TIMC Data Science Tools and Techniques

Detecting Social Influence

Words of wisdom

“We can’t let up....

This is something we cannot be episodic about.

The defense of our Nation,

the defense of our elections

[will be part of my focus]

every single day

for as long as I can see into the future.”

GEN P. M. Nakasone

DIRNSA, Commander US CYBERCOM

Reagan National Defense Forum, December 7, 2019.

Tools and Techniques

HDBSCAN:

Towards pushbutton density-based clustering

HDBSCAN

- HDBSCAN: Hierarchical Density-Based Spatial Clustering of Applications with Noise
  - Campello-Moulavi-Sander, Density-Based Clustering Based on Hierarchical Density Estimates, Pacific-Asia KDD 2013, 160-172.
  - Robust single linkage clustering with flat cluster extraction

https://github.com/scikit-learn-contrib/hdbscan

```
pip install hdbscan
```

Wish–list for density–based clustering

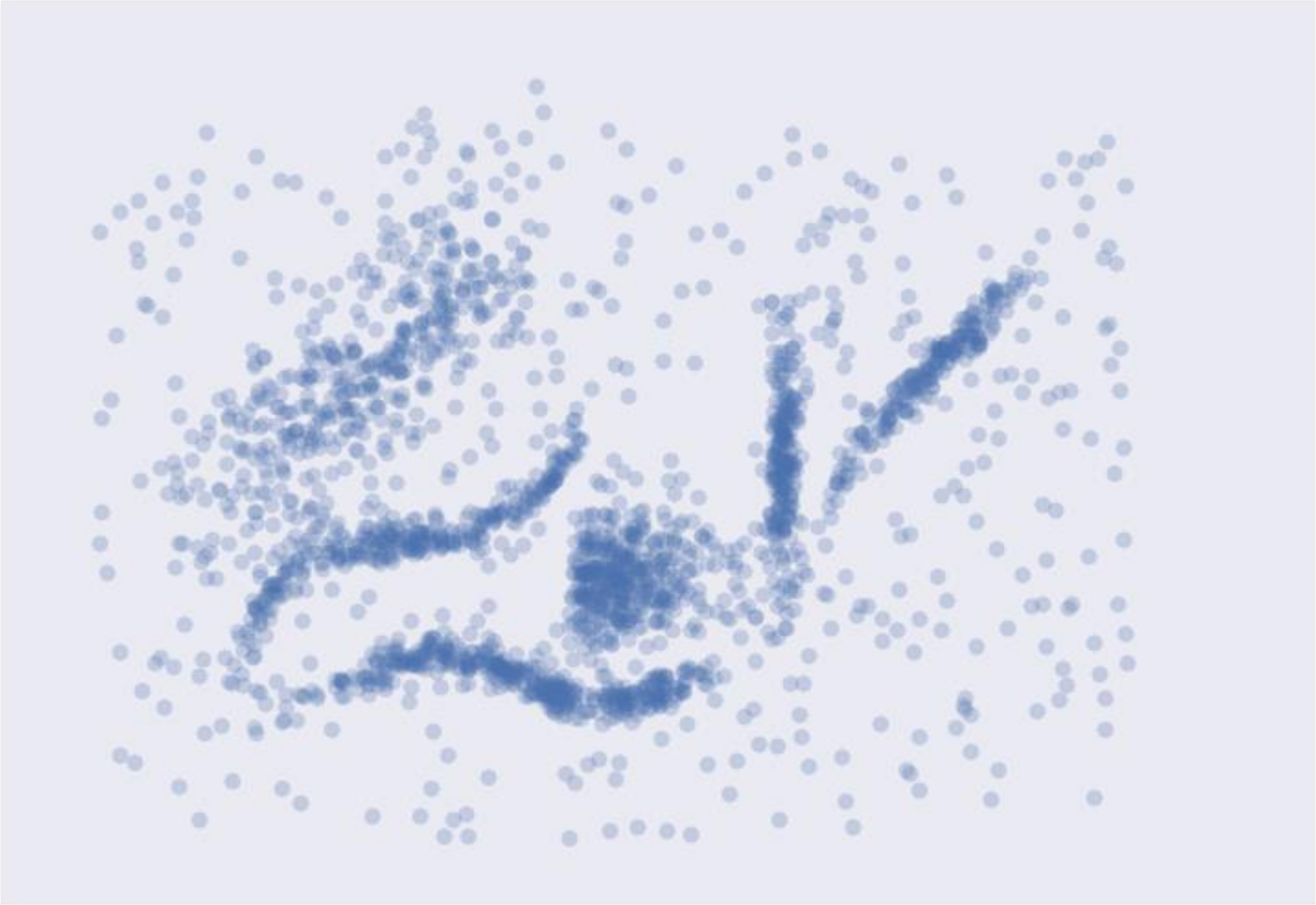
We'd like an algorithm that:

- Is density-based
- Is suitable for any metric (e.g., Euclidean, Hamming, Manhattan)
- Does not require a fixed number of clusters
- Is robust to noise and small perturbations in data
- Is parameter-free*

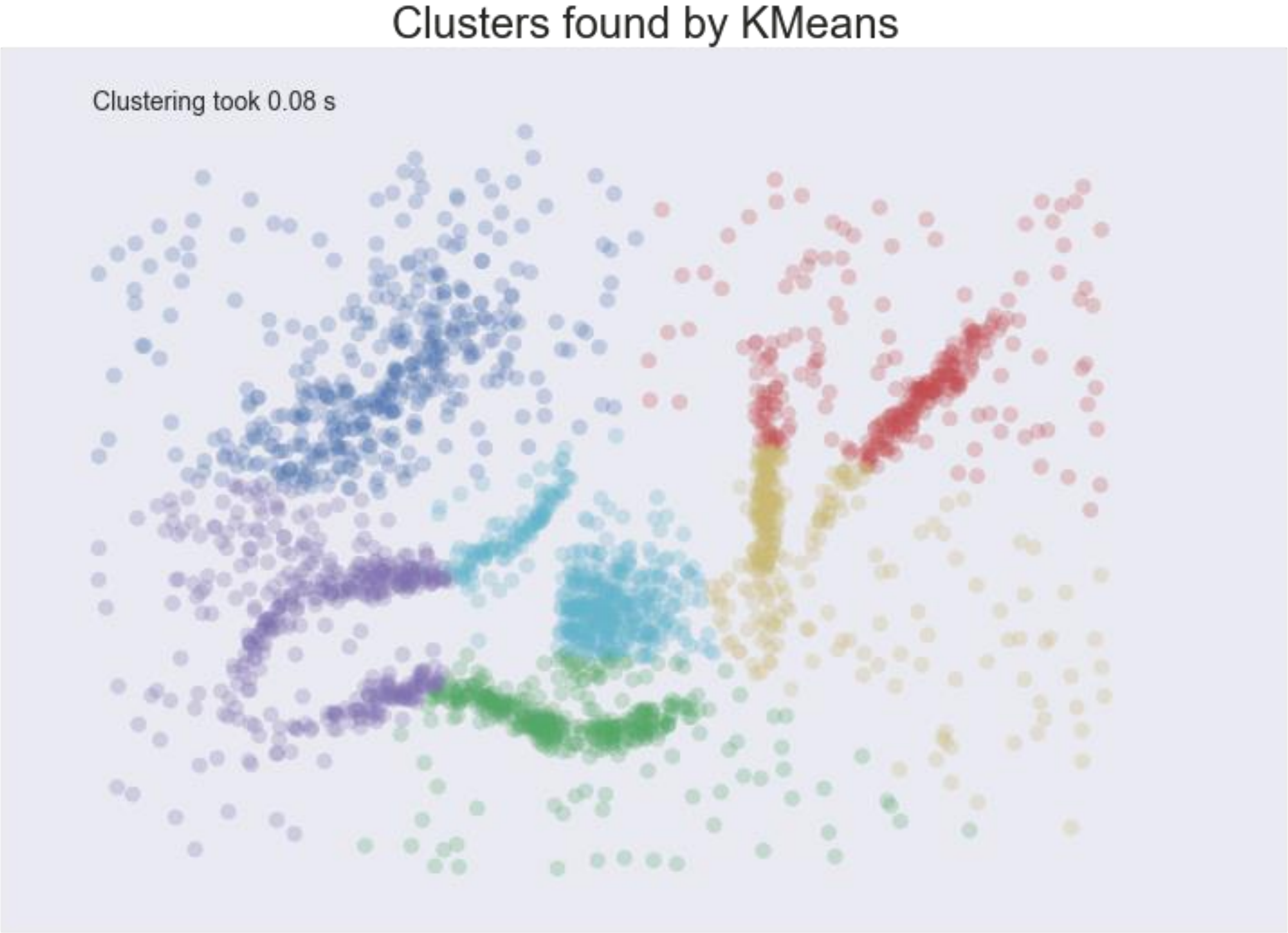
How HDBSCAN works

1. Transform the space by changing the distance between points (mutual reachability)
2. Build the minimum spanning tree of the distance weighted graph of connections
3. Construct a cluster hierarchy of connected components
4. Condense the cluster hierarchy based on minimum cluster size
5. Extract stable clusters from the condensed tree
6. Use fast methods for nearest neighbors/spanning trees

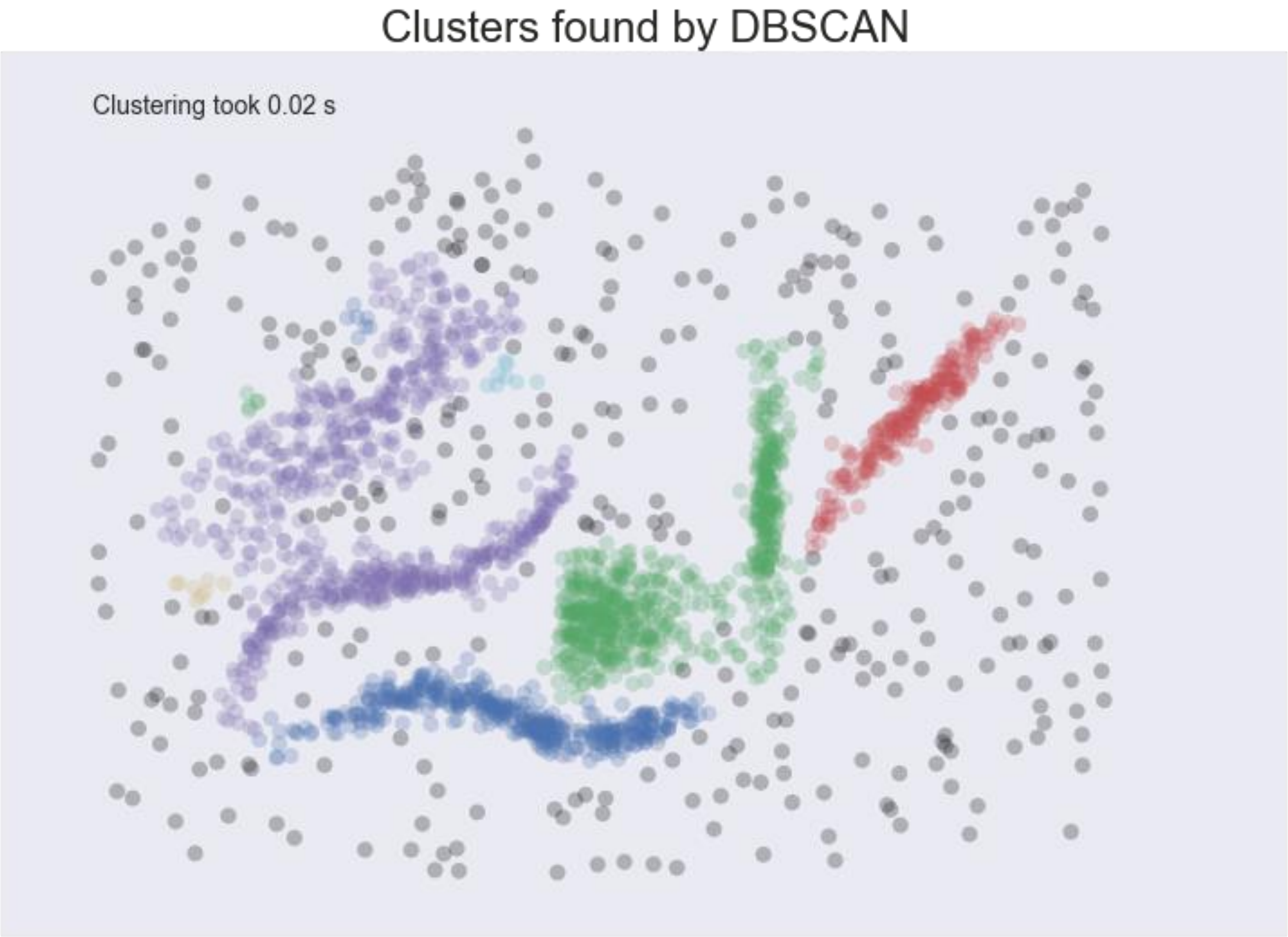
HDBScan: A comparison



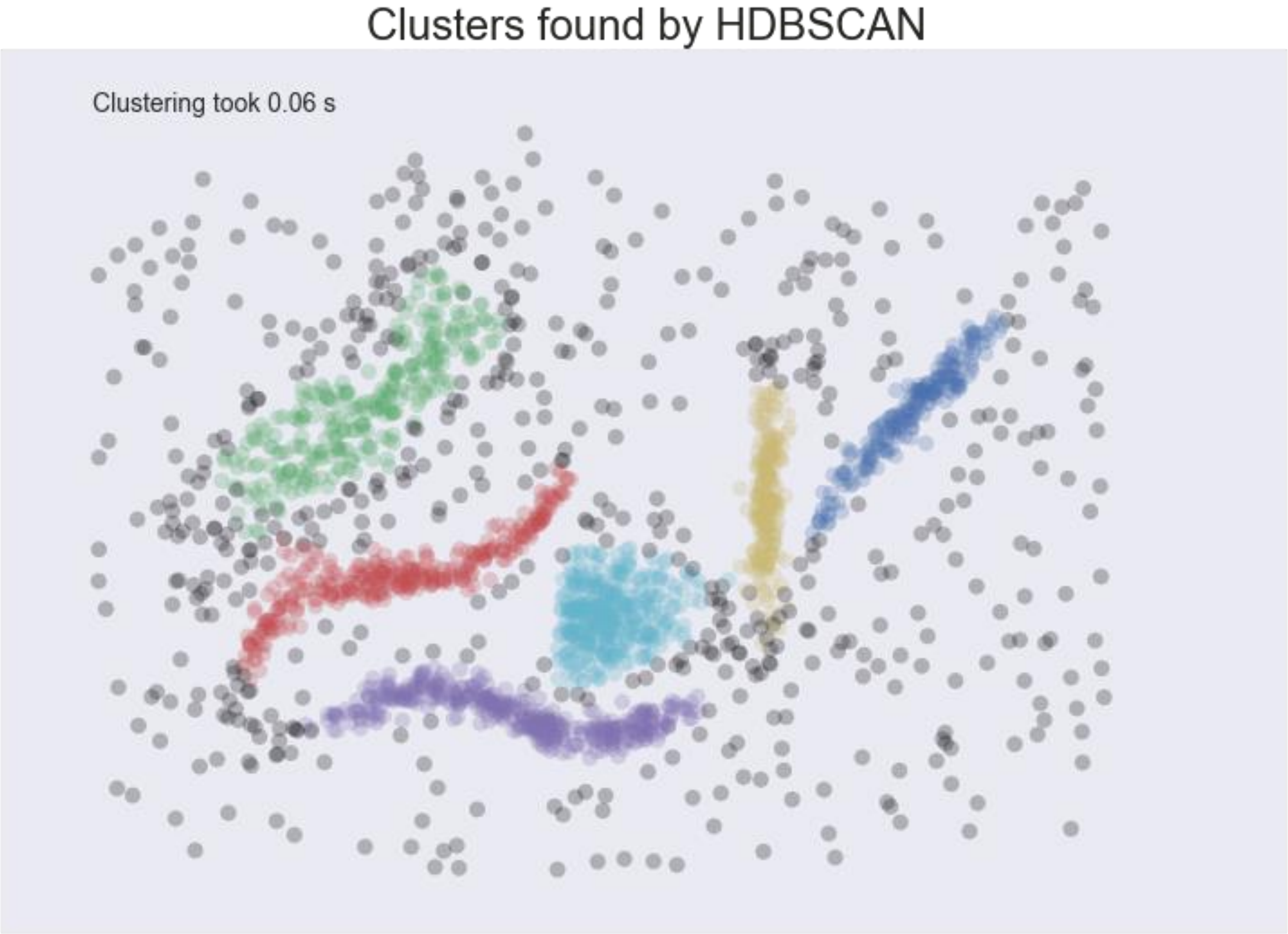
HDBScan: A comparison



HDBScan: A comparison



HDBScan: A comparison



HDBSCAN: Performance

	Number of points
Interactive	100,000
Over coffee	500,000
Over lunch	1,000,000
Over night	5,000,000

- Small-to-moderate dimension; precompiled distance

HDBSCAN: Performance

- See also:
  - Remember Leland McInnes' excellent NSC 2016 talk
  - John Healy's PyData NYC 2018 talk https://youtu.be/dGsxd67IFiU
  - Leland McInnes' SciPy 2016 talk https://youtu.be/AgPQ76RIi6A
  - Read the Docs: How HDBSCAN works

UMAP:

Dimensionality reduction grounded in theory

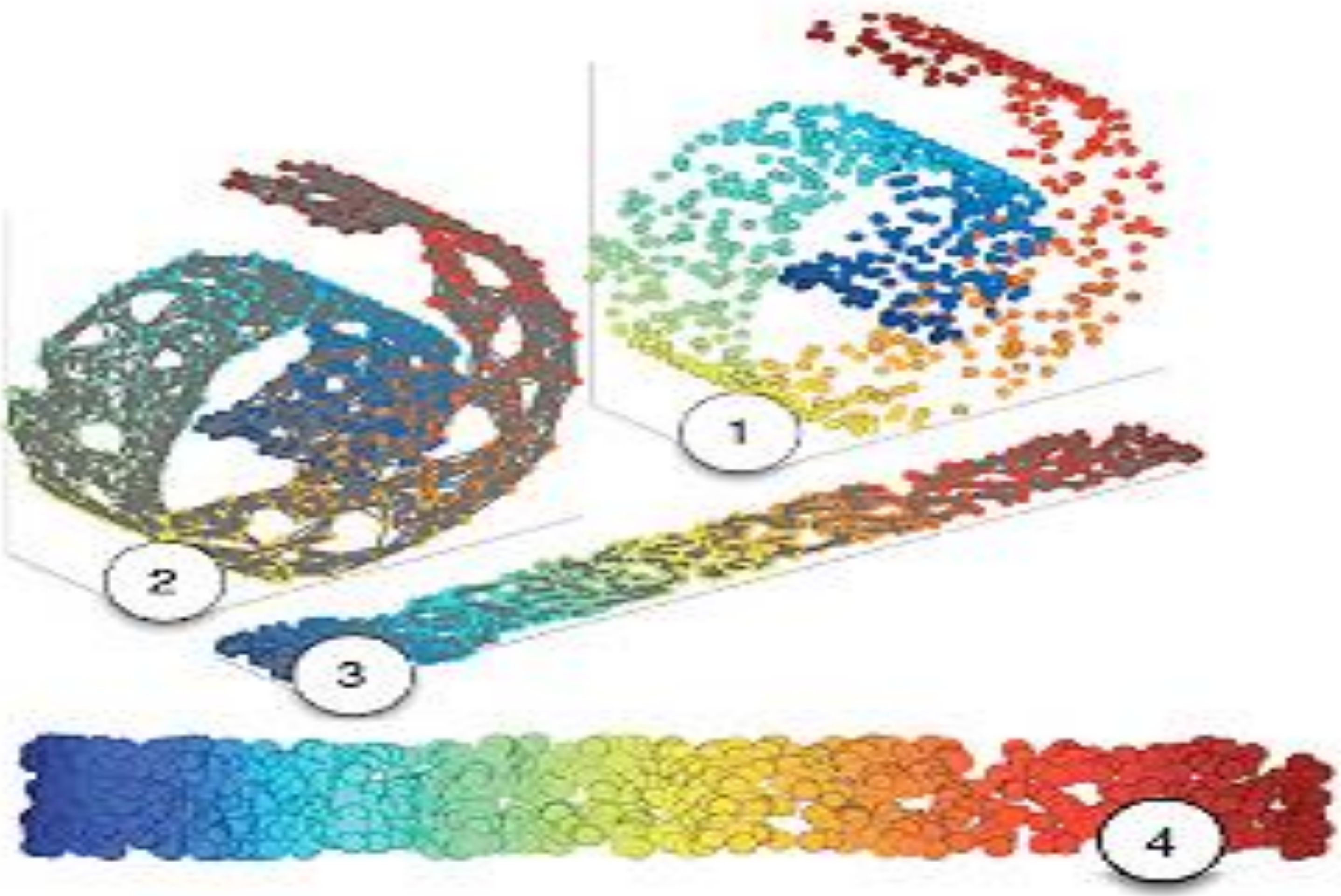
UMAP

- UMAP: Uniform Manifold Approximation and Projection for Dimension Reduction
- Leland McInnes, John Healy, James Melville, https://arxiv.org/abs/1802.03426
  - Fuzzy topology-based low-dimension models of data

https://github.com/lmcinnes/umap

pip install umap-learn

What is manifold learning?



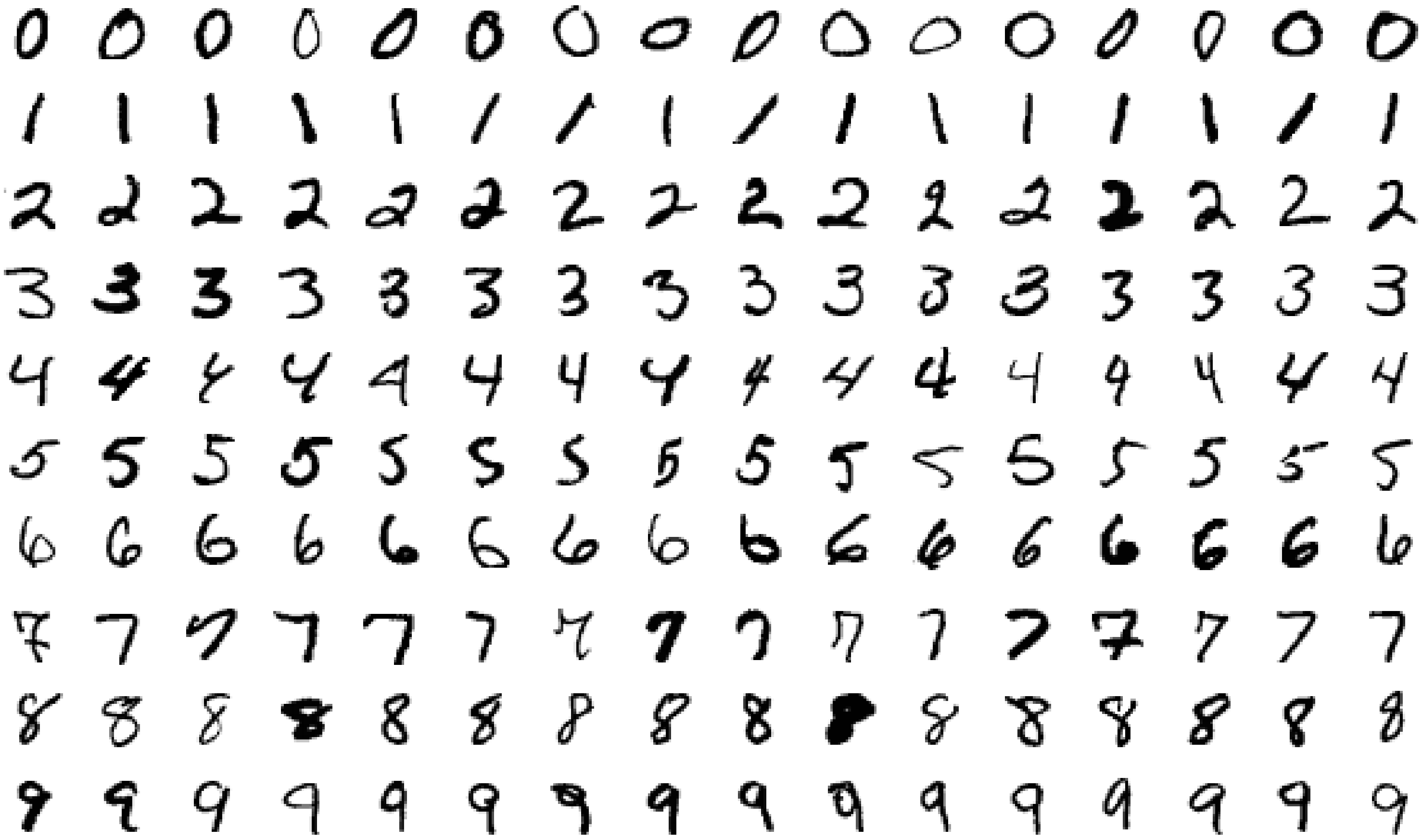
https://prateekvjoshi.com/2014/06/21/what-is-manifold-learning/

How UMAP works in one slide

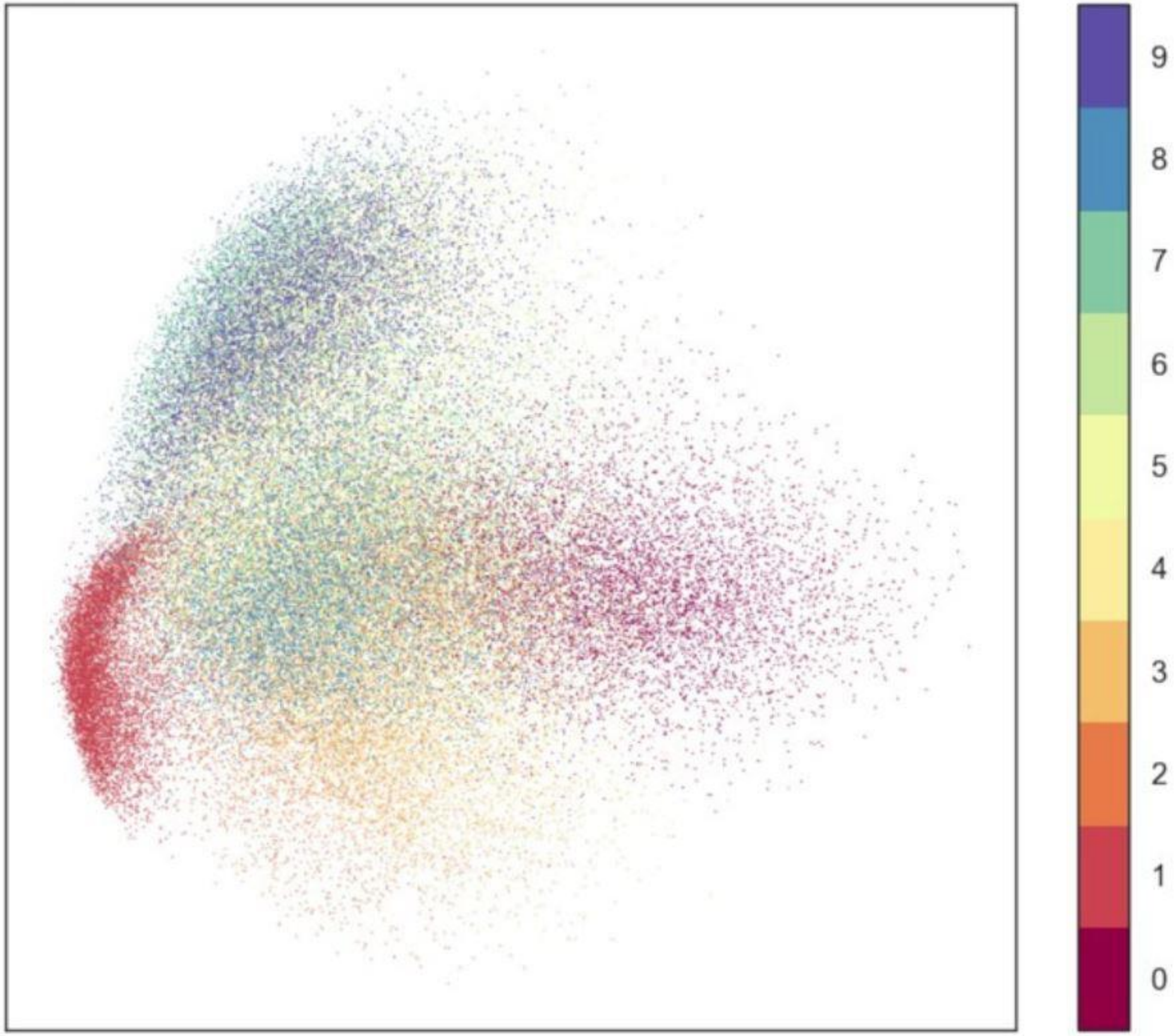
- **UMAP Assumption:** Data is uniformly distributed on a manifold
  - Possibly with non-uniform metric!
  - But the metric can be modelled as locally constant.

1. Learn the underlying topological structure
2. Iteratively solve an optimization of projections that respect this underlying structure

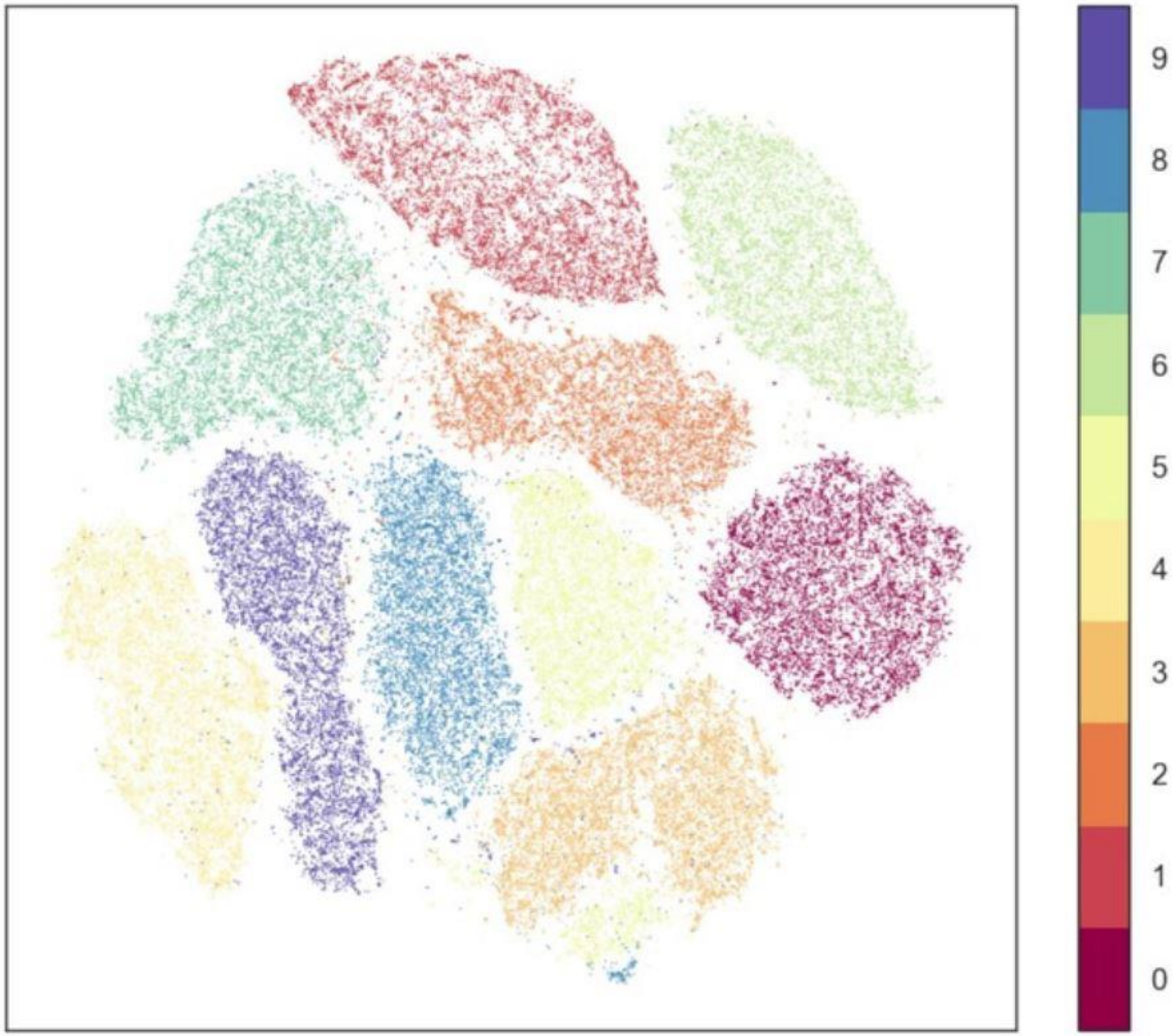
MNIST Digits



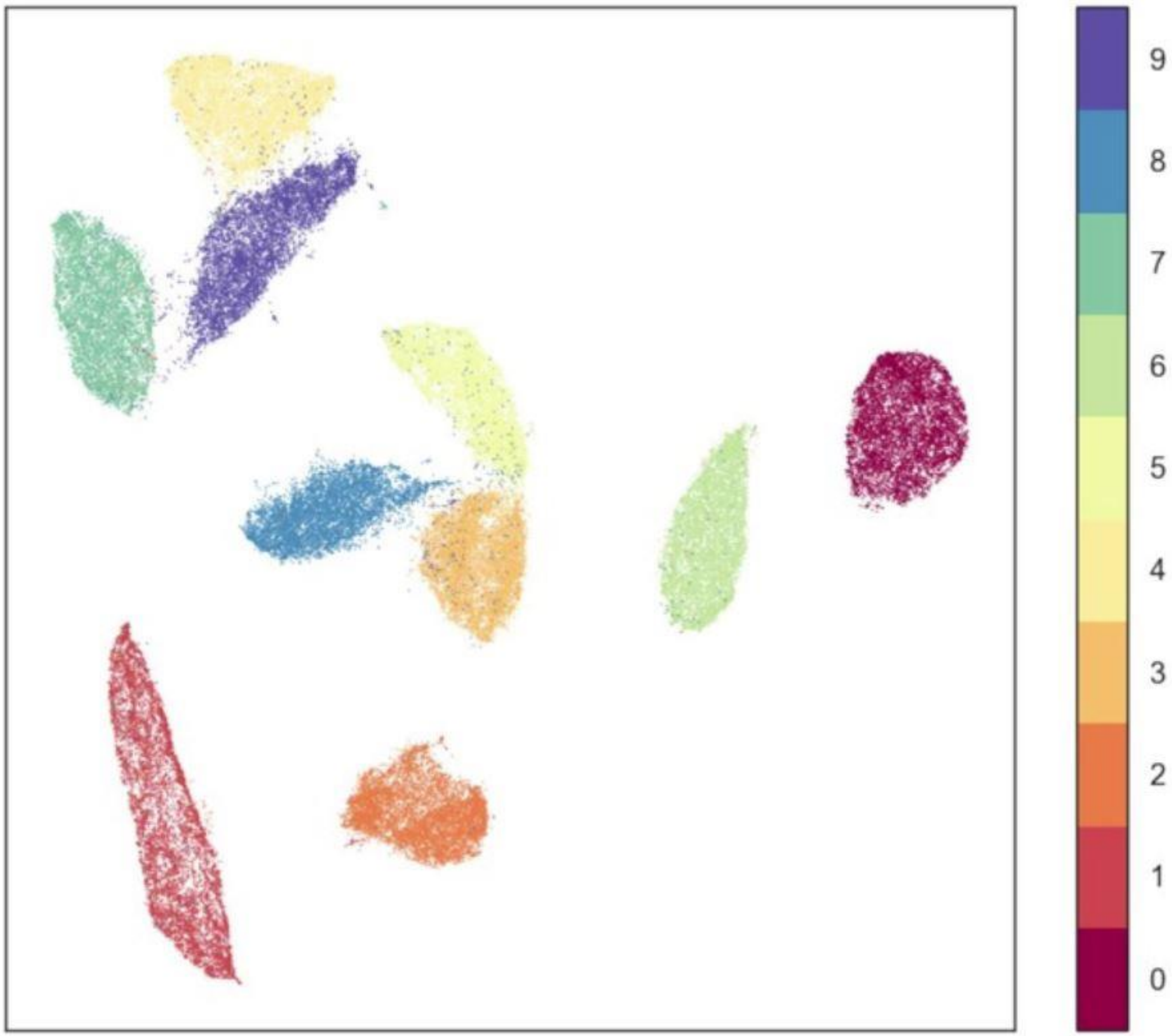
PCA (linear; SVD-based) on MNIST



t−SNE on MNIST



UMAP on MNIST



UMAP: see also

- Read the Docs: How UMAP works
- A really great Google PAIR article (/w interactive animations) https://pair-code.github.org.io/understanding-umap
- Leland McInnes YouTube talks (just a sample):
  - Topological Techniques for Unsupervised Learning, PyData LA 2019 talk https://youtu.be/7pAVPjwBppo
  - UMAP at SciPy 2018 https://youtu.be/nq6iPZVUxZU
  - PyData Ann Arbor: Modern Approaches to Dimension Reduction https://youtu.be/YPJQydzTLwQ

Embeddings

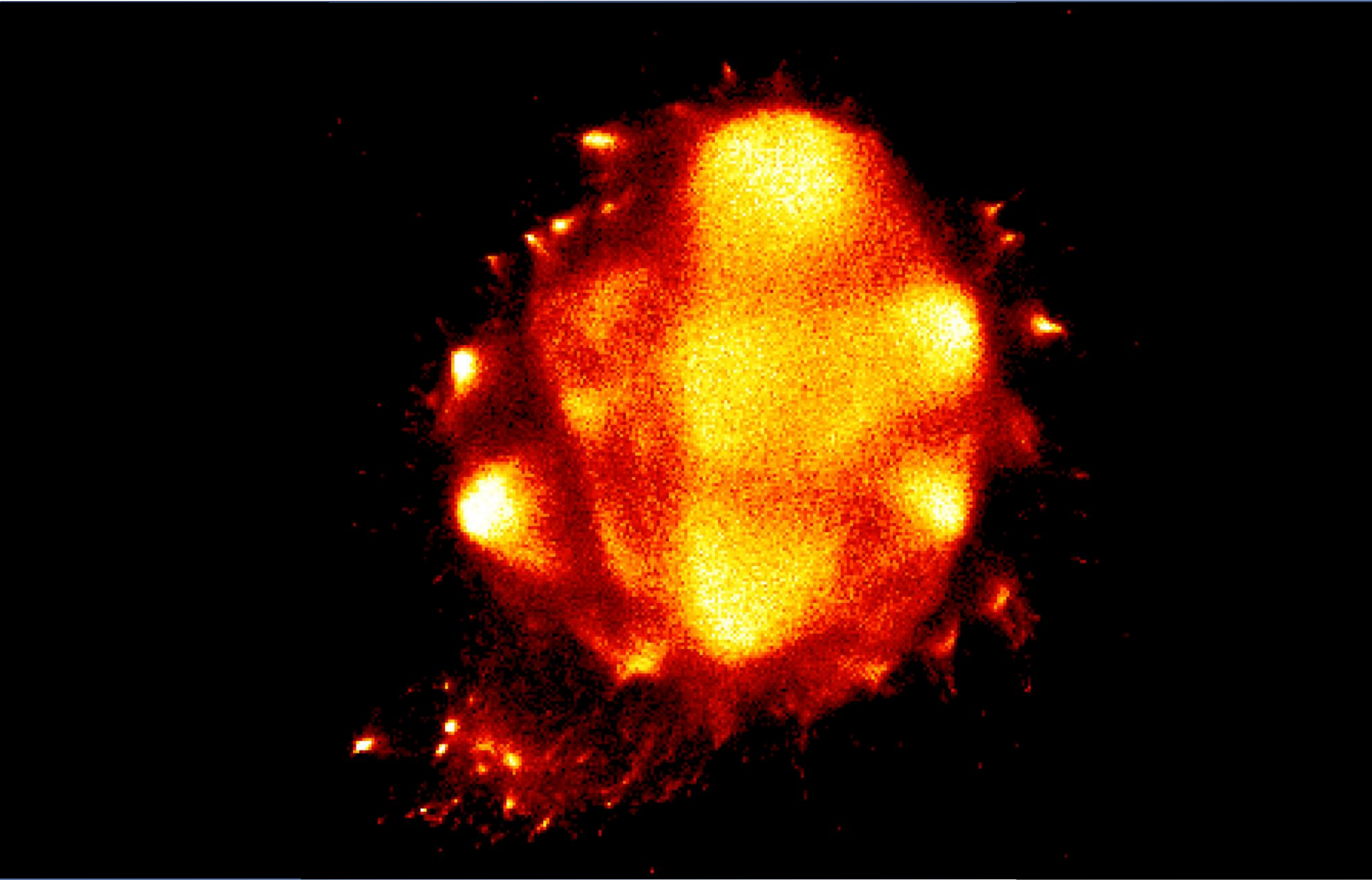
An embedding is

a numeric representation of your data

along with a

distance

A document embedding



I need embeddings for

Clustering

Outlier Detection

Grouping

Anomaly Detection

Unsupervised Learning

Exploratory Data Analysis

Visualization

Document Embedding

(DocMAP)

We’d like to:

Embed documents

Cluster documents

Find similar documents

Find strange or outlier documents

An embedding is

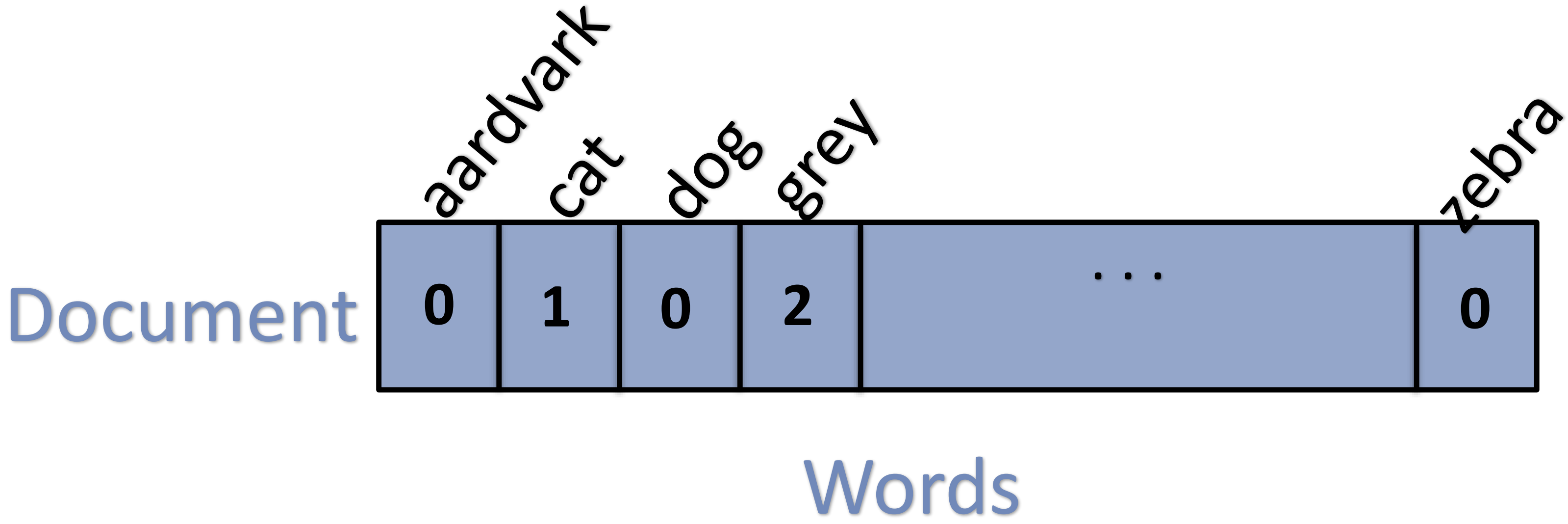
a numeric representation of your data

along with a

distance

Document is a bag of words

“The grey cat sat on the grey rug”



aardvark	cat	dog	grey	. . .	zebra
0	1	0	2		0

Document is a bag of ~~words~~ probabilities

“The grey cat sat on the grey rug”

	aardvark	cat	dog	grey		zebra
Document	0	1/8	0	1/4	. . .	0

Words

Document is a multinomial distribution across our vocabulary space

"The grey cat sat on the grey rug"

	aardvark	cat	dog	grey		zebra
Document	0	1/8	0	1/4	. . .	0

Words

A corpus is a document by word matrix

Documents

aardvark	cat	dog	grey		zebra
				⋮	
0	1/8	0	1/4	· · ·	0
1/3	0	0	1/6	· · ·	0
				⋮	

Vocabulary or words

*We also remove expectation to mitigate the effect of Zipf's law on the column distribution.

An embedding is

a numeric representation of your data

along with a

distance

Theoretical Statistics to the rescue!
Fisher Information Metric:

$$(\Delta_{n-1}, f) \to (S^n, \mu)$$

$$x_i \mapsto \sqrt{x_i}$$

$$d_a(w_a, w_b) = arccos\left(\frac{\sum_{i=1}^{n}\sqrt{a_i b_i}}{\sqrt{|a|_1 |b|_1}}\right)$$

$$arccos(\theta) \approx \sqrt{1-\theta},$$

Hellinger distance

$$d_H(w_a, w_b) = \sqrt{1 - \frac{\sum\sqrt{a_i b_i}}{\sqrt{|a|_1 |b|_1}}}$$

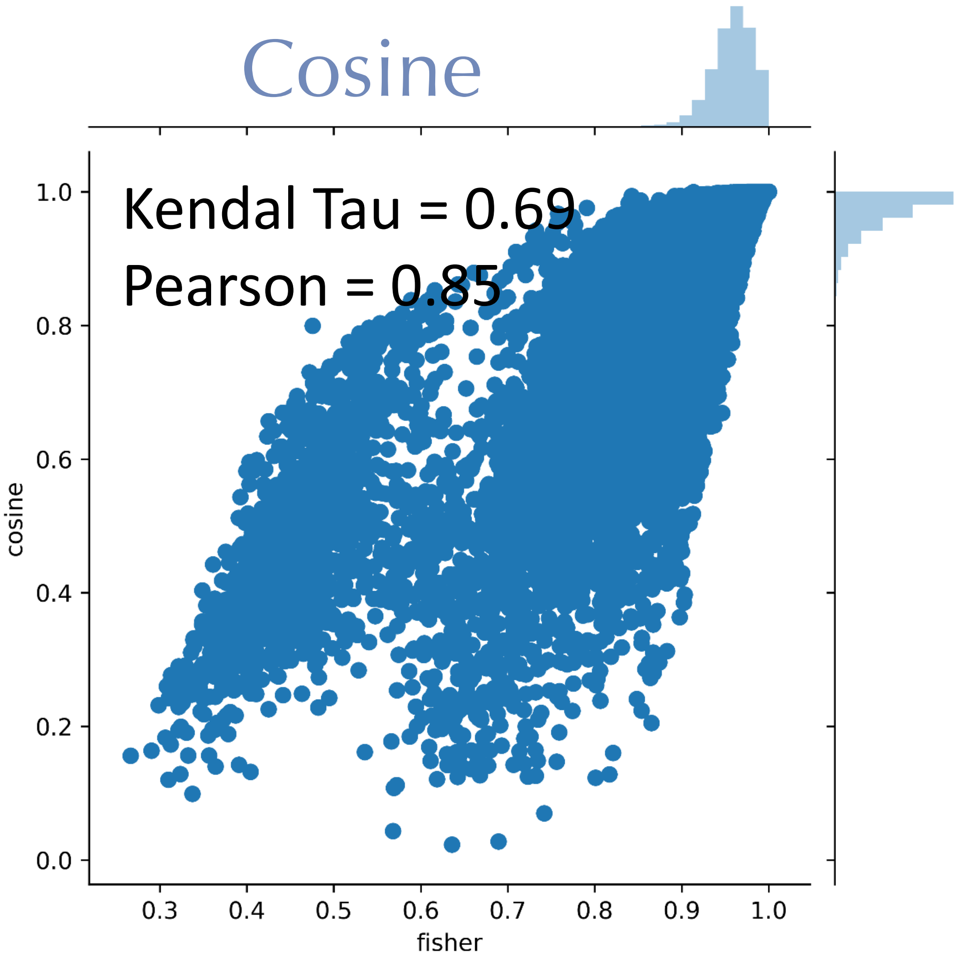
Carter et al 2009

Amari, 2012

Relationship with cosine distance

$$d_H(w_a, w_b) = \sqrt{1 - \frac{\sum \sqrt{a_i b_i}}{\sqrt{|a|_1 |b|_1}}}$$

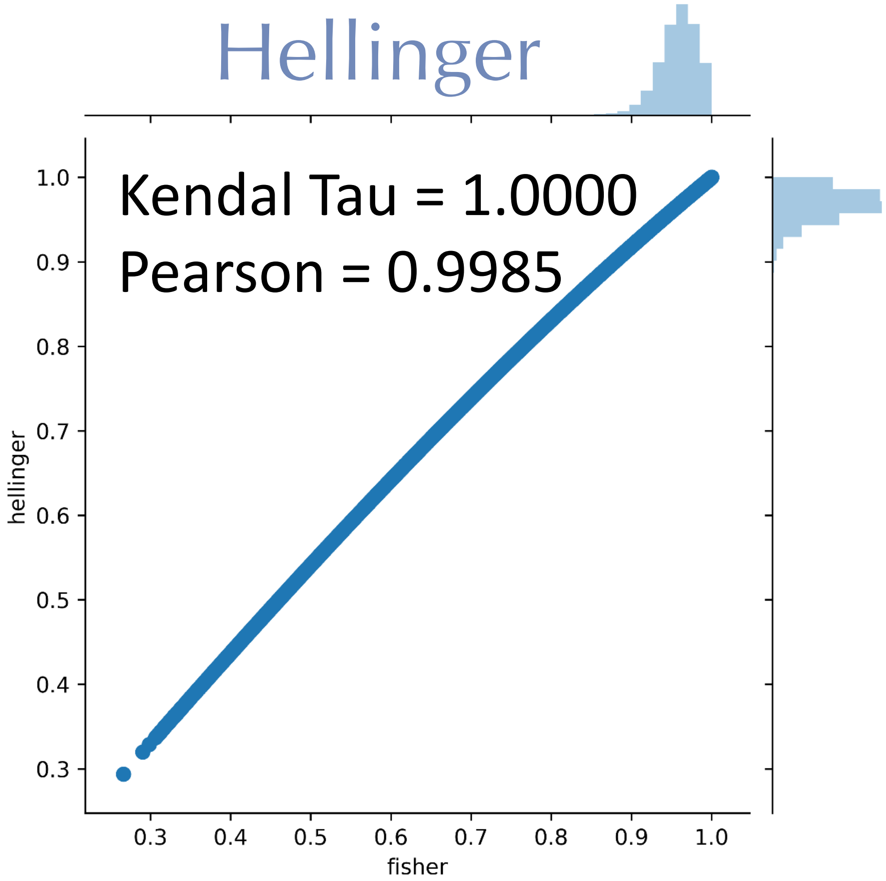
$$d_{cos}(w_a, w_b) = 1 - \frac{\sum a_i b_i}{\sqrt{|a|_2 |b|_2}}$$



Cosine

Kendal Tau = 0.69

Pearson = 0.85



Hellinger

Kendal Tau = 1.0000

Pearson = 0.9985

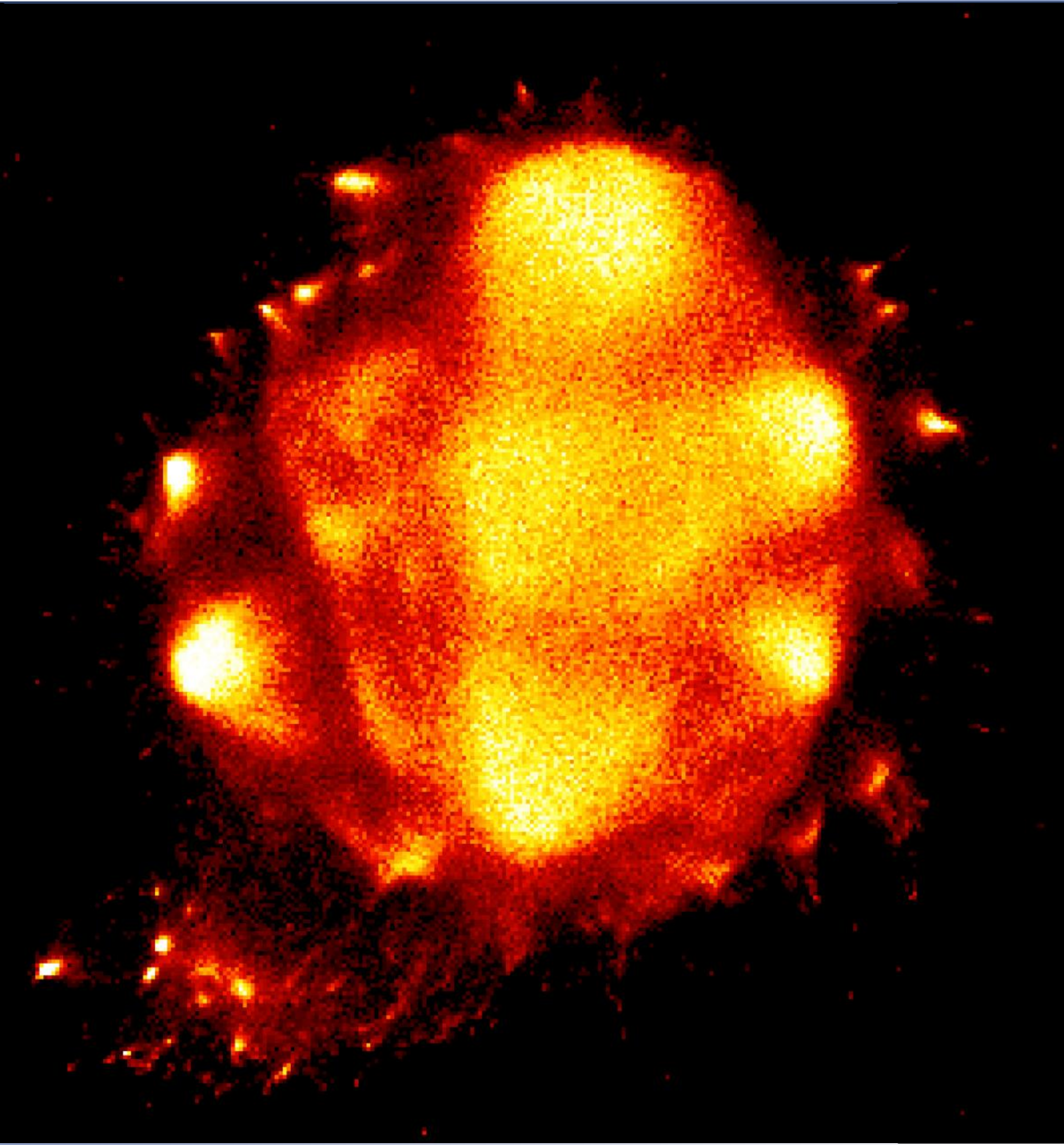
An embedding is

a numeric representation of your data

along with a

distance

Documents are a bag of words



We can:

- Embed documents into low dimensions and visualize
- Cluster those embeddings (e.g., with HDBSCAN)
- Find similar documents via nearest neighbor searches
- Find strange or outlier documents via anomaly detection

Word Embedding

(WordMAP)

We'd like to:

Understand a corpus

Embed short documents

Identify documents that are close to words

“You shall know a word by the company it keeps”

John Rupert Firth, 1957

(a famous linguist)

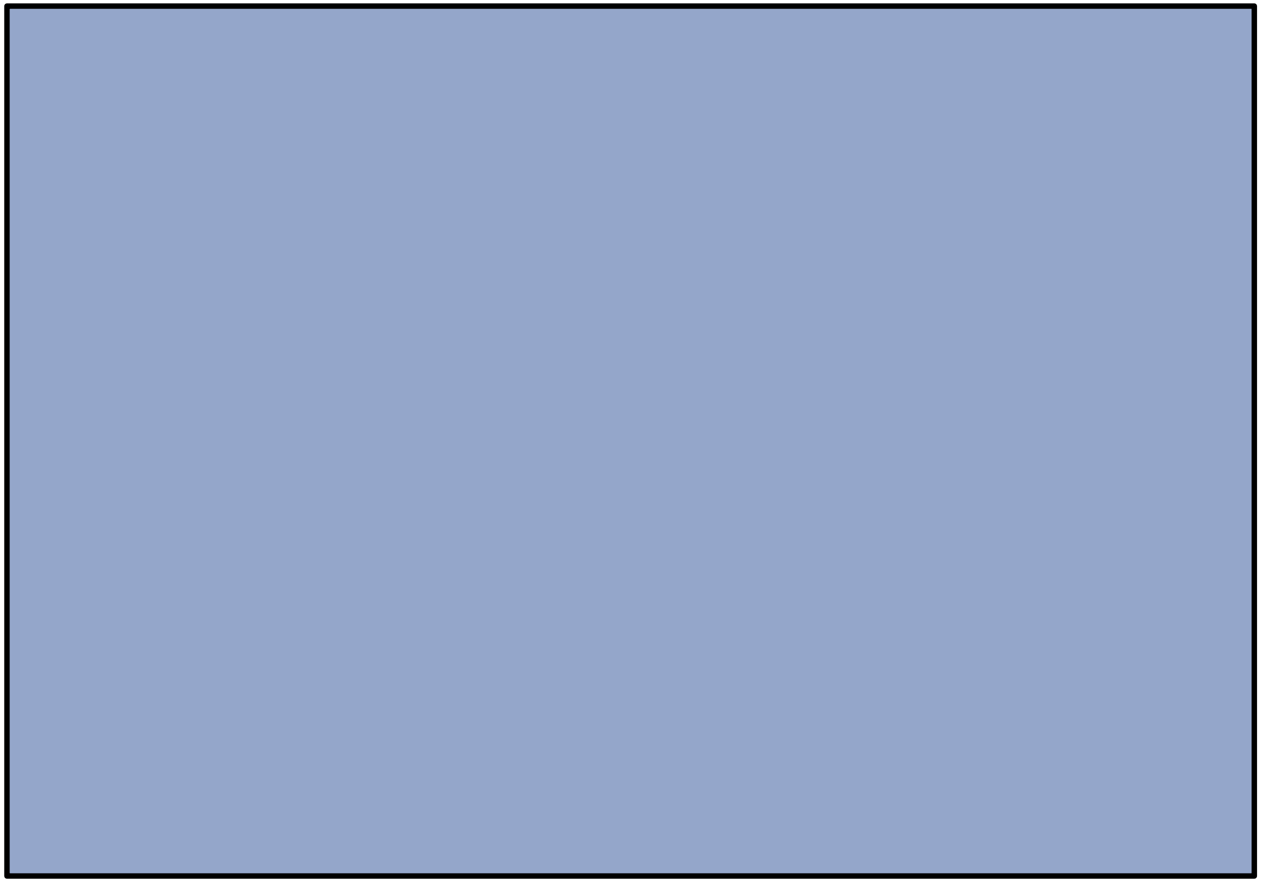
A word is a document of all ______ containing it

sentences

contexts

windows

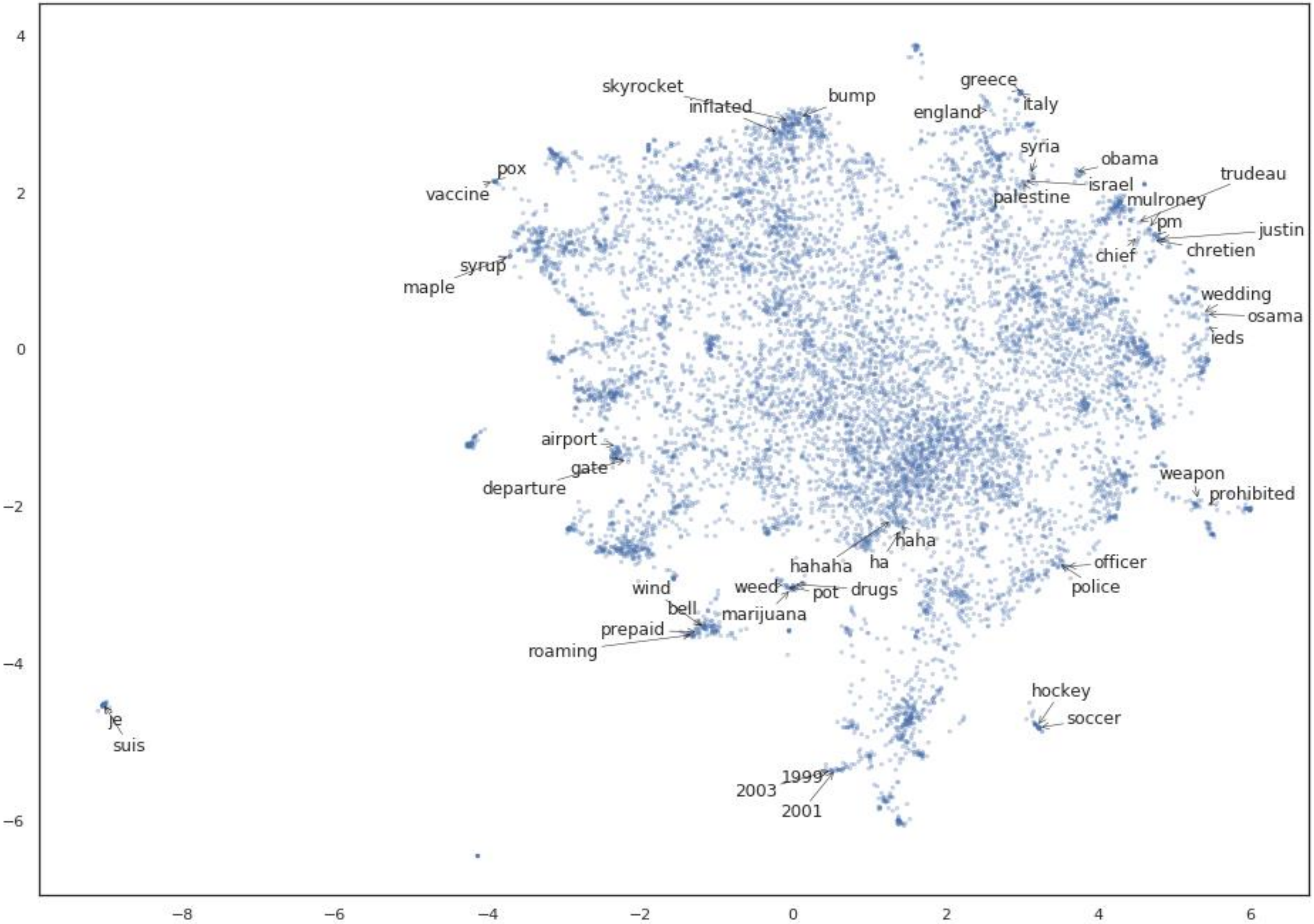
Word usage can be represented by a document by word matrix



Word “documents”

Vocabulary or words

WordMAP



4
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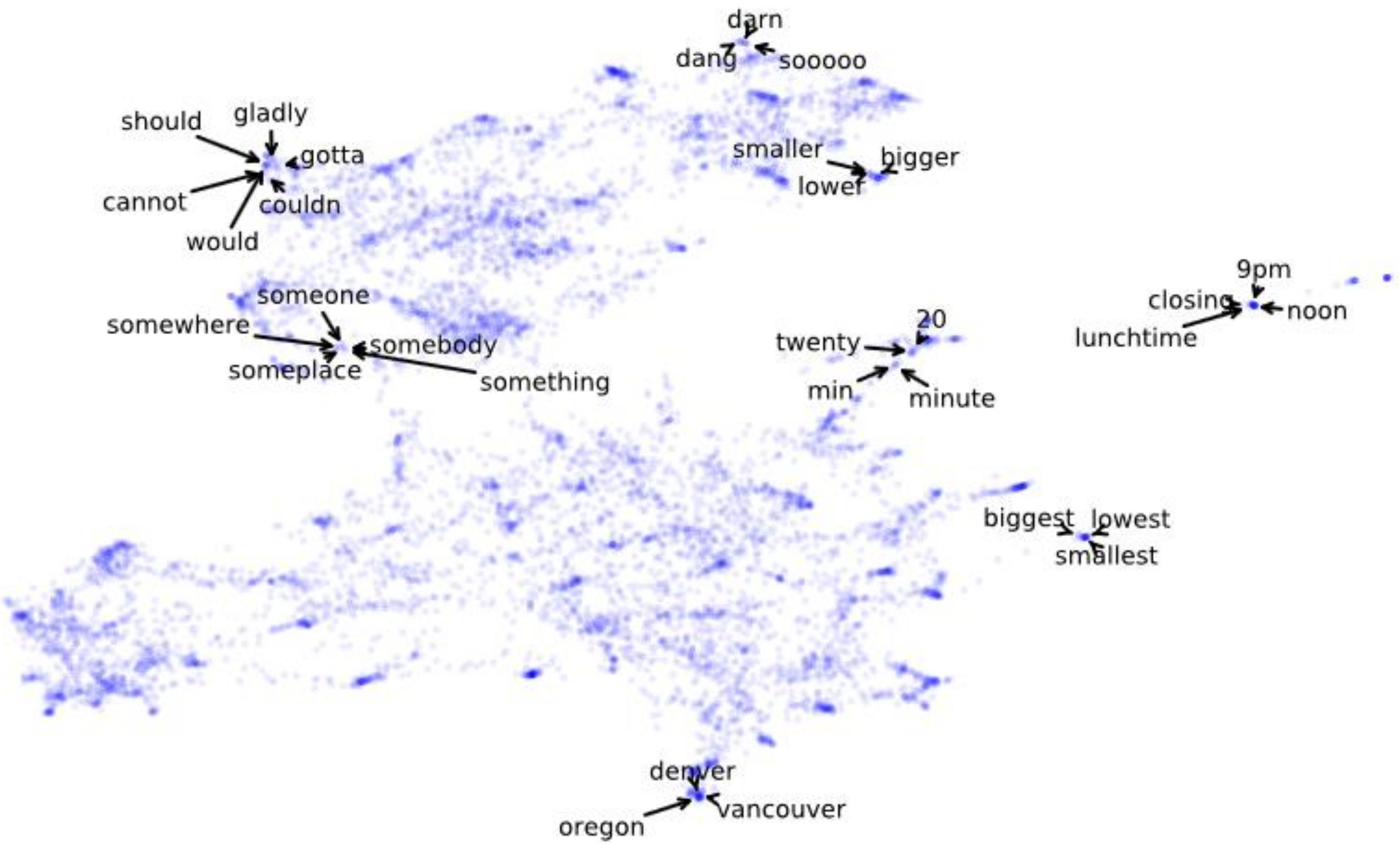
−8
−6
−4
−2
0
2
4
6
skyrocket
inflated
bump
greece
italy
england
syria
obama
israel
palestine
trudeau
mulroney
pm
justin
chretien
chief
pox
vaccine
syrup
maple
wedding
osama
ieds
airport
gate
departure
weapon
prohibited
haha
hahaha
ha
officer
police
wind
weed
pot
drugs
bell
marijuana
prepaid
roaming
hockey
soccer
je
suis
1999
2003
2001

WordMAP with context windows



We can:

Understand a corpus through interactive visualization

Embed short documents via joint embeddings

Perform query expansion by via nearest neighbor search

This is a general technique

_______ is a bag of ______

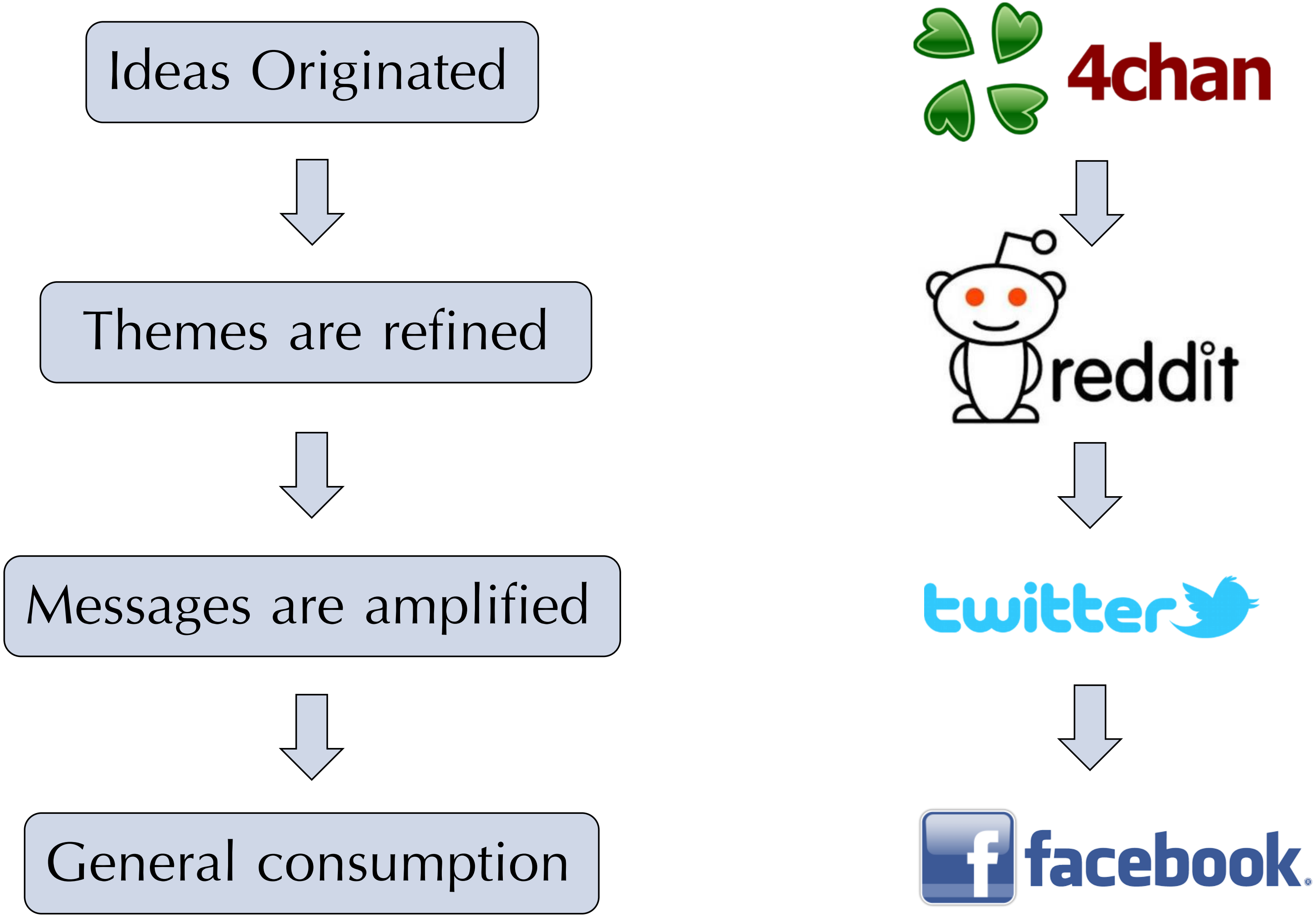
A document is a bag of words

A word is a bag of co-occurring words

We’re limited only by our creativity

Detecting Influence and Effects

Evolution of a disinformation campaign



Ideas Originated

Themes are refined

Messages are amplified

General consumption

Reddit in Canada

- Reddit:
  - “The Front Page of the Internet”
  - Social news aggregation, web content rating, discussion board
  - 9% of online Canadian adults have a Reddit account
  - 5th most popular site in Canada (Google.com, Youtube.com, Facebook.com, Google.ca, Reddit.com)

Topic Modeling

(Top2Vec)

We’d like to:

Characterize a document by a short list of the topics contained within

Find documents that discuss similar topics

What is topic modelling?

A topic is a set of words along with importance weights

co2, temperature, climate, warming → **global warming**

guns, firearms, owners, restricted, rcmp → **gun control**

Top2Vec – Algorithm

Finding topic words:

Step 1: Embed documents

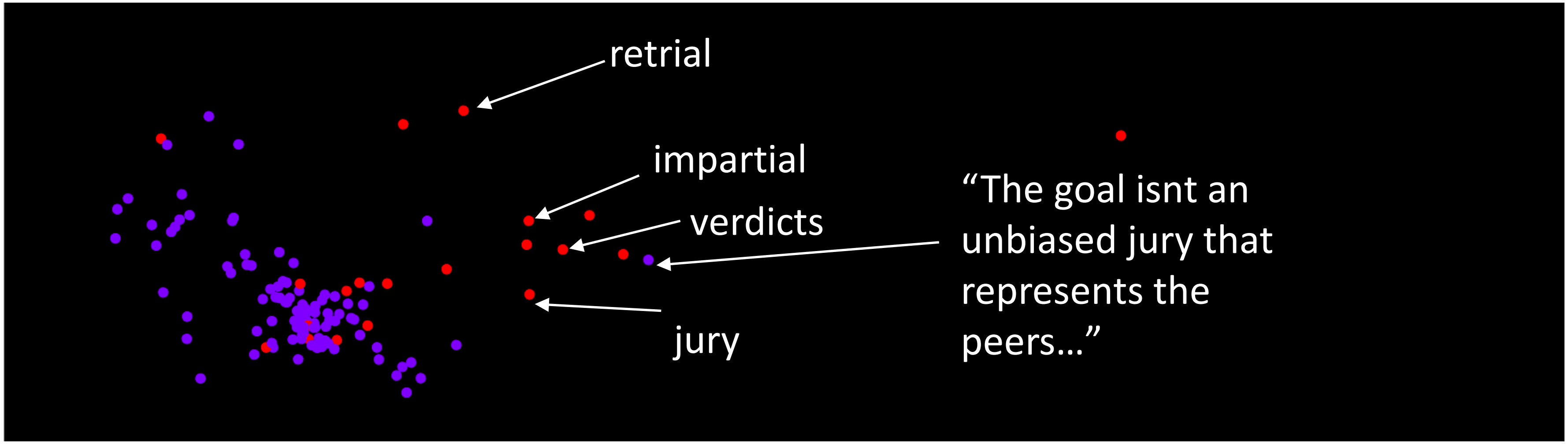
Step 2: Find dense areas (clusters) of documents

Step 3: Find topic vector within dense areas

Step 4: Use topic vector to find topic words

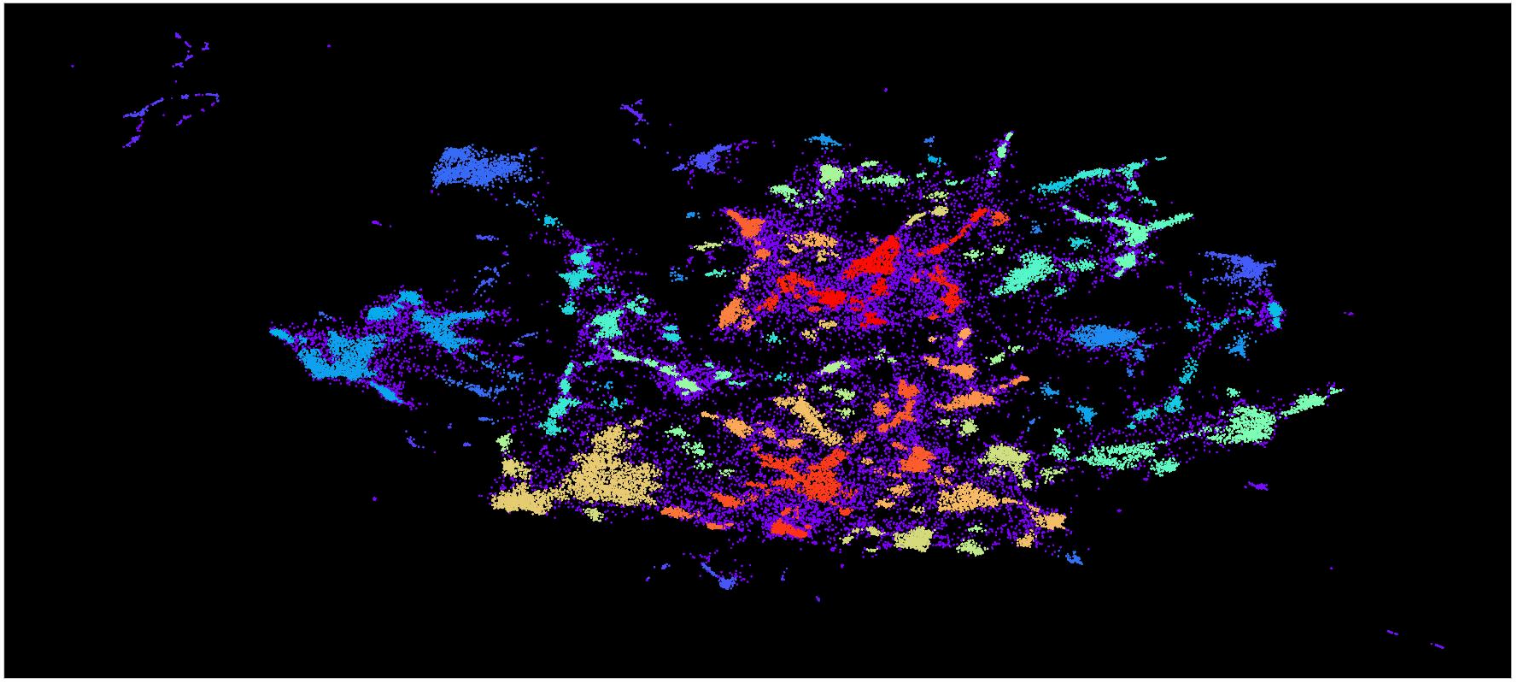
Step 1: Use DocMAP/WordMAP

- Learn word embedding where similar words are close together
- Embed documents in word vector space, placing them close to words that most describe document



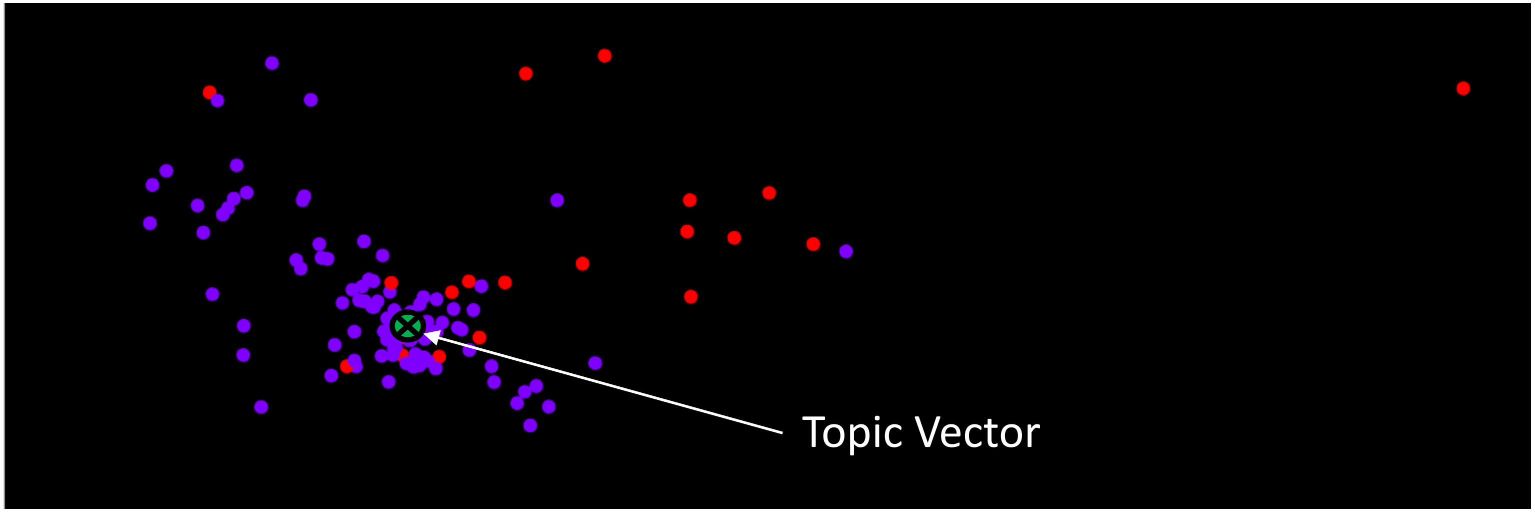
Step 2: Find dense areas of documents

- **Assumption:** dense areas of documents represent common topic
- Use UMAP to project document vectors to lower dimension
- Use HDBSCAN to find dense clusters



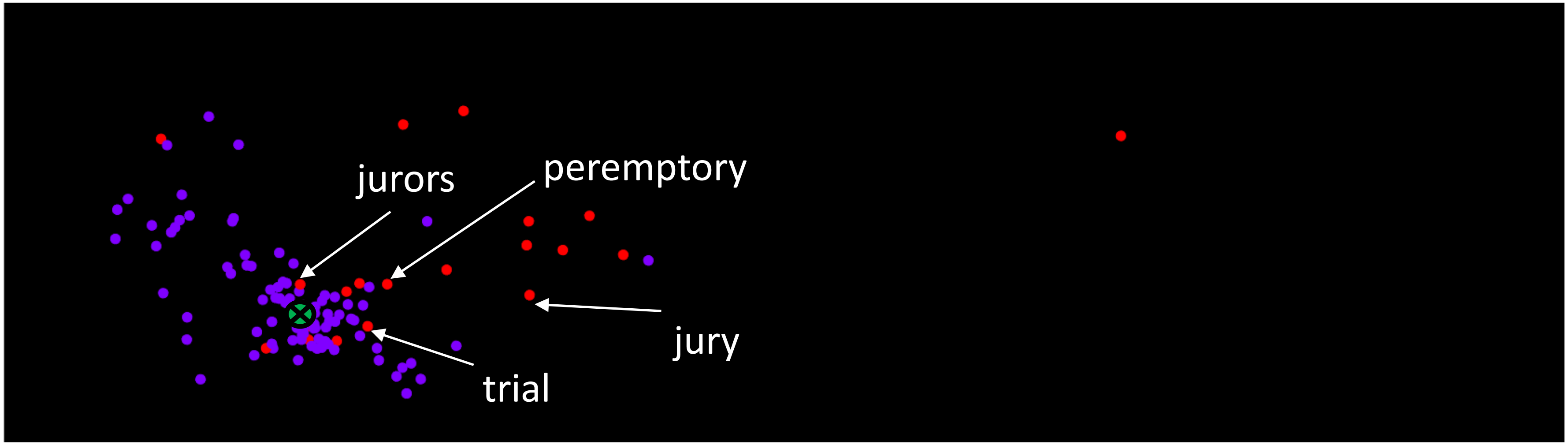
Step 3: Use dense areas to find topic vector

- Find centroid of documents belonging to dense cluster in original space
- Centroid = Topic Vector



Step 4: Use topic vector to find topic words

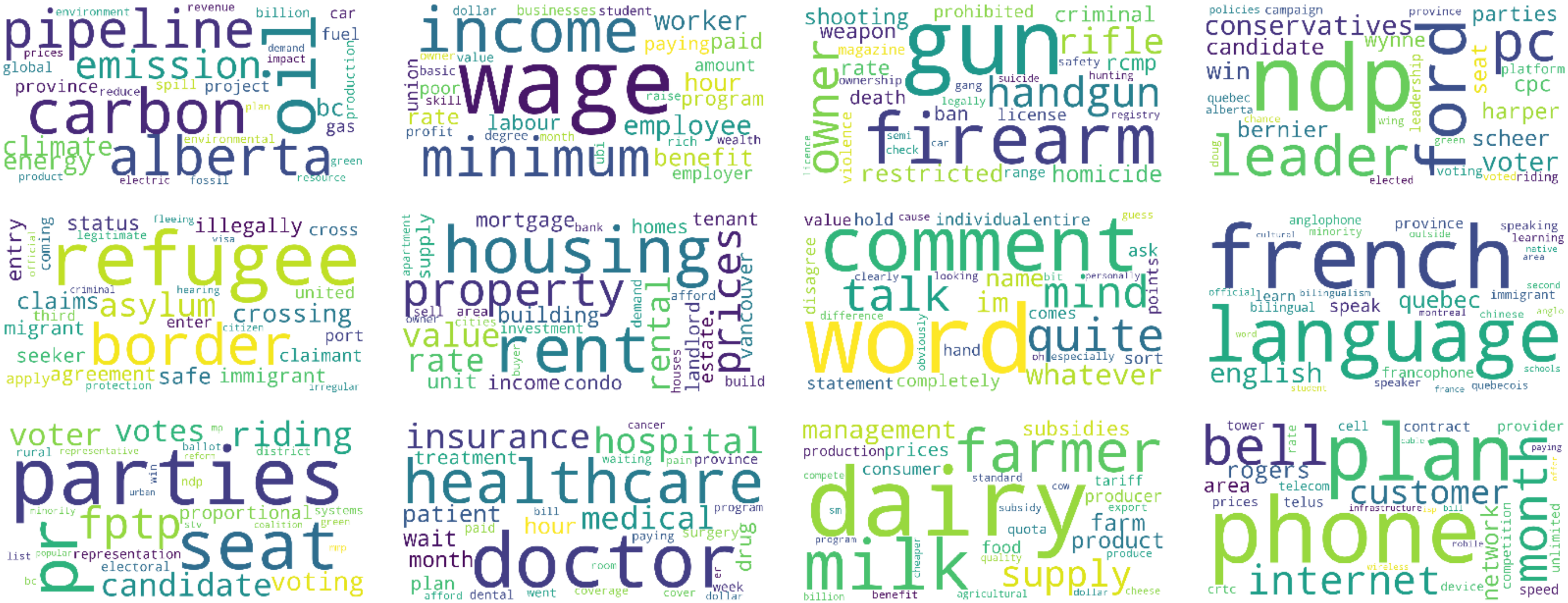
- **Assumption:** The closest words to the centroid will best represent our documents
- Topic = *k*-closest word vectors to topic vector



E.g.: jurors, jury, juries, peremptory, juror, verdict, trial

Topic identification – summarization

Reddit politics 2018 summarization



Changes in time may indicate what bots are talking about

Top2Vec Summary

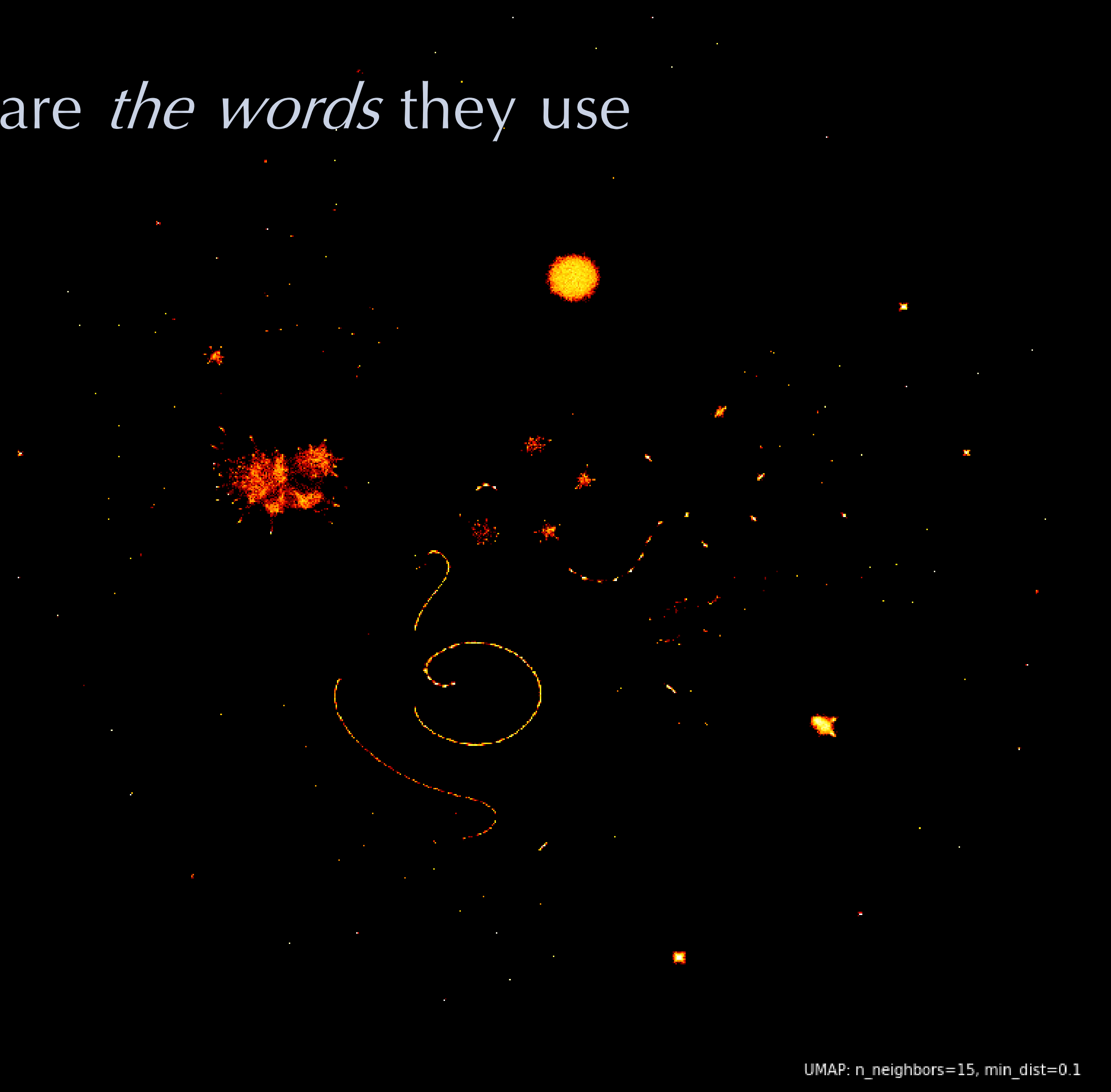
- No need to select number of topics in advance
- No need for stop words
- Jointly embeds documents and words
- Works with short text

User embeddings

- A user is:
  - The set of subreddits they post in, or
  - The words they type, or
  - The topics they talk about, or
  - The time of day they post, or
  - The posts they comment on, or…
- Explore the nearest neighbours/clusters of users
  - Doc2vec/top2vec -> hdbscan -> interact with output

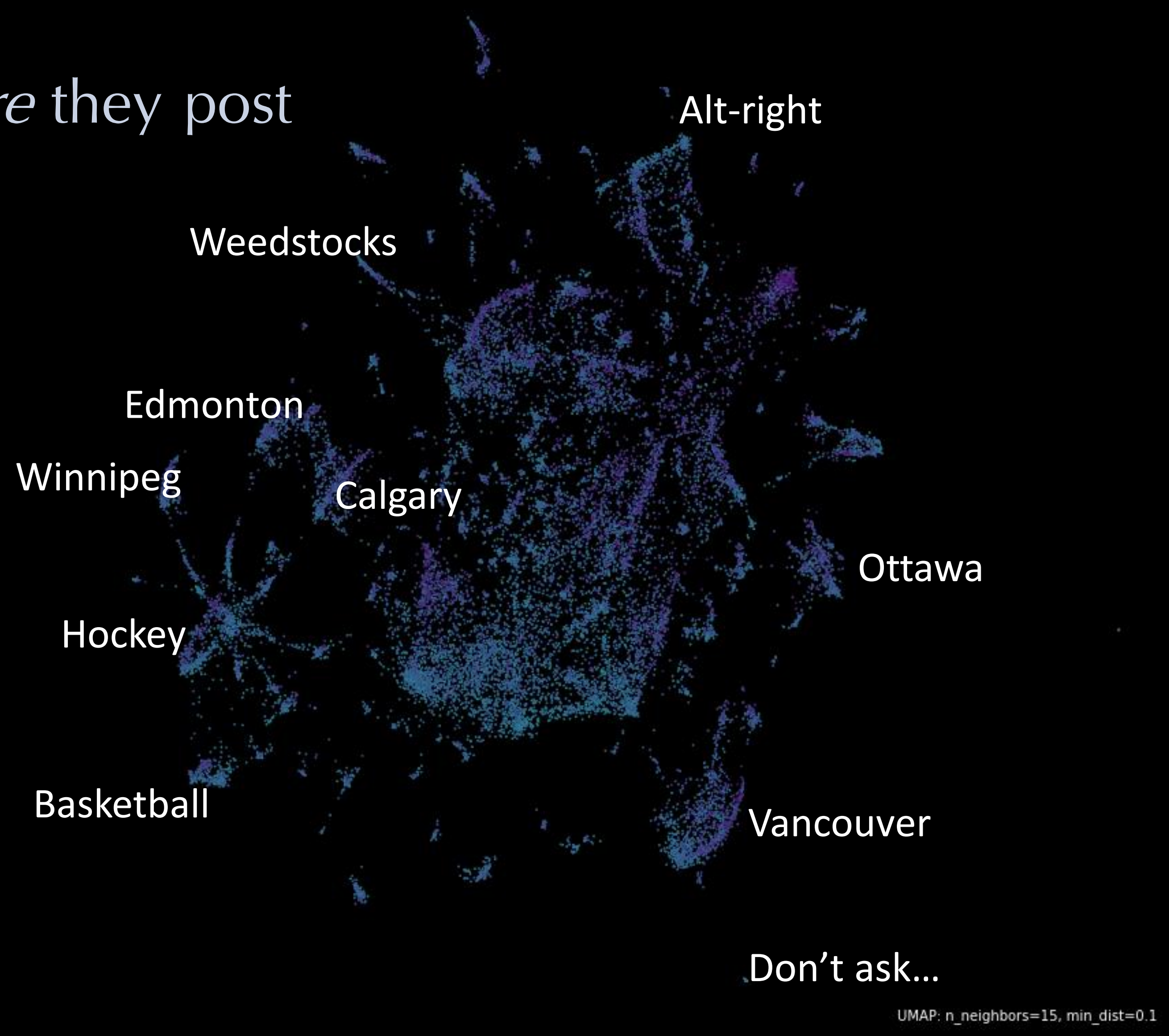
Detection: Lenses

Authors are *the words* they use



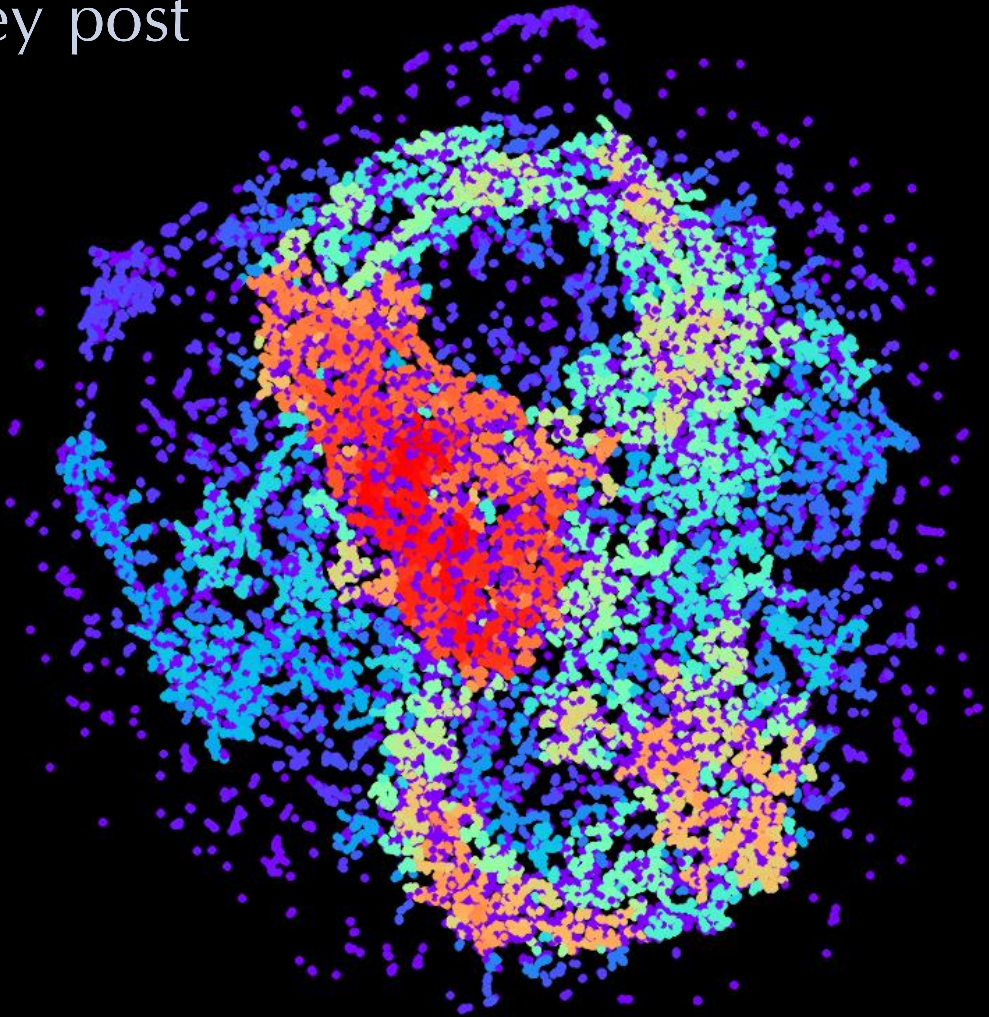
Detection: Lenses

Authors are *where* they post



Detection: Lenses

Authors are *when* they post



This is a general technique

_______ is a bag of ______

A document is a bag of words

A word is a bag of co-occurring words

A subreddit is a bag of users

A user is a bag of post statistics

Malware is a bag of libraries it loads

Bonus tools: Exploring Reddit Authors

- Inspired by Reddit User Analyzer
  - https://atomiks.github.io/reddit-user-analyzer
  - Limited to 1000 most recent comments/submissions
- JuPyter Notebook App
  - Unlimited comments/submissions
  - Customizable (Python + JuPyter)
  - Check it out on Binder

Going forward

Now we have:

- A general technique for embedding “all the things”
  - See also: https://github.com/jc-healy/EmbedAllTheThings
- A series of techniques for summarizing authors, reddit forums, corporii of documents.
- Experience working with our partners to leverage these techniques to empower analysts to search for malicious foreign influence campaigns.

Go Army

BEAT NAVY