Outline

- Vector space models
- Advantages
- Applications

Why learn vector space models?

Where are you heading?

Where are you from?

Different meaning

What is your age?

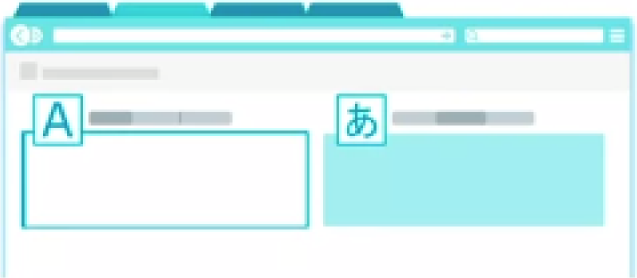
How old are you?

Same Meaning

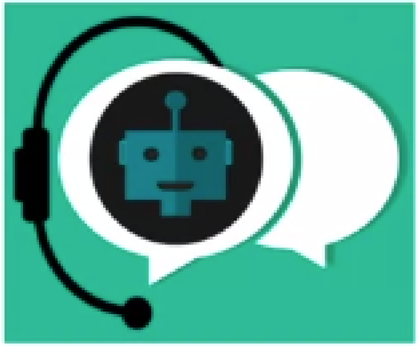
Vector space models applications

- You eat *cereal* from a *bowl*
- You *buy* something and someone else *sells* it

Information Extraction



Machine Translation



Chatbots

Fundamental concept

"You shall know a word by the company it keeps"

Firth, 1957

(Firth, J. R. 1957:11)

Summary

- Represent words and documents as vectors
- Representation that captures relative meaning

Outline

- Co-occurrence $\longrightarrow$ Vector representation
- Relationships between words/documents

Word by Word Design

Number of times they *occur together within a certain distance k*

I like simple data

I prefer simple raw data

k=2

	simple	raw	like	I
data	2	1	1	0

n

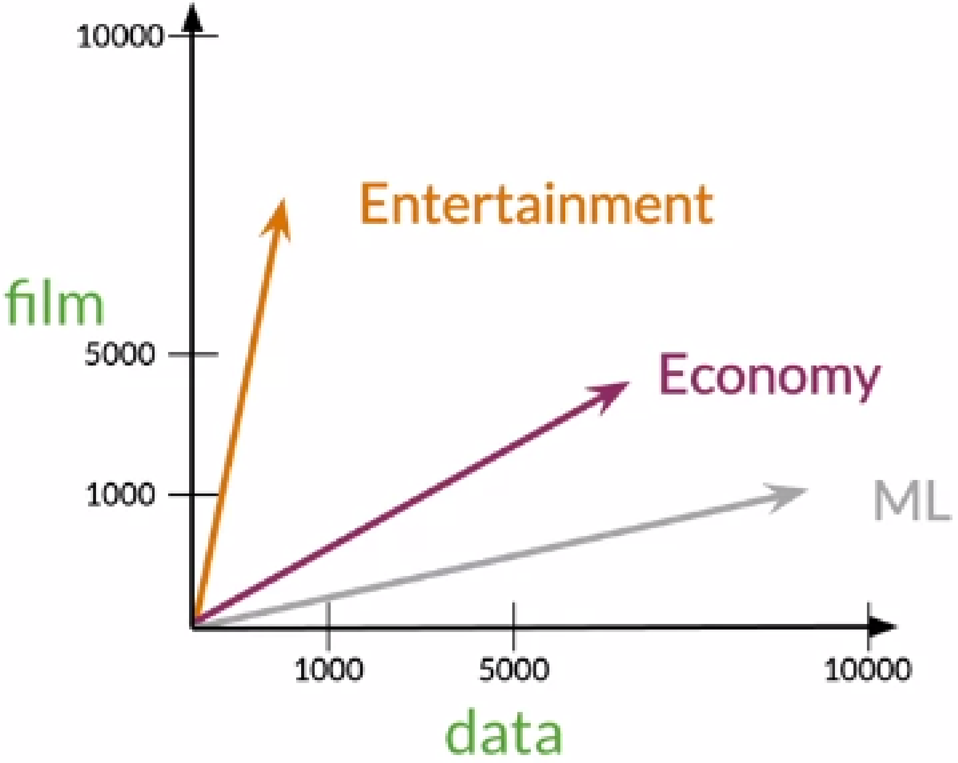
Word by Document Design

Number of times a word *occurs within a certain category*

Entertainment	Economy	Machine Learning

	Entertainment	Economy	Machine Learning
data	500	6620	9320
film	7000	4000	1000

Vector Space



	Entertainment	Economy	ML
data	500	6620	9320
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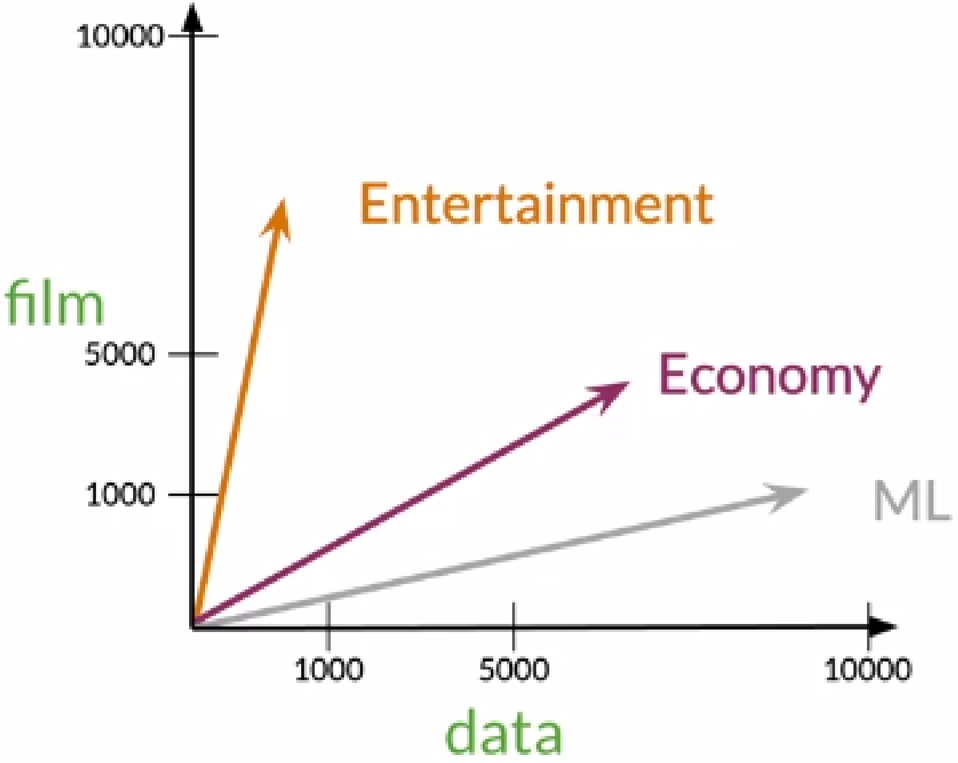
Vector Space



	Entertainment	Economy	ML
data	500	6620	9320
film	7000	4000	1000

Measures of "similarity:"
Angle
Distance

Summary

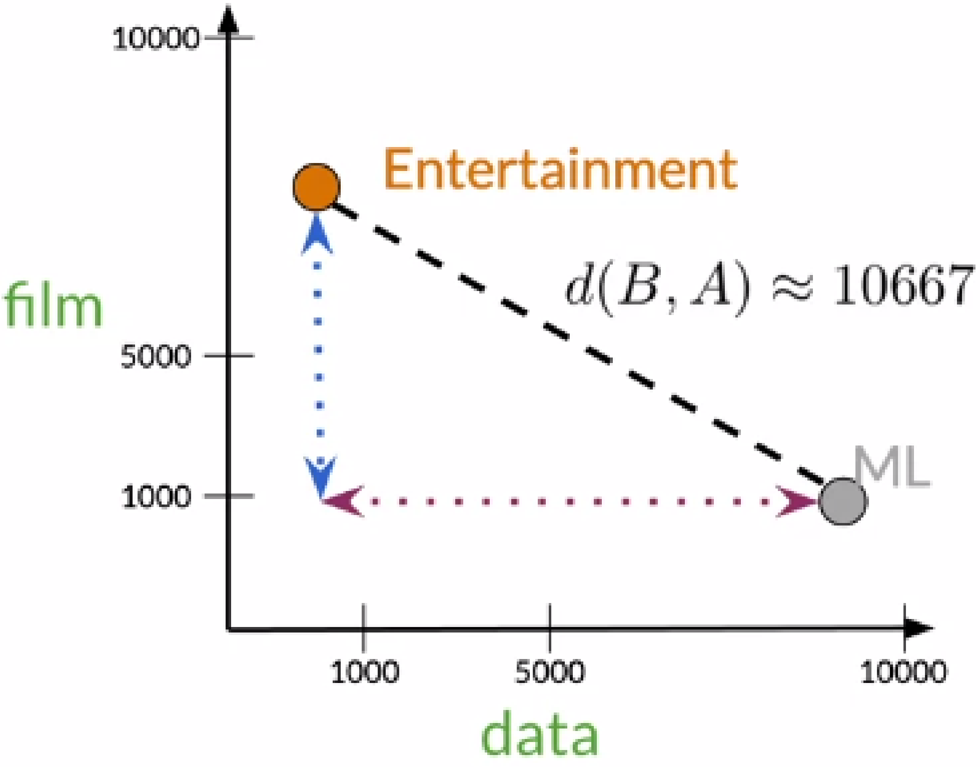
- W/W and W/D, *counts* of occurrence

- Vector Spaces $\longrightarrow$ Similarity between words/documents

Outline

- Euclidean distance
- N-dimension vector representations comparison

Euclidean distance



Corpus A: (500,7000)

Corpus B: (9320,1000)

$$d(B, A) = \sqrt{\underline{(B_1 - A_1)}^2 + \underline{(B_2 - A_2)}^2}$$

$$c^2 = a^2 + b^2$$

$$d(B, A) = \sqrt{(-8820)^2 + (6000)^2}$$

Euclidean distance for n-dimensional vectors

		$\vec{w}$	$\vec{v}$
	data	boba	ice-cream
AI	6	0	1
drinks	0	4	6
food	0	6	8

$$= \sqrt{(1-0)^2 + (6-4)^2 + (8-6)^2}$$

$$= \sqrt{1+4+4} = \sqrt{9} = 3$$

$$d(\vec{v}, \vec{w}) = \sqrt{\sum_{i=1}^{n} (v_i - w_i)^2} \longrightarrow \text{Norm of } (\vec{v} - \vec{w})$$

Euclidean distance in Python

```
# Create numpy vectors v and w
v = np.array([1, 6, 8])
w = np.array([0, 4, 6])

# Calculate the Euclidean distance d
d = np.linalg.norm(v-w)
# Print the result
print("The Euclidean distance between v and w is: ", d)
```

```
The Euclidean distance between v and w is: 3
```

Summary

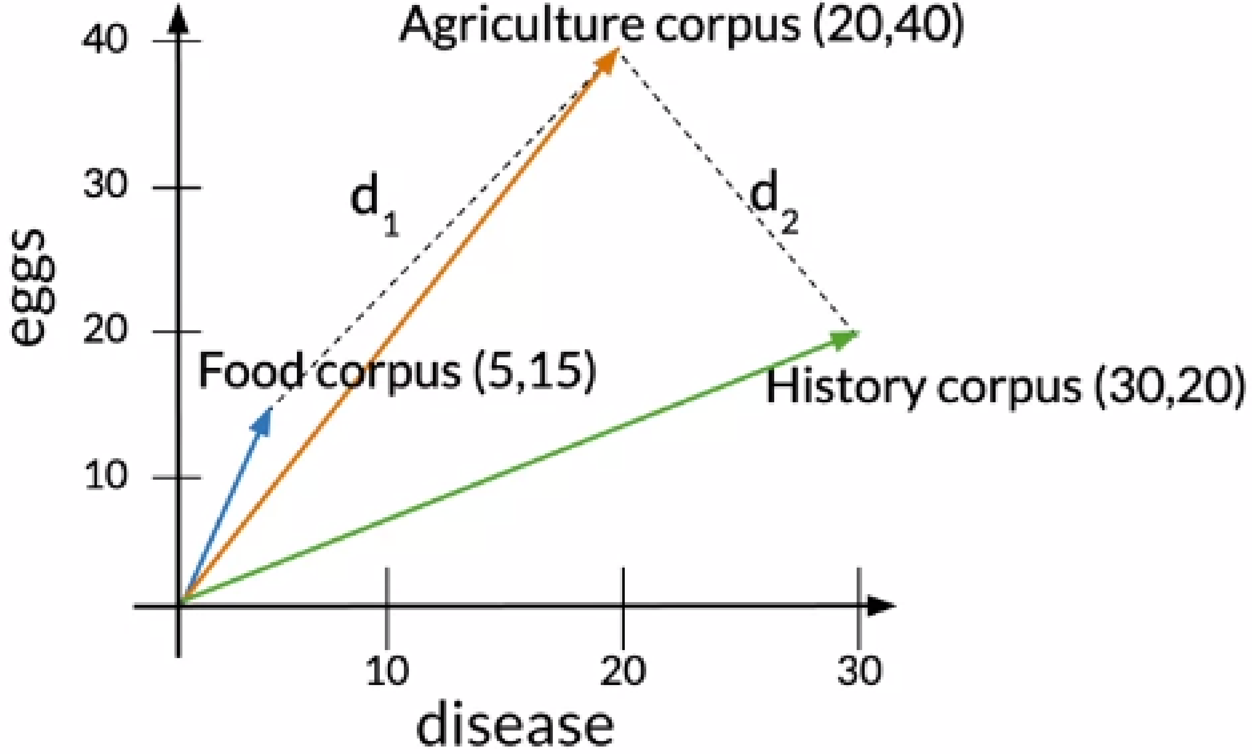
- Straight line between points

- Norm of the difference between vectors

Outline

- Problems with Euclidean Distance
- Cosine similarity

Euclidean distance vs Cosine similarity



Euclidean distance: $d_2 < d_1$

The cosine of the angle between the vectors

Summary

- Cosine similarity when corpora are different sizes

Cosine Similarity

Outline

- How to get the cosine of the angle between two vectors
- Relation of this metric to similarity

Previous definitions

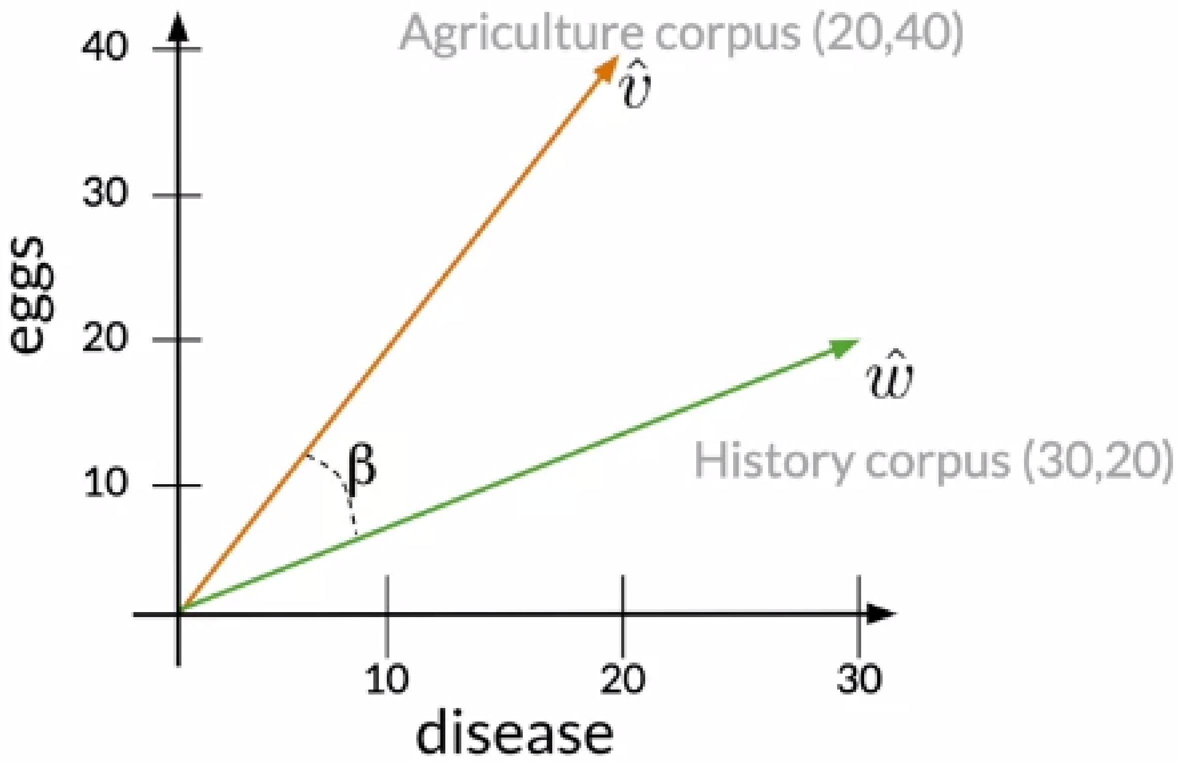
Vector norm

$$\|\vec{v}\| = \sqrt{\sum_{i=1}^{n} v_i^2}$$

Dot product

$$\vec{v}.\vec{w} = \sum_{i=1}^{n} v_i.w_i$$

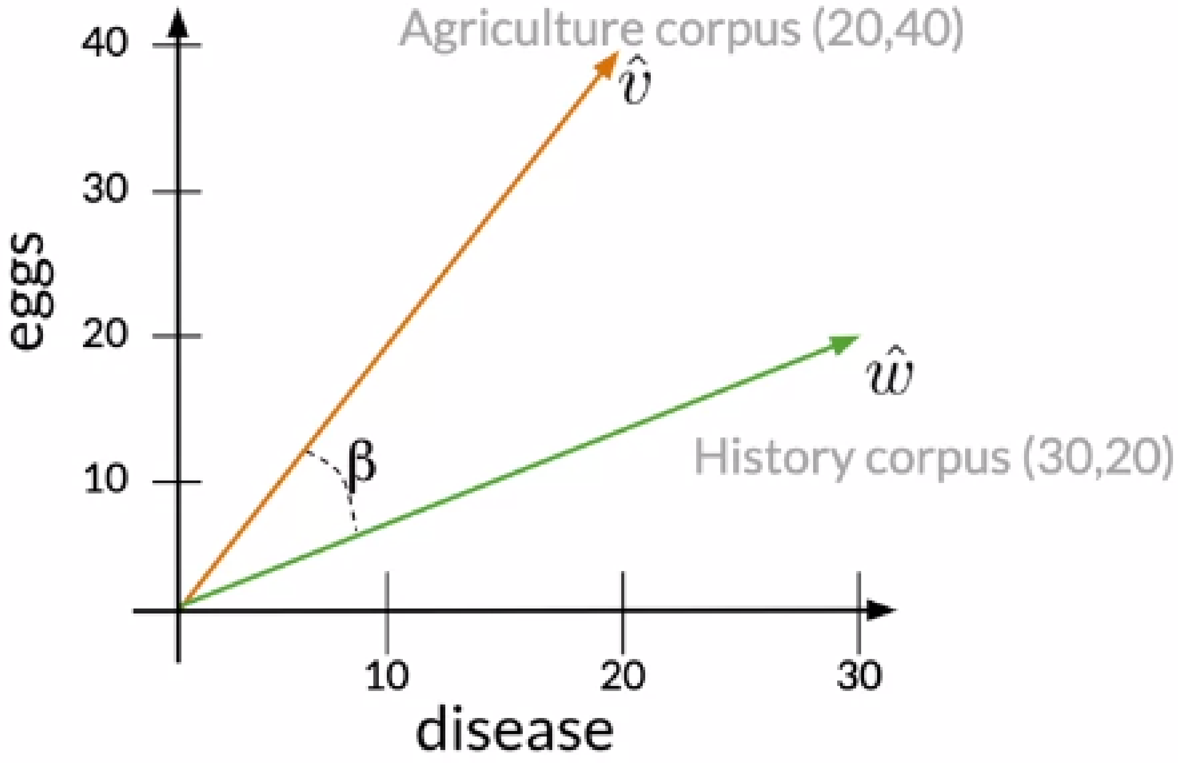
Cosine Similarity



$$\hat{v} \cdot \hat{w} = \|\hat{v}\| \|\hat{w}\| \cos(\beta)$$

$$\boxed{\cos(\beta) = \frac{\hat{v} \cdot \hat{w}}{\|\hat{v}\| \|\hat{w}\|}}$$

Cosine Similarity



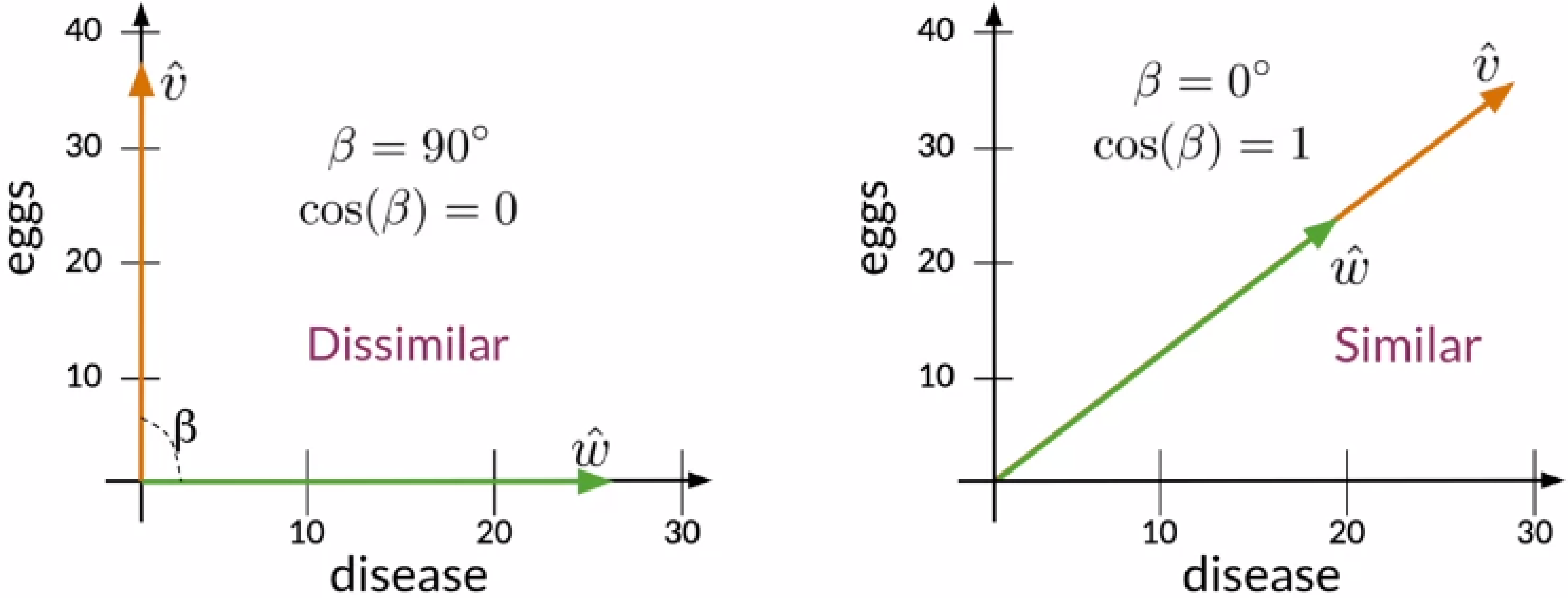
$$\hat{v} \cdot \hat{w} = \|\hat{v}\| \|\hat{w}\| \cos(\beta)$$

$$\boxed{\cos(\beta) = \frac{\hat{v} \cdot \hat{w}}{\|\hat{v}\| \|\hat{w}\|}}$$

$$= \frac{(20 \times 30) + (40 \times 20)}{\sqrt{20^2 + 40^2} \times \sqrt{30^2 + 20^2}}$$

$$= 0.87$$

Cosine Similarity



Summary

- Cosine $\propto$ Similarity

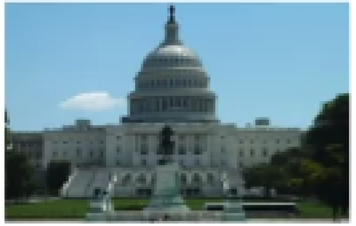
- Cosine Similarity gives values between 0 and 1

Outline

- How to use vector representations

Manipulating word vectors

USA

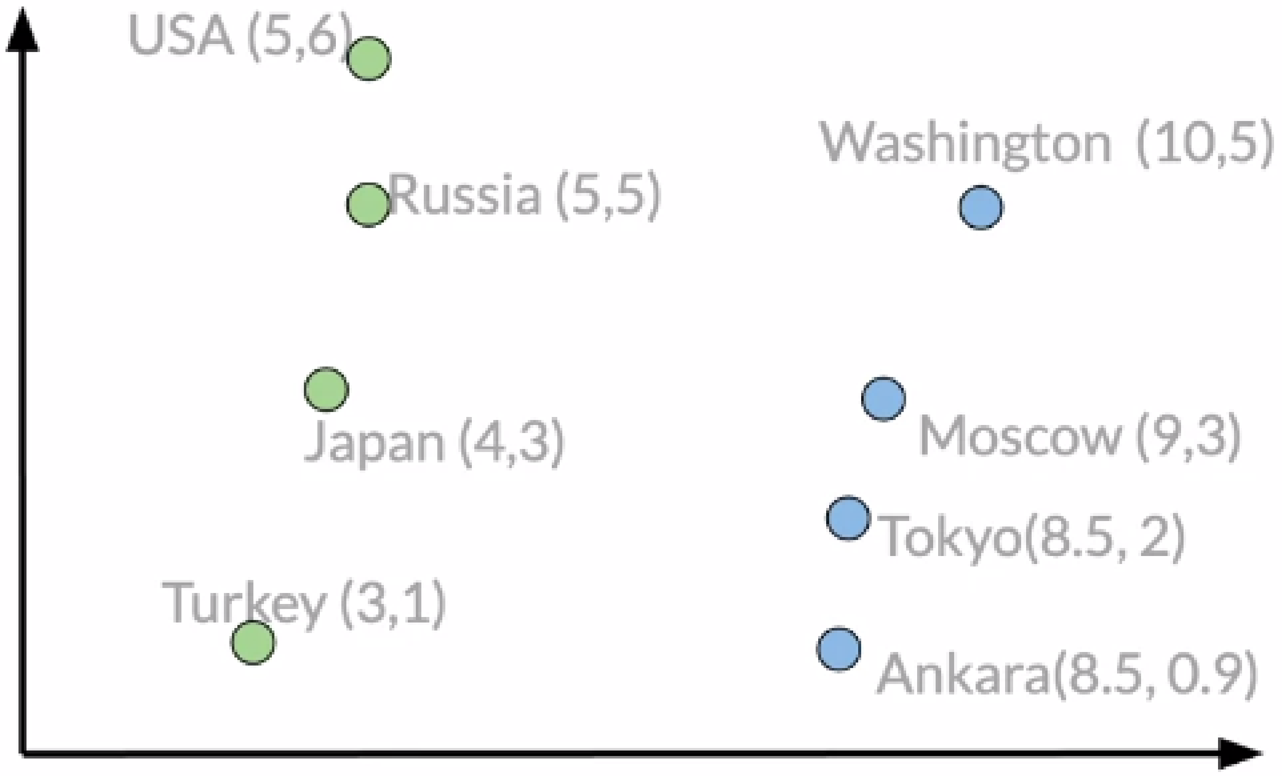


Washington DC

Russia

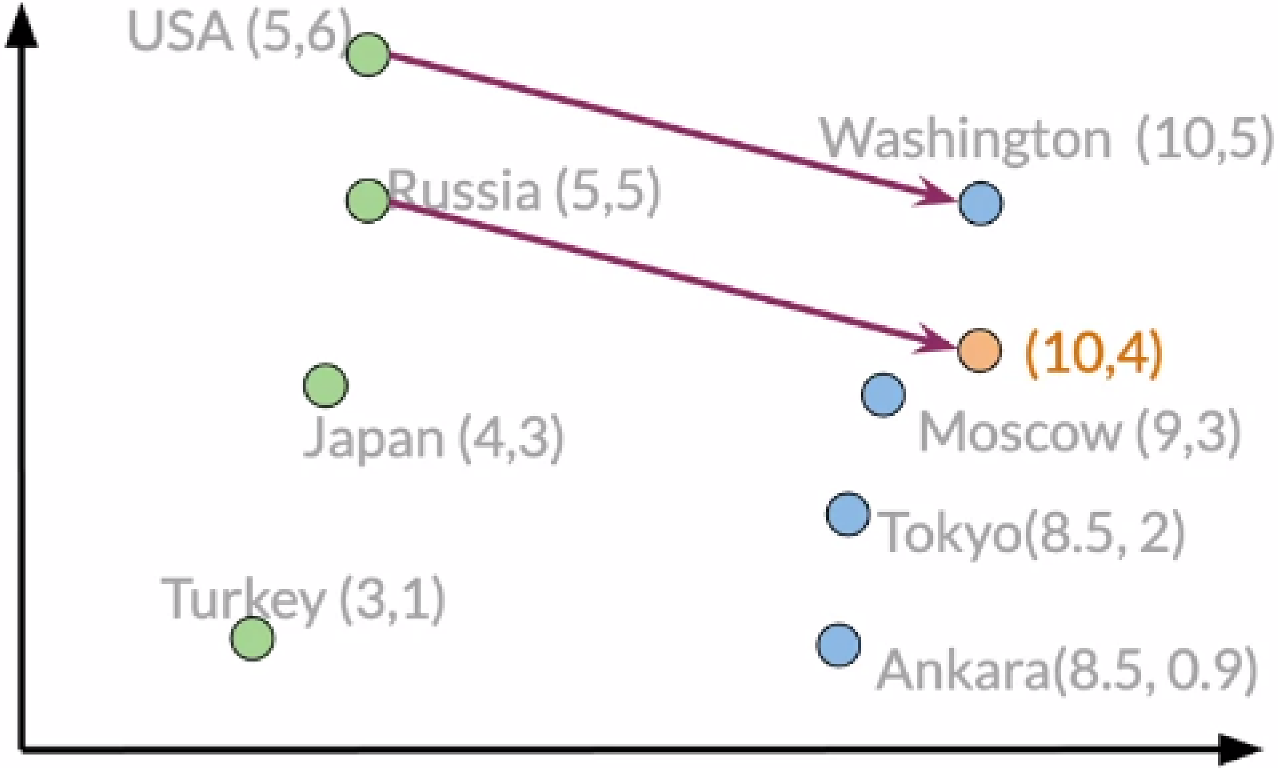
?

Manipulating word vectors



[Mikolov et al, 2013, Distributed Representations of Words and Phrases and their Compositionality]

Manipulating word vectors

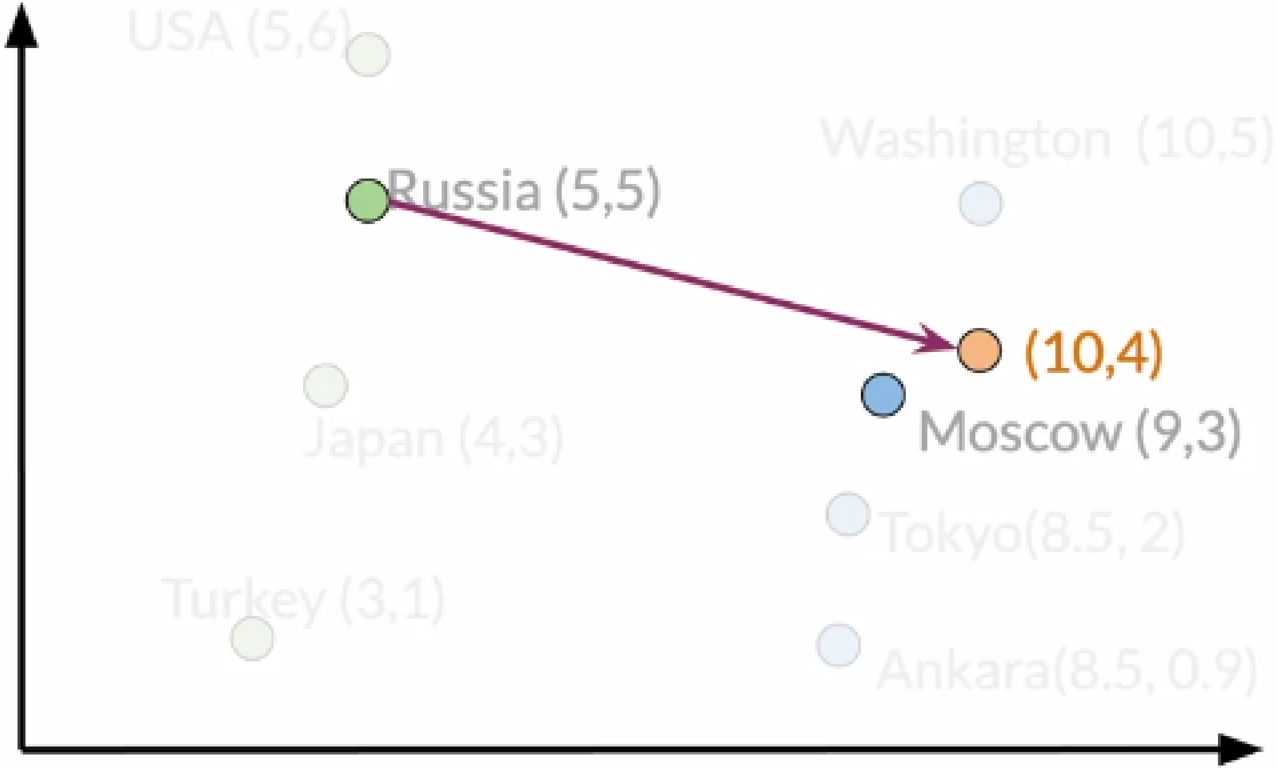


Washington - USA = $\begin{bmatrix} 5 & -1 \end{bmatrix}$

Russia + $\begin{bmatrix} 5 & -1 \end{bmatrix}$ = $\begin{bmatrix} 10 & 4 \end{bmatrix}$

[Mikolov et al, 2013, Distributed Representations of Words and Phrases and their Compositionality]

Manipulating word vectors



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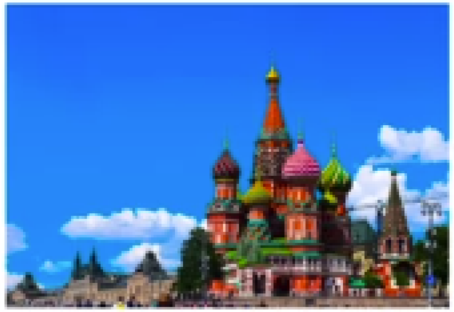


Moscow

[Mikolov et al, 2013, Distributed Representations of Words and Phrases and their Compositionality]

Summary

- Use known relationships to make predictions

Outline

- Some motivation for visualization
- Principal Component Analysis

Visualization of word vectors

$d > 2$

oil	0.20	...	0.10
gas	2.10	...	3.40
city	9.30	...	52.1
town	6.20	...	34.3

How can you visualize if your representation captures these relationships?

oil & gas

town & city

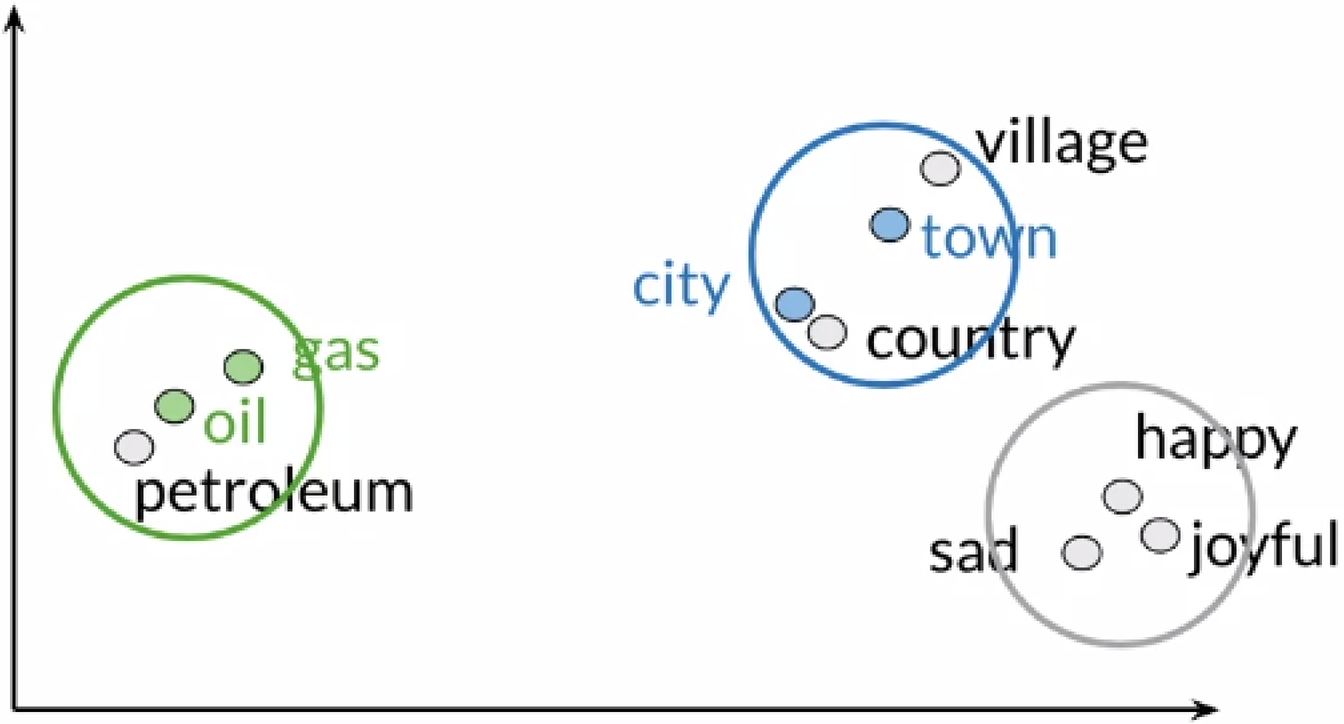
Visualization of word vectors

	$d > 2$		
oil	0.20	...	0.10
gas	2.10	...	3.40
city	9.30	...	52.1
town	6.20	...	34.3

$\xrightarrow{\text{PCA}}$

	$d = 2$	
oil	2.30	21.2
gas	1.56	19.3
city	13.4	34.1
town	15.6	29.8

Visualization of word vectors



Summary

- Original Space → Uncorrelated features → Dimension reduction
- Visualization to see words relationships in the vector space