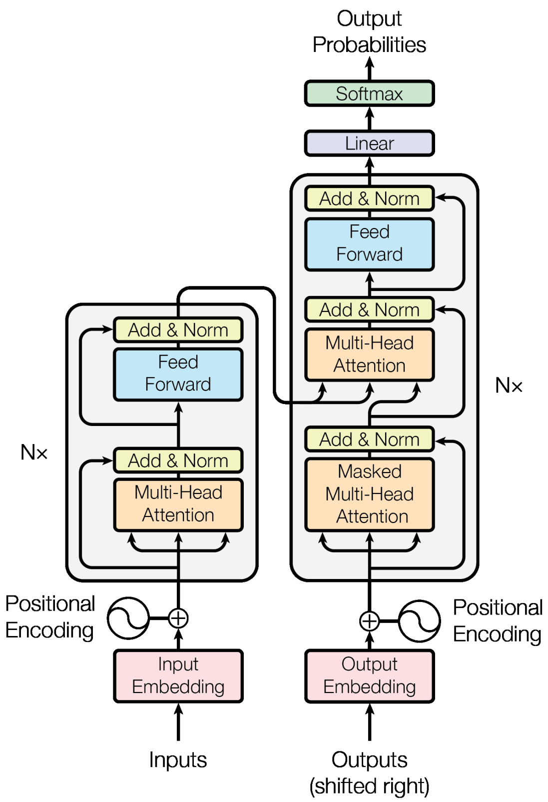
Transformer: Intuition

We try to briefly explain what each the "moving parts" of the Transformer is doing.

Transformer (Encoder/Decoder)



General

Each of the paths in the Transformer is a vector of length d_{model}

- sometimes just referred to as d

Having a common length simplifies the architecture

- can stack Transformer blocks (since input and output are same size)
- Self-Attention and Cross-Attention:
    - map a query of size d to an output of size d
- Needed for the Residual Connection (Add and Norm)
    - adding the input of Attention to the output of Attention
        - need to be same length

Residual connections

- Residual connections from Intro course (RNN_Residual_Networks.ipynb)

Encoder

The Encoder style Transformer can either be used

- stand-alone: create a fixed length, alternate length representation of the input
    - for further processing: e.g., Classification
- as part of an Encoder-Decoder architecture
    - transform the Input sequence $\mathbf{x}$ in a *processed sequence* $\bar{\mathbf{h}}_{(1)}, \ldots, \bar{\mathbf{h}}_{(\bar{T})}$
    - to be consumed by a Decoder

Encoder Self-Attention

The Self-Attention allows each $\bar{\mathbf{h}}_{(\bar{t})}$ to depend on the **complete** input sequence $\mathbf{x}$.

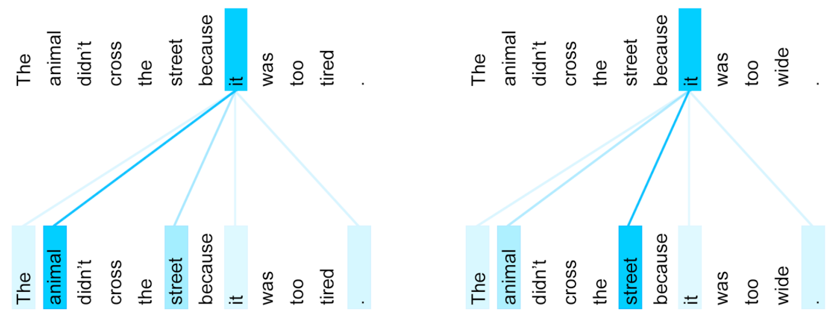
If we view $\bar{\mathbf{h}}_{(\bar{t})}$ as the "meaning" of $\mathbf{x}_{(t)}$

- it is a meaning based on the *full context*
    - not just the preceding elements $\mathbf{x}_{(1:t-1)}$

By making the meaning dependent on the full context, we can disambiguate the meaning of the world "it"

Attention weights

Thickness of the blue lines indicate the strength of attention to other tokens



Picture from: https://1.bp.blogspot.com/-AVGK0ApREtk/WaiAuzddKVI/AAAAAAAAB_A/WPV5ropBU-cxrcMpqJBFHg73K9NX4vywwCLcBGAs/s1600/image2.png

Decoder

The salient characteristic of a Decoder style Transformer is the *autoregressive* behavior

- generates an output one token at a time
- by appending each generated token to the sequence of already-generated tokens

The Decoder style Transformer can either be used

- stand-alone: for generative tasks
- as part of an Encoder-Decoder architecture

Decoder Self-Attention

The input needs to decide why of the previously-generated Decoder outputs (now Decoder inputs) to attend to.

There are multiple potential uses for this

- to help generate the "next" token (goal of the Decoder), by referencing the partially complete Decoder output
- to help in the Cross Attention step
    - decide which part of the Inputs $\mathbf{x}$ (Decoder Outputs) to attend to
    - "looking up" facts, e.g., our Question Answering example or Language Translation example

Note the use of Causal Masking

- we can only reference the Decoder output already generated

Decoder-Encoder Cross-Attention

The output of the Decoder Self-Attention is used as a "query"

- to reference the relevant part of the Input $\mathbf{x}$

Feed Forward Network (FFN)

Maps the output of the Decoder-Encoder Attention into the "next output token".

- actually: it is still an embedding of the next token, rather than the true next token
    - that way: it can be appended to the already-generated output to become the Decoder input for next position

This acts as a Classifier

- mapping the input
- to a vector of logits
    - one element per possible element of the Output Vocabulary

There is some evidence that

- the parameters of the FFN are where "world knowledge" is stored
    - every "fact" learned during training

Linear

This layer is append *only* to the final block in the stacked Transformer blocks

- Projects the final block's output of length d
- to the length of the Vocabulary representation
    - a vector of length equal to number of elements of the Vocabulary
    - logits
        - to be converted into probability distribution over elements of the Vocabulary
- typical Classifier output behavior

It's only purpose is to make sure that the output is the correct shape

- no non-linearity

Softmax

Converts the logit for each possible element of the Vocabulary

- into Probability that the element is the next Decoder Output

In [2]:

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print("Done")
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Done