

Explicit Semantic Analysis

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The ocean of text



Web pages

Emails

Blogs

Tweets

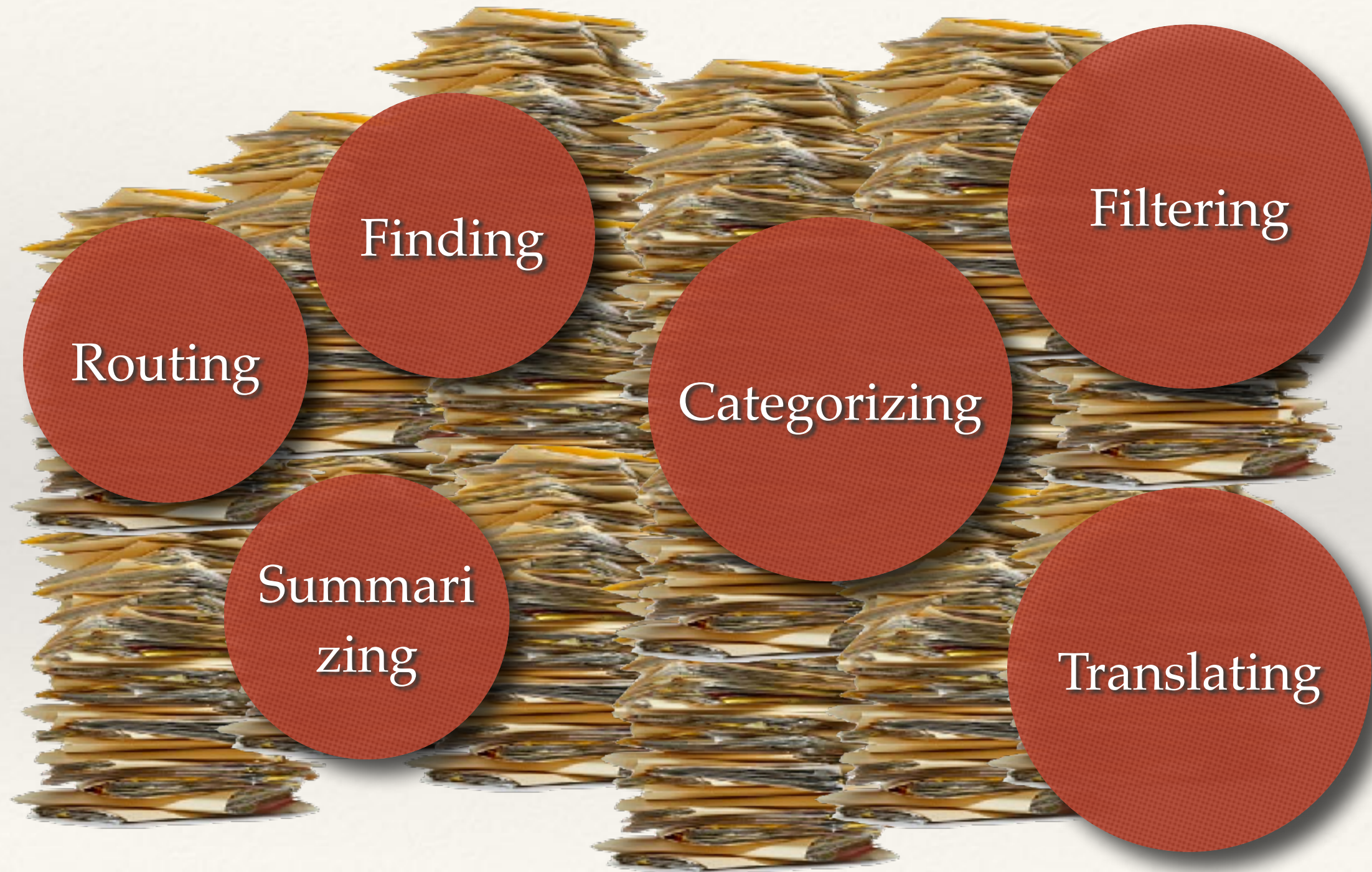
News stories

Digital books

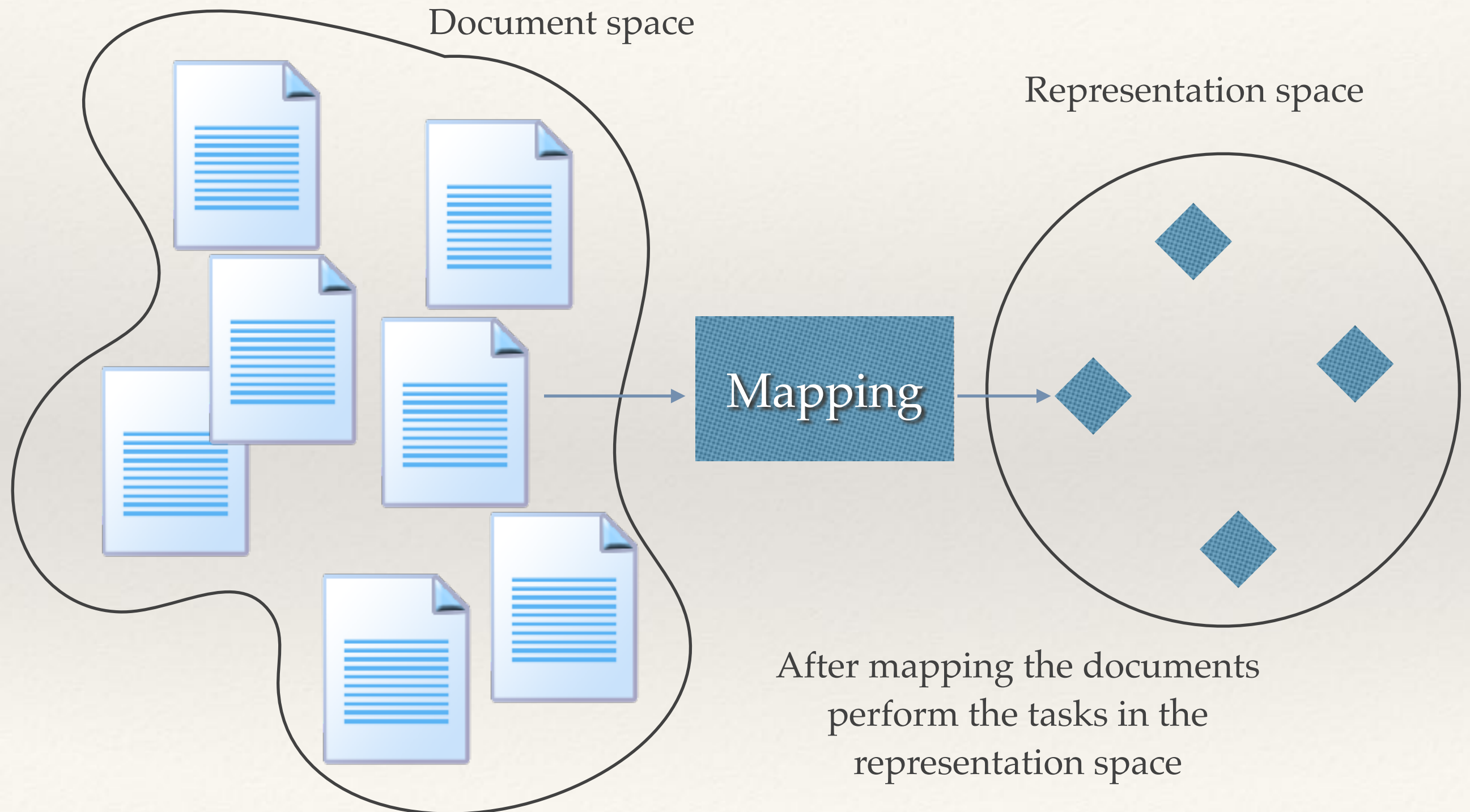
SMS messages

Facebook posts

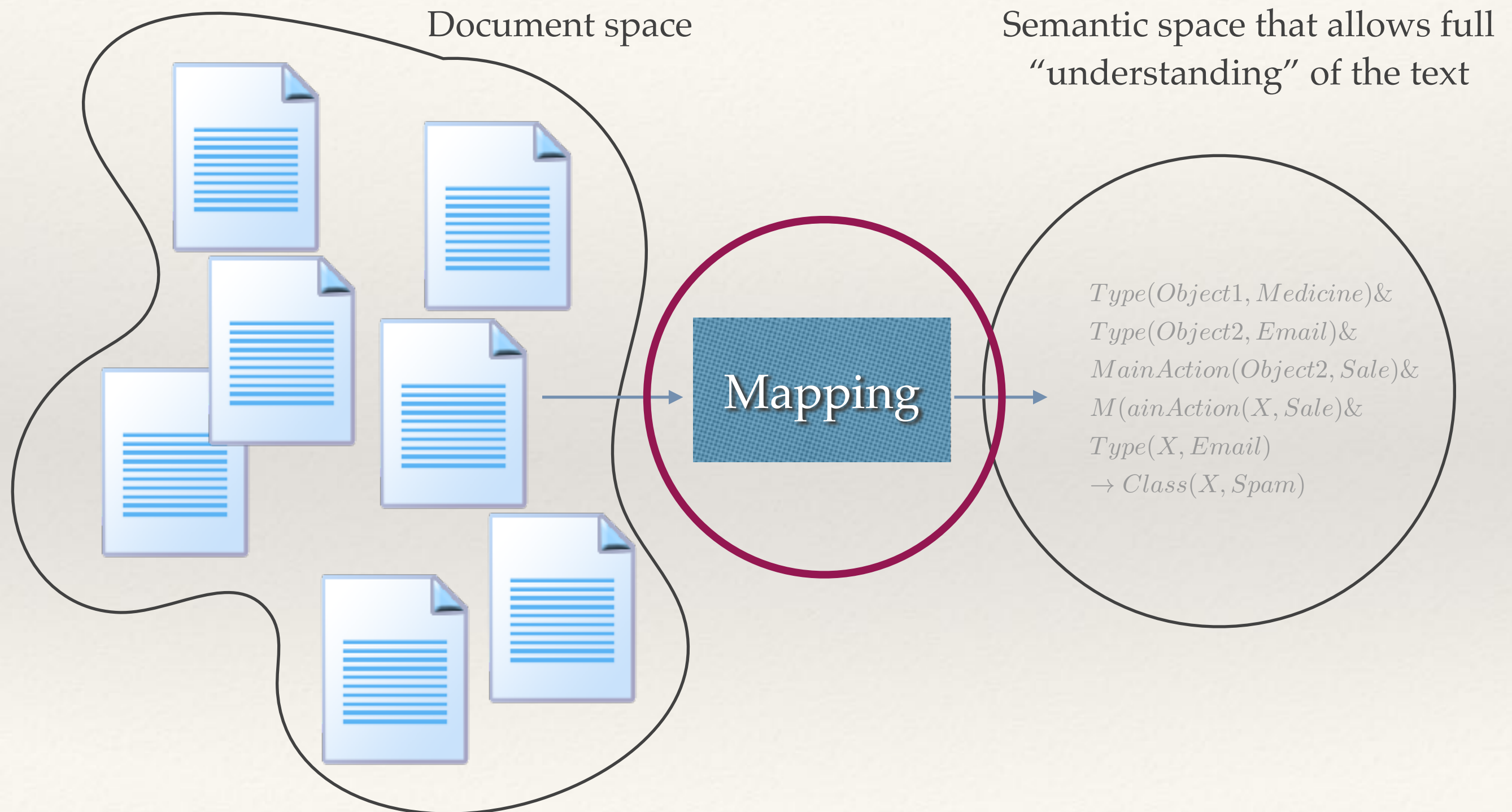
Processing Texts



General approach - representation space



Ideal approach – full semantics



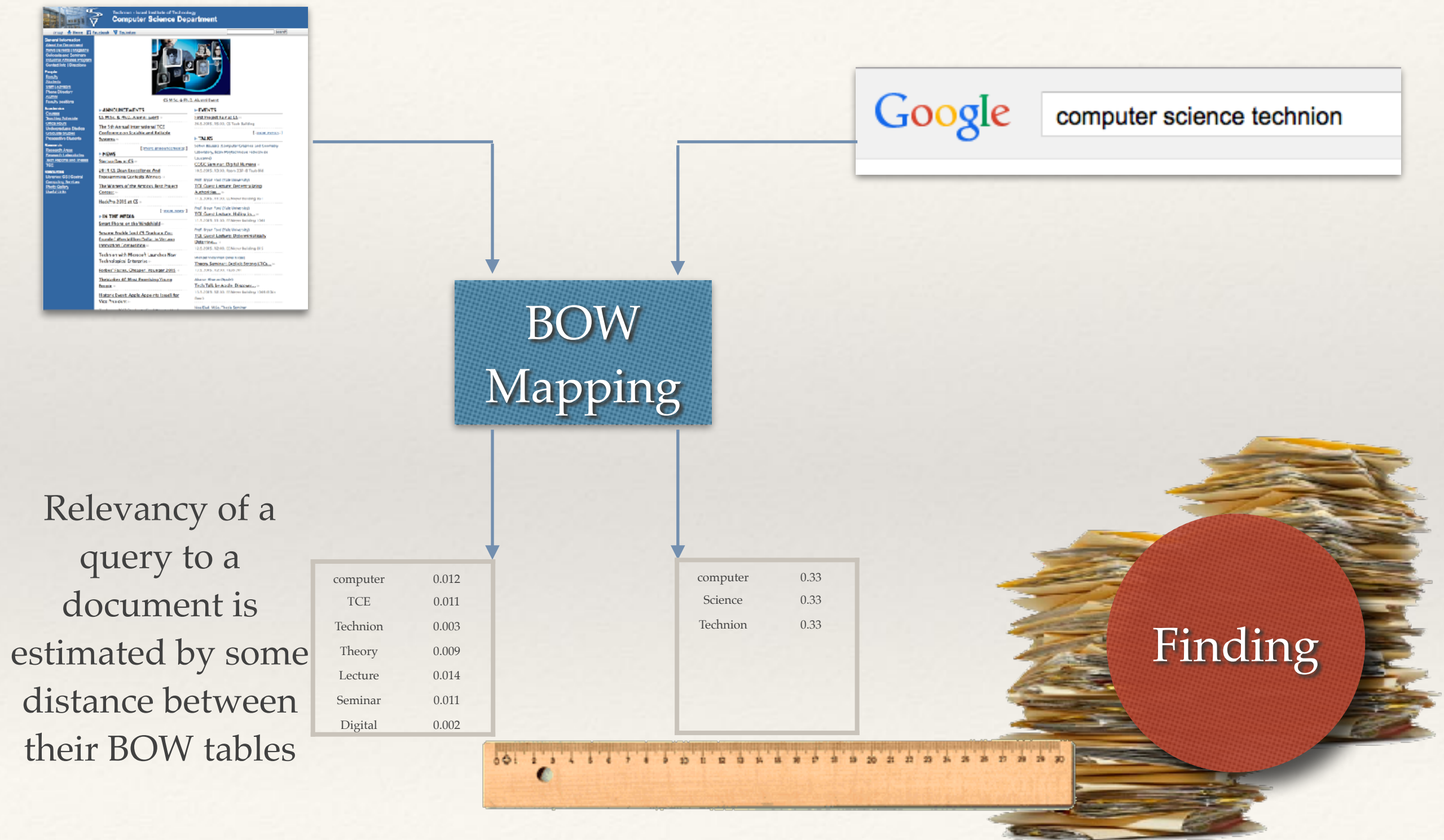
Most common approach: BOW representation



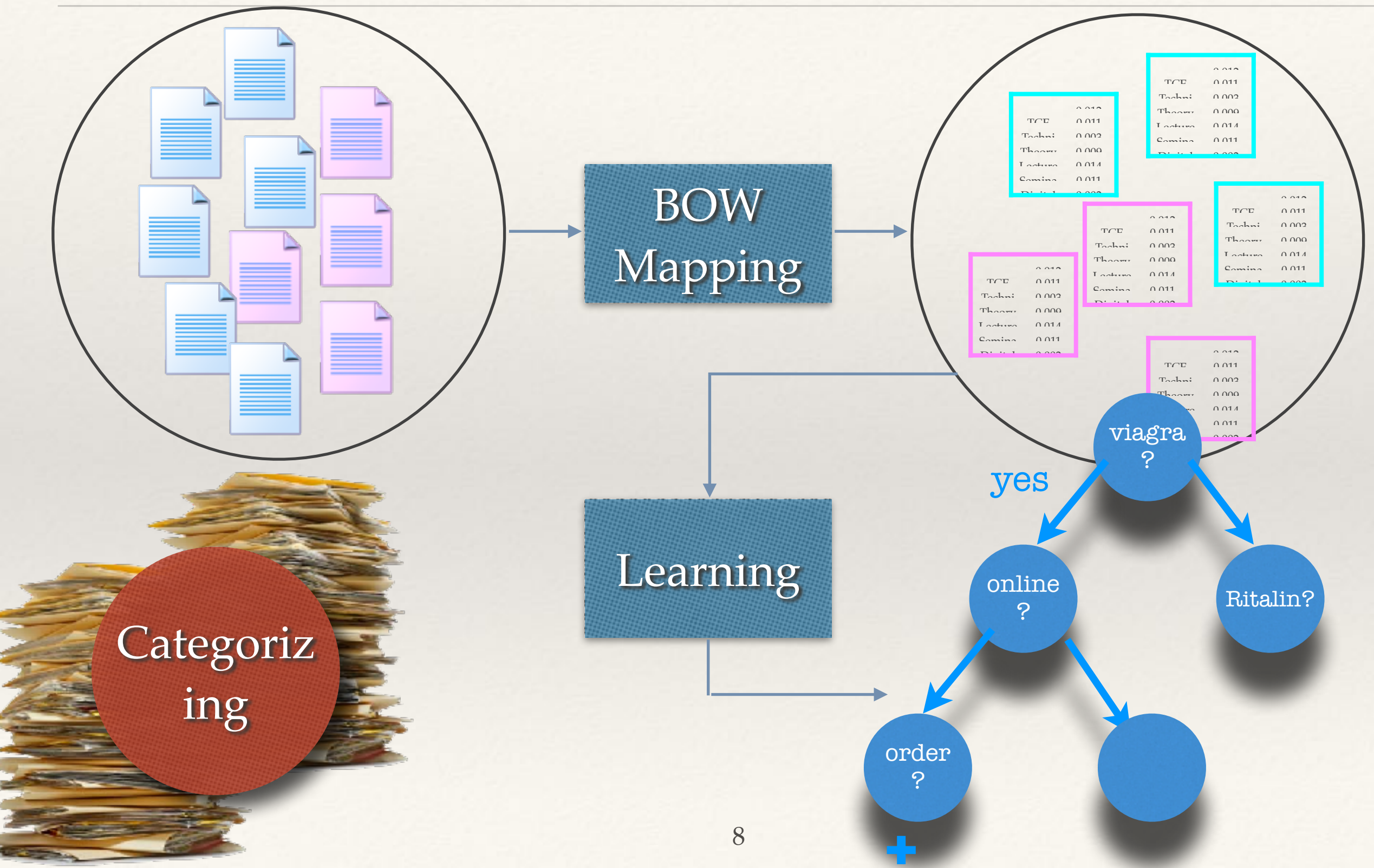
computer	0.012
TCE	0.011
Technion	0.003
Theory	0.009
Lecture	0.014
Seminar	0.011
Digital	0.002

A document is represented as a table of (normalized) words' frequency

Working in the BOW space: Finding



Working in the BOW space: Categorizing



Advantages and Disadvantages of BOW

	BOW	
Universal (allow automatic mapping of any text)	✓	
Language independent	X	
Easy estimation of semantic distance	✓	
Support for polysemy and synonymy	X	
Encompasses common-sense knowledge	X	
Allow full understanding	X	
Automatically generated	✓	

How about full semantics?

	Full Semantics
Universal (allow automatic mapping of any text)	X
Language independent	✓
Easy estimation of semantic distance	✓
Support for polysemy and synonymy	✓
Encompasses common-sense knowledge	✓
Allow full understanding	✓
Automatically generated	X

Can we design something in between?

	BOW		Full Semantics
Universal (allow automatic mapping of any text)	✓		X
Language independent	X		✓
Easy estimation of semantic distance	✓	?	✓
Support for polysemy and synonymy	X		✓
Encompasses common-sense knowledge	X		✓
Allow full understanding	X		✓
Automatically generated	✓		X

Explicit Semantic Analysis (ESA)

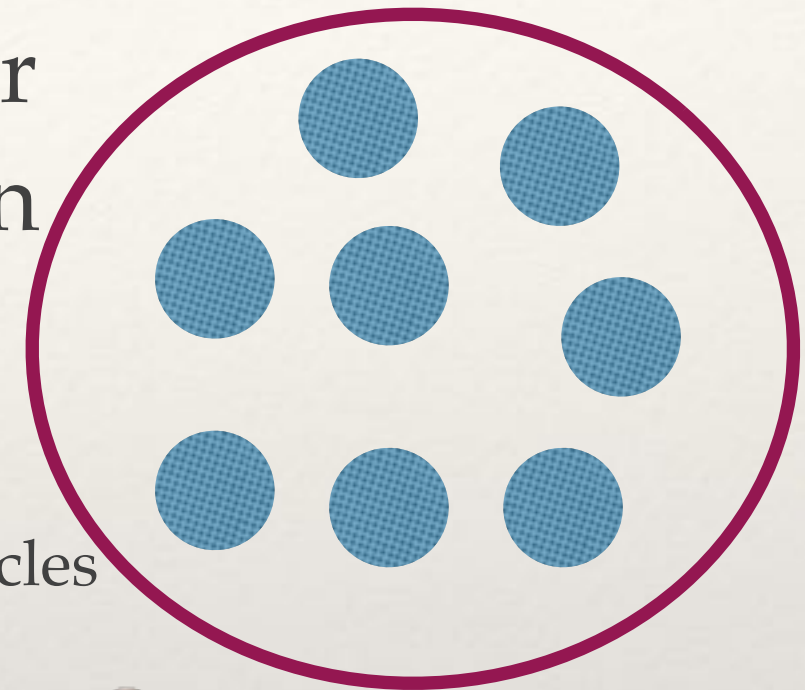
	BOW	ESA	Full Semantics
Universal (allow automatic mapping of any text)	✓	✓	X
Language independent	X	✓	✓
Easy estimation of semantic distance	✓	✓	✓
Support for polysemy and synonymy	X	✓	✓
Encompasses common-sense knowledge	X	✓	✓
Allow full understanding	X	X	✓
Automatically generated	✓	✓	X



ESA Semantics

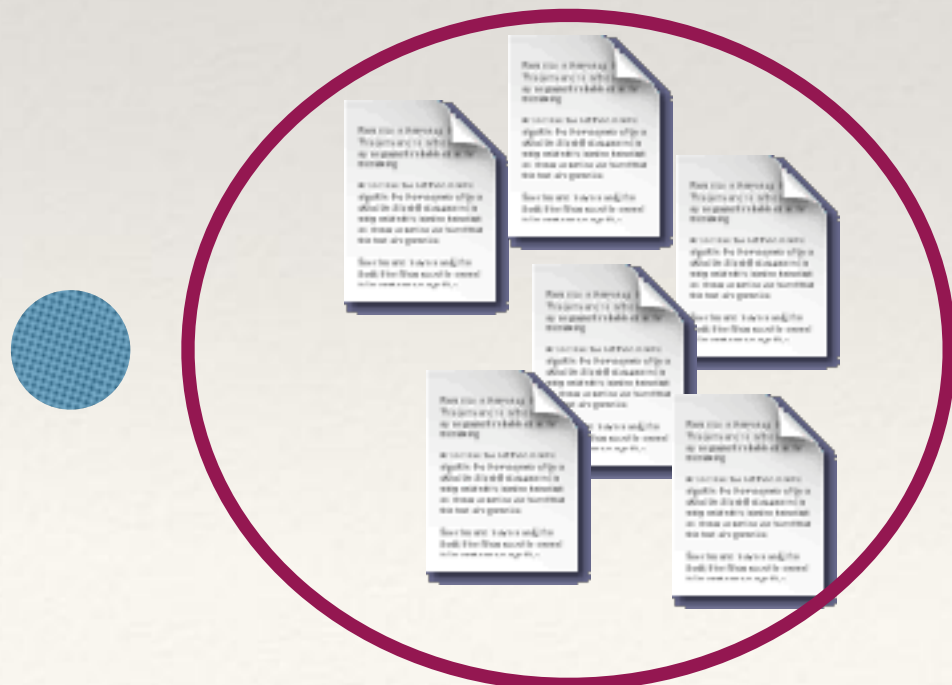
Ingredients

An ontology: A flat or hierarchical collection of concepts



Wikipedia articles

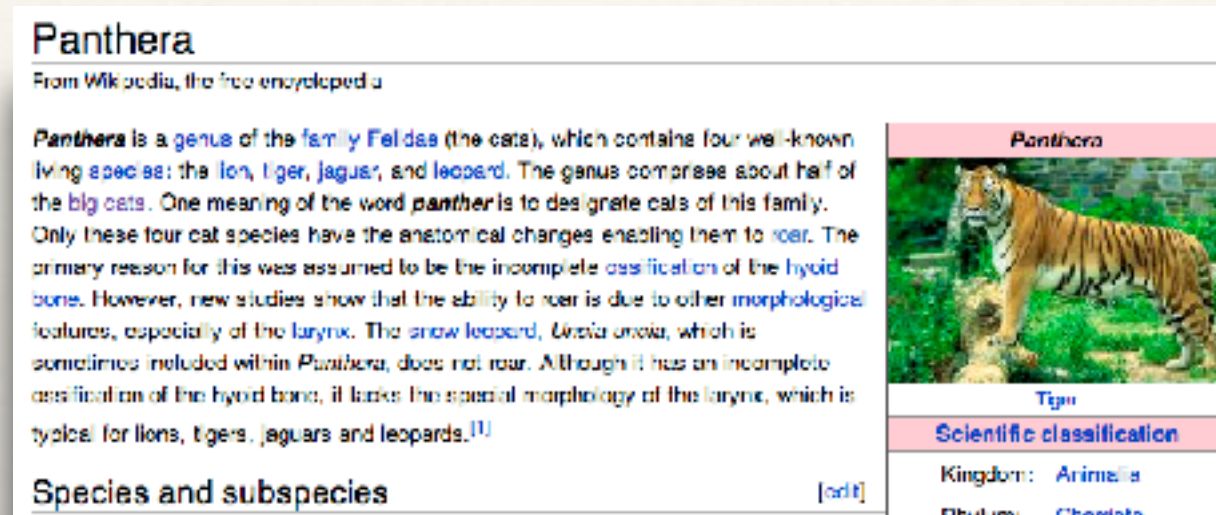
A collection of textual documents associated with each concept



Wikipedia text



Every Wikipedia article represents a **concept**



A wikipedia
article

A concept

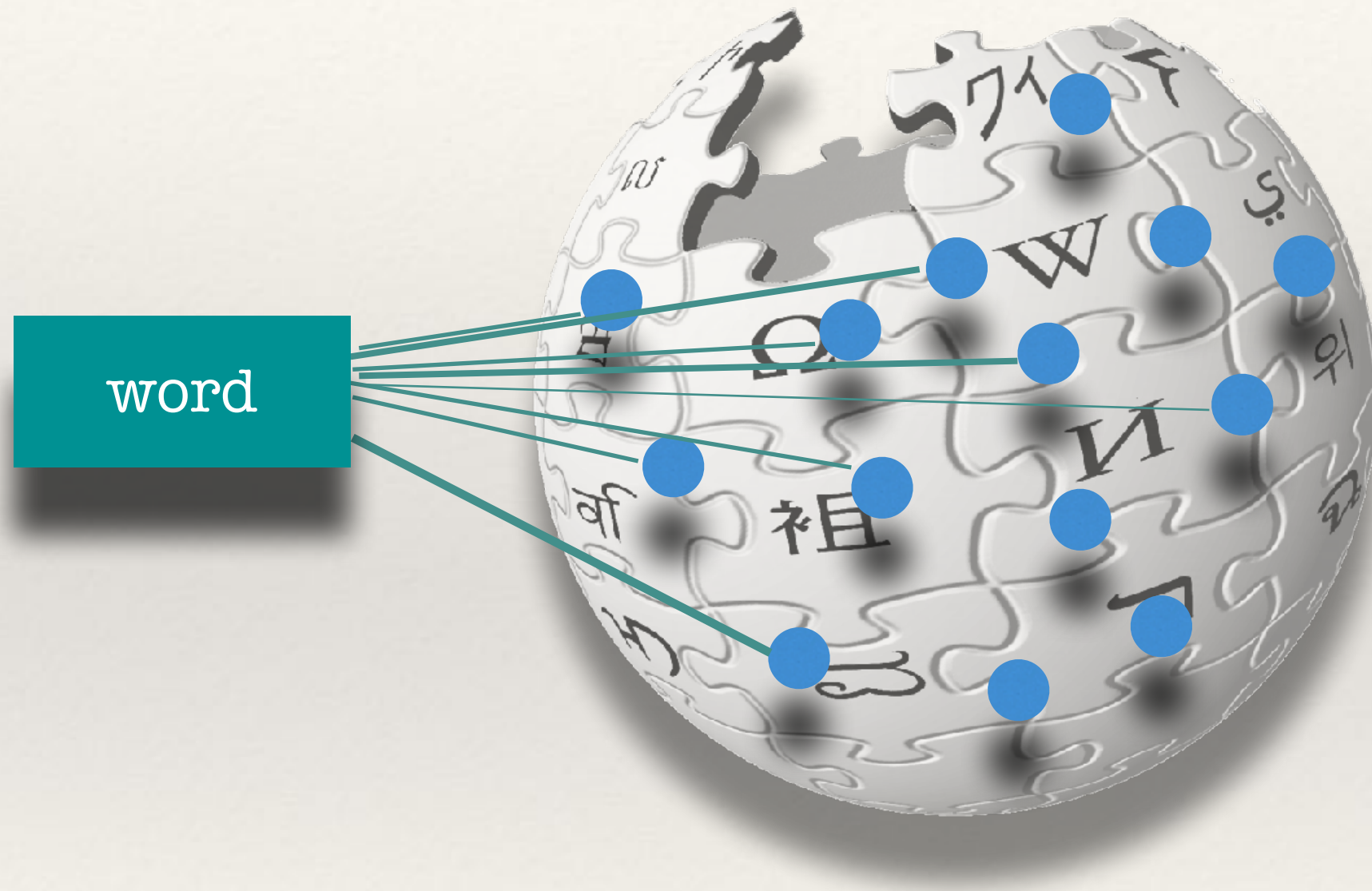
Panthera

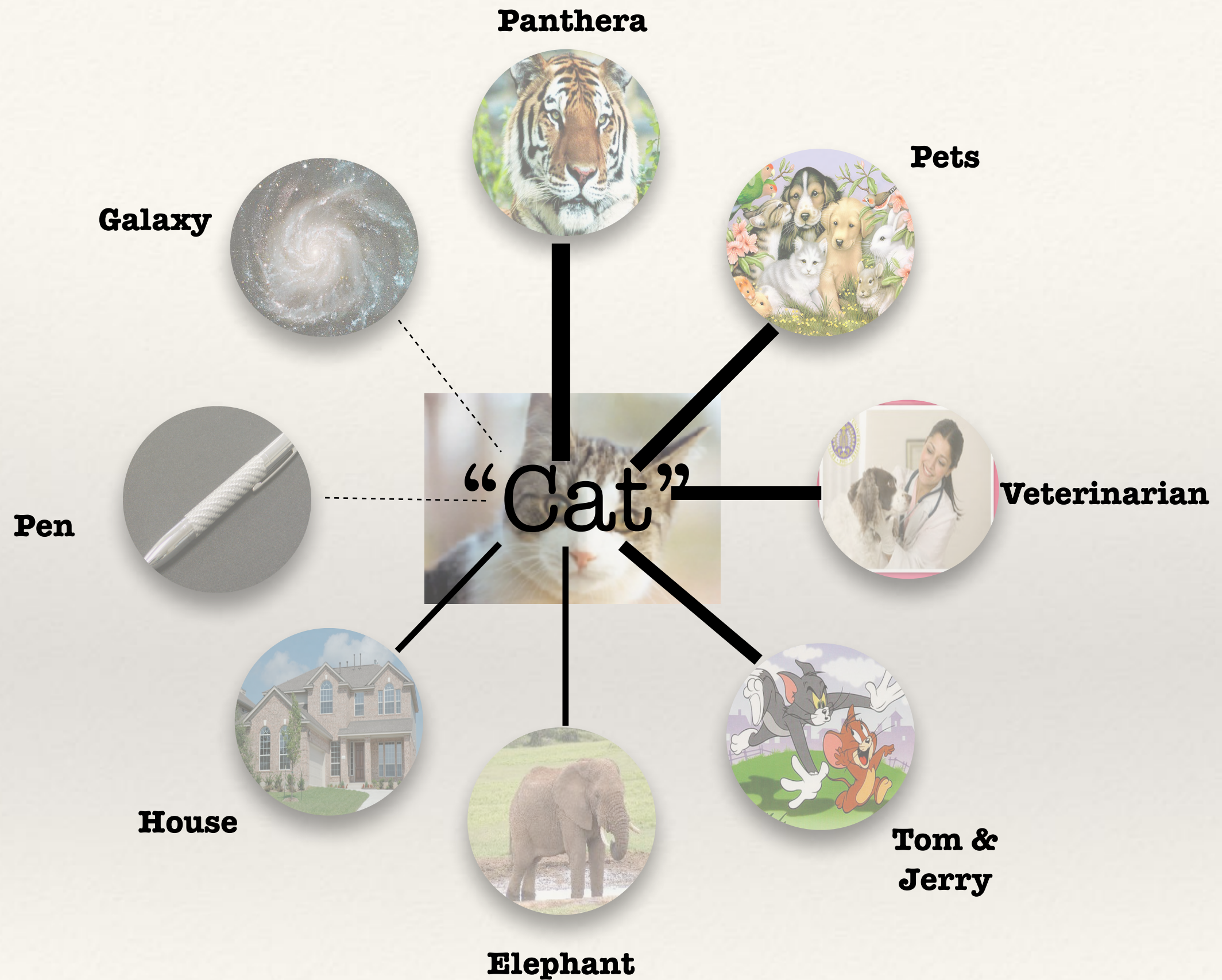
Wikipedia can be viewed as an **ontology** — a collection of concepts



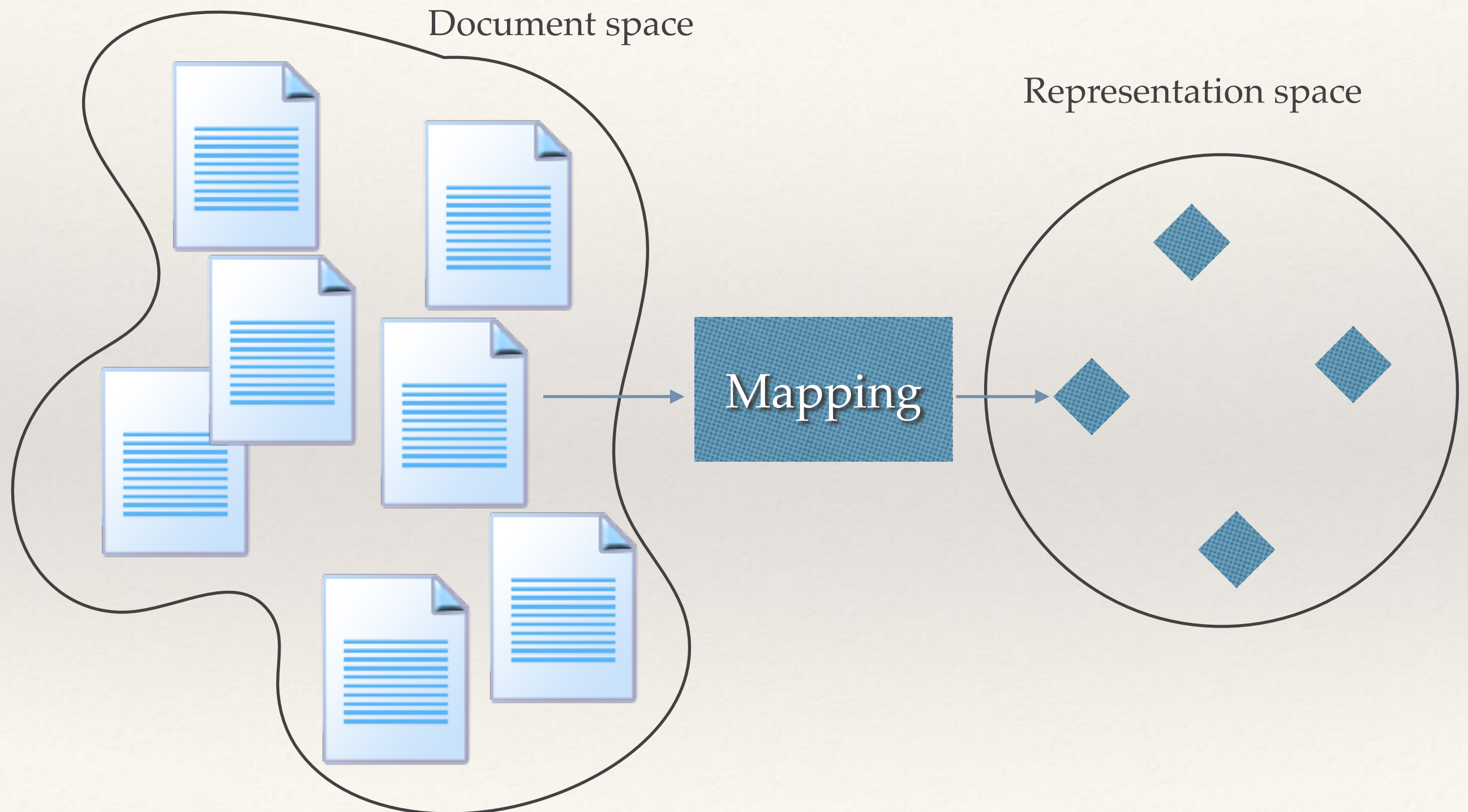
Note that our semantic atoms, the concepts, are language independent - the title can be replaced by an arbitrary ID

The **semantics** of a word is the vector of its **associations** with Wikipedia concepts





Building the mapping function - the ESA interpreter



Building ESA interpreter for a single word

input: a word

output: a vector of
weights over
wikipedia concepts





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A word is strongly associated with a concept if its normalized frequency in the texts associated with the concept is high


Panthera

From Wikipedia, the free encyclopedia

Panthera is a **genus** of the family **Felidae** (the cats), which contains four well-known living **species**: the lion, tiger, jaguar, and leopard. The genus comprises about half of the **big cats**. One meaning of the word **panther** is to designate cats of this family. Only these four cat species have the anatomical changes enabling them to **roar**. The primary reason for this was assumed to be the incomplete ossification of the hyoid bone. However, new studies show that the ability to roar is due to other morphological features, especially of the larynx. The snow leopard, *Uncia uncia*, which is sometimes included within *Panthera*, does not roar. Although it has an incomplete ossification of the hyoid bone, it lacks the special morphology of the larynx, which is typical for lions, tigers, jaguars and leopards.^[1]

Species and subspecies [edit]

Panthera

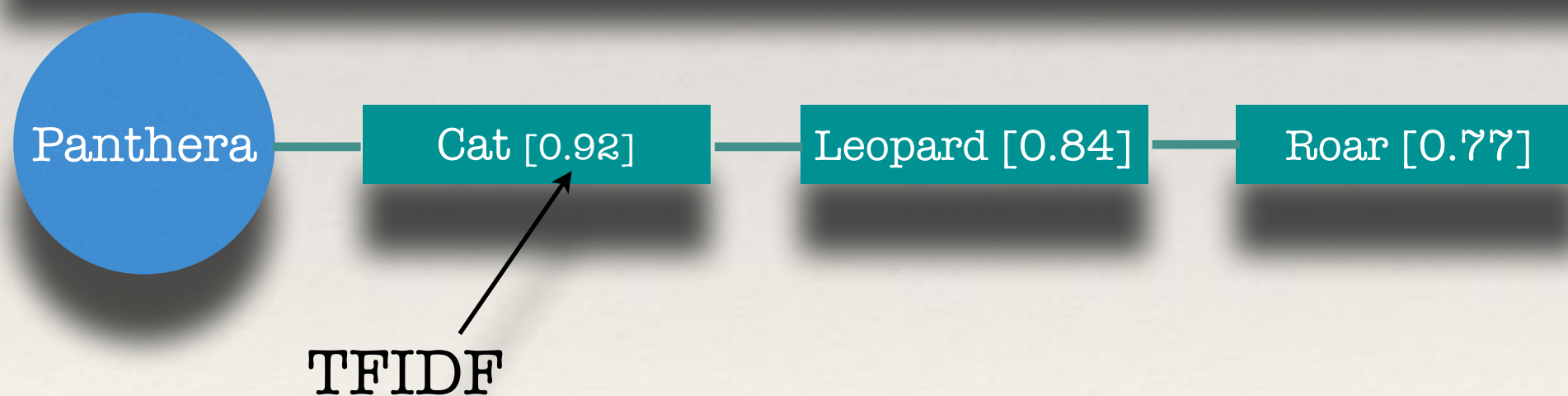


Tiger

Scientific classification

Kingdom: **Animalia**

Phylum: **Chordata**



Cat

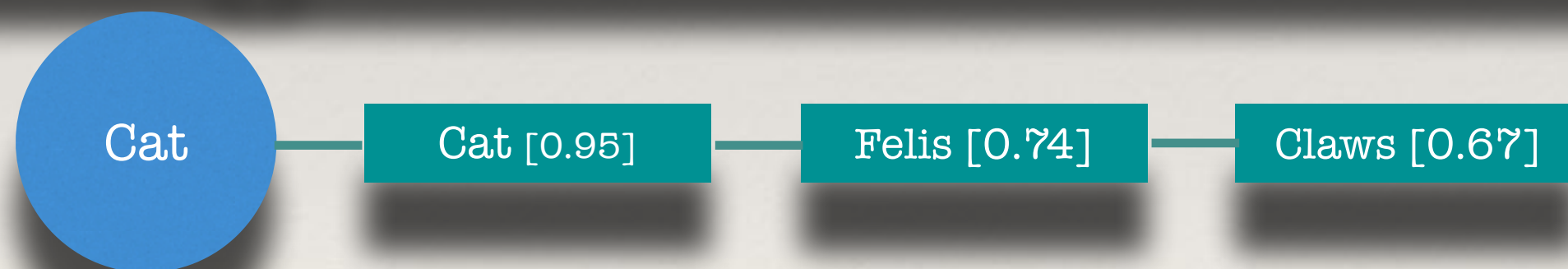
From Wikipedia, the free encyclopedia

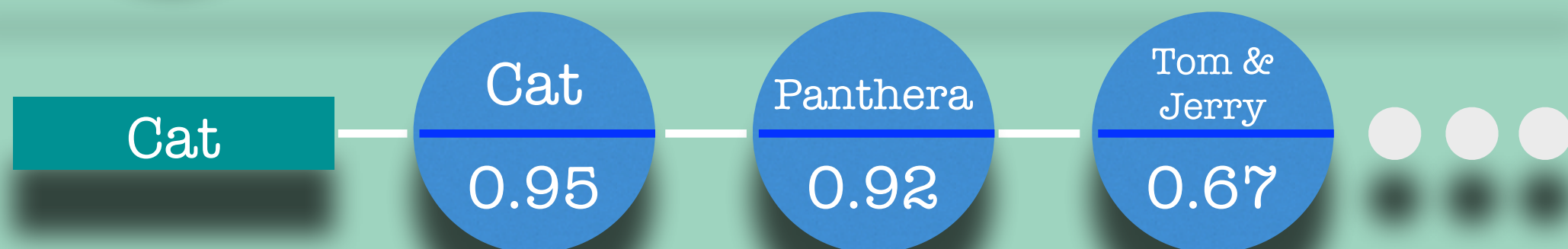
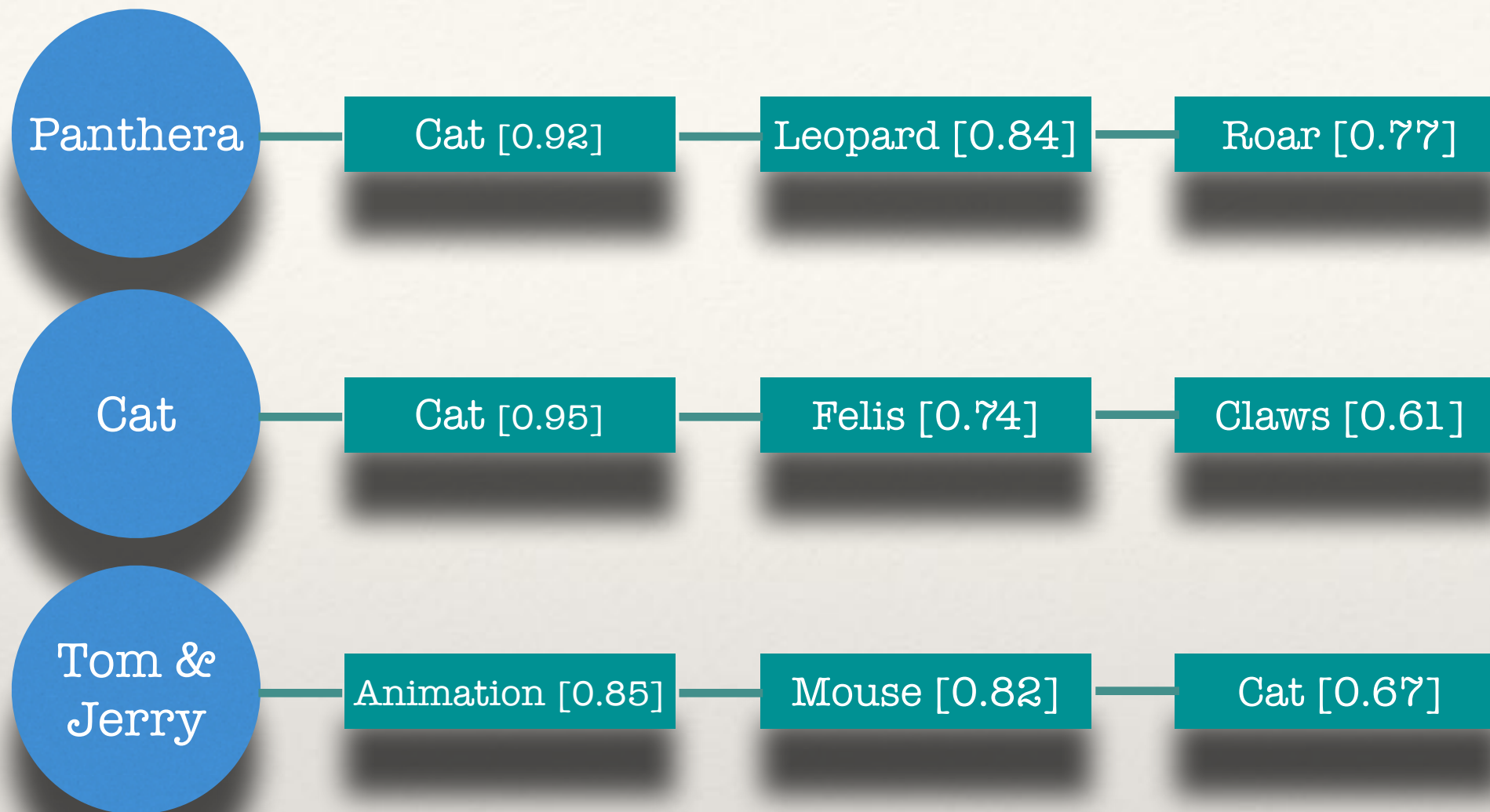
This article is about domestic felines. For other uses, see [Cat \(disambiguation\)](#).

The **cat** (or **domestic cat**, **house cat**) is a small **carnivorous mammal**. It is valued by **humans** for its companionship and its ability to destroy **vermin**. A skilled **predator**, the **cat** is known to hunt over 1,000 species for food. Intelligent, the **cat** can be trained to obey simple commands, and has been known to teach itself to manipulate simple mechanisms (see **cat intelligence**).

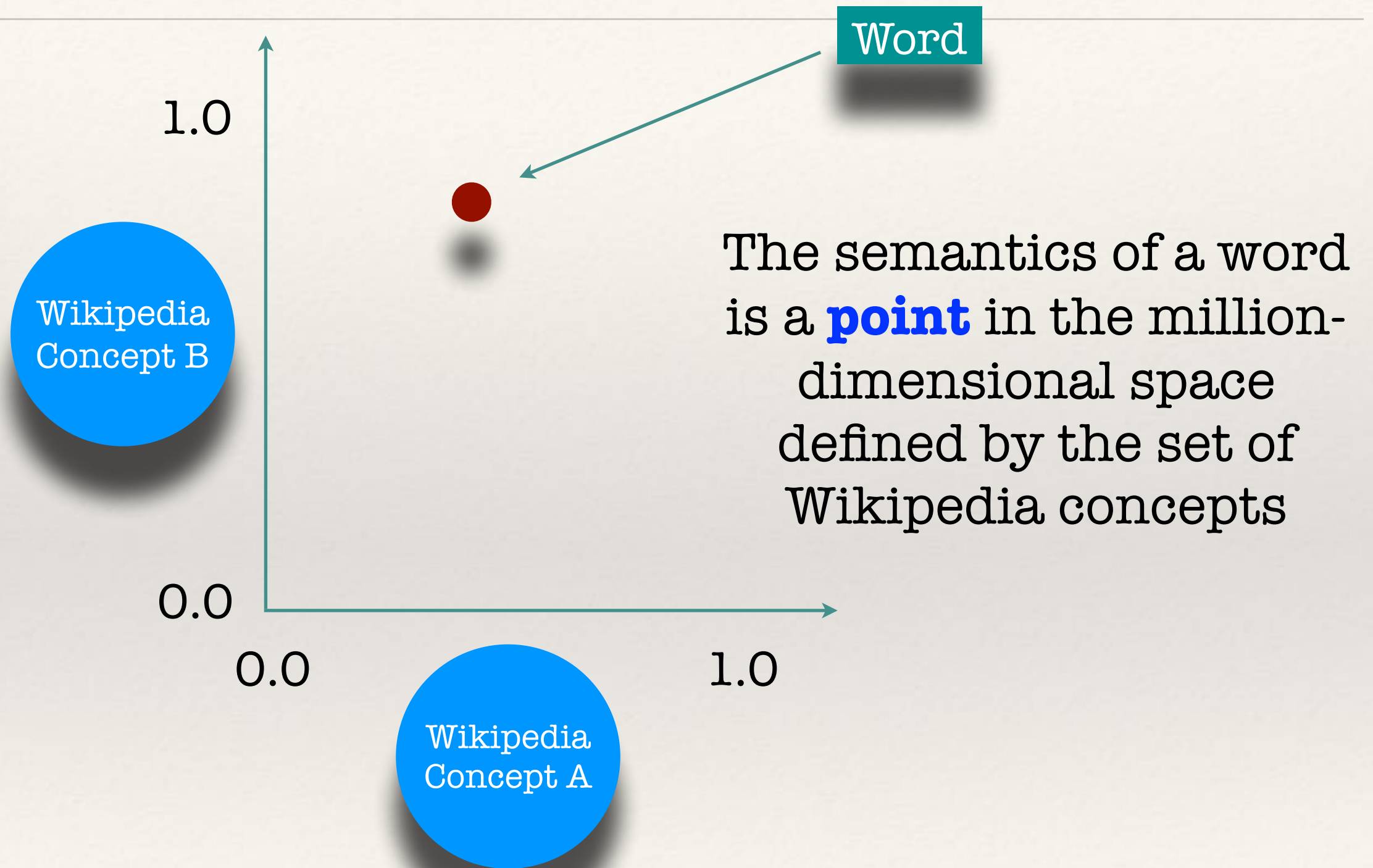
The **trinomial name** of the domestic **cat** is ***Felis silvestris catus***. Its closest pre-domesticated ancestor is believed to be the **African wild cat**, ***Felis silvestris lybica***.^[1] Humans have developed **several dozen breeds** of **cat**, in a variety of colours.

Cats have lived in close association with humans for at least 9,500 years. The Egyptians believed that slim **cats** brought good luck.^[2] ^[3]





The semantics of a word



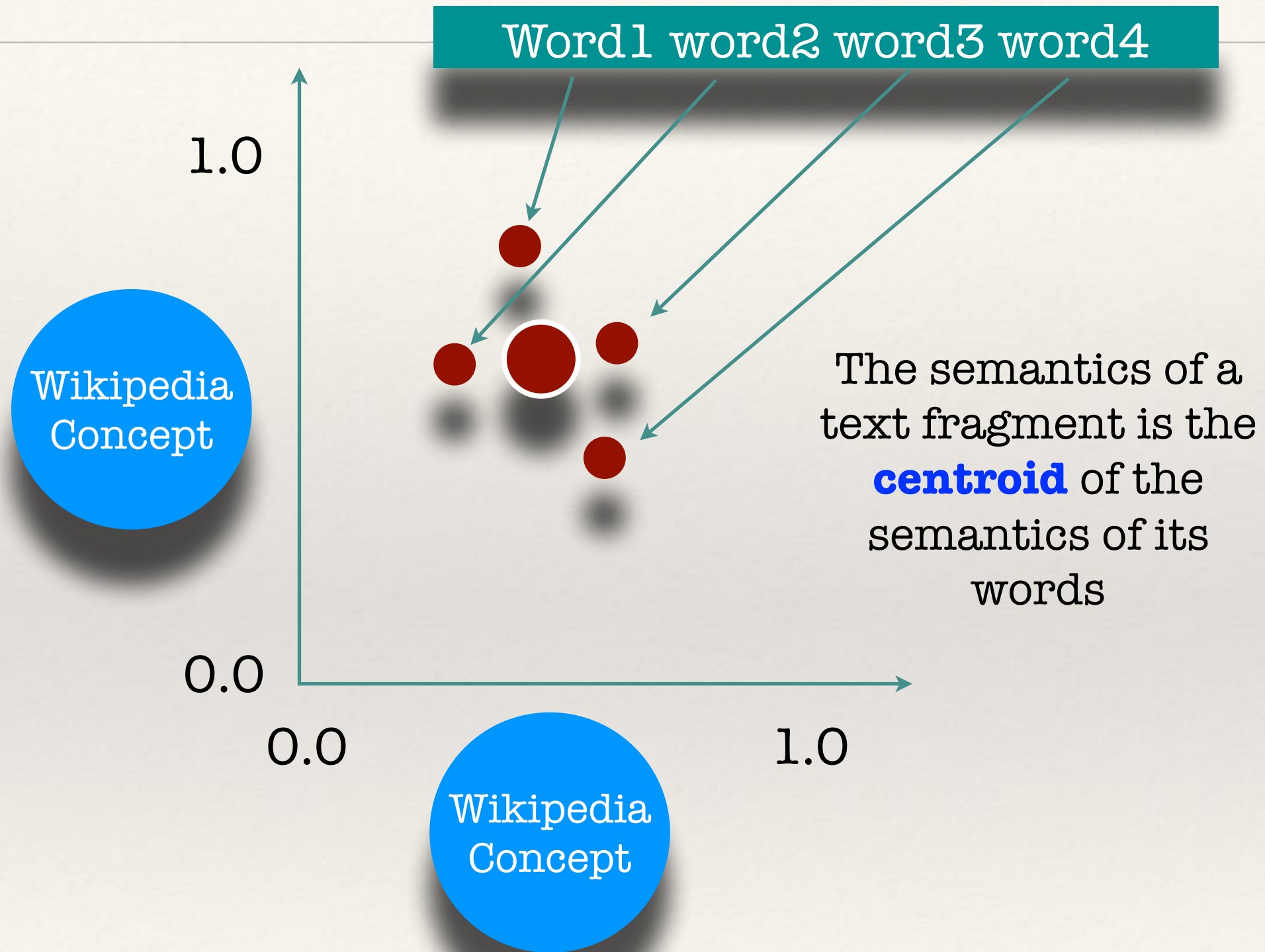
Building ESA interpreter for multiword texts

input: a sequence of words

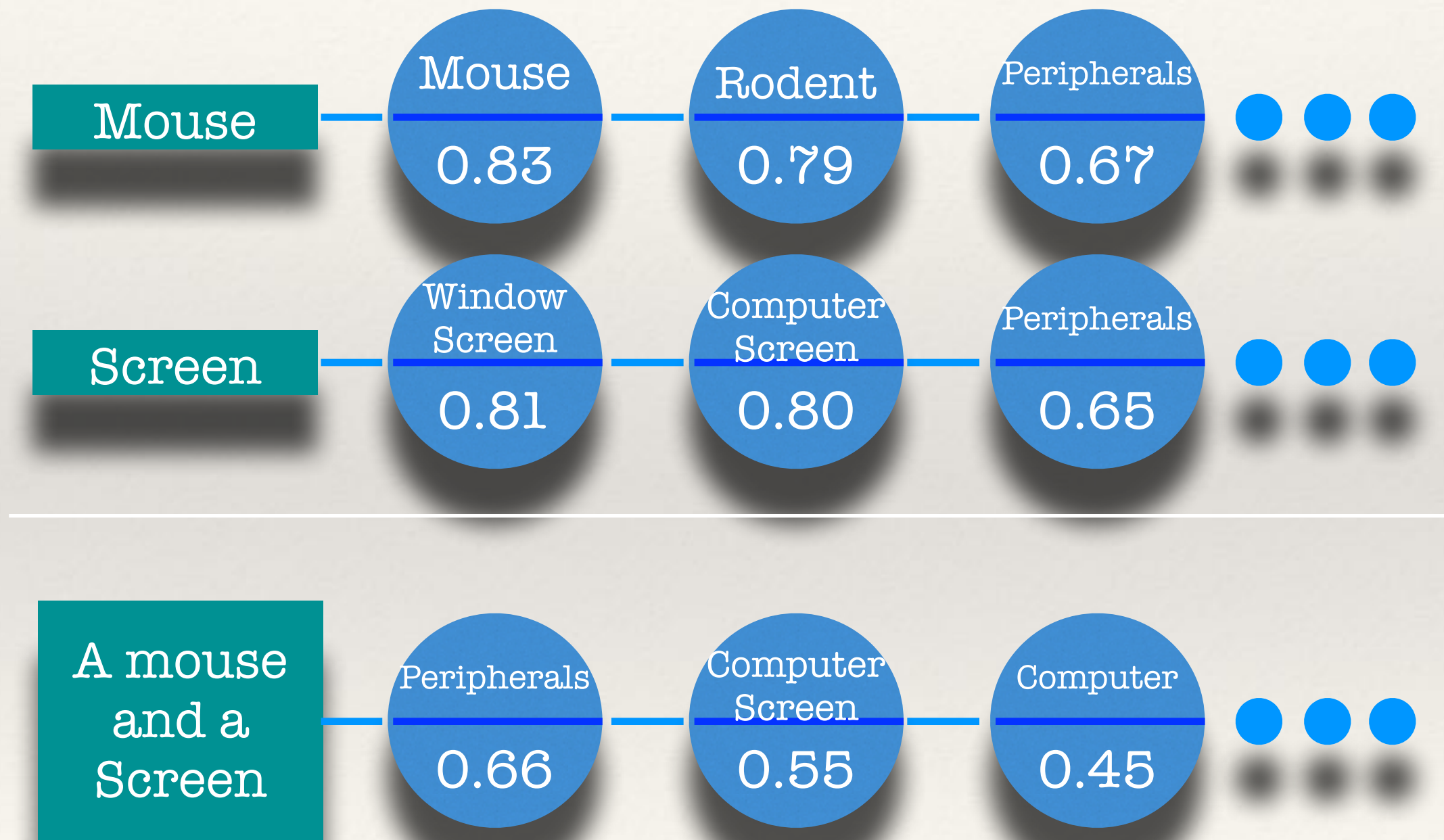
output: a vector of
weights over
wikipedia concepts



The semantics of text

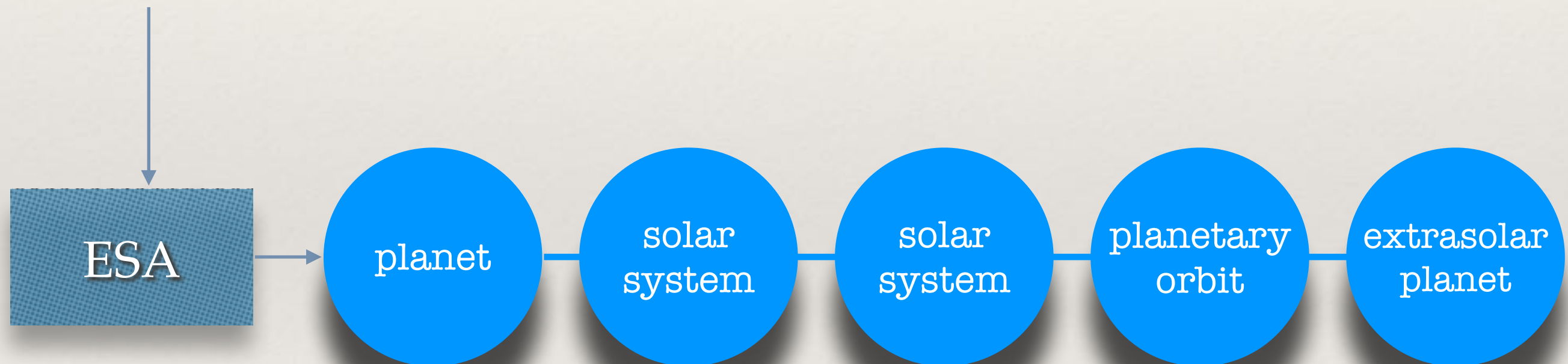


Disambiguation



Real example

“A group of European-led astronomers has made a photograph of what appears to be a planet orbiting another star. If so, it would be the first confirmed picture of a world beyond our solar system.”





Using ESA

Concept-based text processing with Explicit Semantic Analysis (our group)

- ❖ **Computing semantic relatedness of words and texts**

[Gabrilovich & Markovitch - IJCAI 2007, JAIR 2009]

- ❖ ESA is used to represent words and texts in the space of Wikipedia concepts

- ❖ **Text categorization:** assigning category labels to documents

[Gabrilovich & Markovitch - IJCAI 2005, JMLR 2007, JAIR 2009]

- ❖ ESA is used for feature generation (top concepts)

- ❖ **Information retrieval:** find documents relevant to a query

[Egozi, Gabrilovich, Markovitch AAAI 2008, TOIS 2012]

- ❖ ESA is used for measuring the distance between queries and documents

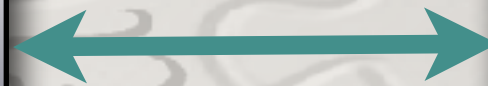
- ❖ **Word sense disambiguation:** identify the right word sense

[Raviv & Markovitch AAAI 2012]

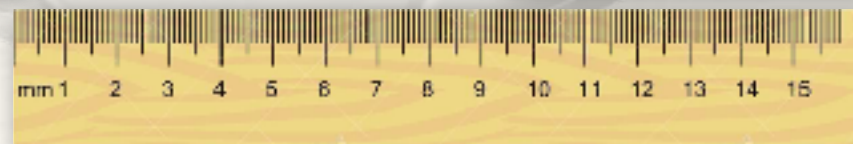
- ❖ ESA is used for measuring the distance between contexts and meanings

Using the ESA for Computing Semantic Relatedness (semantic distance)

Assemble impressive presentations using Apple-designed themes or open existing Microsoft PowerPoint files.



Choose a font smoothing style from the pop-up menu at the bottom. Depending on the type of display you have,



Why computing semantic distance?



Clustering

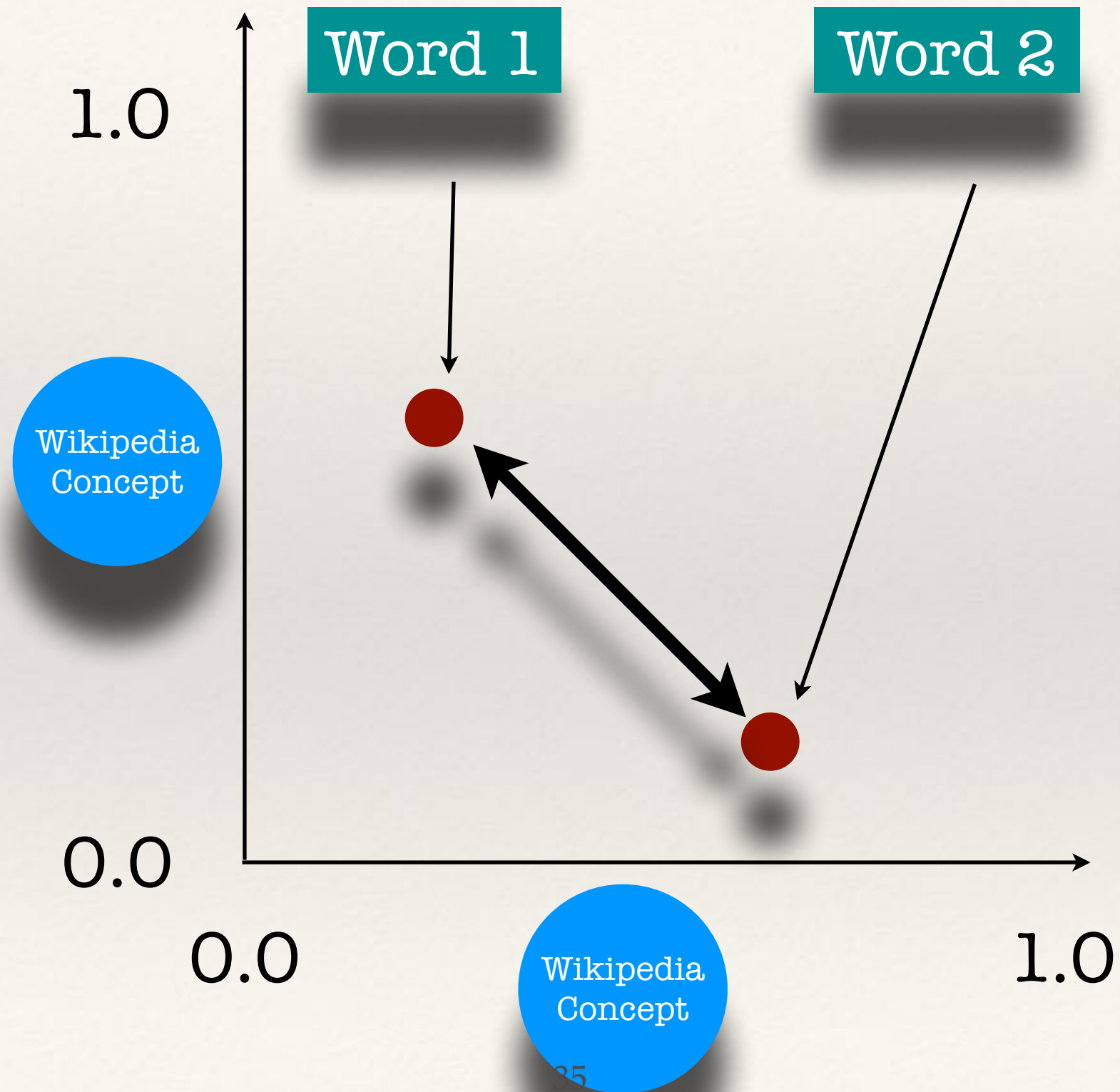
Categorization

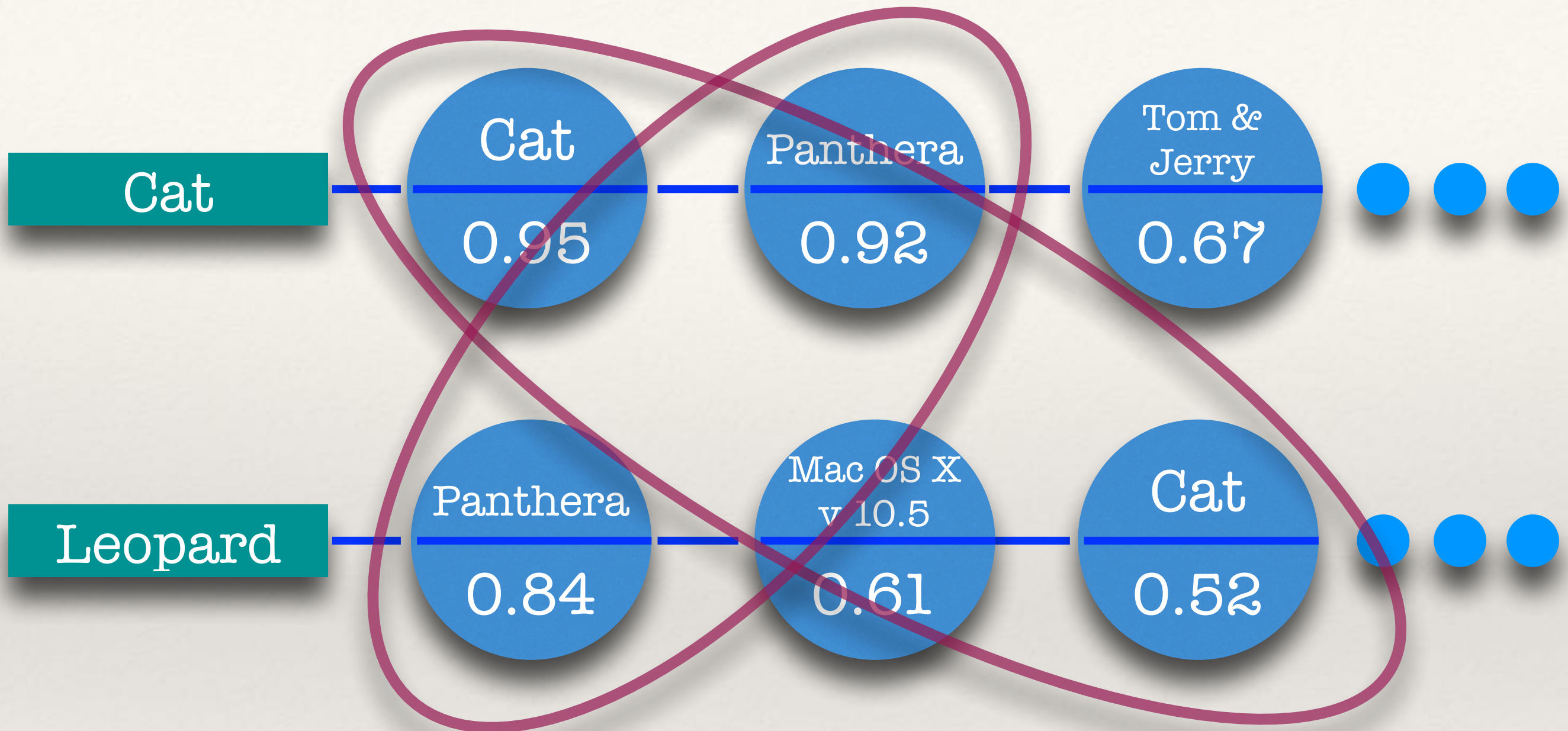
Filtering

Search

Semantic distance is an
atomic operator in
many NLP tasks

Computing semantic relatedness between words



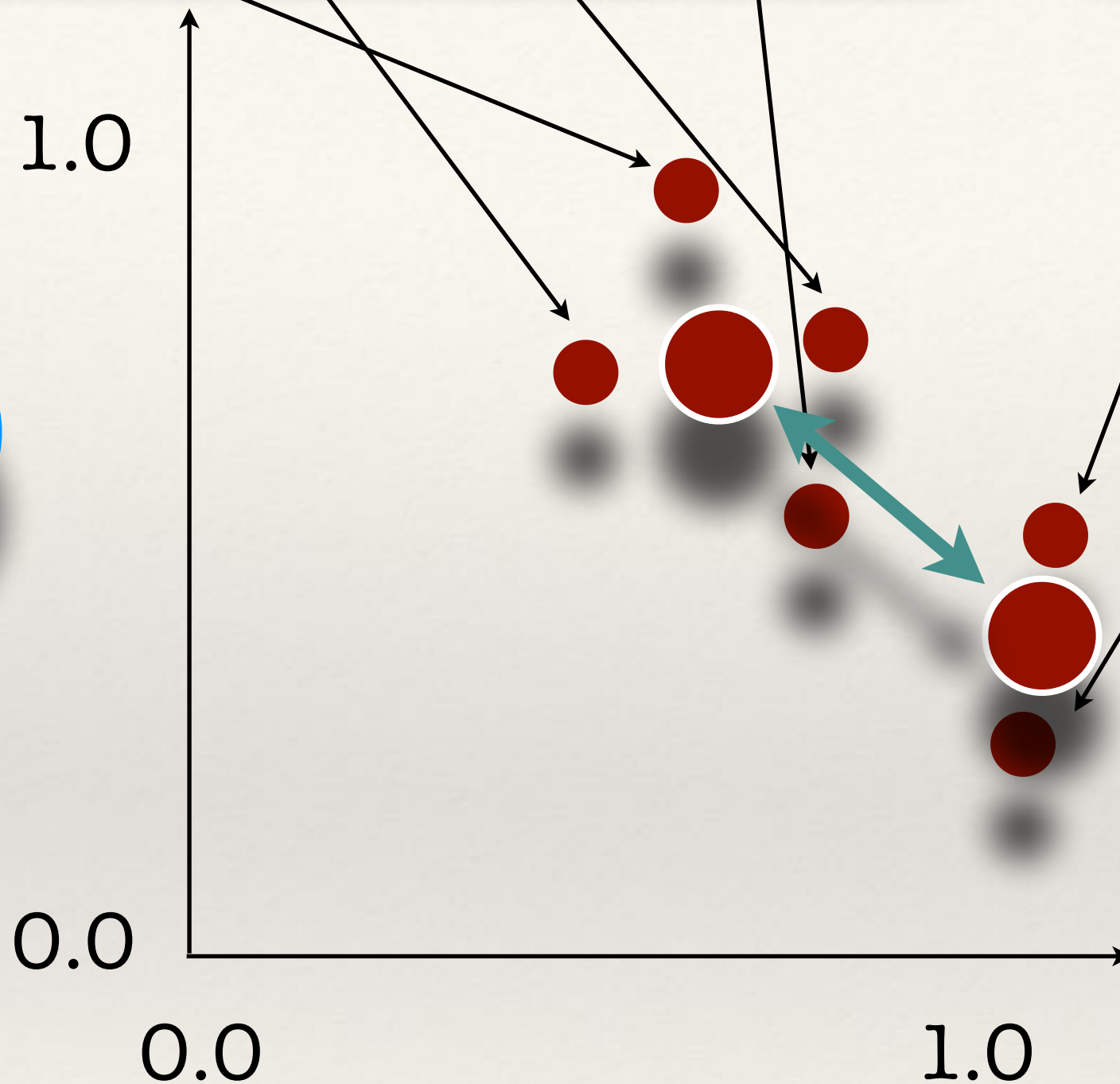


Words are strongly related if
they share highly weighted
concepts

Word1 word2 word3 word4

Word5 word6

Wikipedia
Concept



Wikipedia
Concept

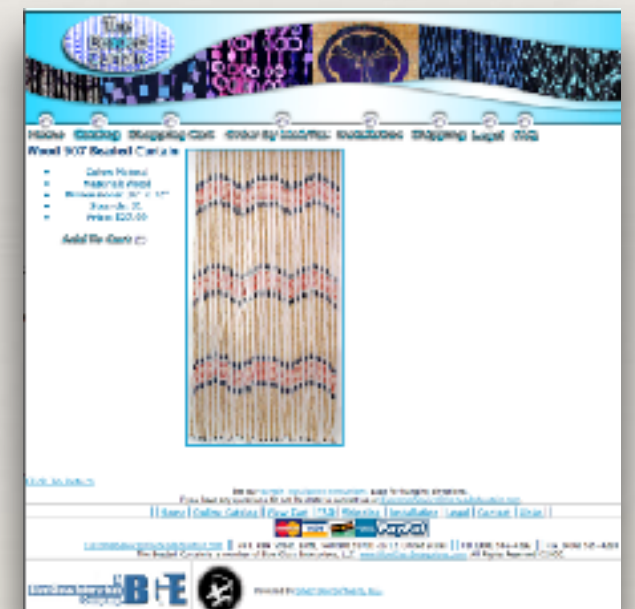
Computing
semantic
relatedness
between text
fragments



A web site of a computer store

I need a curtain and a screen

I need a mouse and a screen



A web site of a home improvement store

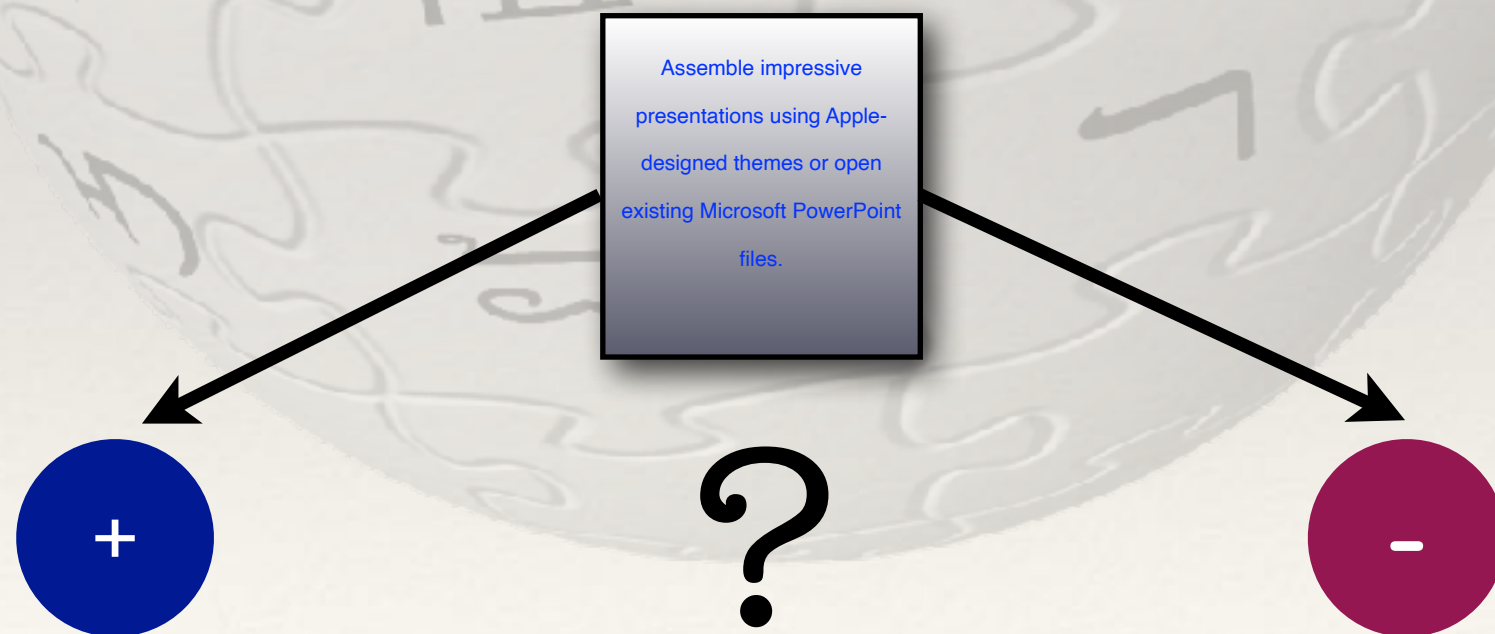
Evaluation on word-relatedness

Algorithm	Correlation with human
Wordnet-based (Jarmaz, 2003)	0.33-0.35
Roget's Thesaurus (Jarmasz, 2003)	0.55
LSA (Finkelstein et al., 2002a)	0.56
Wikirelate (Strube & Ponzetto, 2006)	0.19-0.48
ESA-ODP	0.65
ESA-Wikipedia (11-11-05)	0.74
ESA-Wikipedia (26-3-06)	0.75

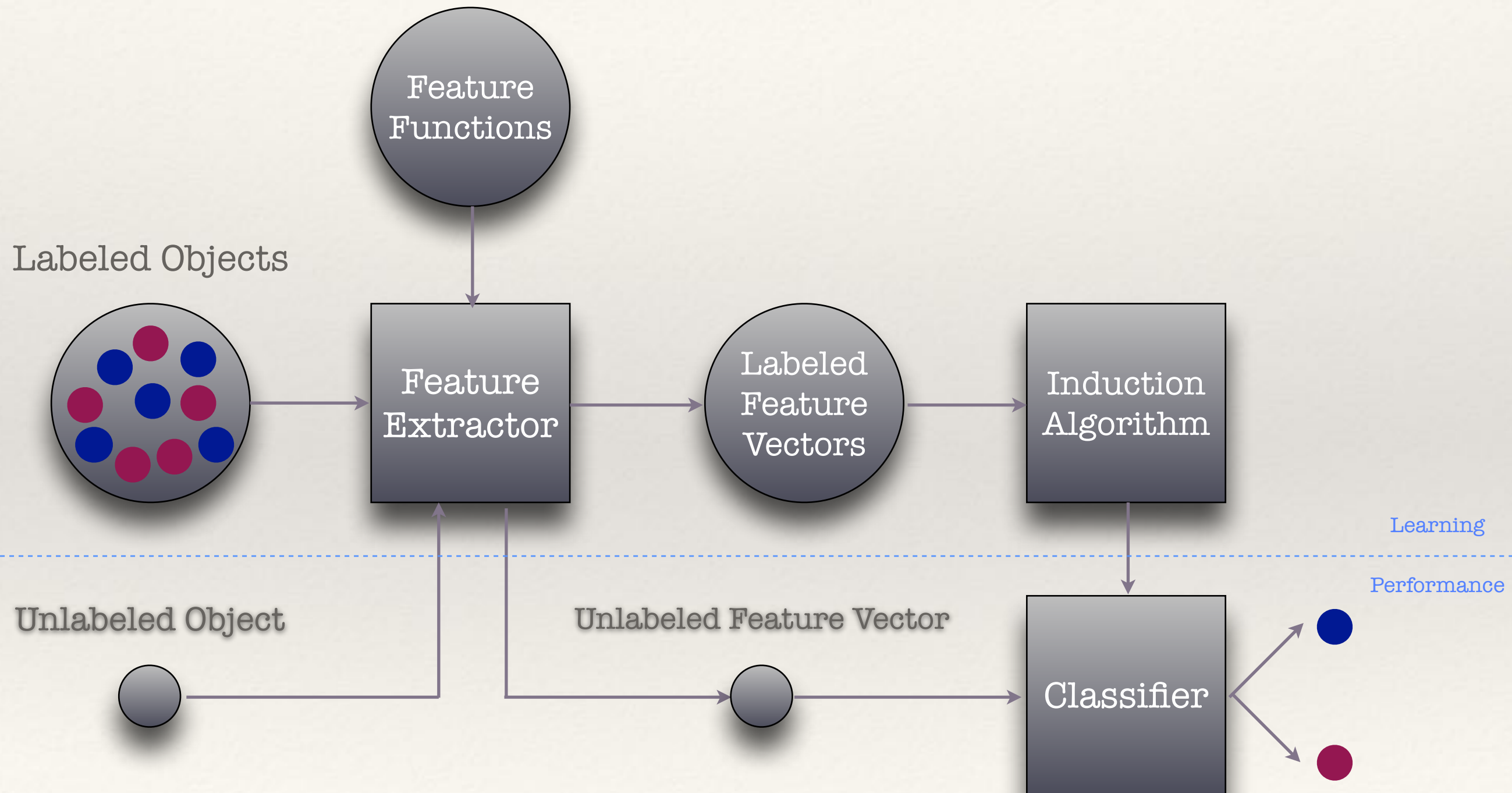
Evaluation on text-relatedness

Algorithm	Correlation with human
Bag of words (Lee et. al., 2005)	0.1-0.5
LSA (Lee et. al., 2005)	0.6
ESA-ODP	0.69
ESA-Wikipedia (11-11-05)	0.71
ESA-Wikipedia (26-3-06)	0.72

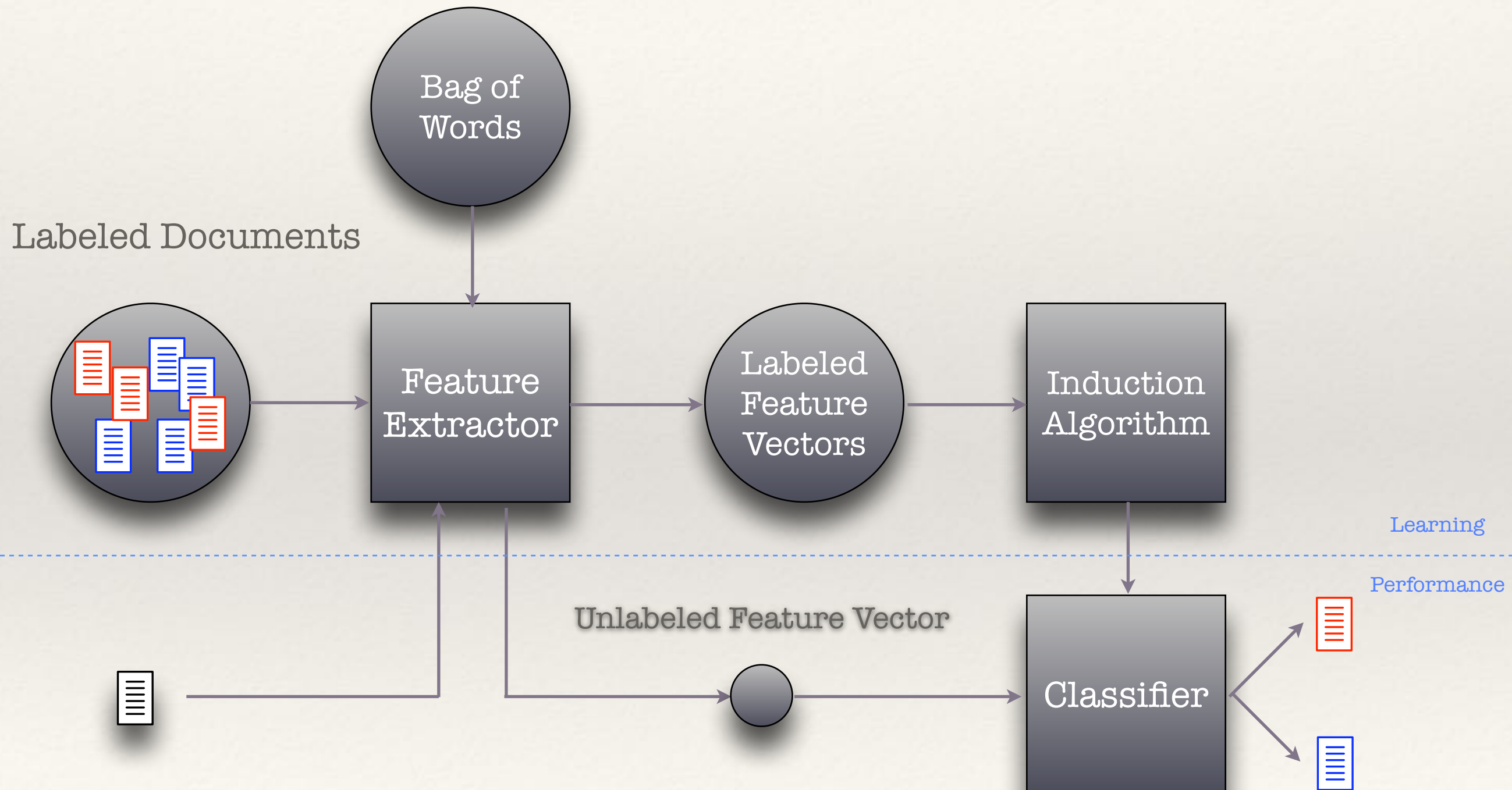
Using ESA for Text Categorization

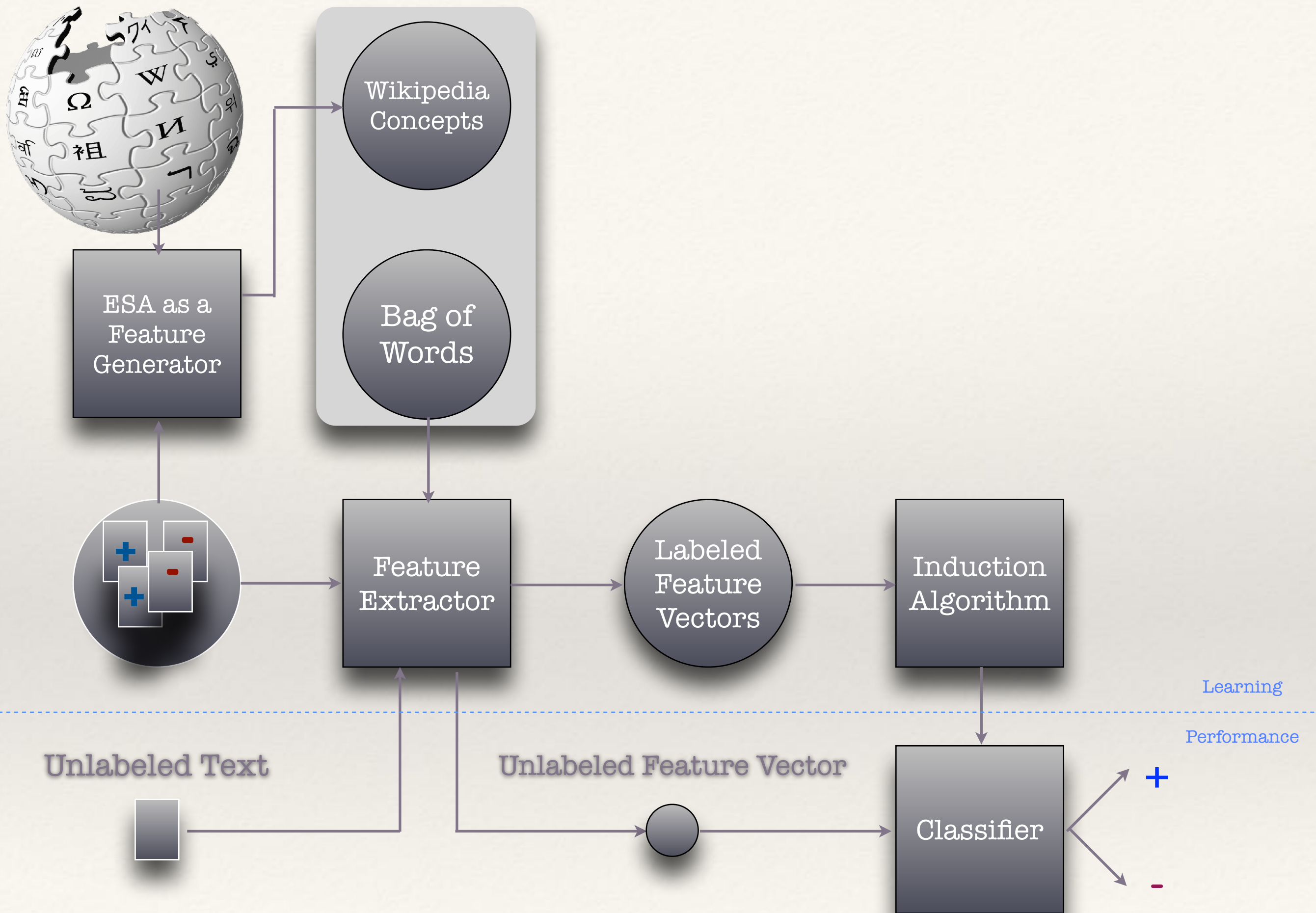


The induction process

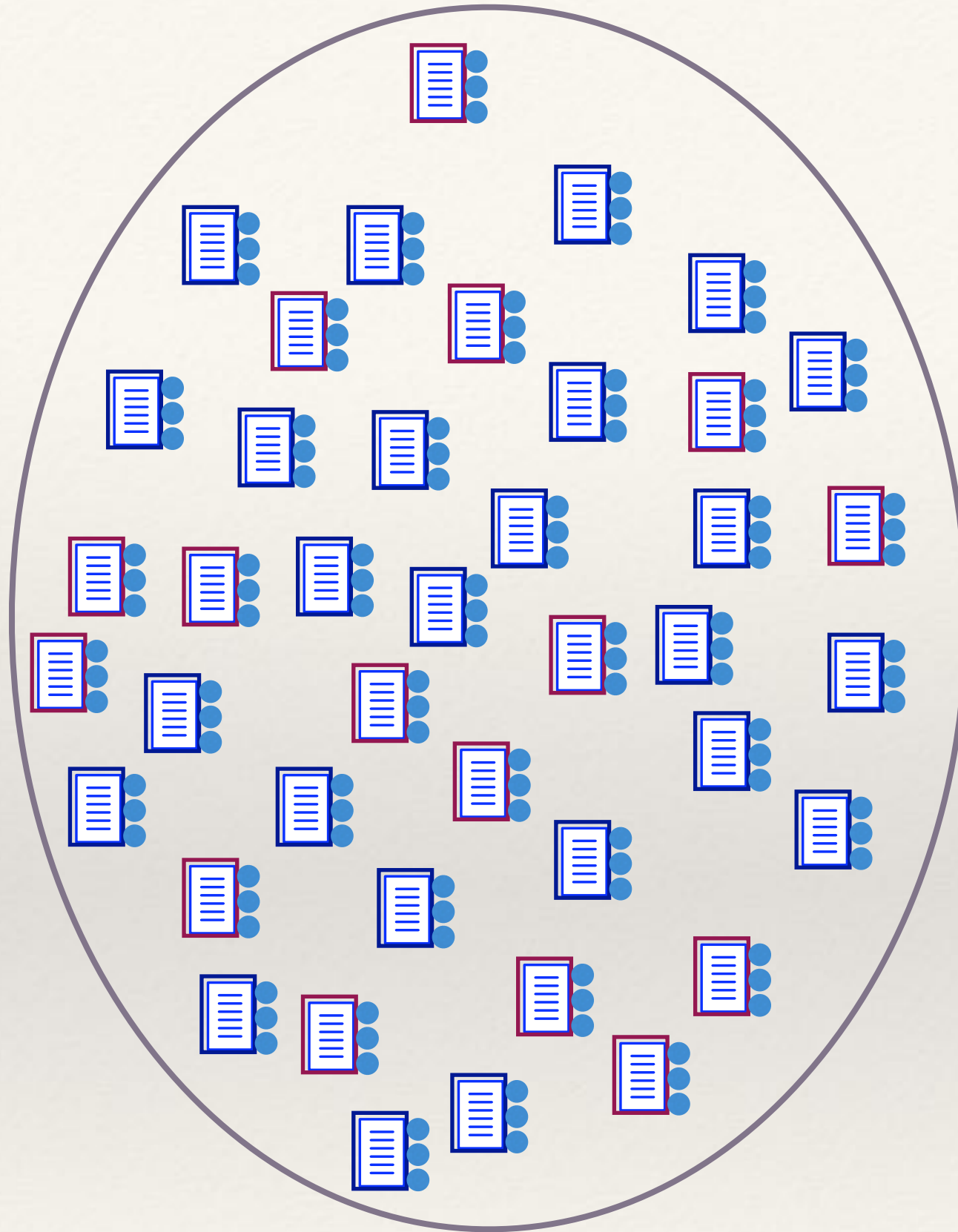


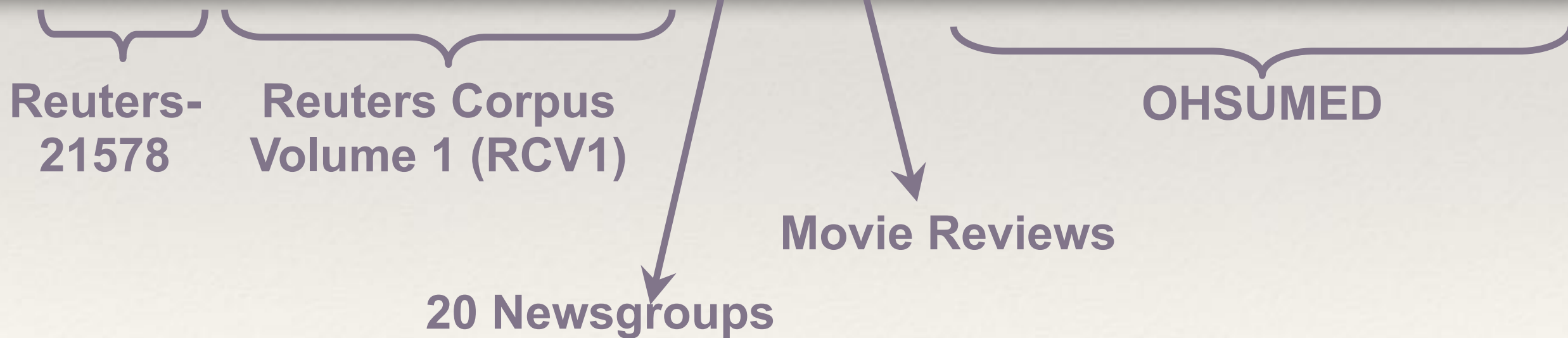
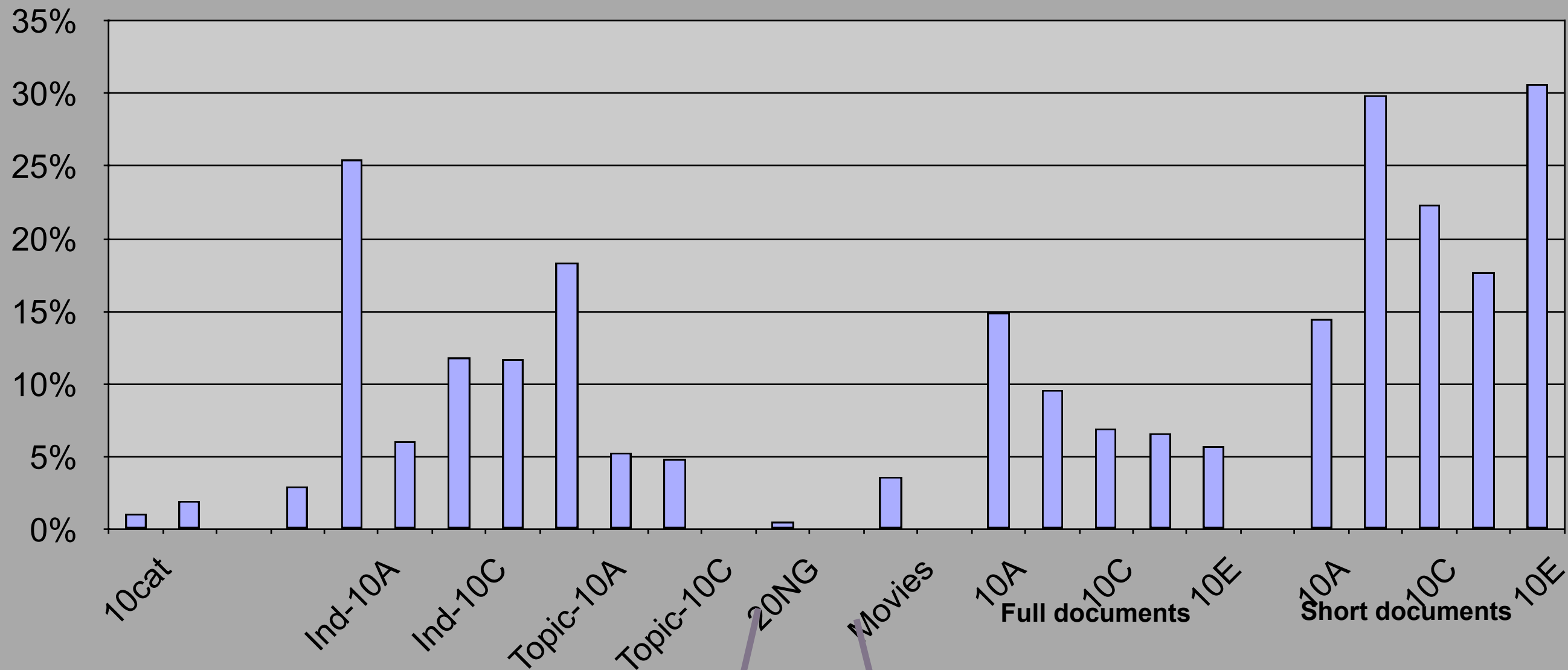
Text Categorization





Enriched Examples





Tasks (other groups)

- Cross-language information retrieval
- Query-intent prediction
- Cross-language plagiarism detection
- Event-driven ad placement
- News recommendation
- Query session detection
- Dataless classification
- Automatic image tagging
- Link discovery
- Social-media driven image retrieval
- Blog analysis
- Humanoid robot conversation
- Measuring descriptiveness of web comments

Additional applications of ESA (by other research groups)

- ❖ Information retrieval
 - ❖ Query-intent prediction [Hu et al. '09]
 - ❖ Query expansion [Luo et al. '12]
 - ❖ Query session detection [Hagen et al. '11]
 - ❖ Search mission detection [Hagen et al. '13]
 - ❖ Document indexing [Janusz et al. '12]
 - ❖ Semantic search on the linked data web [Freitas et al. '12]
 - ❖ Clustering of scientific articles [Szcuka & Janusz '13]
 - ❖ Named entity disambiguation [Fernandez et al. '11]
 - ❖ Author disambiguation [Kang '12]
 - ❖ Semantic indexing [Swieboda et al 2014]
 - ❖ An Arabic Question Answering System for the Holy Quran [Abdelnasser et. al. 2014]

Additional applications of ESA (by other research groups)

- ❖ Natural language processing
 - ❖ Document summarization [Zhou et al. '10]
 - ❖ Textual entailment [Zesch et al. '13]
 - ❖ Multi-domain language model adaptation [Kilgour et al. '11]
 - ❖ Opinion mining [Ma & Wan '08]
 - ❖ Machine translation [Matsuno & Ishida '12]
 - ❖ Question answering [Walter et al. '12]
 - ❖ Automatic answer-quality evaluation [Peleg et. al. 2016]
 - ❖ Question answering system over linked data [Park et. al. '14]
 - ❖ Non-Factoid question answering [Yang et. al. 2016]
 - ❖ Keyword Question Answering [Han et. al. '15]
 - ❖ Ontology translation [Asooja et al. '12]
 - ❖ Sentiment classification [Negi & Rosner '13]
 - ❖ Named entity disambiguation [Fernandez et al. '11]
 - ❖ Author disambiguation [Kang '12]
 - ❖ Semantic tagging [Janusz et al '14]

Additional applications of ESA (cont'd)

- ❖ Multimedia applications
 - ❖ Recommendation of web resources [Scholl et al. '10]
 - ❖ Social-media driven image retrieval [Popescu & Grefenstette '11]
 - ❖ Automatic image tagging [Leong et al. '10]
 - ❖ Matching texts and images (recommending text advertisements) [Zhang et al. '12]
 - ❖ Recommending Missing Symbols [Voros et al 2014]
 - ❖ Music genre classification [Aryafar & Shokoufandeh '11]
 - ❖ Fusion of Text and Audio Semantic Representations [Aryafar and Shokoufandeh '15]

Additional applications of ESA (cont'd)

- ❖ Recommendation systems
 - ❖ News recommendation [Son et al. '13]
 - ❖ Tweet recommendation [Lu, Lam & Zhang '12]
 - ❖ Recommending learning resources [Schmidt et al. '11]
- ❖ User modeling
 - ❖ Personalized TV guide [Musto et al. '12]
 - ❖ Enriching user profiles [Narducci et al. '11]

Additional applications of ESA (cont'd)

- ❖ Healthcare
 - ❖ Labeling fire and rescue incidents with threats [Krasuski & Janusz '13]
 - ❖ Identifying verbal impairments [Gaspers et al. '12]
 - ❖ Computing Semantic Relatedness of Biomedical Text [Jaiswal & Bhargava 2014]
- ❖ Software engineering
 - ❖ Traceability link recovery [Mahmoud, Niu & Xu '12]
 - ❖ Knowledge driven query sharding in databases [Krasuski & Szczuka '12]
 - ❖ Web service discovery [Metke-Jimenez et al. '11]

Additional applications of ESA (cont'd)

- ❖ Multi-lingual applications
 - ❖ Cross-language information retrieval [Potthast et al., '08; Sorg & Cimiano '08]
 - ❖ Cross-language plagiarism detection [Potthast et al. '11]
 - ❖ A Multilingual and Cross-lingual Text Analytics Toolkit [Zhang & Rettinger 2014]

Additional applications of ESA (cont'd)

- ❖ Other applications
 - ❖ Humanoid robot conversation [Kraft et al. '10]
 - ❖ Career guidance based on semantic relatedness [Gurevych et al. '07]
 - ❖ Dataless classification [Chang et al. '08, Song & Roth '14]
 - ❖ Link discovery [Hoffart et al. '09; Knoth et al. '11]

Cross-Language IR

- ❖ It is important to understand the following:
 - ❖ ESA concepts are language-independent. They are actually represented by meaningless ID
 - ❖ The only component that is language-dependent is the interpreter
 - ❖ For each language, we need the articles' text in that language to build the language-specific interpreter
 - ❖ The output of all the interpreters will be in the same space - space of concepts (IDs)

Steve Jobs

From Wikipedia, the free encyclopedia

This article is about the person. For the biography, see [Steve Jobs \(book\)](#).

Steven Paul "Steve" Jobs (/dʒɒbs/; February 24, 1955 – October 5, 2011)^[a]^[b] was an American entrepreneur,^[a] marketer,^[a] and inventor,^[a] who was the cofounder, chairman, and CEO of **Apple Inc.** Through Apple, he was widely recognized as a charismatic and design-driven pioneer of the personal computer revolution^[a]^[a] and for his influential career in the computer and consumer electronics fields, transforming "one industry after another, from computers and smartphones to music and movies."^[a] Jobs served as chief executive of Pixar Animation Studios; he became a member of the board of directors of The Walt Disney Company in 2006, when Disney acquired Pixar. Jobs was among the first to see the commercial potential of Xerox PARC's mouse-driven graphical user interface, which led to the creation of the Apple Lisa and a year later, the Macintosh. He played a role in introducing the LaserWriter, the first laser printer to feature vector graphics that started desktop publishing to the market.^[11]

These are texts in
different languages
associated with the
concept 6744251

6744251

סטיב ג'ובס

סטיבן פול ג'ובס (באנגלית: **Steven Paul Jobs**;‏ 24 בפברואר 1955 - 5 באוקטובר 2011) היה איש עסקים וממציא אמריקאי שהשתתף בהקמת חברת אפל והיה המנכ"ל שלה. תפקידו שימש בין השנים 1976–1983, ולאחר מכן משנת 1997 ועד חודשים ספורים לפני מותו ב-2011. בזכות מחשב Apple II מודרן הדרך, נחשב ג'ובס לאחד מחלוצי המחשוב האישי. הוא נמנה עם המנצחים העיקריים להבאת ממשק המשתמש הגרפי למחשב האישי במחשבי מקינטוש, ונחשב לדמות המרכזית שמאחורי היוזם הפיננסי של חברת אפל בראשית המאה ה-21, בזכות מוצרים פופולריים וחדשניים כדוגמת iPod, iPad ו-iPhone. ג'ובס היה גם שותף להקמת חברת האנימציה פיקסאר ולהקמת חברת NeXT. הוא נמנה עם עשירי העולם המוצלחים, והונה הוער בספטמבר 2011 ב-7 מיליארד דולר.^[1]

ג'ובס נפטר ב-5 באוקטובר 2011 לאחר מאבק ממושך בסרטן הכלבלב.

הערות שוליים (הסתרה)
<div>1 חזיר</div>
<div>2 נאמין</div>
<div>3 לקראת ג'ובס</div>
<div>4 קטגוריה: חשבוניות</div>
<div>5 הערות שוליים</div>

חזיר [עריכת קוד מקור | עזרה]

ג'ובס נולד ללואיס קארול שניבל, אחותהאנה, ומריאן שוויצברג, ולעדה אל-האדאד.

It is very likely that
a document talking
about Apple Inc. in
any of these
languages will be
mapped to concept
6744251

စတီဗ်ဂျော့ဗ်

၁၉၅၅ ခုနှစ်၊ ဖေဖော်ဝါရီလ ၂၄ ရက်နေ့တွင် အိမ်ထောင်ရေးတိုက် တစ်ကိုယ်တည်းနေ ပီဒီဒူ ငွေ့မွေးဖွားခဲ့သော စတီဗ်ဂျော့ဗ် ခုနစ်ရက်သားအရွယ်တွင် ခံတွဲတစ်တွဲက မွေးစားခဲ့ပြီး တစ်ချိန်တွင် စီလီကွန်စတာင်ကြီးဟု ထင်ရှားလာမည့် Cupertino နေရာတွင် ကြီးပြင်းလာခဲ့သူ ဖြစ်သည်။
အထက်တန်းတန်းတက်သော အရွယ်တွင် Palo Alto ရှိ William Hewlett တို့ ငွန်းတက်တာ ကျောင်းသင်ခန်းစာ ပရောဂျက်တစ်ခု အတွက် အစိတ်အပိုင်းများ လိုချင်ကြောင်း တောင်းဆိုခဲ့သူ ဖြစ်သည်။ ထို့နောက် HP ကုမ္ပဏီတွင် နေရာထိ အလုပ်တစ်ခု ဝင်လုပ်ခဲ့ပြီး အင်ဂျင်နီယာ စတီဗ်ဂျော့ဗ်နှင့် ပတ်သက် ဖြစ်ခဲ့သည်။

ကျောင်းသား အောင်ချိန်ရှိ နှိုင်းခြင်း Ravi ကောလိပ်သို့ တက်ရောက်ခဲ့ပြီး သင်တန်းကာလတစ်ပိုင်း အပြီးတွင် ကောလိပ်မှ ထွက်ခဲ့ပြီး သင်တန်းများ ဆက်လက် တက်နေခဲ့သည်။ ထိုသင်တန်းများထဲတွင်

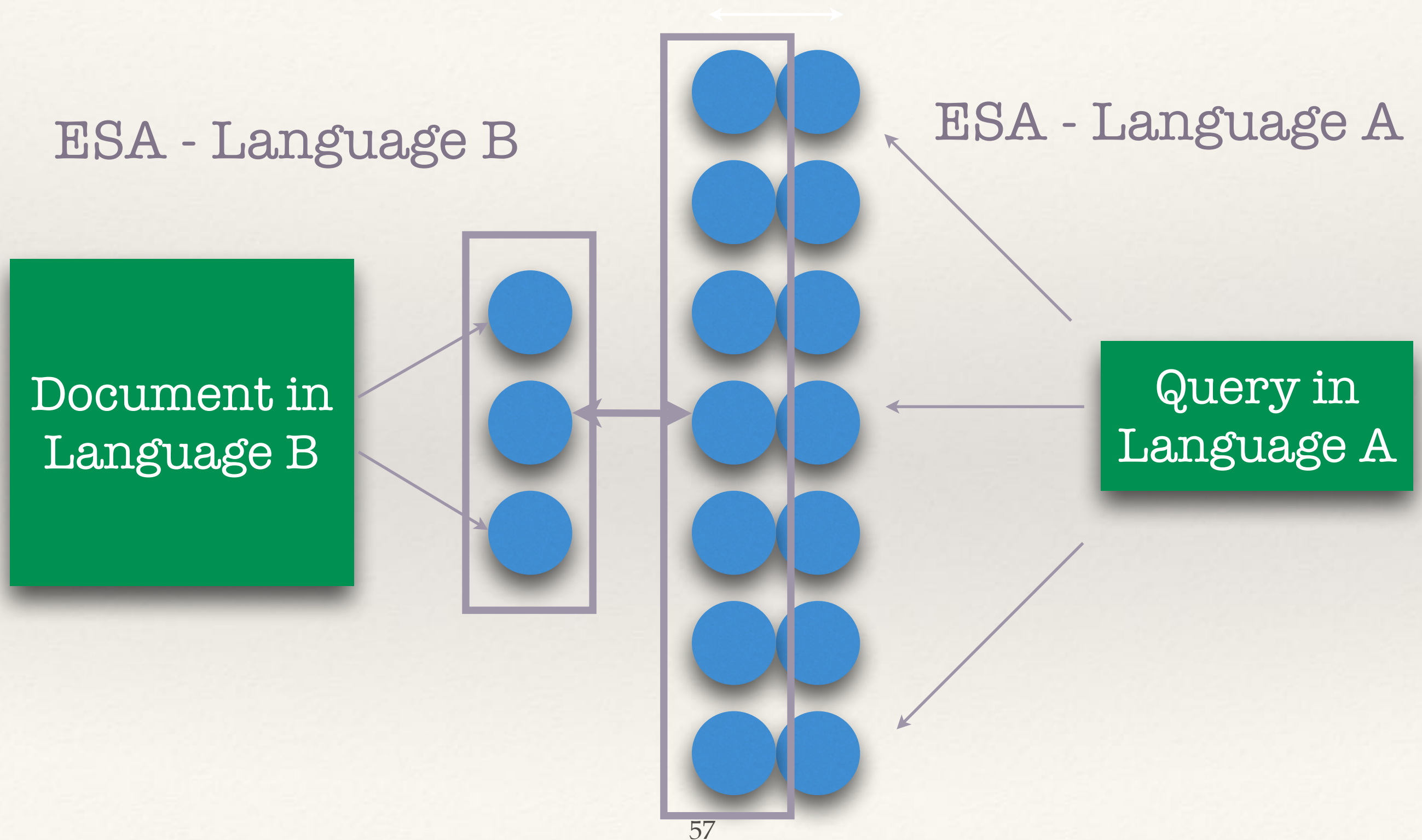
စတီဗ်ဂျော့ဗ်



၂၀၁၁ ခုနှစ် Worldwide Developers Conference တွင် Jobs နဲ့သူ့ iPhone 4

မွေးဖွား စတီဗ် ဂျော့ဗ်
၂၄ ဖေဖော်ဝါရီ
အိမ်ထောင်ရေးတိုက်
ပီဒီဒူ
၁၉၅၅ ခုနှစ်

Cross-Language IR



Extensions and modifications of **ESA**

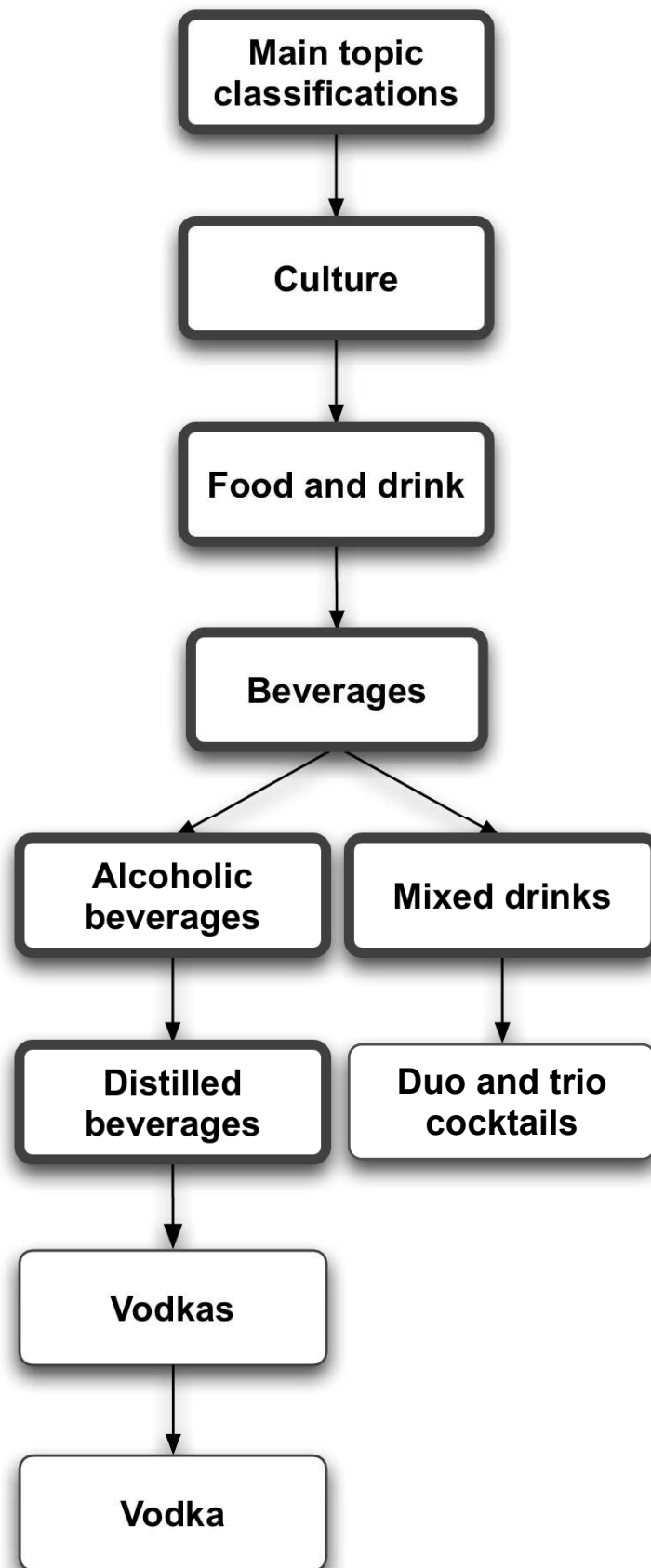
- ❖ Using multiple knowledge resources (+ Wiktionary, WordNet, GermaNet) [Szarvas et al. '11]
- ❖ Temporal Semantic Analysis [Radinsky et al. '11]
- ❖ Compact Hierarchical ESA [Lieberman & Markovitch '09]
- ❖ Explicit Localized Semantic Analysis [Son et al. '13]
- ❖ Self-adaptive (context aware) ESA [Wang et al. '08]
- ❖ Wikipedia-based kernels for text categorization [Minier et al. '07]
- ❖ Stratified ESA, Thematically Reinforced ESA [Haralambous & Klyuev '12, '14]
- ❖ Music genre classification [Aryafar & Shokoufandeh '11]
- ❖ Econo-ESA [Rahutomo & Aritsugi '14]
- ❖ Thematically Reinforced Explicit Semantic Analysis [Haralambous & Klyuev, 2014]
- ❖ Sense-aware ESA [Wu & Giles 2015]

Compact Hierarchical ESA

	<i>Vodka</i>	<i>Brandy</i>
1	Vodka	Brandy
2	Absolut Vodka	Albrecht Brandi
3	Smirnoff	George Brandis
4	SKYY vodka	Kristina Brandi
5	Bloody Mary (cocktail)	Brandy (entertainer)
6	Gin (Case Closed)	Brandi Chastain
7	Mixed drink shooters and drink shots	Jonathan Brandis
8	Vodka Belt	Brandy & Mr. Whiskers
9	Grey Goose (vodka)	Brandi Carlile
10	Beer cocktail	Tom Brandi

ESA representation for “vodka” and “Brandy”

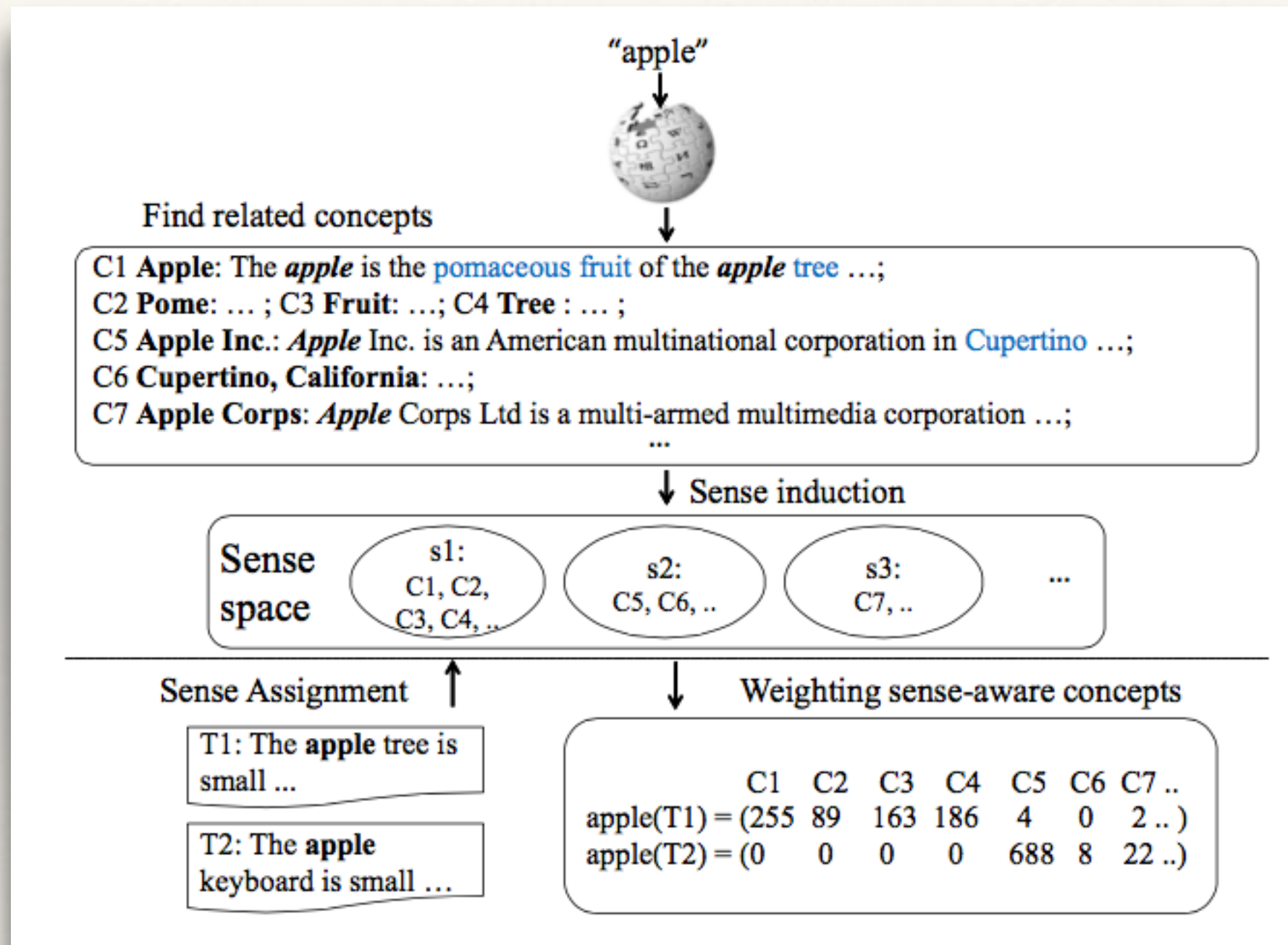
CHESA
representation
for “vodka”
and “Brandy”



Temporal Semantic Analysis



Sense-aware ESA



Using Other Ontologies

- ❖ We used the Open Directory Project
- ❖ Other groups used various domain-specific ontologies, for domains such as biomedical IR or Quran QA

[advanced](#)

[Arts](#)

[Movies](#), [Television](#), [Music](#)...

[Games](#)

[Video Games](#), [RPGs](#), [Gambling](#)...

[Kids and Teens](#)

[Arts](#), [School Time](#), [Teen Life](#)...

[Reference](#)

[Maps](#), [Education](#), [Libraries](#)...

[Shopping](#)

[Clothing](#), [Food](#), [Gifts](#)...

[World](#)

[Català](#), [Dansk](#), [Deutsch](#), [Español](#), [Français](#), [Italiano](#), [日本語](#), [Nederlands](#), [Polski](#), [Русский](#), [Svenska](#)...

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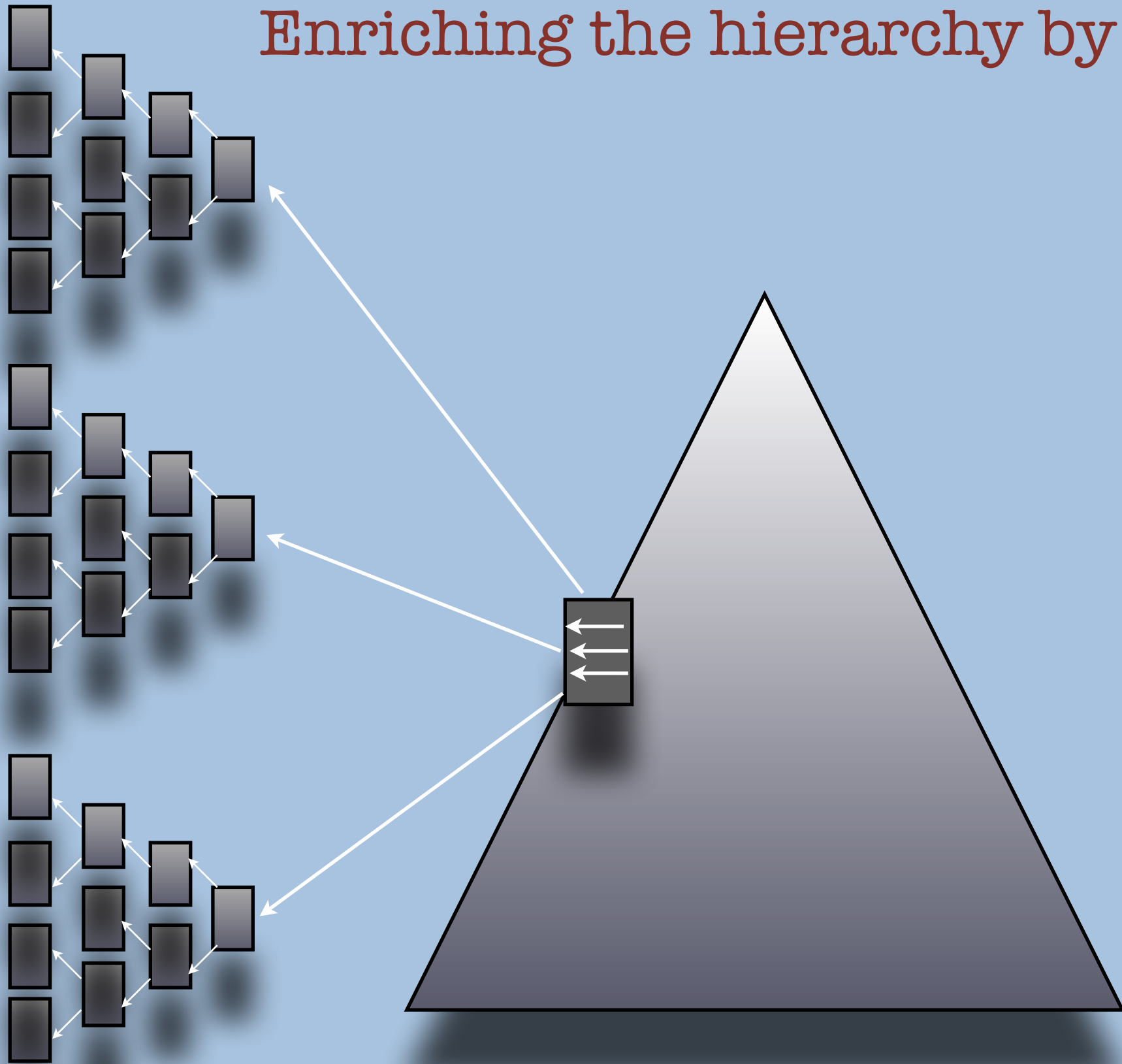
Copyright © 2011 Netscape

4,870,495 sites - 90,550 editors - over 1,006,708 categories

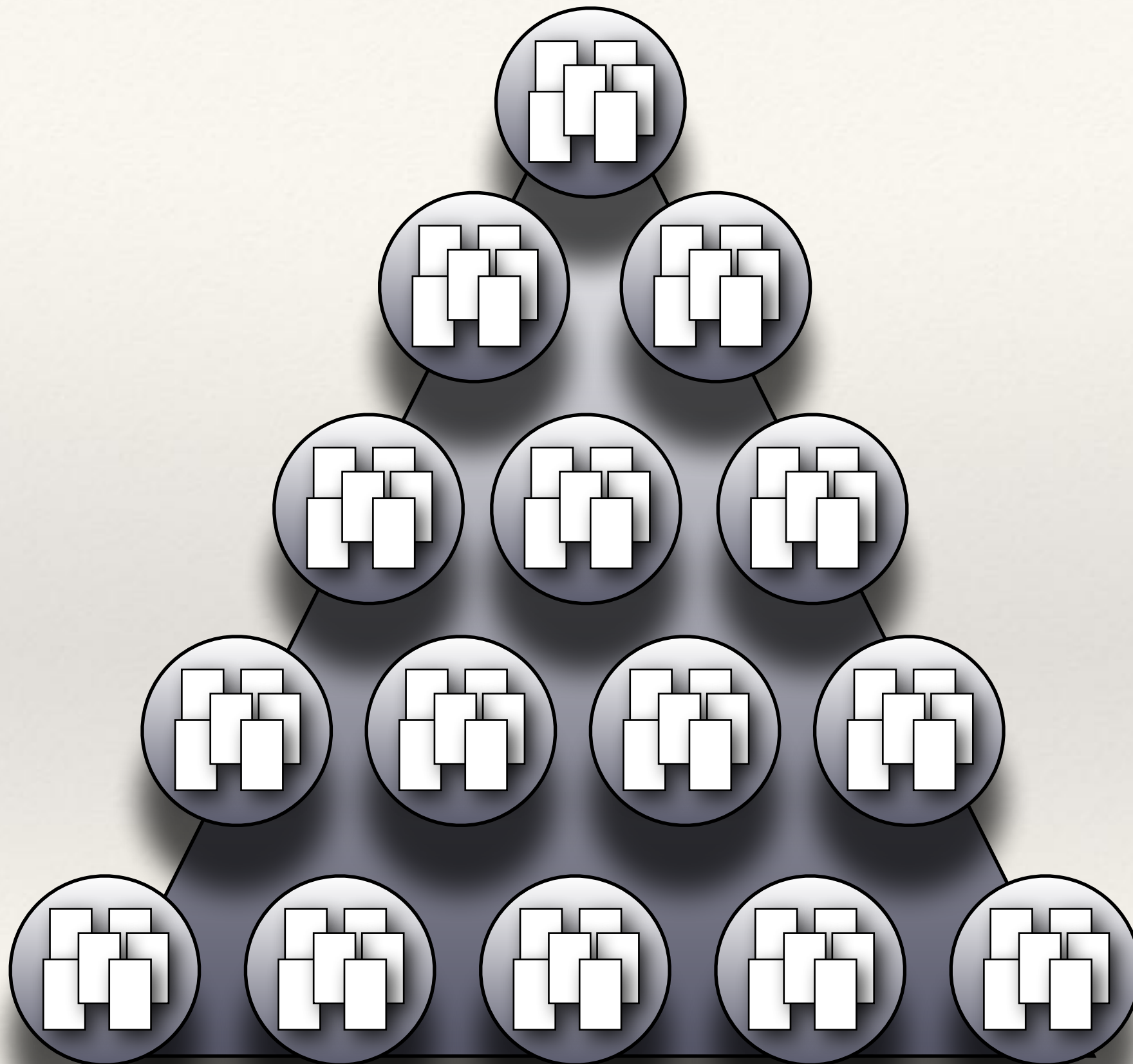
Top:Computers:Artificial Intelligence:Machine Learning

- [David W. Aha: Machine Learning Page](#)★ - A machine learning resources from Applications to Tutorials.
- [Computational Learning Theory](#) - A research field devoted to studying the design and analysis of algorithms for making predictions about the future based on past experiences. The emphasis in COLT is on rigorous mathematical analysis. COLT is largely concerned with computational and data efficiency.
- [Gowachin](#) - A competition on Grammatical Inference.
- [Grammatical Inference](#) - Repository of information on grammatical inference, automata induction, and language acquisition.
- [Integrated Optimization - Artificial Intelligence](#) - Site dedicated to research of artificial intelligence algorithms applied to information retrieval, data mining and optimization methods. Includes FAQs and AI resources for math/science teachers and students.
- [Kernel machines](#) - A central information source for the area of Support Vector Machines, Gaussian Process prediction, Mathematical Programming with Kernels, Regularization Networks, Reproducing Kernel Hilbert Spaces, and related methods. Provides links to papers, upcoming events, datasets, code.
- [Machine Learning in Games](#) - How computers can learn to get better at playing games. This site is for artificial intelligence researchers and intrepid game programmers. I describe game programs and their workings; they rely on heuristic search algorithms, neural networks, genetic algorithms, temporal differences, and other methods.

Enriching the hierarchy by web crawling



Enriched hierarchy



Rumsfeld appeared with Gen. Richard Myers, “ ”.chairman of the Joint Chiefs of Staff

Society/Issues/Government Operations

Society/Politics

Society/Issues/Warfare and Conflict/Specific Conflicts/Iraq,

Science/Technology/ Military Science

Society/Issues/Warfare and Conflict/Weapons

Society/History/By Region/North America/United States/Presidents/Bush, George Walker

Society/Politics/ConservatismSociety/Politics/Conservatism

On a night when Dirk Nowitzki (34 points), Jerry Stackhouse (29), Josh“ Howard (19) and Jason Terry (17) all came up big, he couldn’t match their”.offensive contributions

Sports/Basketball/Professional/NBA/Dallas_Mavericks

The power of context - the text itself does not mention sports or the name of the team. The names of the players mentioned in the context occur often in the Web sites cataloged under this concept, including
www.nba.com/mavericks,
dallasbasketball.com
sports.yahoo.com/nba/teams/dal

Summary

- ❖ Exogenous knowledge is crucial for text understanding
 - ❖ Can be derived from collaboratively generated content
- ❖ ESA is a novel method for representing text meaning with Wikipedia-based semantics
- ❖ Numerous studies have shown that concept-based representation benefits a large variety of tasks

IJCAI-JAIR Best Paper Prize

Overview

The Annual IJCAI-JAIR Best Paper Prize is awarded to an outstanding paper published in JAIR in the preceding five calendar years. The prize committee is comprised of associate editors and members of the JAIR Advisory Board; their decision is based on both the significance of the paper and the quality of presentation. The recipient(s) of the award receives a prize of US\$500 (to be split amongst the authors of a co-authored paper). Funding for this award was provided by the International Joint Conferences on Artificial Intelligence.

2014

2014 Prize:

Evgeniy Gabrilovich and Shaul Markovitch (2009) "[Wikipedia-based Semantic Interpretation for Natural Language Processing](#)", Volume 34, pages 443-498.