Bootcamp 2023

Natural Language Processing

UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING
Centre for Analytics and Artificial Intelligence Engineering

What is Natural Language Processing (NLP)?

- Subfield of AI that focuses on reading, deciphering and producing human language
- Combines computational linguistics (e.g. rule-based modelling of language) with statistical, ML, and deep learning approaches
- Through NLP, machines can understand, analyze and generate language in ways that are meaningful and contextually appropriate
- While LLMs have driven an explosion in interest, there are many older technologies which paved the way

Common Applications

- **Text Classification:** e.g. spam detection, news classification
- **Question Answering:** processing input and finding relevant information
- **Machine Translation**
- **Sentiment Analysis**
- **Code Generation**

Challenges in NLP

- **Ambiguity:** Words can mean different things depending on context
- **Nuances:** Languages are full of idioms, slang, cultural references, sarcasm…
- **Syntax vs Semantics:** A grammatically correct sentence might not make sense, or a grammatically incorrect one might be easy to understand

- I saw a man on the hill with the telescope
- That's a cool cat
- Colourless green ideas sleep furiously
- Me went store

Quick history of NLP

- **1950s:**
  - Alan Turing publishes “Computing Machinery and Intelligence”, in which he proposes the Turing test
  - Noam Chomsky publishes “Syntactic Structures”, an attempt to construct a formal theory of linguistic structure
- **1960s:**
  - Georgetown University develops a machine translation system, which automatically translates 60 Russian sentences into English using an extremely complex flowchart and a limited vocabulary
  - The authors claim machine translation could be a solved problem in five years

Quick history of NLP

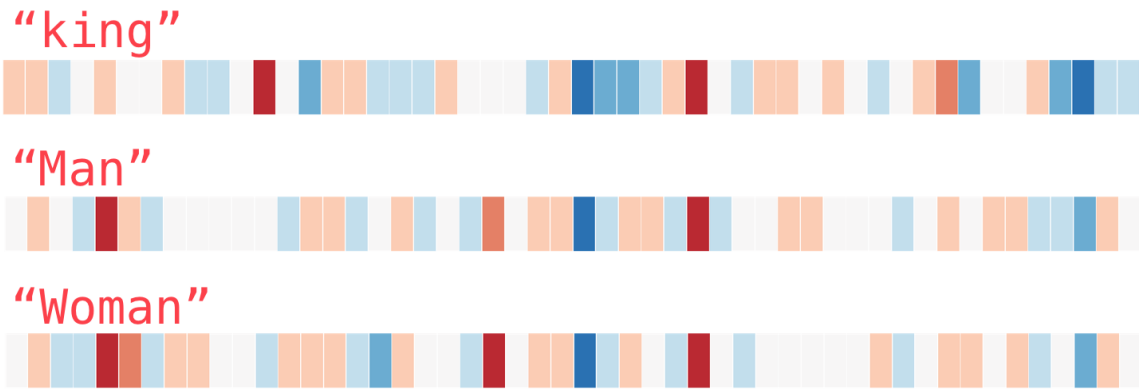
- **1980s – 1990s:**
  - Transition from rule-based to statistical approaches
  - Idea of using existing text to train a model begins to appear (e.g. bilingual documents from the Canadian parliament)
- **2000s – 2010s:**
  - Deep Learning takes over
  - Tools such as convolutional networks, and later RNNs, transform the field
- **2020s: The era of the Large Language Model**

Foundations of LLMs

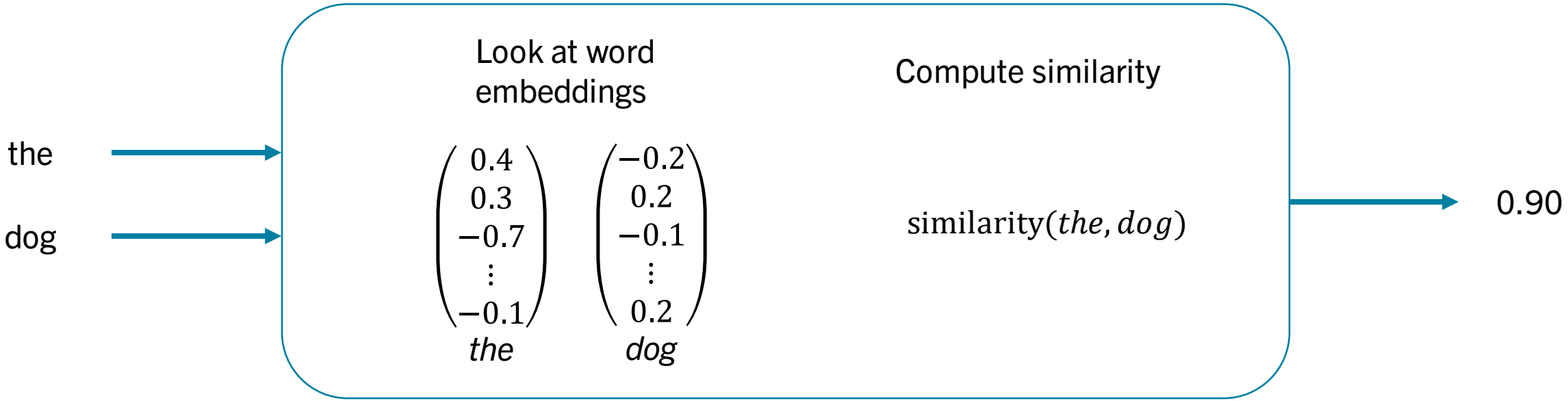
- Fundamental goal of language modelling: next word prediction
- $P(cat \mid the\ dog\ and\ the)$
- To generate, pick the word with highest likelihood
- Early models could handle one, two words of context
- Locally coherent, but longer texts quickly lose meaning
- More context requires more complexity!

How does an LM “understand” word meaning?

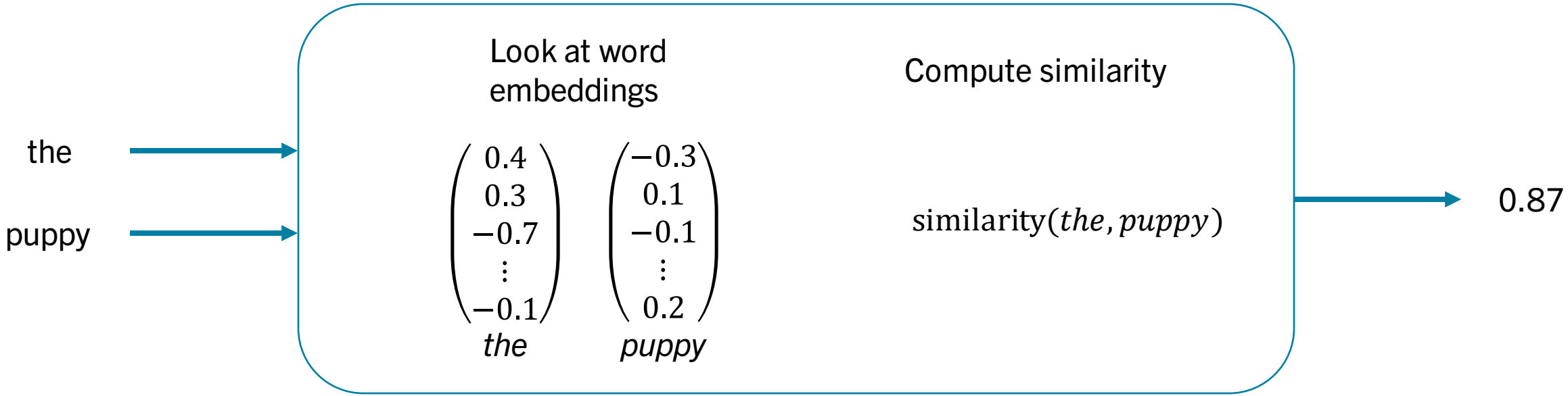
- In order to predict the likelihood of a word, we must have some sense of its meaning
- Some words have similar meanings, and can easily fit in the same place
- In the same way CNNs convert an image into a set of feature maps, we can convert a word into a set of abstract linguistic features
- Word2Vec: 300 features
- GPT-3: 12,888



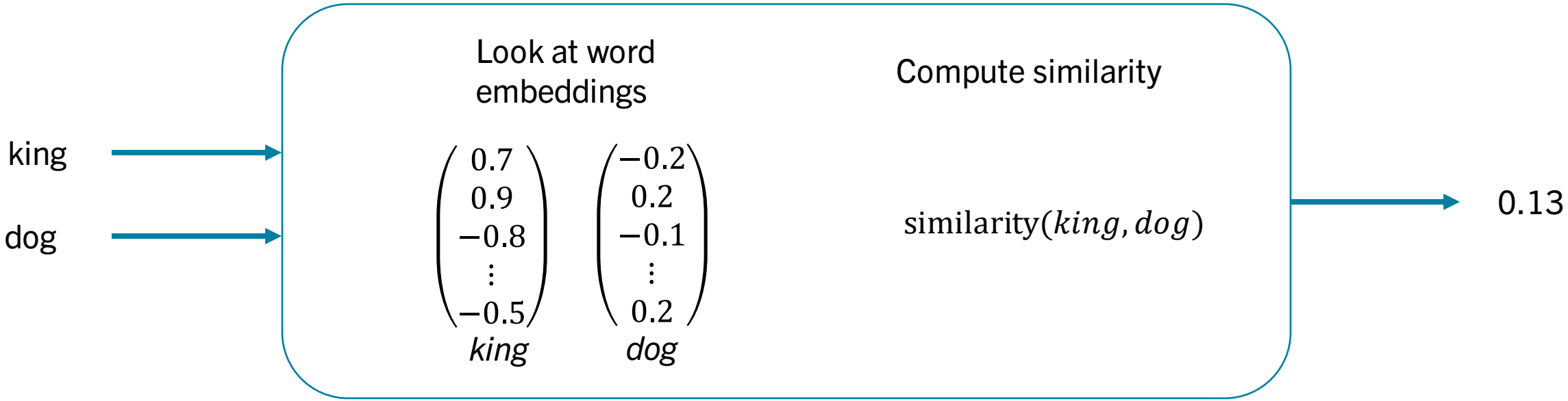
Building Word Embeddings



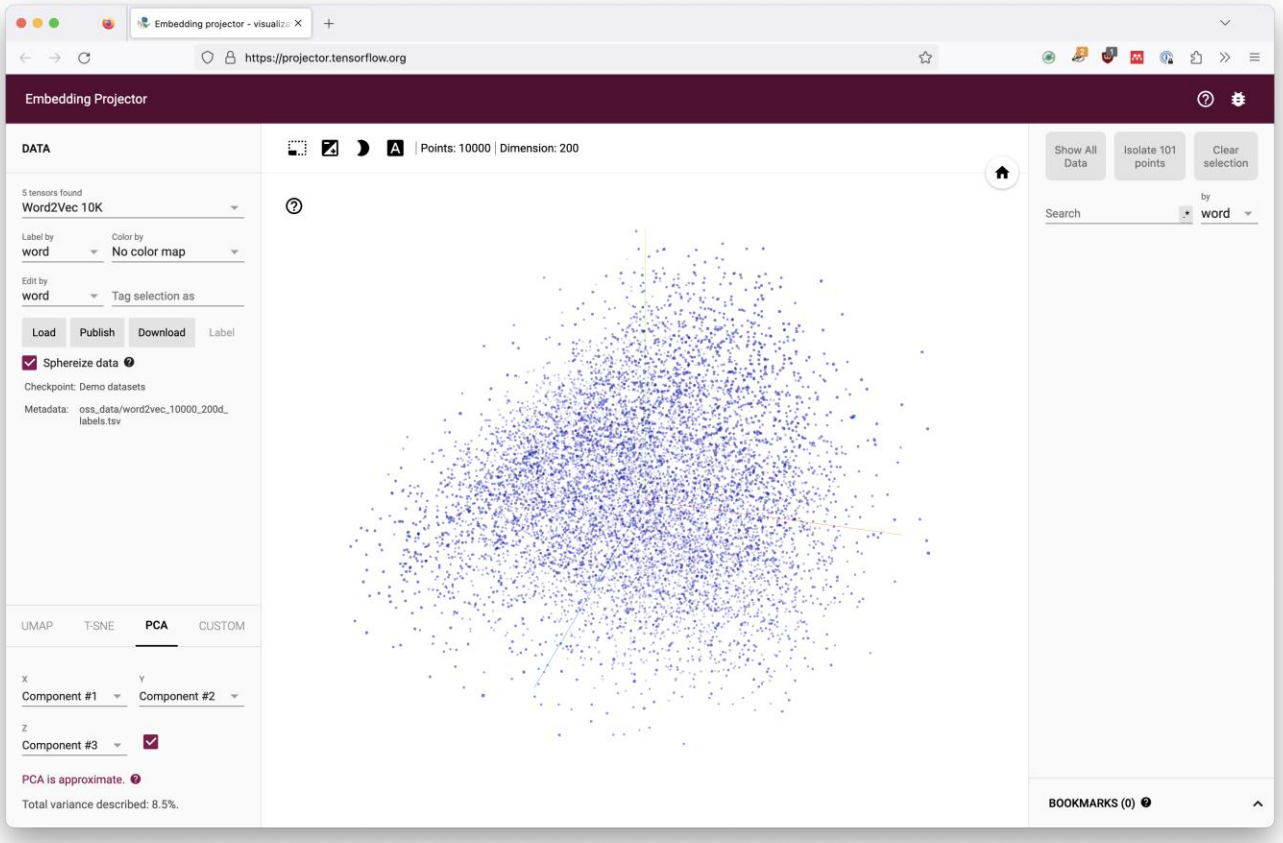
Building Word Embeddings



Building Word Embeddings



Results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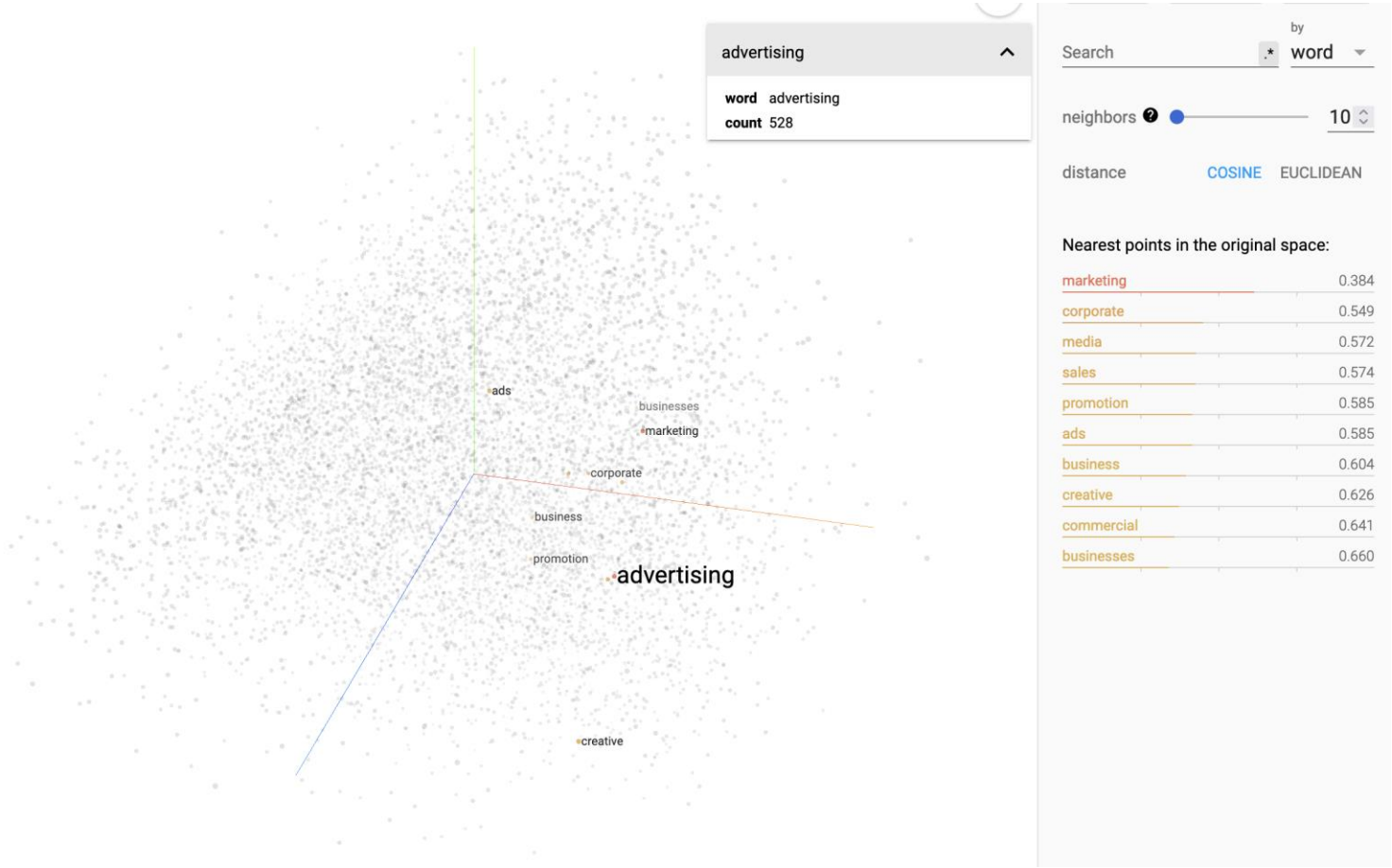
https://projector.tensorflow.org
Embedding Projector
DATA
5 tensors found
Word2Vec 10K
Label by
word
Color by
No color map
Edit by
word
Tag selection as
Load
Publish
Download
Label
Sphereize data
Checkpoint: Demo datasets
Metadata: oss_data/word2vec_10000_200d_labels.tsv
UMAP
T-SNE
PCA
CUSTOM
X
Component #1
Y
Component #2
Z
Component #3
PCA is approximate.
Total variance described: 8.5%.
Points: 10000 | Dimension: 200
Show All Data
Isolate 101 points
Clear selection
Search
by
word
BOOKMARKS (0)

Results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Nearest points in the original space:
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corporate 0.549
media 0.572
sales 0.574
promotion 0.585
ads 0.585
business 0.604
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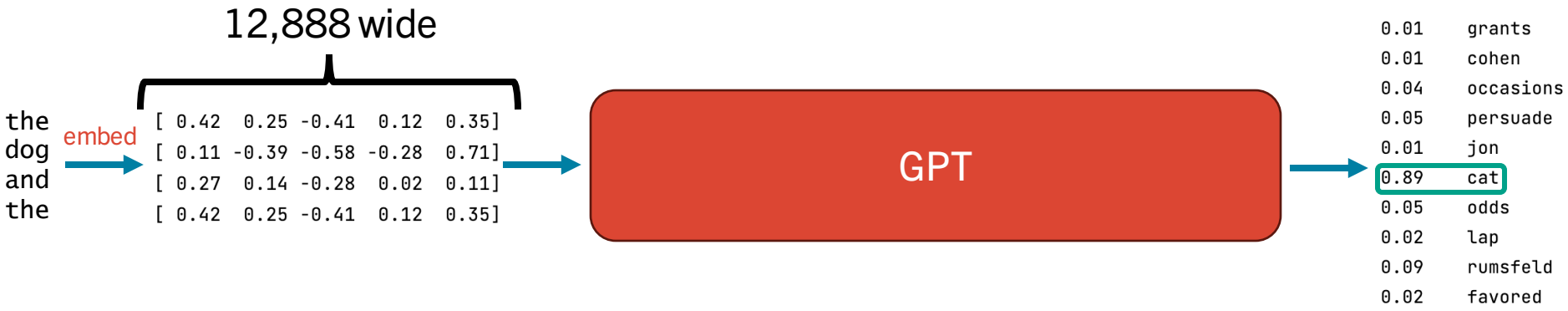
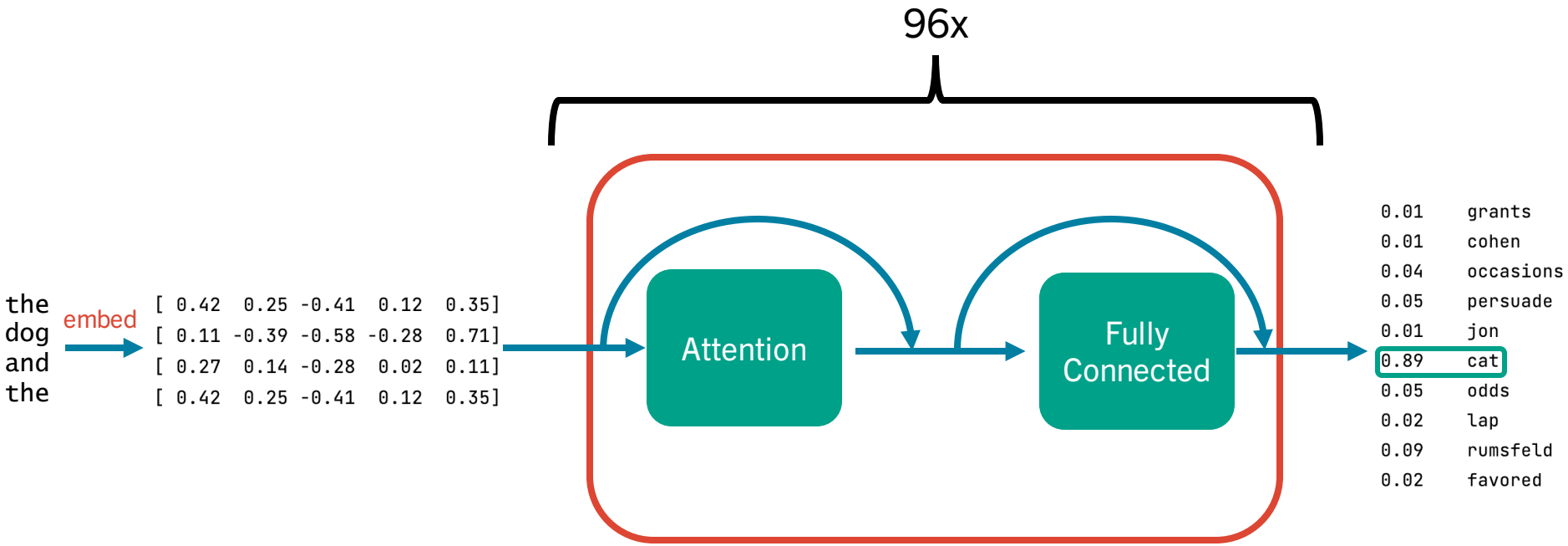
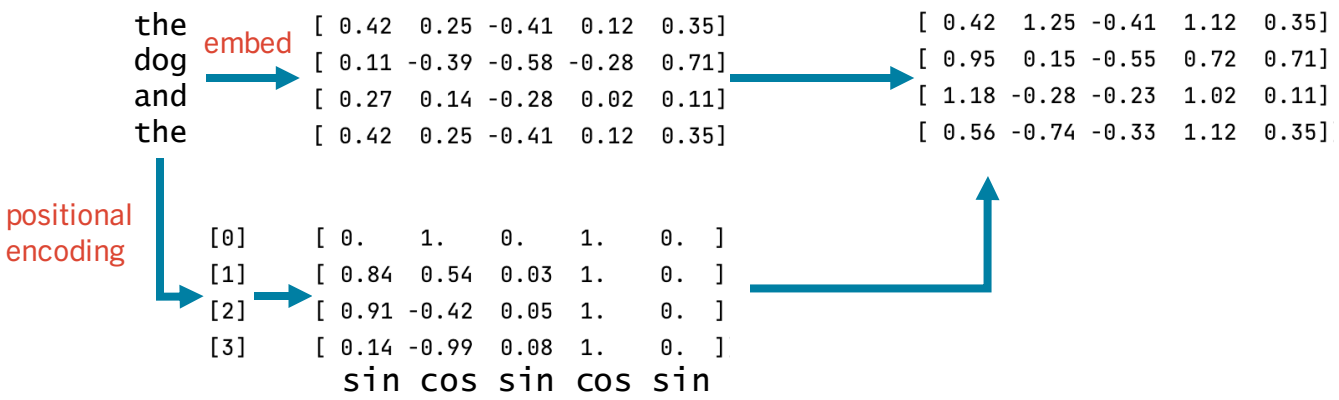
Building GPT

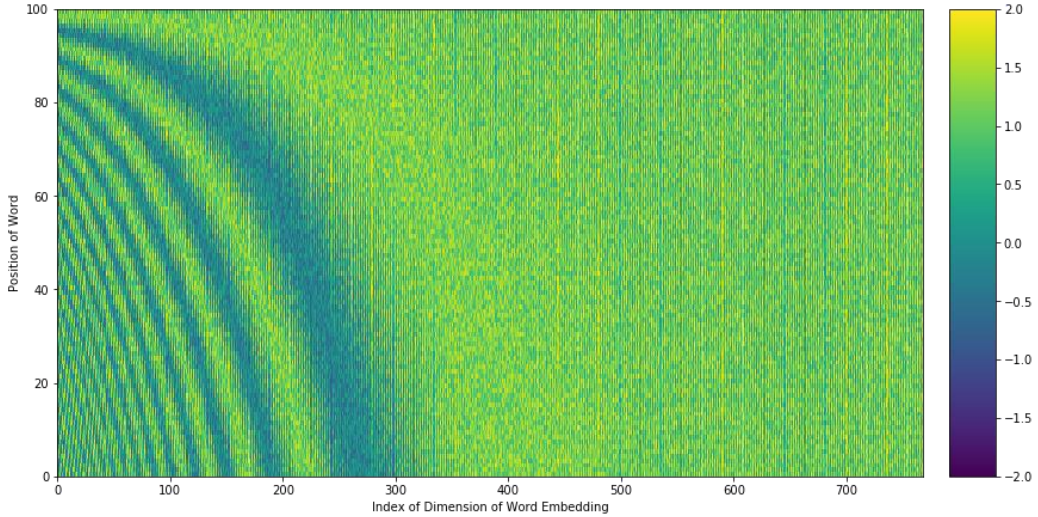


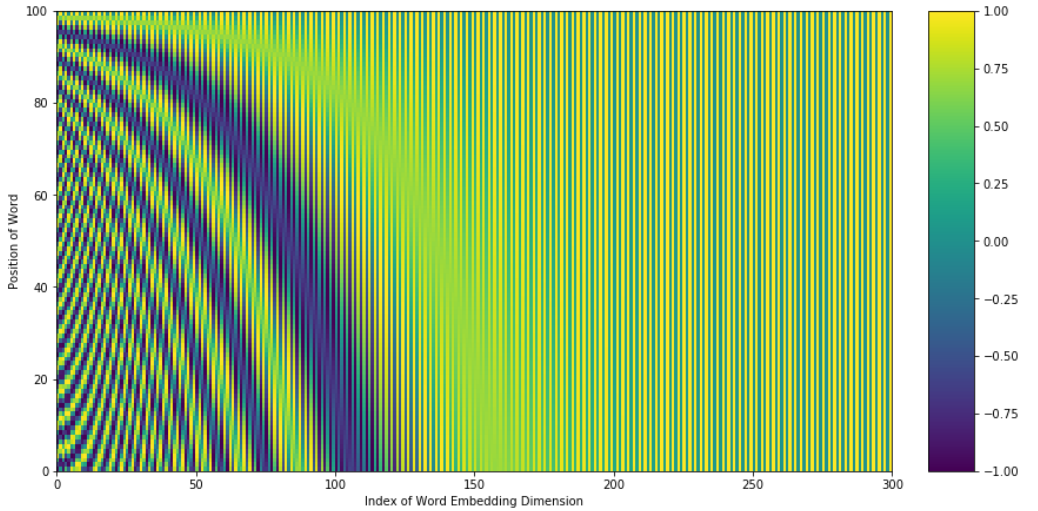
Building GPT: The Transfomer



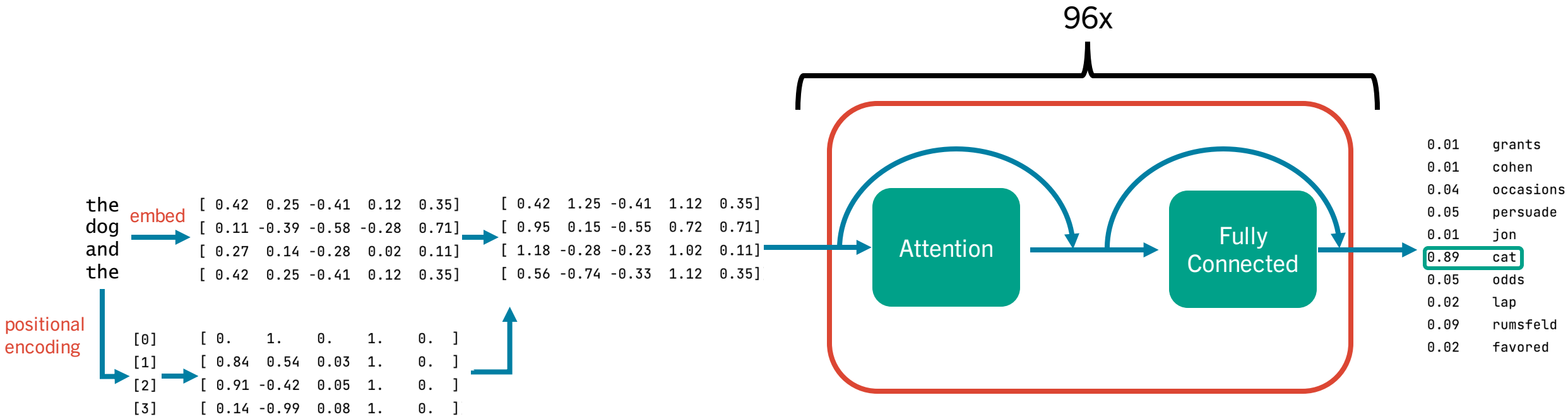
Building GPT: Positional Embedding







Building GPT



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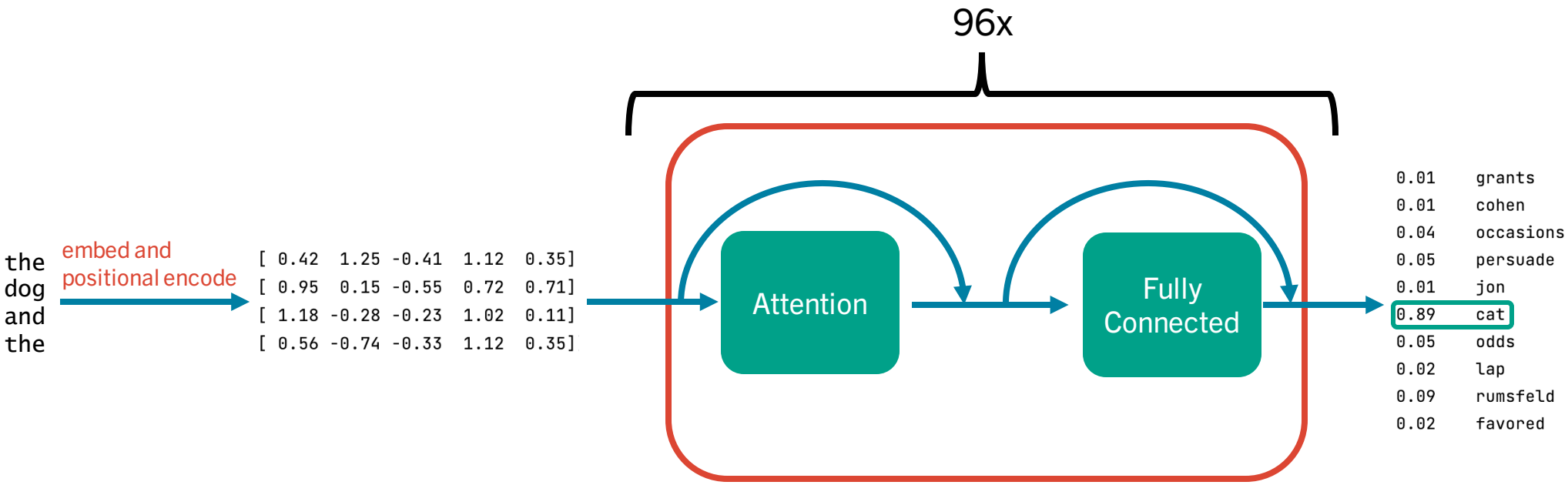
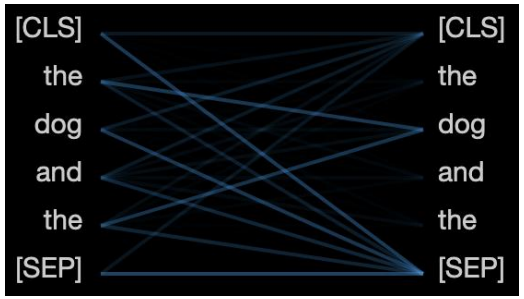
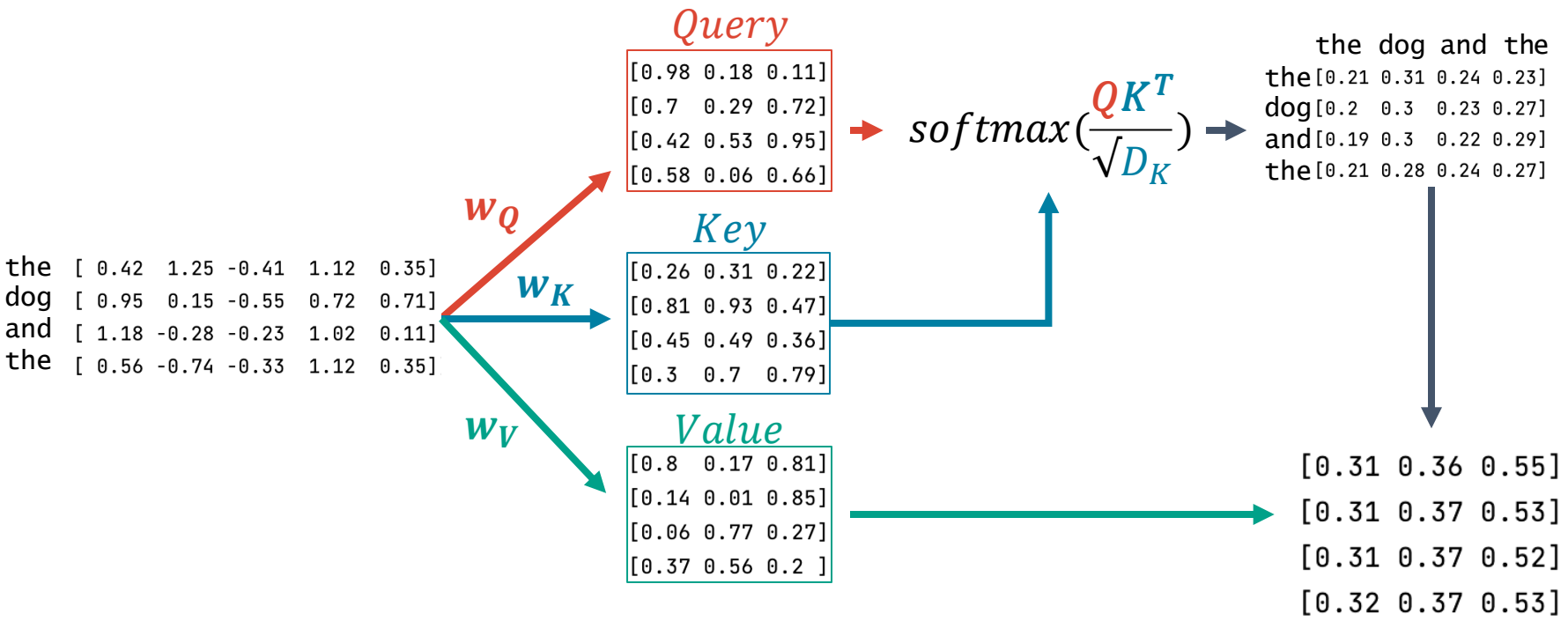
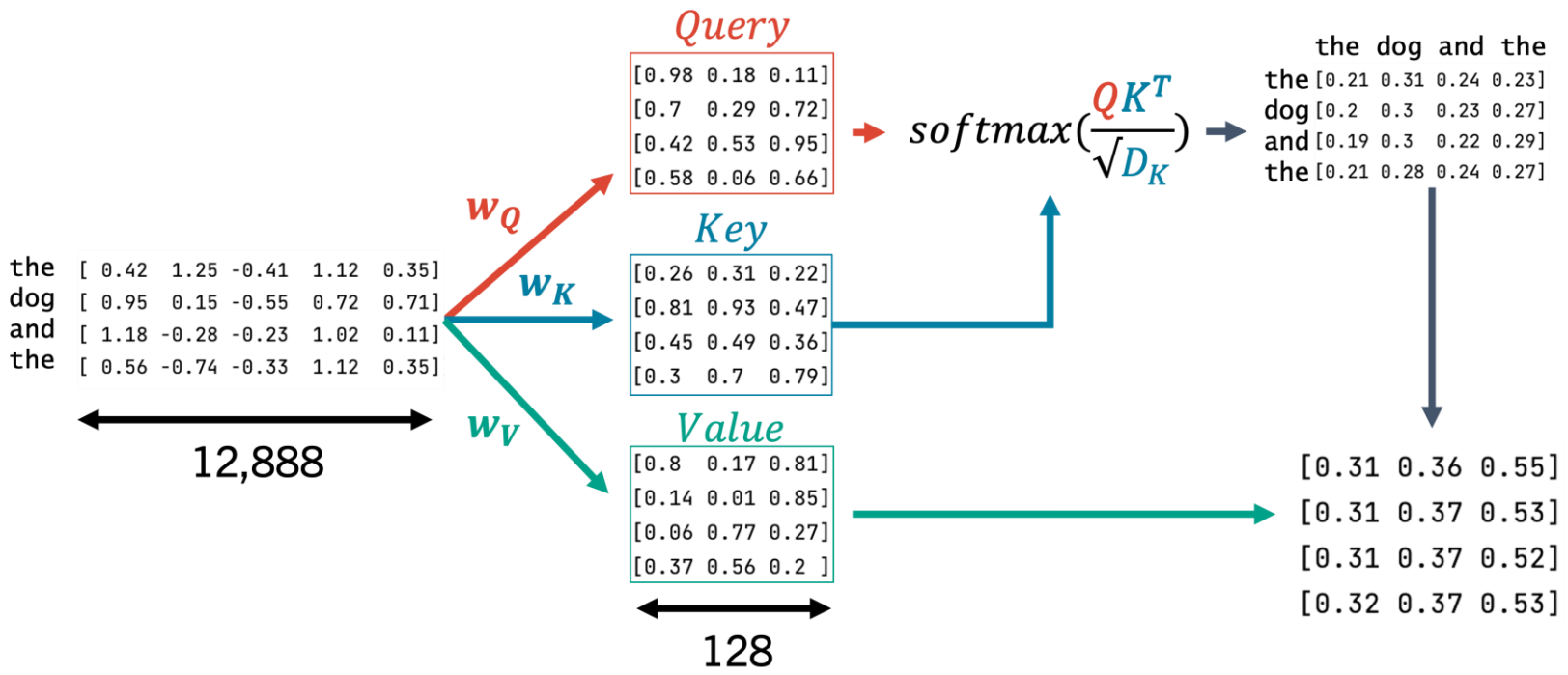


Building GPT: Attention

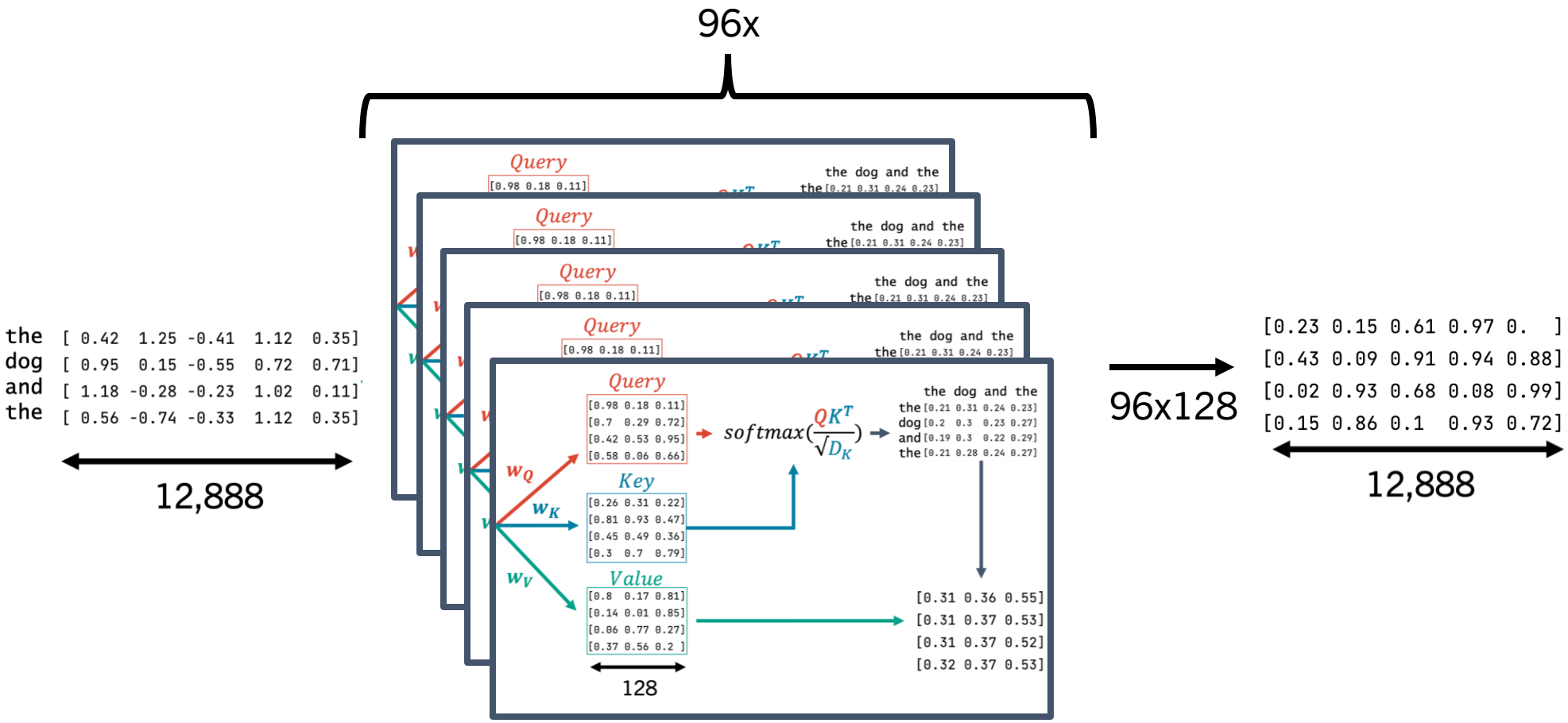




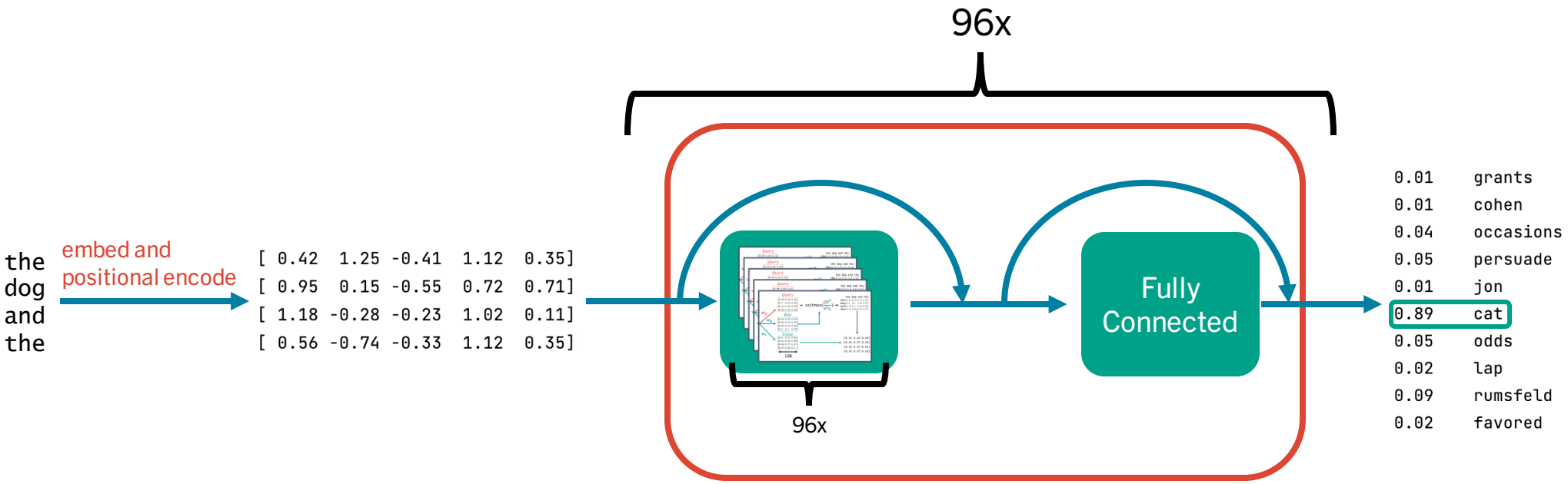
Building GPT: Attention



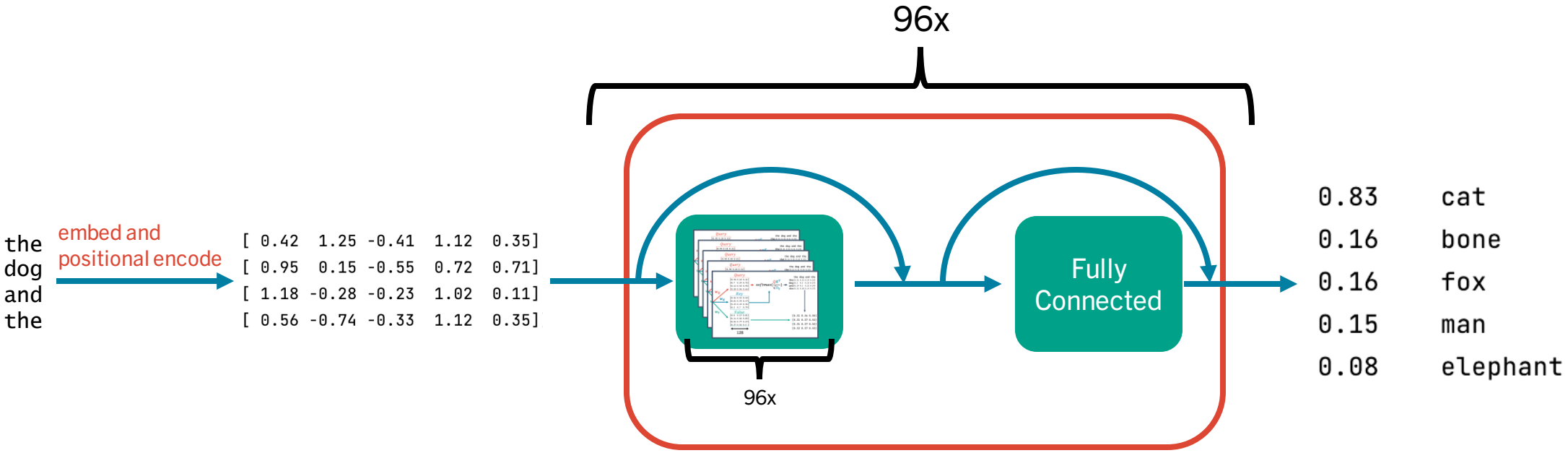
Building GPT: Attention



Building GPT



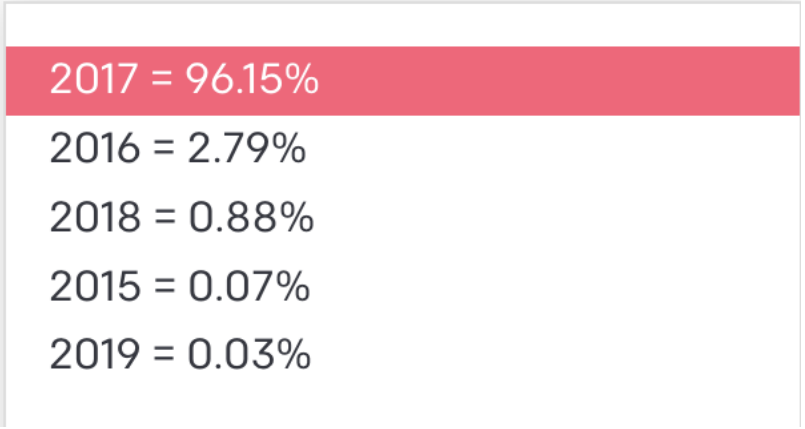
Building GPT: Top-P



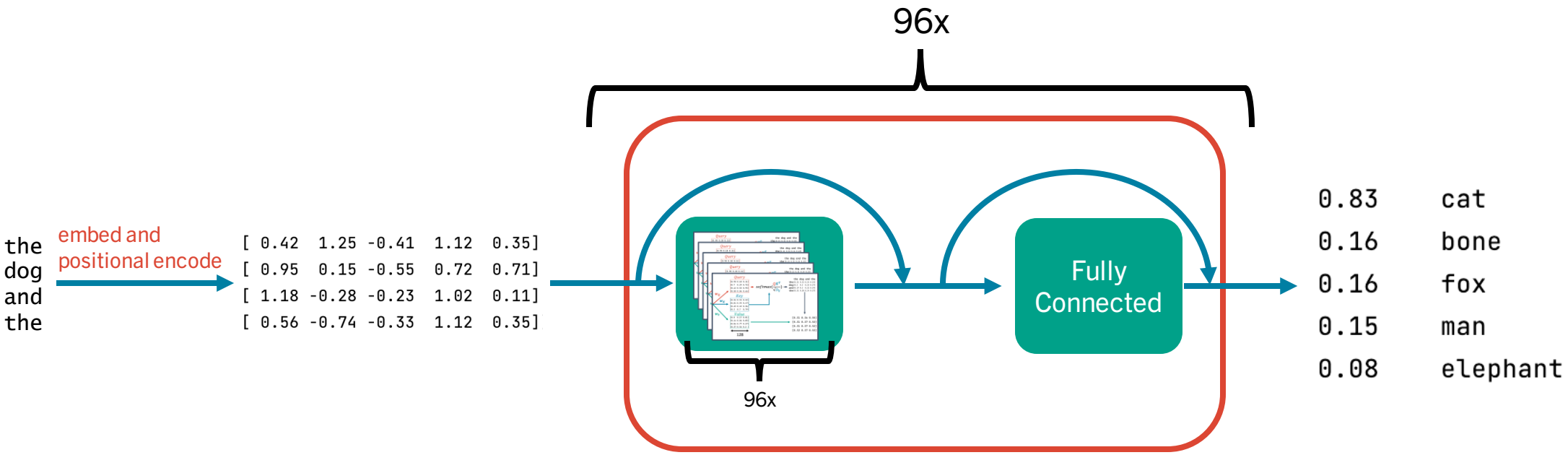
Building GPT: Top-P

Top 10 documentaries about artificial intelligence:

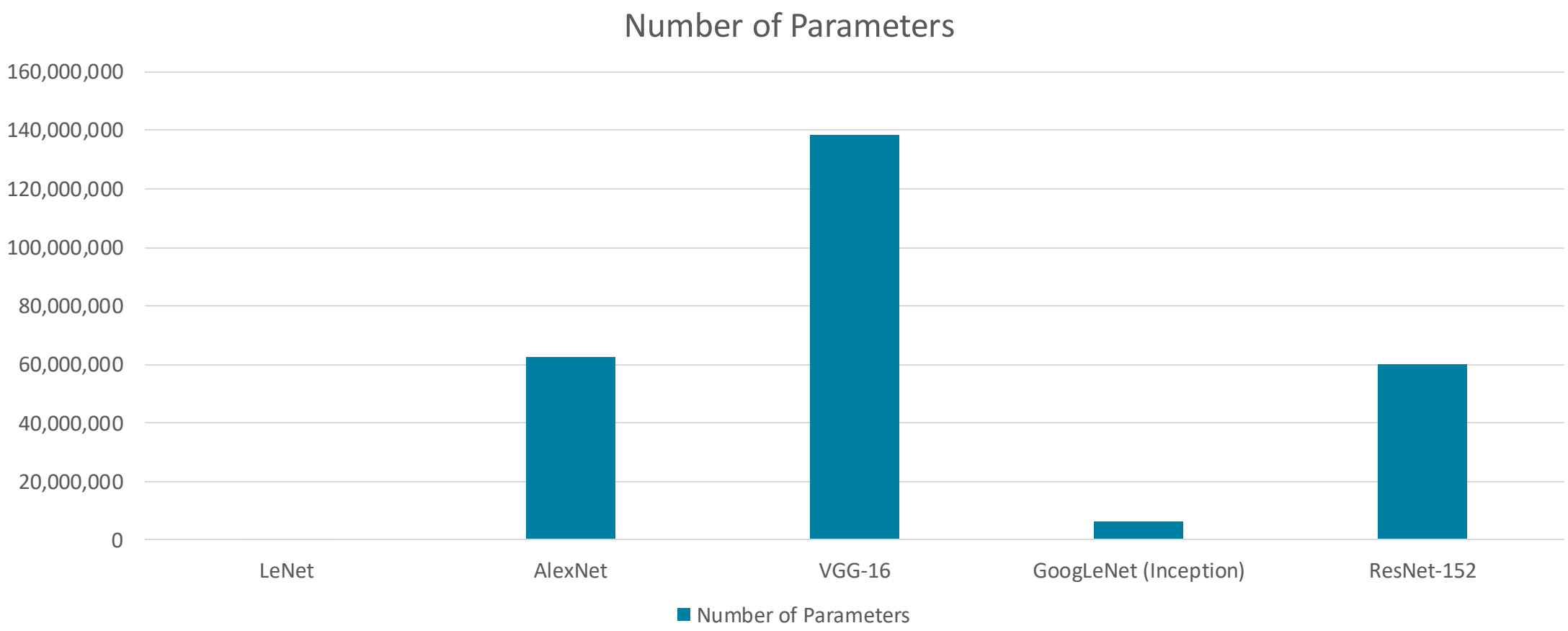
1. AlphaGo (2017)



Building GPT



Scale of GPT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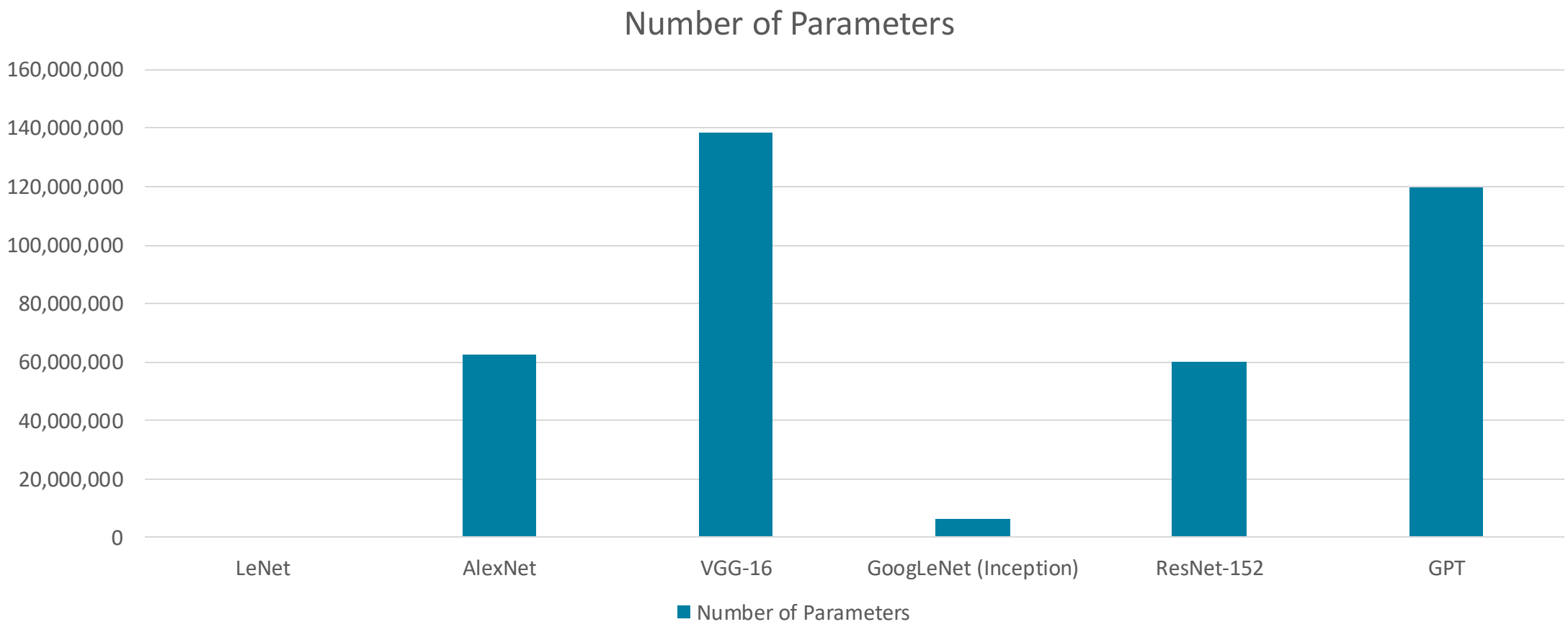
GoogLeNet (Inception)
ResNet-152
Number of Parameters

Scale of GPT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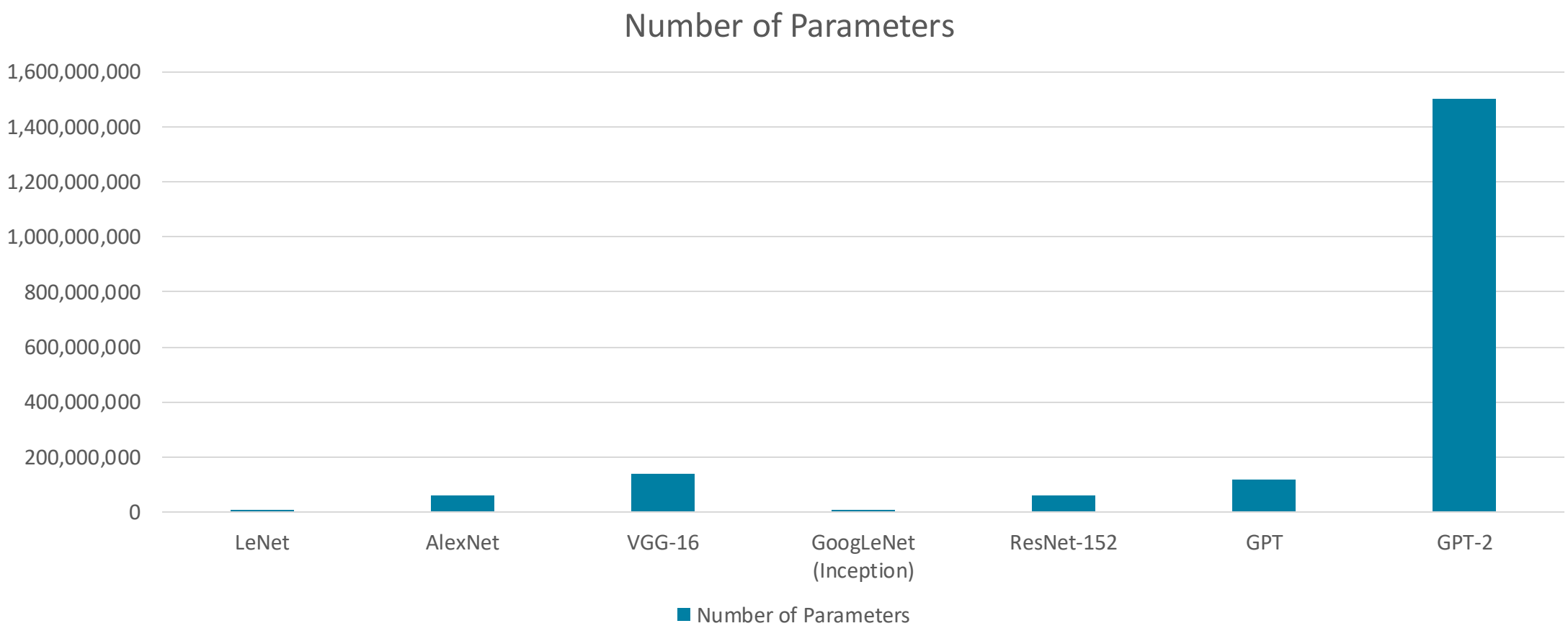
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GPT-2
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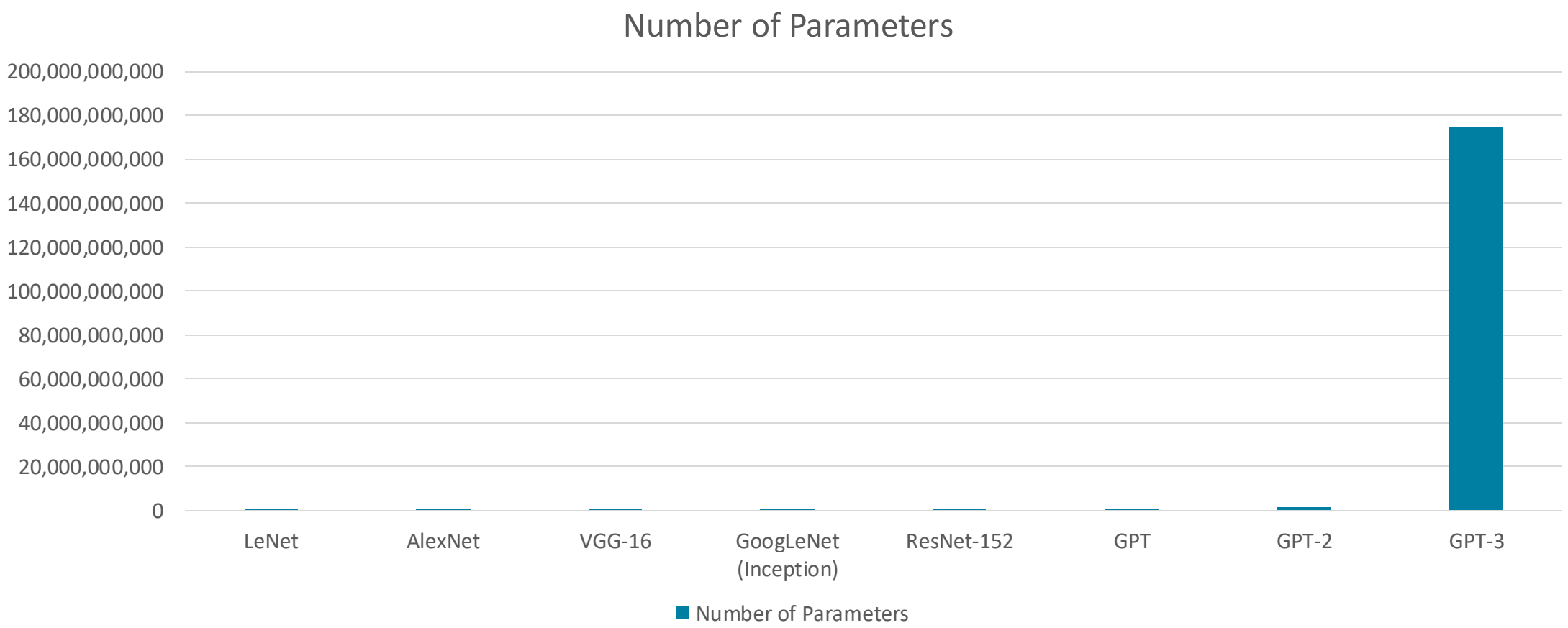
Scale of GPT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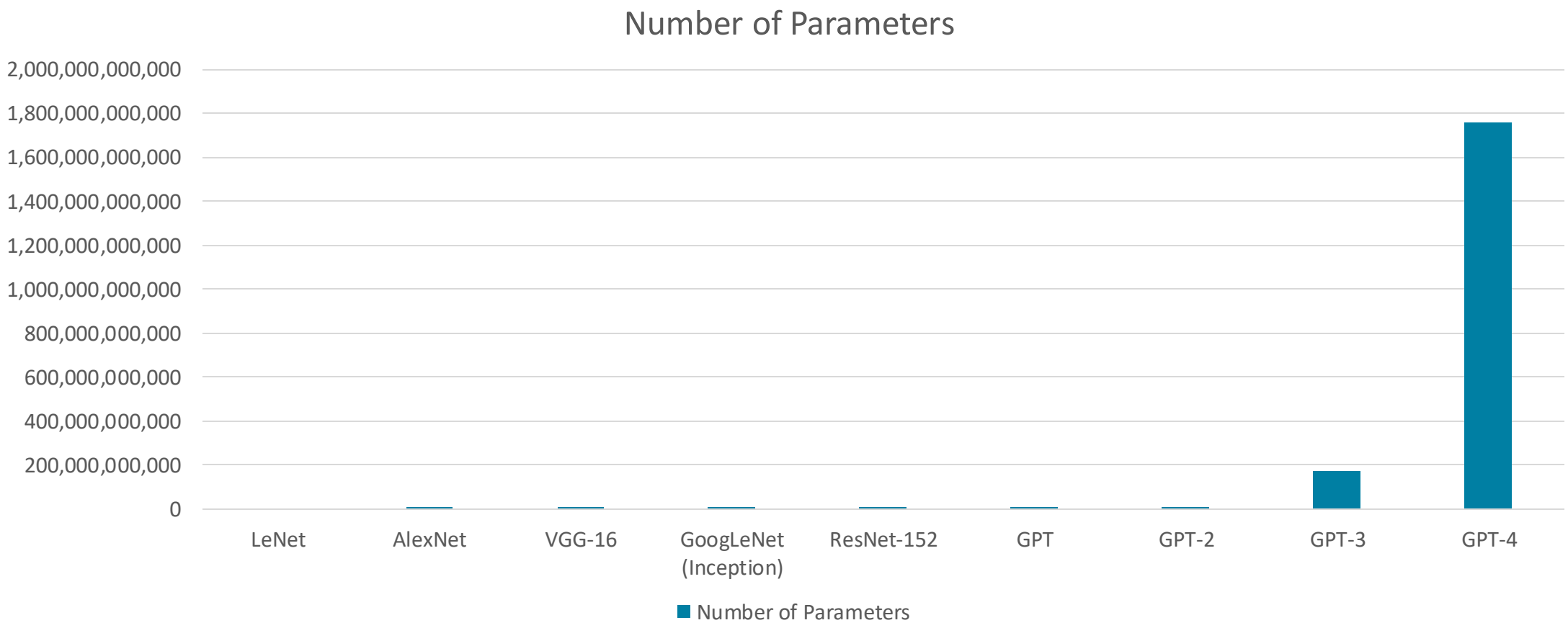
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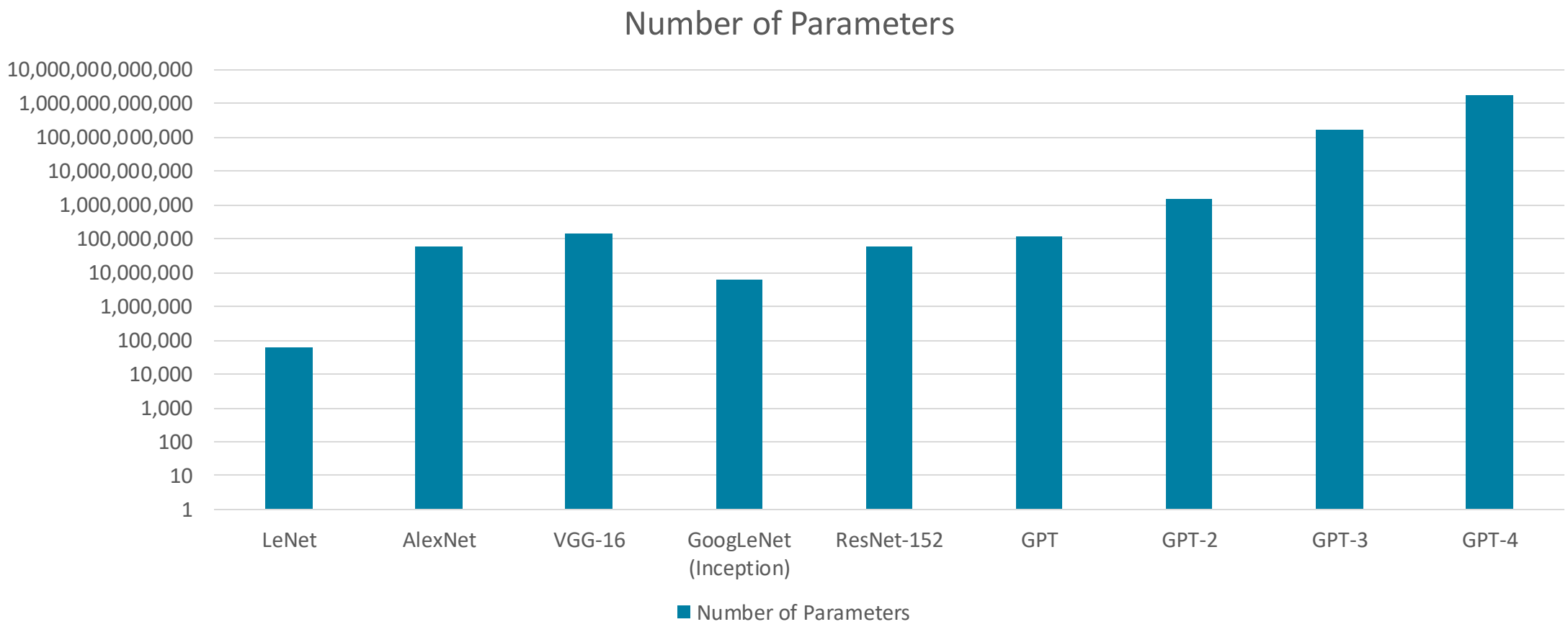
Scale of GPT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GoogLeNet (Inception)
ResNet-152
GPT
GPT-2
GPT-3
GPT-4
Number of Parameters

GPT's Training Data

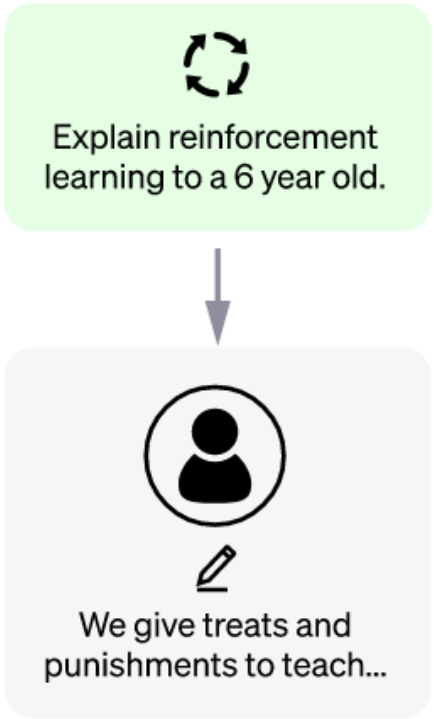
- 1 token ≈ ¾ word
- Some datasets are sampled more times than others
- Common Crawl: billions of webpages collected over 7 years
- Webtext2: Dataset of webpages that have been shared on Reddit
- Books1: Free ebooks (?)
- Books2: Secret!
- English Wikipedia

Dataset	Quantity (tokens)	Weight in training mix
Common Crawl (filtered)	410 billion	60%
WebText2	19 billion	22%
Books1	12 billion	8%
Books2	55 billion	8%
Wikipedia	3 billion	3%

The training innovation of ChatGPT

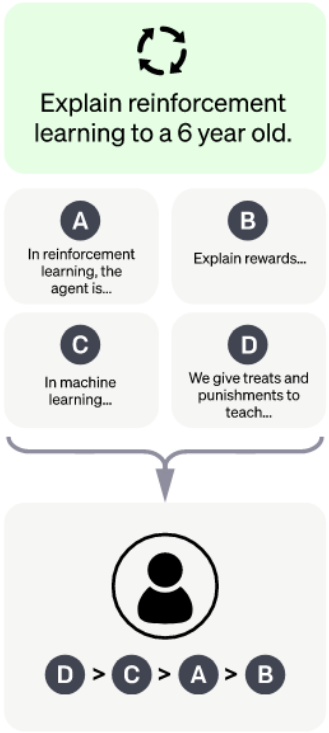
No more humans involved!

Human annotators write answers to questions



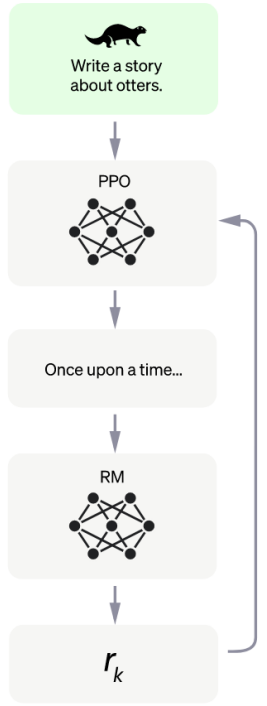
The generalist GPT model is taught from these Q&A pairs

Human annotators write <u>more</u> answers, and someone else ranks them



A <u>separate</u> model learns to rate the quality of an answer

GPT writes answers to sampled questions



The reward model rates each answer, allowing GPT to keep learning

Figures: https://openai.com/blog/chatgpt/

Winograd Schema

- ”Artificial language processing remains ten years away” – Tom Scott, 2020
- GPT-3 performance: 68.8%
- GPT-4 performance: 94.4%
- Today, 22 models outperform human baselines on the GLUE benchmark