CS772: Deep Learning for Natural Language Processing (DL-NLP)

Self Attention, Vaswani et al 2018

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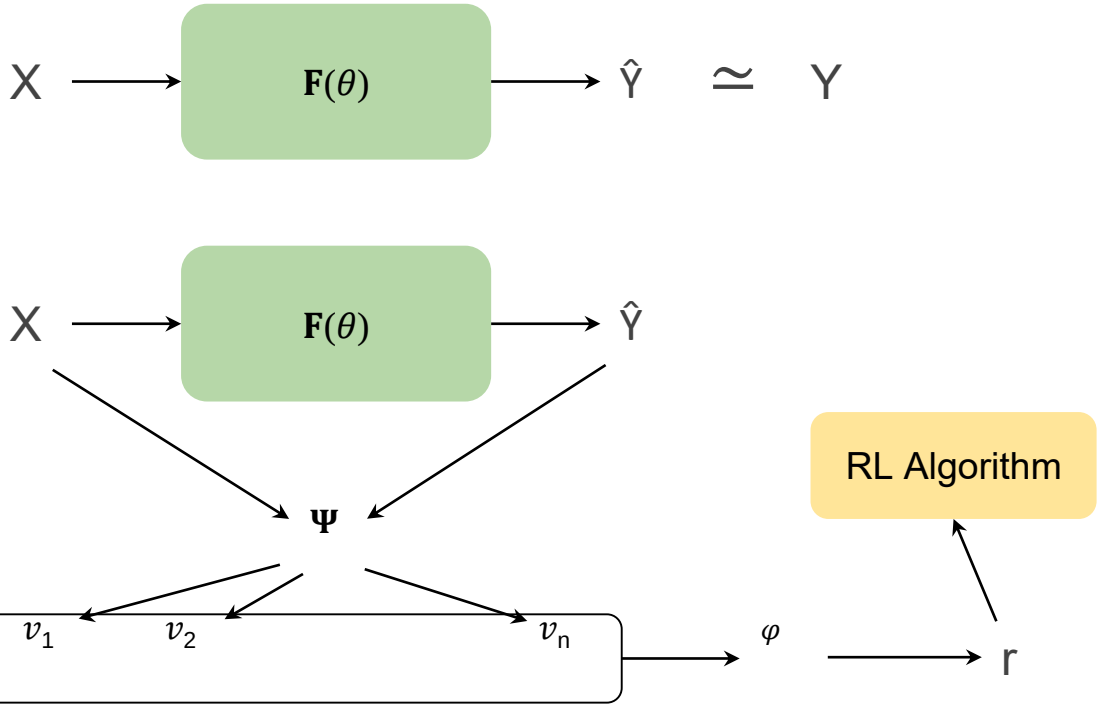
(Thursday lecture was on elastic LLMs by Dr. Prateek Jain, Google Research)

1-slide recap

$$\tilde{e} = \underset{e \in e^*}{\operatorname{argmax}}\, p(e|f) = \underset{e \in e^*}{\operatorname{argmax}}\, p(f|e)p(e)$$

SMT



Domain specific RLHF

Self attention

Self attention in real life… (1/2)

- Coreference Resolution
- **Sentence-1 (S_1):** *The$_1$ cat$_2$ could$_3$ not$_4$ climb$_5$ the$_6$ wall$_7$ because$_8$ it$_9$ was$_{10}$ too$_{11}$ steep$_{12}$ and$_{13}$ smooth$_{14}$.$_{15}$*
- **Sentence-2 (S_2):** *The$_1$ cat$_2$ could$_3$ not$_4$ climb$_5$ the$_6$ wall$_7$ because$_8$ it$_9$ was$_{10}$ too$_{11}$ weak$_{12}$ and$_{13}$ wounded$_{14}$.$_{15}$*
  - **S_1: Coref(9)=7**
  - **S_2: Coref(9)=2**

Self attention in real life… (2/2)

- Semantic Role Labelling (SRL)

- **Sentence-3 (S_3):** I_1 *promised*$_2$ *him*$_3$ *to*$_4$ *give*$_5$ a_6 *party*$_7$.$_8$
- **Sentence-4 (S_4):** I_1 *forced*$_2$ *him*$_3$ *to*$_3$ *give*$_4$ a_5 *party*$_7$.$_8$
  - **S_3: agent(5)=1**
  - **S_4: agent(5)=3**

Probing through translation (1/2)

- I promised him to give a party
- I forced him to give a party
- The cat could not climb the wall because it was too steep
- The cat could not climb the wall because it was too weak

- मैंने उससे पार्टी देने का वादा किया
- मैंने उस पर पार्टी देने के लिए दबाव डाला
- बिल्ली दीवार पर नहीं चढ़ सकी क्योंकि वह बहुत खड़ी थी
- बिल्ली दीवार पर नहीं चढ़ सकी क्योंकि वह बहुत कमज़ोर थी

Google Translate

Probing through translation (2/2)

- The child could not climb the wall because it was too steep
- The child could not climb the wall because it was too small
- The child could not climb the wall because it was too weak

- बच्चा दीवार पर नहीं चढ़ सका क्योंकि वह बहुत खड़ी थी
- बच्चा दीवार पर नहीं चढ़ सका क्योंकि वह बहुत छोटी थी
- बच्चा दीवार पर नहीं चढ़ सका क्योंकि वह बहुत कमजोर थी

Google Translate

IIT Translator: Probing through translation (1/2)

- I promised him to give a party
- I forced him to give a party
- The cat could not climb the wall because it was too steep
- The cat could not climb the wall because it was too weak

- मैंने उनसे पार्टी देने का वादा किया था।
- मैंने उसे एक पार्टी देने के लिए मजबूर किया
- बिल्ली दीवार पर चढ़ नहीं सकती थी क्योंकि यह बहुत खड़ी थी।
- बिल्ली दीवार पर चढ़ नहीं सकती थी क्योंकि वह बहुत कमजोर थी

IIT Translator: Probing through translation (2/2)

- The child could not climb the wall because it was too steep
- The child could not climb the wall because it was too small
- The child could not climb the wall because it was too weak

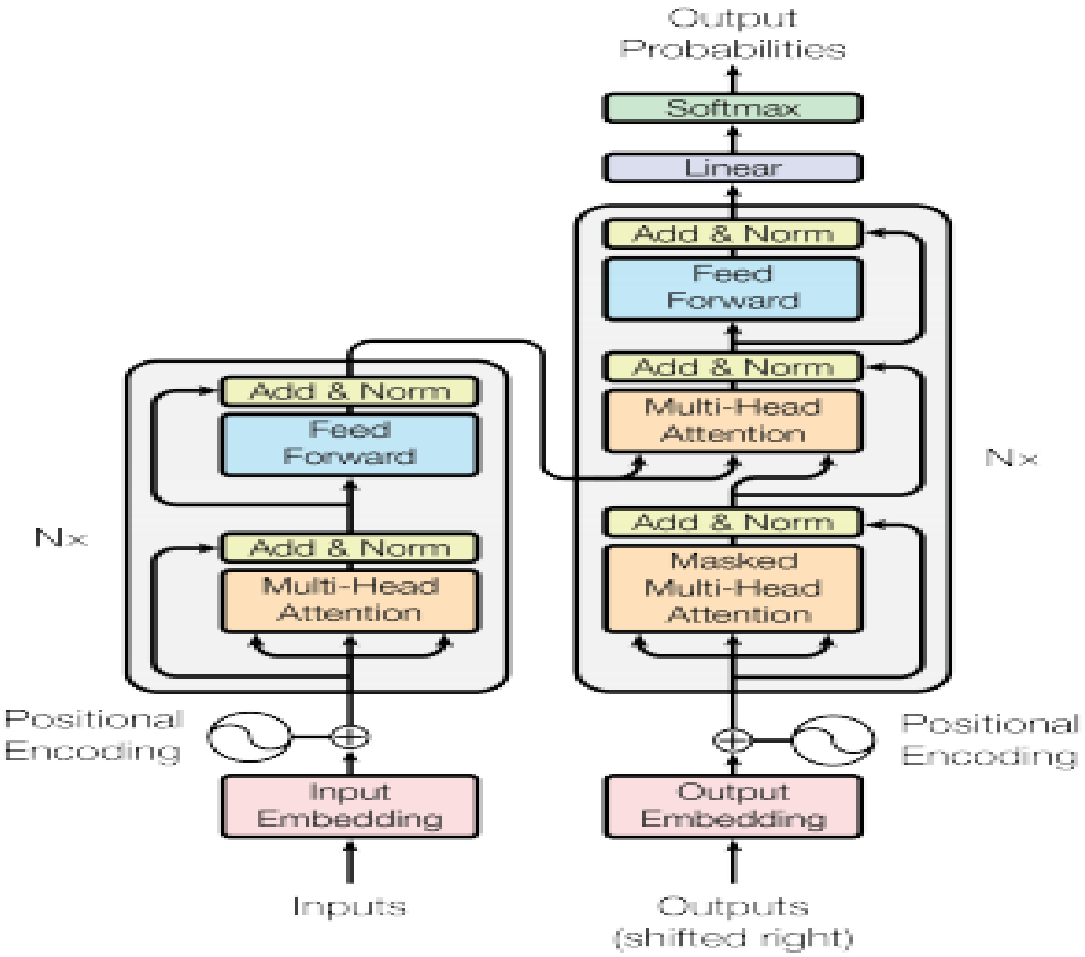
- बच्चा दीवार पर चढ़ नहीं सका क्योंकि यह बहुत खड़ी थी।
- बच्चा दीवार पर चढ़ नहीं सका क्योंकि वह बहुत छोटा था
- बच्चा दीवार पर नहीं चढ़ सका क्योंकि वह बहुत कमजोर था

Digression: Linguistic Probe

- How do we know ‘cat’ is a noun?
- ‘cat’ can replace ‘dog’- which is a NOUN (known from another source)- in identical syntactic environment
- *I saw a dog* ←→ *I saw a cat*

Vaswani et al 2018

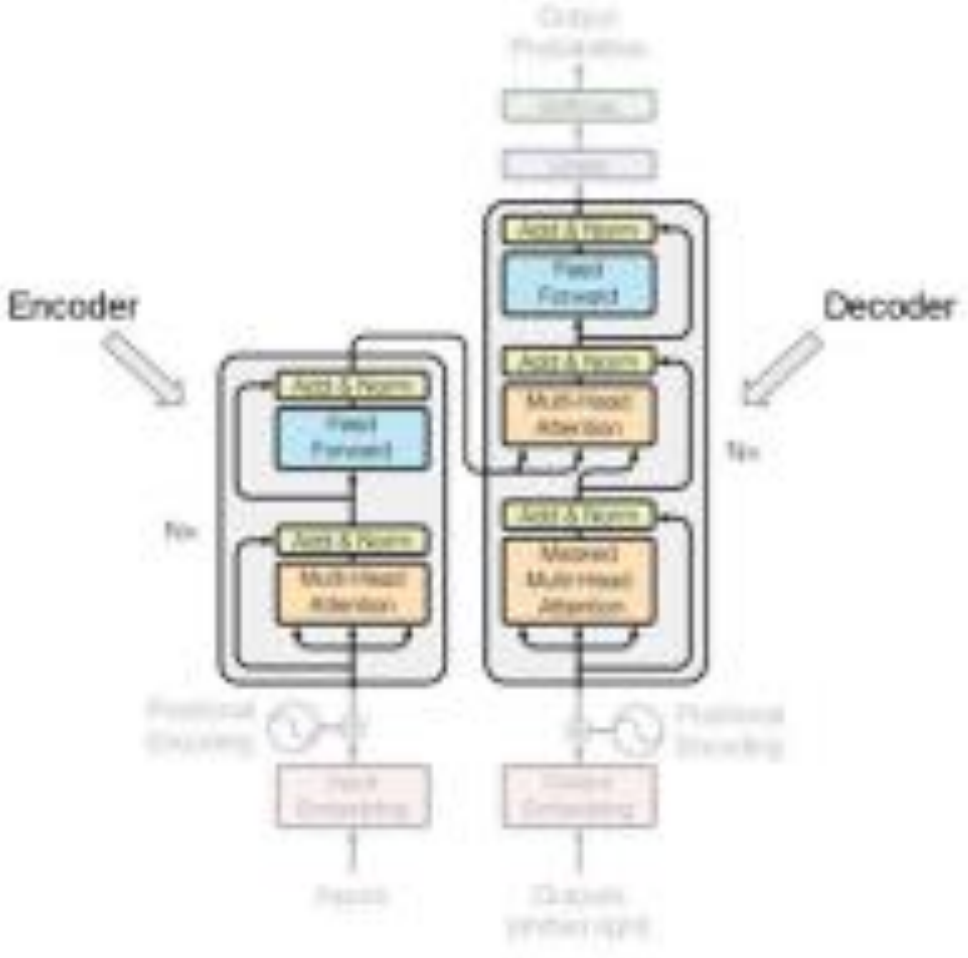
A classic diagram and a classic paper



Vaswani, Ashish, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Lukasz Kaiser, and Illia Polosukhin. "Attention is all you need." NeurIPS (2017).

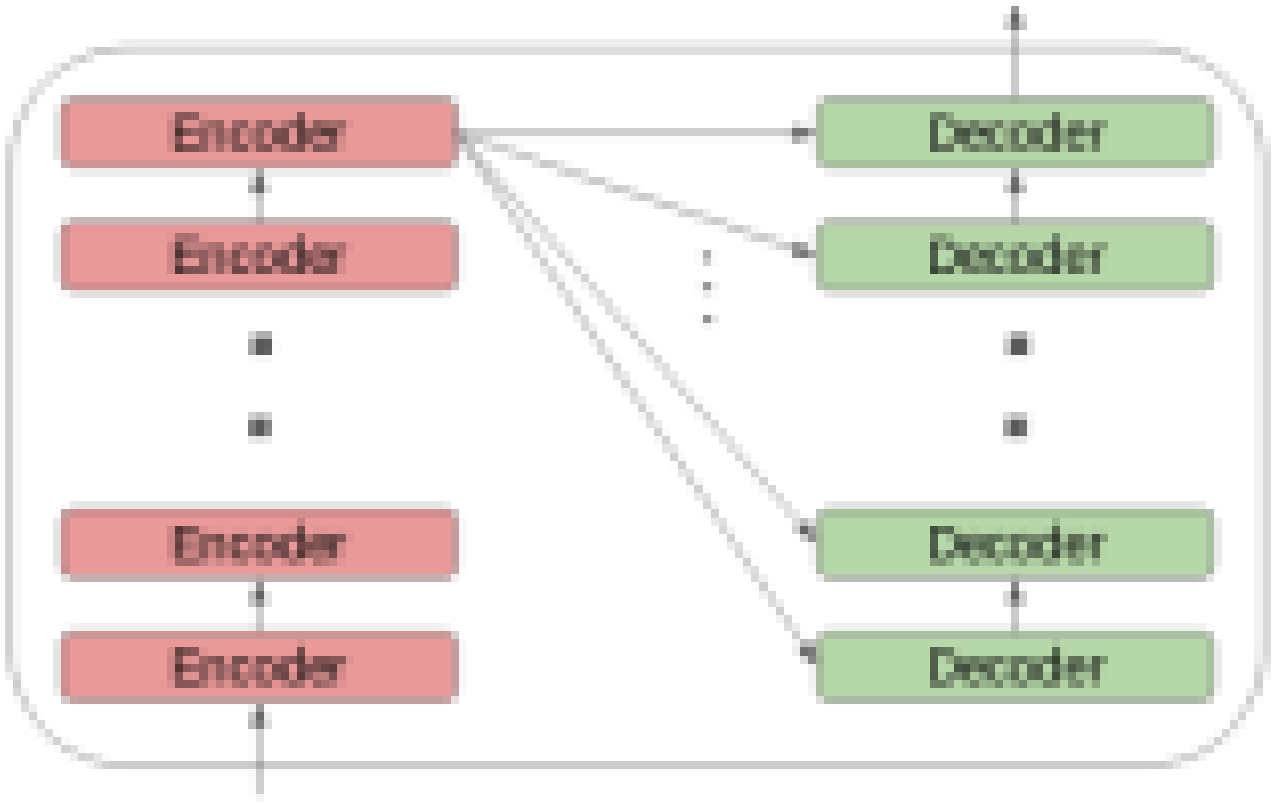
http://nlp.seas.harvard.edu/2018/04/03/attention.html
http://jalammar.github.io/illustrated-transformer/

The transformer

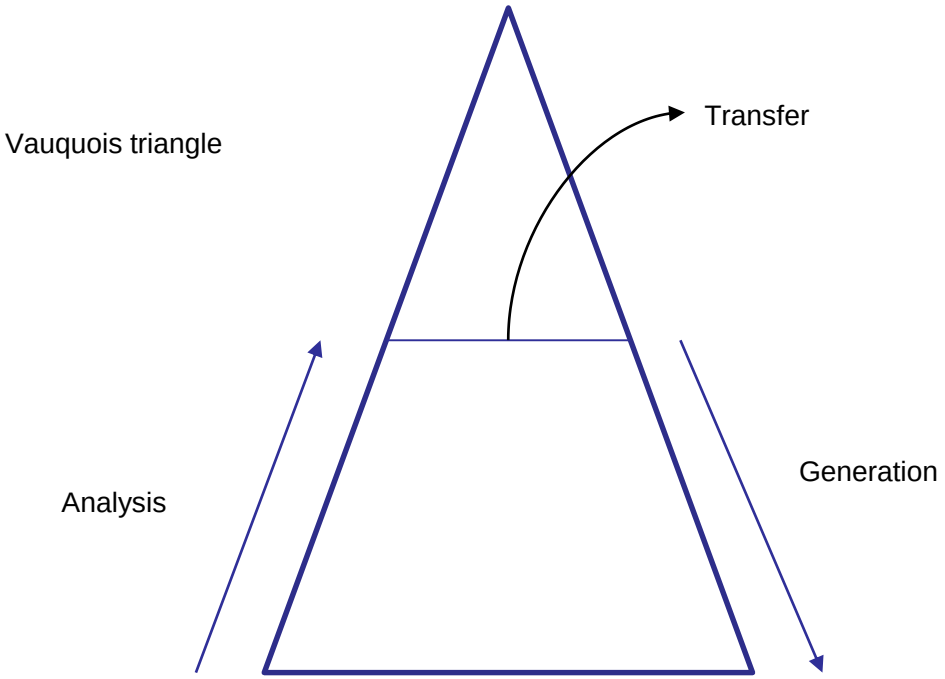


Nx means N times; N=6 conventionally

Encoder decoder interaction



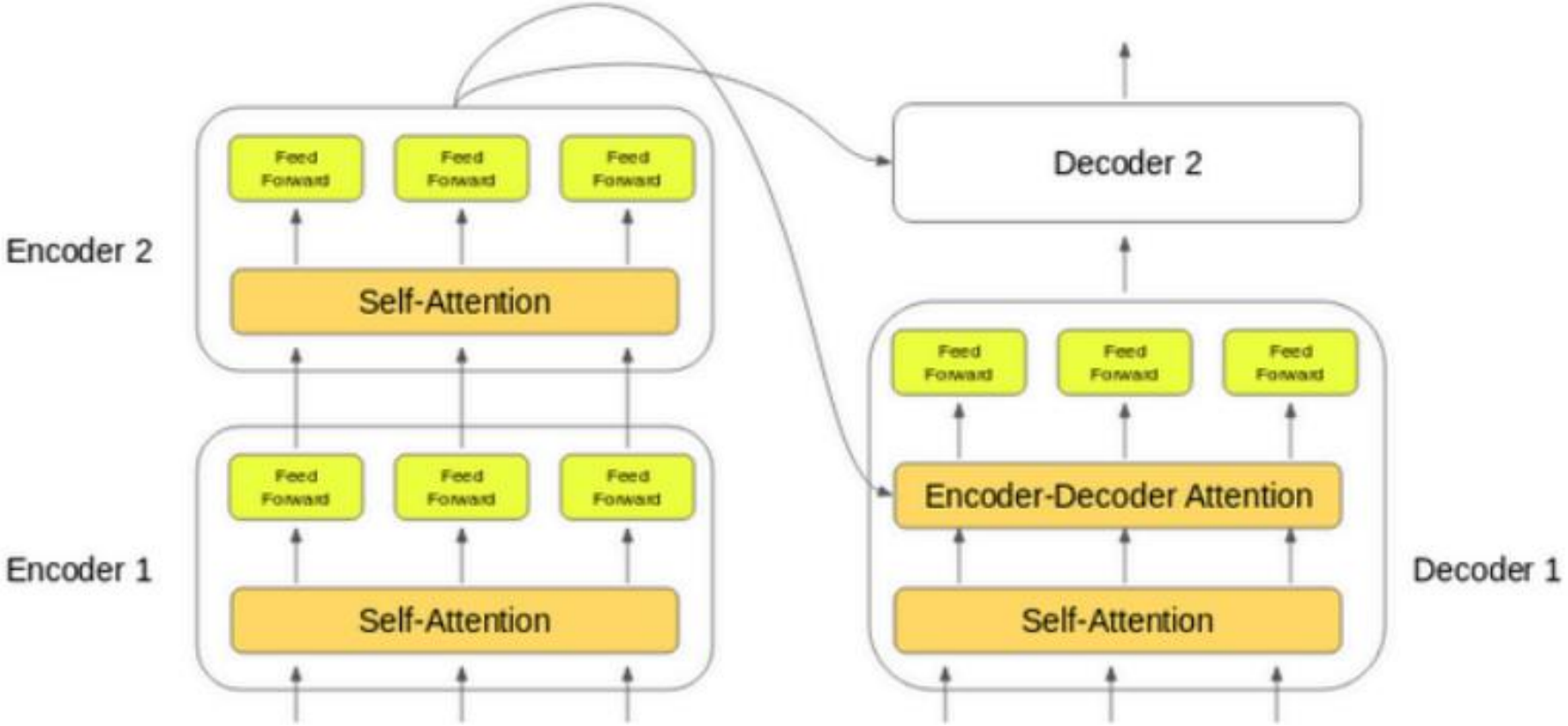
Vauquois triangle



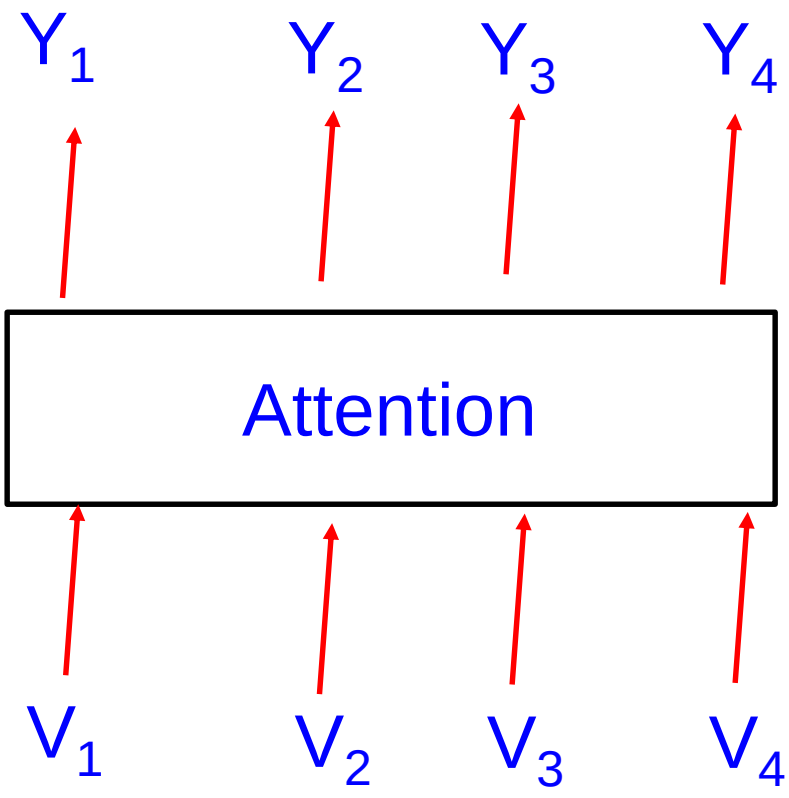
Stages of NL Generations (NLG)

- Vocab generation
- Morph and function word generation
- Syntax planning
- Example
  - Input: Peter slept early
  - Vocab: पीटर सो जल्दी (Peter so jaldii)
  - Morph and function words: पीटर सोया जल्दी (Peter soya jaldii)
  - Syntax planning: पीटर जल्दी सोया (Peter jaldii soya)

Self Attention as part of the architecture



Self Attention Block



Bank of the river

Word Embedding and Contextual Word Embedding

- Consider the phrase "*bank of the river*"
- Word embeddings of '*bank*', '*of*', '*the*', '*river*': V_1, V_2, V_3, V_4
- Now create a 'score' vector S_i for each word vector
- S_1: ($V_1.V_1$, $V_1.V_2$, $V_1.V_3$, $V_1.V_4$)
- Similarly, S_2, S_3, S_4

S-matrix

$$S = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix}$$

S-scaled matrix

$$S - scaled = \frac{1}{\sqrt{d_k}} \times \begin{bmatrix} s_{11} & s_{12} & s_{13} & s_{14} \\ s_{21} & s_{22} & s_{23} & s_{24} \\ s_{31} & s_{32} & s_{33} & s_{34} \\ s_{41} & s_{42} & s_{43} & s_{44} \end{bmatrix}$$

W-matrix

$$W = \begin{bmatrix} w_{11} & w_{12} & w_{13} & w_{14} \\ w_{21} & w_{22} & w_{23} & w_{24} \\ w_{31} & w_{32} & w_{33} & w_{34} \\ w_{41} & w_{42} & w_{43} & w_{44} \end{bmatrix}$$

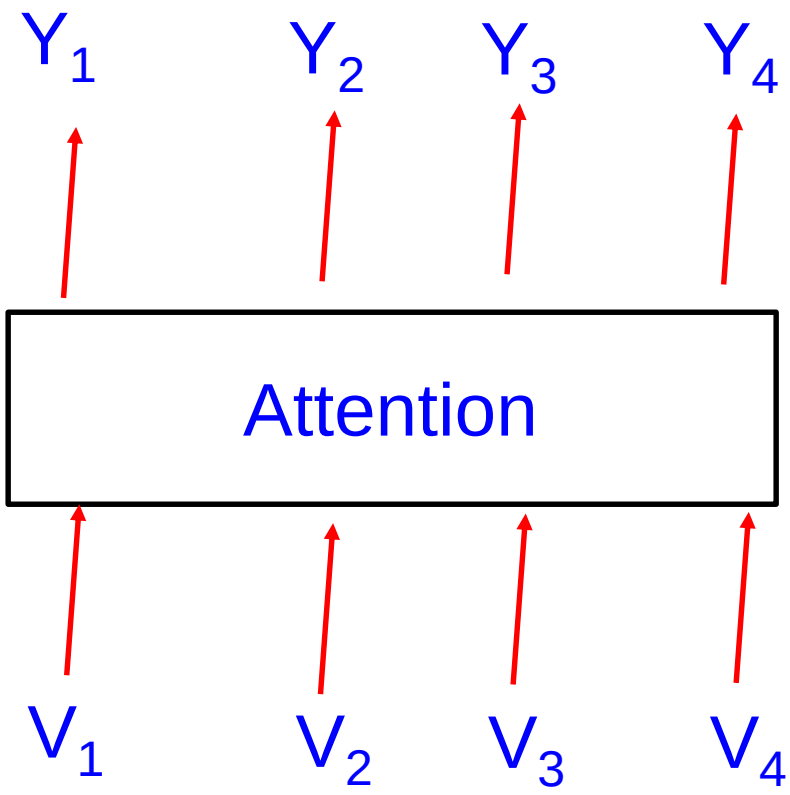
$$W_i - vector = soft\max\left(\frac{S_i - vector}{\sqrt{d_k}}\right)$$

Y-matrix

$$Y = \begin{bmatrix} y_{11}\, y_{12}\, y_{13}\, y_{14} \\ y_{21}\, y_{22}\, y_{23}\, y_{24} \\ y_{31}\, y_{32}\, y_{33}\, y_{34} \\ y_{41}\, y_{42}\, y_{43}\, y_{44} \end{bmatrix}$$

$$Y_i - vector = w_{11}.V_1 + w_{12}.V_2 + w_{13}.V_3 + w_{14}.V_4$$

Attention Block



Bank of the river

Deeper dive into attention

Self Attention (1/3)

- Create 3 vectors using the input embeddings (x).
  - Query (q)
  - Key (k)
  - Value (v)
- Obtain these vectors by matrix multiplication with the weight matrix W^Q, W^K, W^V which are the parameters of the self attention module
- These matrices are learnable

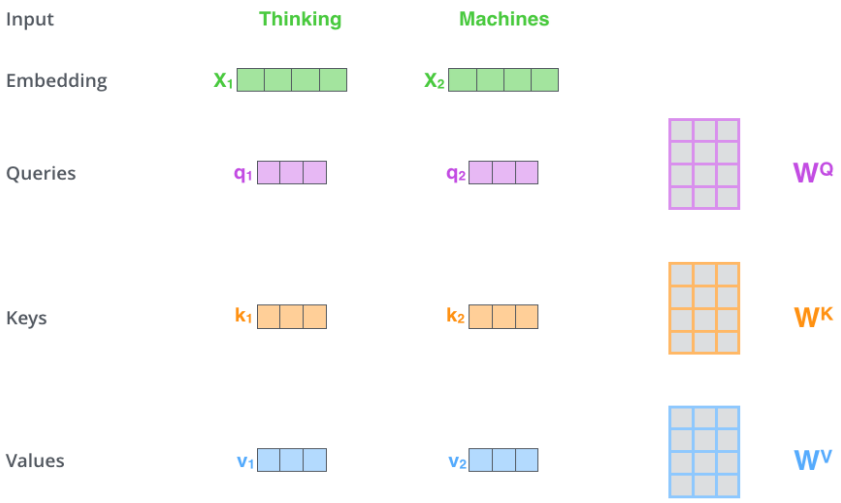
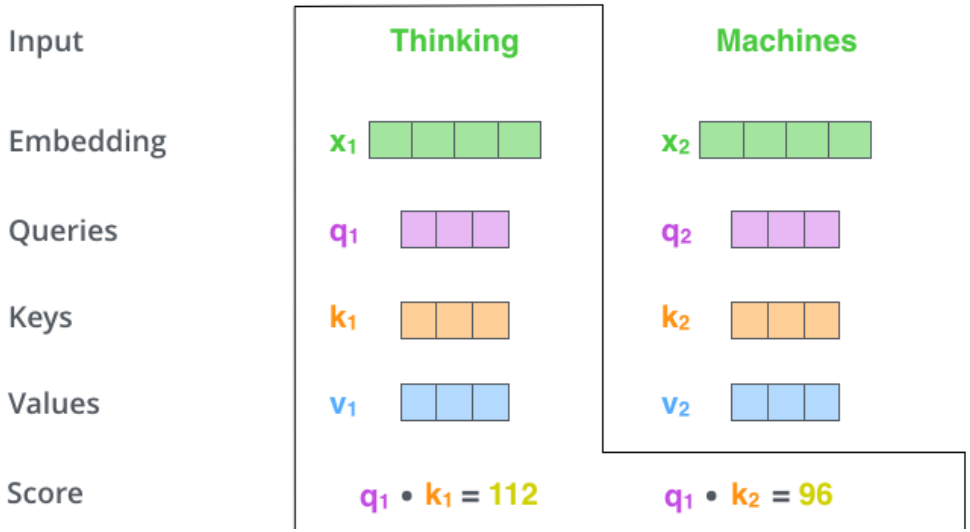


Image Source: The Illustrated Transformer, https://jalammar.github.io/illustrated-transformer/

Self Attention (2/3)

Take the dot product of the query(q) vector of current word with the key(k) vector of each input word.



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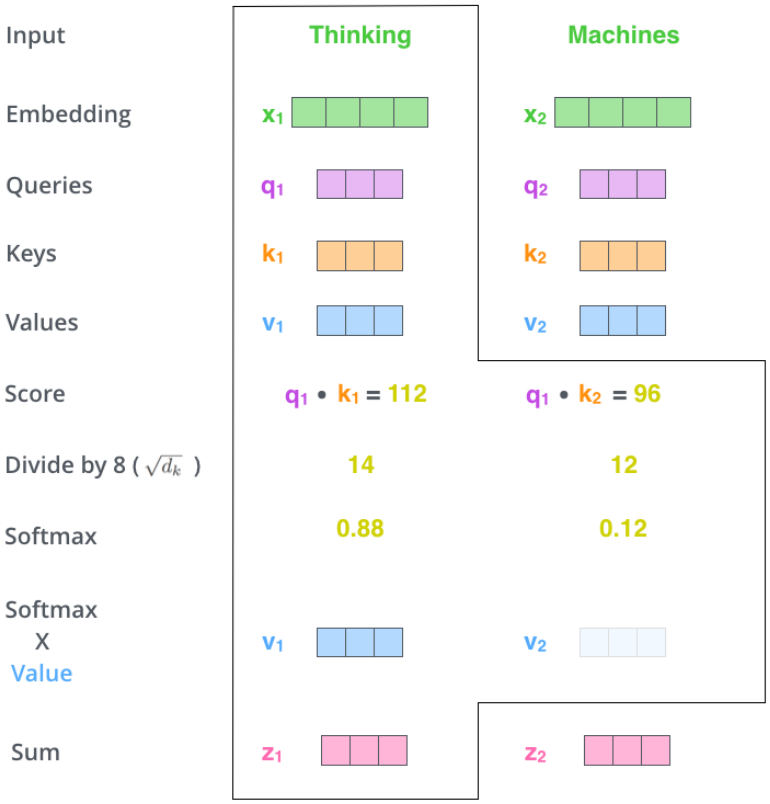
Self Attention (3/3)

- Scale the scores by dividing the scores by d_k and then we perform the softmax operation on the scores.
- Weight the value (v) vectors by multiplying the vectors with the corresponding scores of that position.
- Compute the weighted sum of the value (v) vectors which forms the output of self attention layer.



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