

GRAPH EMBEDDING

An introduction

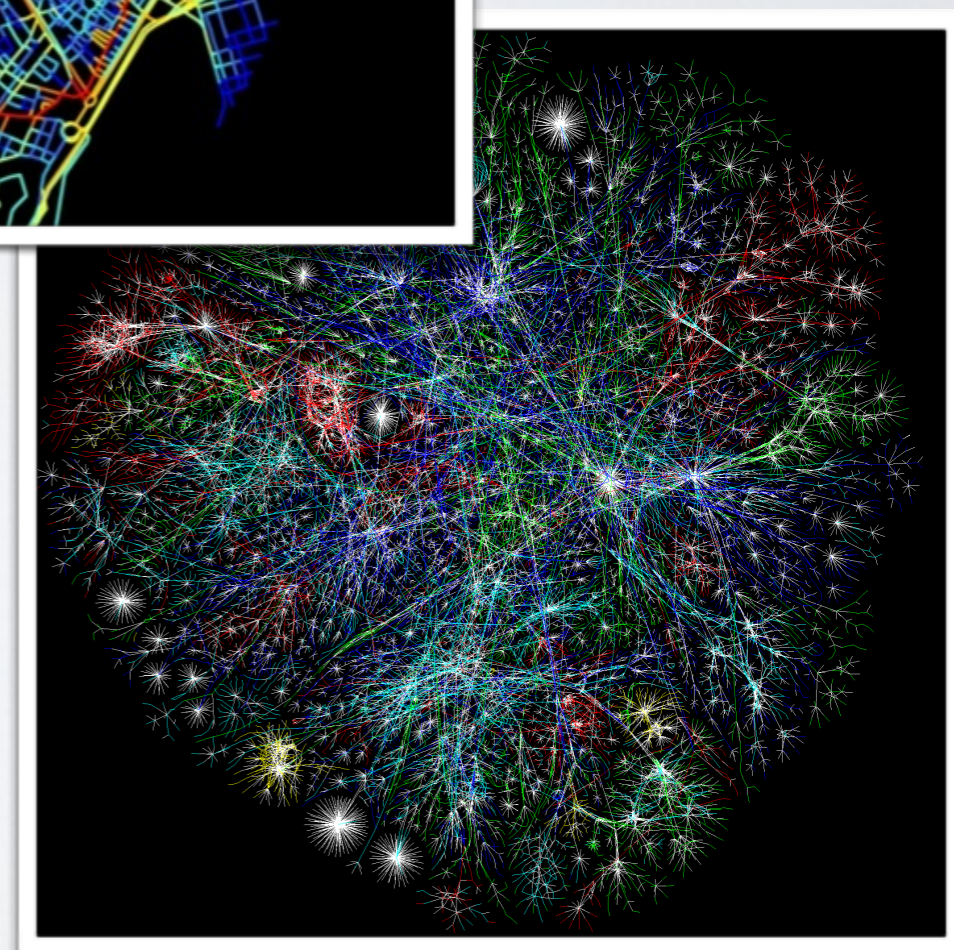
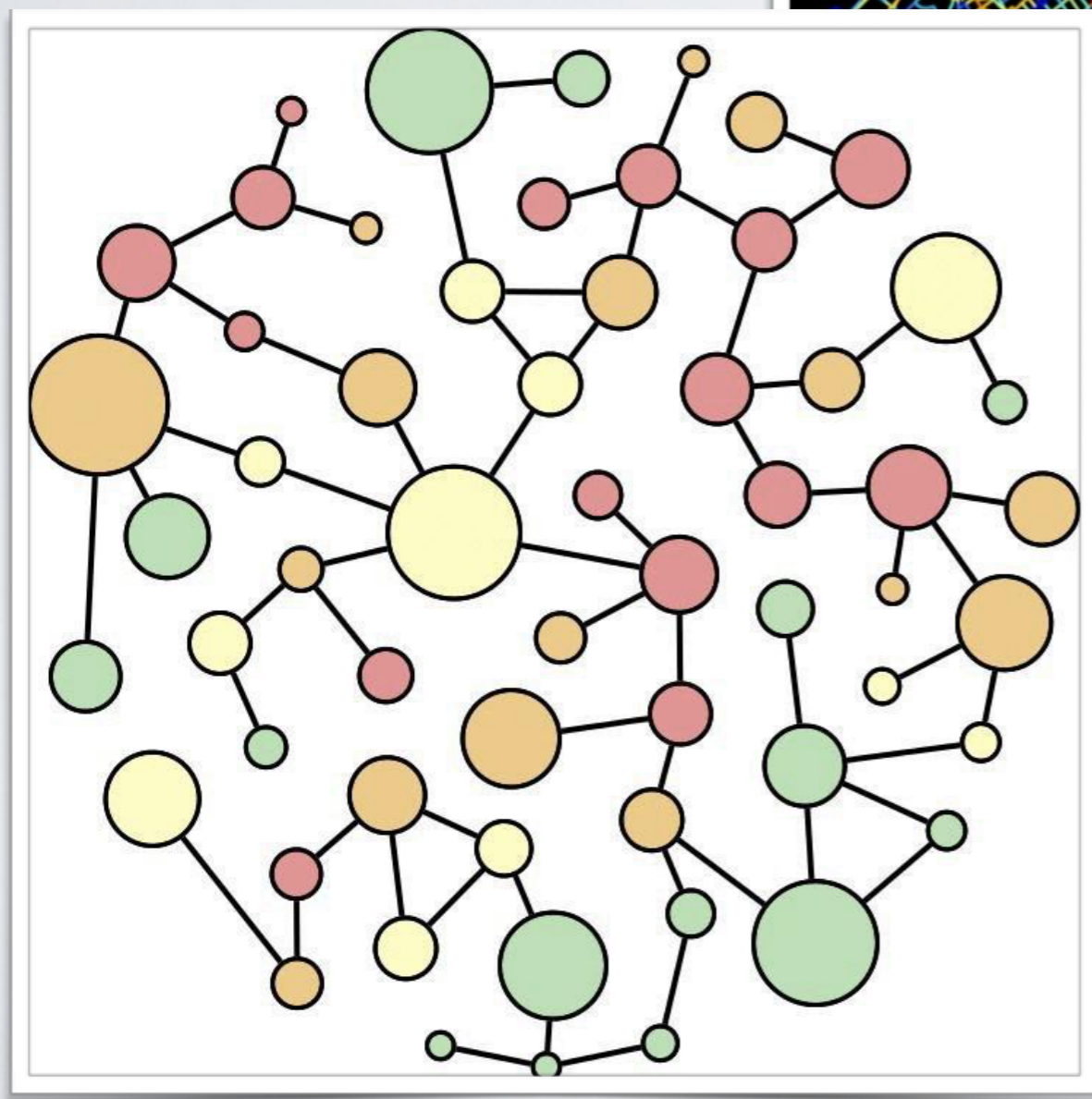
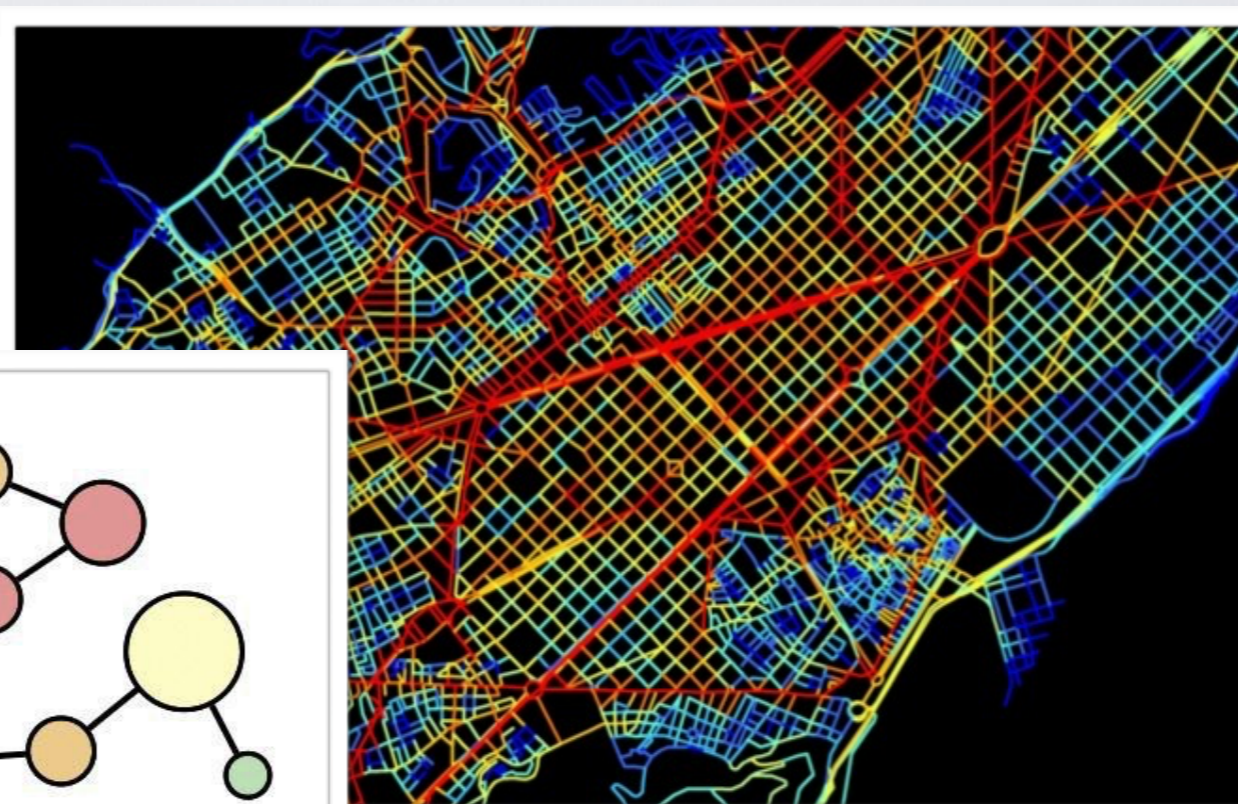
Rémy Cazabet

DISCLAIMER

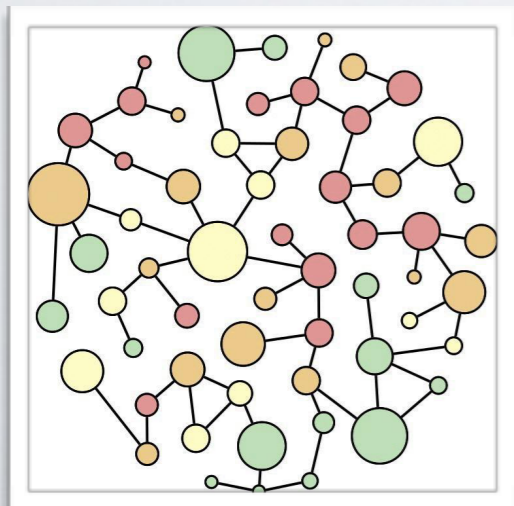
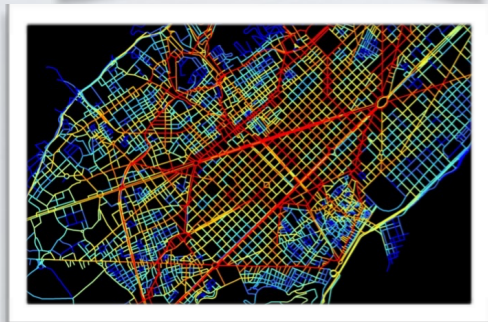
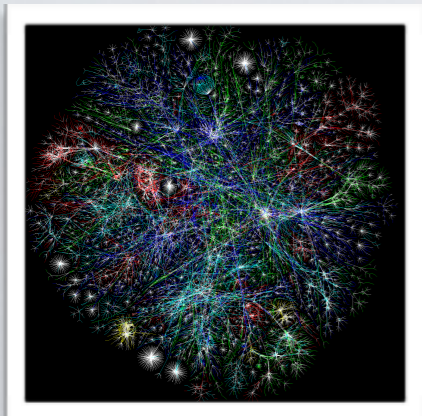
- I'm not an expert in Graph embedding !
- It is “my” vision:
 - Someone from “Network Science”
 - Who see Graph Embedding arriving from the Machine Learning Community

WHAT IS
GRAPH EMBEDDING ?

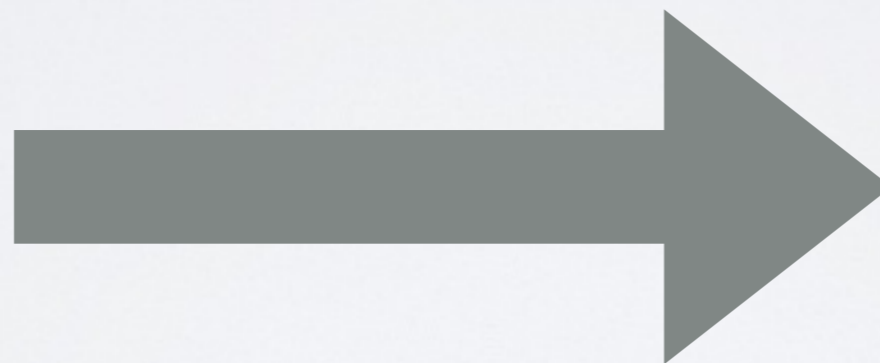
GRAPHS / NETWORKS



GRAPHS / NETWORKS



Ad Hoc
Network Algorithms

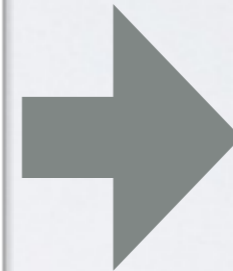
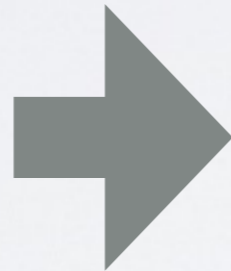


Link prediction
Community detection
Graph reconstruction
Node classification

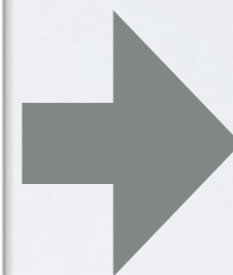
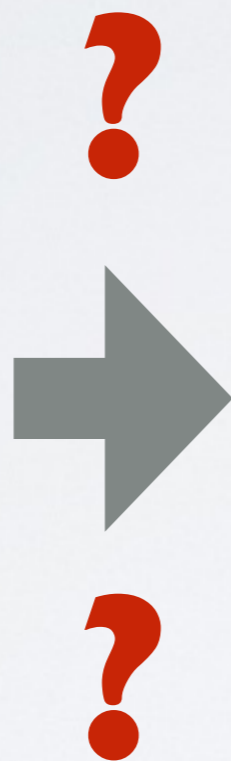
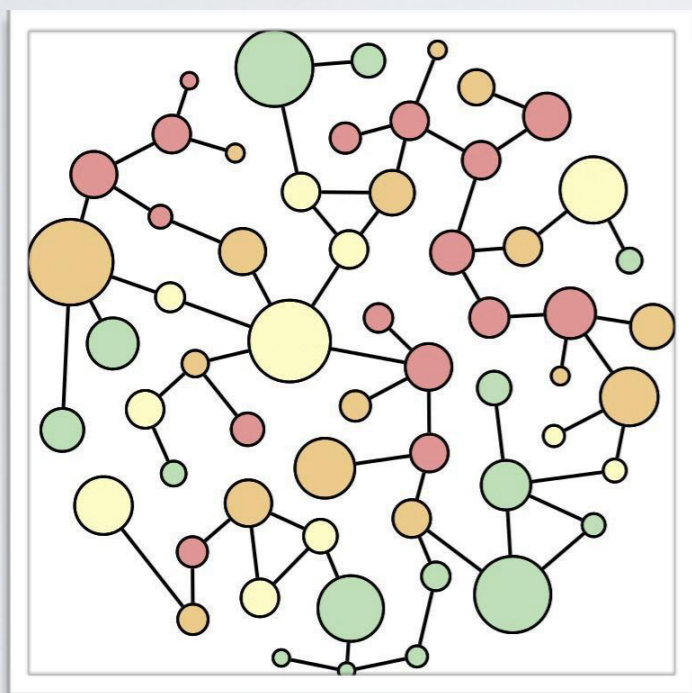
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MACHINE LEARNING

Features as vectors

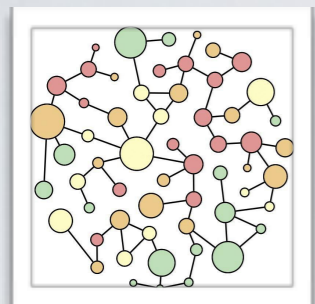


Prediction
Classification
Clustering
...



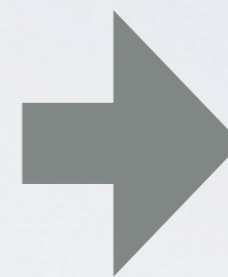
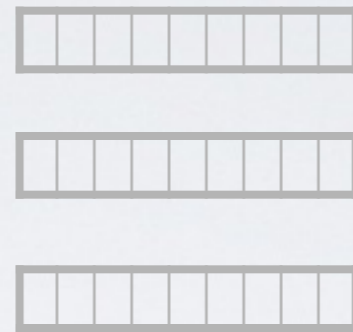
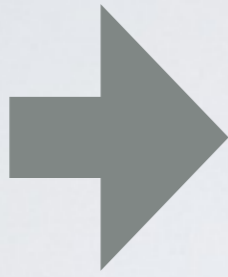
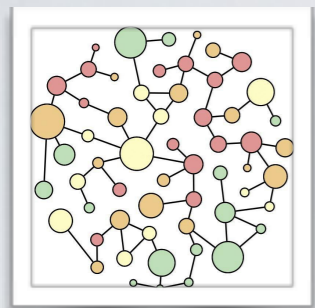
Prediction
Classification
Clustering
...

Graph embedding



Graph embedding

Machine Learning

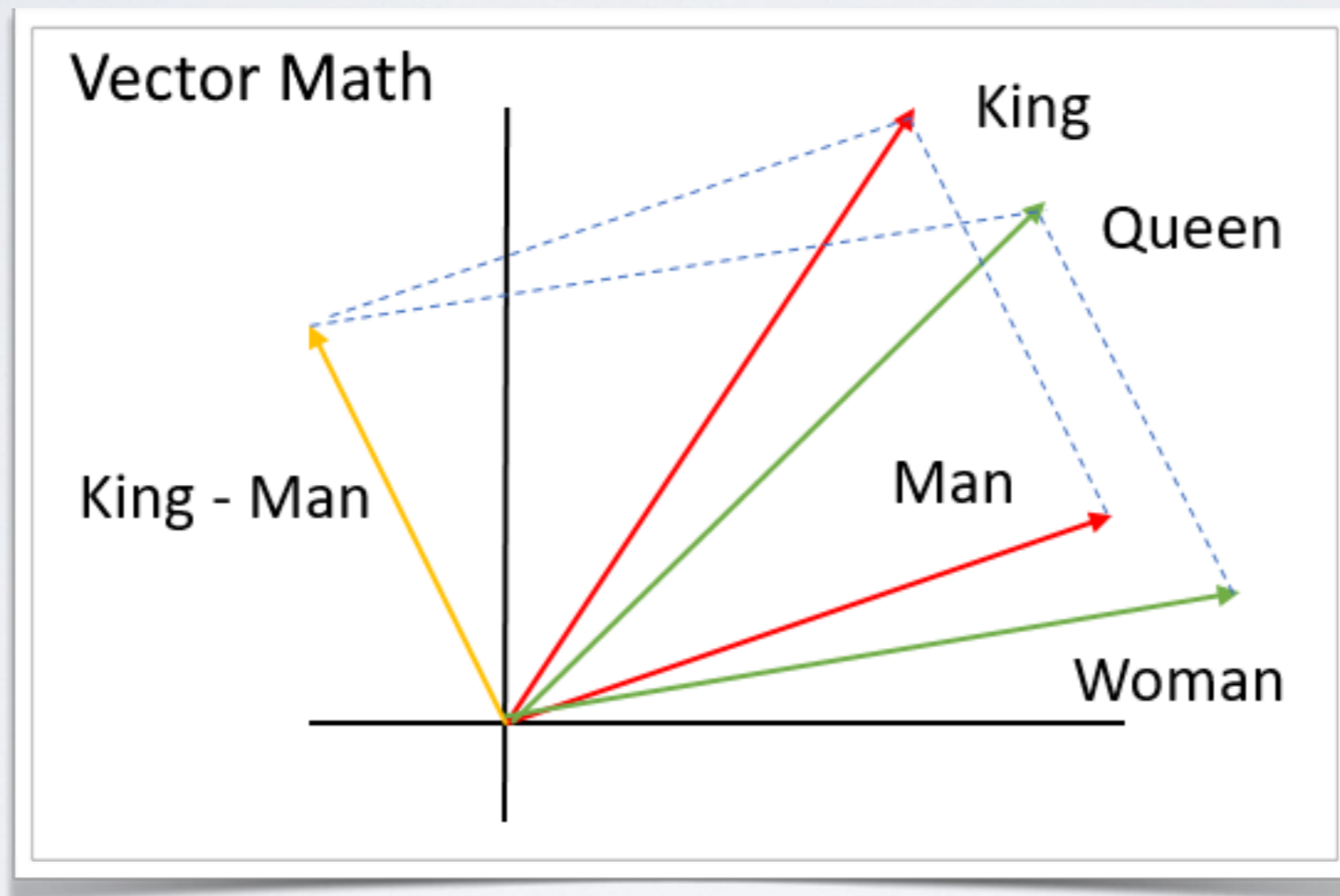


- Link prediction = Prediction
- Graph reconstruction = Prediction
- Community detection = Clustering
- Node classification = Classification
- ...
- ...

WHY DOES
GRAPH EMBEDDING
MATTERS ?

WORD EMBEDDING

Word2vec, Skipgram, ...



GENERIC “SKIPGRAM”

Table 8: *Examples of the word pair relationships, using the best word vectors from Table 4 (Skip-gram model trained on 783M words with 300 dimensionality).*

Relationship	Example 1	Example 2	Example 3
France - Paris	Italy: Rome	Japan: Tokyo	Florida: Tallahassee
big - bigger	small: larger	cold: colder	quick: quicker
Miami - Florida	Baltimore: Maryland	Dallas: Texas	Kona: Hawaii
Einstein - scientist	Messi: midfielder	Mozart: violinist	Picasso: painter
Sarkozy - France	Berlusconi: Italy	Merkel: Germany	Koizumi: Japan
copper - Cu	zinc: Zn	gold: Au	uranium: plutonium
Berlusconi - Silvio	Sarkozy: Nicolas	Putin: Medvedev	Obama: Barack
Microsoft - Windows	Google: Android	IBM: Linux	Apple: iPhone
Microsoft - Ballmer	Google: Yahoo	IBM: McNealy	Apple: Jobs
Japan - sushi	Germany: bratwurst	France: tapas	USA: pizza

GRAPH EMBEDDING

- Word embedding: a revolution in Natural Language Processing
- Graph embedding: a revolution in Network Science/Graph Analysis?
- How to do it?
- How well does it works?

RANDOM NOTES

SKIPGRAM

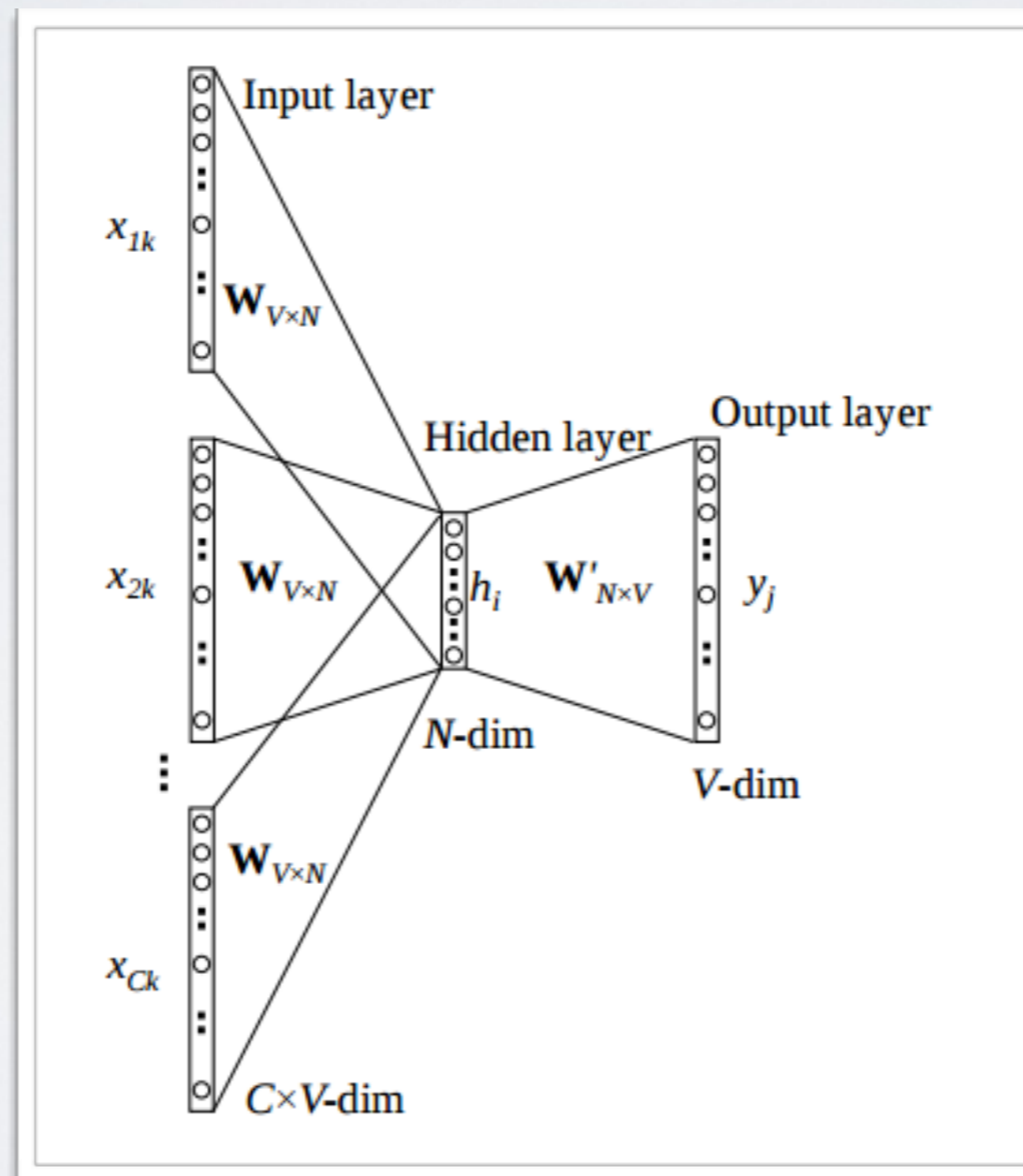
Word embedding

Natural language => vectors

Source Text	Training Samples
The quick brown fox jumps over the lazy dog. →	(the, quick) (the, brown)
The quick brown fox jumps over the lazy dog. →	(quick, the) (quick, brown) (quick, fox)
The quick brown fox jumps over the lazy dog. →	(brown, the) (brown, quick) (brown, fox) (brown, jumps)
The quick brown fox jumps over the lazy dog. →	(fox, quick) (fox, brown) (fox, jumps) (fox, over)

INTUITIVE/NAIVE IDEA

- Recent methods based on “neural networks”



INTUITIVE/NAIVE IDEA

- Normal Classifier:
 - ▶ For a set of items with n **features** and a known **class**
 - ▶ Learn n **weights** to predict the class of any item. (similar to linear regression)
- Word2vec:
 - ▶ A set of items (nodes) with
 - no known features
 - A “class”: the node(s) in its “context” (random walks)
 - ▶ Find the best d **features** that allow to find the d best **weights** that best predict the **class**
 - ▶ => Technically, 2 chained “gradient descent”, one for weights, one for features.

NOTE

- There are completely different methods that also produce “embeddings”
 - ▶ Graph factorization (NMF non-negative matrix factorization)
 - ▶ Graph Layouts (Force Layout, ...). Often used in 2d but can be used in any dimension

EMBEDDING... WHAT ?

- Embeddings aim to “preserve the structural organization”
- But what does it means ?
 - We understand intuitively what layout preserves...
 - What about other more recent embeddings ?
- (Another note: interest of recent embeddings: scalability)