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Semantic Text Similarity

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Semantic textual similarity

- What is semantic similarity?
- Semantic similarity in word level
- Semantic similarity in sentence level
- Semantic textual similarity in Python

Semantic textual similarity

- What is semantic similarity?
- Semantic similarity in word level
- Semantic similarity in sentence level
- Semantic textual similarity in Python

Semantic textual similarity

- Semantic textual similarity (STS) deals with determining how similar two pieces of texts are
- It’s about measuring semantic similarity between words/terms, sentences, paragraphs or documents
- Semantic similarity methods usually give a ***ranking*** or ***percentage*** of similarity between texts, rather than a binary decision as similar or not similar
- Related tasks are ***paraphrase identification***, or ***duplicate identification***

Semantic textual similarity

- The techniques like Bag of Words (BoW) and TF-IDF are used to represent text, as real value vectors
- However, these techniques did not attribute to the fact that words have different meanings and different words can be used to represent a similar concept

John and David studied Math and Science.

≠

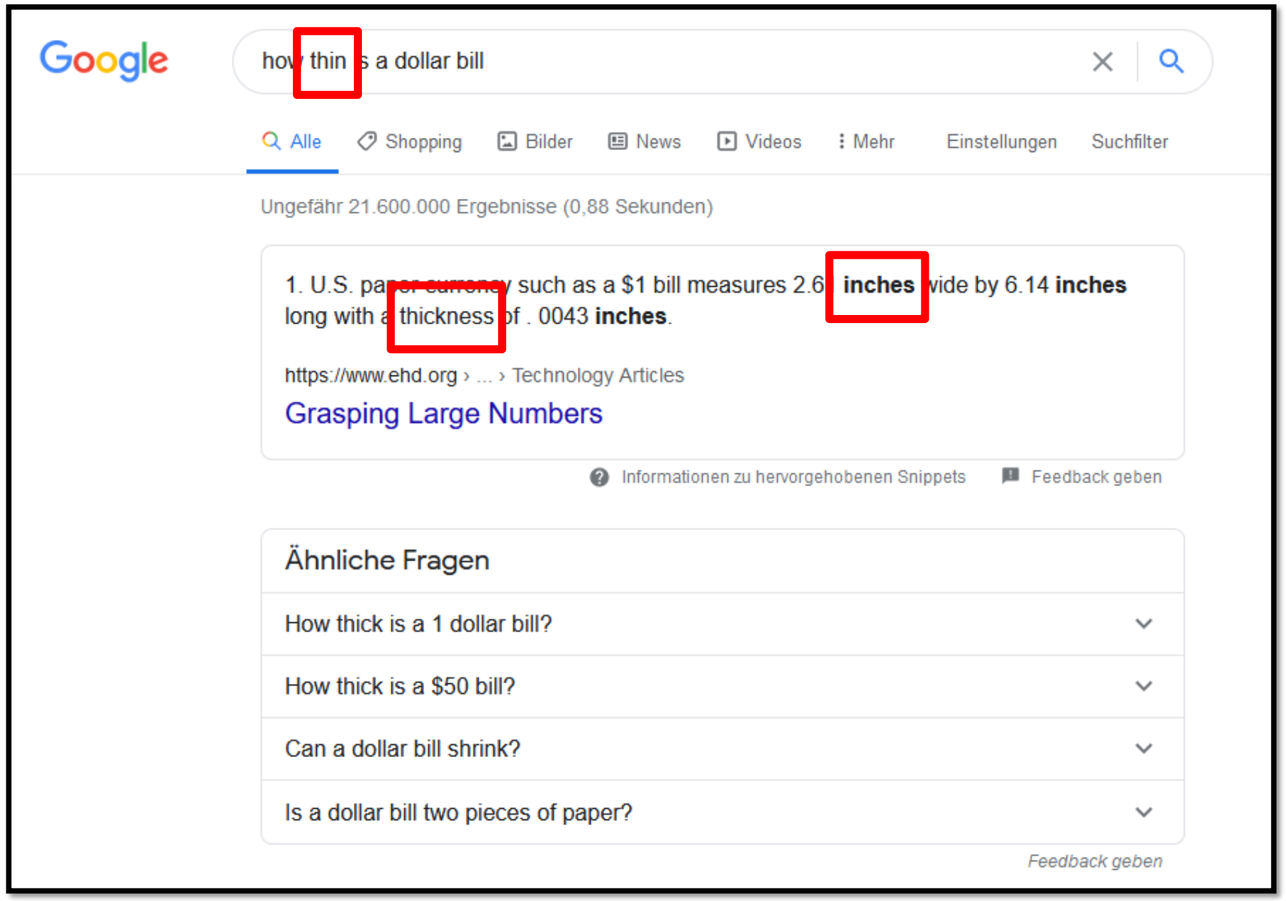
John studied Math and David studied Science.

Mary is allergic to dairy products. = Mary is lactose intolerant.

Examples from Chandrasekaran, D., & Mago, V. (2020). Evolution of Semantic Similarity--A Survey. *arXiv preprint arXiv:2004.13820*

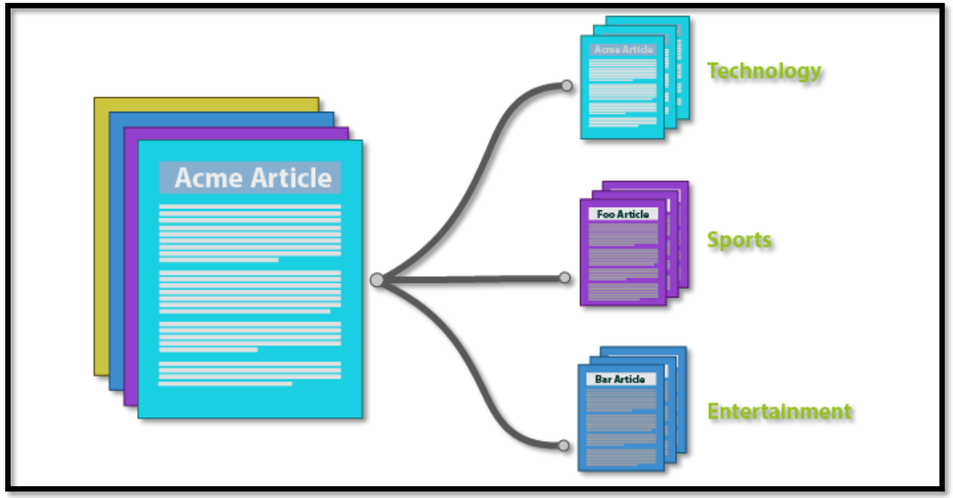
Semantic textual similarity

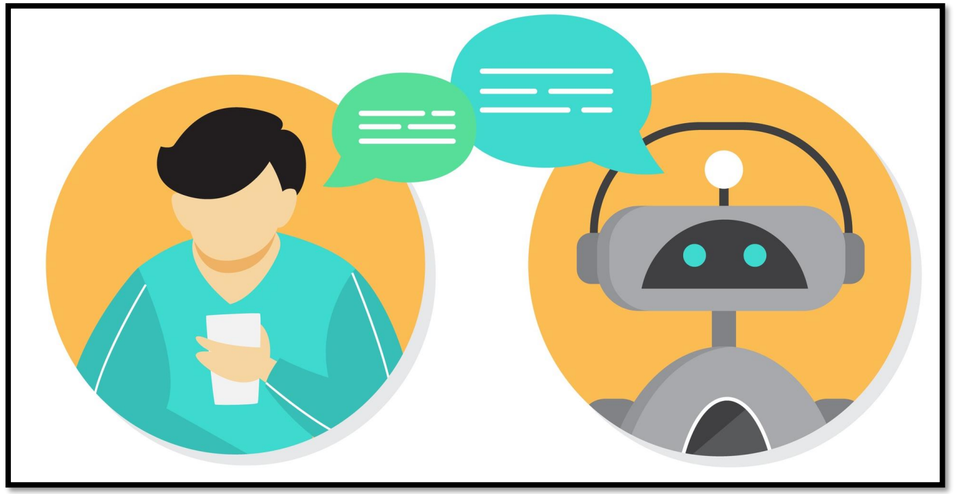
- Why does it matter?



Semantic textual similarity

- Applications
  - Plagiarism detection
  - Document clustering
  - Question answering





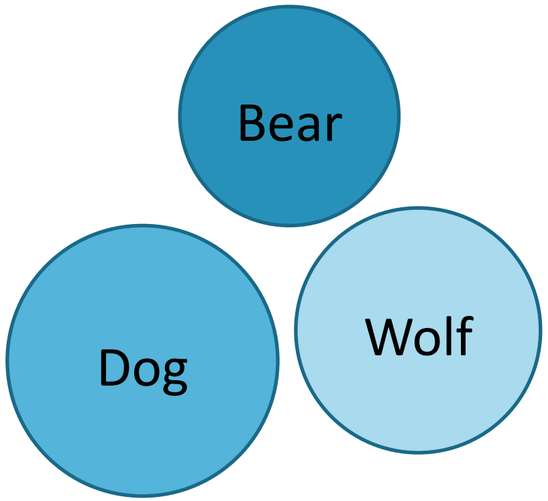
Semantic textual similarity

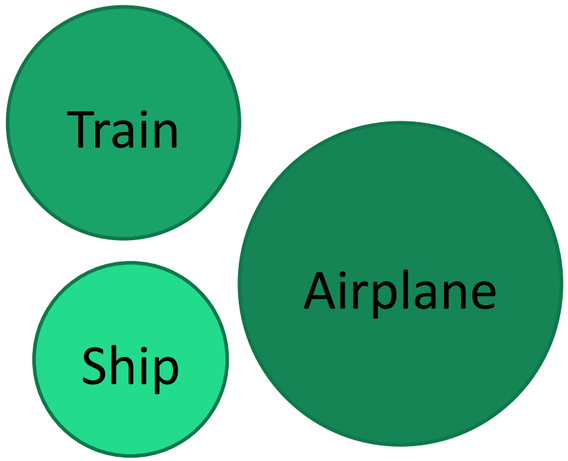
- What is semantic similarity?
- Semantic similarity in word level
- Semantic similarity in sentence level
- Semantic textual similarity in Python

Semantic similarity in word level

- It tells how close two words/terms are, semantically
- Semantic similarity is often used ***synonymously*** with semantic ***relatedness***

Ship	Airplane	3.8
Ship	Bear	0.2
Dog	Wolf	4.5
Wolf	Bear	3.6





Semantic similarity in word level

- The approaches can be divided into the following categories:
  - Distributional semantics
    - Frequency based
    - Prediction based
  - Knowledge based methods

Distributional semantics

- Frequency based
- PMI

$$PMI(W_1, W_2) = \log_2 \frac{P(W_1, W_2)}{P(W_1)P(W_2)}$$

Distributional semantics

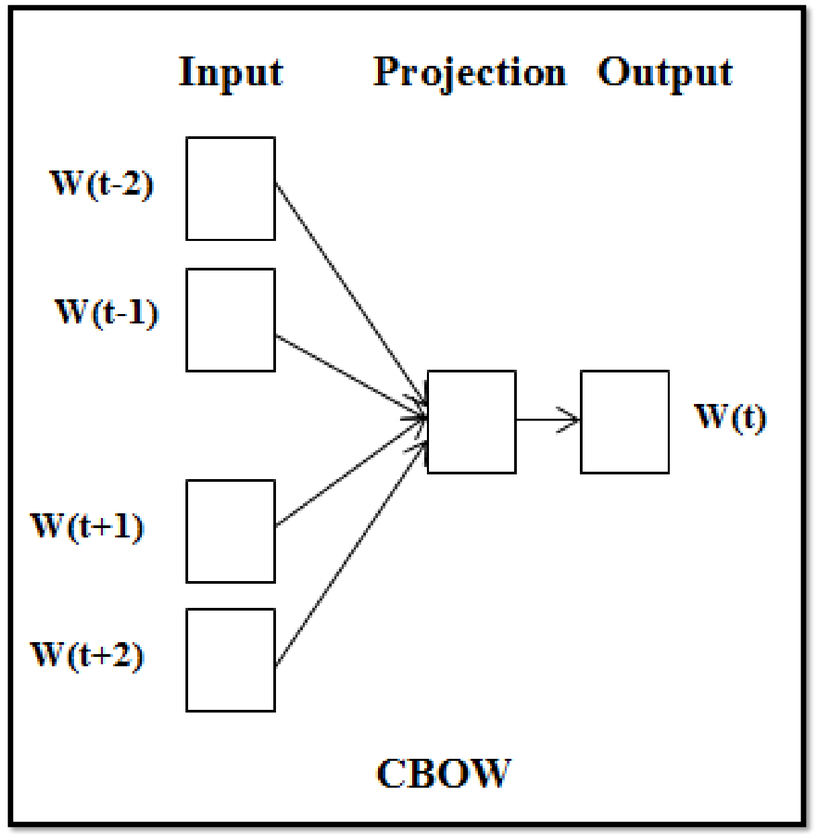
	text	is	a	complex	human	language	representation	natural	and	also	diverse
text	0	1	1	0	0	0	0	0	0	0	0
is	1	0			1	1	0	0	1	0	0
a	1	1			1	0	0	0	0	0	0
complex	0	2			1	2	0	0	1	1	0
human	0	**1**	1	1	0	2	1	**1**	0	0	0
language	0	1	0	2	2			1	0	0	0
representation	0	0	0	0	1				0	0	0
natural	0	0	0	0	1				0	0	0
and	0	2	0	1	0			0	0	1	0
also	0	1	0	1	0	0	0	0	1	0	1
diverse	0	1	0	0	0	0	0	0	0	1	0

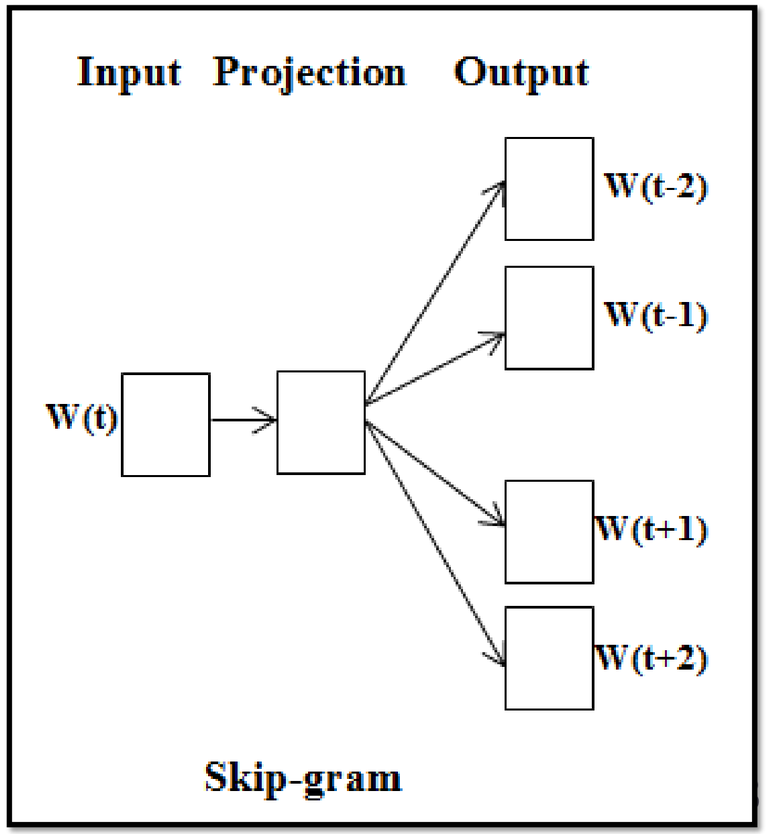
$PMI = -0.51$

$PMI = +1.8$

Distributional semantics

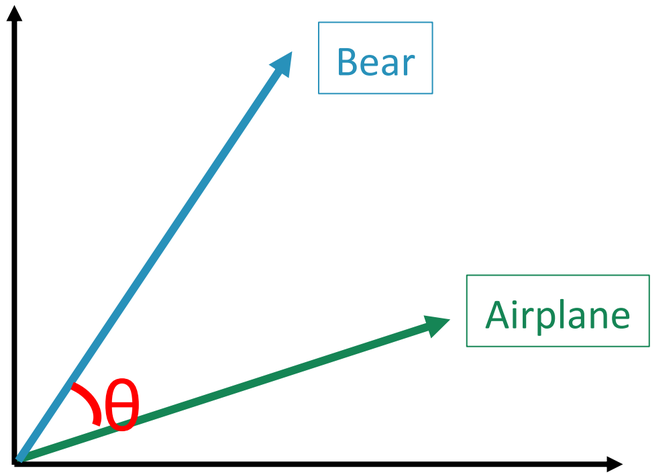
- Frequency based
  - PMI
- Prediction based
  - Word2Vec





Distributional semantics

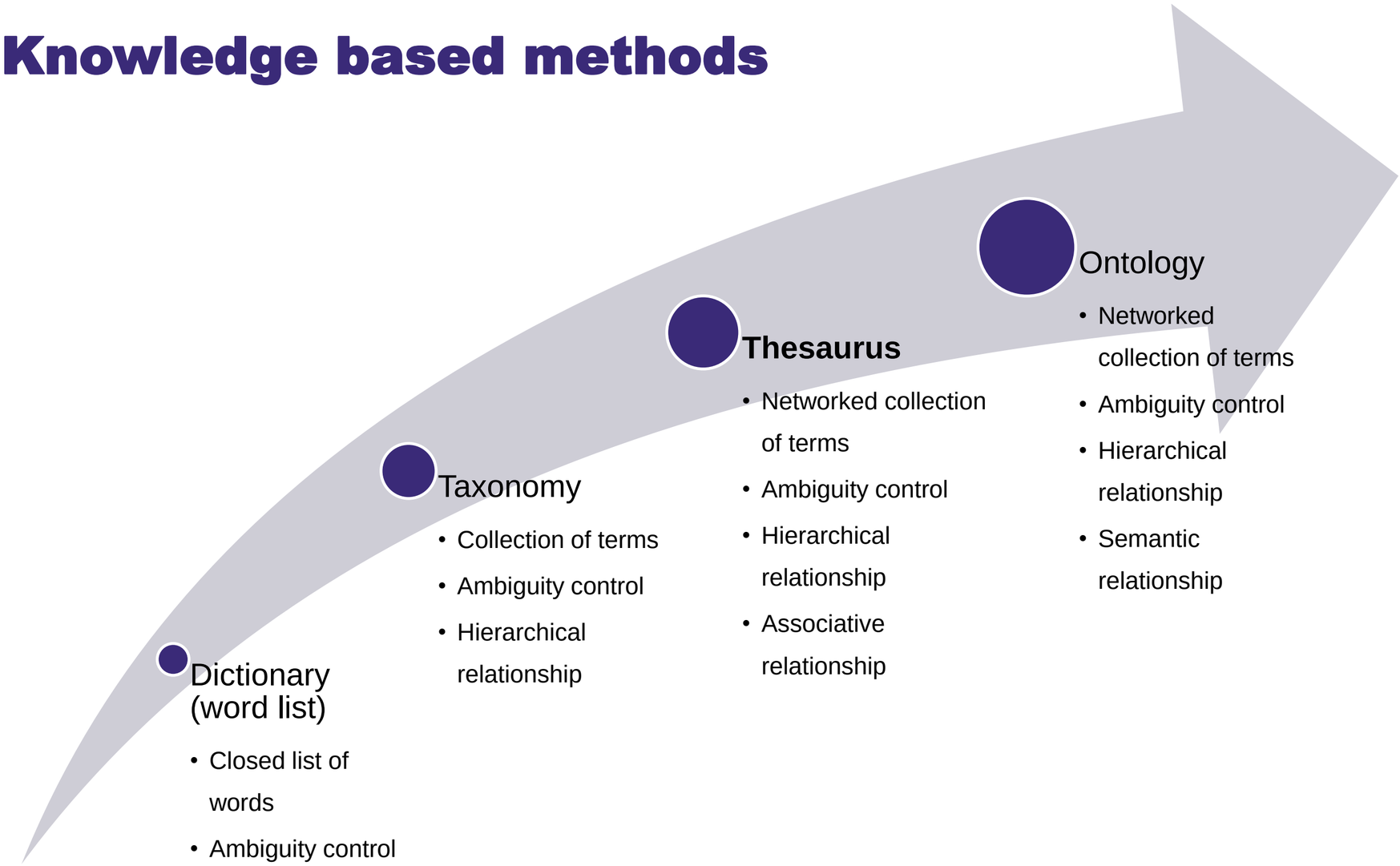
Ship	0.003	- 0.01	0.001	…	0.321	- 0.076	0.014
Airplane	0.002	- 0.009	- 0.001	…	0.337	- 0.054	0.014
Wolf	0.469	0.015	0.373	…	- 0.049	0.533	- 0.148
Dog	0.143	0.445	0.180	…	- 0.683	0.167	- 0.428
Bear	0.397	0.236	- 0.110	…	- 0.256	0.257	- 0.148



Knowledge based methods

- Knowledge-based semantic similarity methods calculate semantic similarity between two terms based on the information derived from underlying knowledge sources like ***ontology***, ***thesaurus***, ***taxonomy***, ***dictionary***
- Ontology, thesaurus, taxonomy, dictionary
- Machine readable knowledge sources that represents how objects are related

Knowledge based methods



Knowledge based methods

Dictionary (term list)

rework

/riːˈwəːk/ⓘ

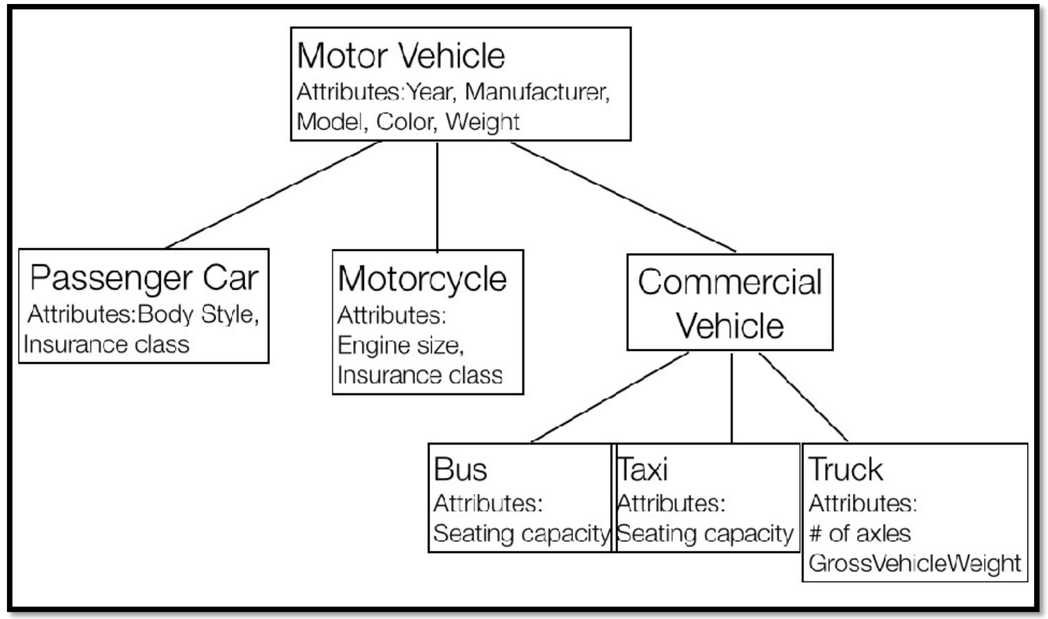
verb

Make changes to the original version of (something)

Sample: Over the course of our trip, the President continually reworked his speech.

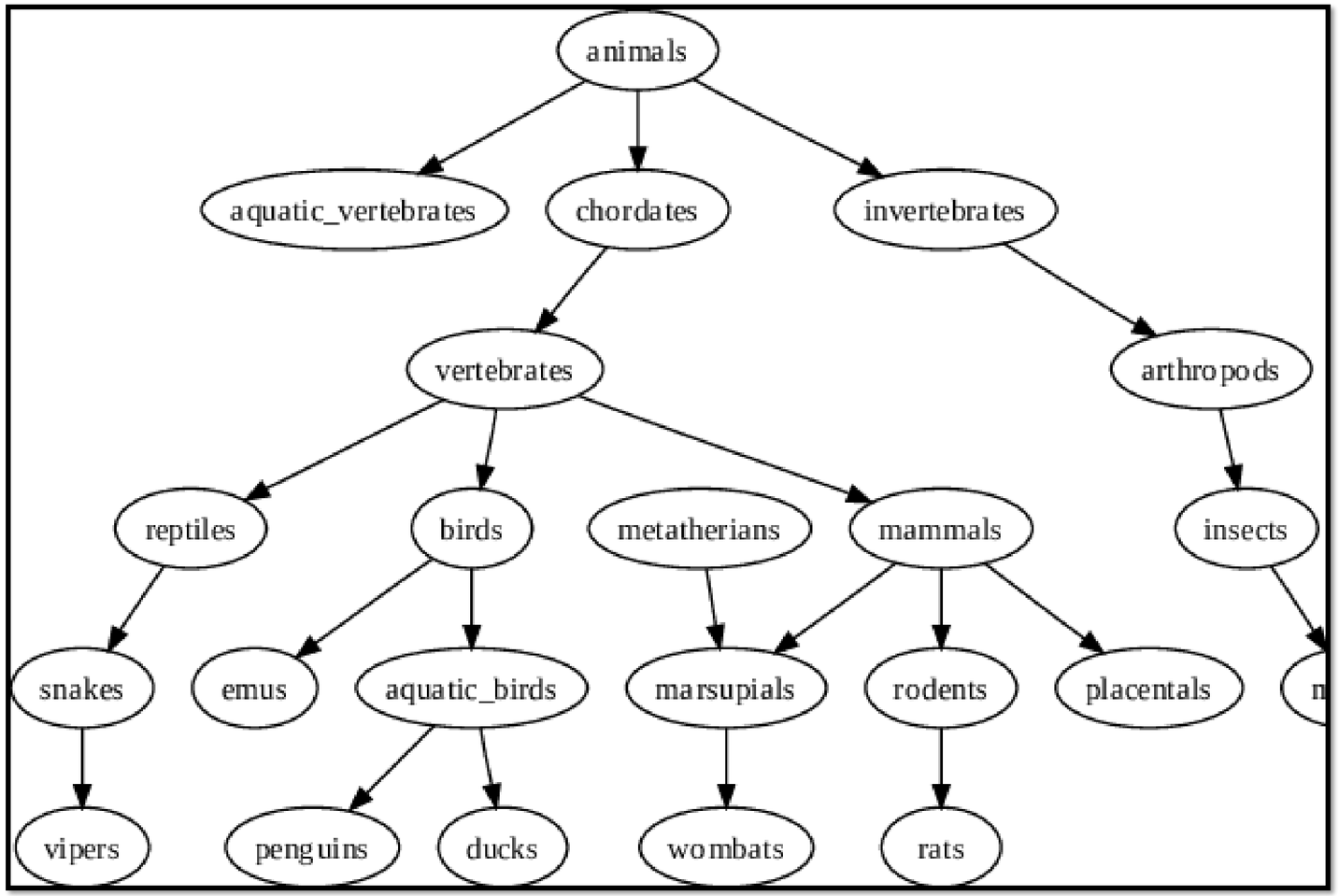
Sample: He reworked the orchestral score for two pianos.

Taxonomy



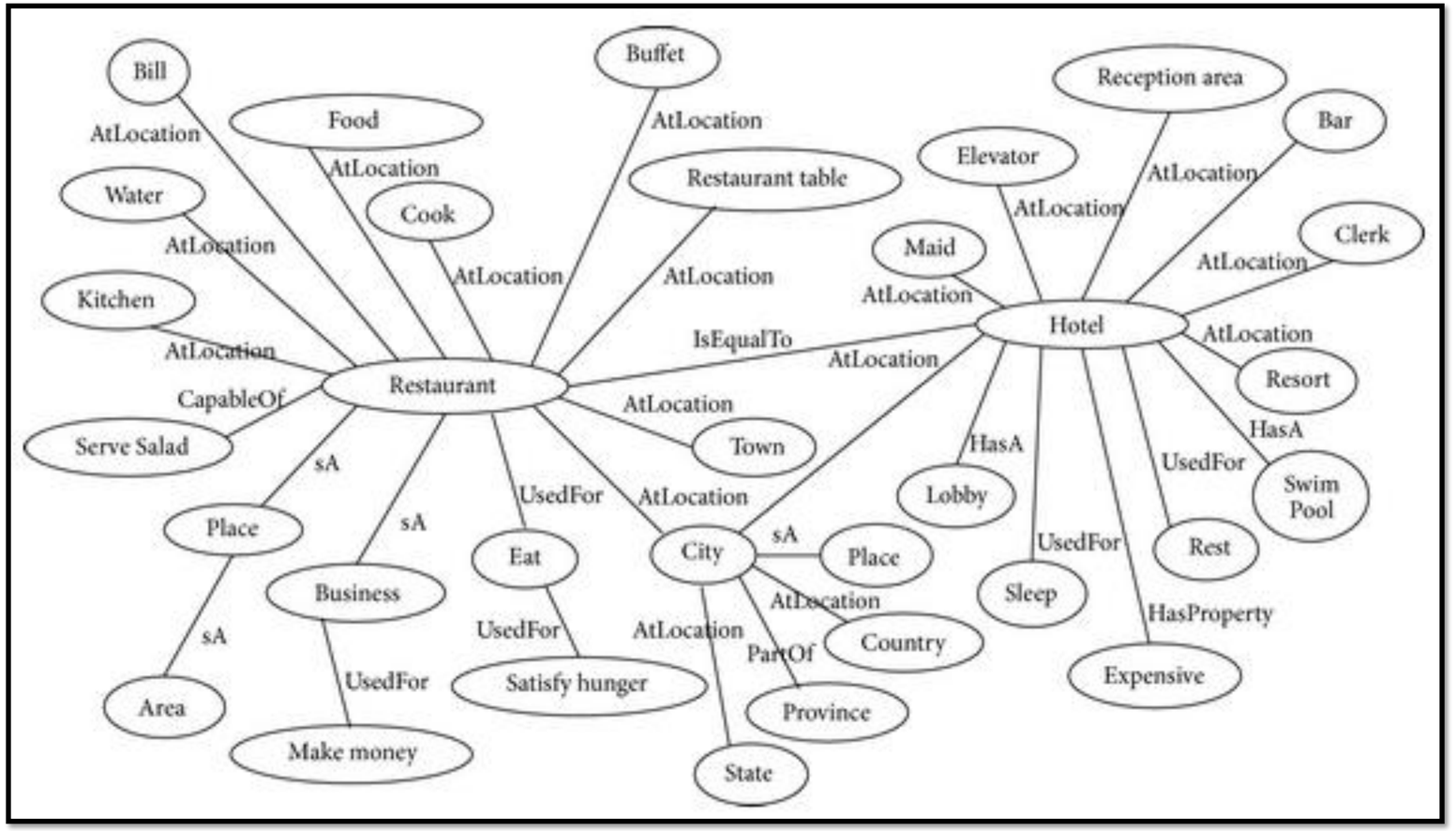
Knowledge based methods

Thesaurus



Knowledge based methods

Ontology



Knowledge based methods

- Thesaurus
- Wordnet
  - WordNet® is a large lexical database of English
  - Nouns, verbs, adjectives and adverbs are grouped into sets of cognitive **synonyms** (**synsets**), each expressing a distinct concept
  - Synsets are interlinked by means of conceptual-semantic and lexical relations

Knowledge based methods

Java

Noun

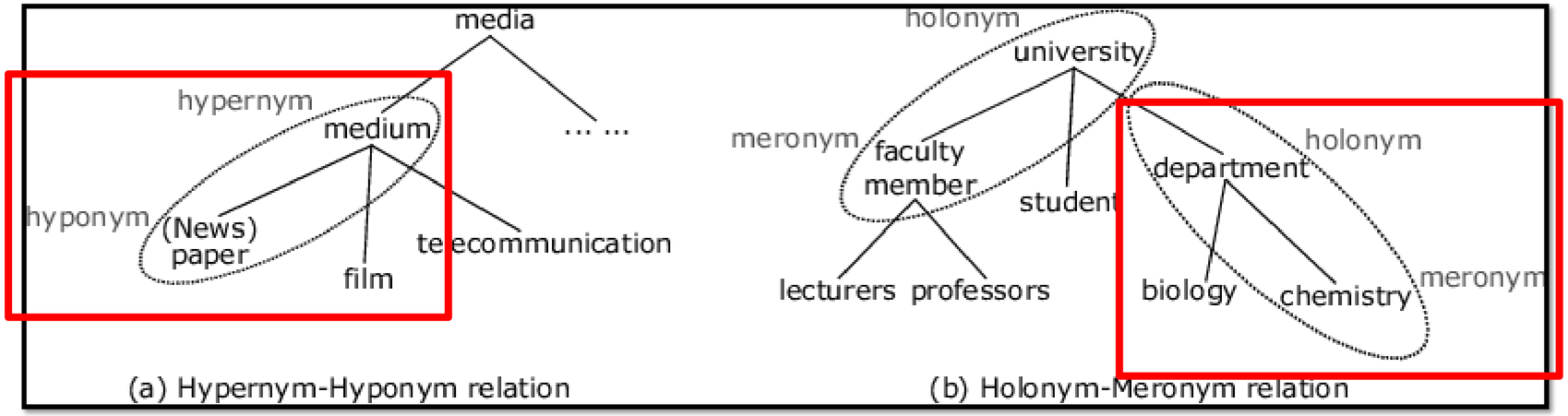
- S: (n) **Java** (an island in Indonesia to the south of Borneo; one of the world's most densely populated regions)
- S: (n) coffee, **java** (a beverage consisting of an infusion of ground coffee beans) *"he ordered a cup of coffee"*
- S: (n) **Java** (a platform-independent object-oriented programming language)

- S: (n) **Java** (a platform-independent object-oriented programming language)
  - ***direct hypernym*** / *inherited hypernym* / *sister term*
    - S: (n) object-oriented programming language, object-oriented programing language ((computer science) a programming language that enables the programmer to associate a set of procedures with each type of data structure) *"C++ is an object-oriented programming language that is an extension of C"*

- S: (n) coffee, **java** (a beverage consisting of an infusion of ground coffee beans) *"he ordered a cup of coffee"*
  - ***direct hyponym*** / *full hyponym*
    - S: (n) coffee substitute (a drink resembling coffee that is sometimes substituted for it)
    - S: (n) Irish coffee (sweetened coffee with Irish whiskey and whipped cream)
    - S: (n) cafe au lait (equal parts of coffee and hot milk)
    - S: (n) cafe noir, demitasse (small cup of strong black coffee without milk or cream)
    - S: (n) decaffeinated coffee, decaf (coffee with the caffeine removed)
    - S: (n) drip coffee (coffee made by passing boiling water through a perforated container packed with finely ground coffee)
    - S: (n) espresso (strong black coffee brewed by forcing hot water under pressure through finely ground coffee beans)
    - S: (n) cappuccino, cappuccino coffee, coffee cappuccino (equal parts of espresso and hot milk topped with cinnamon and nutmeg and usually whipped cream)
    - S: (n) iced coffee, ice coffee (a strong sweetened coffee served over ice with cream)
    - S: (n) instant coffee (dehydrated coffee that can be made into a drink by adding hot water) *"the advantages of instant coffee are speed of preparation and long shelf life"*
    - S: (n) mocha, mocha coffee (a superior dark coffee made from beans from Arabia)
    - S: (n) Turkish coffee (a drink made from pulverized coffee beans; usually sweetened)
    - S: (n) cafe royale, coffee royal (black coffee with Cognac and lemon peel and sugar)

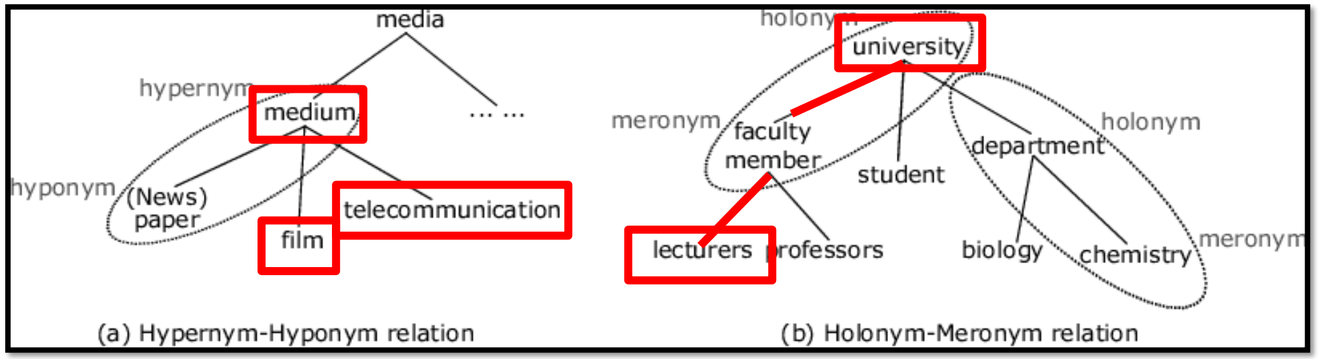
Knowledge based methods

- Semantic relations in Wordnet
  - **Hypernyms**: Y is a hypernym of X if every X is a (kind of) Y (vehicle is a hypernym of bicycle)
  - **Hyponyms**: Y is a hyponym of X if every Y is a (kind of) X (bicycle is a hyponym of vehicle)
  - **Meronym**: Y is a meronym of X if Y is a part of X (window is a meronym of building)
  - **Holonym**: Y is a holonym of X if X is a part of Y (building is a holonym of window)



Knowledge based methods

- How to capture semantic similarity in wordnet?
  - *path* measure
  - *wup* measure



$$sim_{path}(W_1, W_2) = \frac{1}{1 + \min\_length(W_1, W_2)}$$

$$sim_{wup}(W_1, W_2) = \frac{2 \times depth(Least\ Common\ Subsumer)}{depth(W_1) + depth(W_2)}$$

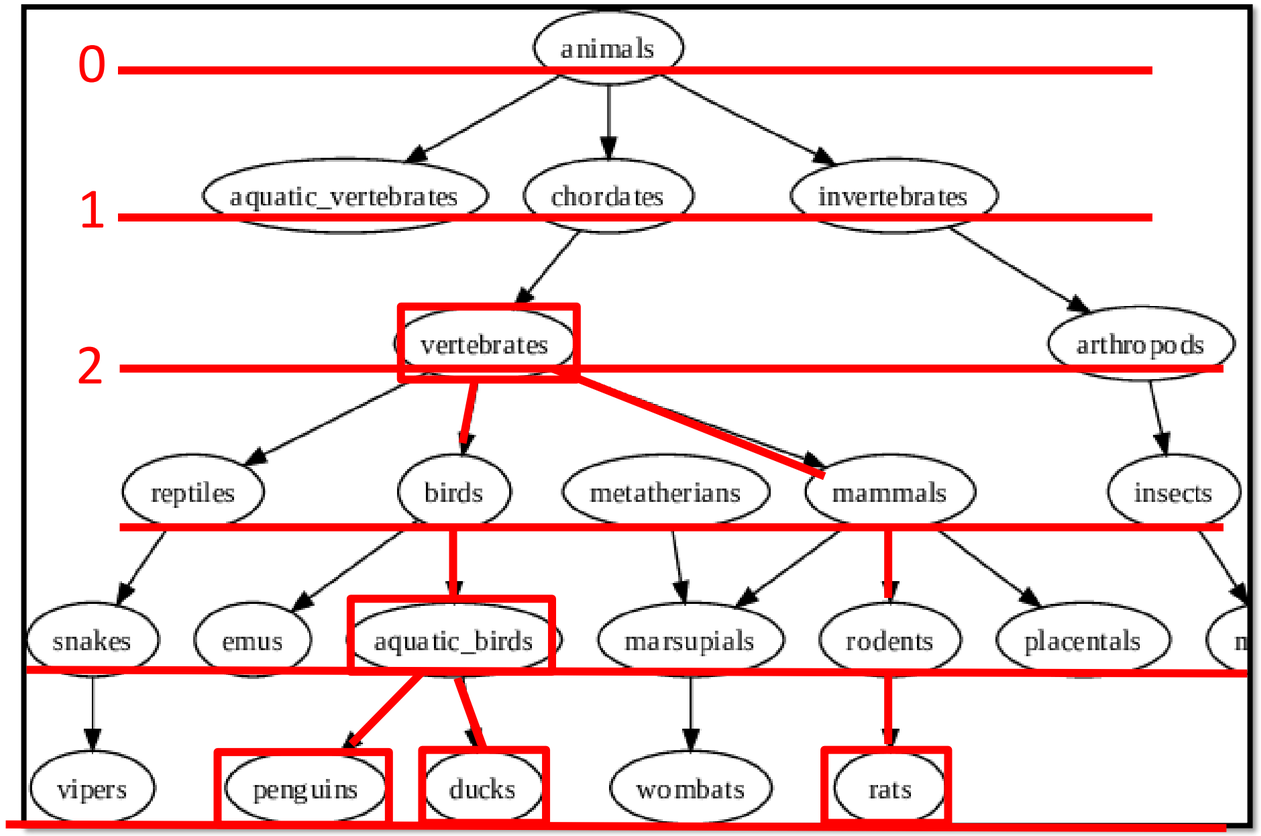
Knowledge based methods

$$sim_{path}(duck, rat) = \frac{1}{7}$$

$$sim_{path}(penguin, duck) = \frac{1}{3}$$

$$sim_{wup}(duck, rat) = \frac{2 \times 2}{5 + 5} = 0.4$$

$$sim_{wup}(penguin, duck) = \frac{2 \times 4}{5 + 5} = 0.8$$

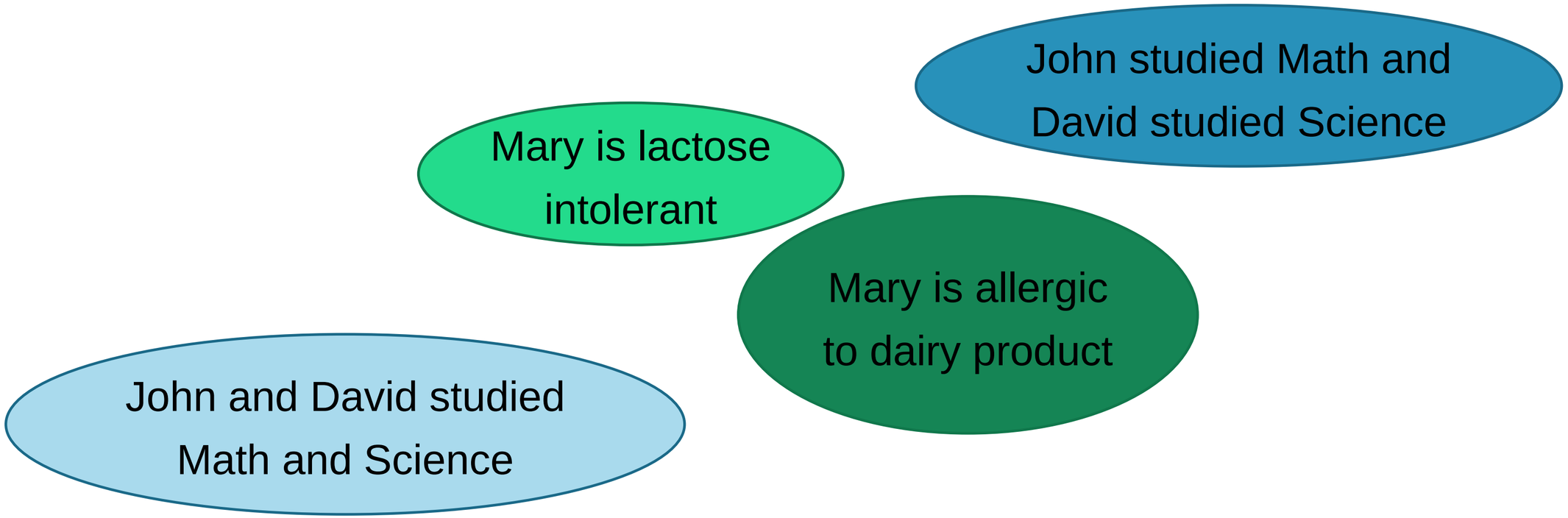


Semantic textual similarity

- What is semantic similarity?
- Semantic similarity in word level
- Semantic similarity in sentence level
- Semantic textual similarity in Python

Semantic similarity in sentence level

- It tells how close two texts (sentences) are, semantically



Semantic similarity in sentence level

- The approaches can be divided into the following categories:
  - Distributional semantics
  - Knowledge based methods

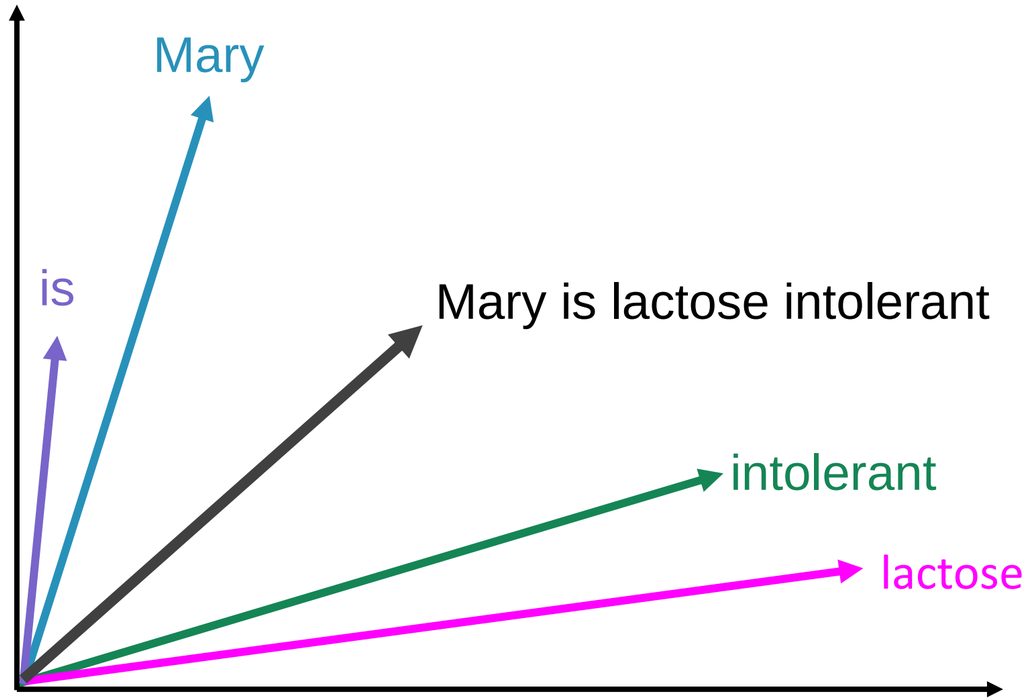
Distributional semantics

- Computing sentence vectors
  - Average of word vectors
  - Average of word vectors with TF-IDF
  - Doc2Vec

Distributional semantics

- Average of word vectors

Mary is lactose intolerant



Distributional semantics

- Average of word vectors

Mary is lactose intolerant

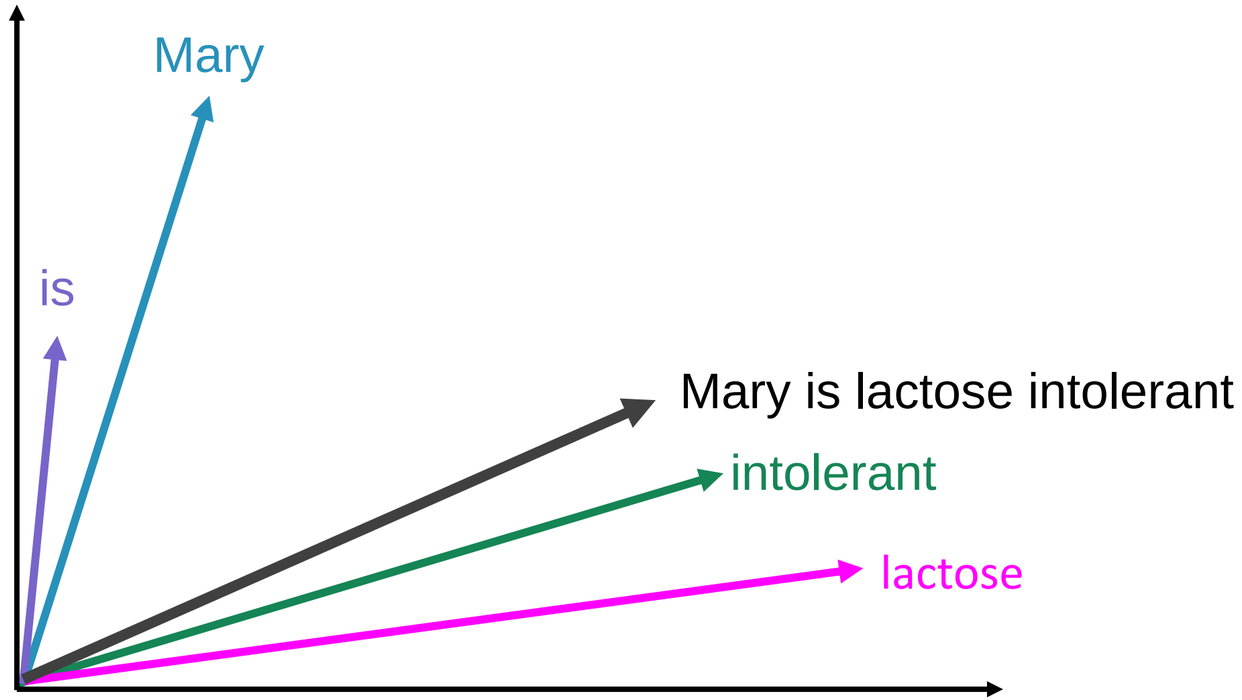
Mary	1	0	1	3	5
is	1	4	2	2	2
lactose	0	3	7	1	1
intolerant	2	1	1	1	2
Sentence	1	2	2.75	1.7	2.5

Distributional semantics

- Average of word vectors with TF-IDF

	TFIDF
Mary	0.5
is	0.1
lactose	5
intolerant	7

Mary is lactose intolerant



Distributional semantics

- Average of word vectors with TF-IDF

Mary is lactose intolerant

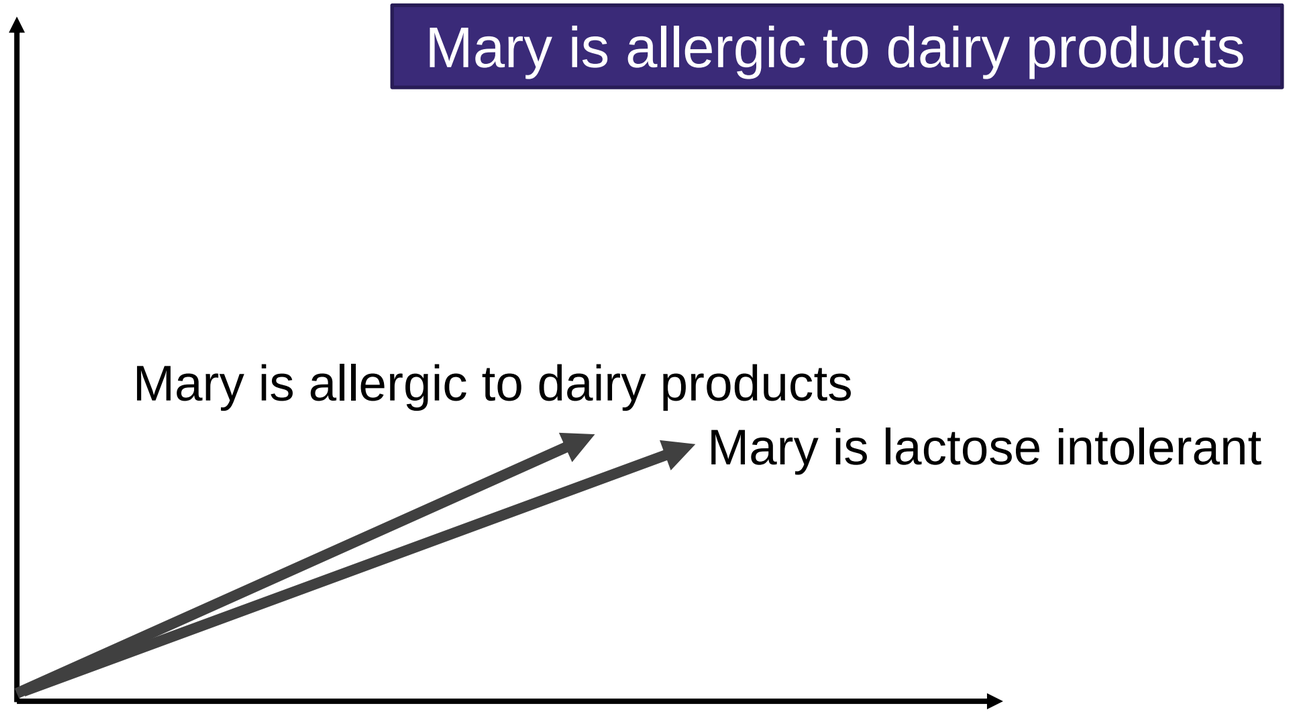
	TF-IDF					
Mary	0.5	1	0	1	3	5
is	0.1	1	4	2	2	2
lactose	5	0	3	7	1	1
intolerant	7	2	1	1	1	2
Sentence	-	1.15	1.93	3.30	1.15	1.74

Distributional semantics

- Cosine similarity

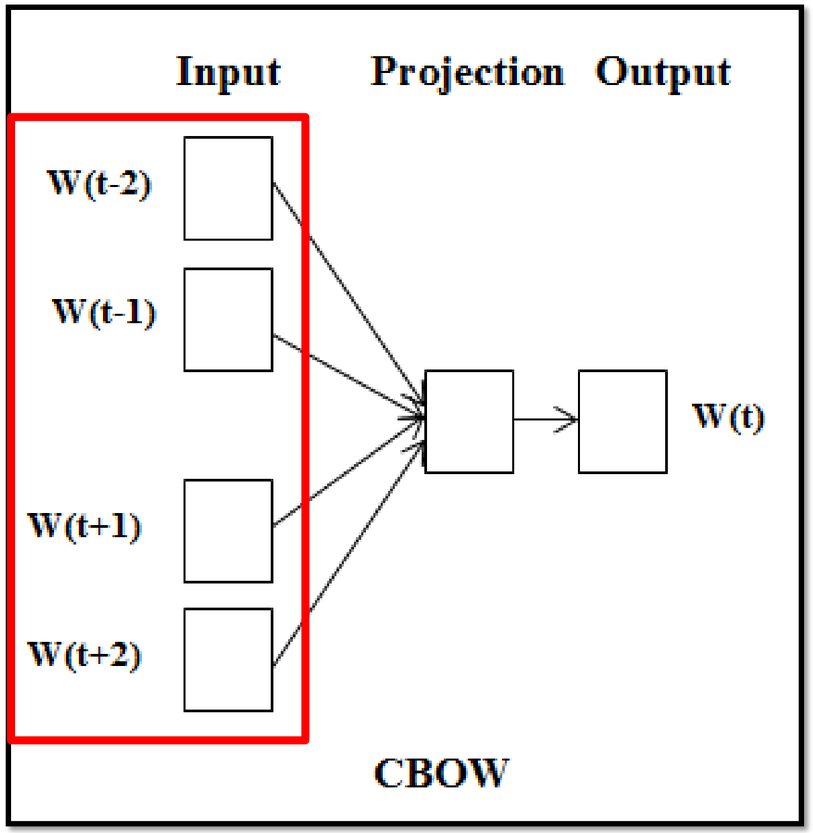
Mary is lactose intolerant

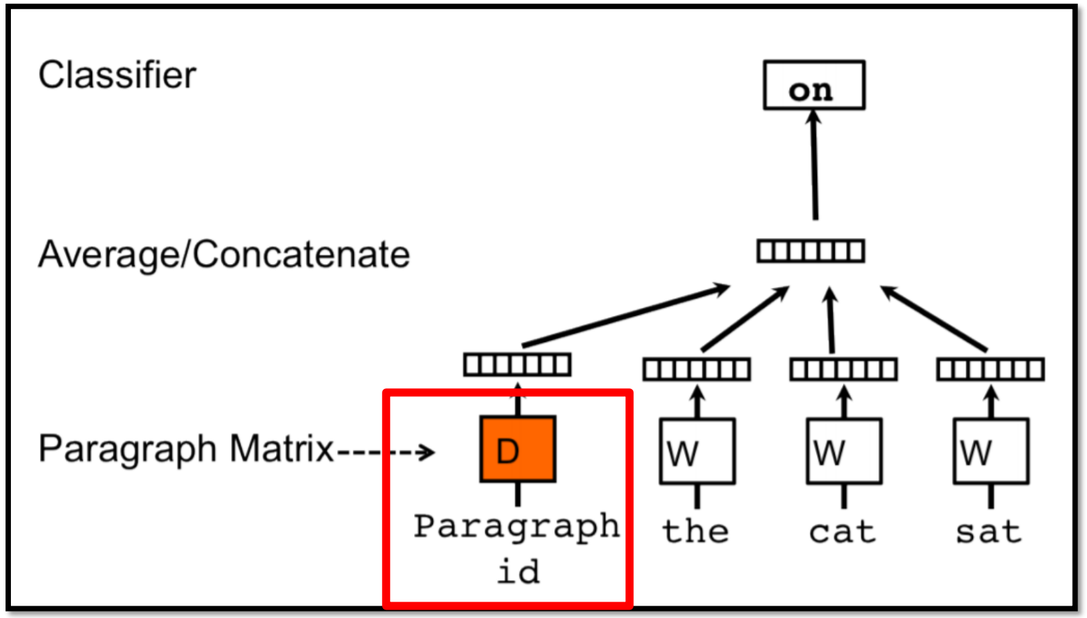
Mary is allergic to dairy products



Distributional semantics

- Doc2Vec



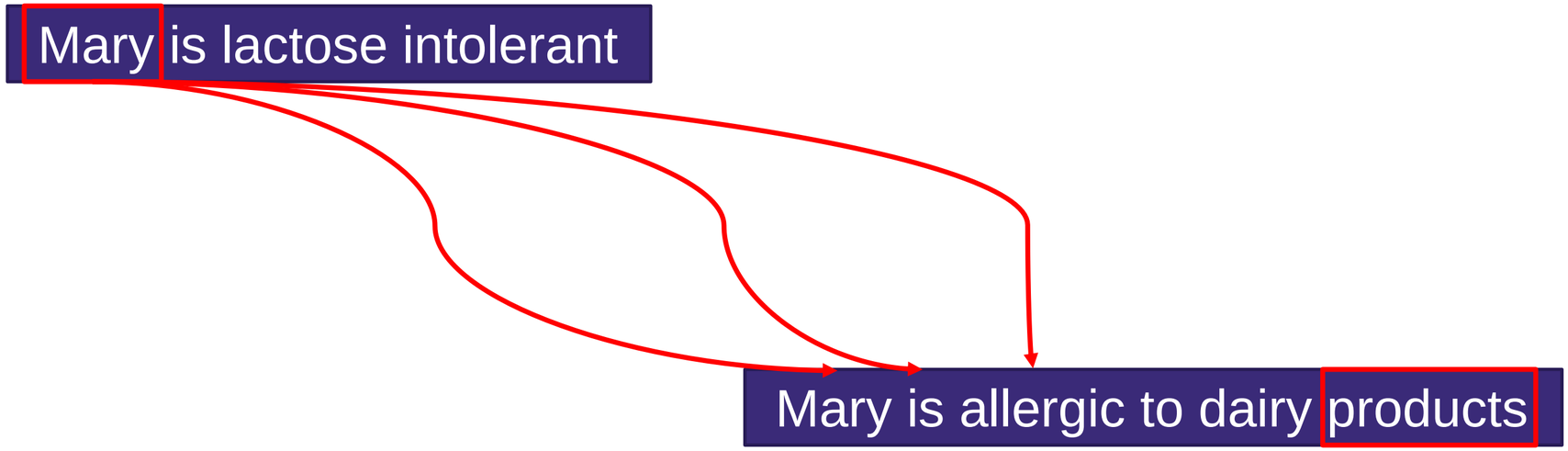


Distributional semantics

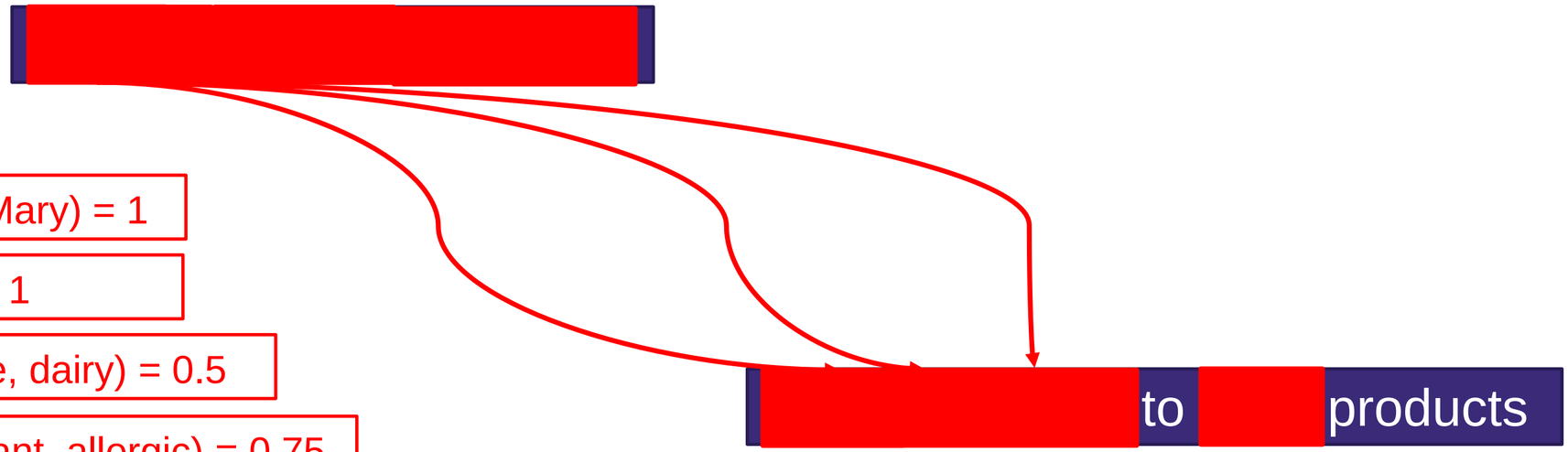
- Doc2Vec

Mary is lactose intolerant	0.112	0.091	0.357	…	- 0.483	0.249	0.747
Mary is allergic to dairy products	0.818	0.343	0.108	…	- 0.777	- 0.310	0.314

Knowledge based methods



Knowledge based methods



Sim(Mary,Mary) = 1

Sim(is,is) = 1

Sim(lactose, dairy) = 0.5

Sim(intolerant, allergic) = 0.75

$Sim(S_1, S_2) = ave(sim) = 0.81$

Semantic textual similarity

- What is semantic similarity?
- Semantic similarity in word level
- Semantic similarity in sentence level
- Semantic textual similarity in Python

NLTK

- Wordnet synset

```
>>> from nltk.corpus import wordnet
>>> wordnet.synsets('dog')
[Synset('dog.n.01'), Synset('frump.n.01'), Synset('dog.n.03'),
Synset('cad.n.01'), Synset('frank.n.02'), Synset('pawl.n.01'),
Synset('andiron.n.01'), Synset('chase.v.01')]
>>> print(wordnet.synset('dog.n.01').definition())
a member of the genus Canis (probably descended from the common
wolf) …
```

Noun

- S: (n) **Java** (an island in Indonesia to the south of Borneo; one of the world's most densely populated regions)
- S: (n) coffee, **java** (a beverage consisting of an infusion of ground coffee beans) *"he ordered a cup of coffee"*
- S: (n) **Java** (a platform-independent object-oriented programming language)

NLTK

- Wordnet similarity

```
>>> from nltk.corpus import wordnet
>>> dog = wordnet.synset('dog.n.01’)
>>> cat = wordnet.synset('cat.n.01’)
>>> print(dog.path_similarity(cat))
0.2
>>> dog.wup_similarity(cat)
0.85
```

Gensim

- Doc2Vec

```
>>> from gensim.test.utils import common_texts
>>> from gensim.models.doc2vec import Doc2Vec, TaggedDocument
>>> documents = [TaggedDocument(doc, [i]) for i, doc in
        enumerate(common_texts)]
>>> print(documents[0])
TaggedDocument(['human', 'interface', 'computer'], [0])
>>> model = Doc2Vec(documents, vector_size=5)
>>> vector = model.infer_vector([“semantic", “text“, ”similarity”])
>>> print(vector)
[-0.07941077, -0.0955774, -0.06963827, -0.02995487, 0.09318832]
```

Summary

- Semantic textual similarity (STS) deals with determining how similar two pieces of texts are

John and David studied Math and Science.

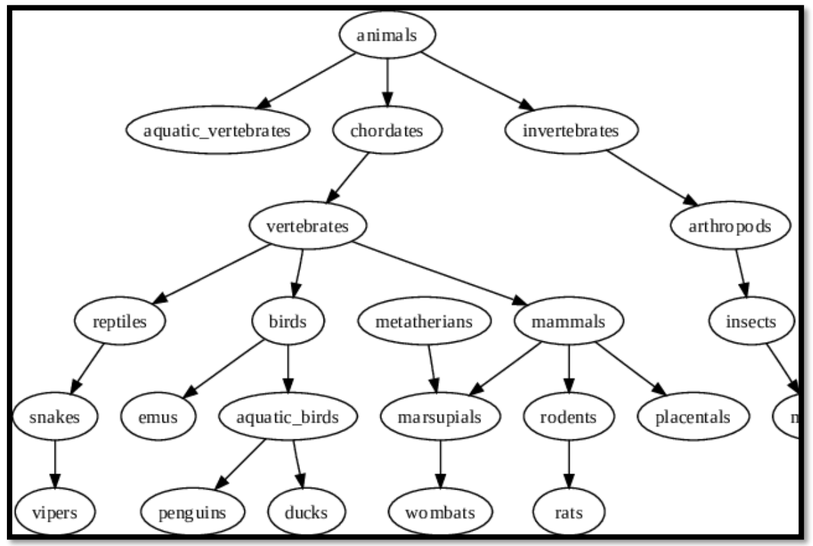
≠

John studied Math and David studied Science.

Mary is allergic to dairy products. = Mary is lactose intolerant.

Summary

- Semantic similarity in word level
  - Distributional semantics
    - Frequency based
    - Prediction based
  - Knowledge based methods



Dictionary (word list)
- Closed list of words
- Ambiguity control

Taxonomy
- Collection of terms
- Ambiguity control
- Hierarchical relationship

Thesaurus
- Networked collection of terms
- Ambiguity control
- Hierarchical relationship
- Associative relationship

Ontology
- Networked collection of terms
- Ambiguity control
- Hierarchical relationship
- Semantic relationship

Summary

- Semantic similarity in sentence level
  - Average of word vectors
  - Average of word vectors with TF-IDF
  - Doc2Vec
  - Knowledge based methods