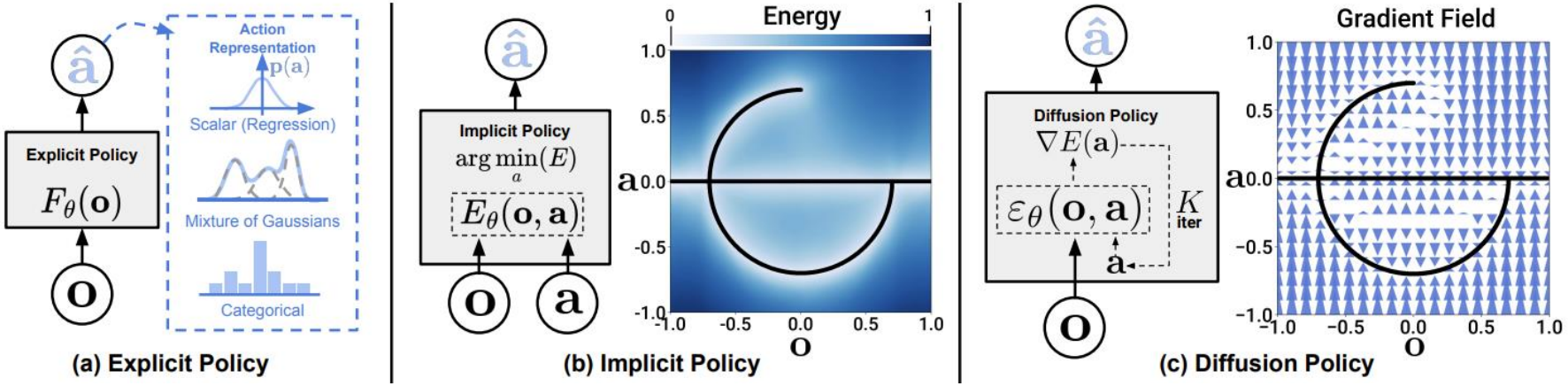
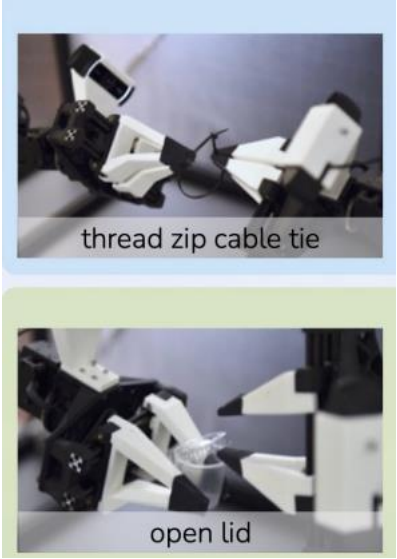
Advanced Behavioral Cloning

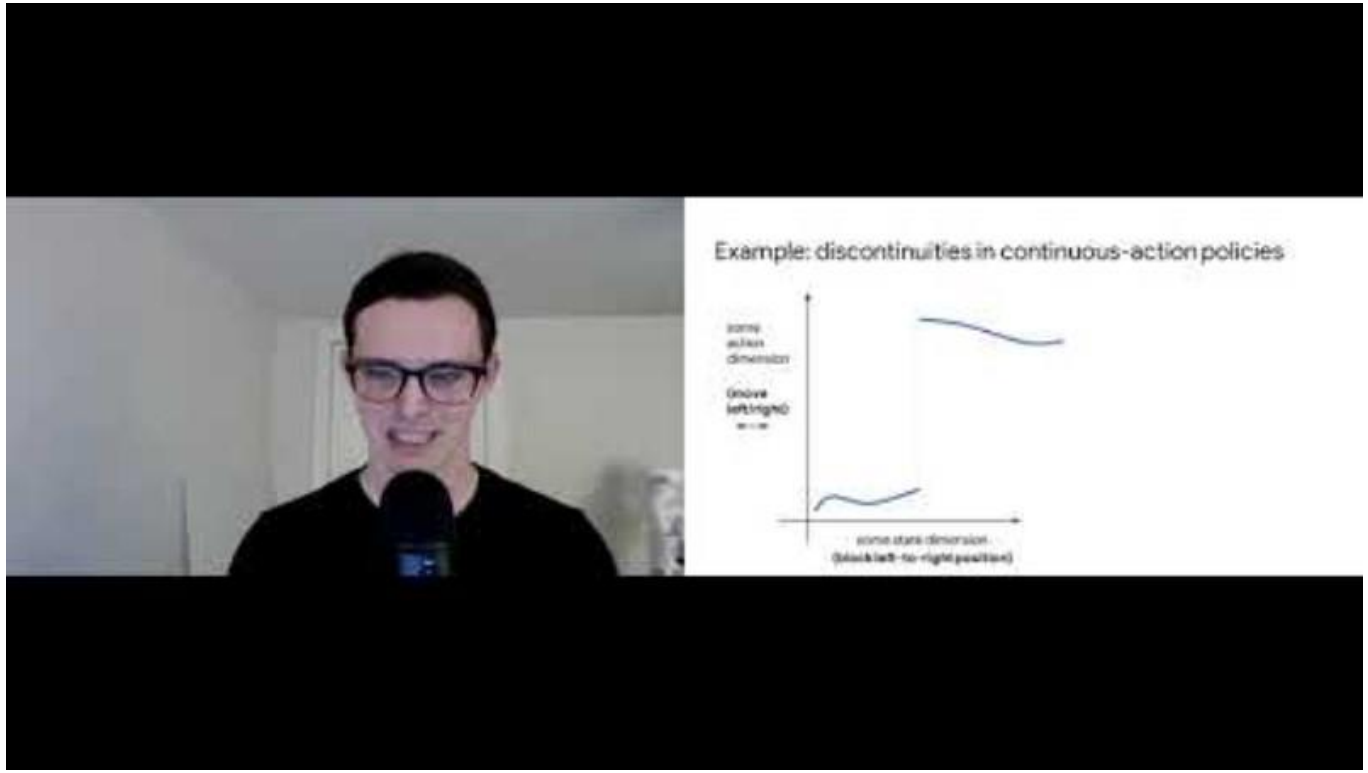




Instructor: Daniel Brown

Implicit Behavioral Cloning

- Paper: https://arxiv.org/abs/2109.00137
- Video: https://www.youtube.com/watch?v=QslGqRUSRzs

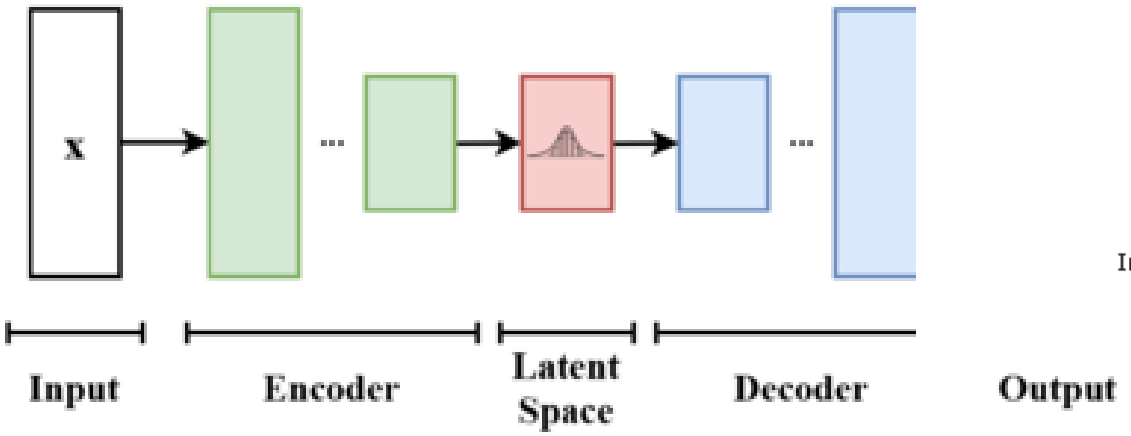


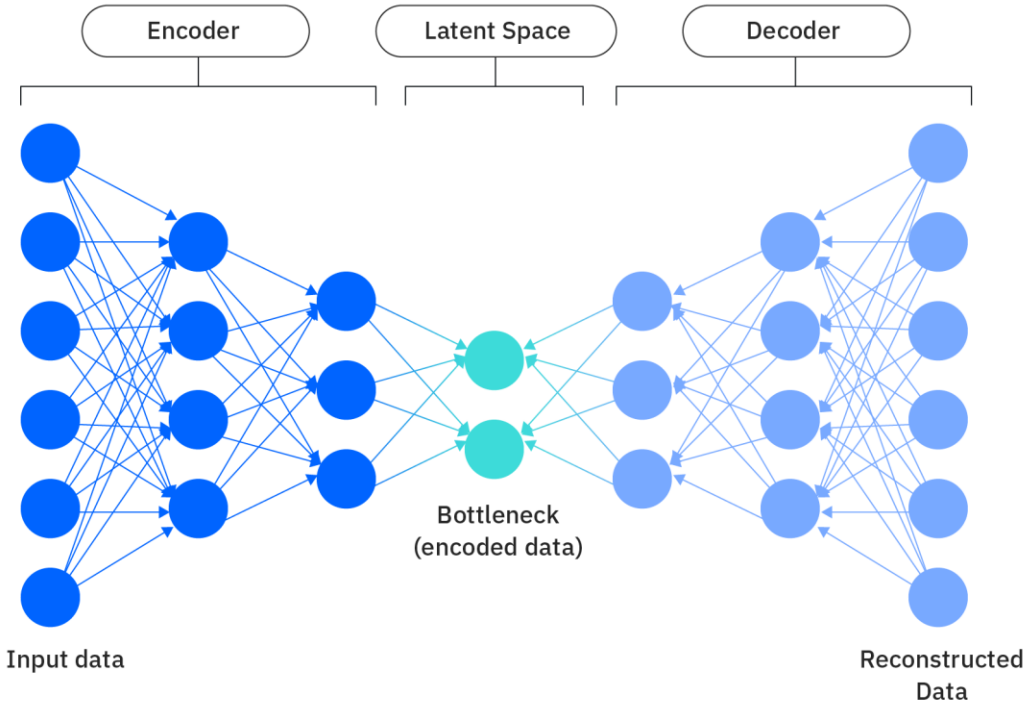
Action Chunking with Transformers (ACT)

- Paper: https://arxiv.org/pdf/2304.13705
- Videos: https://tonyzhaozh.github.io/aloha/

Variational Autoencoders (VAEs)

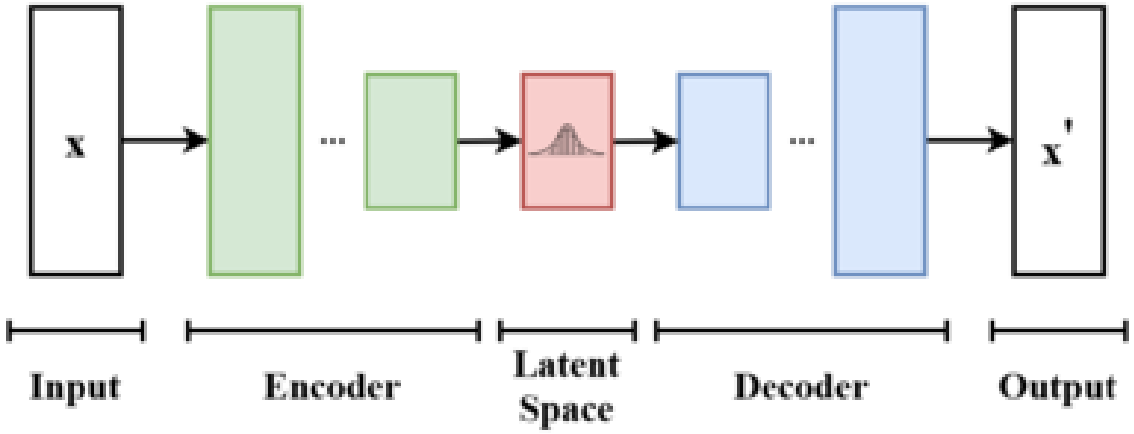
- Autoencoders learn latent representations





Variational Autoencoders (VAEs)

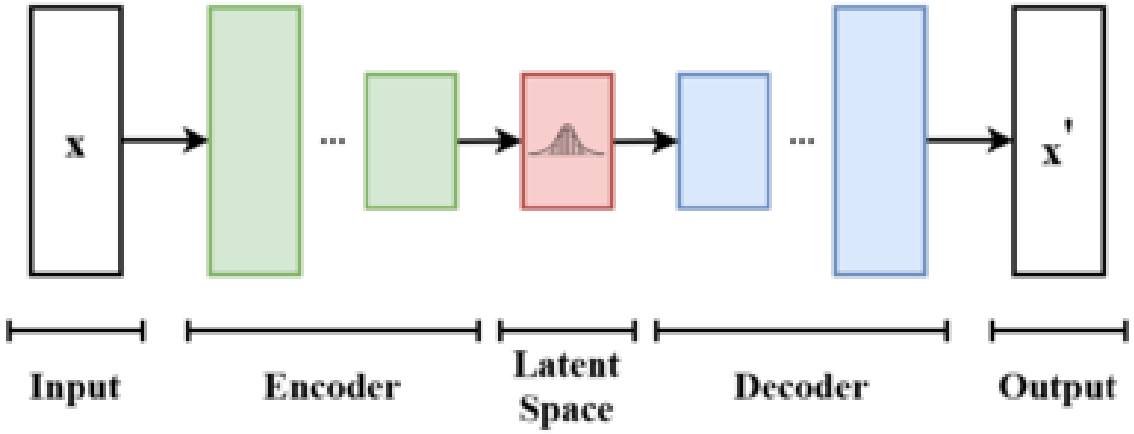
- Autoencoders learn latent representations
- VAEs map input into a distribution over latent variables z
- Loss function is reconstruction plus KL divergence



$$\mathcal{L} = \mathbb{E}_{q(z|x)}[\log p(x|z)] - D_{\mathrm{KL}}(q(z|x)||p(z))$$

Conditional Variational Autoencoders (CVAEs)

- Encoder and decodre both condition on extra info y



- Loss function is reconstruction plus KL divergence

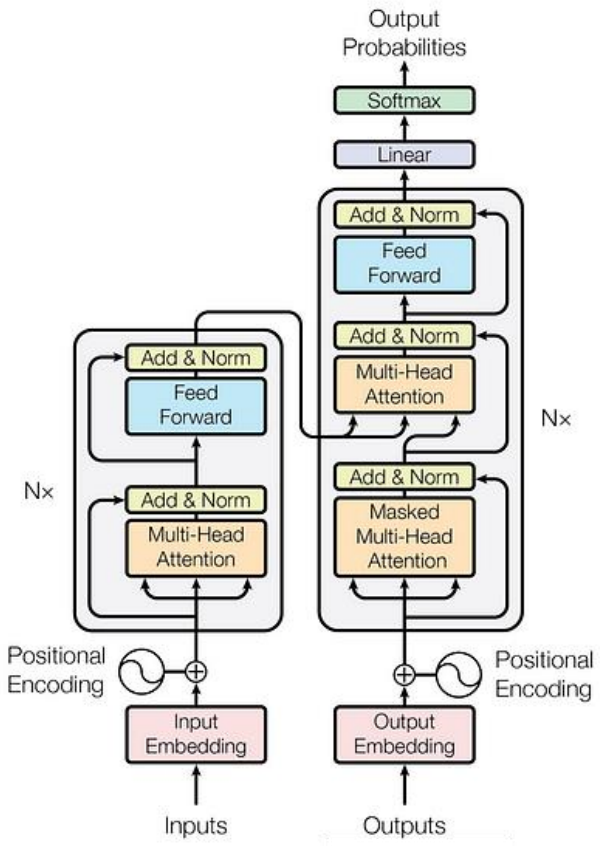
$$\mathcal{L} = \mathbb{E}_{q(z|x,y)}[\log p(x|z,y)] - D_{\mathrm{KL}}(q(z|x,y)||p(z|y))$$

Transformers

- State of the art ways to ingest and output sequential data.

BERT

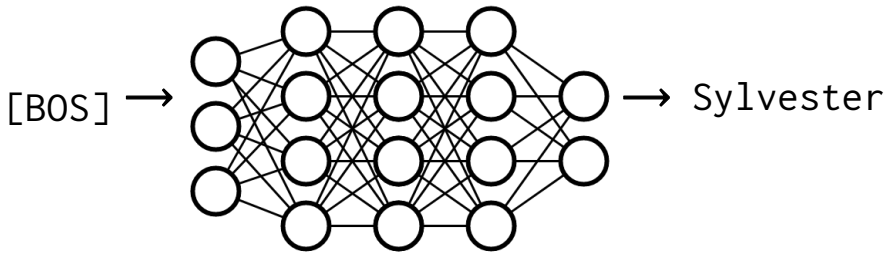
Encoder



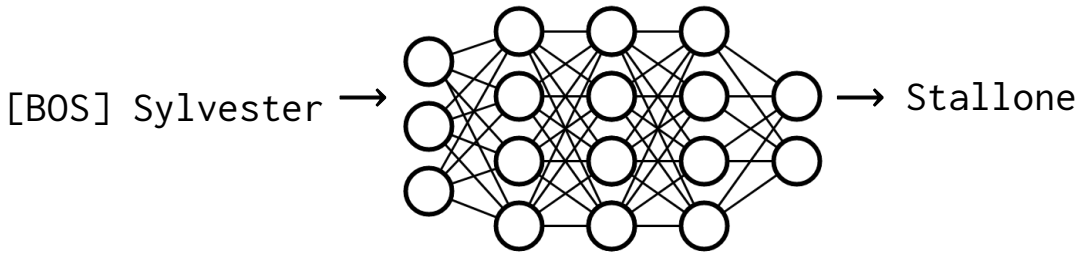
GPT

Decoder

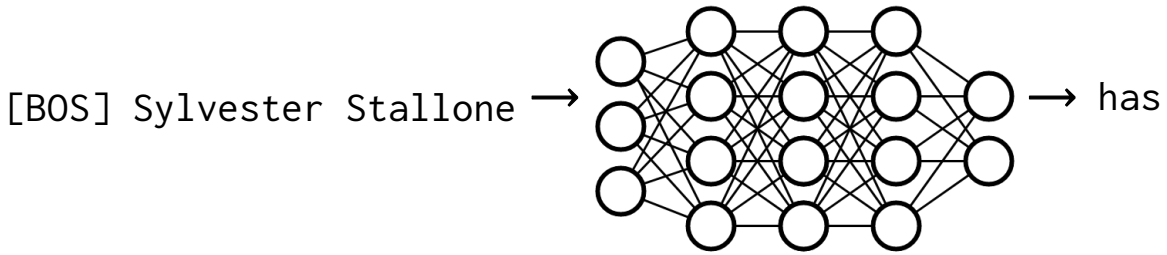
Neural language modeling



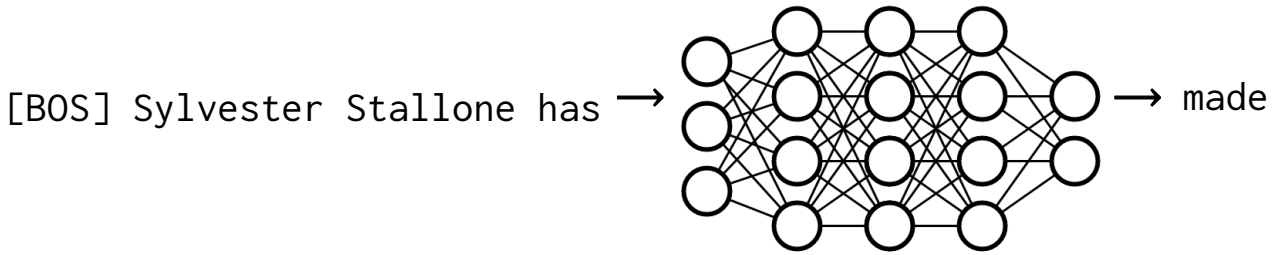
Neural language modeling

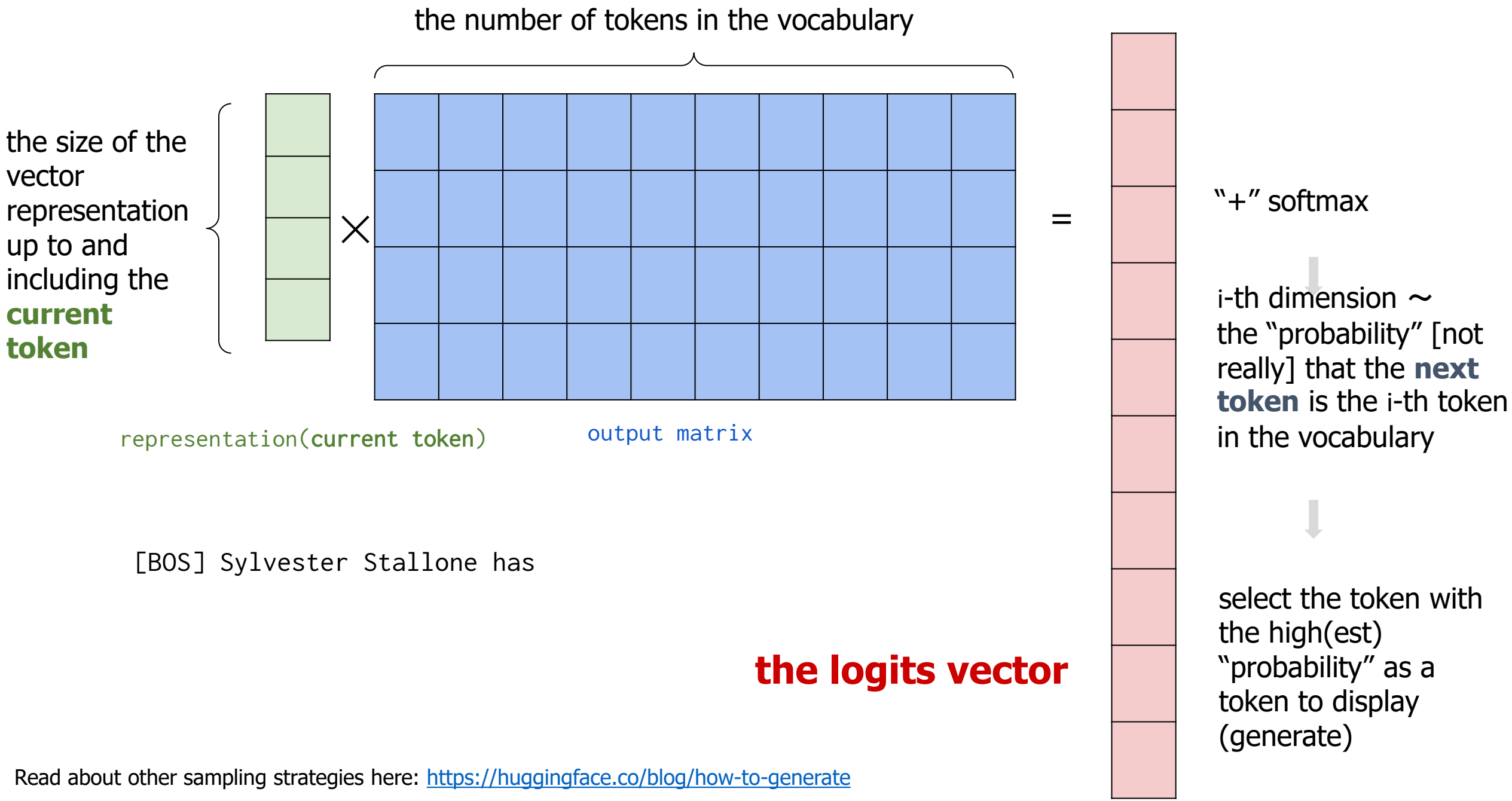


Neural language modeling



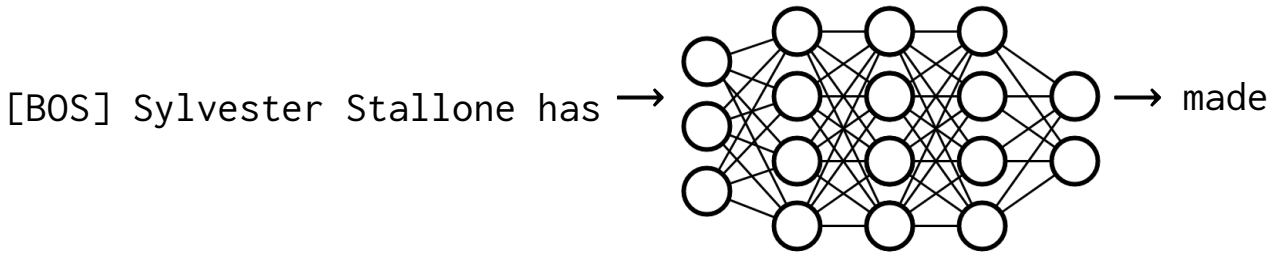
Neural language modeling





Read about other sampling strategies here: https://huggingface.co/blog/how-to-generate

Neural sequence modeling

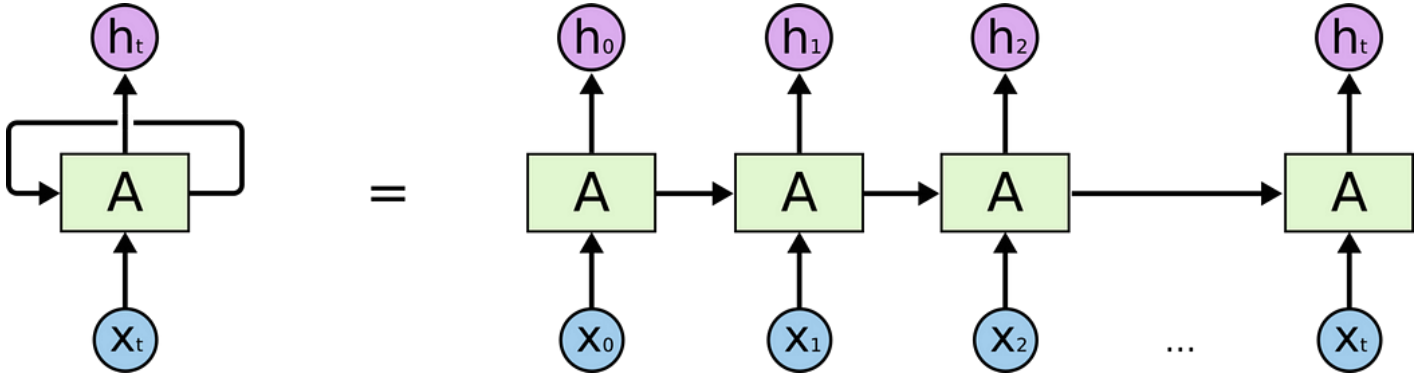


Problems:

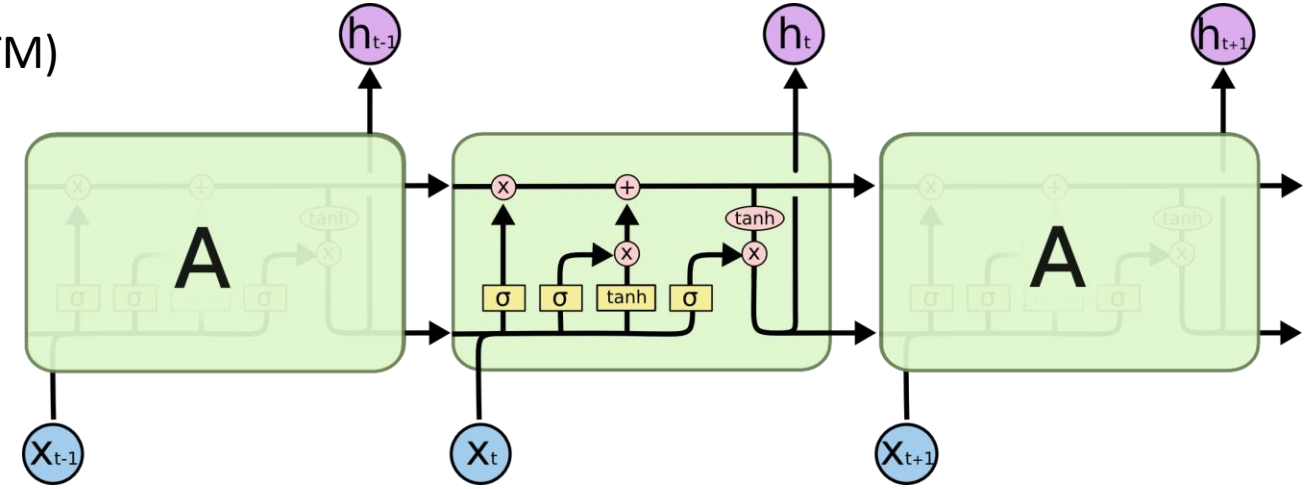
- How do we deal with different length inputs?
- How do we model long-range dependencies?

Recurrent Neural Networks

- Standard RNN

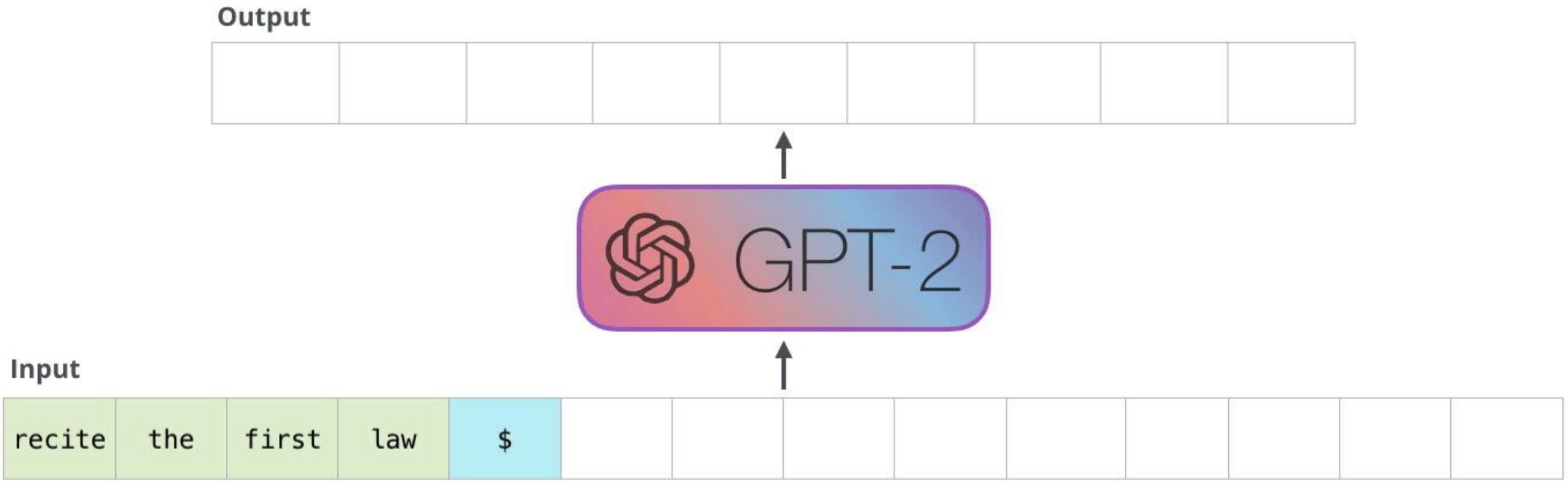


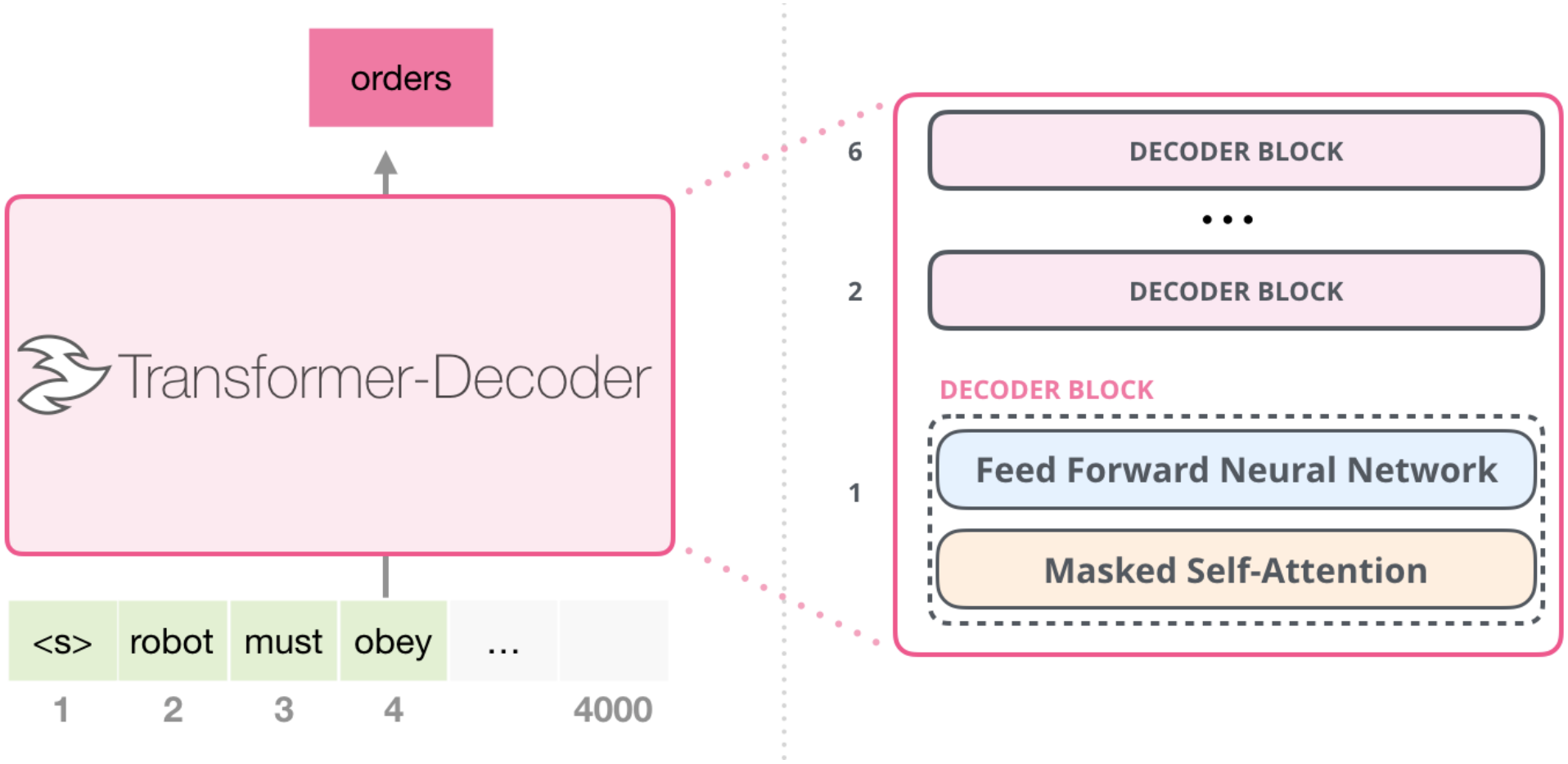
- Long short-term memory (LSTM)

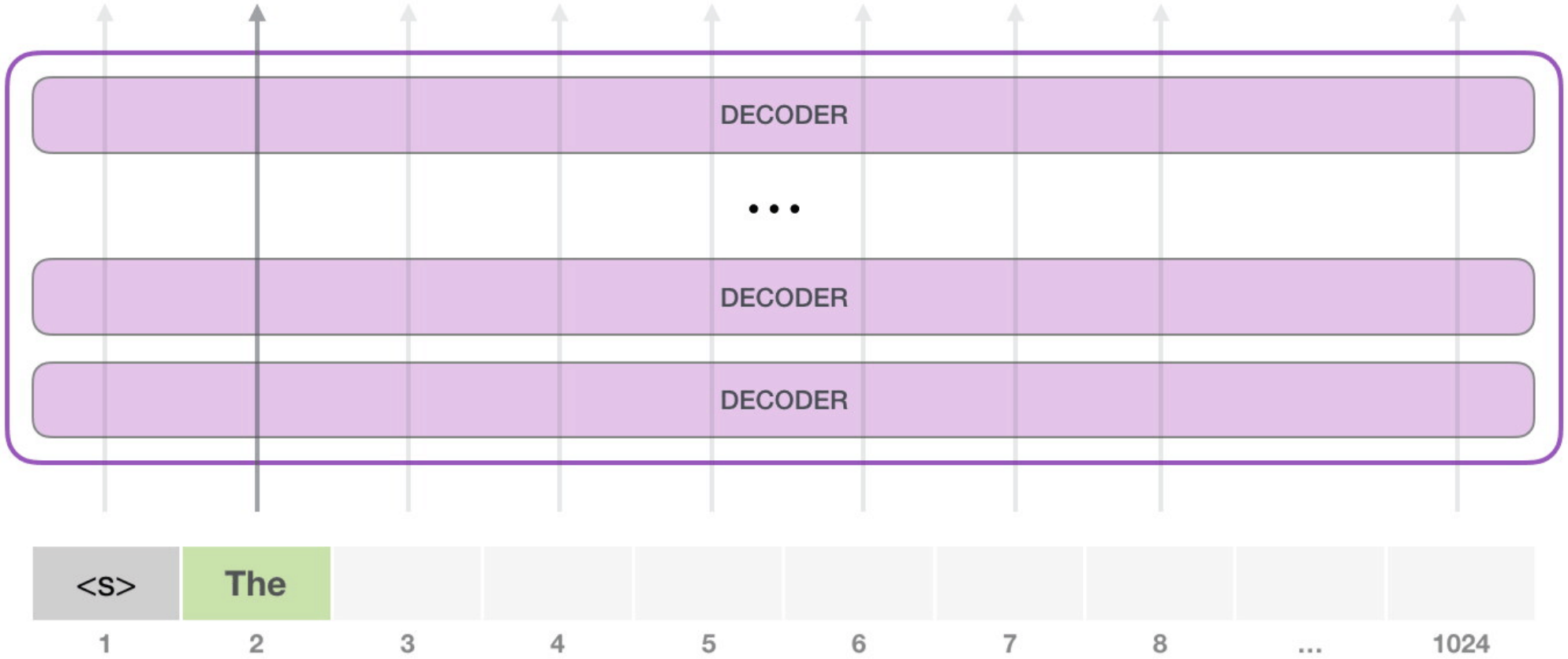


https://colah.github.io/posts/2015-08-Understanding-LSTMs/

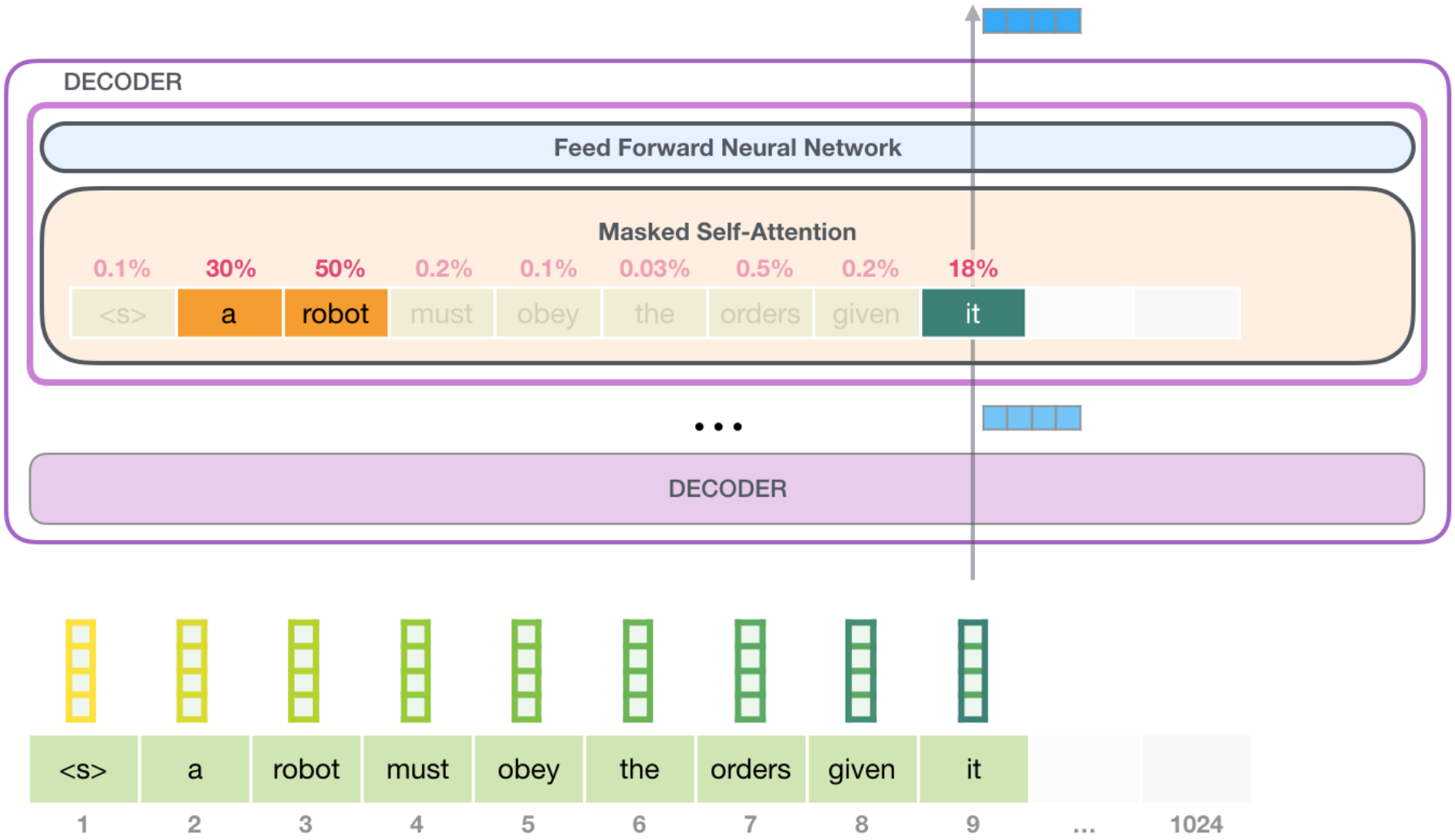
Large Language Models

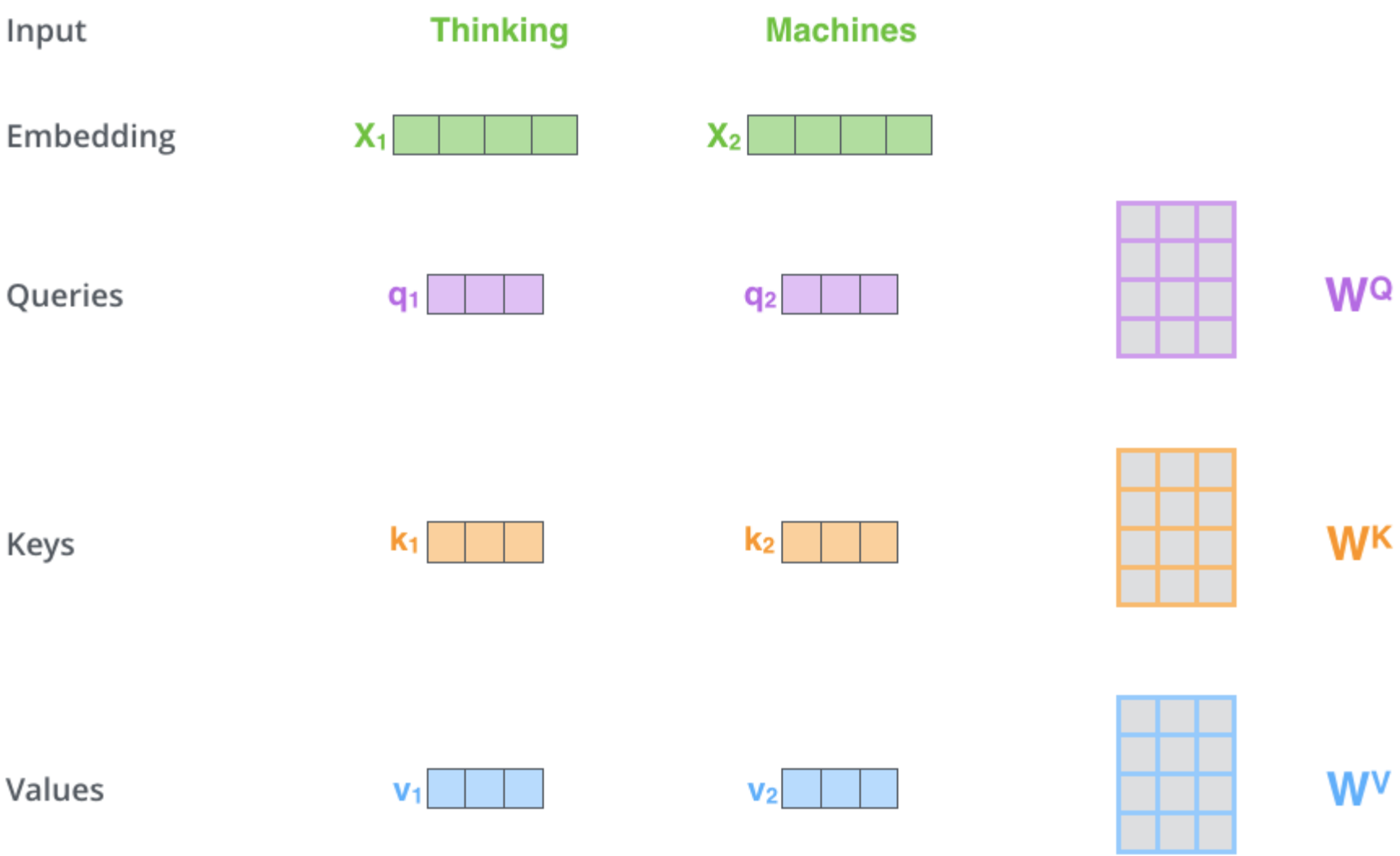



orders
Transformer-Decoder
<s>
robot
must
obey
...
1
2
3
4
4000
6
DECODER BLOCK
2
DECODER BLOCK
DECODER BLOCK
1
Feed Forward Neural Network
Masked Self-Attention

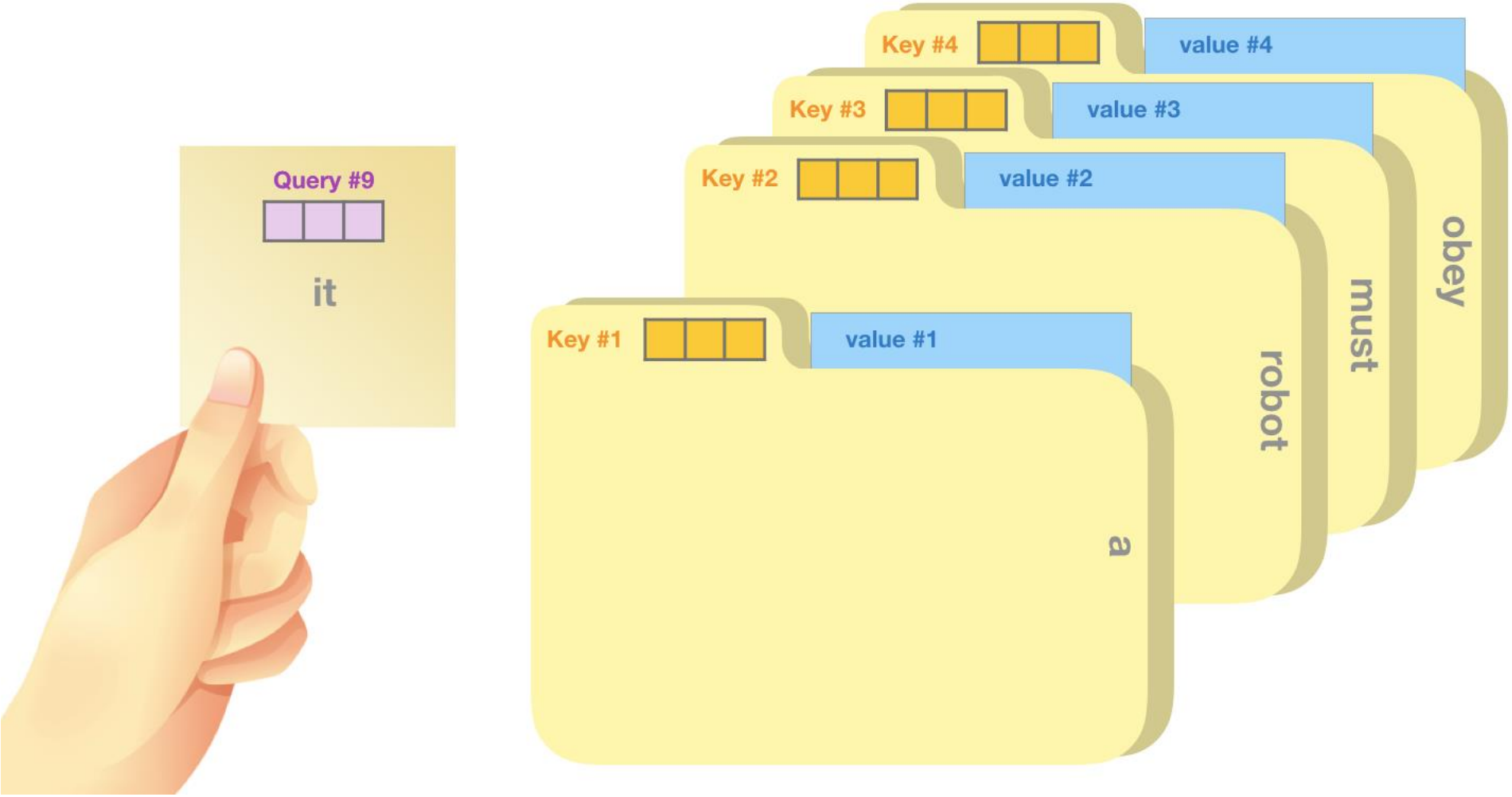

DECODER
• • •
DECODER
DECODER
<s>
The
1
2
3
4
5
6
7
8
...
1024


DECODER
...
DECODER
=
Positional encoding for token #1
+
Token embedding of <s>
<s>
1
2
...
1024
Token Embeddings
Positional Encodings

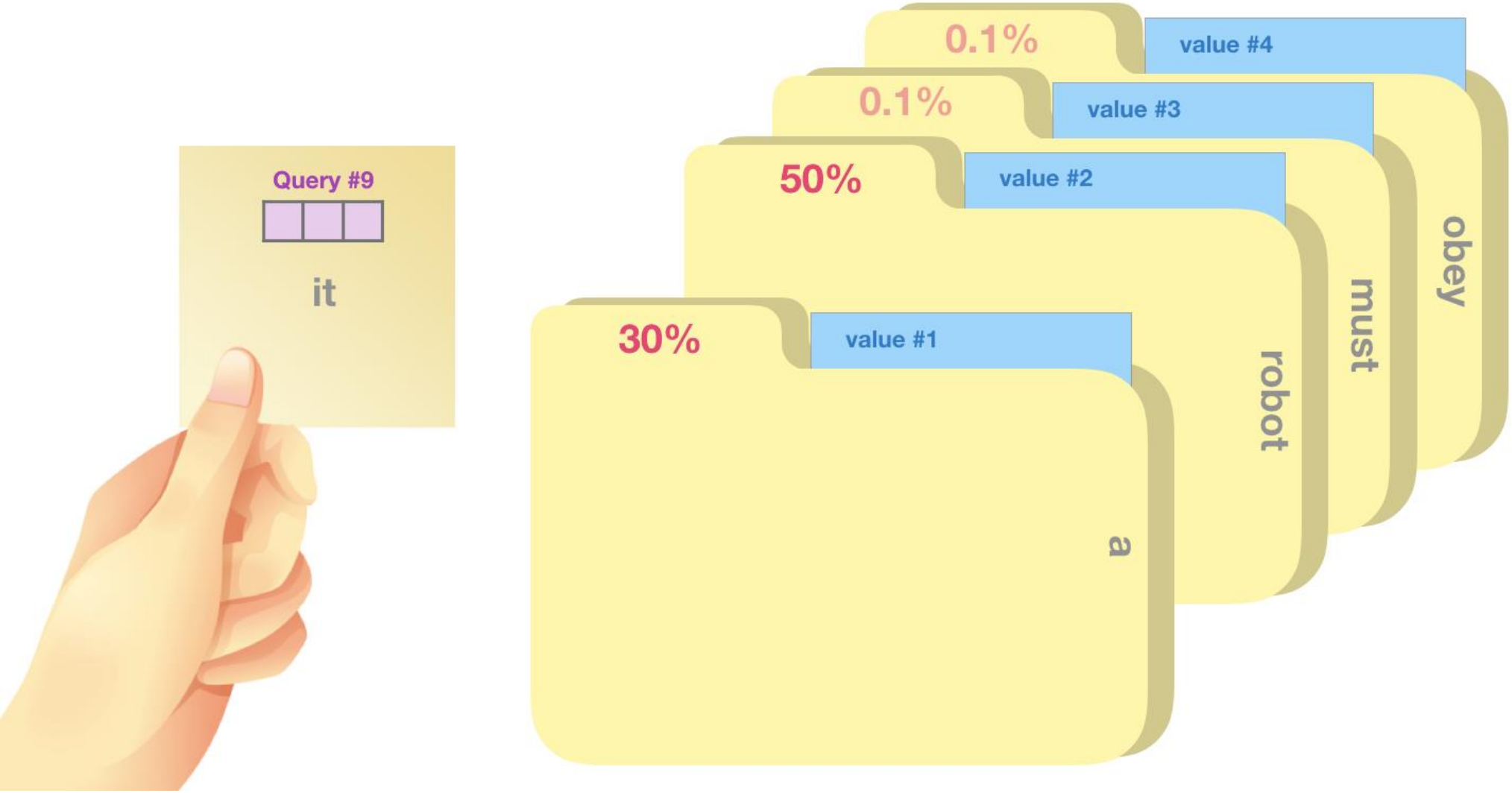

DECODER
Feed Forward Neural Network
Masked Self-Attention
0.1%
30%
50%
0.2%
0.1%
0.03%
0.5%
0.2%
18%
<s>
a
robot
must
obey
the
orders
given
it
DECODER
<s>
a
robot
must
obey
the
orders
given
it
1
2
3
4
5
6
7
8
9
...
1024


Input
Thinking
Machines
Embedding
X1
X2
Queries
q1
q2
WQ
Keys
k1
k2
WK
Values
v1
v2
WV

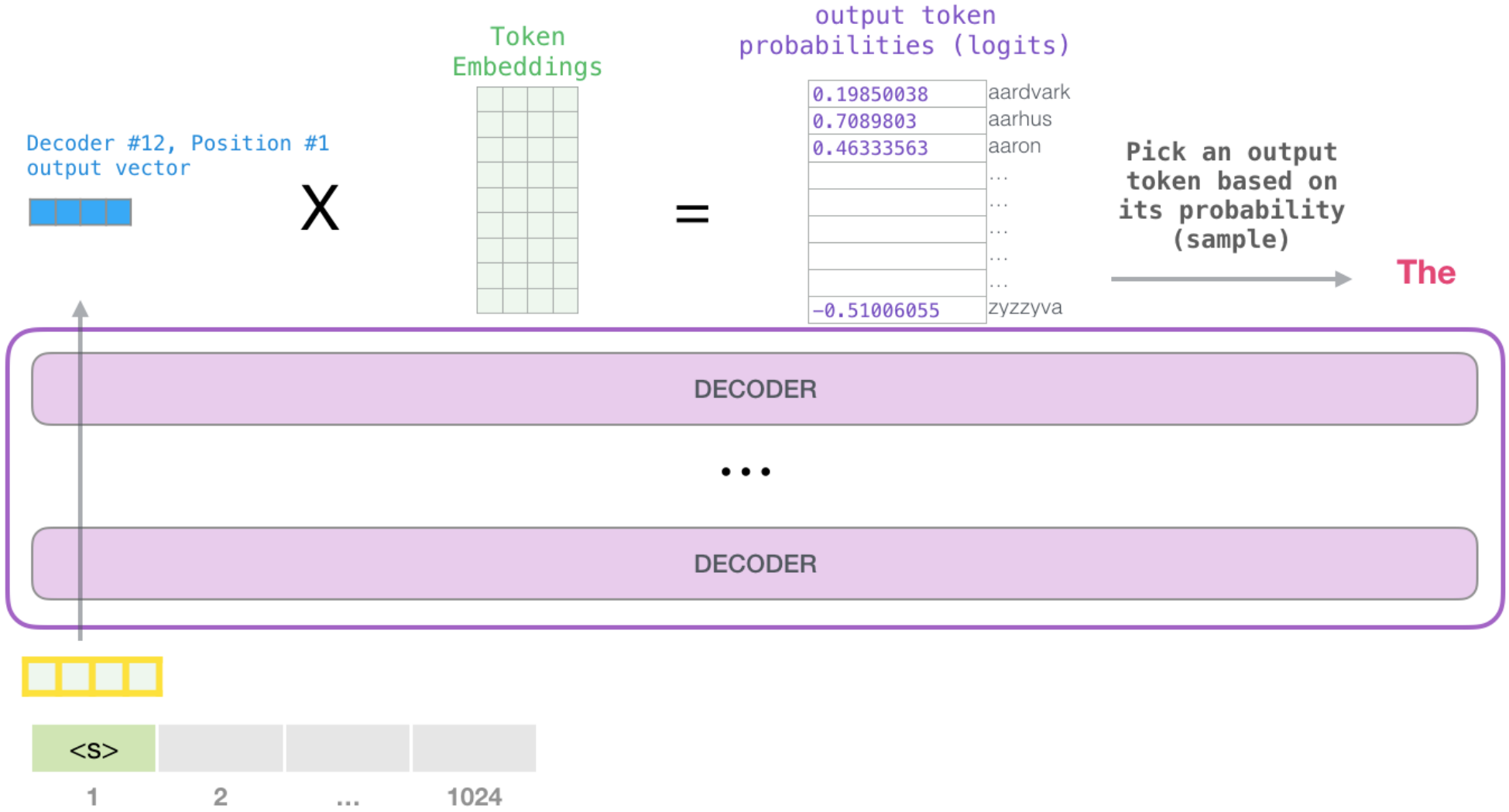
Perform dot product between query and all keys to get a raw score for each previous word (including current word).

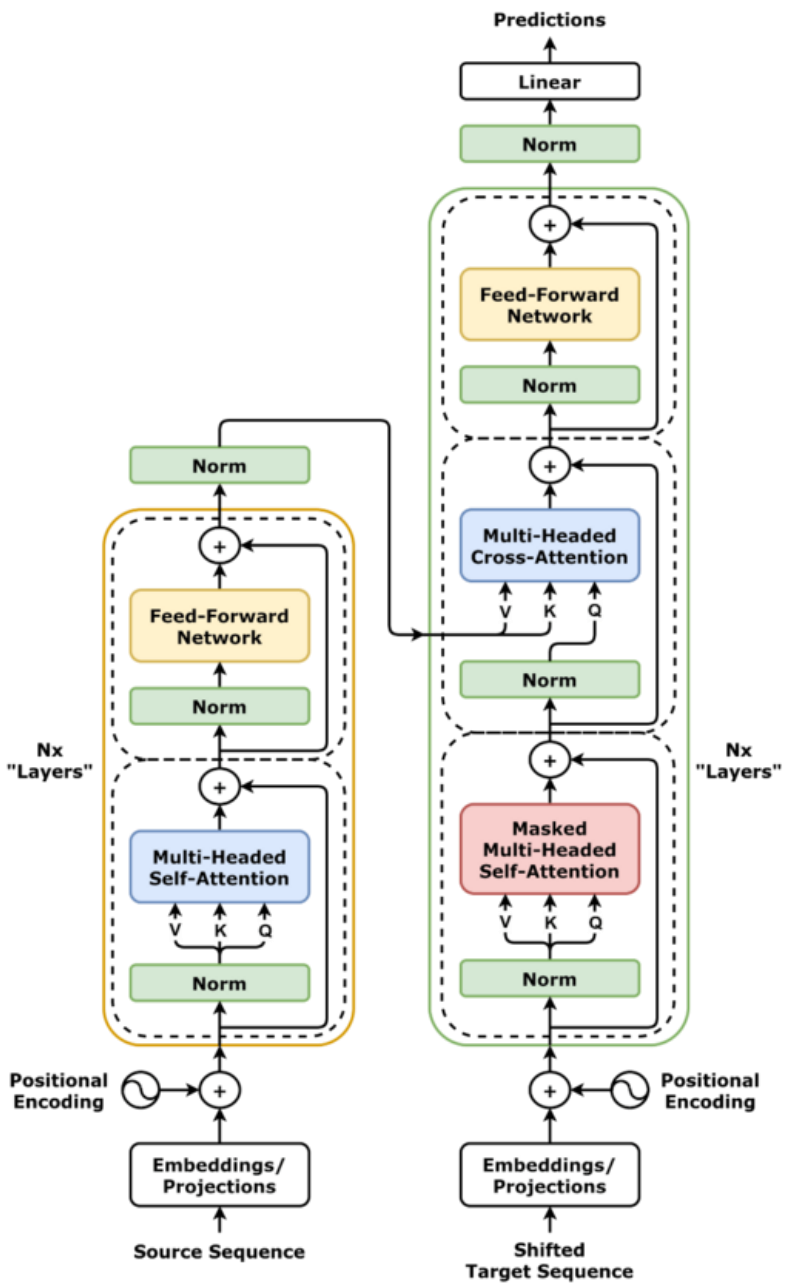


Normalize these scores via a softmax to get a probability distribution. Then return a weighted sum of the values.



Word	Value vector	Score	Value X Score
<s>		0.001	
a		0.3	
robot		0.5	
must		0.002	
obey		0.001	
the		0.0003	
orders		0.005	
given		0.002	
it		0.19	
		Sum:	


Decoder #12, Position #1
output vector
X
Token
Embeddings
=
output token
probabilities (logits)
0.19850038
0.7089803
0.46333563
-0.51006055
aardvark
aarhus
aaron
...
zyzzyva
Pick an output
token based on
its probability
(sample)
The
DECODER
...
DECODER
<s>
1
2
...
1024


Predictions
Linear
Norm
Feed-Forward Network
Norm
Multi-Headed Cross-Attention
V K Q
Norm
Masked Multi-Headed Self-Attention
V K Q
Norm
Nx "Layers"
Positional Encoding
Embeddings/ Projections
Shifted Target Sequence
Norm
Feed-Forward Network
Norm
Multi-Headed Self-Attention
V K Q
Norm
Nx "Layers"
Positional Encoding
Embeddings/ Projections
Source Sequence

Diffusion Policy

- Paper: https://arxiv.org/pdf/2303.04137v4
- Videos: https://diffusion-policy.cs.columbia.edu/

Denoising Diffusion (high-level)