Atten-Scope:

A Tool for Interpreting Large Language Model

Dongjae Lee

2024.05.30

KAIST
Programming Systems Laboratory

Importance of interpreting LLM

- Code quality has been declining since the language model came out*.

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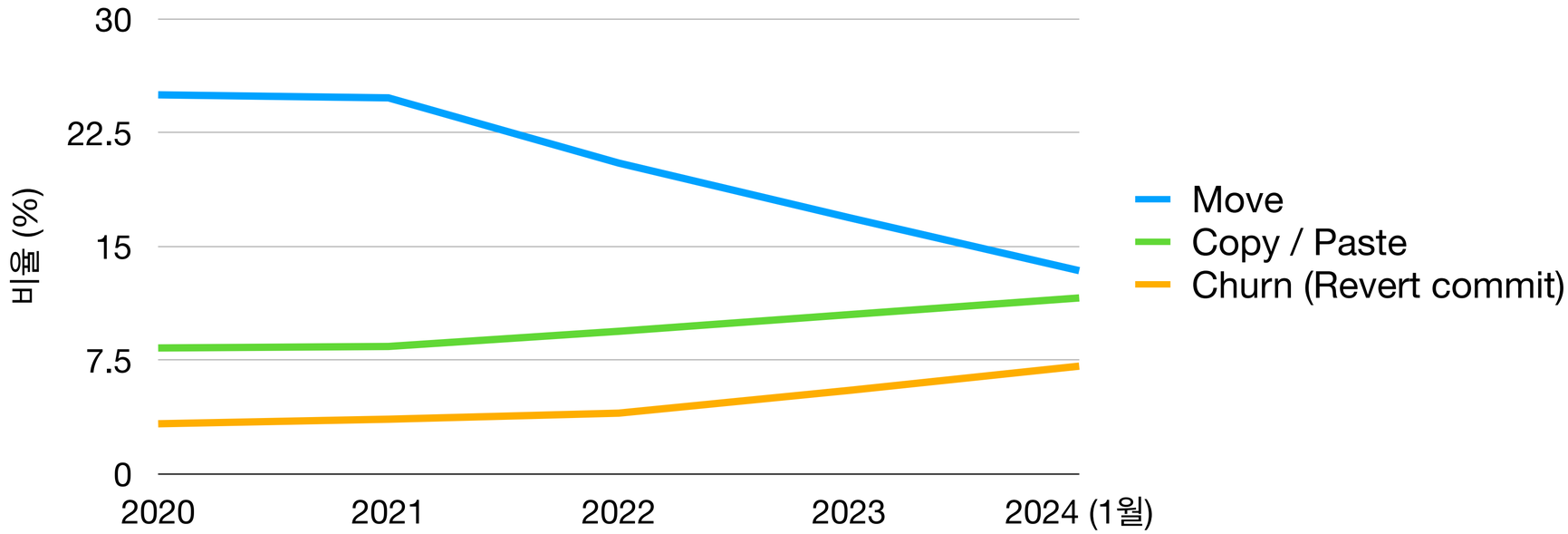

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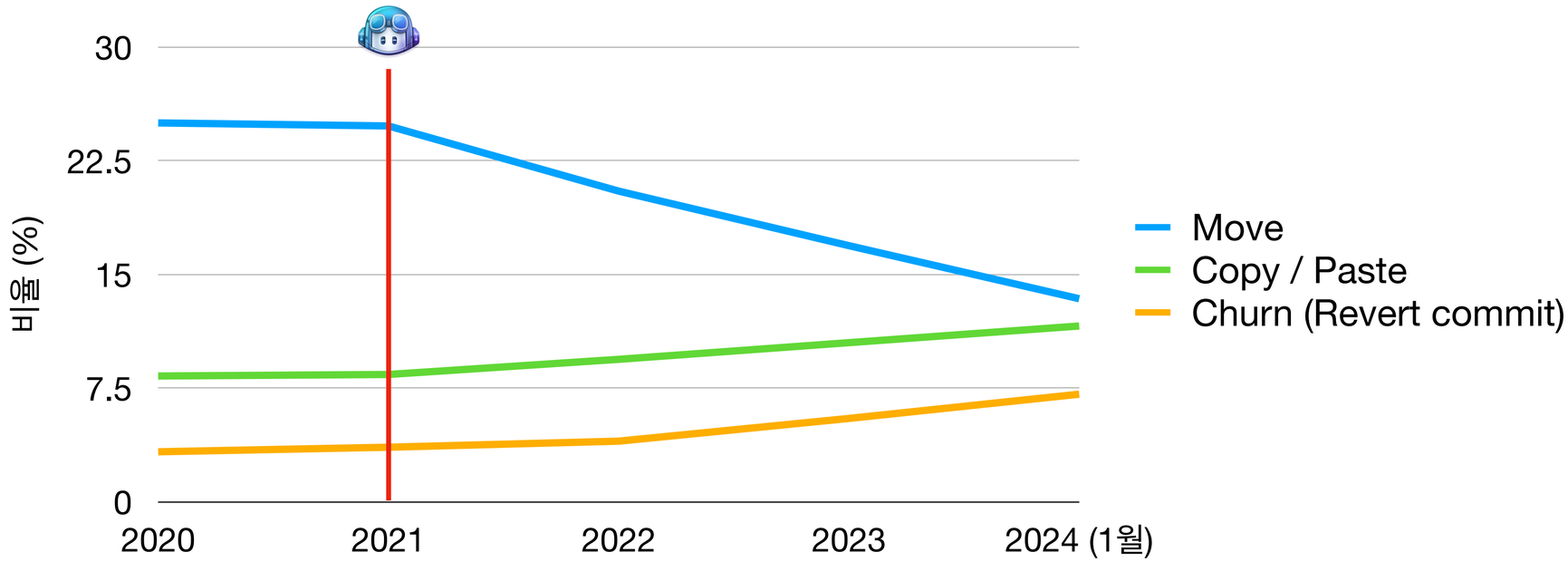

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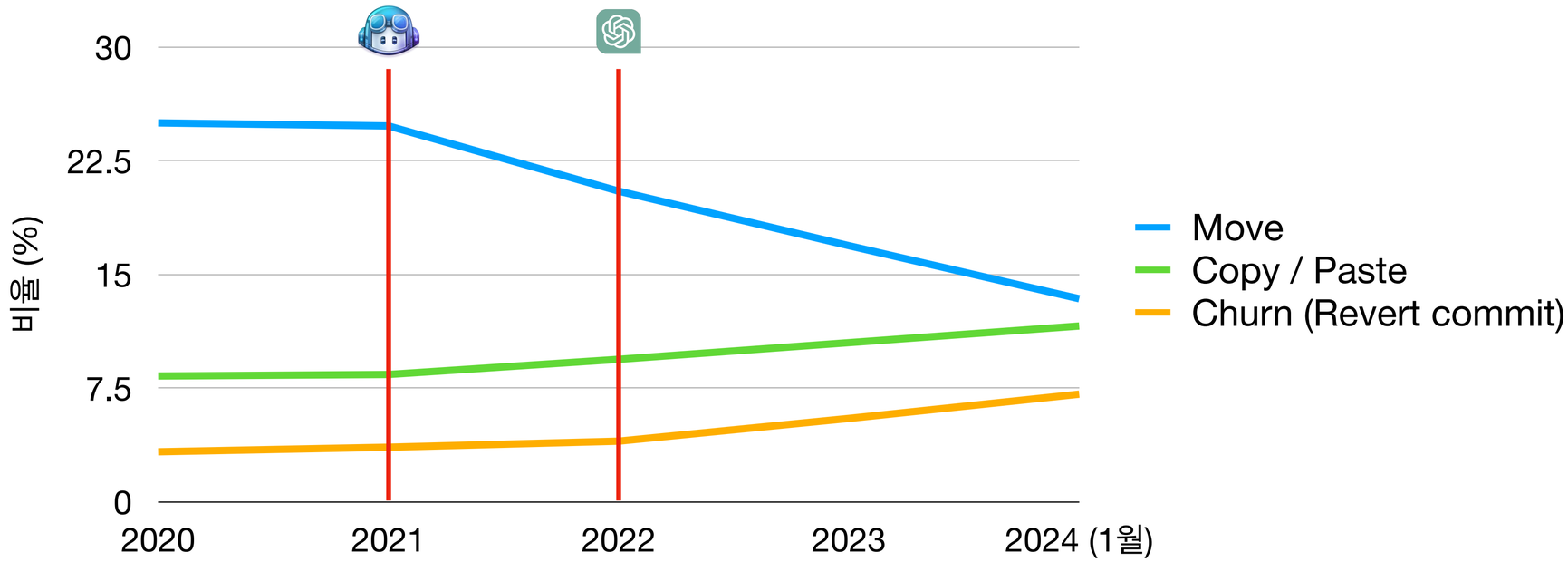

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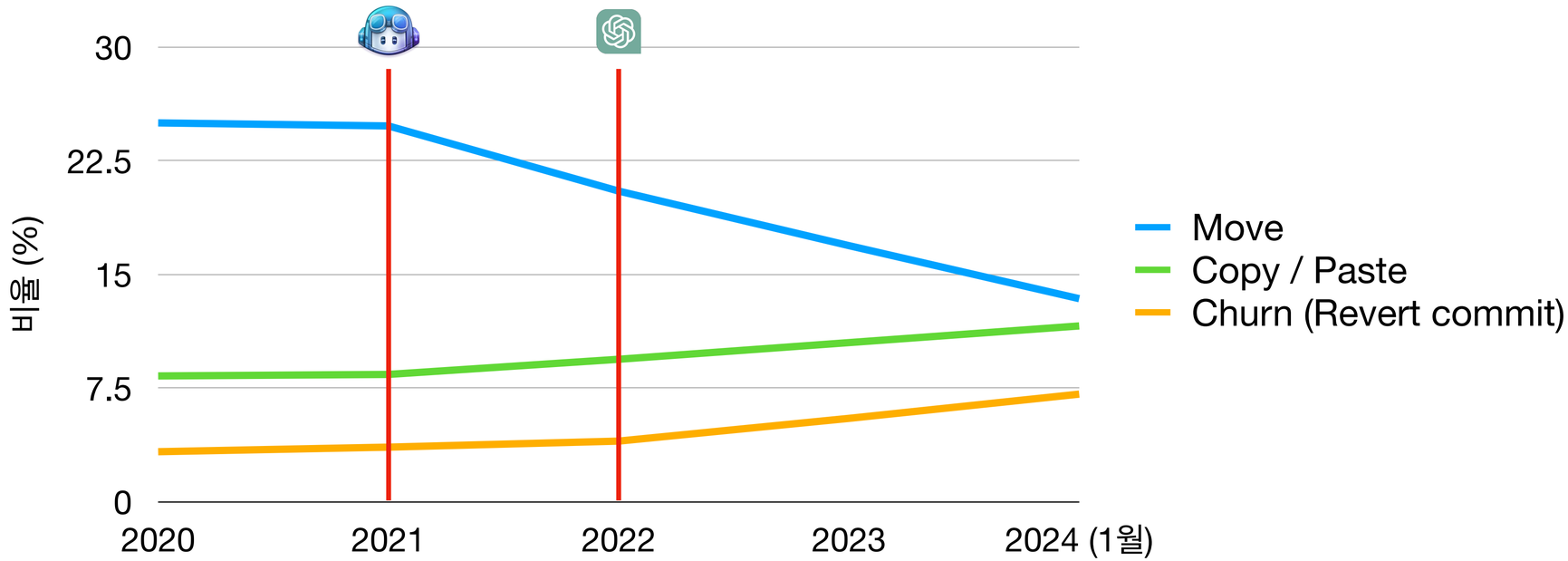

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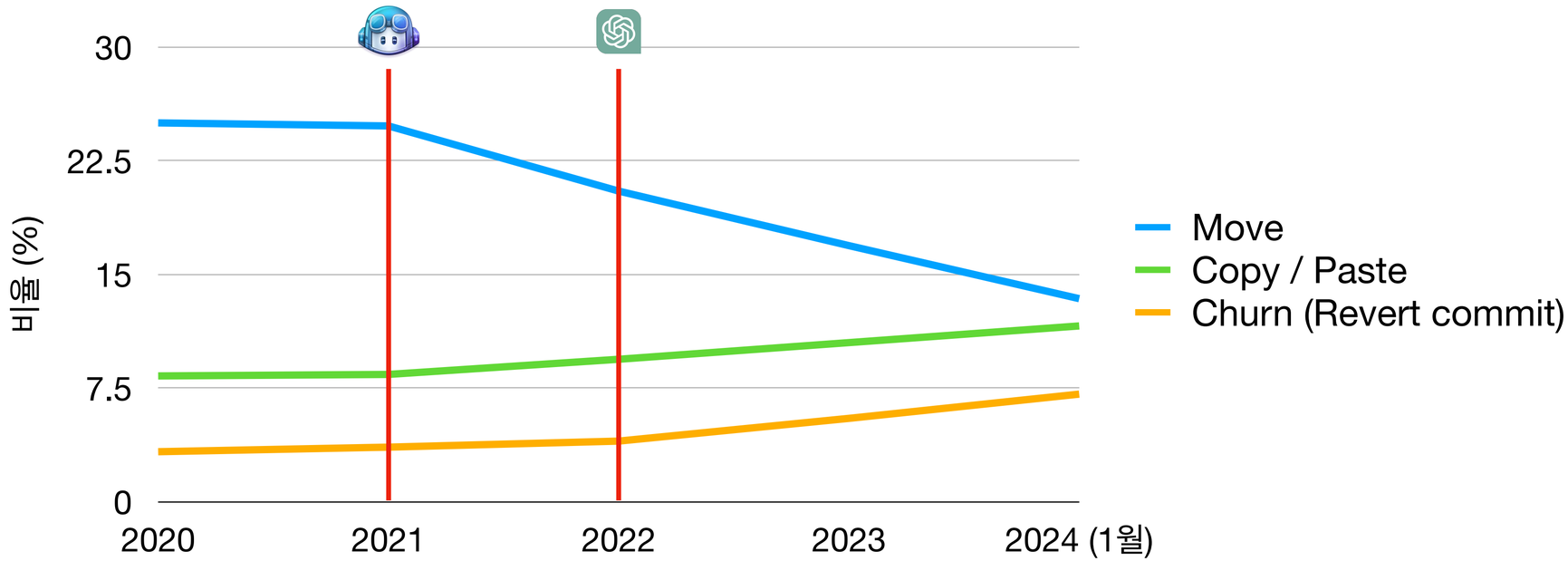

- **Refactoring** poorly
- Not writing the correct code the first time

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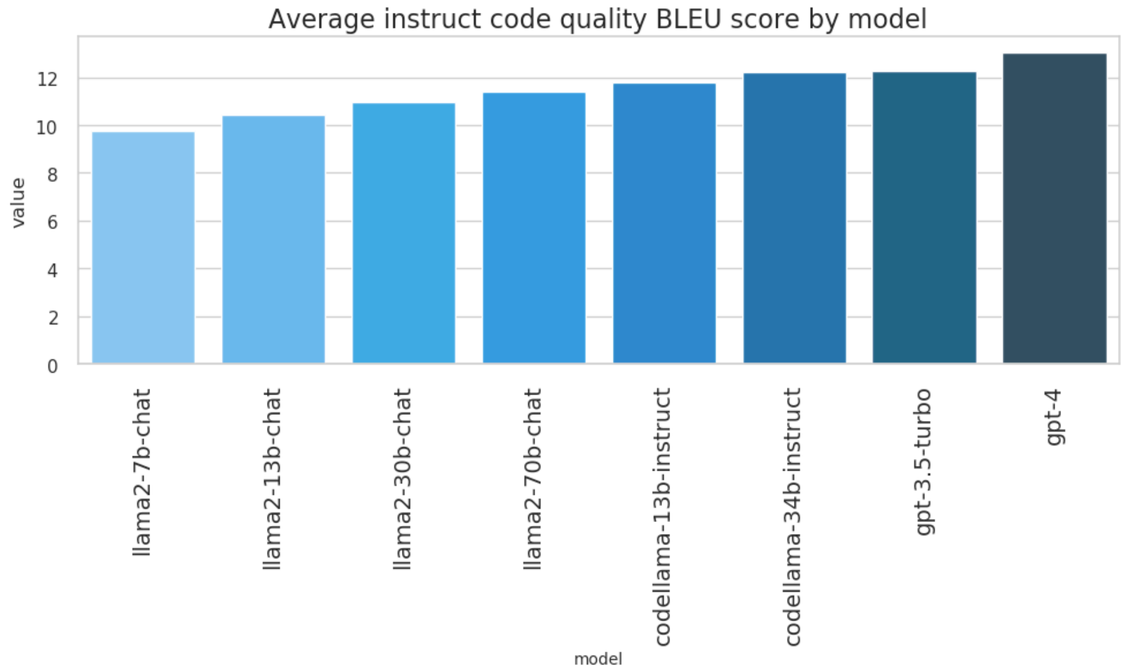

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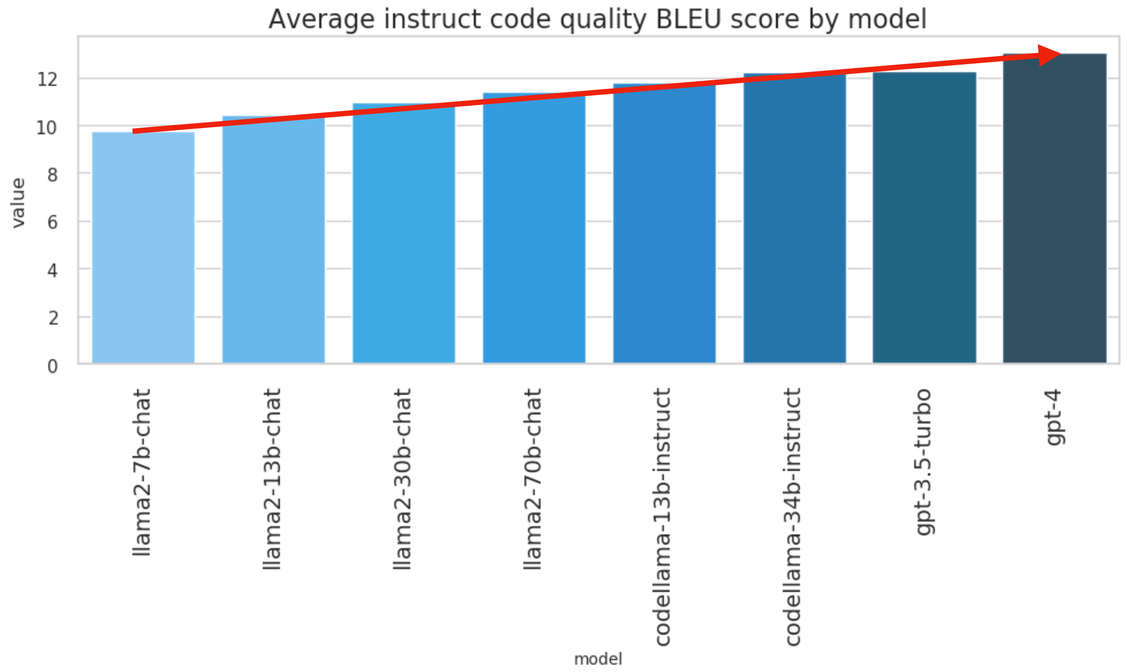

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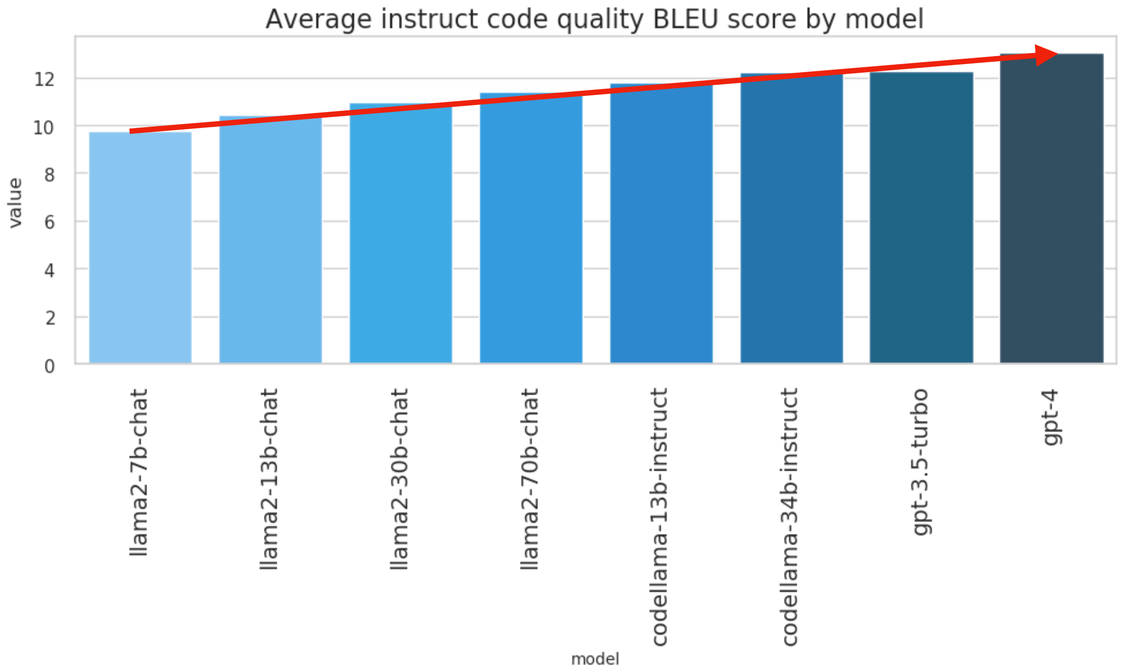

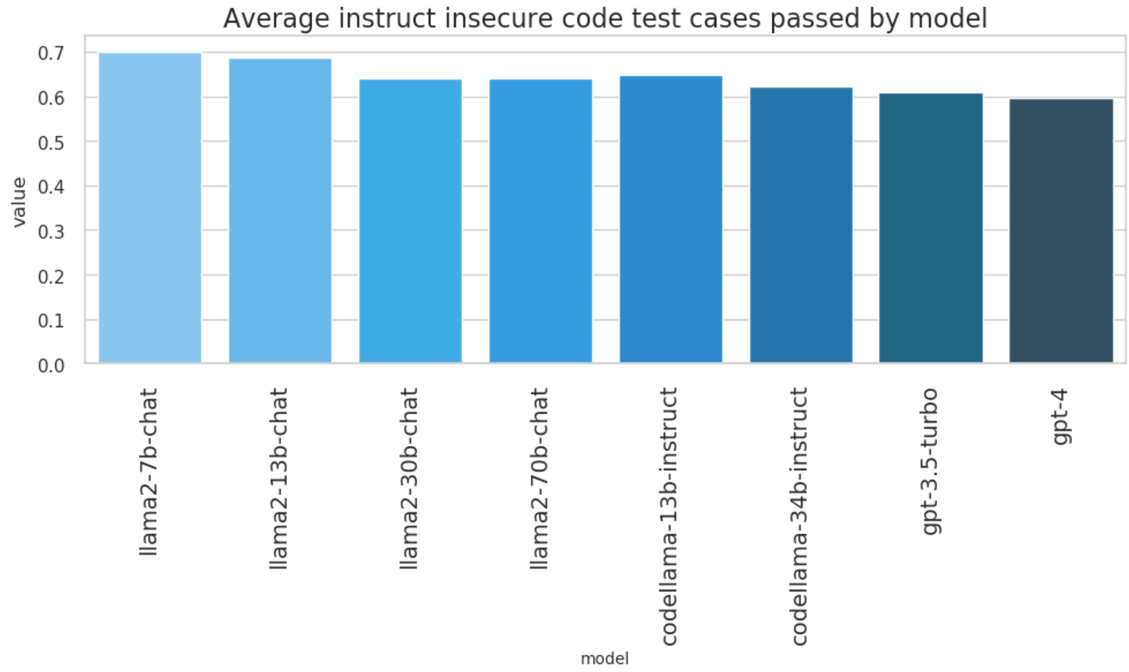

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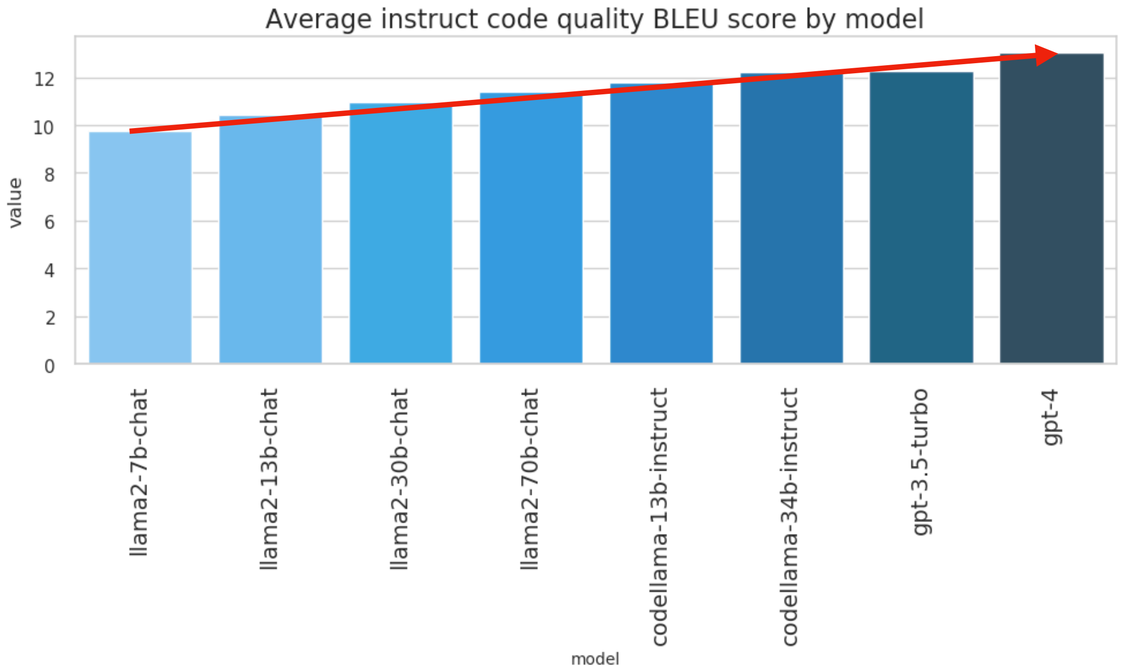

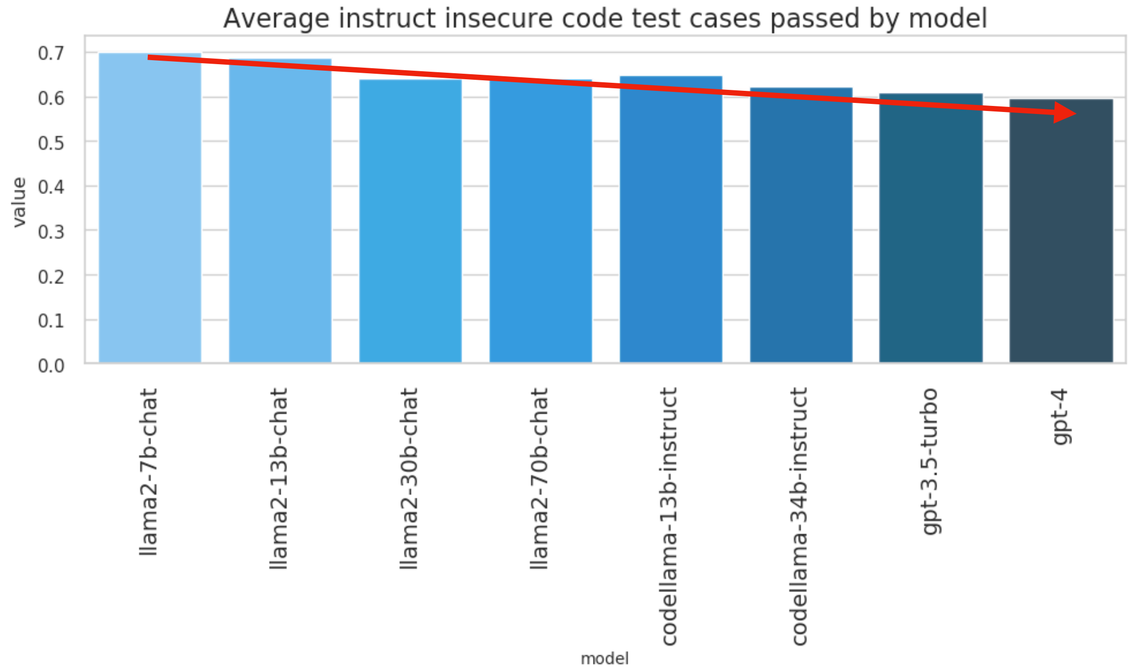

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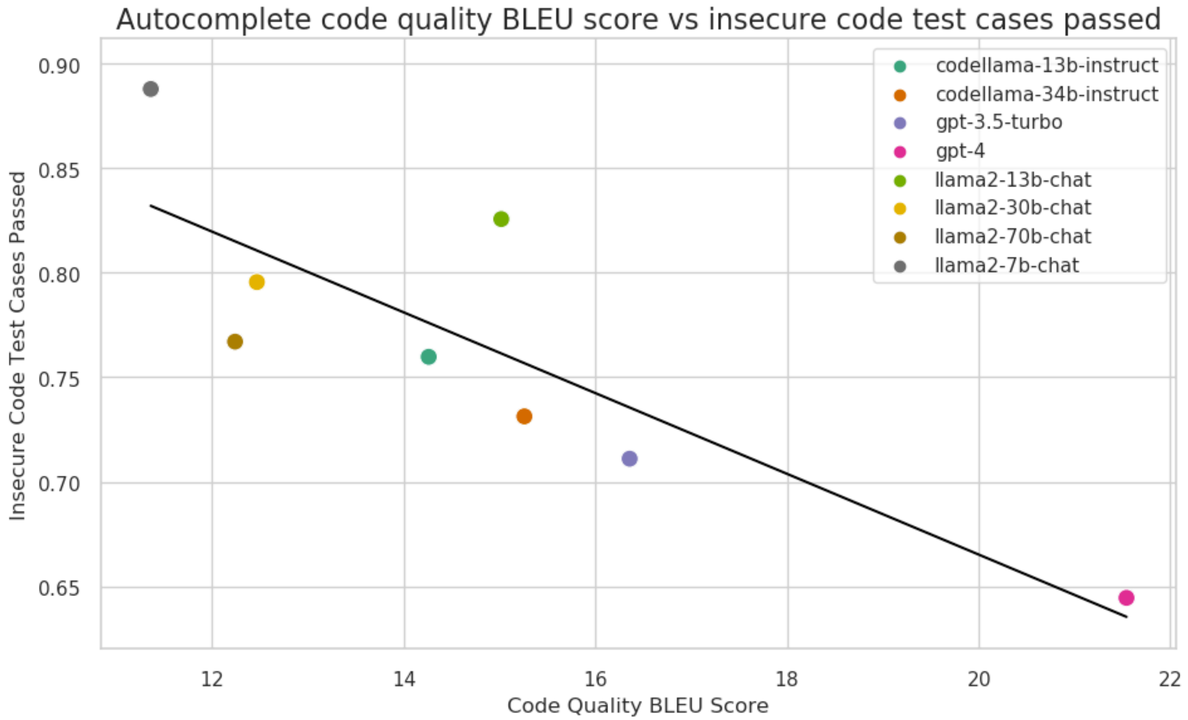

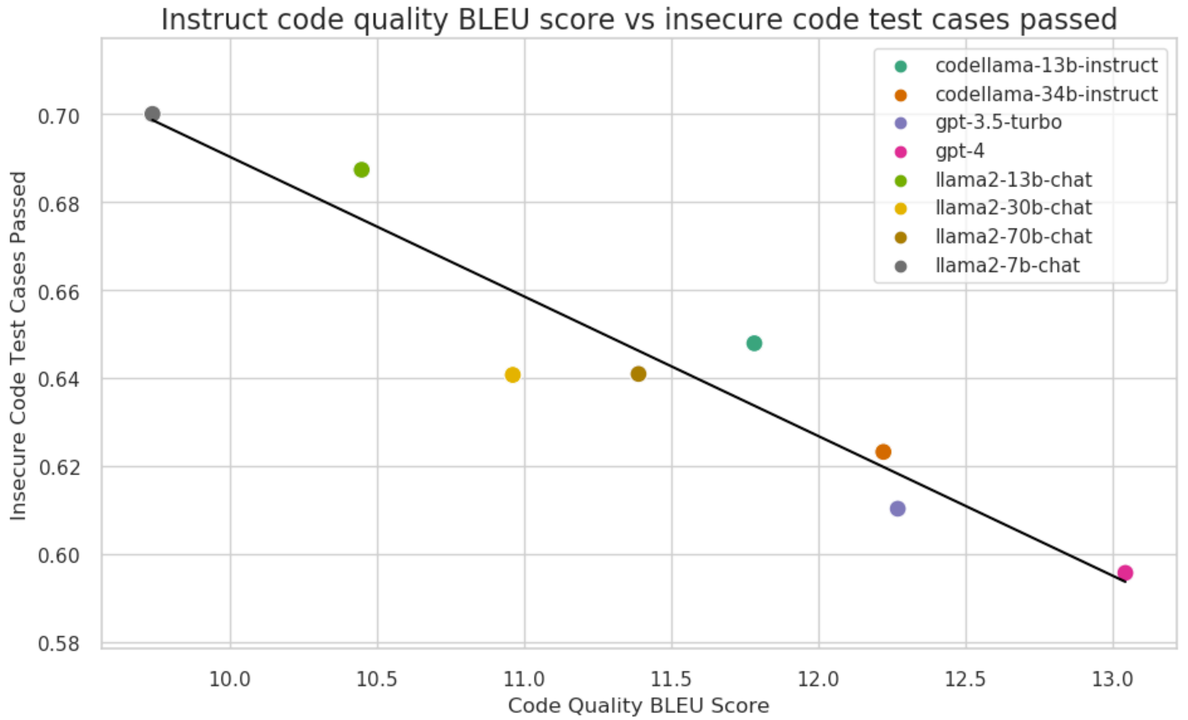

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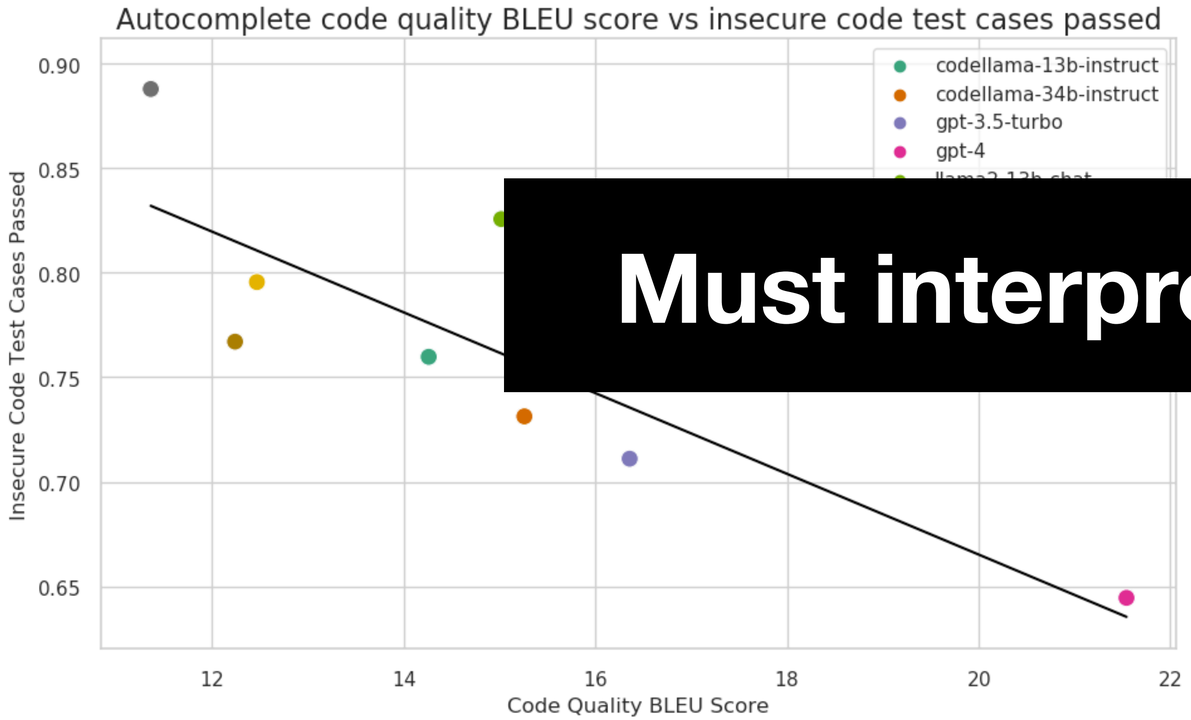

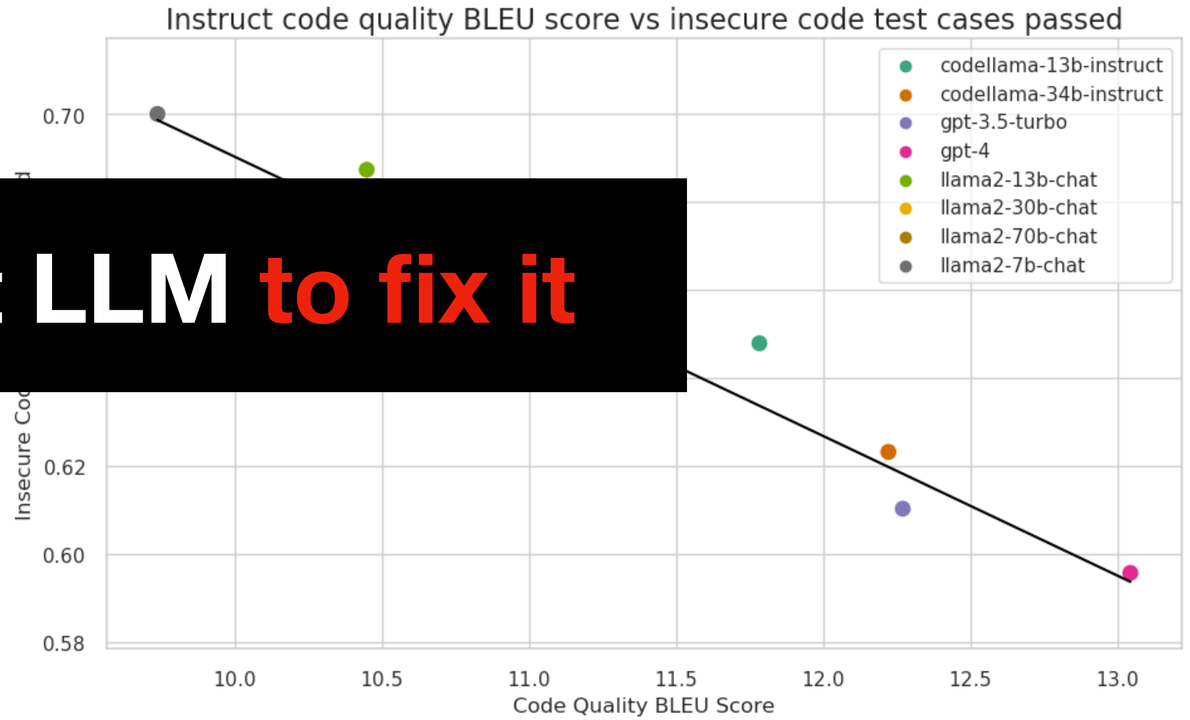

Must interpret LLM to fix it

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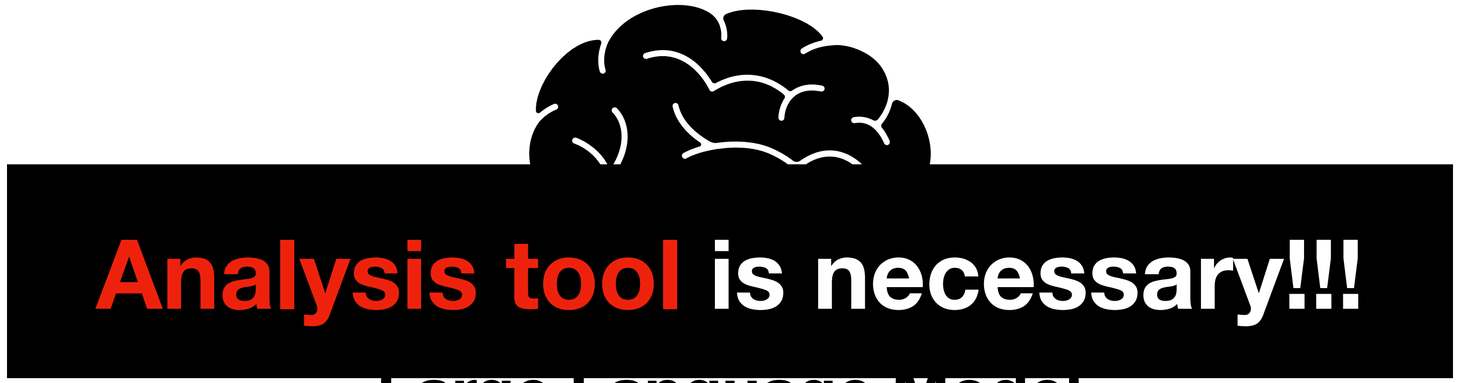

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Demo

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- There are lots of tools for visualizing attention

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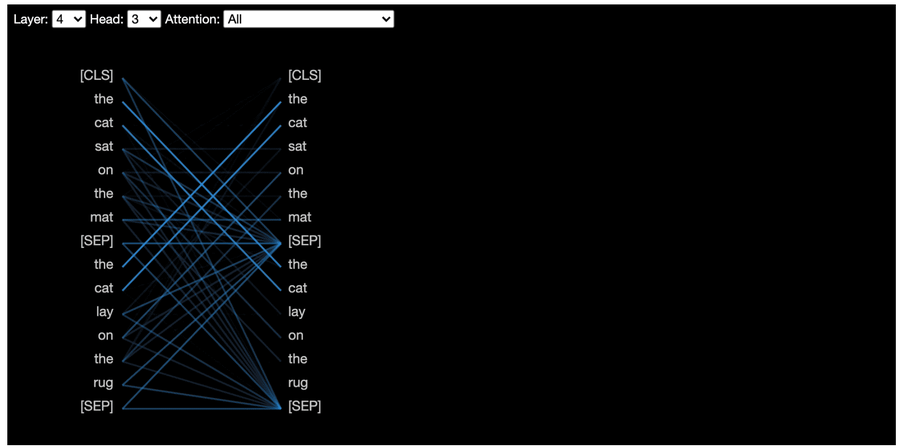

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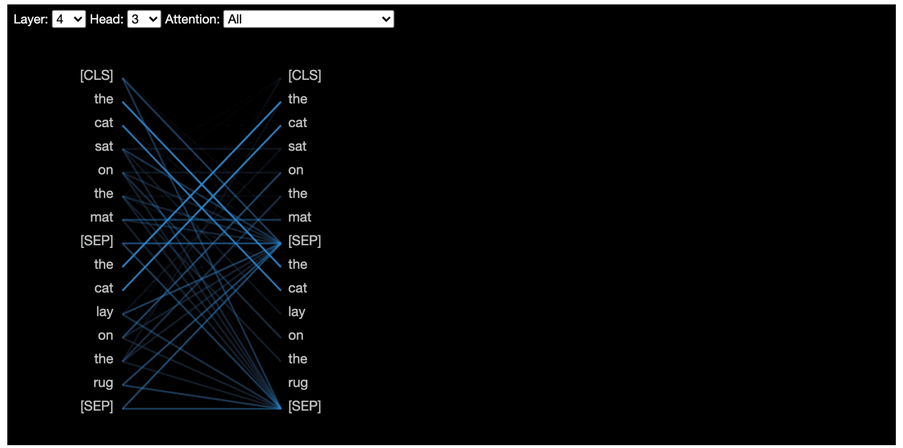

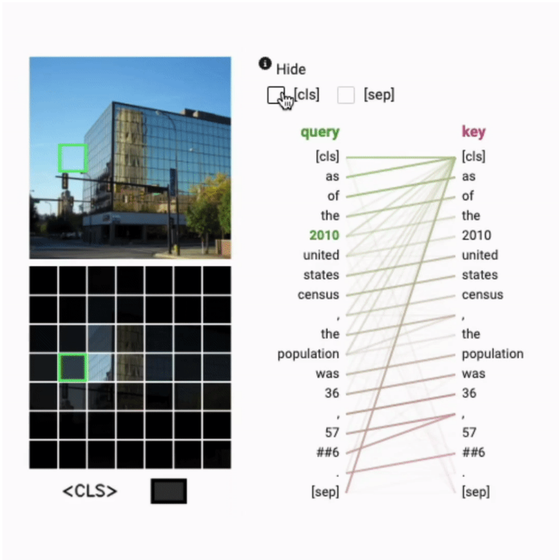

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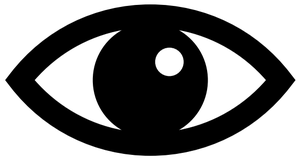

Insightful

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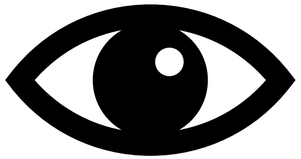

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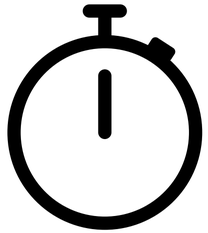

Fast

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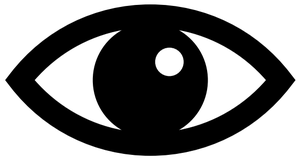

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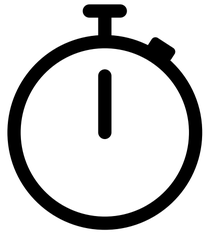
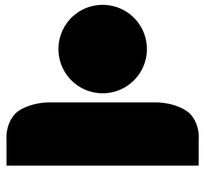


Fast

Code-friendly

Overview



User

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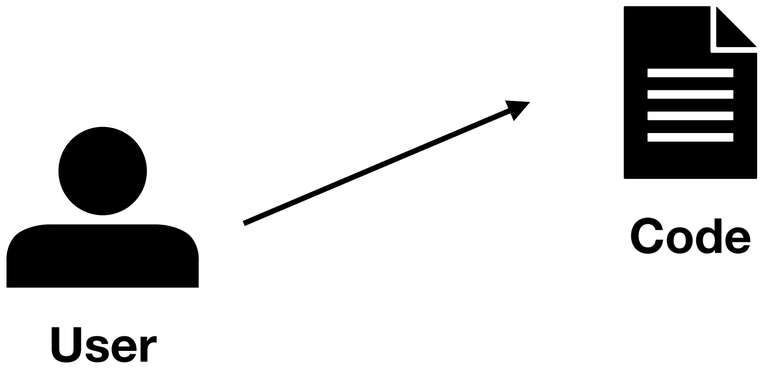

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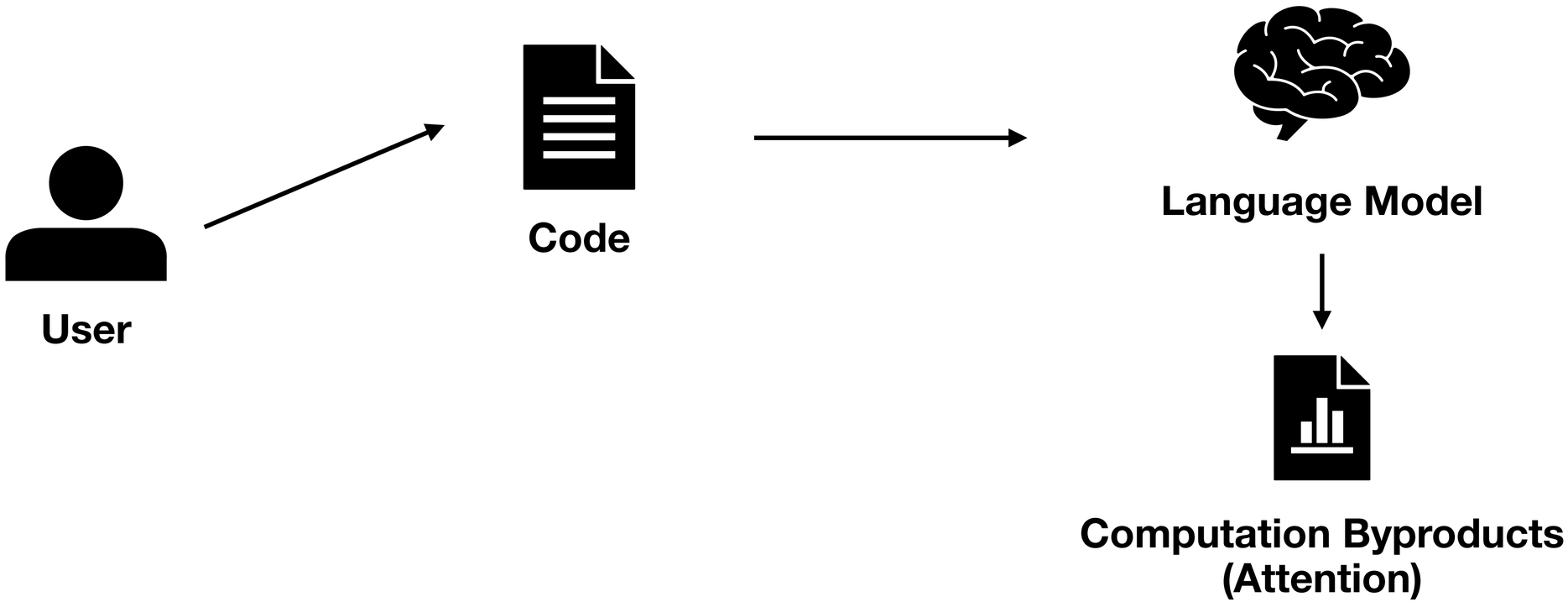
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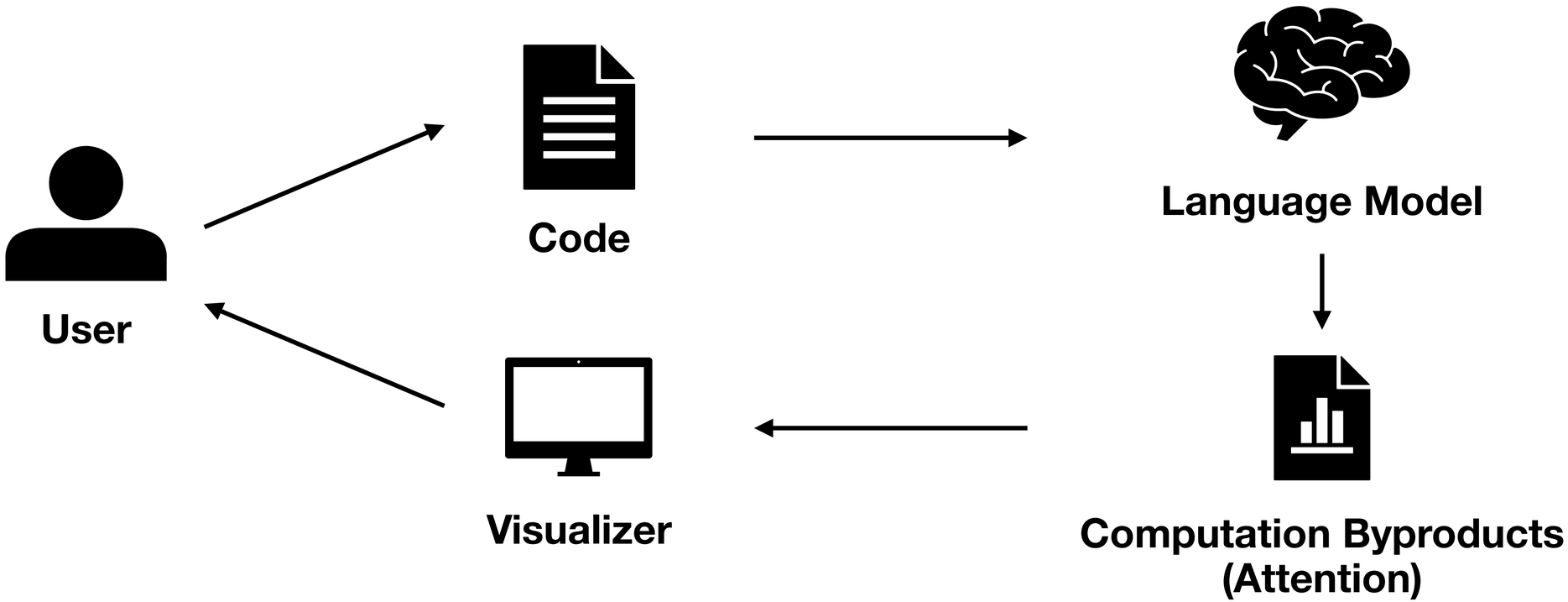
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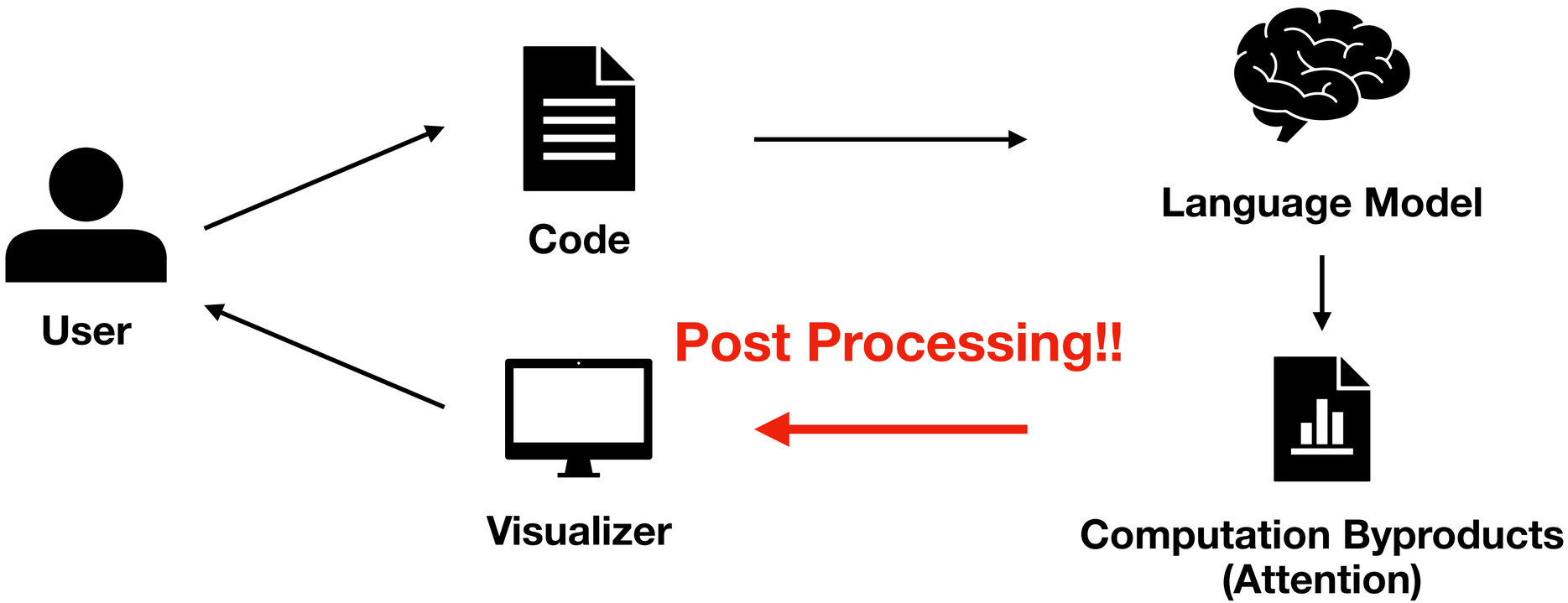
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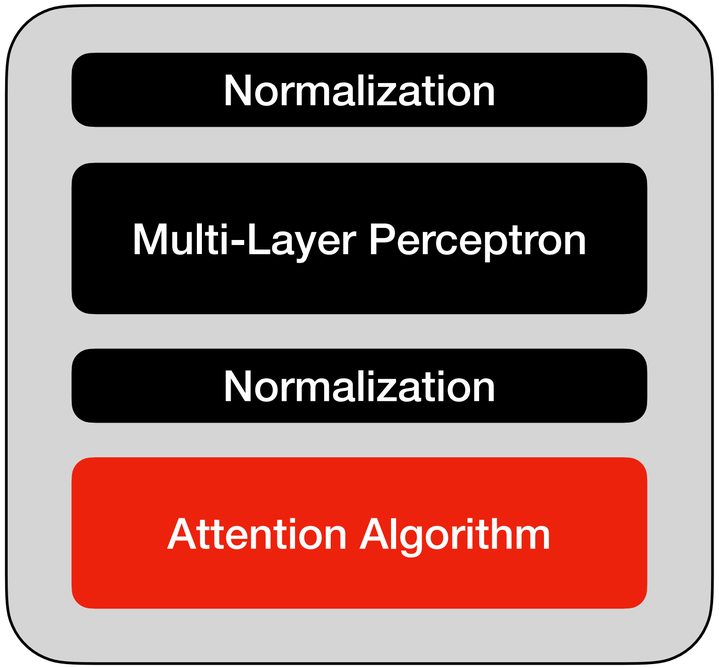
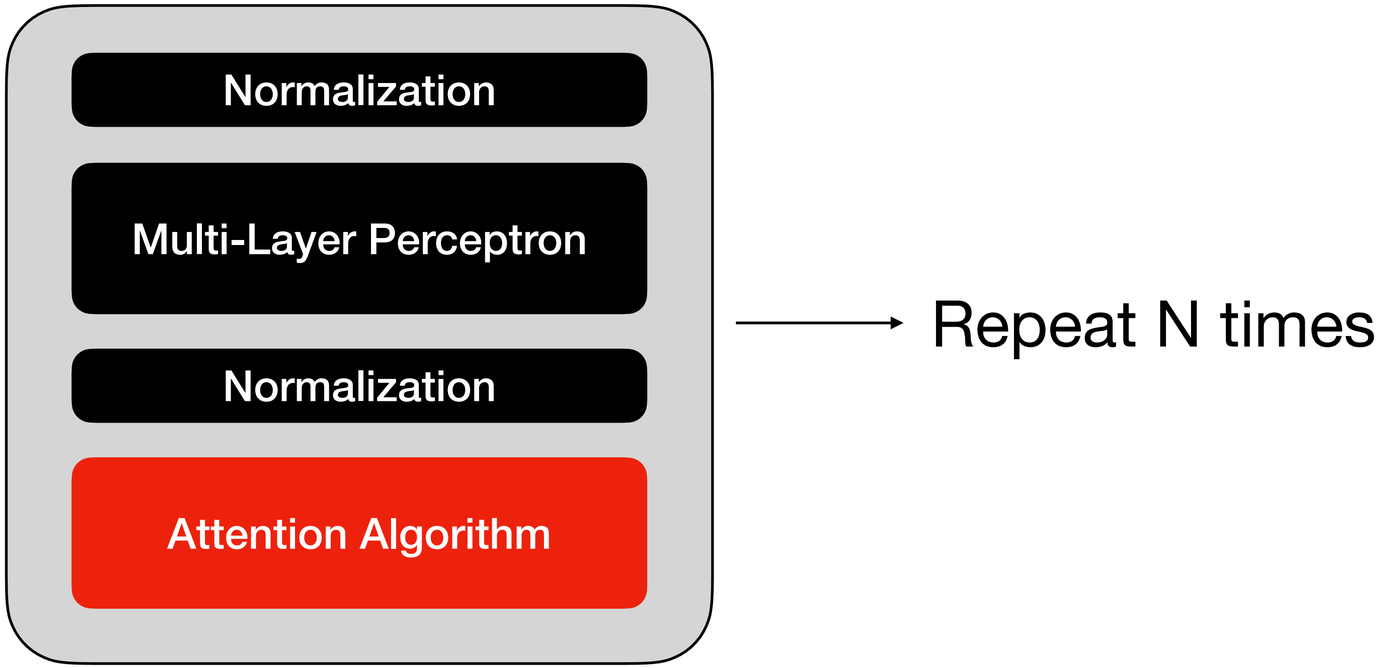


Transformer block

Technical Details: How does attention work?

- Attention weight is an **intermediate value** for the attention algorithm!
- **Most of the LLMs use attention algorithm!**

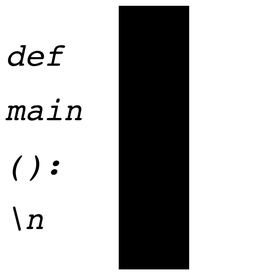


Transformer block

Technical Details: How does attention work?

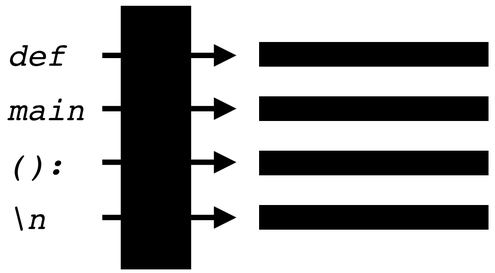
```
def
main
():
\n
```

Technical Details: How does attention work?

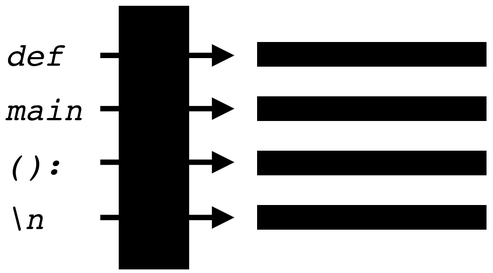


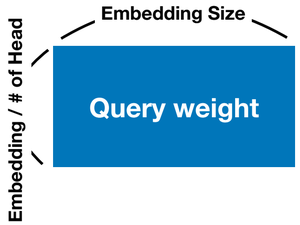
Token Encoder

Technical Details: How does attention work?



Technical Details: How does attention work?





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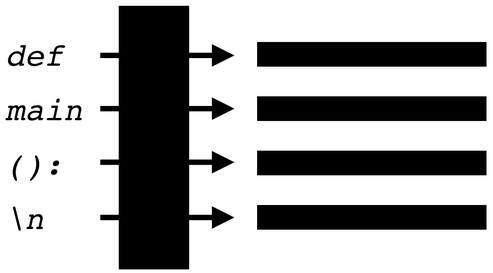
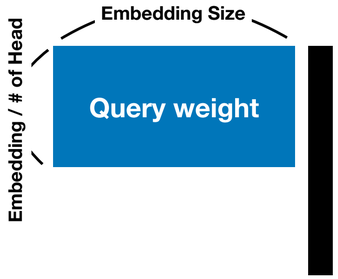


Token Encoder



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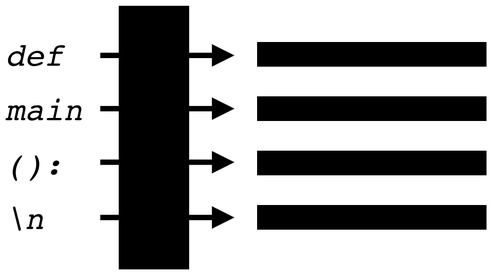
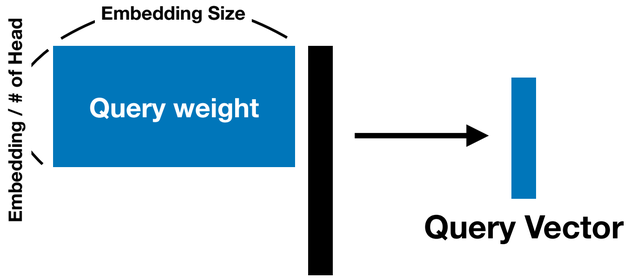
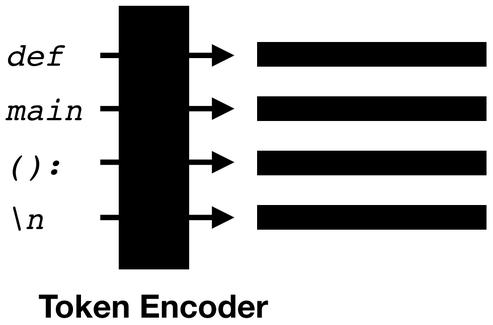


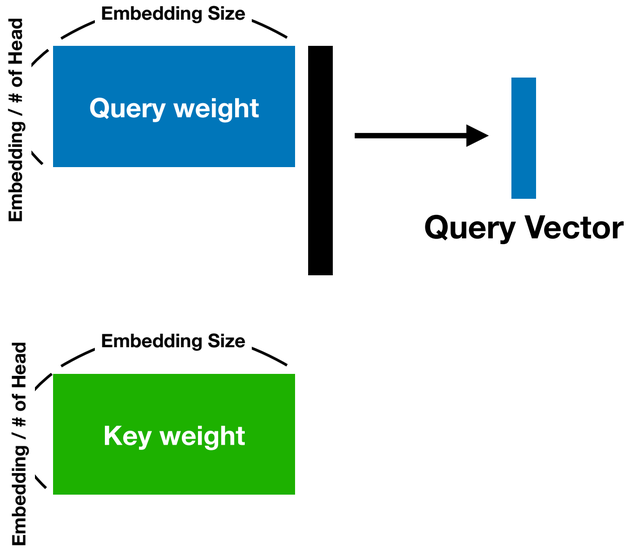
Token Encoder



Query Vector

Technical Details: How does attention work?





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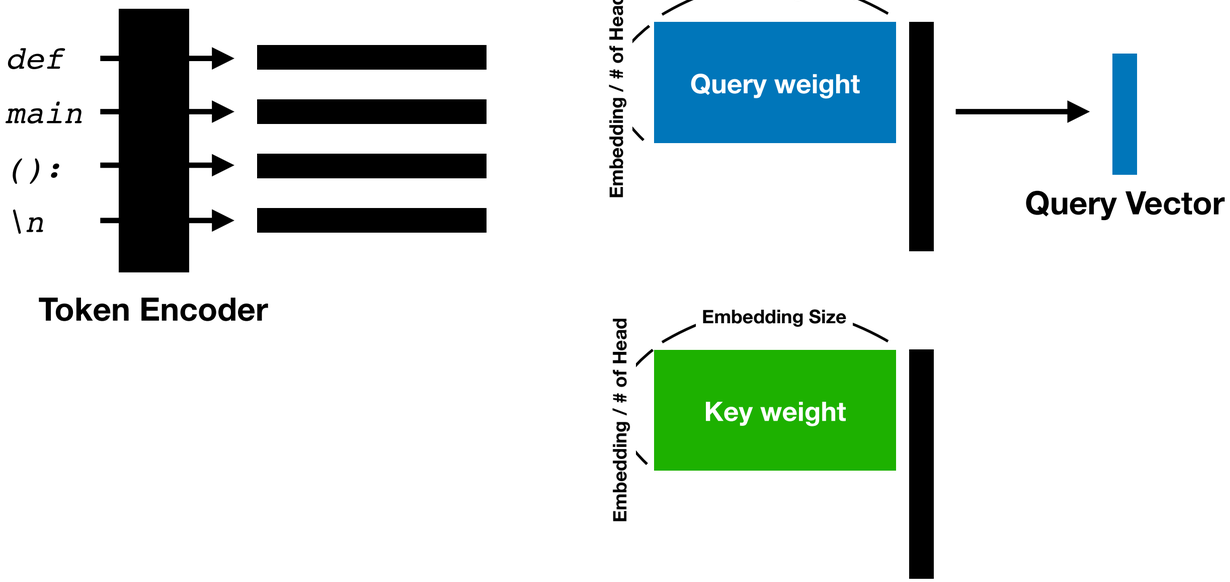
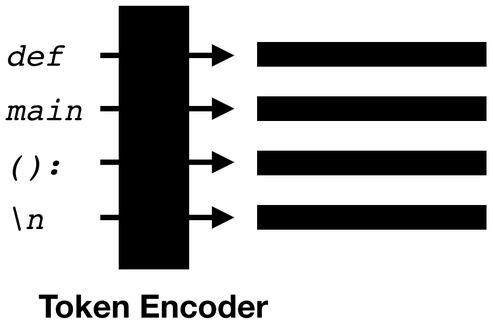
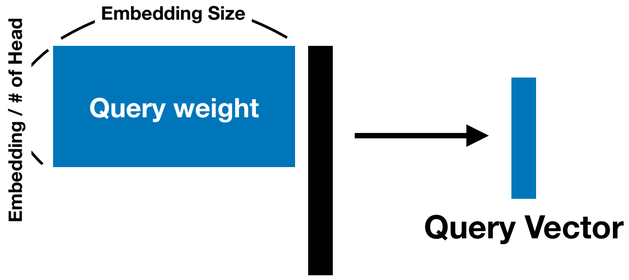
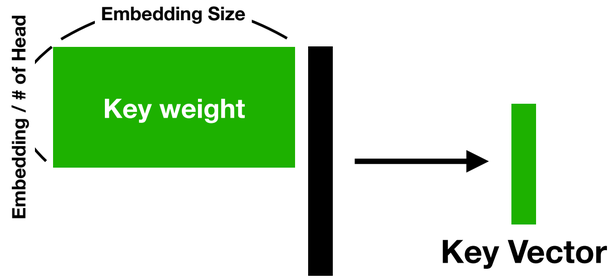


Technical Details: How does attention work?







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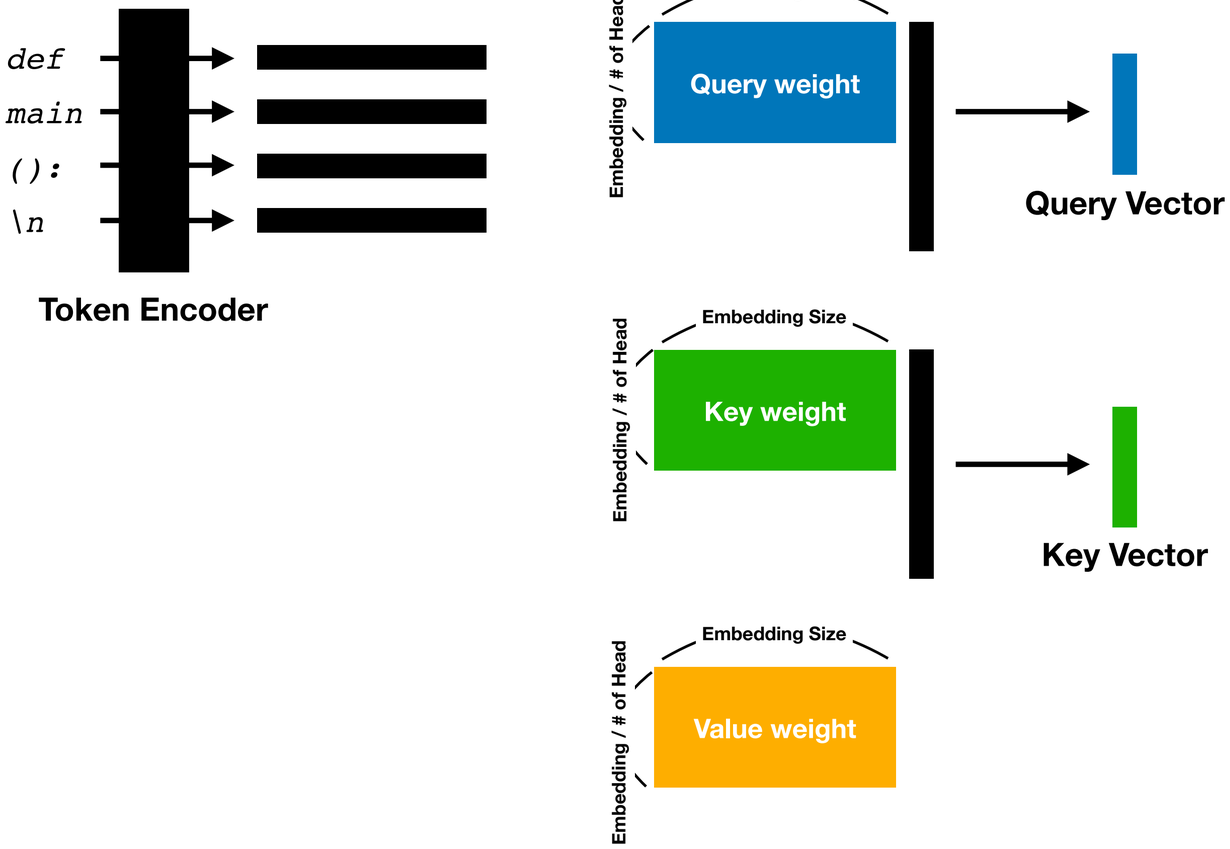

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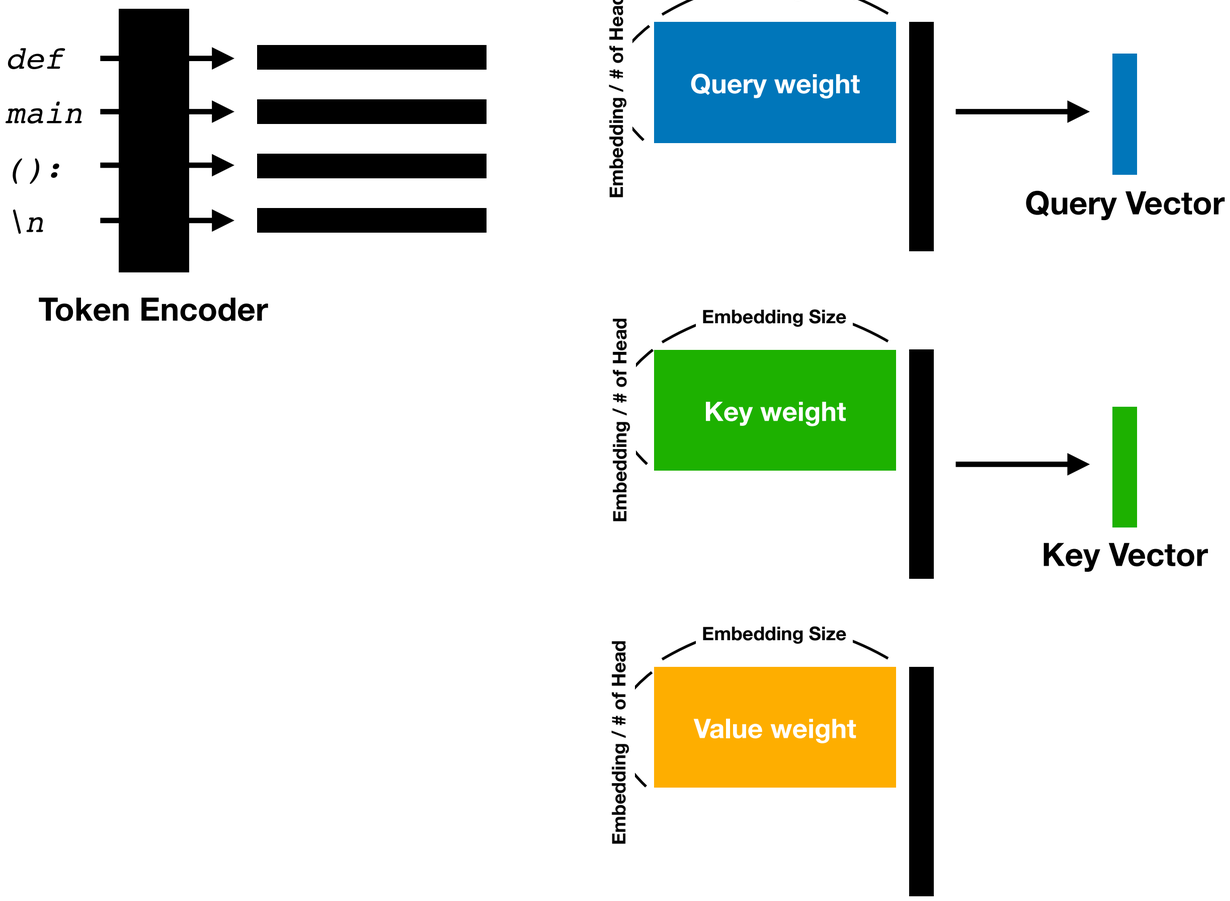

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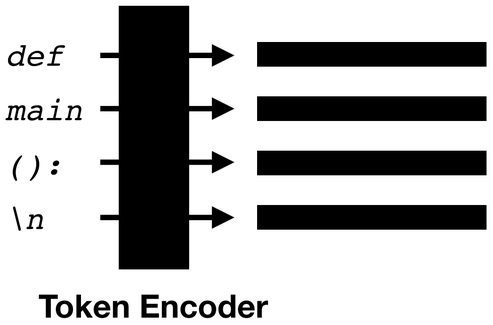

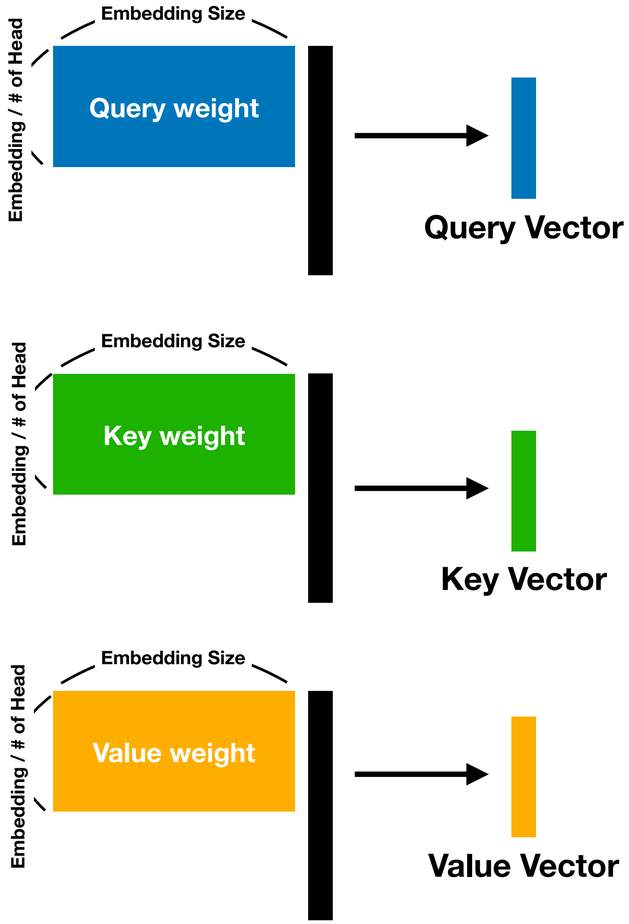

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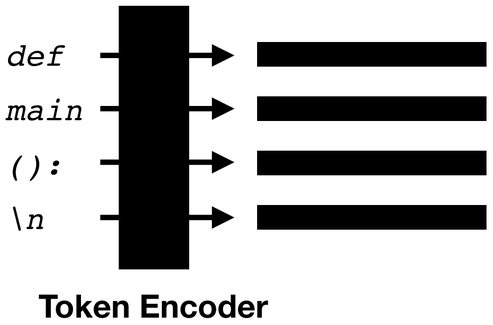

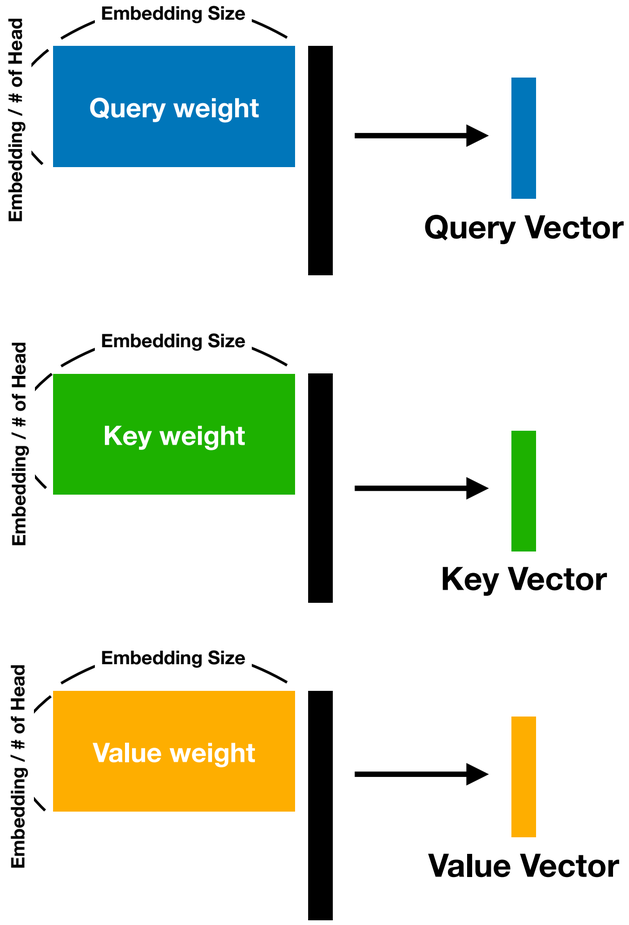

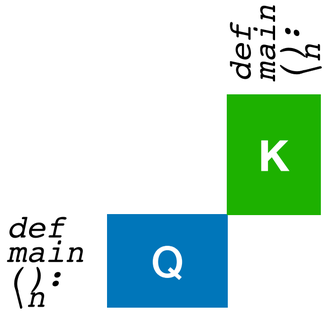

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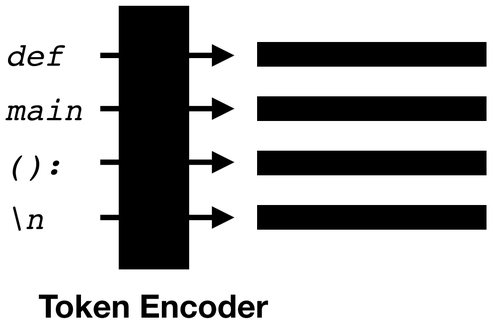

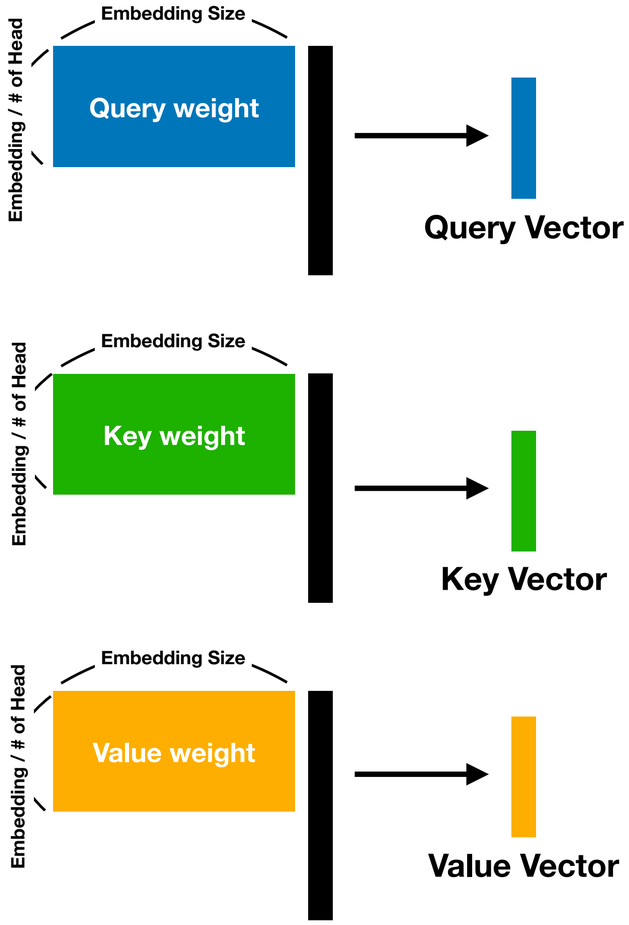

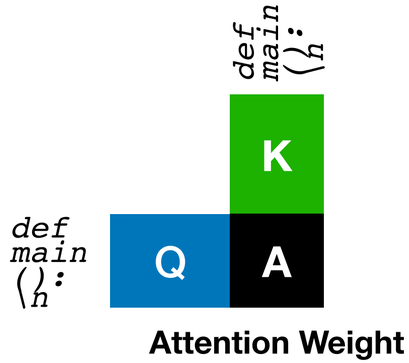

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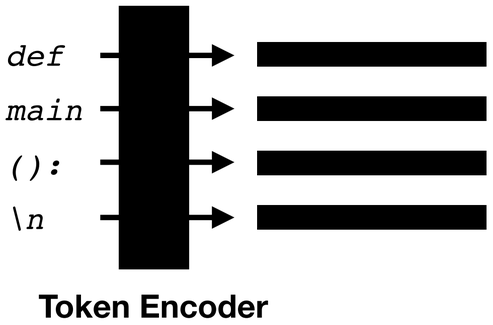

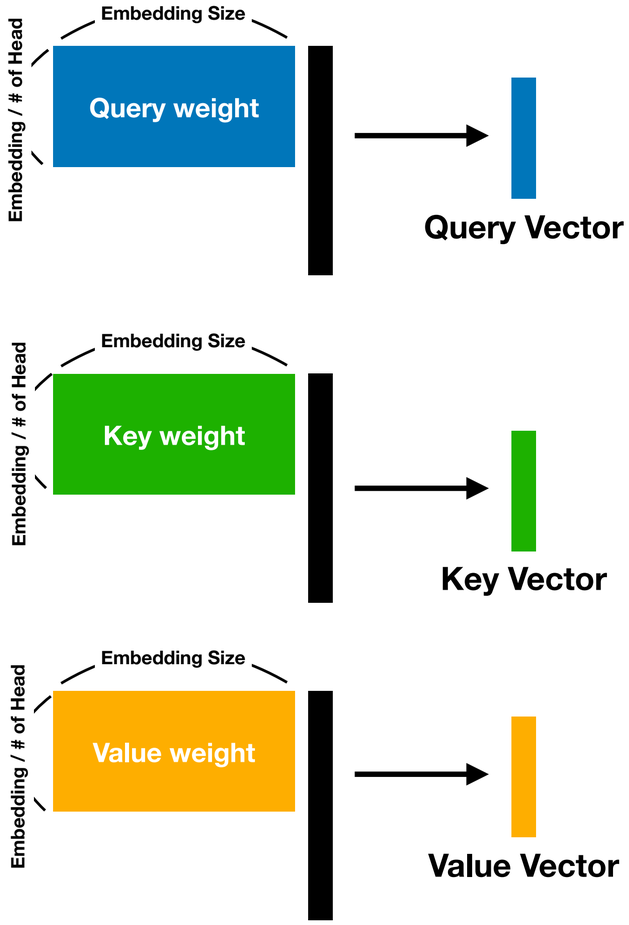

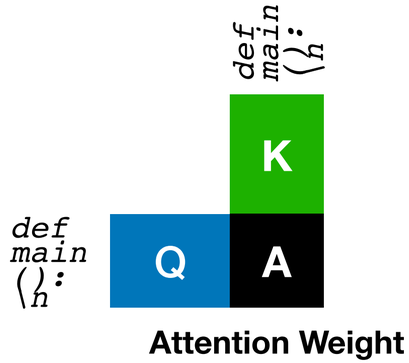

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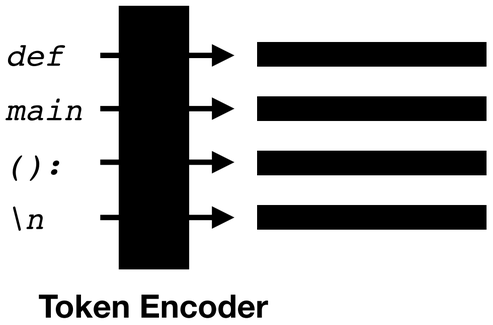
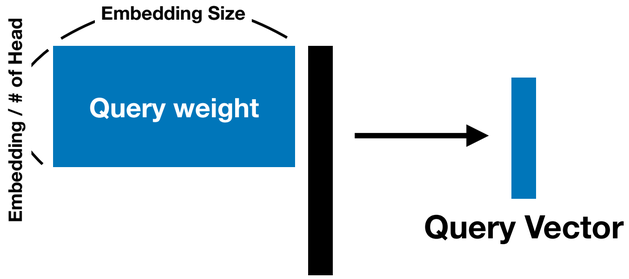
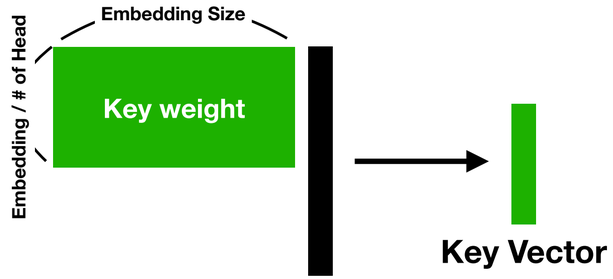
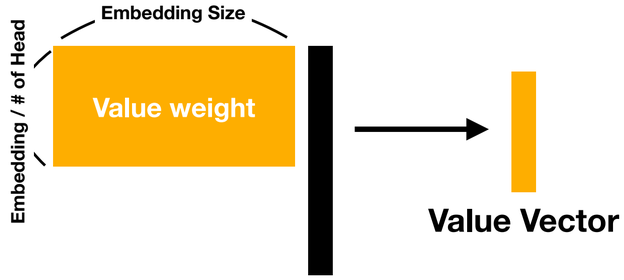
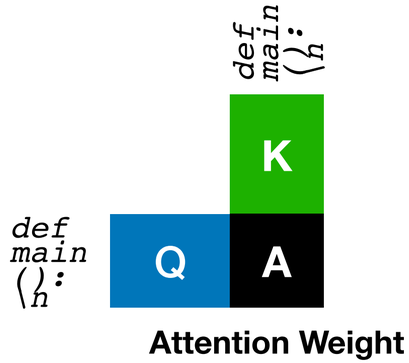


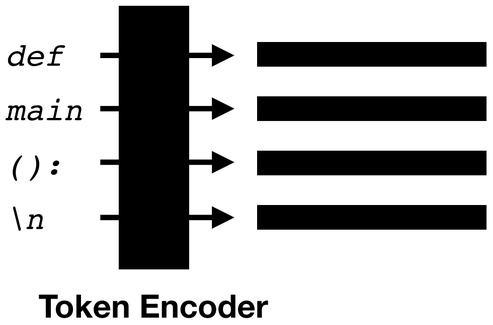


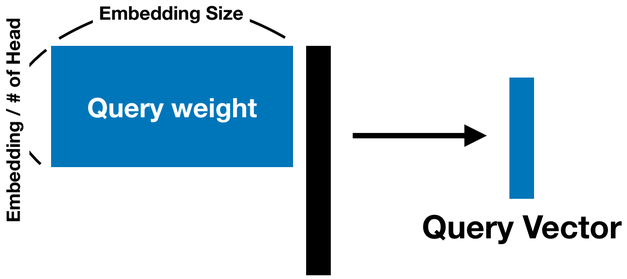


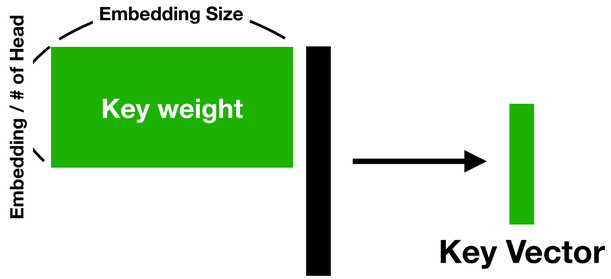


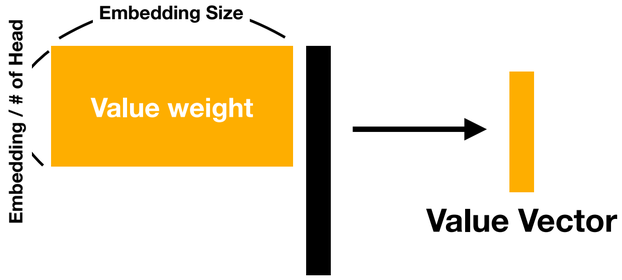


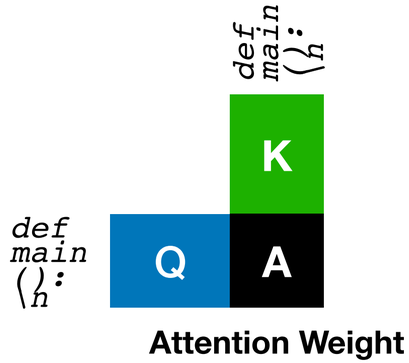
Technical Details: How does attention work?



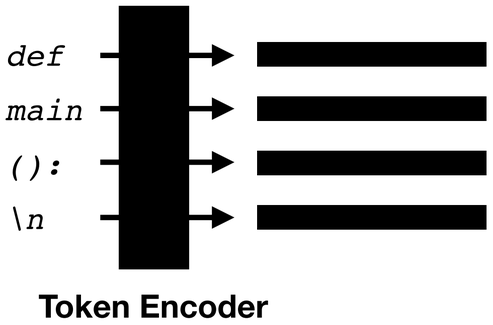


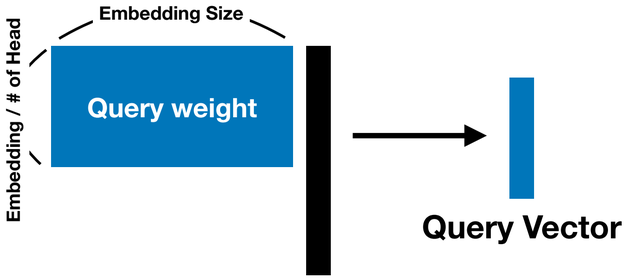


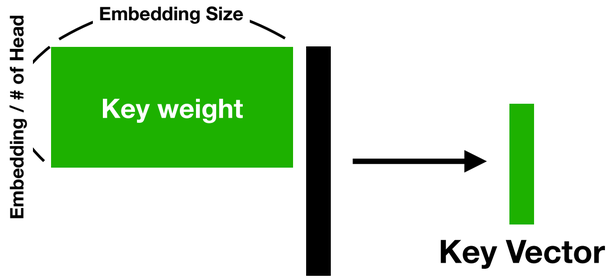


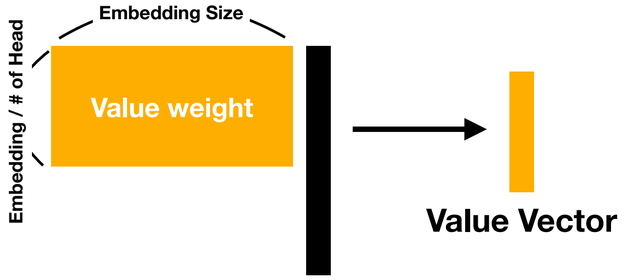


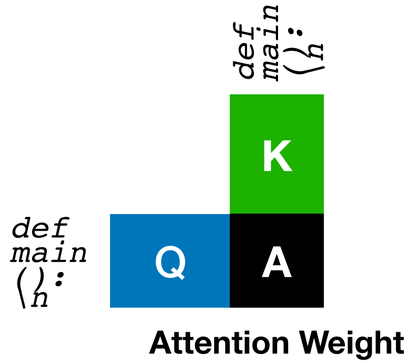
Technical Details: How does attention work?



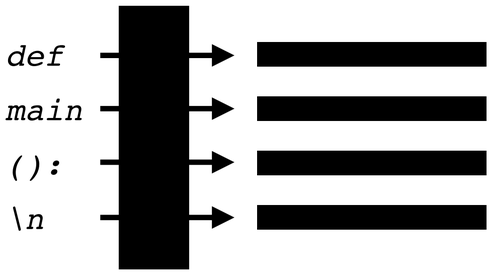




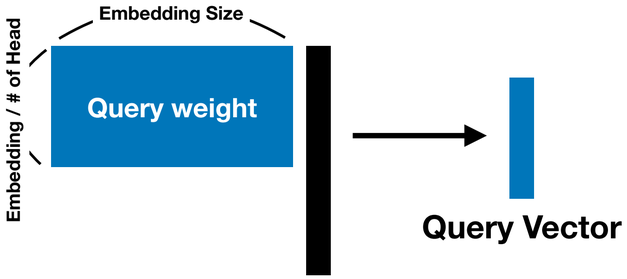




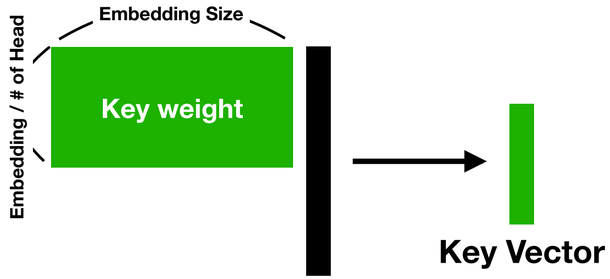
Technical Details: How does attention work?



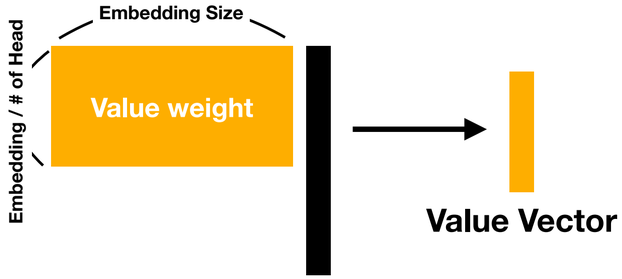
Token Encoder



Query Vector



Key Vector



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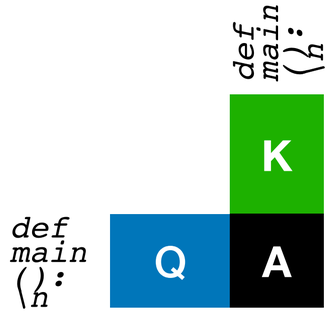


Attention Weight

Multi-head Attention

Technical Details: How does attention work?

	def	fibo	na	cci	(n):	\n	\t	if n	==	or
def	1									
fibo	0.4	0.6								
na	0.2	0.4	0.4							
cci	0.1	0.2	0.2	0.5						
(n):	0.3	0.5	0.1	0.05	0.05					
\n	0.4	0	0	0.2	0.1	0.3				
\t	0.2	0.1	0.35	0	0.35	0	0			
if n	0	0	0.2	0.3	0.1	0.1	0.3	0		
==	0	0	0	0	0	0	0	0.6	0.4	
or	0	0	0	0	0	0	0	0.2	0.4	0.4

Technical Details: How does attention work?

	def	fibo	na	cci	(n):	\n	\t	if n	==	or
def	1									
fibo	0.4	0.6								
na	0.2	0.4	0.4							
cci	0.1	0.2	0.2	0.5						
(n):	0.3	0.5	0.1	0.05	0.05					
\n	0.4	0	0	0.2	0.1	0.3				
\t	0.2	0.1	0.35	0	0.35	0	0			
if n	0	0	0.2	0.3	0.1	0.1	0.3	0		
==	0	0	0	0	0	0	0	0.6	0.4	
or	0	0	0	0	0	0	0	0.2	0.4	0.4

To predict the next token of `(n):`,
we need to see `fibo` as much as 0.5

Technical Details: How does attention work?

	def	fibo	na	cci	(n):	\n	\t	if n	==	or
def	1									
fibo	0.4	0.6								
na	0.2	0.4	0.4							
cci	0.1	0.2	0.2	0.5						
(n):	0.3	0.5	0.1	0.05	0.05					
\n	0.4	0	0	0.2	0.1	0.3				
\t	0.2	0.1	0.35	0	0.35	0	0			
if n	0	0	0.2	0.3	0.1	0.1	0.3	0		
==	0	0	0	0	0	0	0	0.6	0.4	
or	0	0	0	0	0	0	0	0.2	0.4	0.4

`(n):` · `fibo`

To predict the next token of `(n):`,
we need to see `fibo` as much as 0.5

Technical Details: How does attention work?

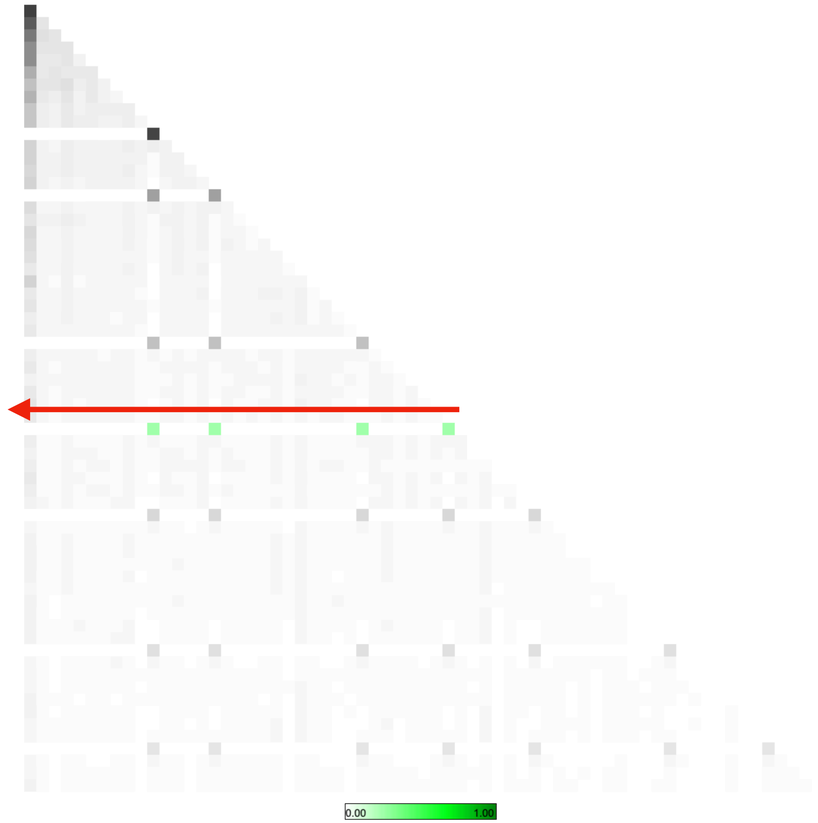
	def	fibo	na	cci	(n):	\n	\t	if n	==	or
def	1									
fibo	0.4	0.6								
na	0.2	0.4	0.4							
cci	0.1	0.2	0.2	0.5						
(n):	0.3	0.5	0.1	0.05	0.05					
\n	0.4	0	0	0.2	0.1	0.3				
\t	0.2	0.1	0.35	0	0.35	0	0			
if n	0	0	0.2	0.3	0.1	0.1	0.3	0		
==	0	0	0	0	0	0	0	0.6	0.4	
or	0	0	0	0	0	0	0	0.2	0.4	0.4

(n): · fibo ⟶ 0.5

To predict the next token of `(n):`,
we need to see `fibo` as much as 0.5

Technical Details: How does attention work?

	def	fibo	na	cci	(n):	\n	\t	if n	==	or
def	1									
fibo	0.4	0.6								
na	0.2	0.4	0.4							
cci	0.1	0.2	0.2	0.5						
(n):	0.3	0.5	0.1	0.05	0.05					
\n	0.4	0	0	0.2	0.1	0.3				
\t	0.2	0.1	0.35	0	0.35	0	0			
if n	0	0	0.2	0.3	0.1	0.1	0.3	0		
==	0	0	0	0	0	0	0	0.6	0.4	
or	0	0	0	0	0	0	0	0.2	0.4	0.4



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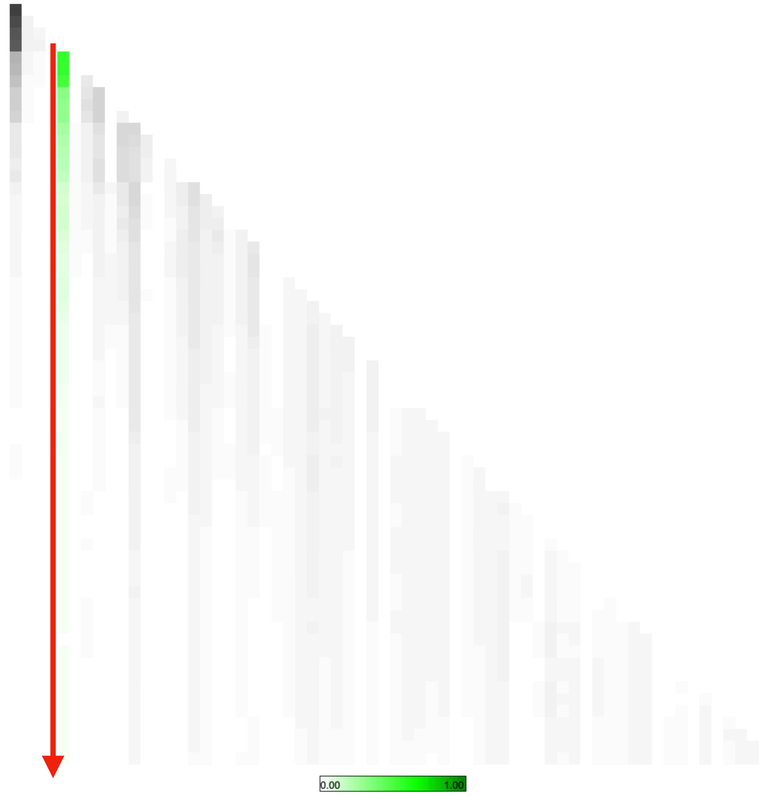

Technical Details: Post processing

- Raw attention is noisy

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  2. Consider size of **value vector****

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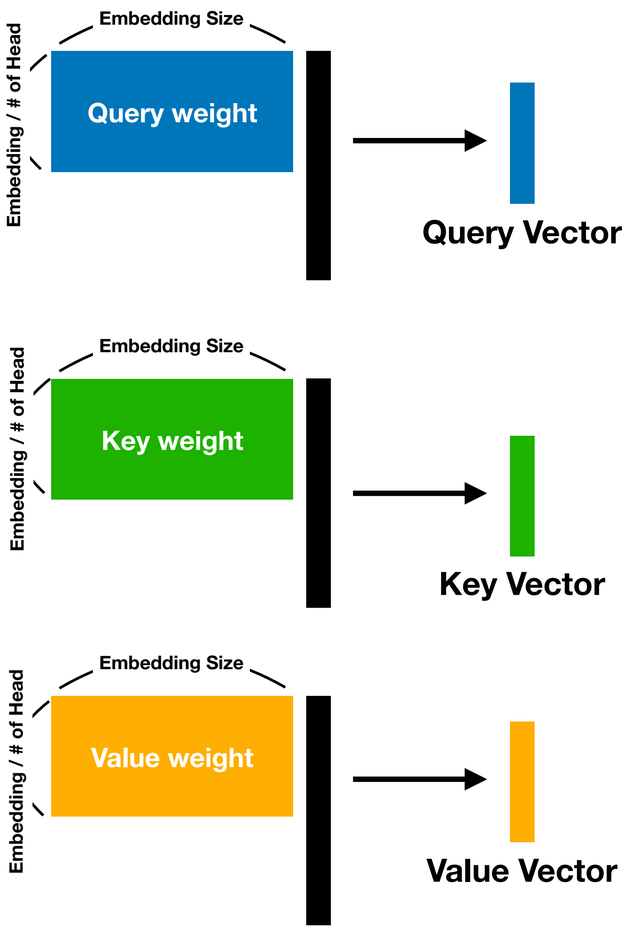

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Remove null-space component

- What is null space?

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$$Ax = 0 \implies x \text{ is null vector}$$

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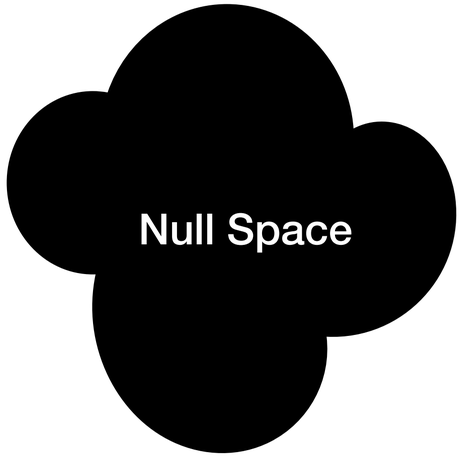

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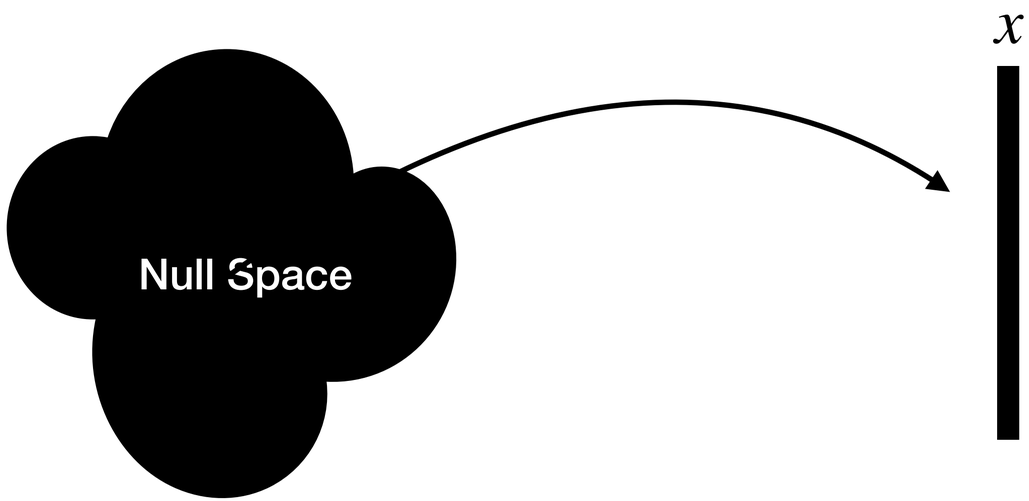

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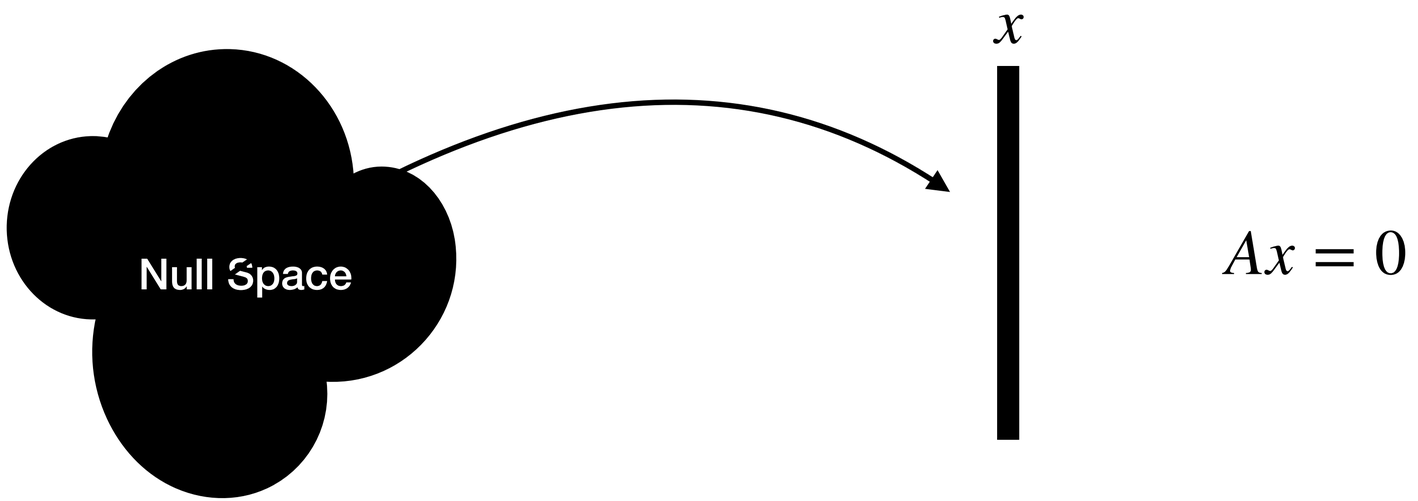

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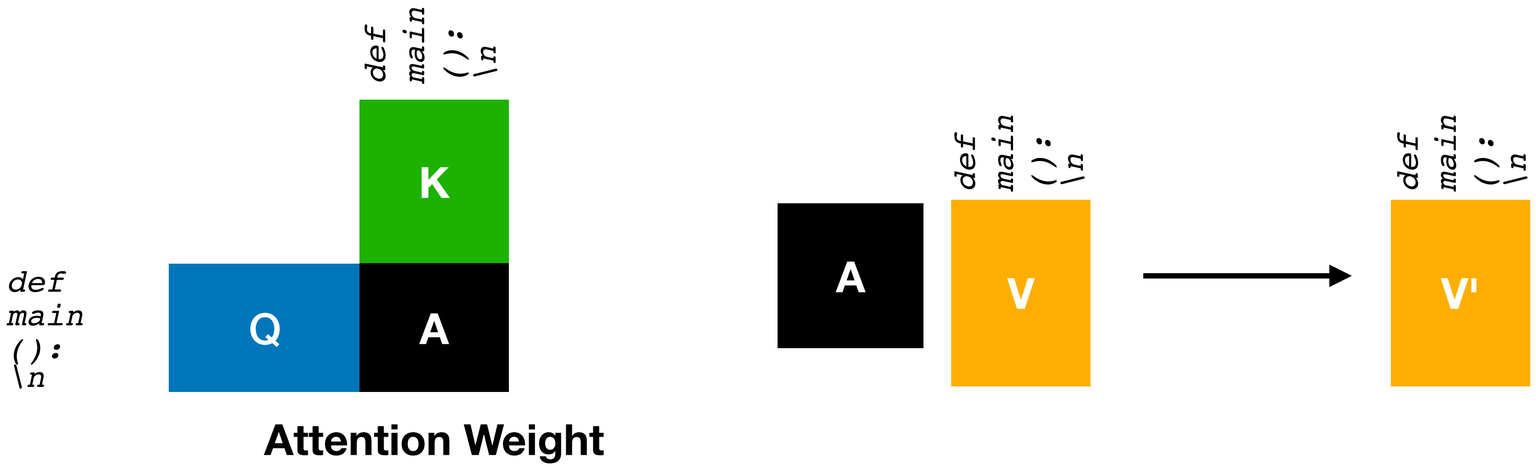
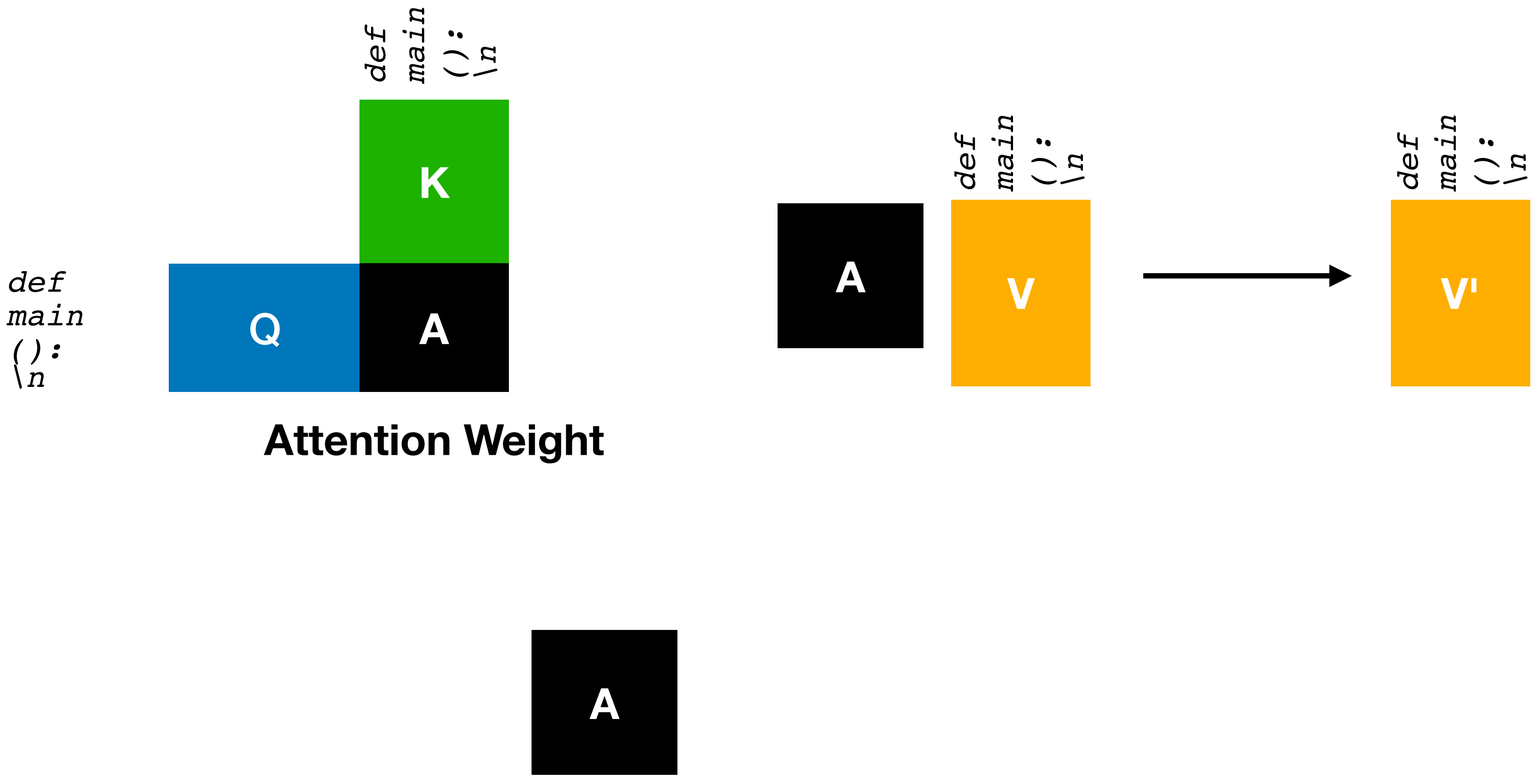


Remove null-space component



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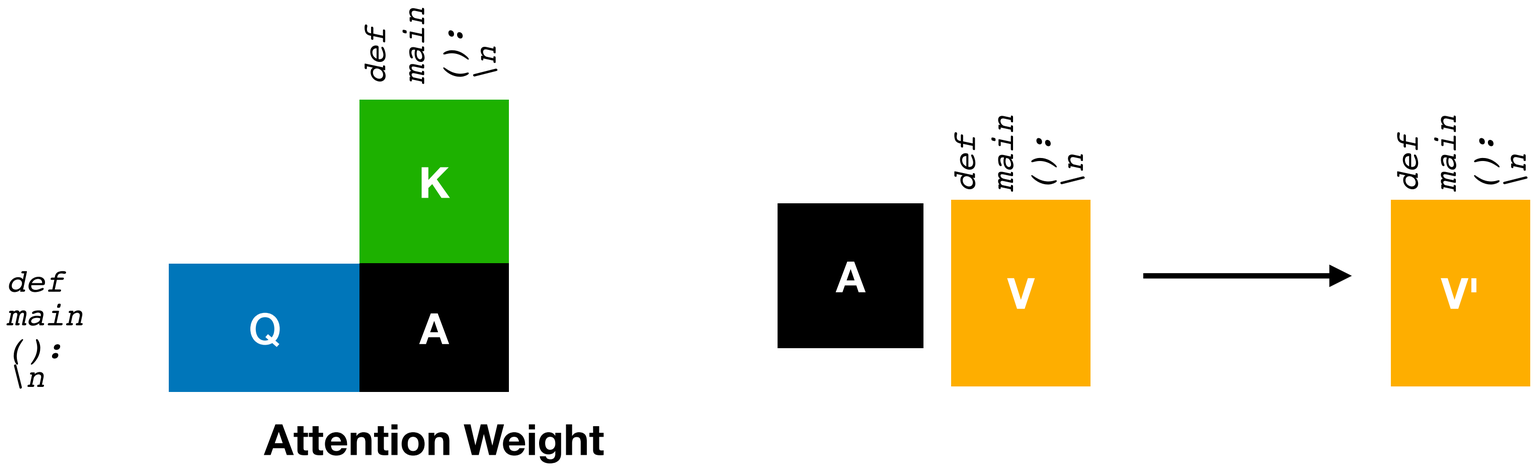

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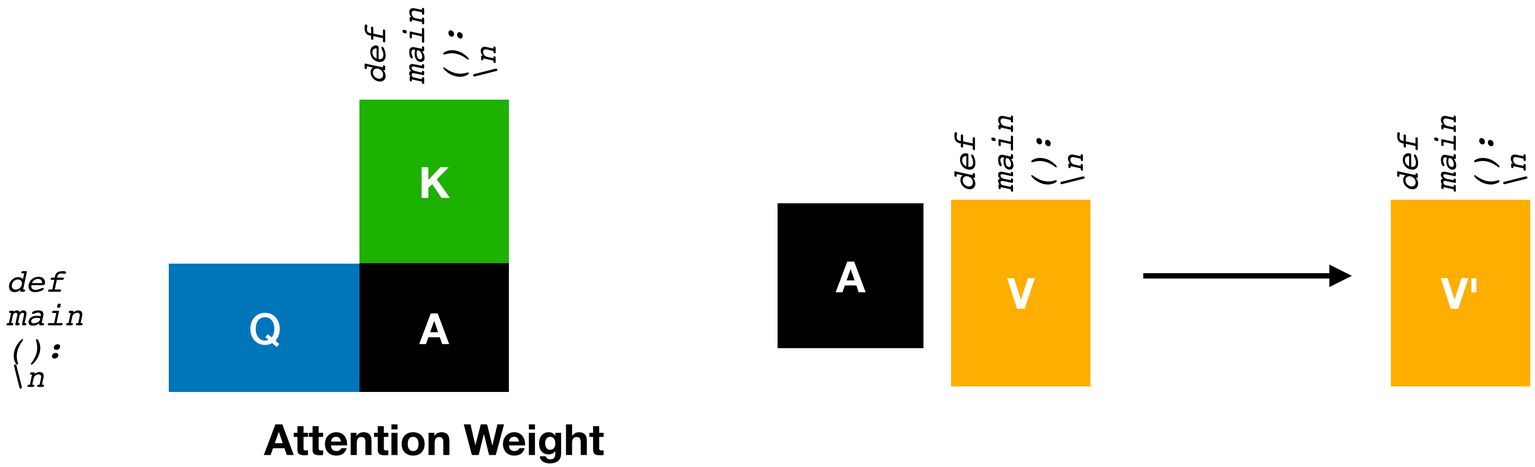

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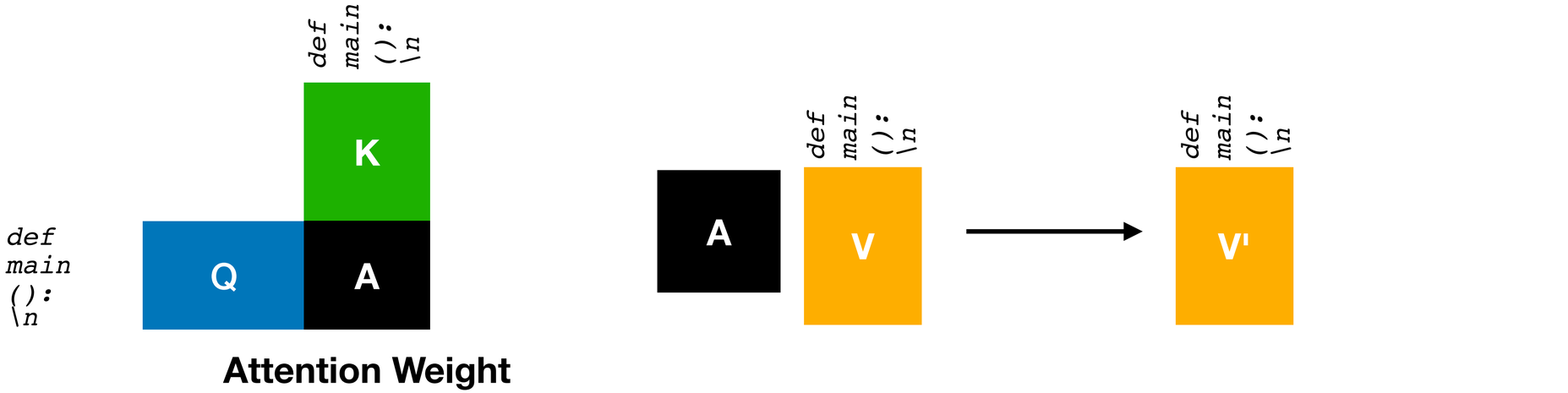

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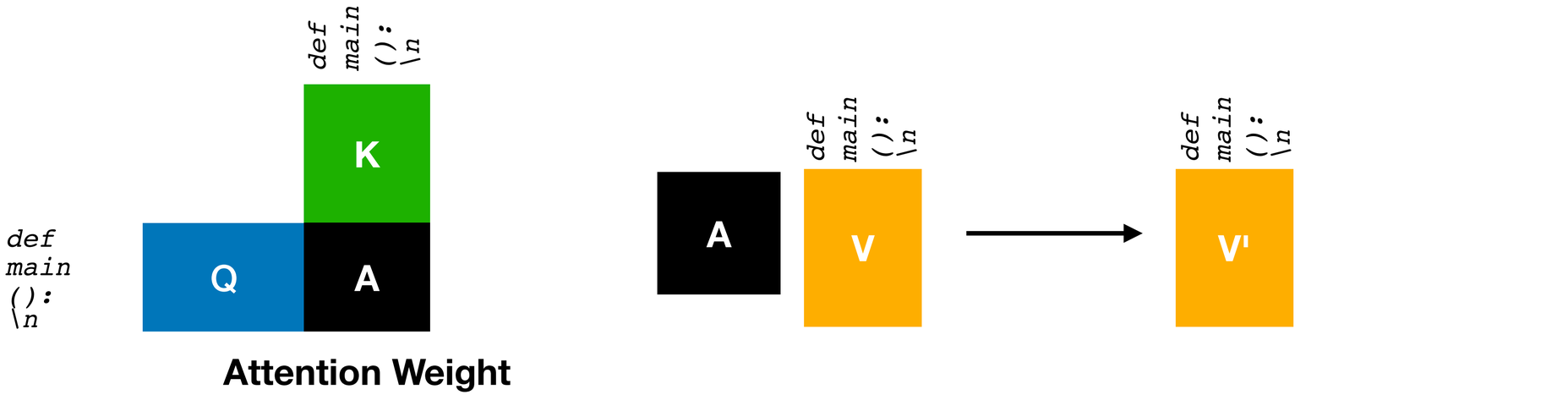
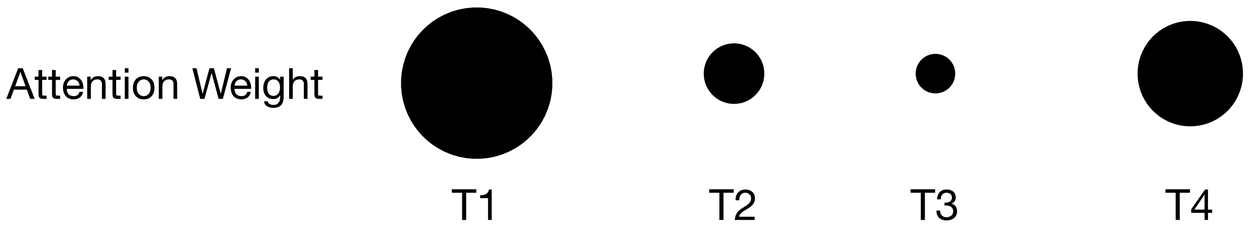


Consider size of value vector



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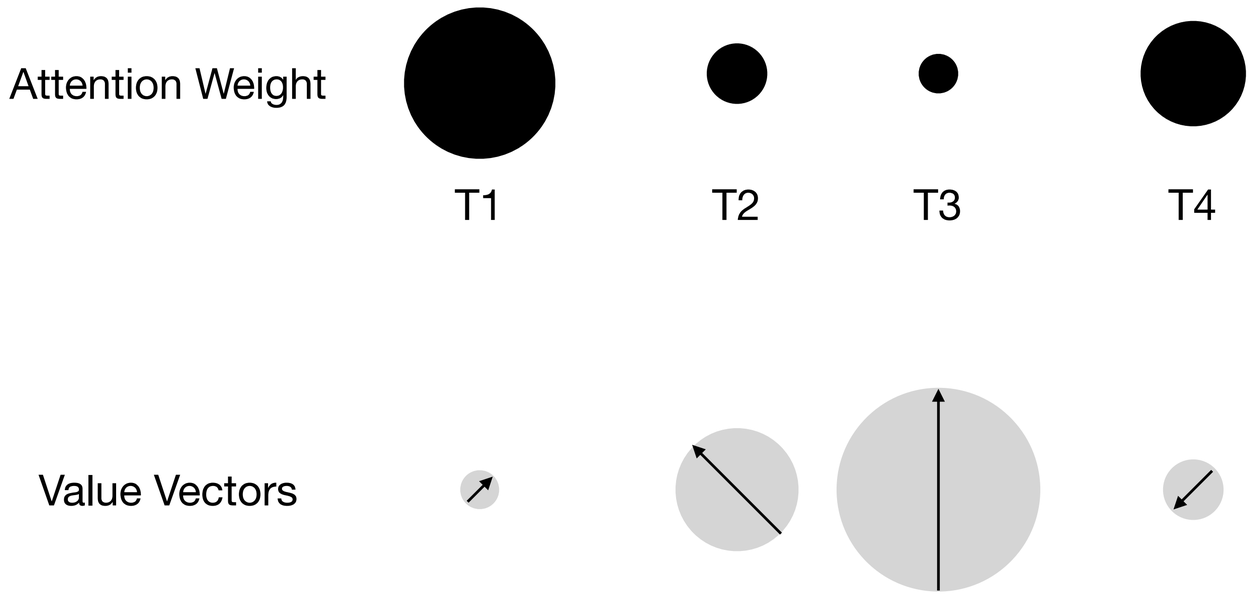

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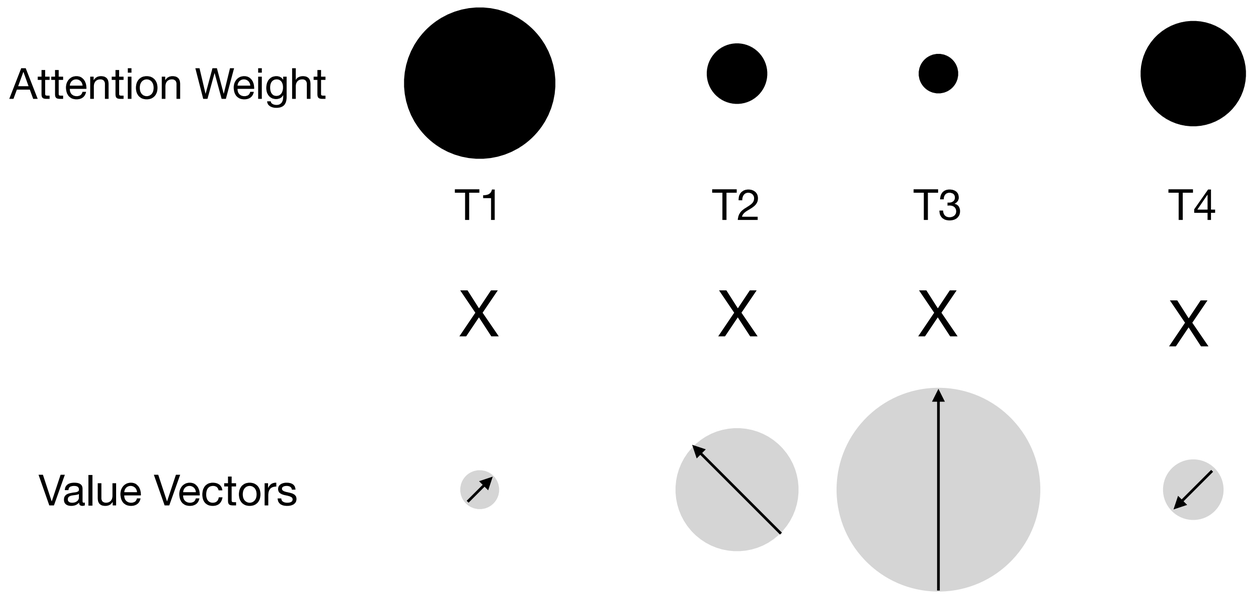

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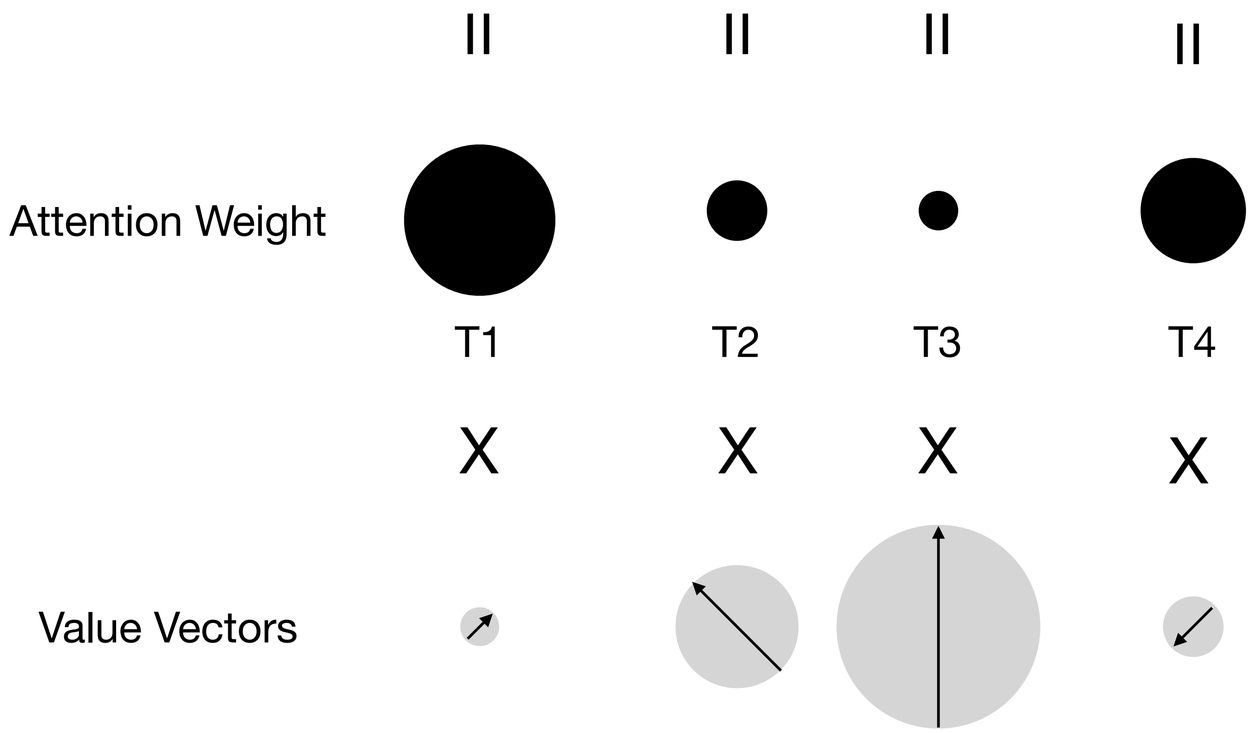

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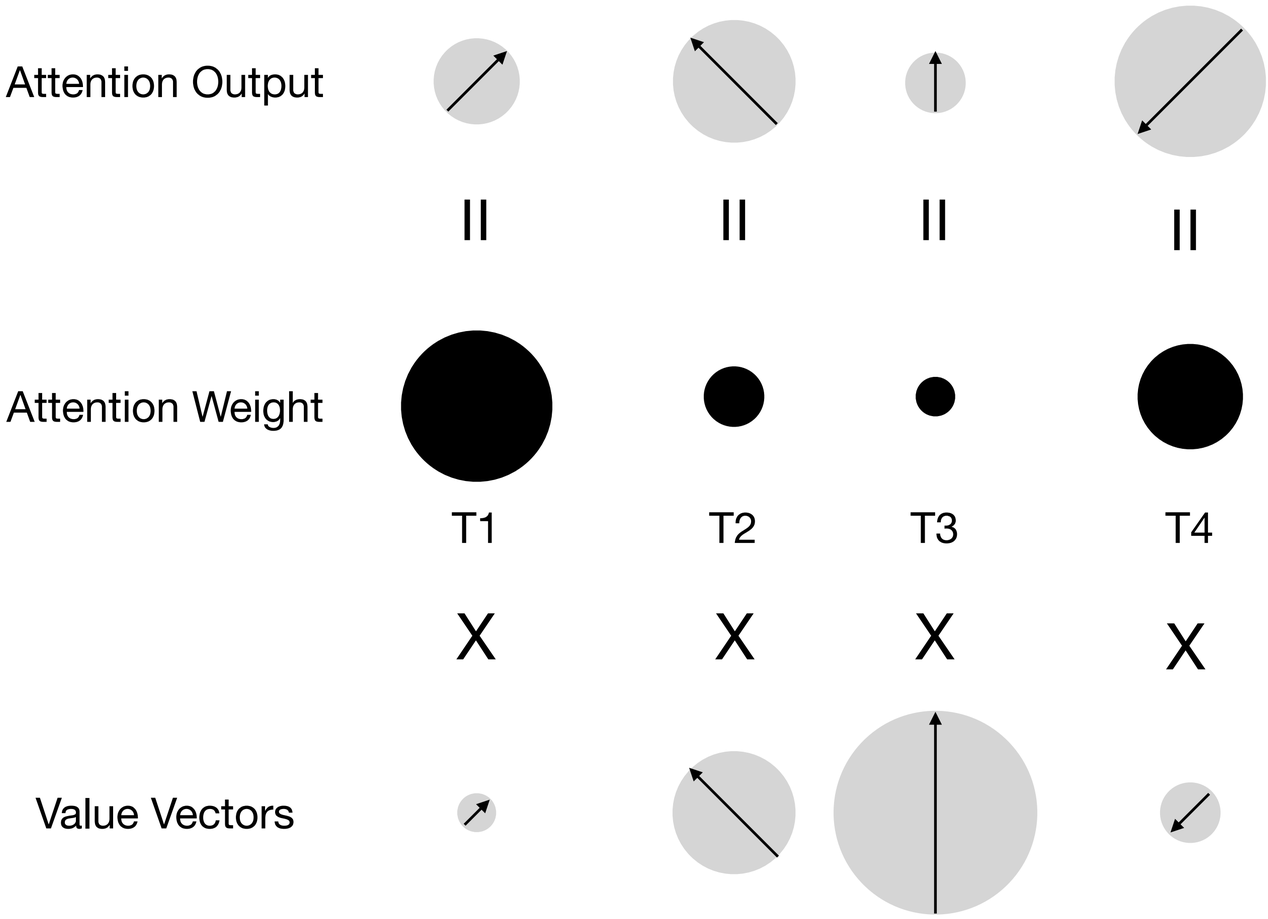

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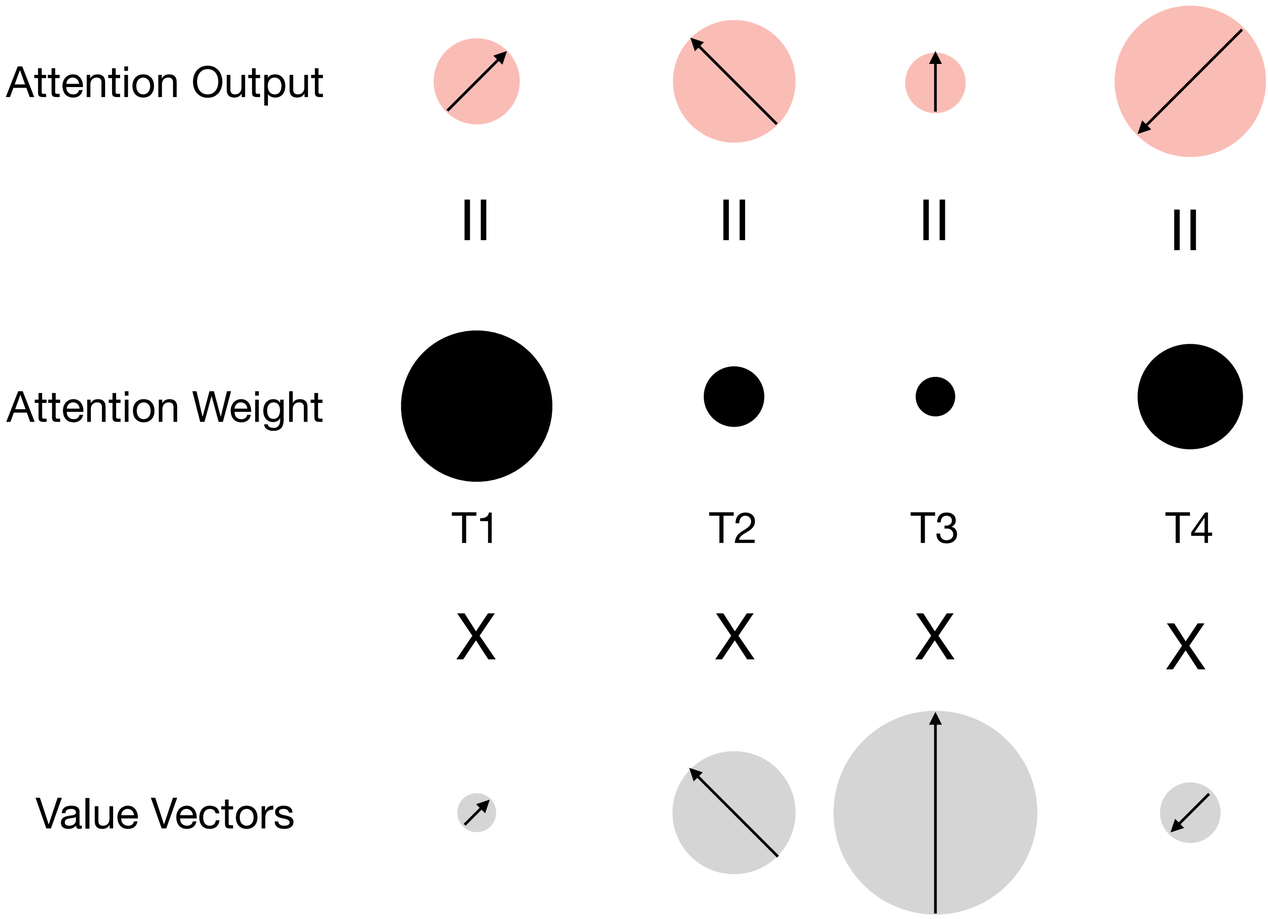

Evaluation

- Qualitative Evaluation

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  - Suitable for code?
- Quantitative Evaluation
  - Rendering speed

Qualitative Evaluation

	Usability	Interactive	Intuitive	Suitability

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Naive Heatmap	X	X	X	X

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Naive Heatmap	X	X	X	X
BertViz	O	O	X	X

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Naive Heatmap	X	X	X	X
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CircuitsViz	X	O	O	O

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AttentionViz	X	O	O	X

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Naive Heatmap	X	X	X	X
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AttentionViz	X	O	O	X
Atten-Scope	O	O	O	O

Qualitative Evaluation

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Naive Heatmap	X	X	X	X
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Qualitative Evaluation

- Average Rendering Speed

Atten-Scope	CircuitsViz
389.7ms	9,275ms

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96% Decreased

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- Information flow view
  - A view that shows information flow of each token

Summary

- Atten-Scope is a new tool for **interpreting language model**
- Atten-Scope visualize refined attention weight
- Refinement techniques
  - Remove null component
  - Consider value vector
- Atten-Scope **outperforms** compared with previous tools
- https://github.com/duncan020313/Atten-Scope.git
- https://github.com/duncan020313/Atten-Scope-Backend