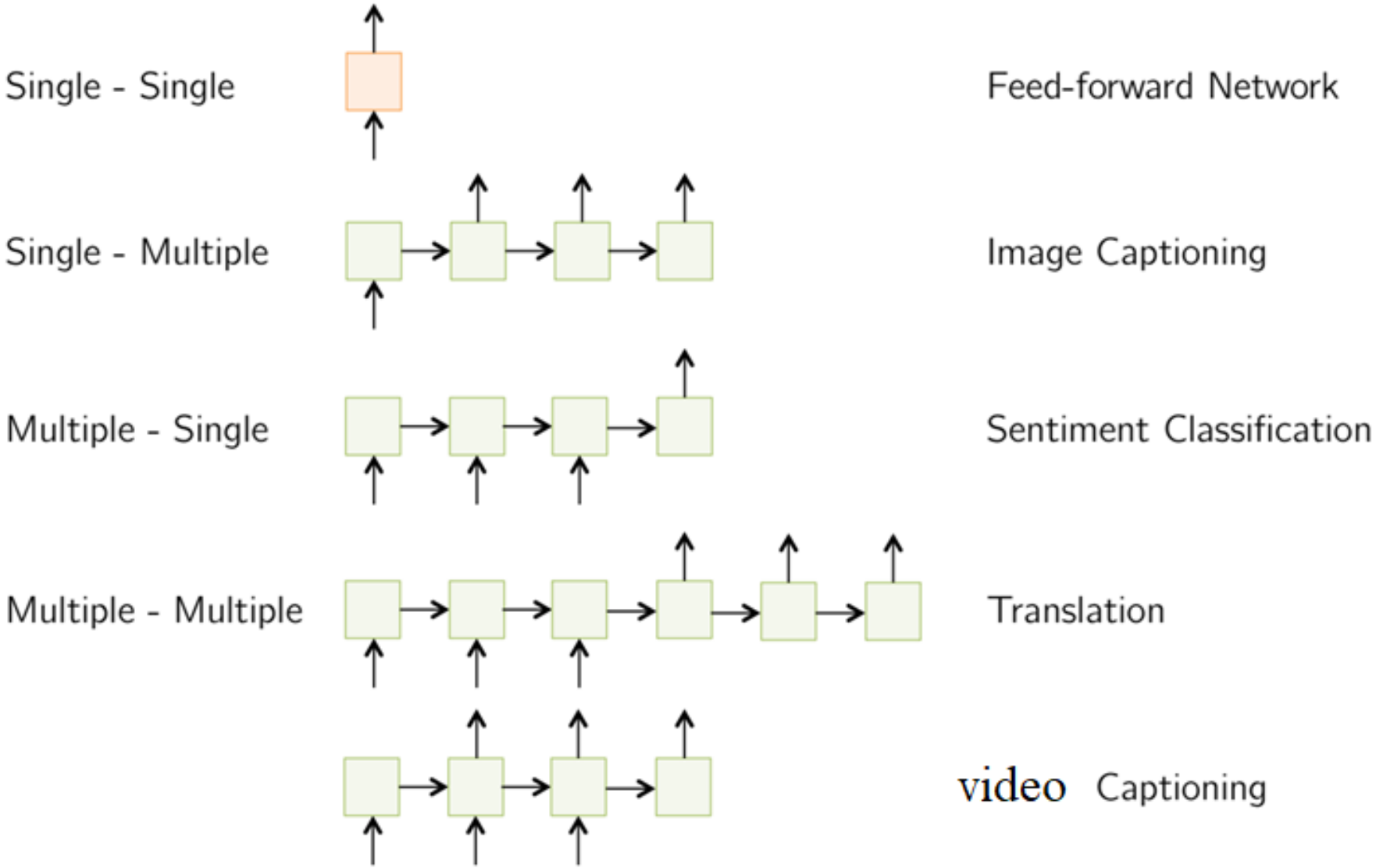


- RNNs take the previous output or hidden states as inputs!
  The composite input at time *t* has some historical
  information about the happenings at time T < *t*
- RNNs are useful as their intermediate values (state) can store information about past inputs for a time that is not
  fixed a priori

Recurrent Neural Networks (RNNs)



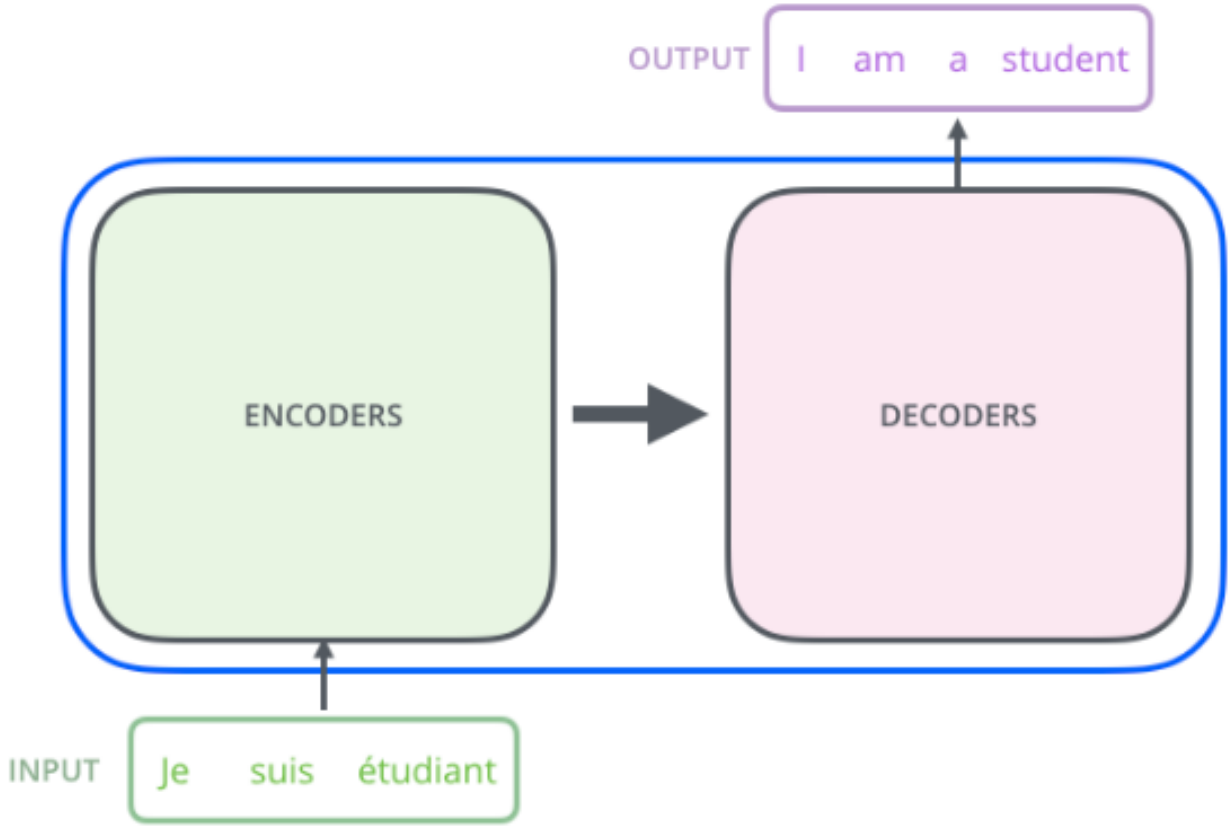
RNNs applications



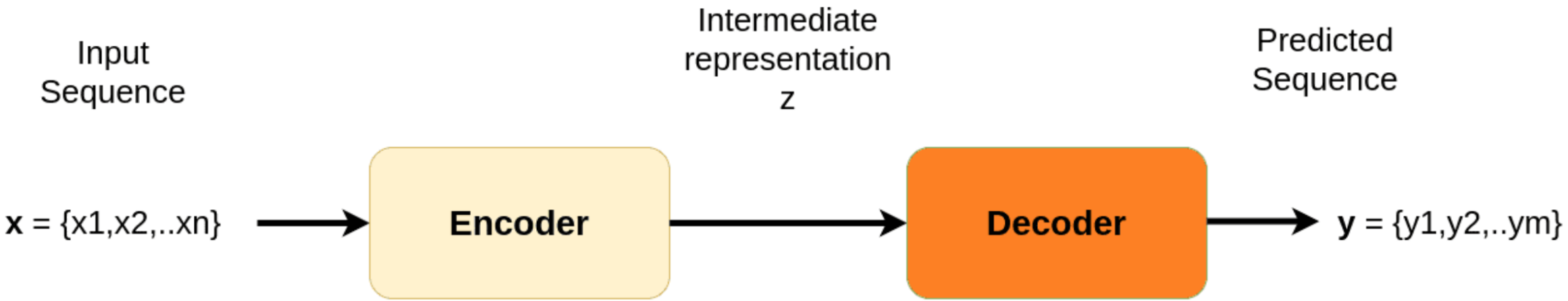
Encoder-decoder networks

- Used in a wide range of applications including machine translation, summarization, question answering, and dialogue modeling.

- RNNs were the most widely-used and successful architecture for both the encoder and decoder.

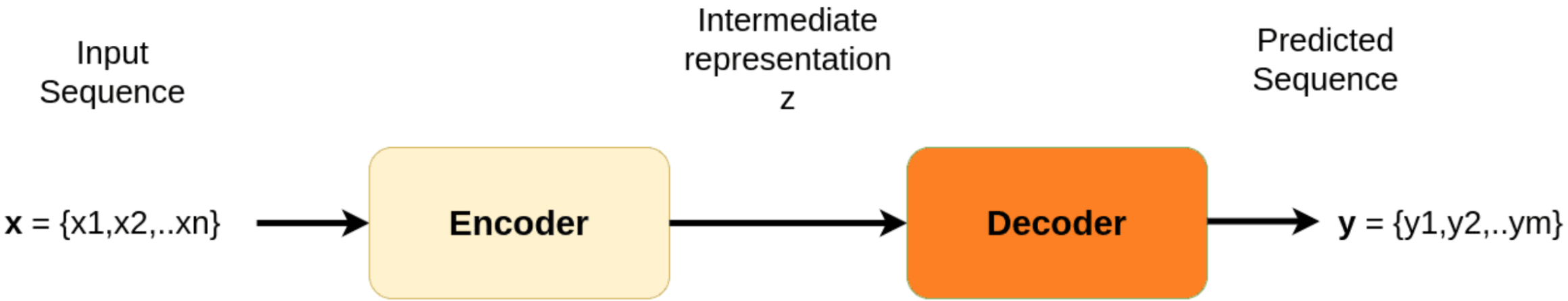


Encoder-decoder: seq2seq

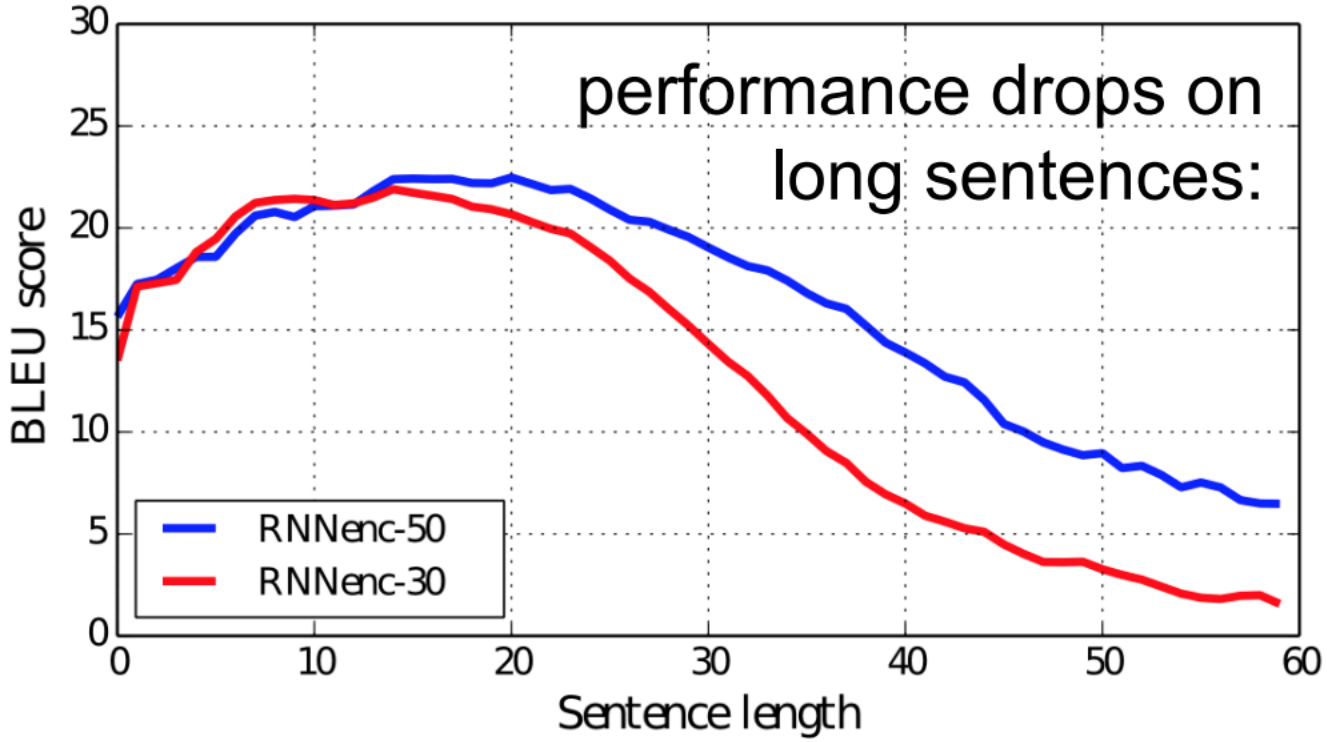


https://theaisummer.com/attention/

What if sequence length is high (say > 30)?



The vector z needs to capture all the information about the source sentence.

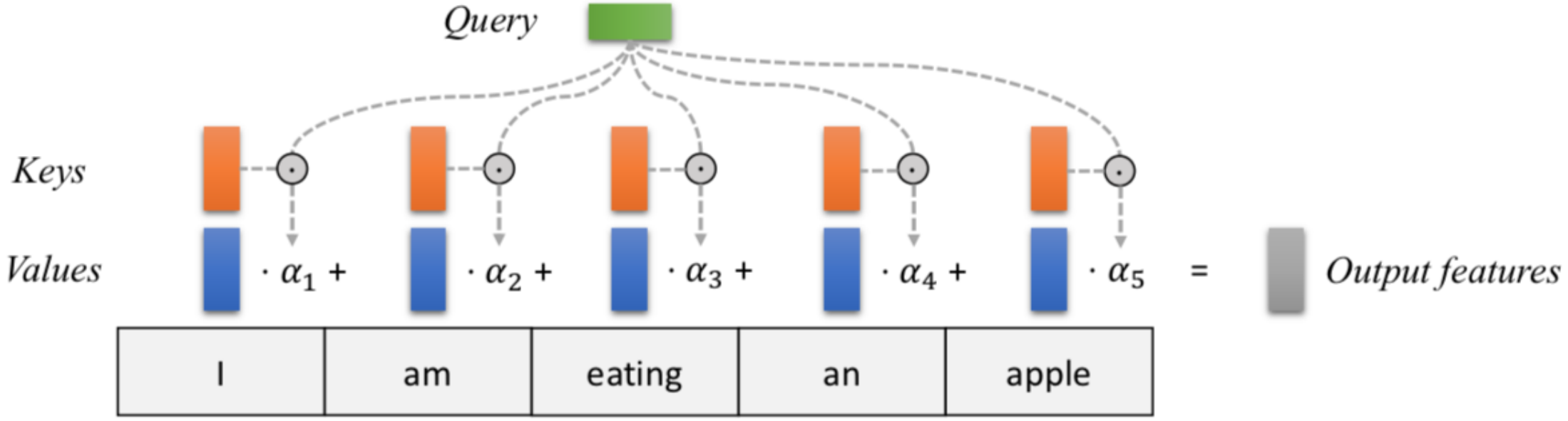


fixed size representation can be the bottleneck

The core idea of **attention** is that the context vector ***z*** should have access to **all** parts of the input sequence instead of just the last one.

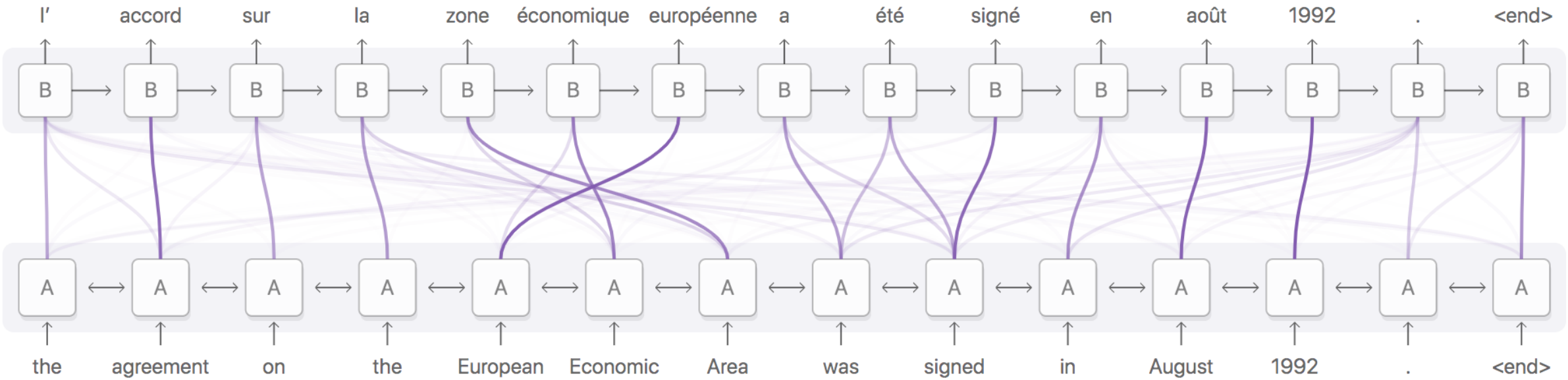
Attention

- A weighted average of (sequence) elements with the weights depending on an input query.
- The idea and the name taken from the intuition that humans attend to certain things at each time.



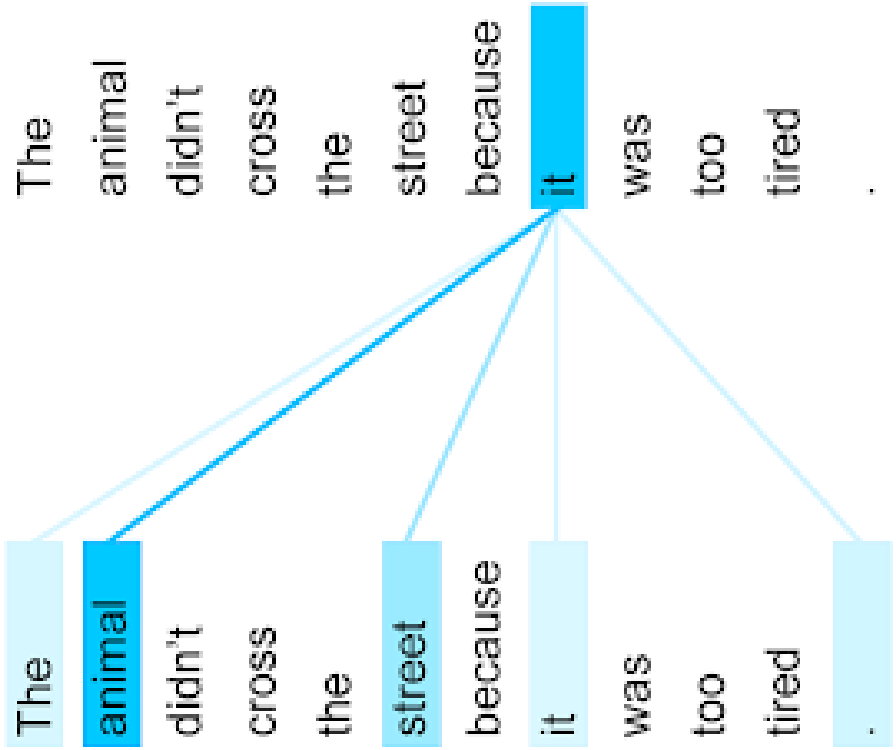
α_i are data-dependent dynamic weights

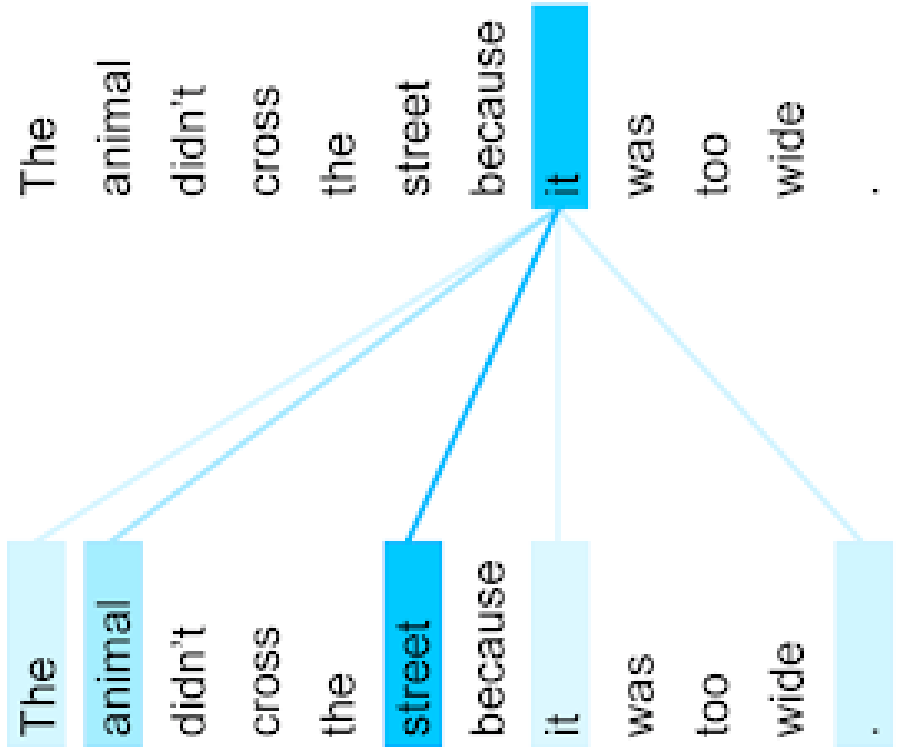
MT


l' accord sur la zone économique européenne a été signé en août 1992 . <end>
B B B B B B B B B B B B B B B B
A A A A A A A A A A A A A A A A
the agreement on the European Economic Area was signed in August 1992 . <end>

Self-Attention

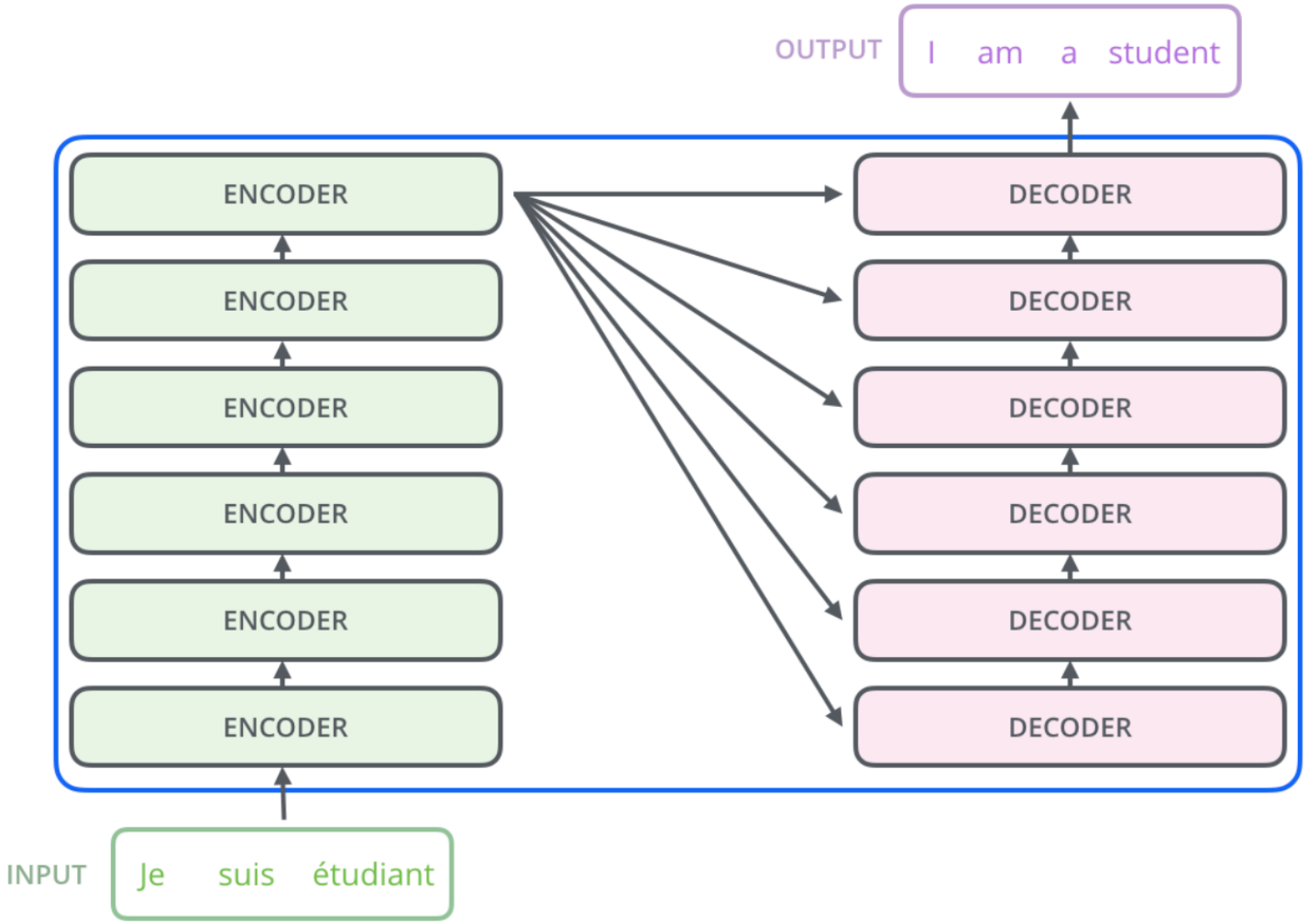
- For each word, self-attention allows the model to look at other positions in the input for a better encoding for this word.





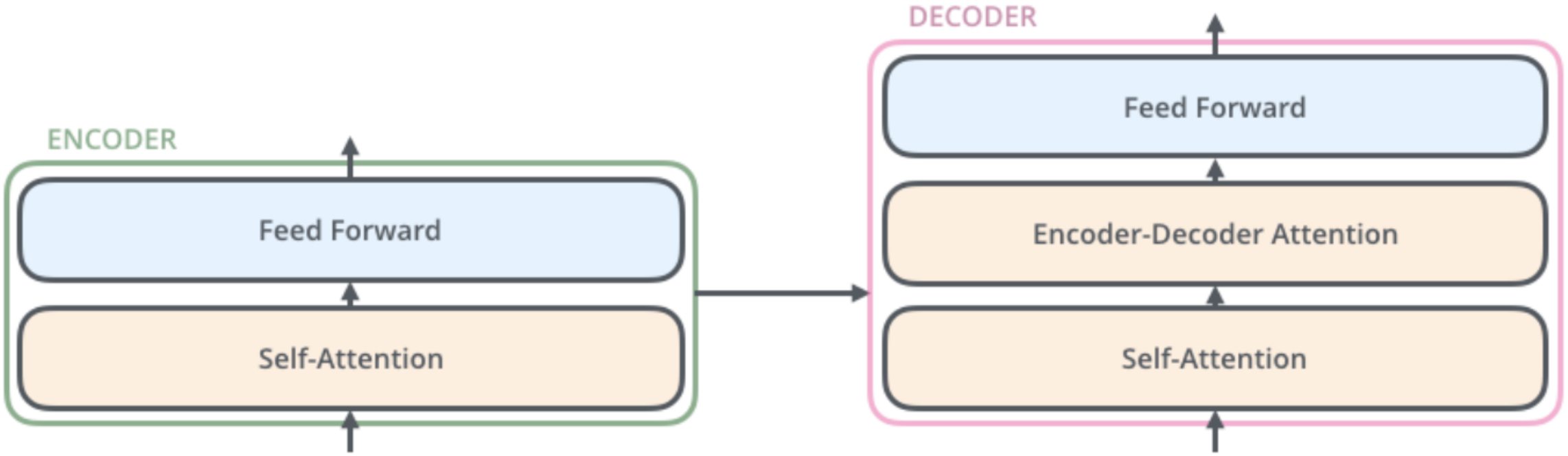
Transformer

Transformer Model



http://jalammar.github.io/illustrated-transformer/

Transformer Model



http://jalammar.github.io/illustrated-transformer/

Transformer model

- Non-recurrent sequence to sequence encoder-decoder model
  - Eliminate recurrence, allows for significantly more parallelization
- Three kinds of attentions:
  - The input and output tokens (solved by traditional attention mechanism)
  - The input tokens themselves
  - The output tokens themselves
- Extend the (self-)attention mechanism to processing input and output sentences as well.