

A photograph showing a row of various national flags on tall poles in front of a modern, curved building with many windows. The flags include those of the United Kingdom, France, Germany, Italy, Spain, and others. The building has a distinctive curved facade and a grid of windows.

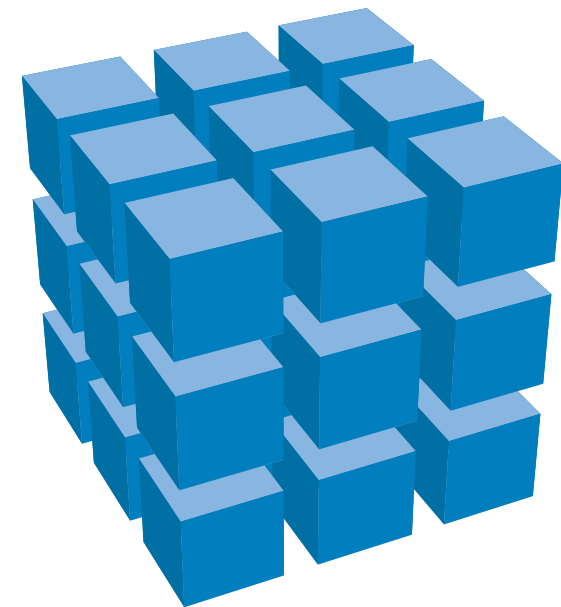
## Discussion of “Artificial intelligence and big holding data: opportunities for central banks” by Gabaix, Koijen, Richmond and Yogo

Hyun Song Shin, Bank for International Settlements  
BIS Annual Conference, 28 June 2024, Basel

Machine learning models excel at imposing mathematical structure on unstructured data, allowing the massive computing power of today's hardware to be unleashed in processing the data

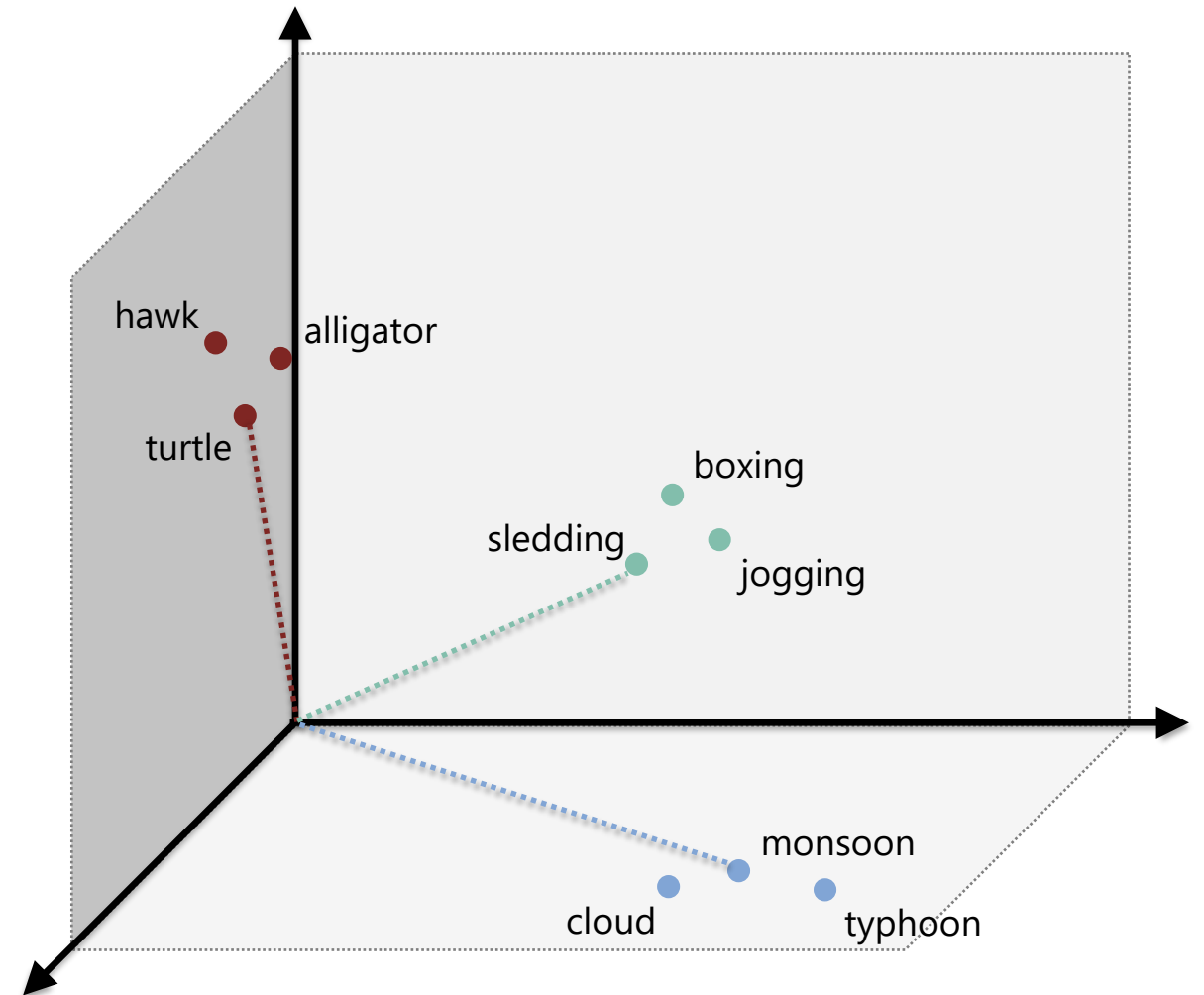


**Unstructured data**

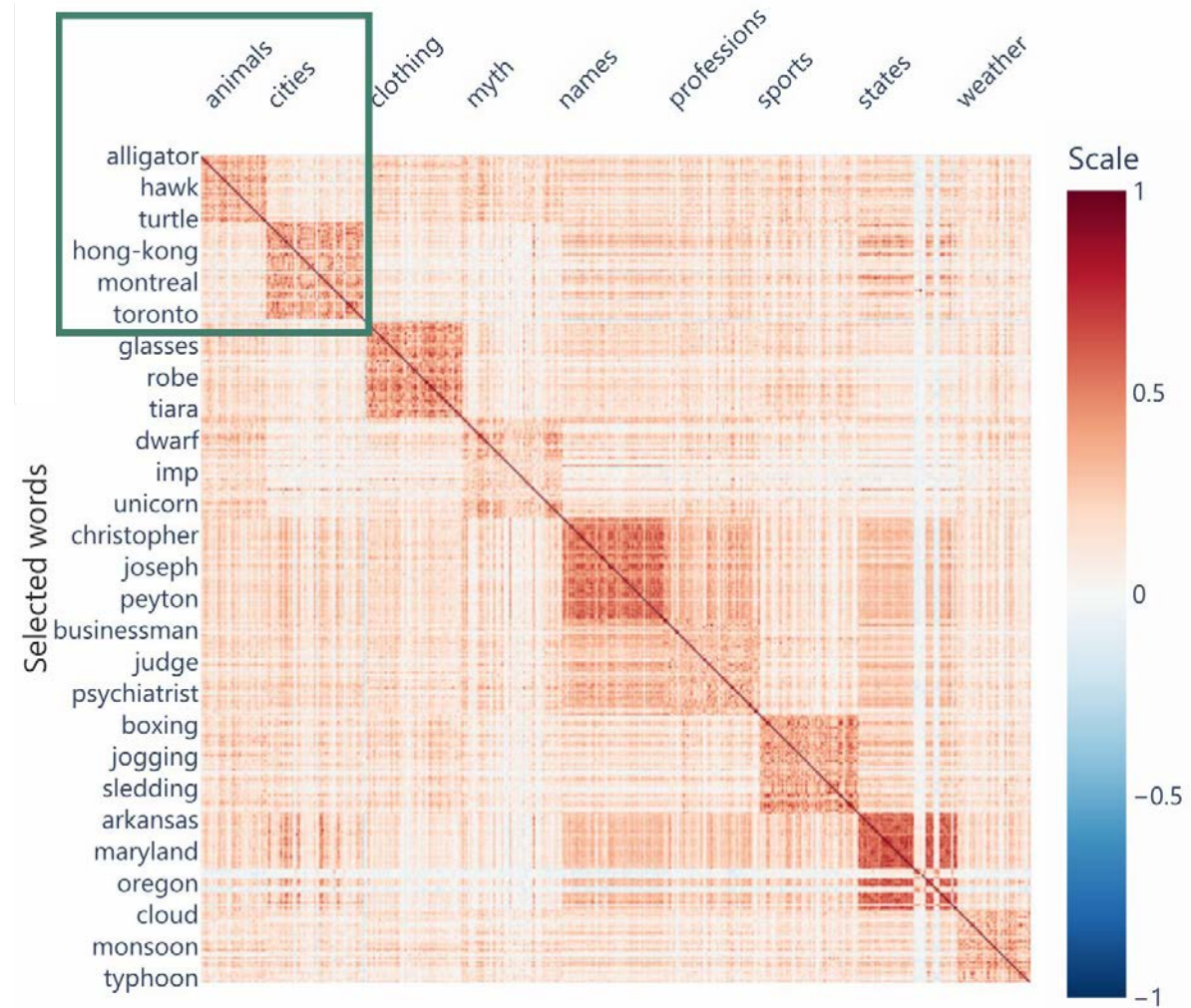


**Structured data**

Best known example is the “embedding” of words as vectors so that words are arrays of numbers; the vectors have meaning, in that similar words are closer together in the vector space

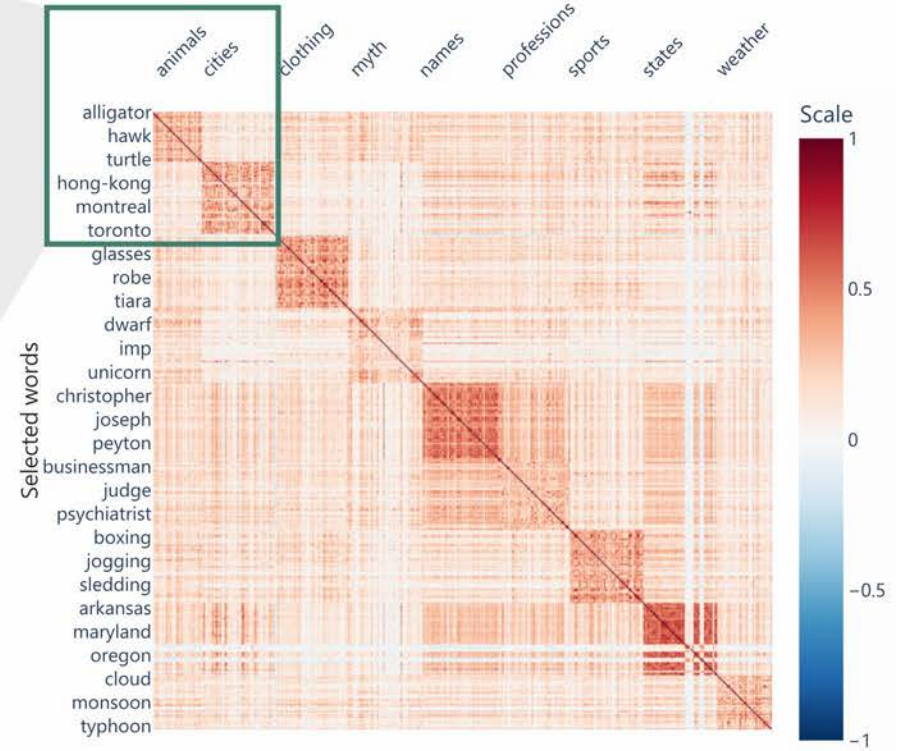
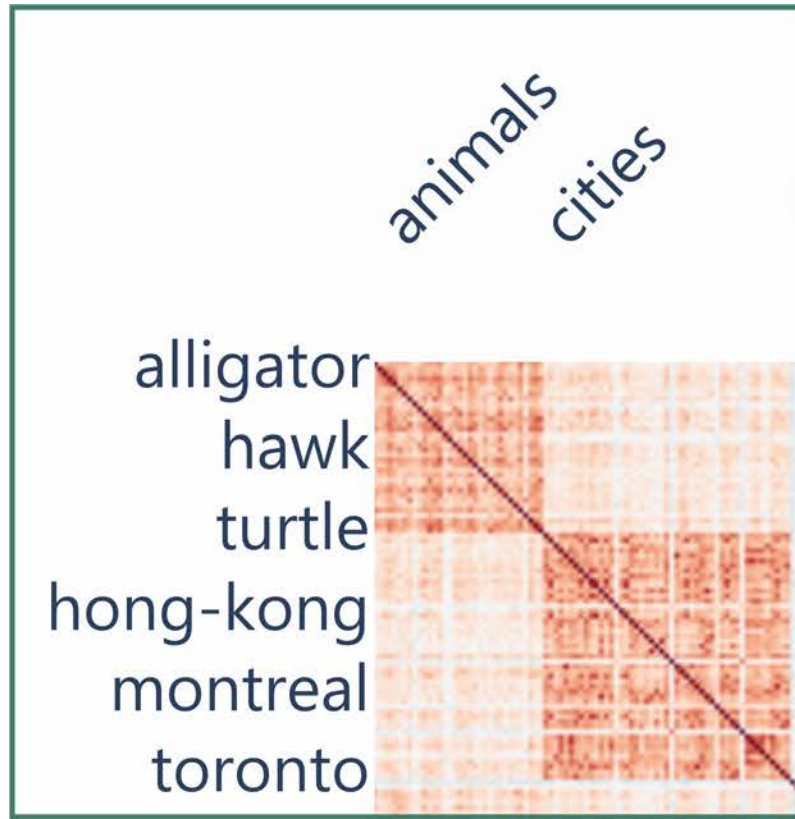


Words with related meaning have similar embeddings

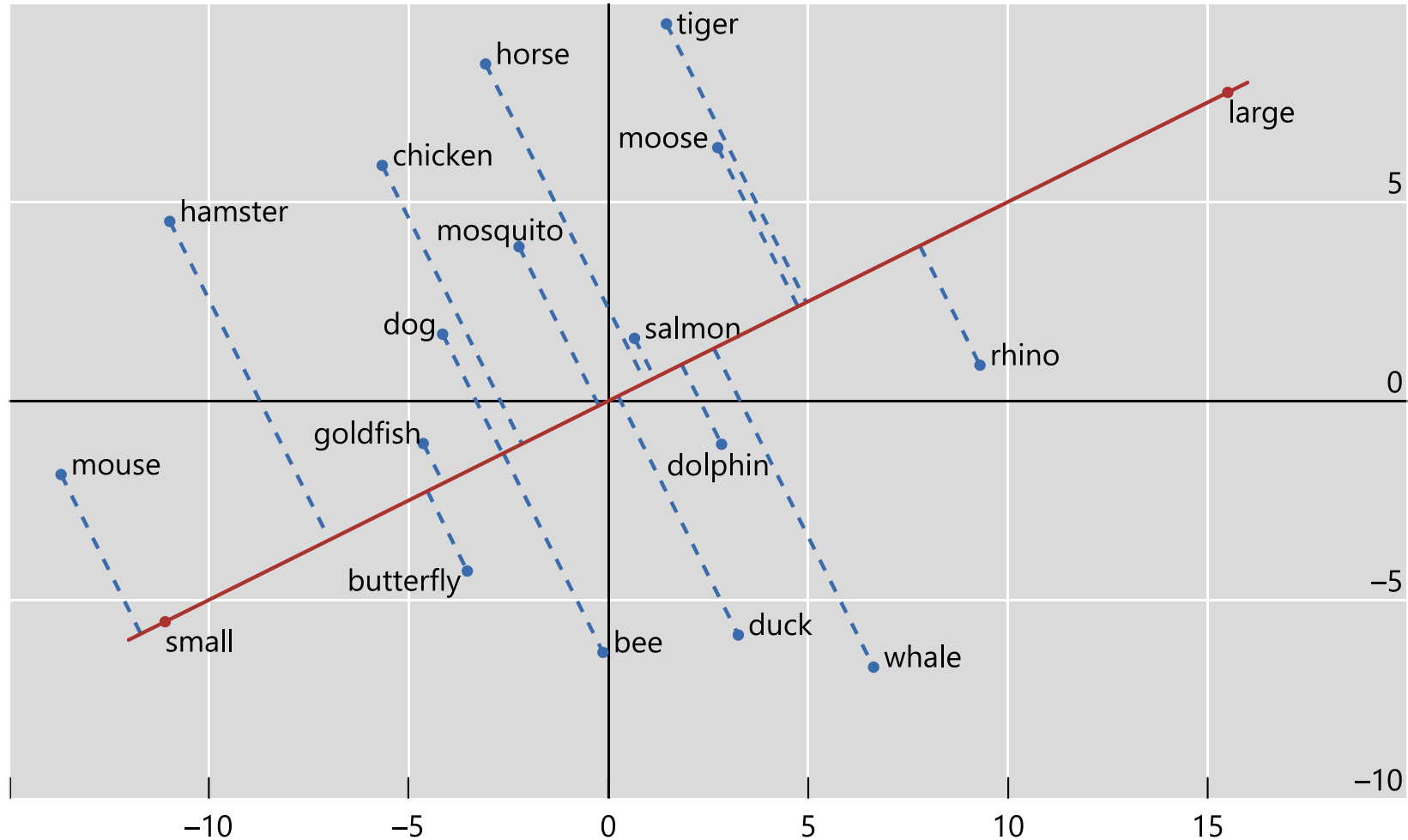




For example, different animals have similar (cosine) similarity, and so do cities



# Vectors preserve meaning when projected on line indicating size



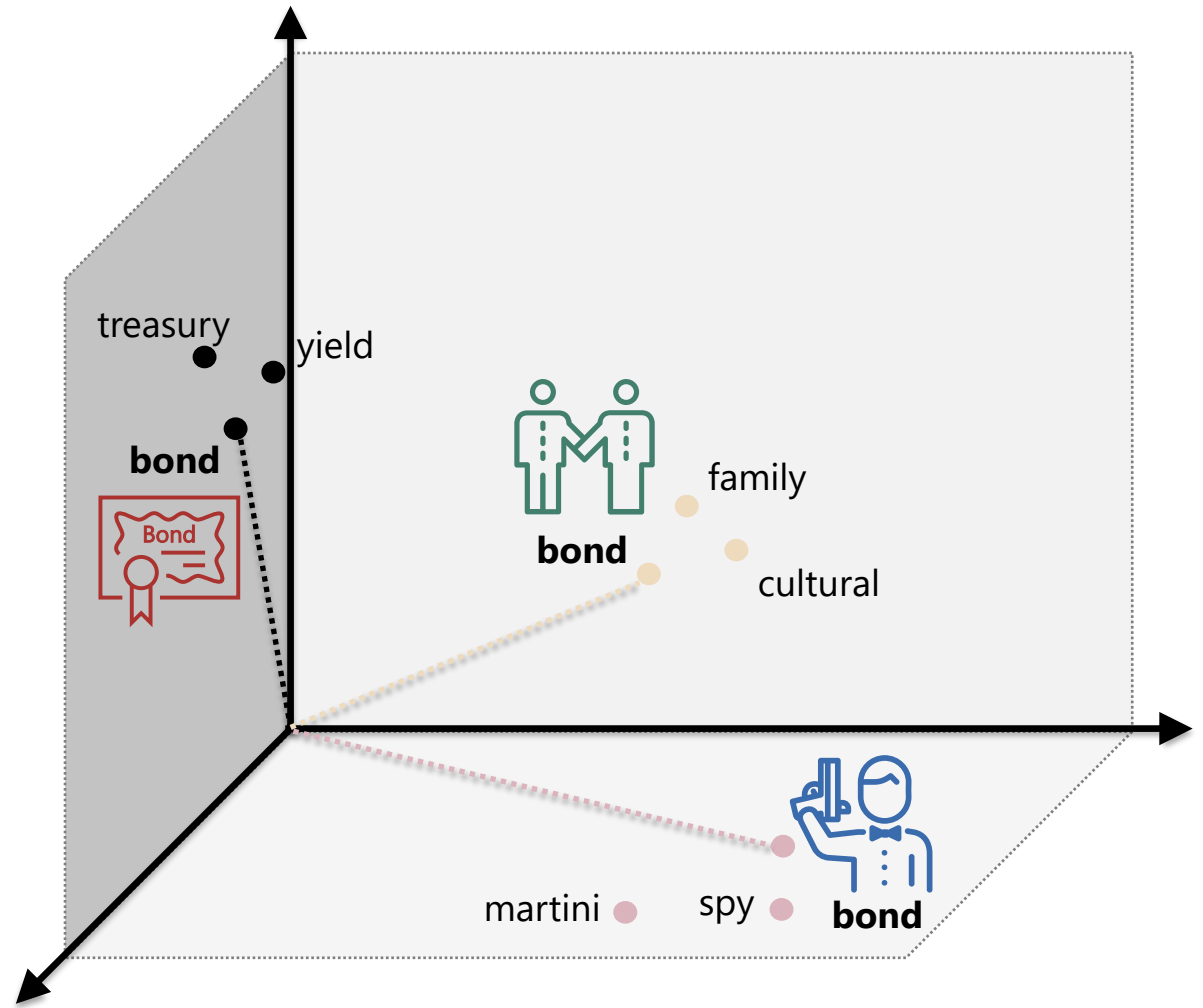
# Linear algebra of words

$$\overrightarrow{queen} = \overrightarrow{woman} + \overrightarrow{king} - \overrightarrow{man}$$

$$\overrightarrow{Quito} = \overrightarrow{Ecuador} + \overrightarrow{Oslo} - \overrightarrow{Norway}$$

$$\overrightarrow{swam} = \overrightarrow{swimming} + \overrightarrow{walked} - \overrightarrow{walking}$$

The latest models based on the **transformer architecture** draw on the surrounding **context** of a word

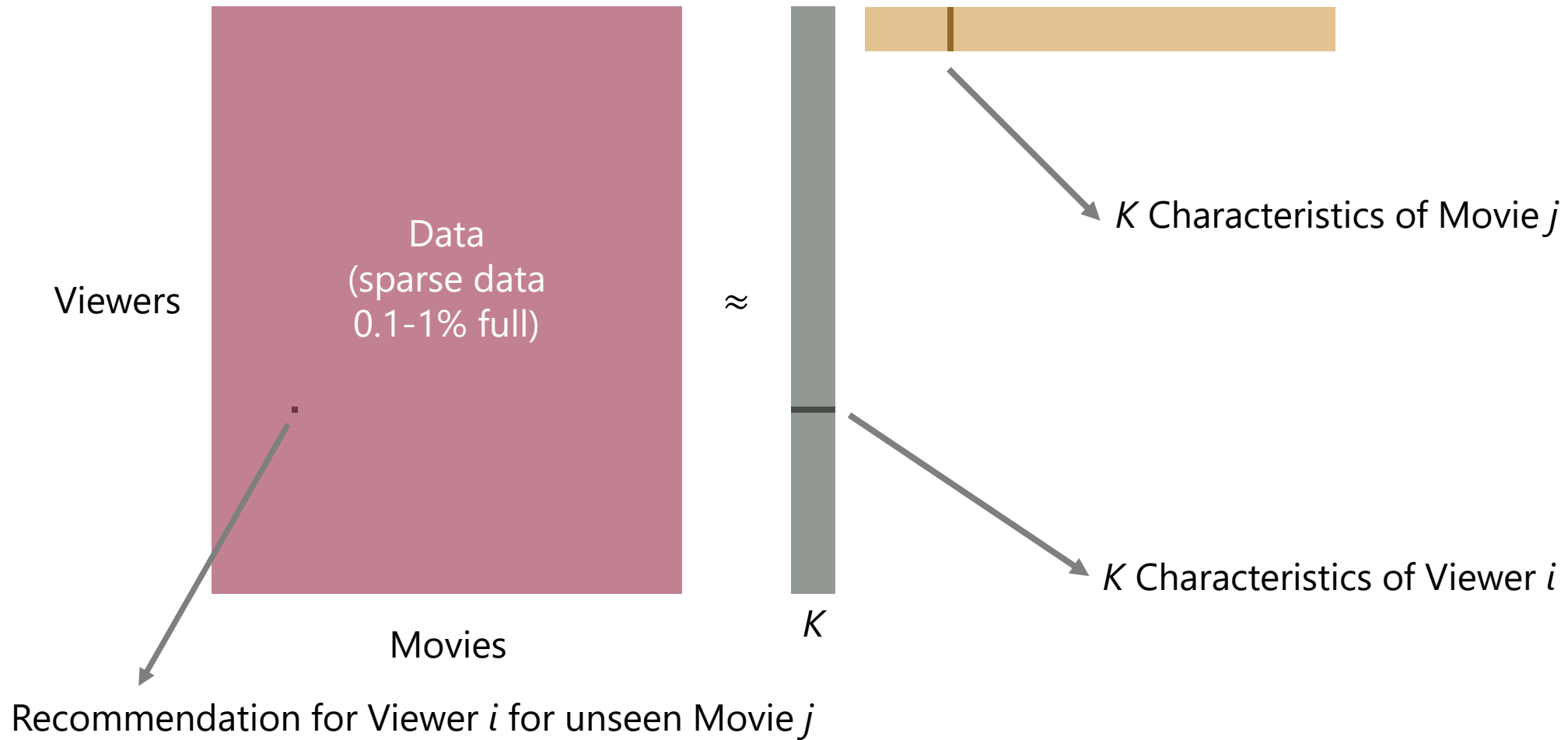




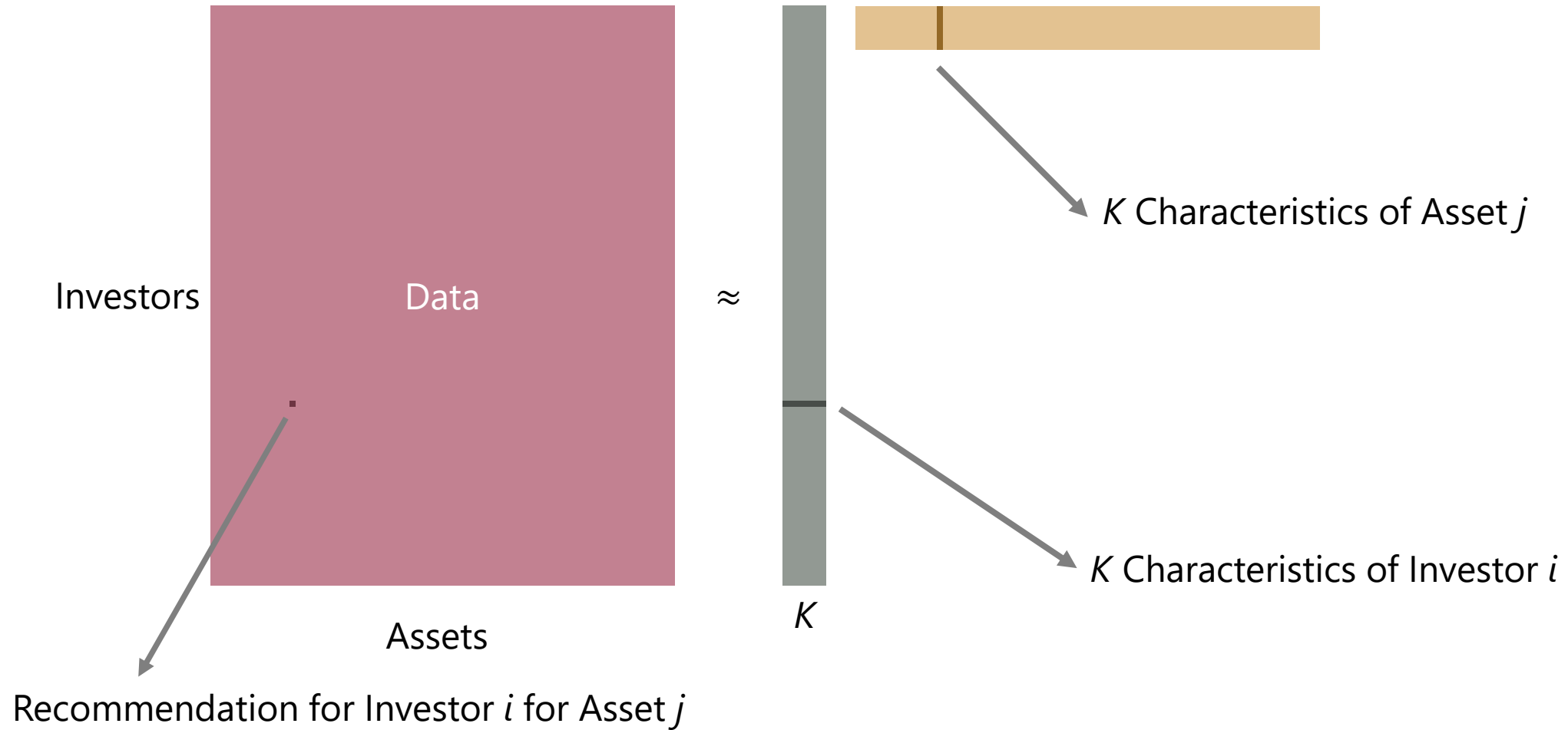
# Recommender system: the Netflix prize



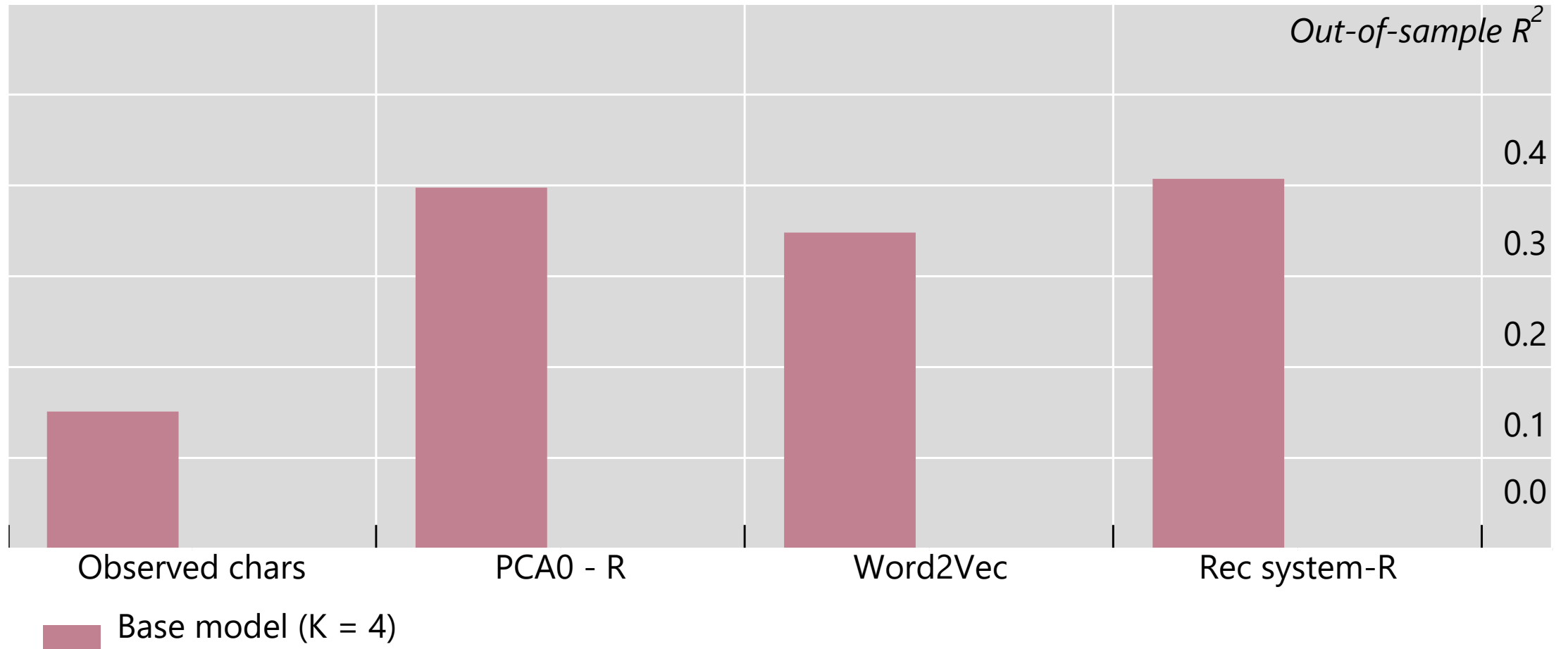
# Recommender System



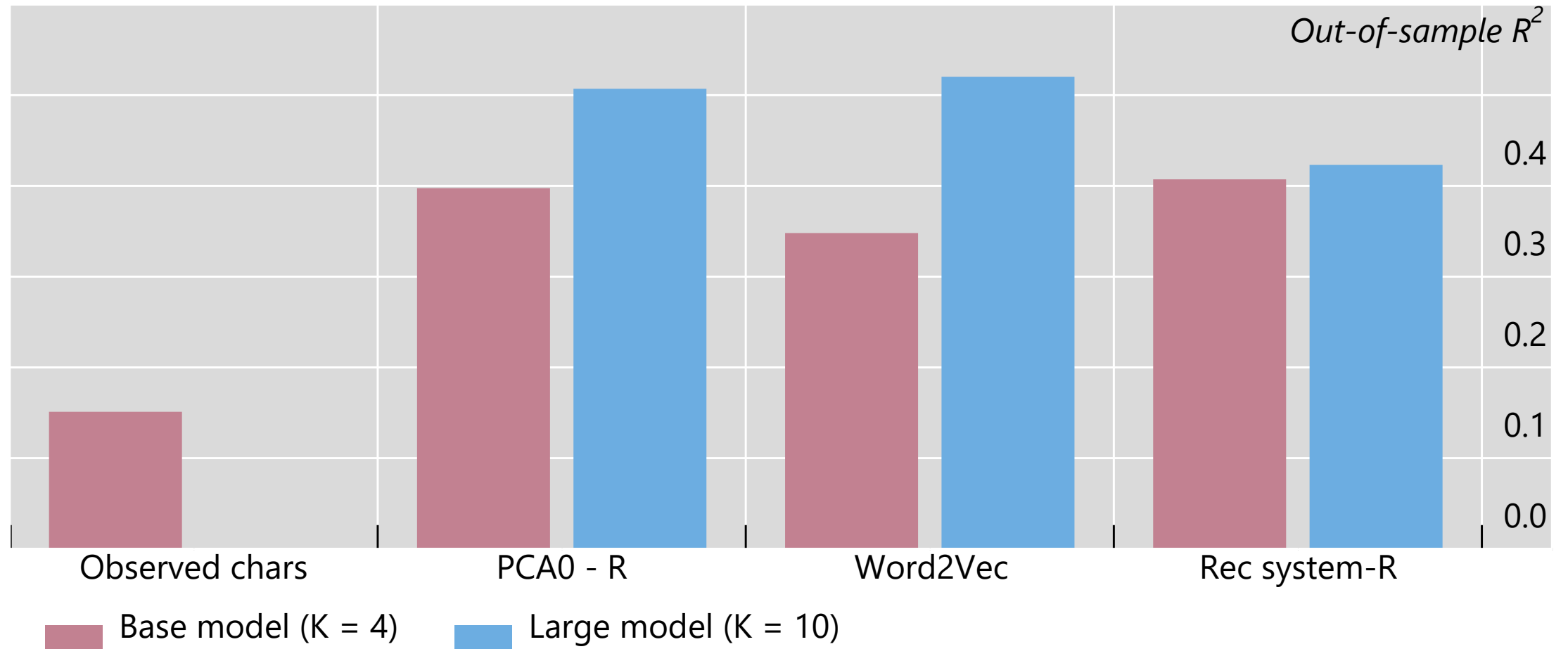
# Recommender System



## Predicting stock holdings



## Predicting stock holdings





## Some questions to consider

- $K$  is small relative to other examples from machine learning; use larger  $K$ ?

## Some questions to consider

- $K$  is small relative to other examples from machine learning; use larger  $K$ ?
- Do asset embeddings present the same characteristics as word embeddings?
  - Closeness:
    - Is Toyota closer to Samsung or Ford? Is Toyota orthogonal to JP Morgan?
    - Is Amazon closer to Walmart or Microsoft?

## Some questions to consider

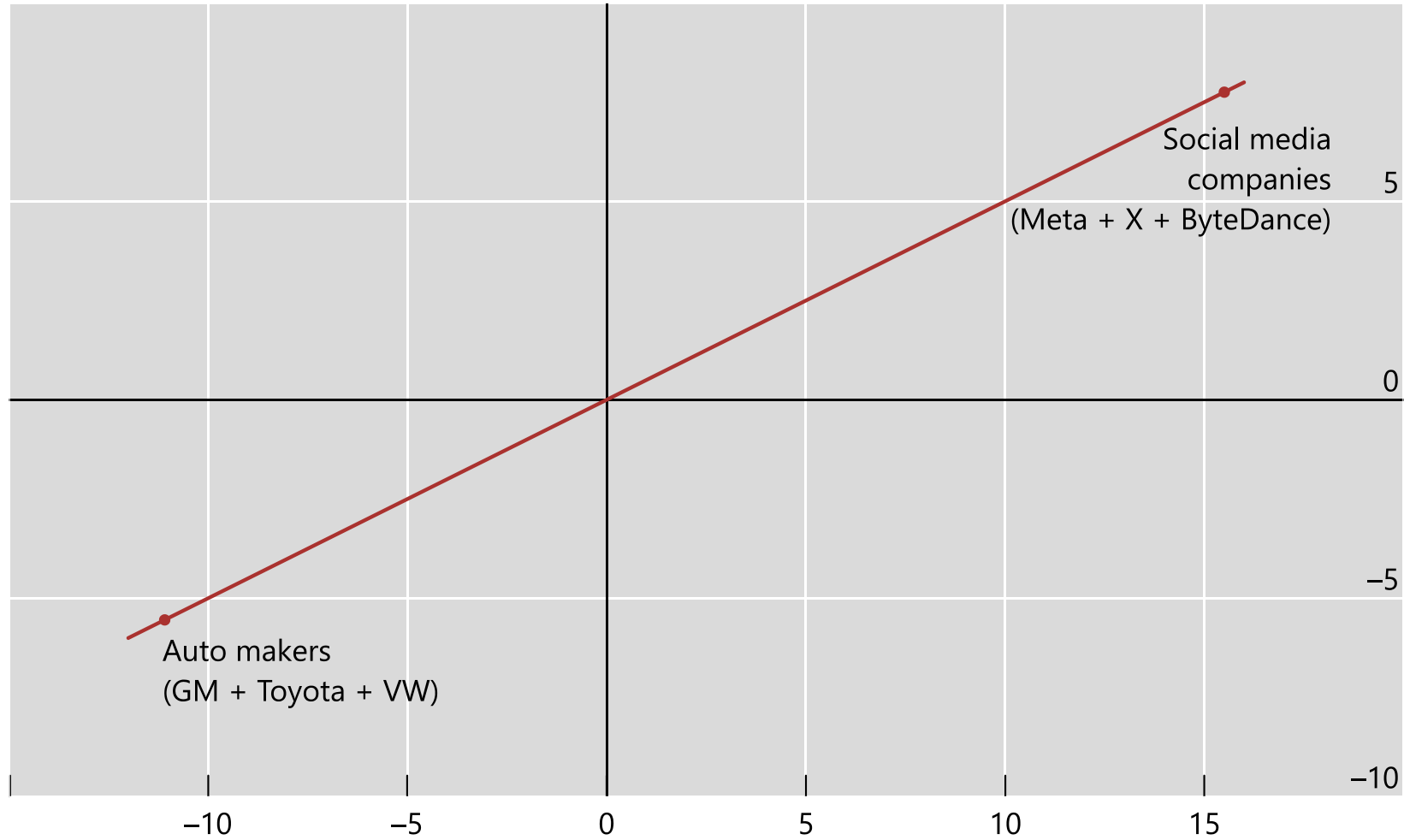
- $K$  is small relative to other examples from machine learning; use larger  $K$ ?
- Do asset embeddings present the same characteristics as word embeddings?
  - Closeness:
    - Is Toyota closer to Samsung or Ford? Is Toyota orthogonal to JP Morgan?
    - Is Amazon closer to Walmart or Microsoft?
- Do they have semantic relations? What company is  $\vec{Z}$  ?

$$\overrightarrow{Amazon} - \overrightarrow{Google} + \overrightarrow{Apple} = \vec{Z}$$

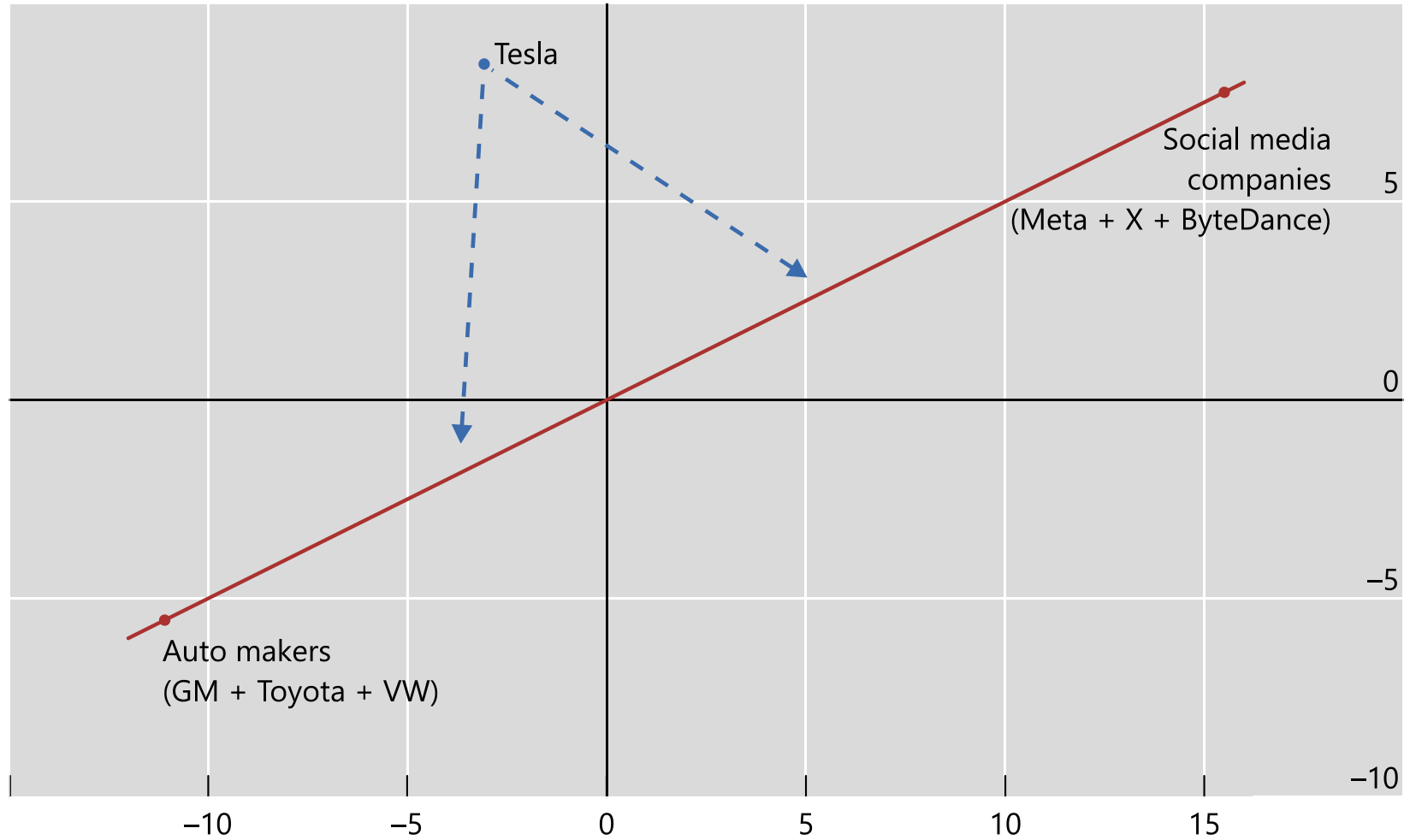
or

$$\overrightarrow{Zara} - \overrightarrow{UBS} + \overrightarrow{ByteDance} = \vec{Z}$$

# Thought experiment

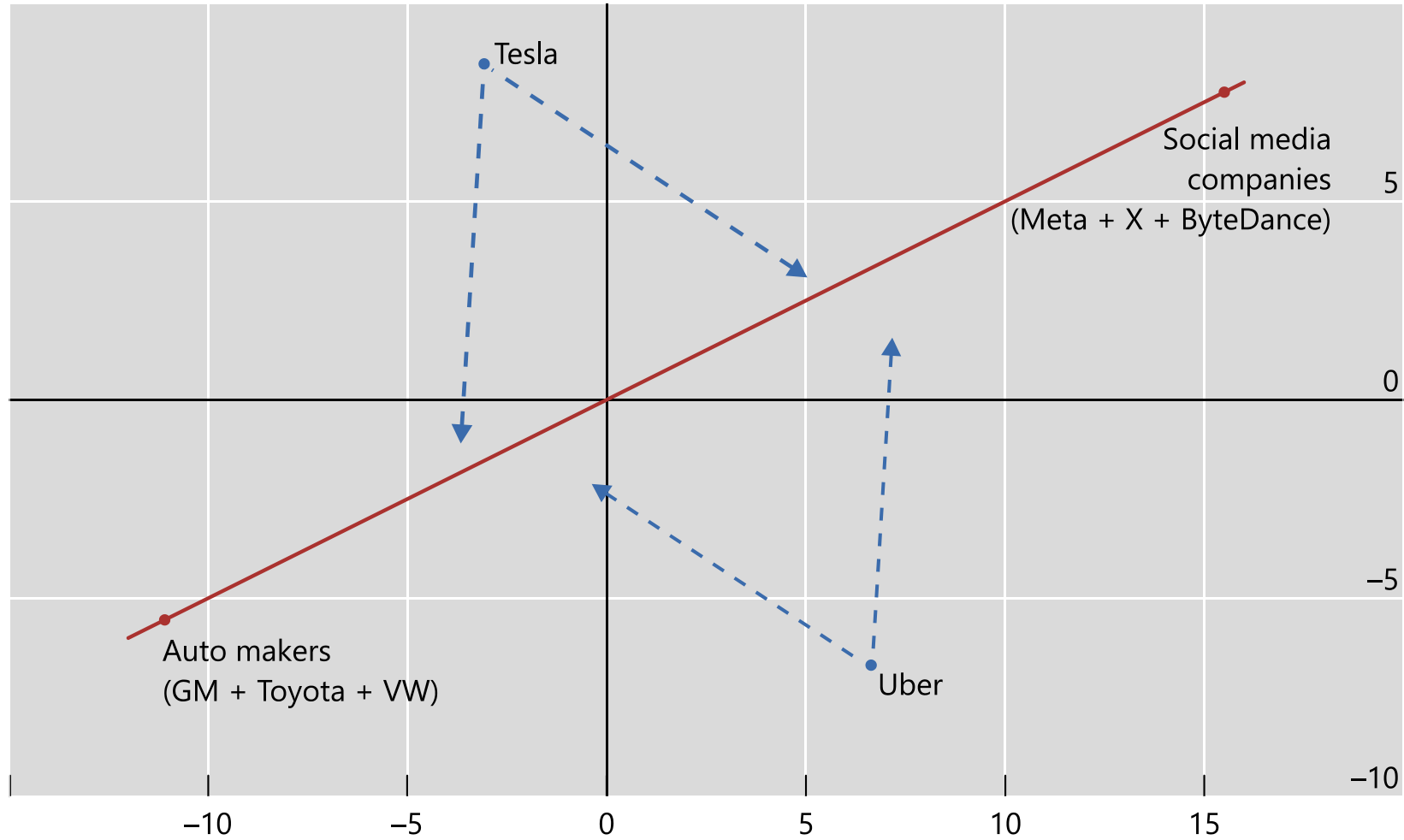


# Thought experiment





# Thought experiment



## Embedding of companies names by OpenAI

OpenAI

Input company	Apple Inc	Citigroup Inc	Walmart Inc
Rank 1	Appian Corp	Citizens Financial Group Inc	Walgreens Boots
Rank 2	Adobe Inc	Goldman Sachs Group Inc	Home Depot Inc
Rank 3	Interdigital Inc	American International Group Inc	Murphy Usa Inc
Rank 4	Microsoft Corp	Comerica Inc	Amazon Com Inc
Rank 5	Gopro Inc	Cigna Corp New	Qurate Retail Inc
Rank 6	Netapp Inc	Capital One Financial Corp	Big Lots Inc
Rank 7	Intel Corp	Caci International Inc	Burlington Stores
Rank 8	Alphabet Inc	Capital City Bank Group	Dollar Tree Inc
Rank 9	Autodesk Inc	C N O Financial Group Inc	Nordstrom Inc
Rank 10	Appfolio Inc	Jpmorgan Chase & Co	Kohls Corp

# Embedding of companies names by OpenAI

## NASDAQ : Company Listings

A B C D E F G H I J K L M

Input company	Apple Inc	Citigroup Inc		Walmart Inc
			App Pharmaceuticals (MM)	
			AppFolio Inc	
			AppHarvest Inc	
Rank 1	Appian Corp	Citizens Finan	AppTech Payments Corporation	Wingreens Boots
Rank 2	Adobe Inc	Goldman Sachs	Appian Corporation	Home Depot Inc
Rank 3	Interdigital Inc	American Inte	Apple Inc	Murphy Usa Inc
Rank 4	Microsoft Corp	Comerica Inc	Appliance Recycling Centers of America	Amazon Com Inc
Rank 5	Gopro Inc	Cigna Corp N	Applied DNA Sciences Inc	Rate Retail Inc
Rank 6	Netapp Inc	Capital One F	Applied Digital Corporation	Costco Lots Inc
Rank 7	Intel Corp	Caci Internati	Applied Digital Solutions (MM)	Arlington Stores
Rank 8	Alphabet Inc	Capital City E	Applied Digital Solutions (MM)	Woolar Tree Inc
Rank 9	Autodesk Inc	C N O Financ	Applied Extrusion (MM)	Wardstrom Inc
Rank 10	Appfolio Inc	Jpmorgan Cha	Applied Genetic Technologies Corporation	Wahls Corp
			Applied Imaging (MM)	

# Embedding of companies names by OpenAI

	OpenAI		New York Stock Exchange
Input company	Apple Inc	Citigroup Inc	A B C D E F G H I J K
Rank 1	Appian Corp	Citizens Financial Group Inc	Wal
Rank 2	Adobe Inc	Goldman Sachs Group Inc	Hor
Rank 3	Interdigital Inc	American International Group Inc	Mu
Rank 4	Microsoft Corp	Comerica Inc	Am
Rank 5	Gopro Inc	Cigna Corp New	Qur
Rank 6	Netapp Inc	Capital One Financial Corp	Big
Rank 7	Intel Corp	Caci International Inc	Bur
Rank 8	Alphabet Inc	Capital City Bank Group	Dol
Rank 9	Autodesk Inc	C N O Financial Group Inc	Nor
Rank 10	Appfolio Inc	Jpmorgan Chase & Co	Kof

Cigna Group
Cimarex Energy Co
Cincinnati Bell Inc New
Cinemark Holdings Inc
Cision Ltd
Citigroup Capital XIV
Citigroup Inc
Citizens Financial Group Inc
Citizens Inc
City Office REIT Inc
Civeo Corporation New

## Embedding of companies names by OpenAI

OpenAI

Input company	Apple Inc	Citigroup Inc	Walmart Inc
Rank 1	Appian Corp	Citizens Financial Group Inc	Walgreens Boots
Rank 2	Adobe Inc	Goldman Sachs Group Inc	Home Depot Inc
Rank 3	Interdigital Inc	American International Group Inc	Murphy Usa Inc
Rank 4	Microsoft Corp	Comerica Inc	Amazon Com Inc
Rank 5	Gopro Inc	Cigna Corp New	Qurate Retail Inc
Rank 6	Netapp Inc	Capital One Financial Corp	Big Lots Inc
Rank 7	Intel Corp	Caci International Inc	Burlington Stores
Rank 8	Alphabet Inc	Capital City Bank Group	Dollar Tree Inc
Rank 9	Autodesk Inc	C N O Financial Group Inc	Nordstrom Inc
Rank 10	Appfolio Inc	Jpmorgan Chase & Co	Kohls Corp