Transformer

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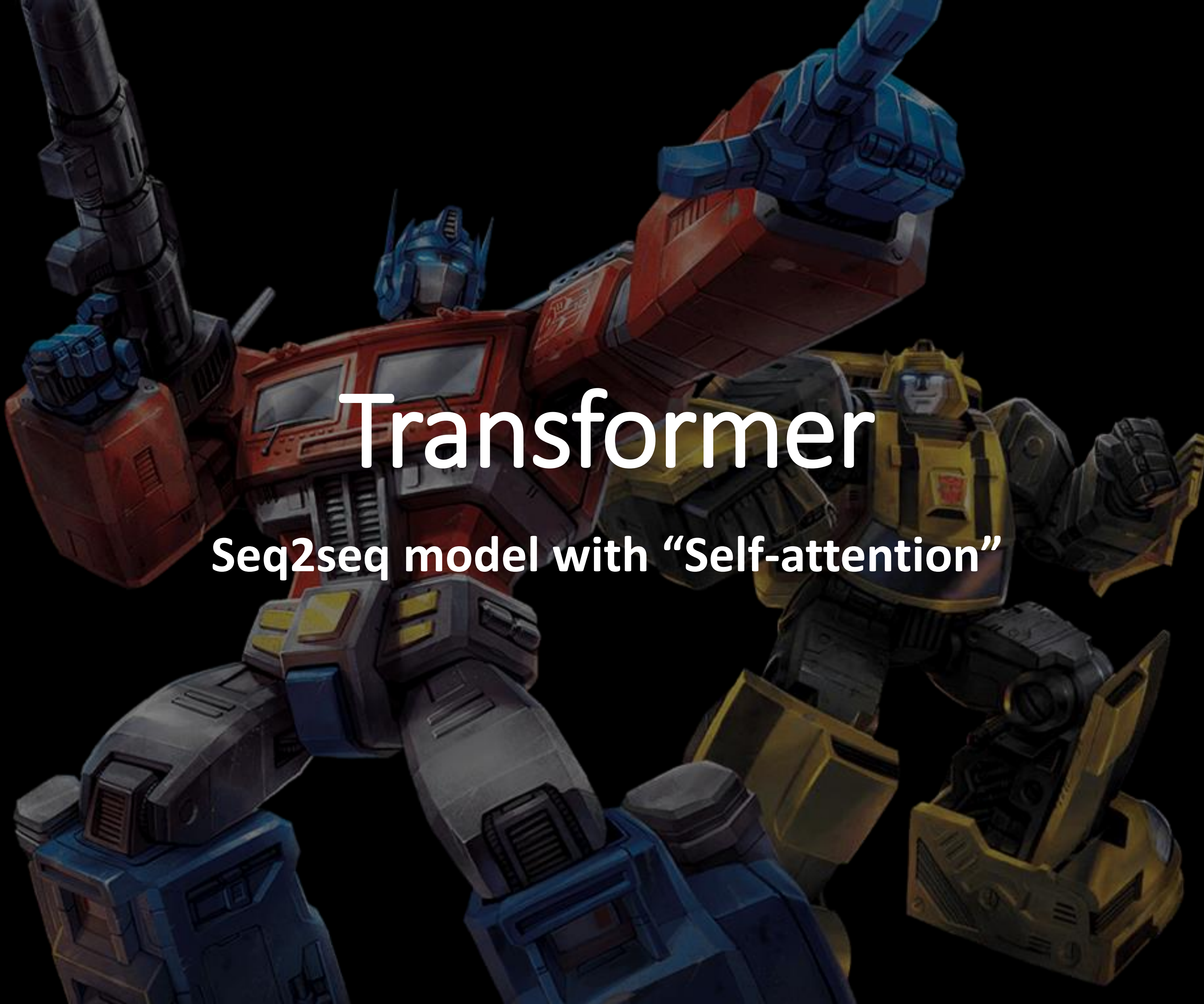
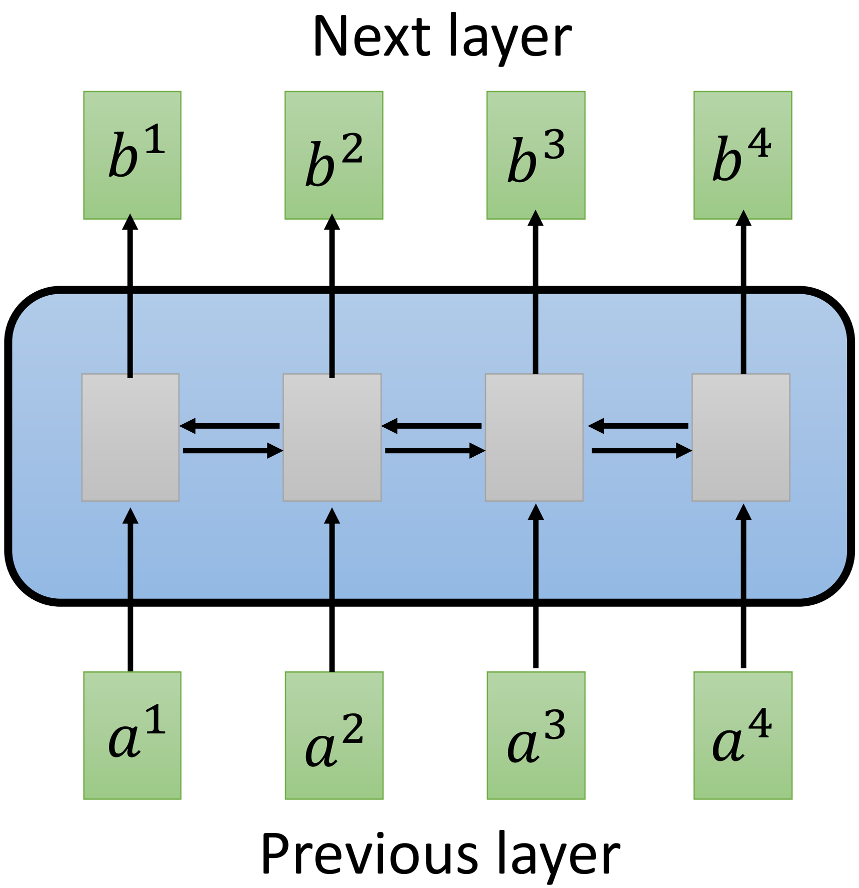


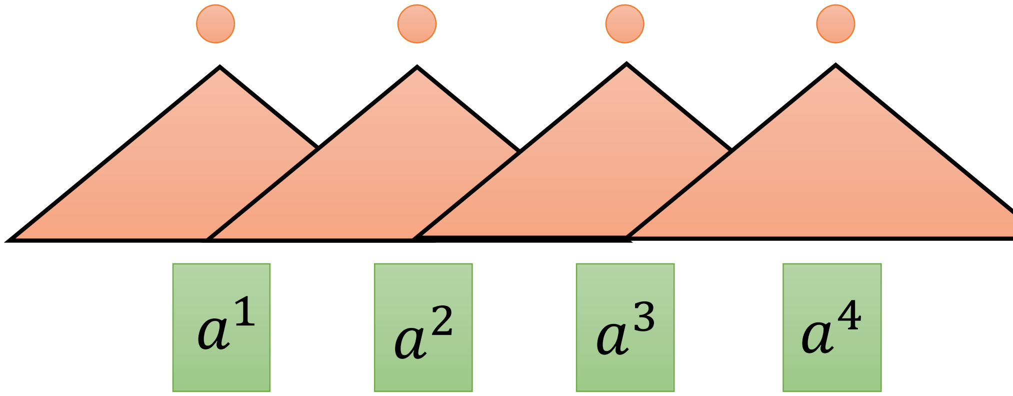
Transformer

Seq2seq model with "Self-attention"

Sequence



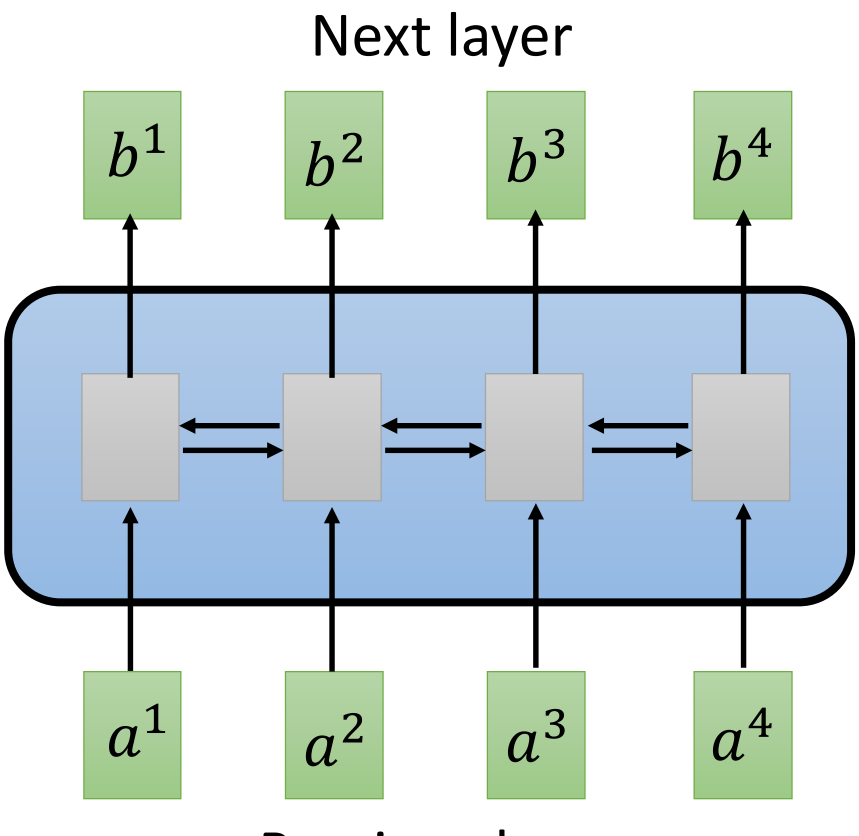
Hard to parallel !



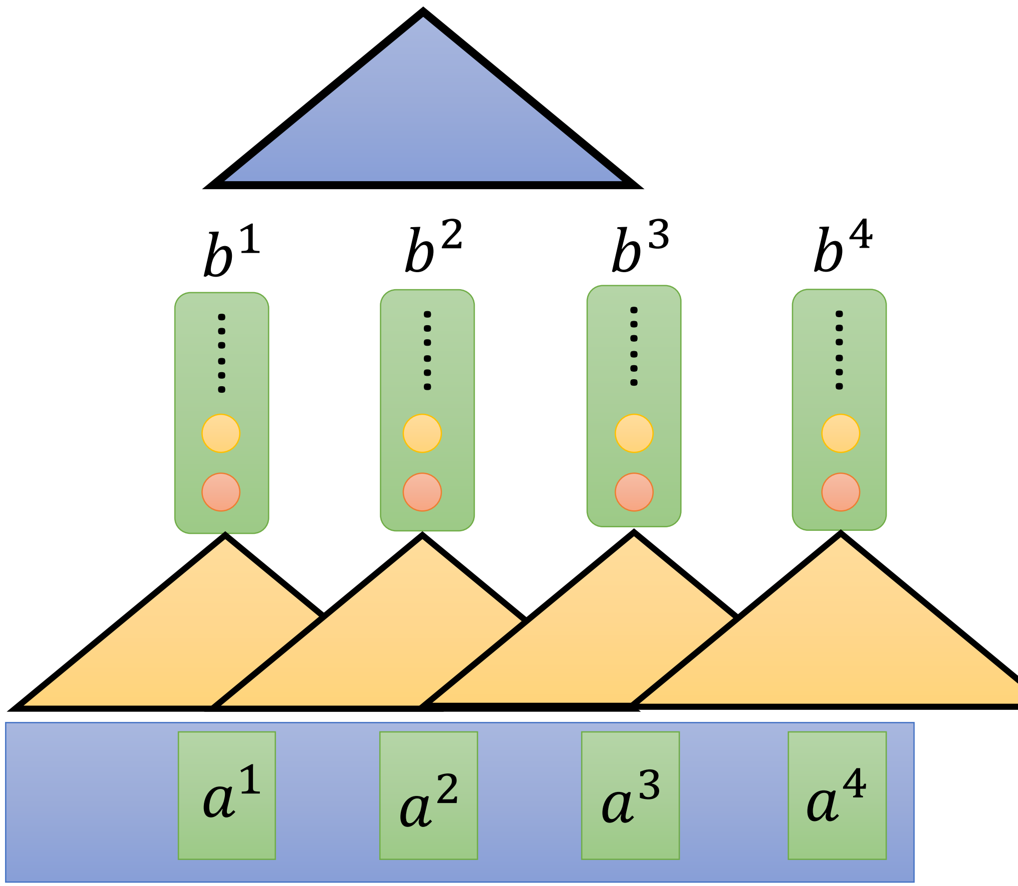
Using CNN to replace RNN

Sequence

Filters in higher layer can consider longer sequence



Hard to parallel



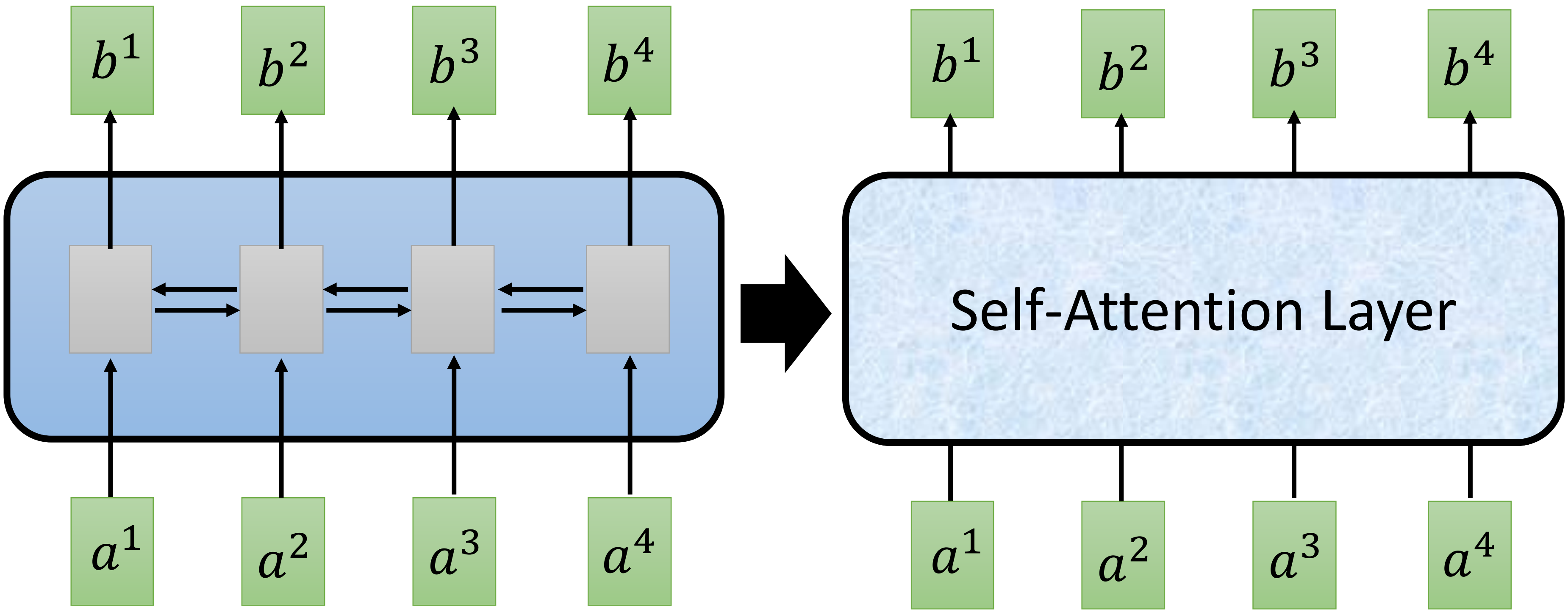
Using CNN to replace RNN (CNN can parallel)

Self Attention

输入为1个sequence
输出也为1个sequence
b1到b4每一个输出也看过了整个sequence
并且b1到b4可以并行同时计算，2017年被提出，
可以取代RNN

b^i is obtained based on the whole input sequence.

b^1, b^2, b^3, b^4 can be parallelly computed.



You can try to replace any thing that has been done by RNN with self-attention.

Self-attention

https://arxiv.org/abs/1706.03762

q: query (to match others)

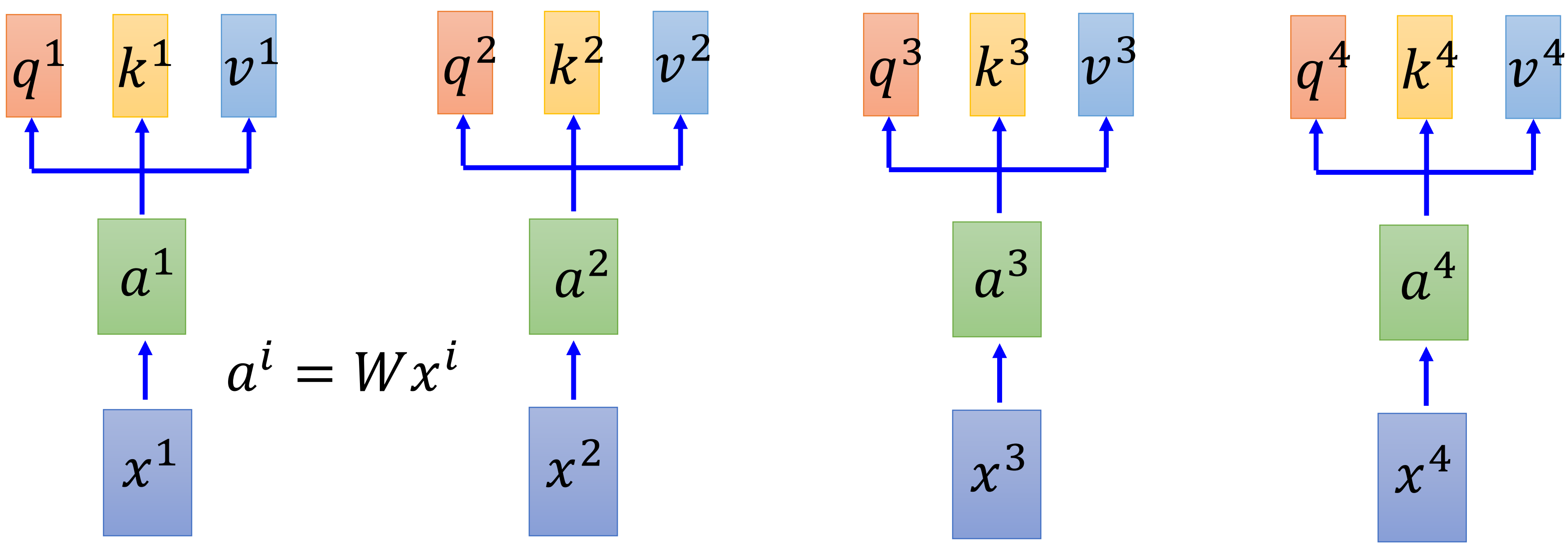
$$q^i = W^q a^i$$

k: key (to be matched)

$$k^i = W^k a^i$$

v: information to be extracted

$$v^i = W^v a^i$$



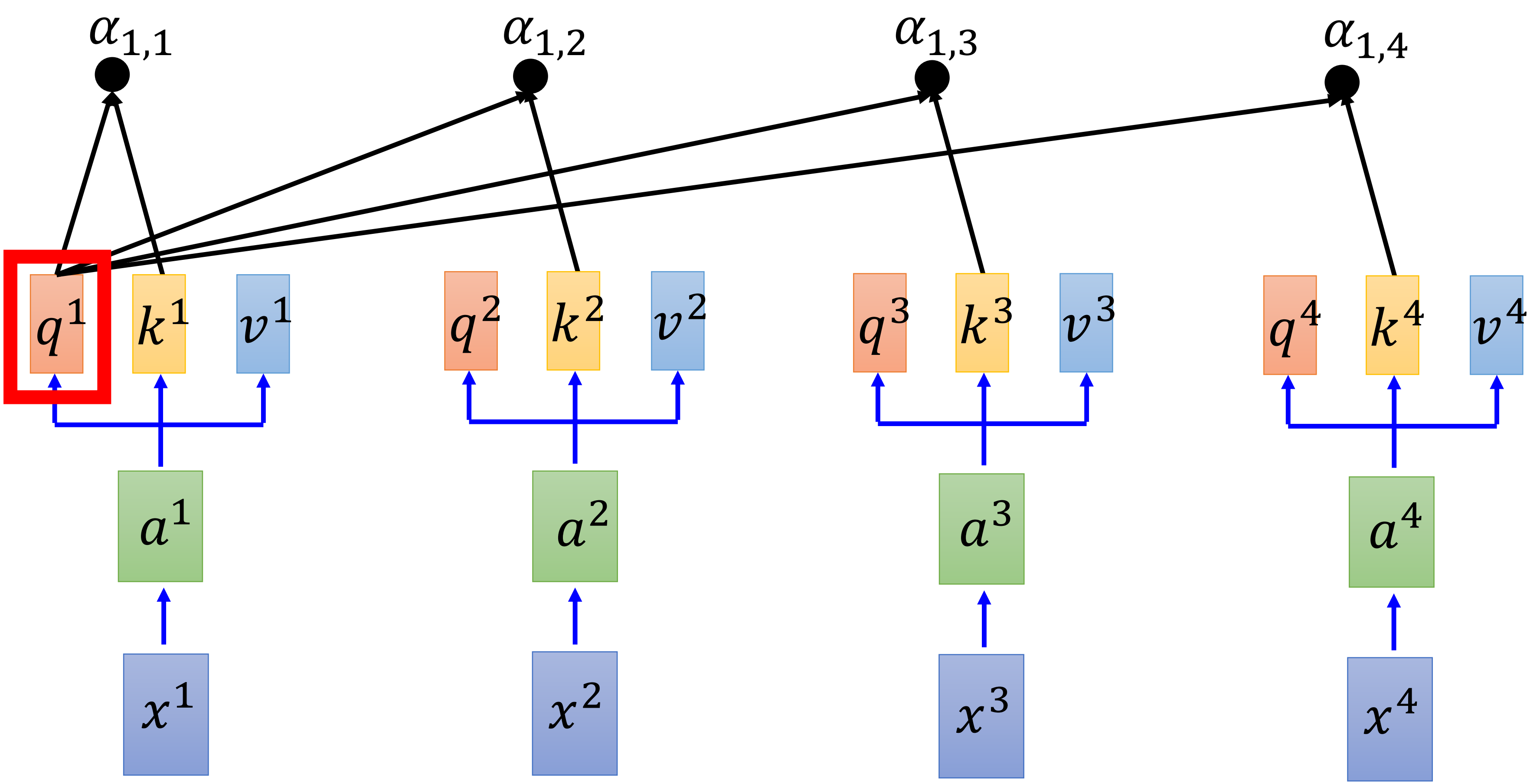
$$a^i = W x^i$$

Self-attention

拿每個 query q 去對每個 key k 做 attention

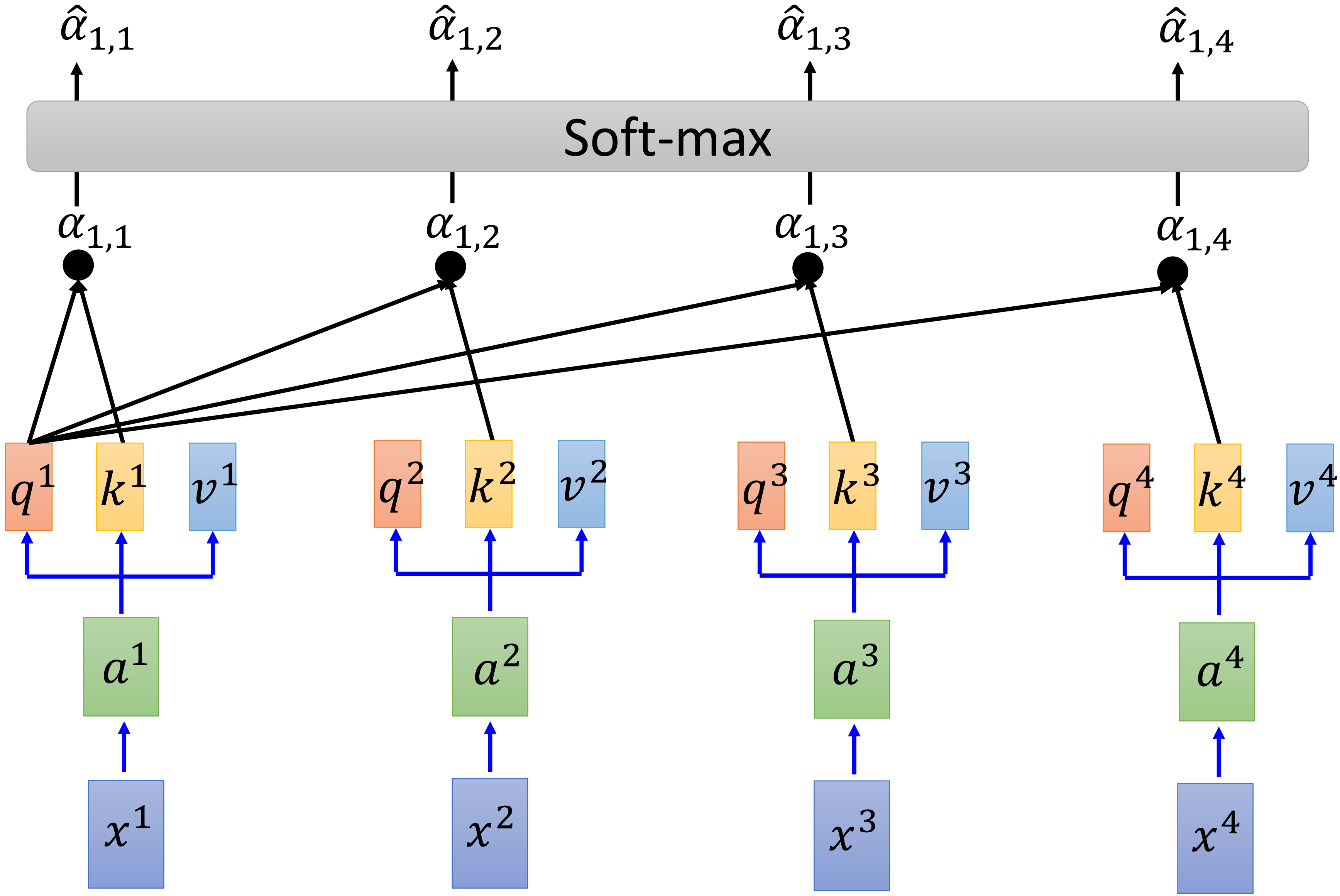
d is the dim of q and k

Scaled Dot-Product Attention: $\alpha_{1,i} = \underbrace{q^1 \cdot k^i}_{\text{dot product}} / \sqrt{d}$



Self-attention

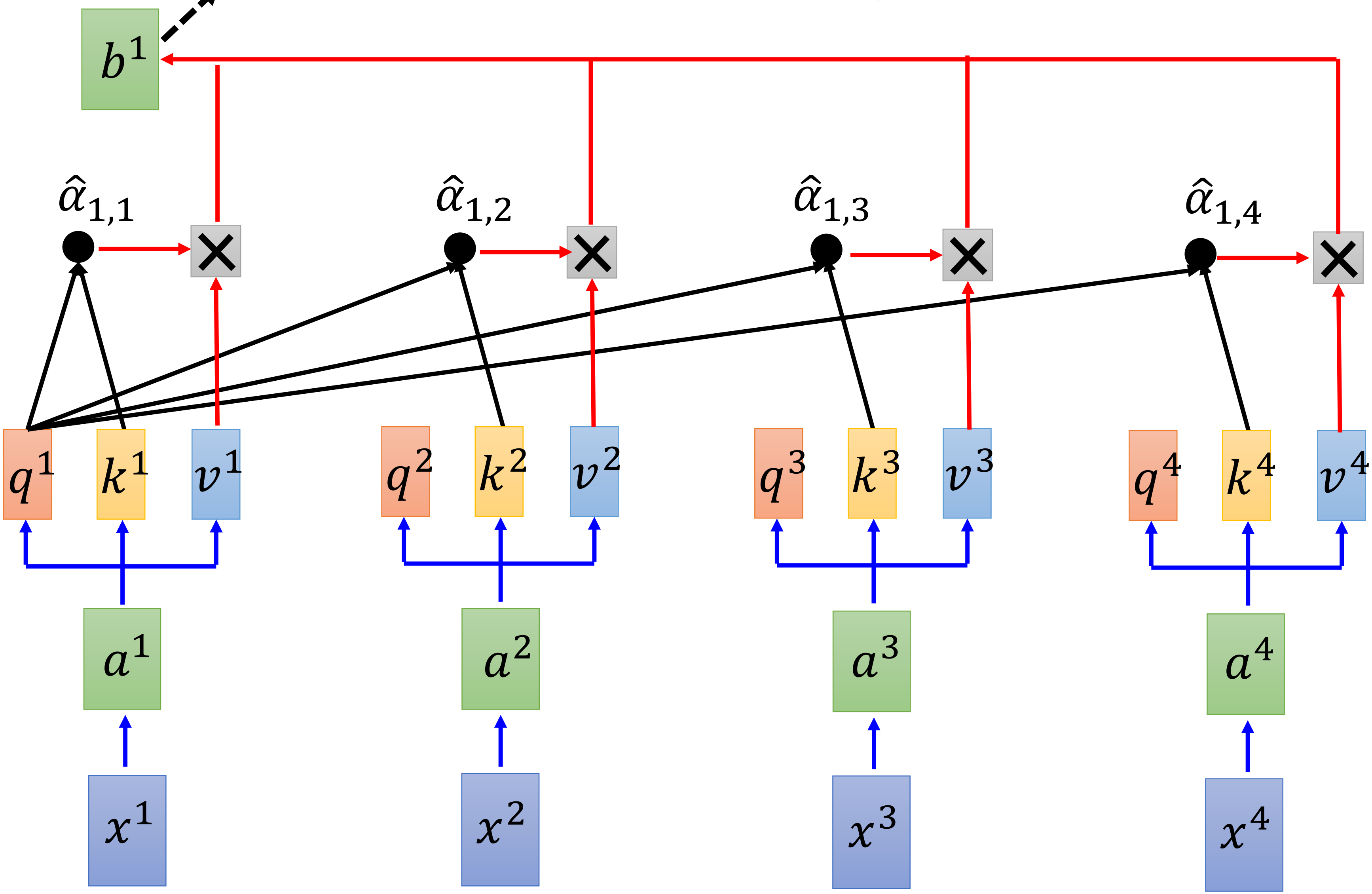
$$\hat{\alpha}_{1,i} = exp(\alpha_{1,i})/\sum_j exp(\alpha_{1,j})$$



Self-attention

$$b^1 = \sum_i \hat{\alpha}_{1,i} v^i$$

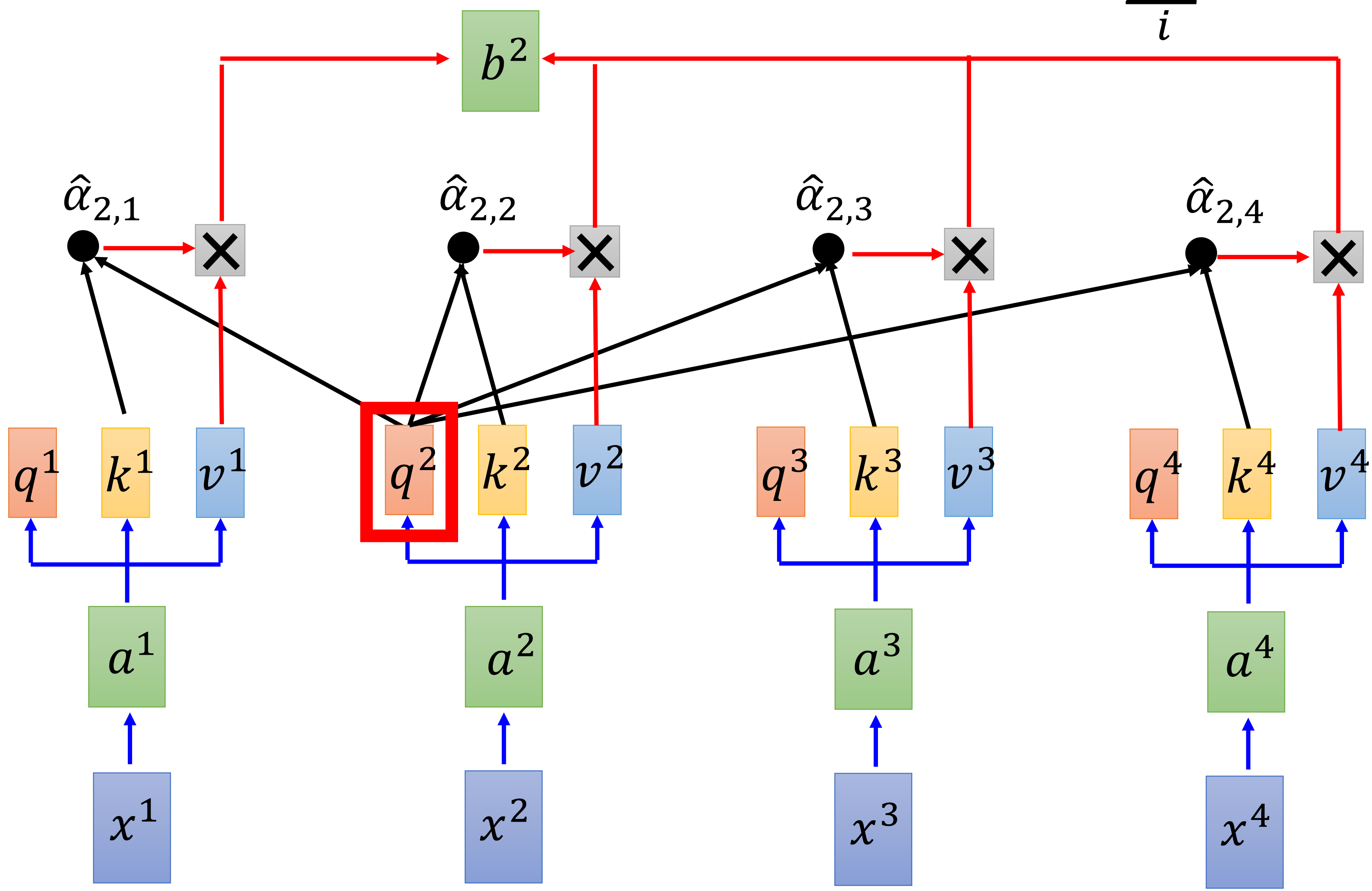
Considering the whole sequence



Self-attention

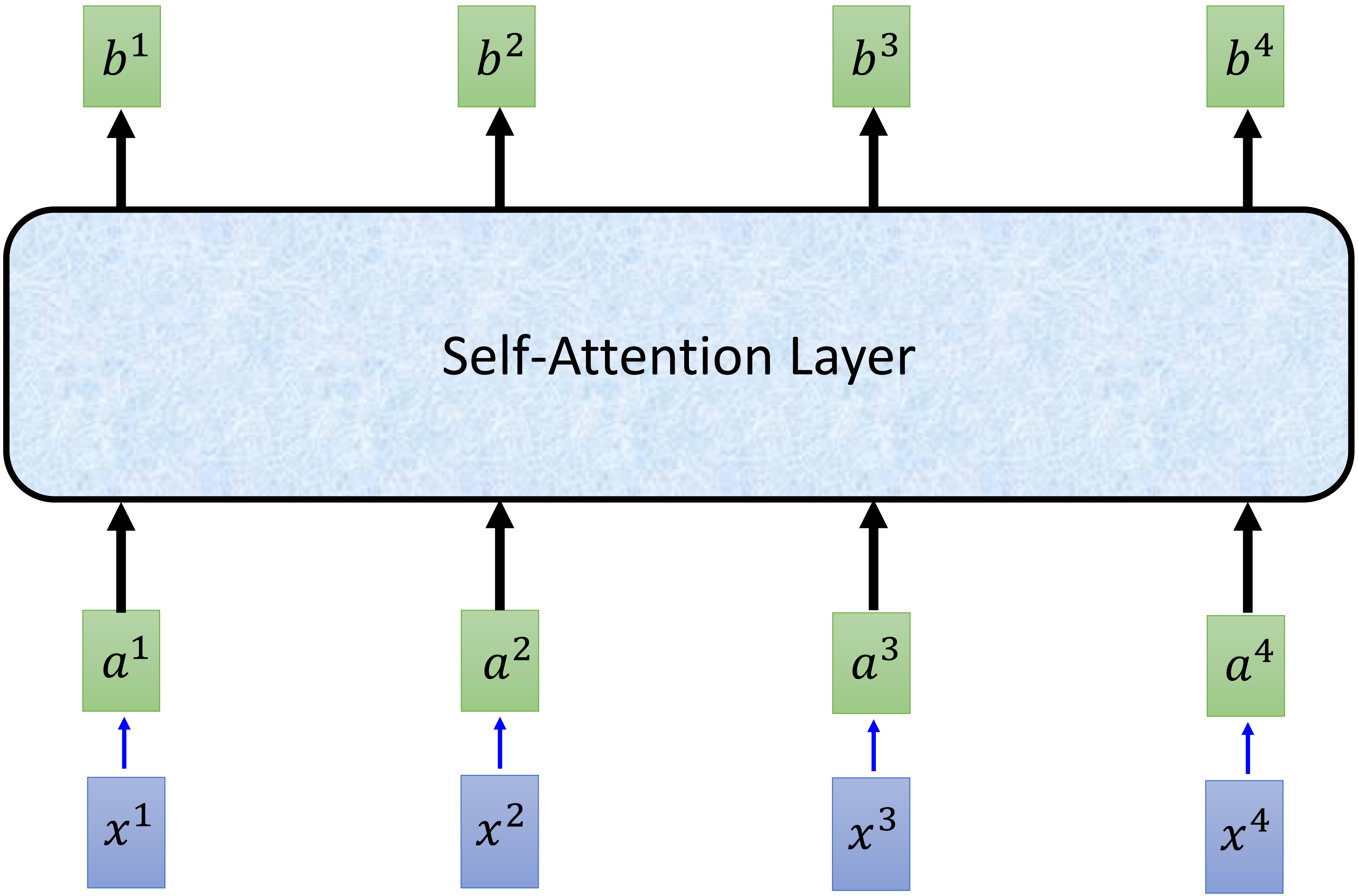
拿每個 query q 去對每個 key k 做 attention

$$b^2 = \sum_i \hat{\alpha}_{2,i} v^i$$



Self-attention

b^1, b^2, b^3, b^4 can be parallelly computed.



Self-attention

$$q^i = W^q a^i$$

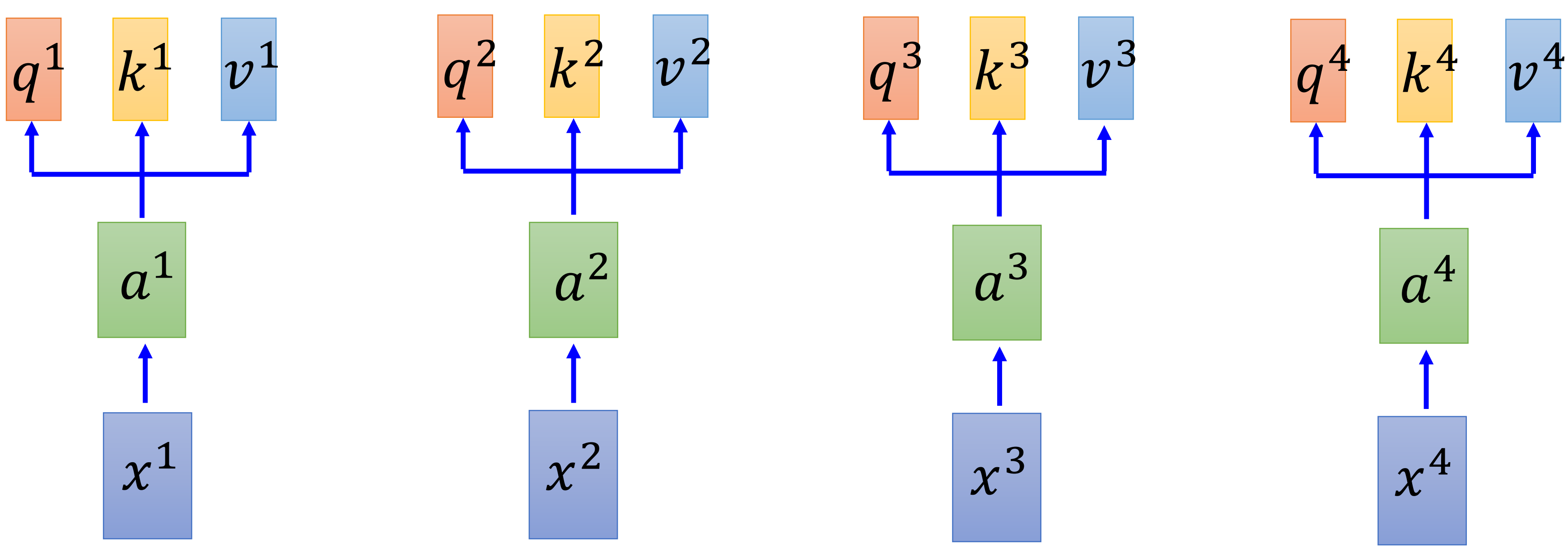
$$k^i = W^k a^i$$

$$v^i = W^v a^i$$

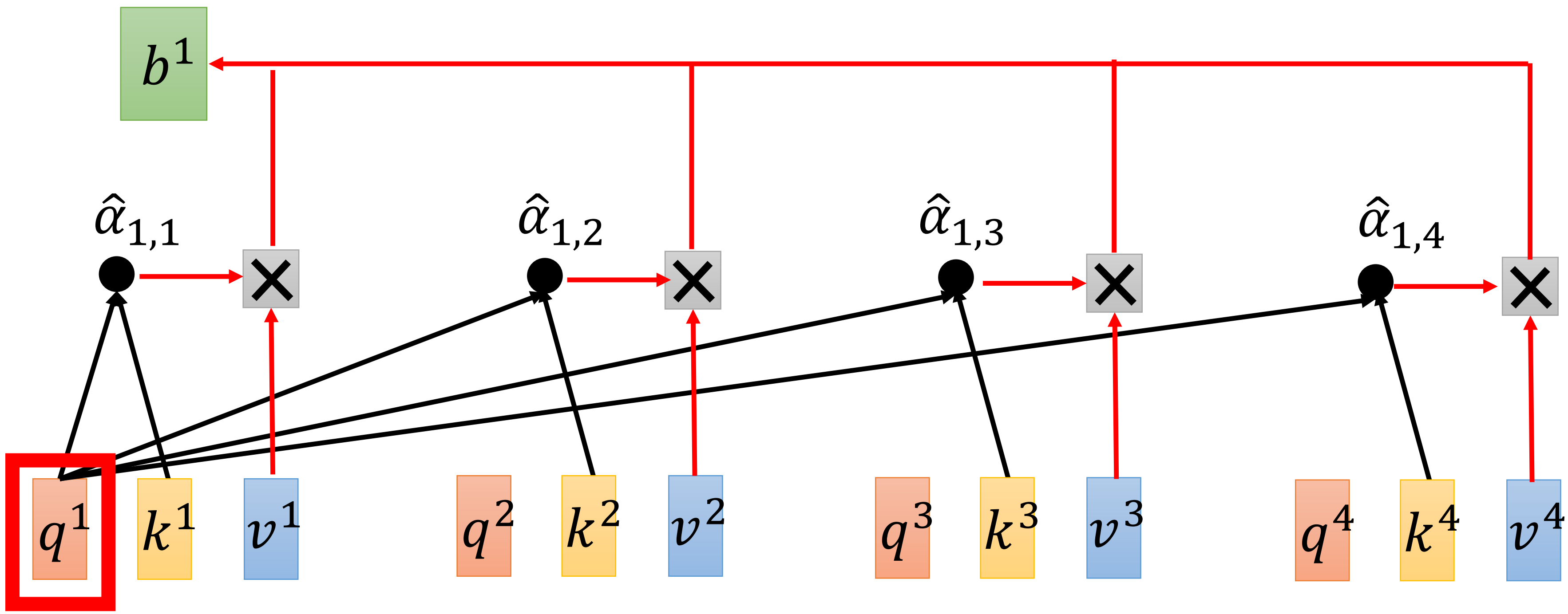
$$\underset{Q}{\begin{bmatrix} q^1 & q^2 & q^3 & q^4 \end{bmatrix}} = W^q \underset{\mathrm{I}}{\begin{bmatrix} a^1 & a^2 & a^3 & a^4 \end{bmatrix}}$$

$$\underset{K}{\begin{bmatrix} k^1 & k^2 & k^3 & k^4 \end{bmatrix}} = W^k \underset{\mathrm{I}}{\begin{bmatrix} a^1 & a^2 & a^3 & a^4 \end{bmatrix}}$$

$$\underset{V}{\begin{bmatrix} v^1 & v^2 & v^3 & v^4 \end{bmatrix}} = W^v \underset{\mathrm{I}}{\begin{bmatrix} a^1 & a^2 & a^3 & a^4 \end{bmatrix}}$$



Self-attention



$\alpha_{1,1} = k^1 q^1$ $\quad$ $\alpha_{1,2} = k^2 q^1$

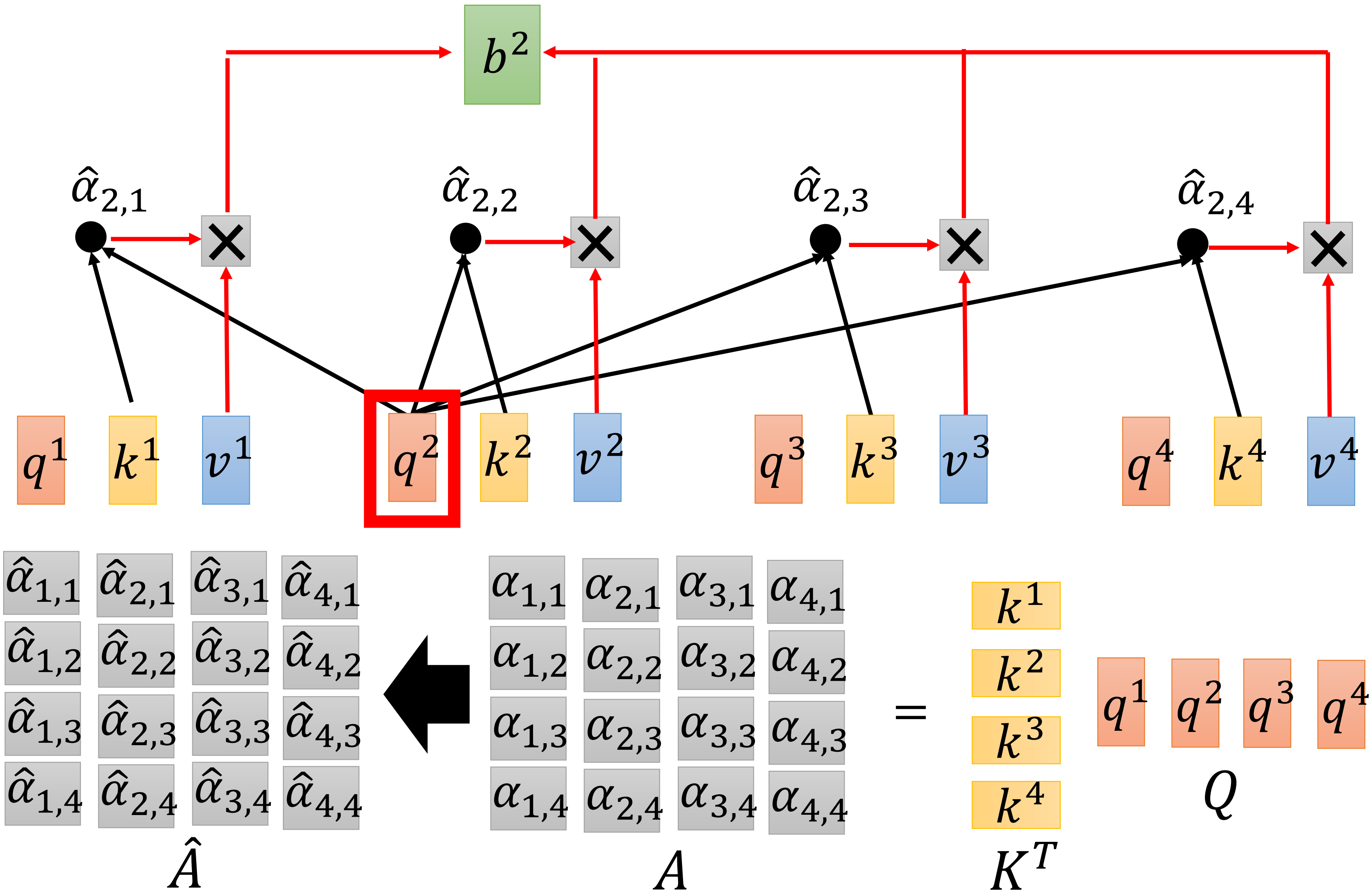
$\alpha_{1,3} = k^3 q^1$ $\quad$ $\alpha_{1,4} = k^4 q^1$

$$\begin{bmatrix} \alpha_{1,1} \\ \alpha_{1,2} \\ \alpha_{1,3} \\ \alpha_{1,4} \end{bmatrix} = \begin{bmatrix} k^1 \\ k^2 \\ k^3 \\ k^4 \end{bmatrix} q^1$$

(ignore $\sqrt{d}$ for simplicity)

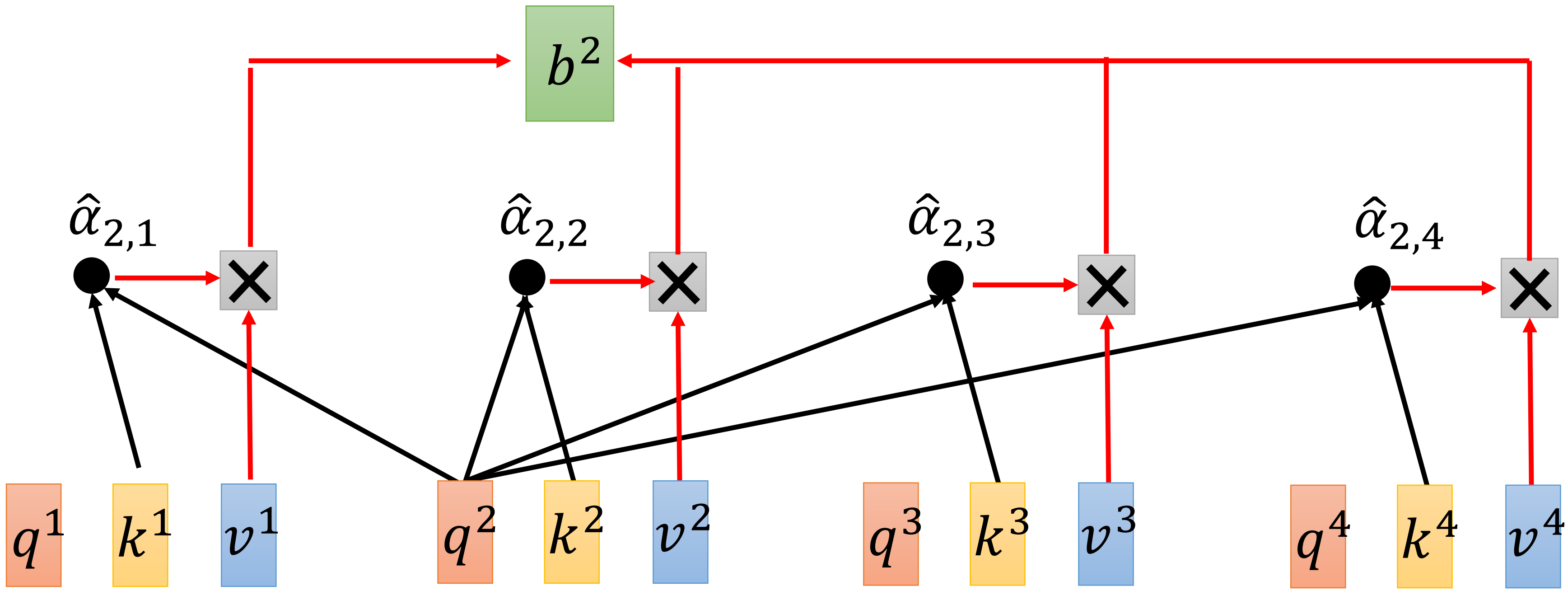
Self-attention

$$b^2 = \sum_i \hat{\alpha}_{2,i} v^i$$



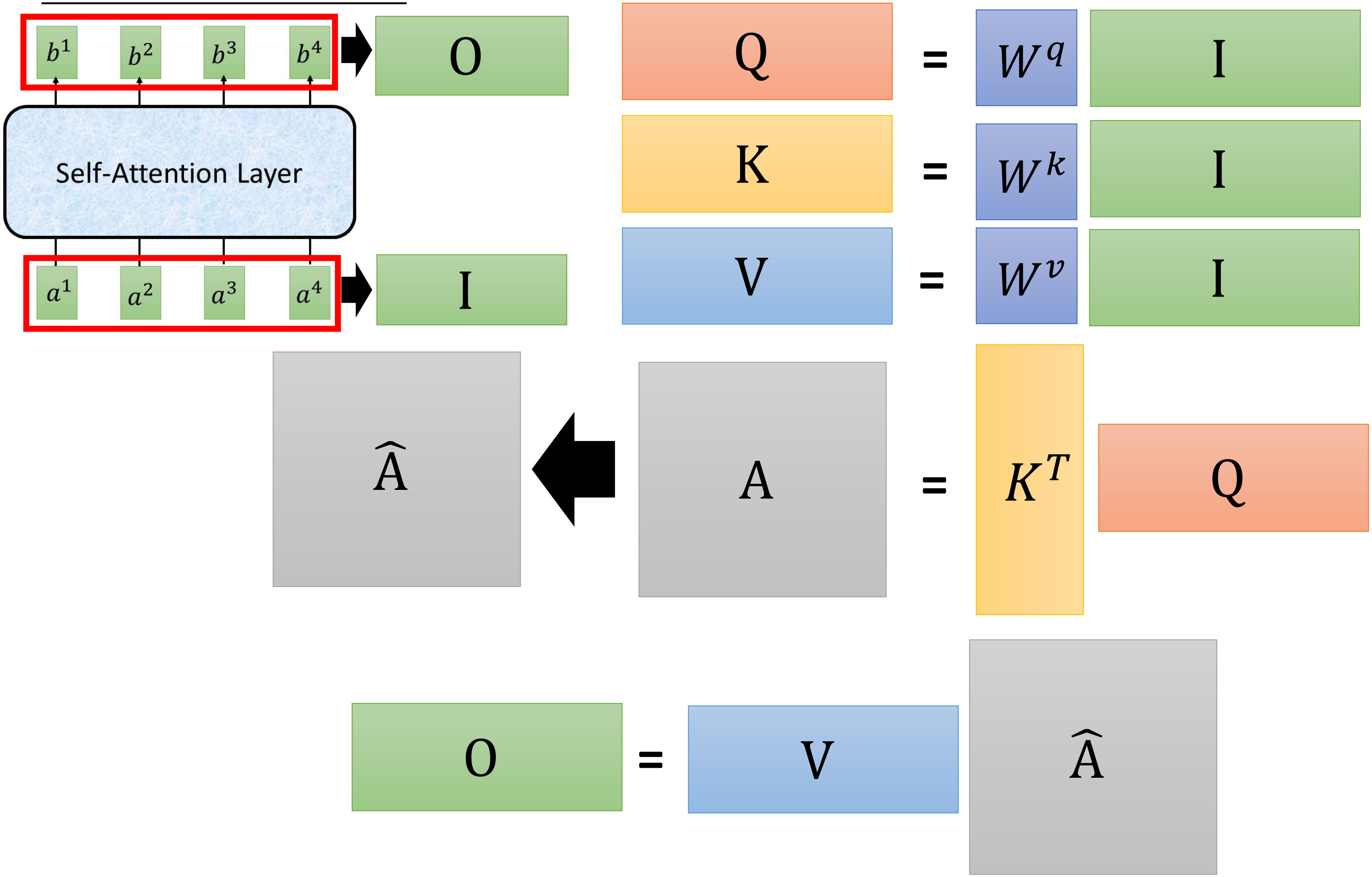
Self-attention

$$b^2 = \sum_i \hat{\alpha}_{2,i} v^i$$



$$\underbrace{b^1\ b^2\ b^3\ b^4}_{O} = \underbrace{v^1\ v^2\ v^3\ v^4}_{V} \underbrace{\begin{bmatrix} \hat{\alpha}_{1,1} & \hat{\alpha}_{2,1} & \hat{\alpha}_{3,1} & \hat{\alpha}_{4,1} \\ \hat{\alpha}_{1,2} & \hat{\alpha}_{2,2} & \hat{\alpha}_{3,2} & \hat{\alpha}_{4,2} \\ \hat{\alpha}_{1,3} & \hat{\alpha}_{2,3} & \hat{\alpha}_{3,3} & \hat{\alpha}_{4,3} \\ \hat{\alpha}_{1,4} & \hat{\alpha}_{2,4} & \hat{\alpha}_{3,4} & \hat{\alpha}_{4,4} \end{bmatrix}}_{\hat{A}}$$

Self-attention

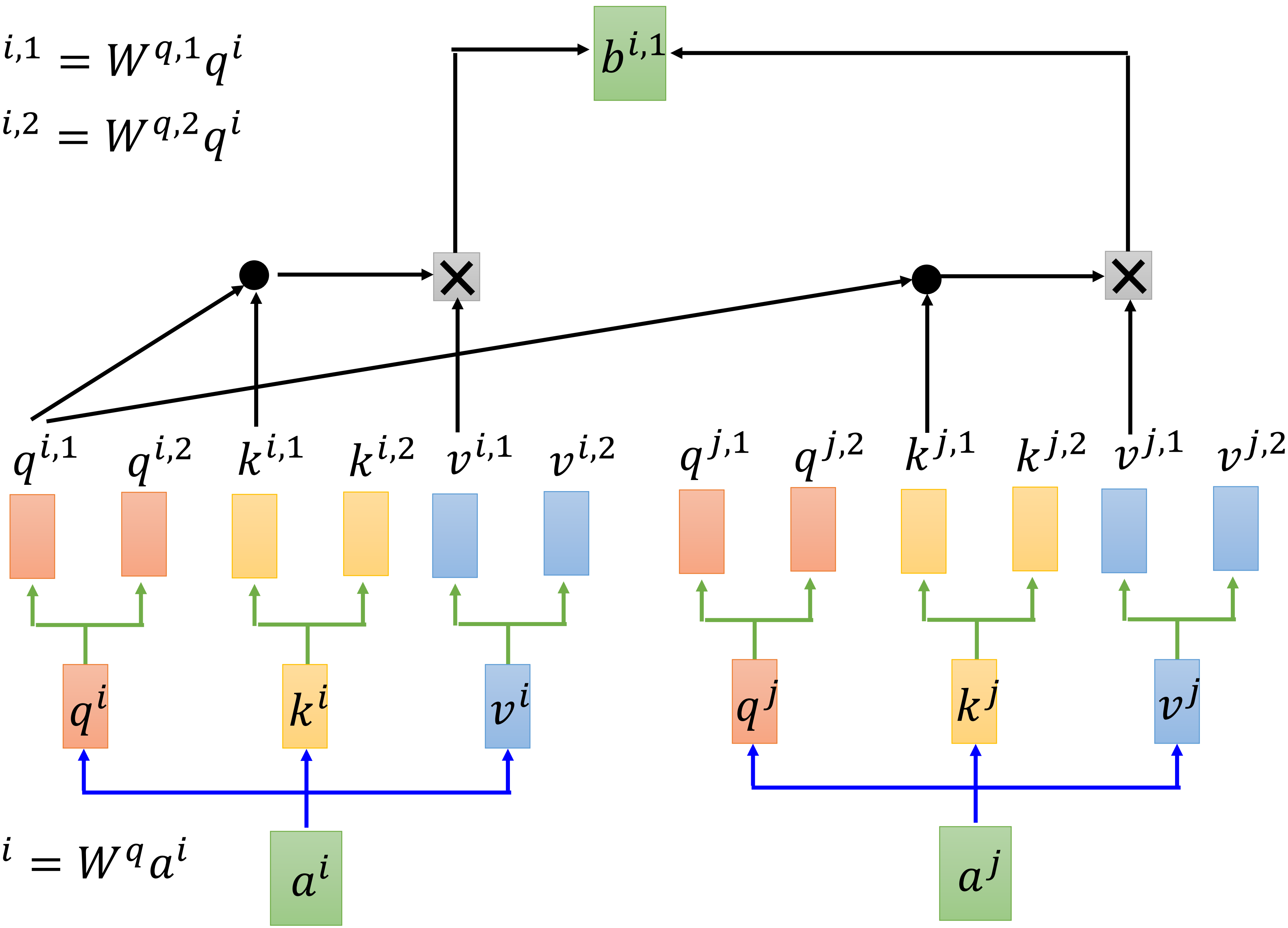


反正就是一堆矩陣乘法，用 GPU 可以加速

Multi-head Self-attention (2 heads as example)

$$q^{i,1} = W^{q,1} q^i$$

$$q^{i,2} = W^{q,2} q^i$$

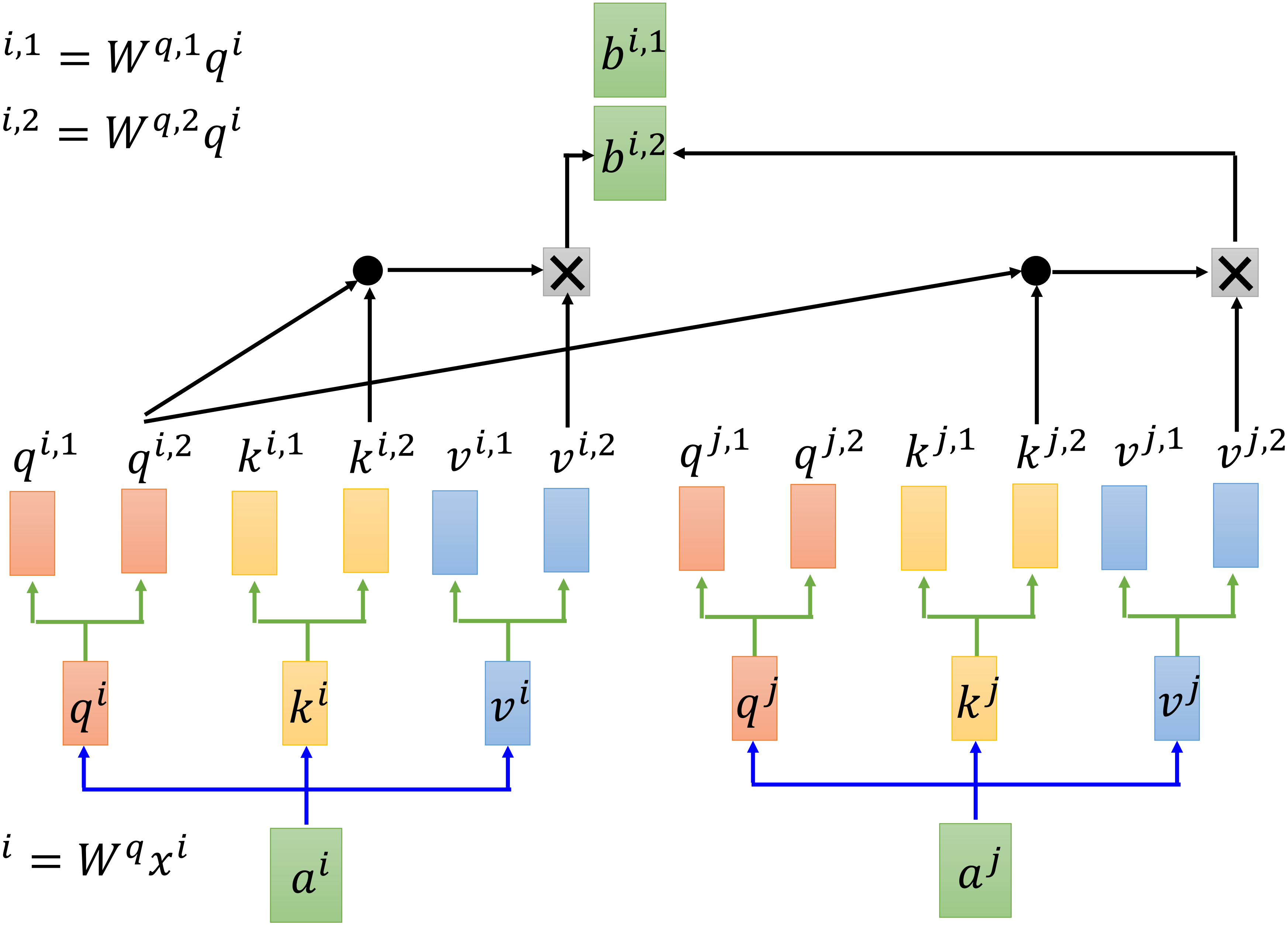


$$q^i = W^q a^i$$

Multi-head Self-attention (2 heads as example)

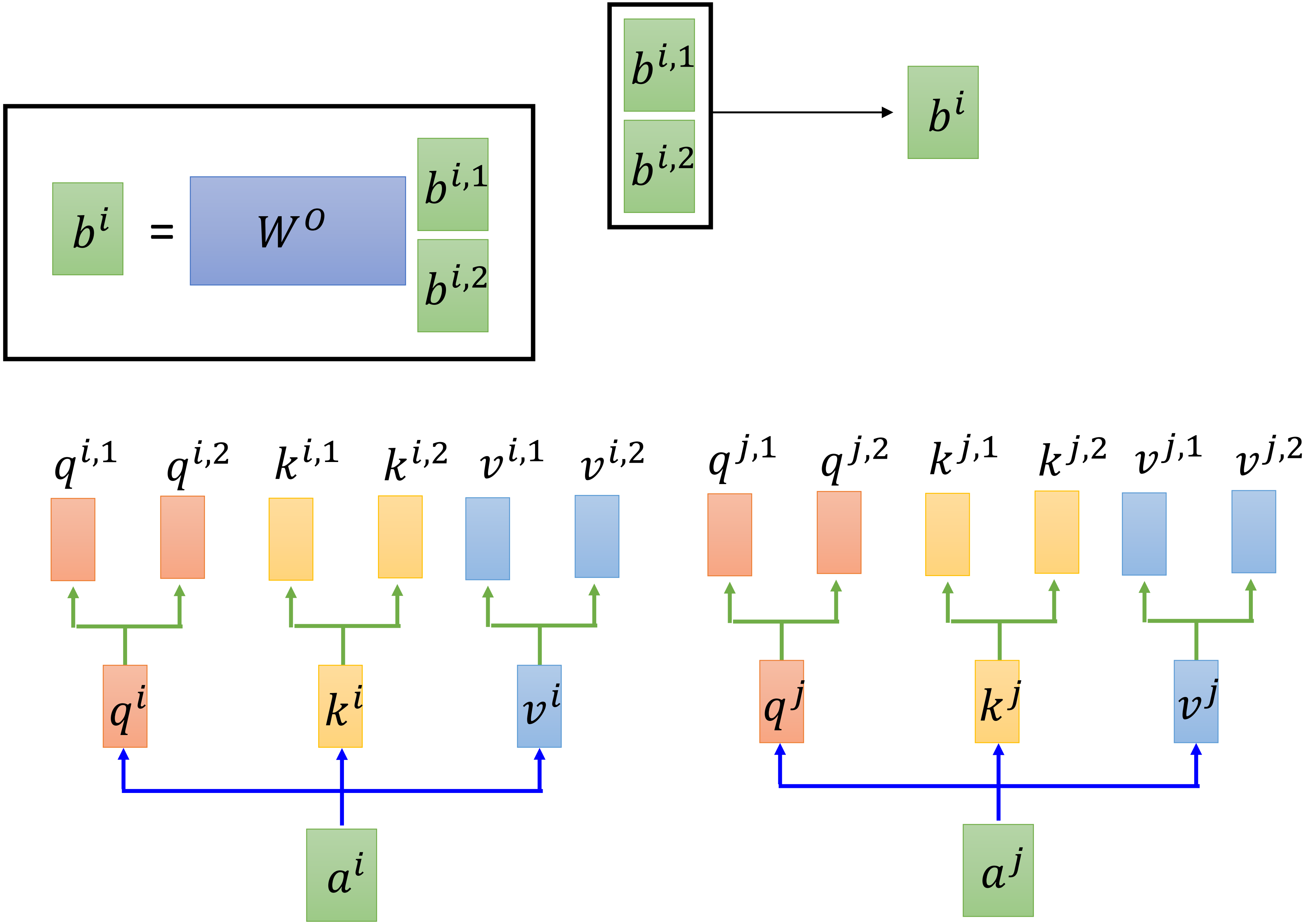
$$q^{i,1} = W^{q,1} q^i$$

$$q^{i,2} = W^{q,2} q^i$$

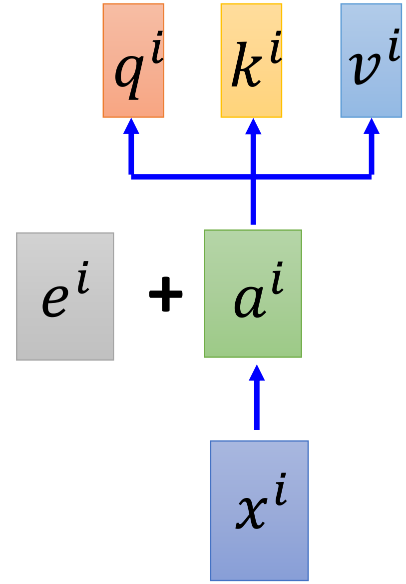


$$q^i = W^q x^i$$

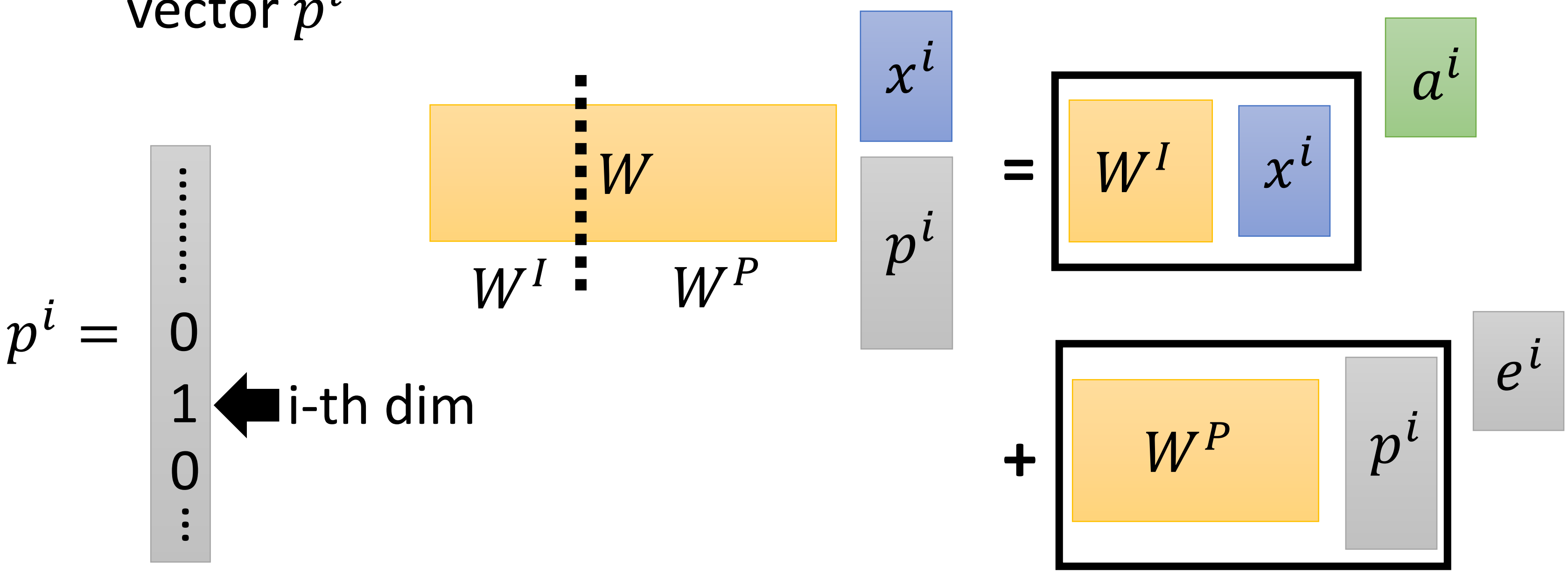
Multi-head Self-attention (2 heads as example)

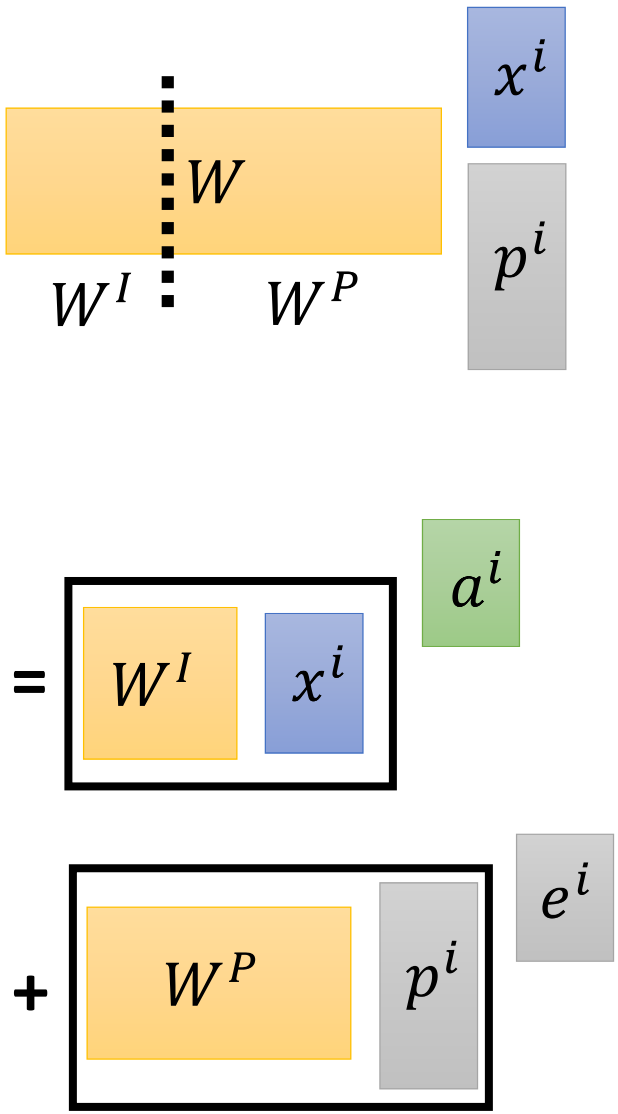


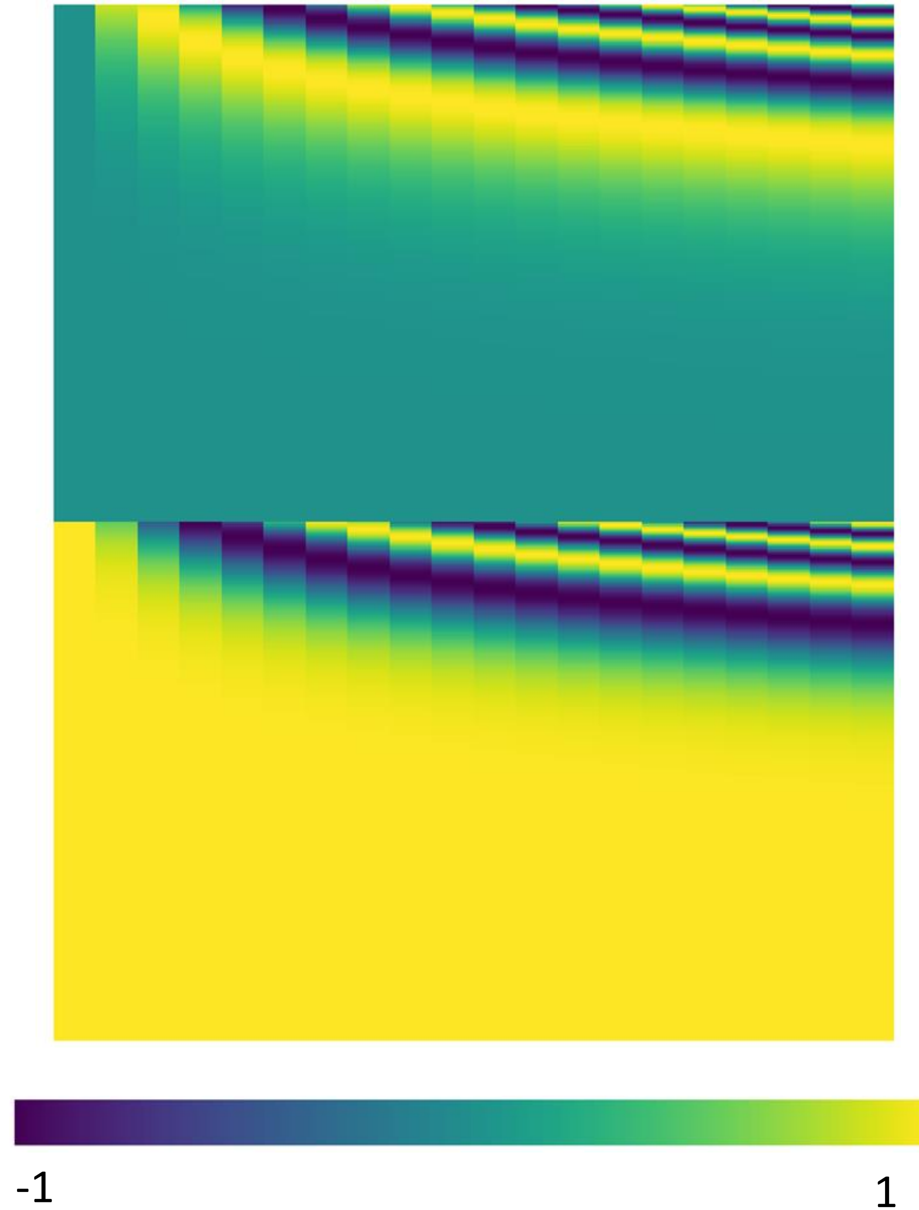
Positional Encoding



- No position information in self-attention.
- Original paper: each position has a unique positional vector e^i (not learned from data)
- In other words: each x^i appends a one-hot vector p^i



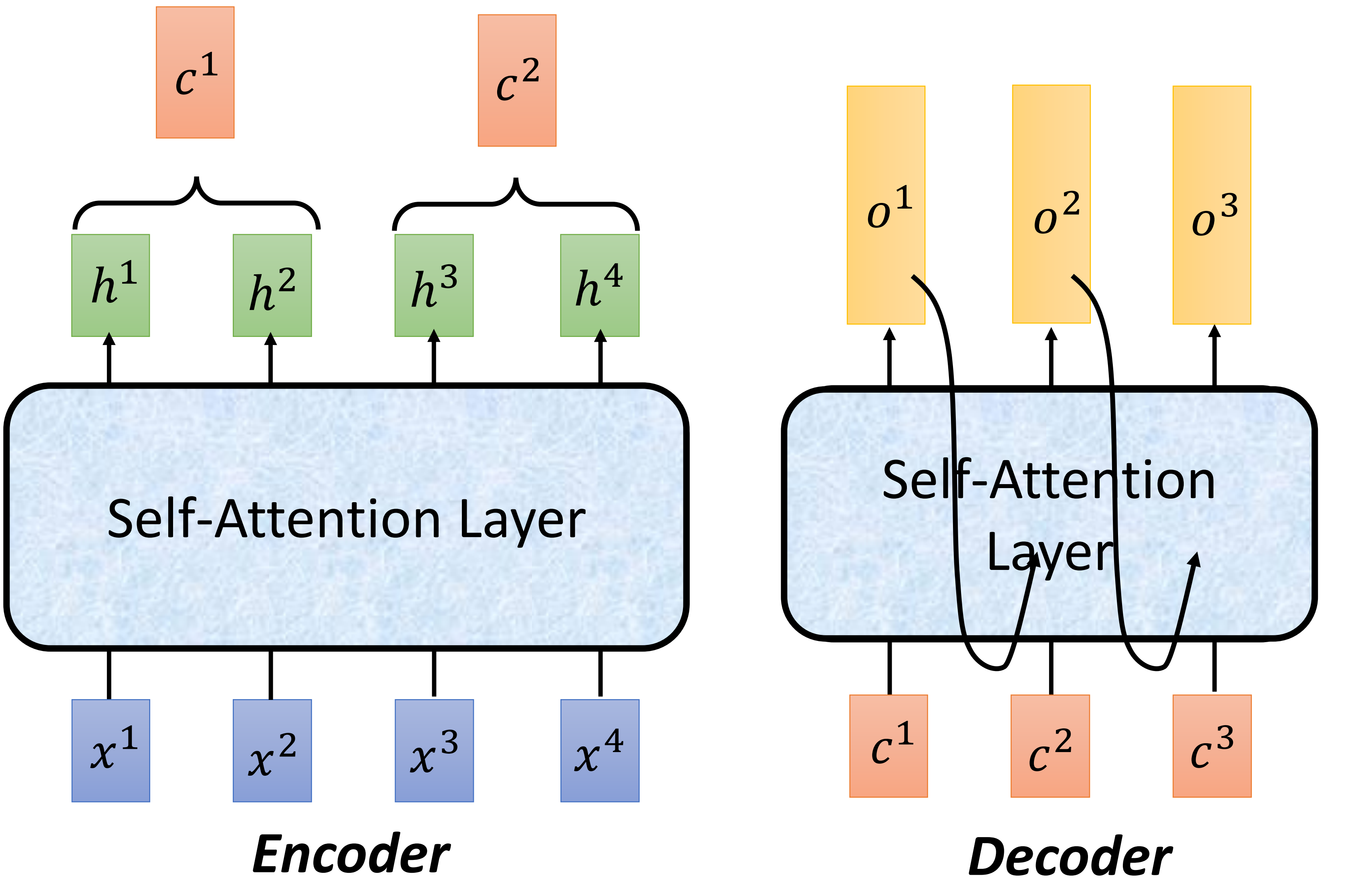




source of image: http://jalammar.github.io/illustrated-transformer/

Review: https://www.youtube.com/watch?v=ZjfjPzXw6og&feature=youtu.be

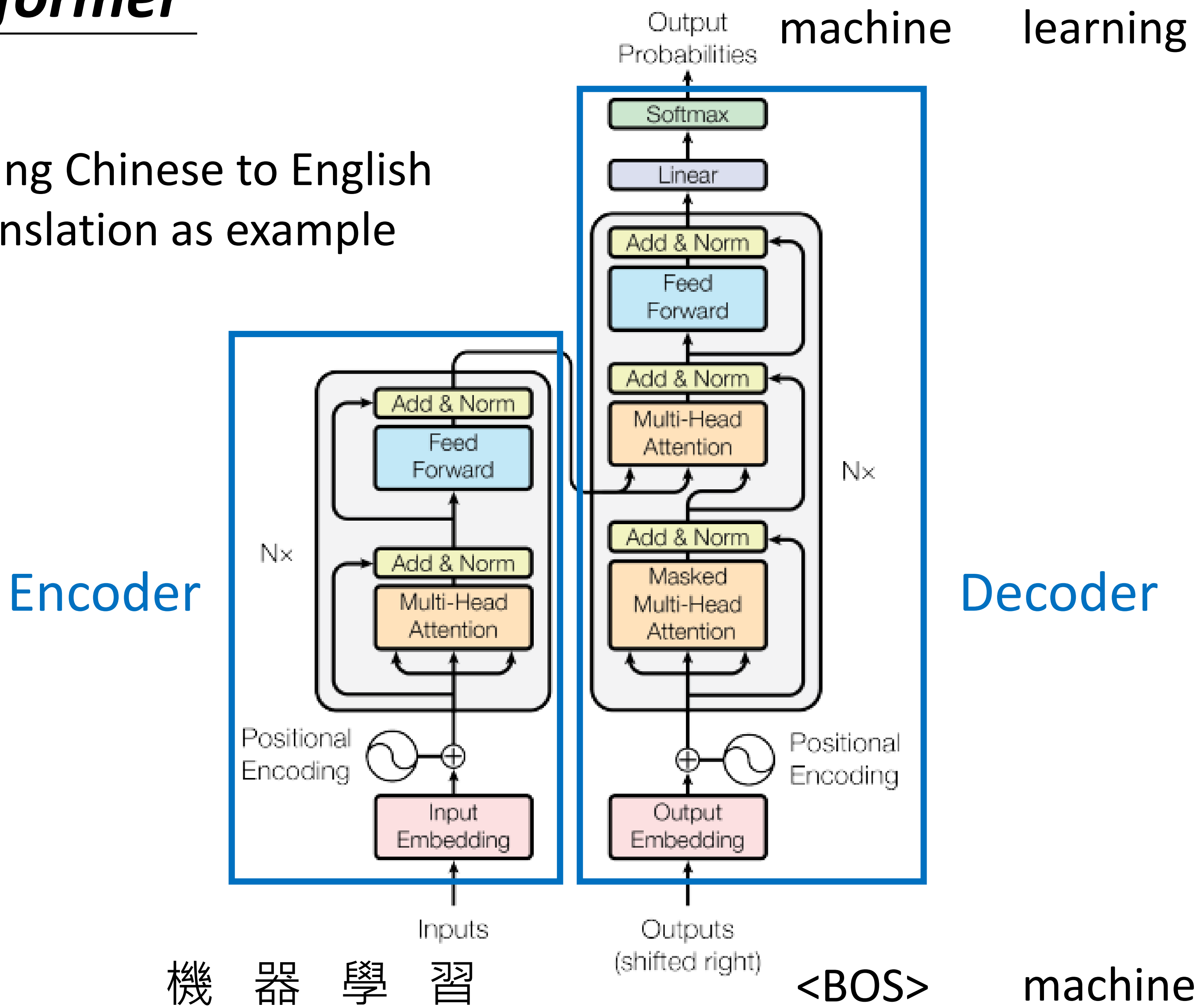
Seq2seq with Attention



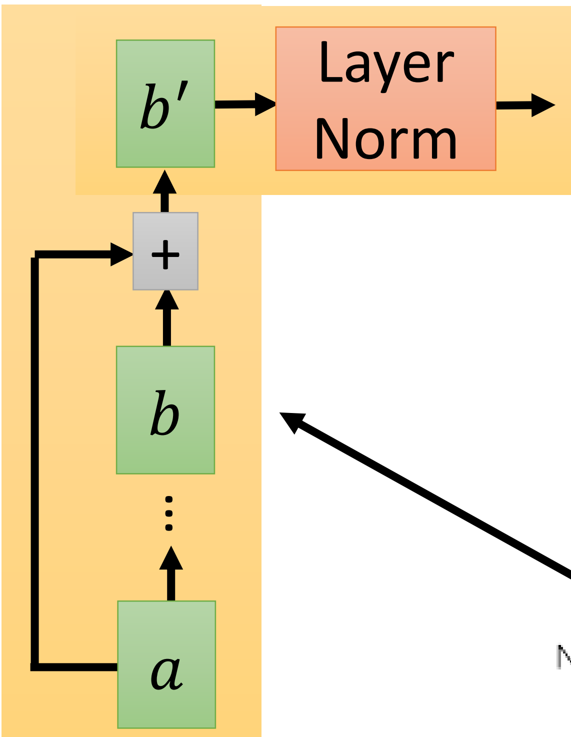
https://ai.googleblog.com/2017/08/transformer-novel-neural-network.html

Transformer

Using Chinese to English translation as example

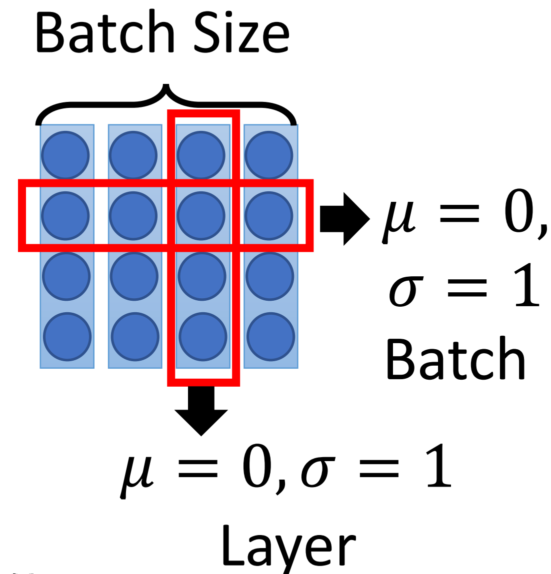


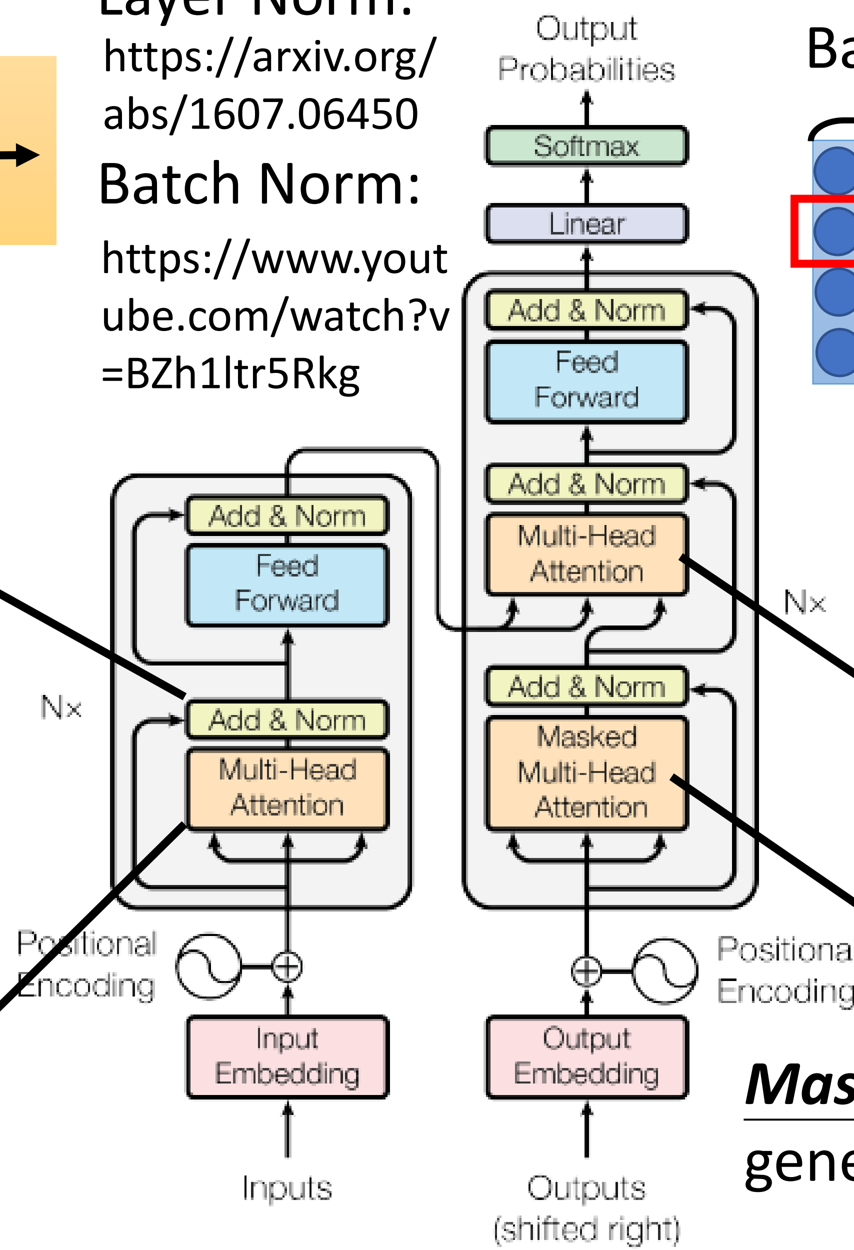
Transformer



Layer Norm: https://arxiv.org/abs/1607.06450

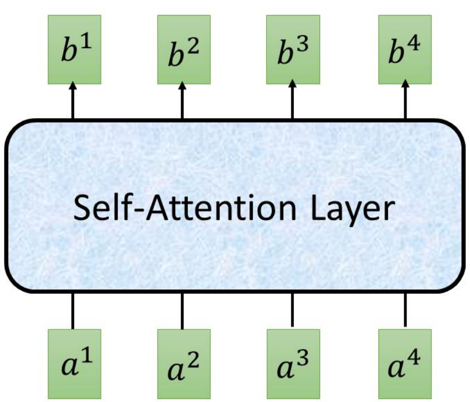
Batch Norm: https://www.youtube.com/watch?v=BZh1ltr5Rkg



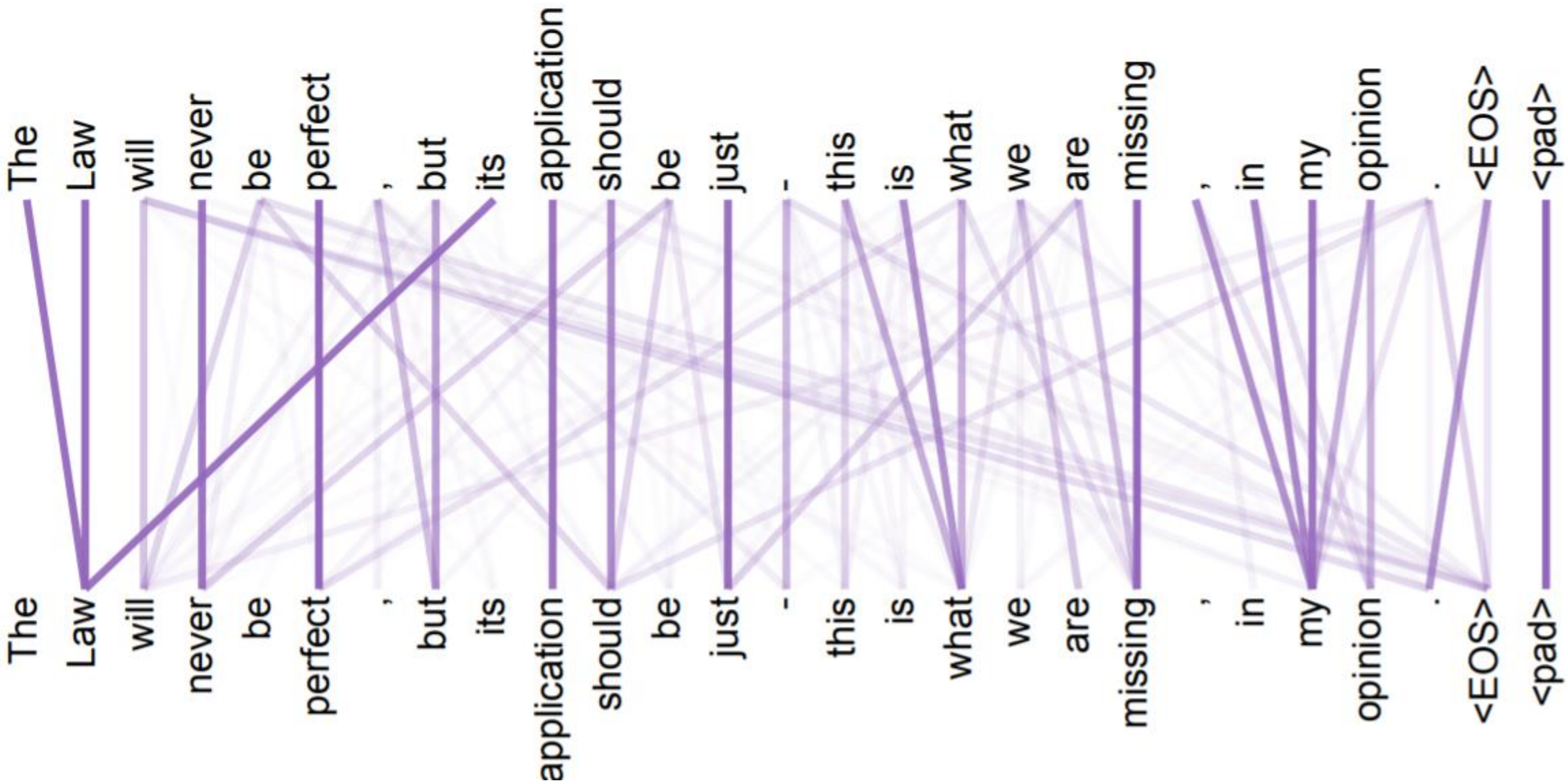


attend on the input sequence

Masked: attend on the generated sequence

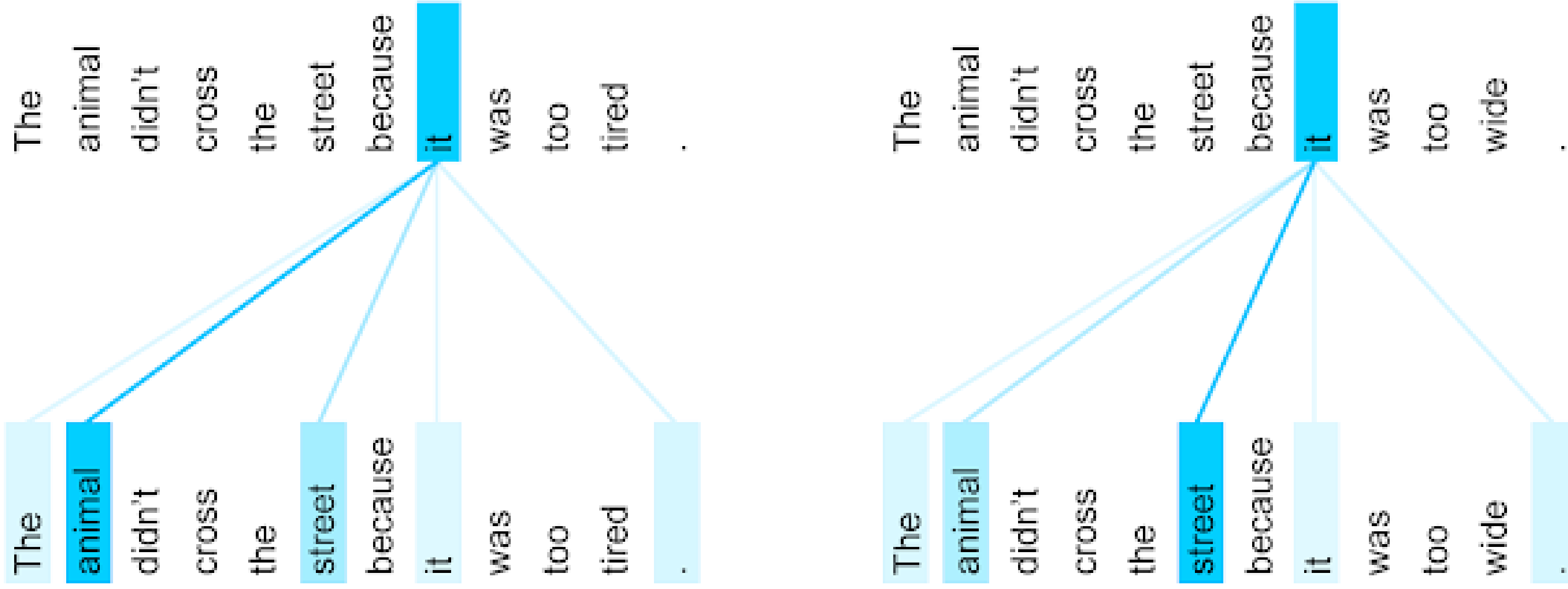


Attention Visualization



https://arxiv.org/abs/1706.03762

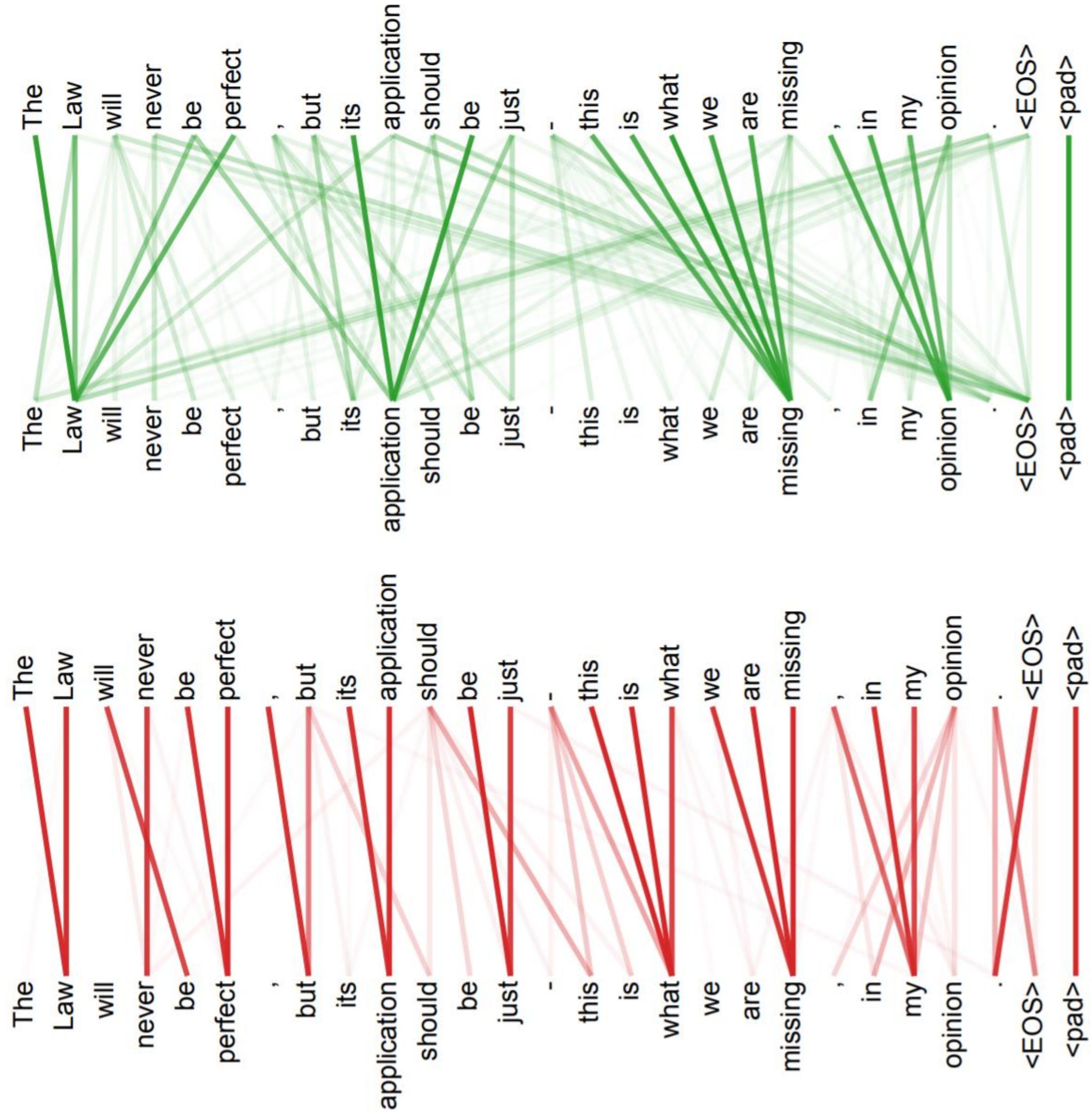
Attention Visualization



The encoder self-attention distribution for the word "it" from the 5th to the 6th layer of a Transformer trained on English to French translation (one of eight attention heads).

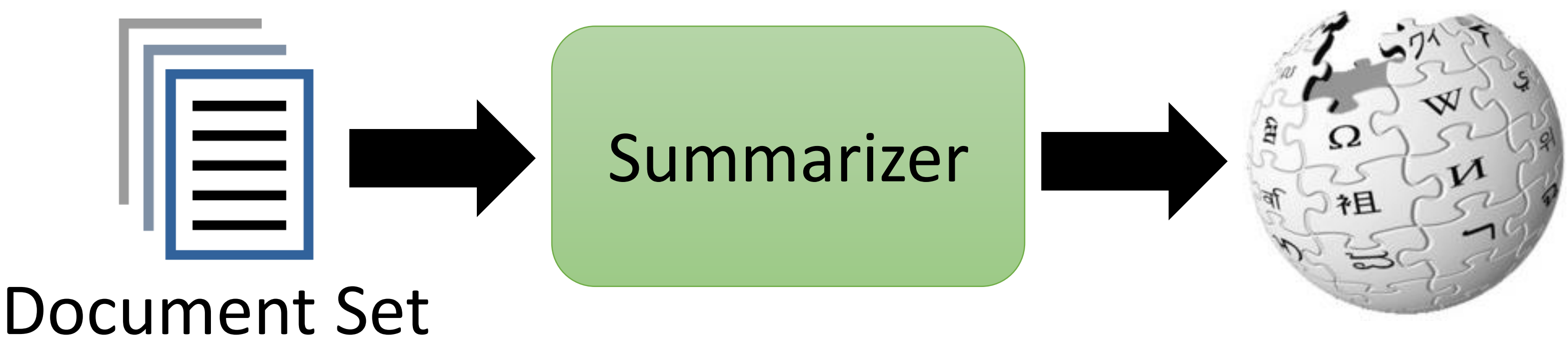
https://ai.googleblog.com/2017/08/transformer-novel-neural-network.html

Multi-head Attention



Example Application

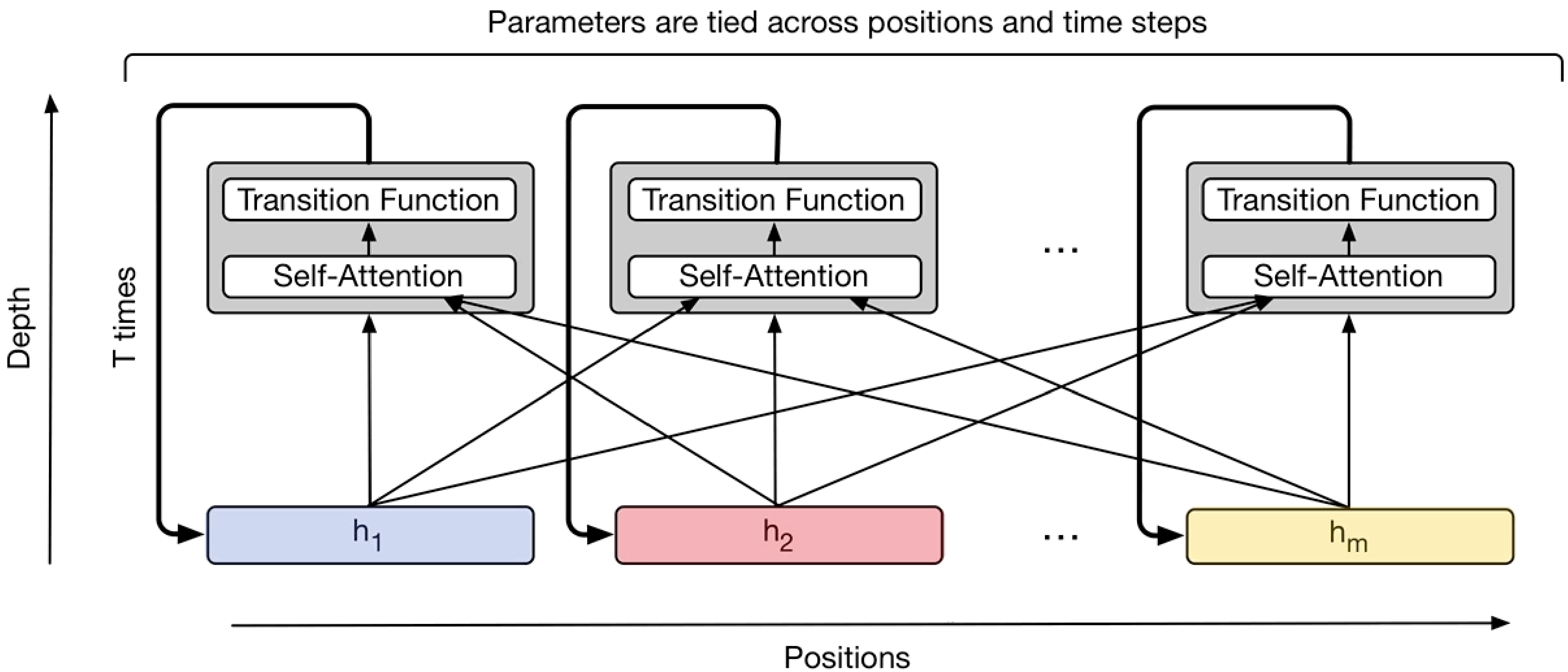
- If you can use seq2seq, you can use transformer.



Dataset	Input	Output	# examples
Gigaword (Graff & Cieri, 2003)	10^1	10^1	10^6
CNN/DailyMail (Nallapati et al., 2016)	10^2–10^3	10^1	10^5
WikiSum (ours)	10^2–10^6	10^1–10^3	10^6

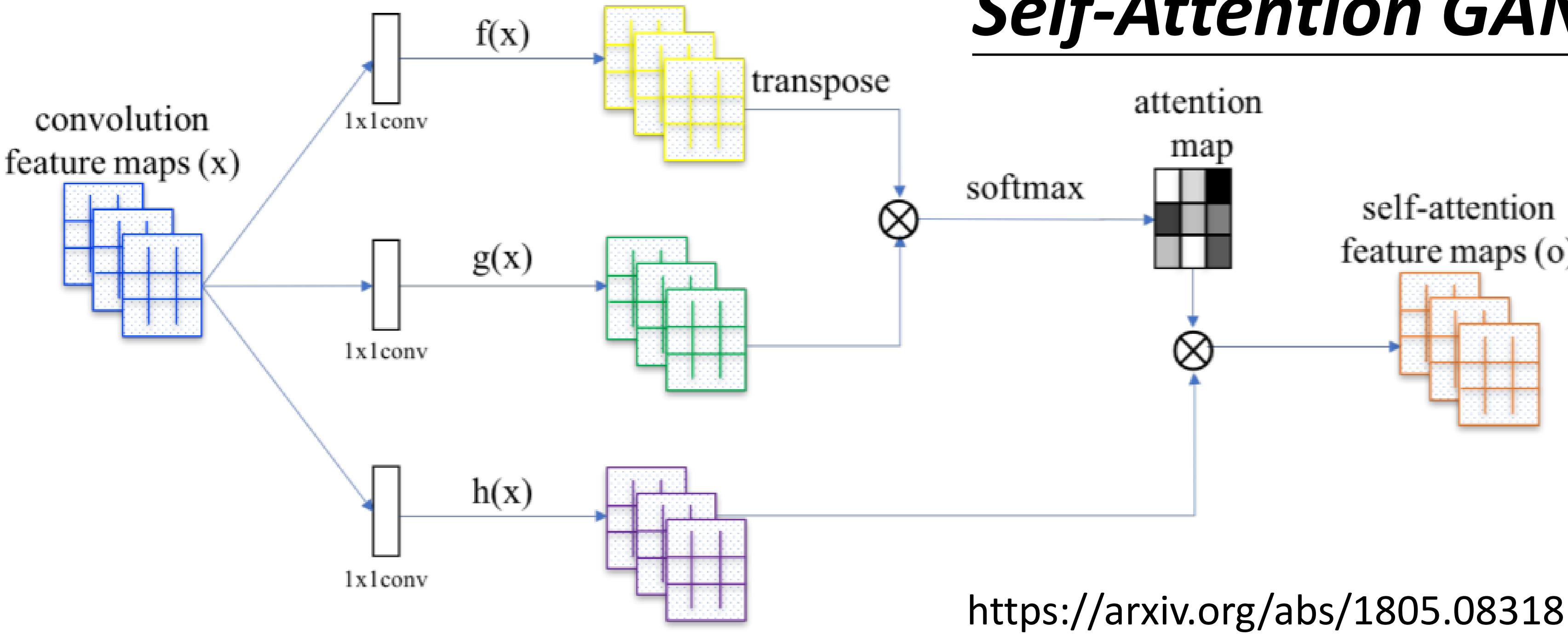
https://arxiv.org/abs/1801.10198

Universal Transformer



https://ai.googleblog.com/2018/08/moving-beyond-translation-with.html

Self-Attention GAN



https://arxiv.org/abs/1805.08318