Entity Linking

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Outline

- Entity Linking
  - introduction
  - methods
  - evaluation

Introduction

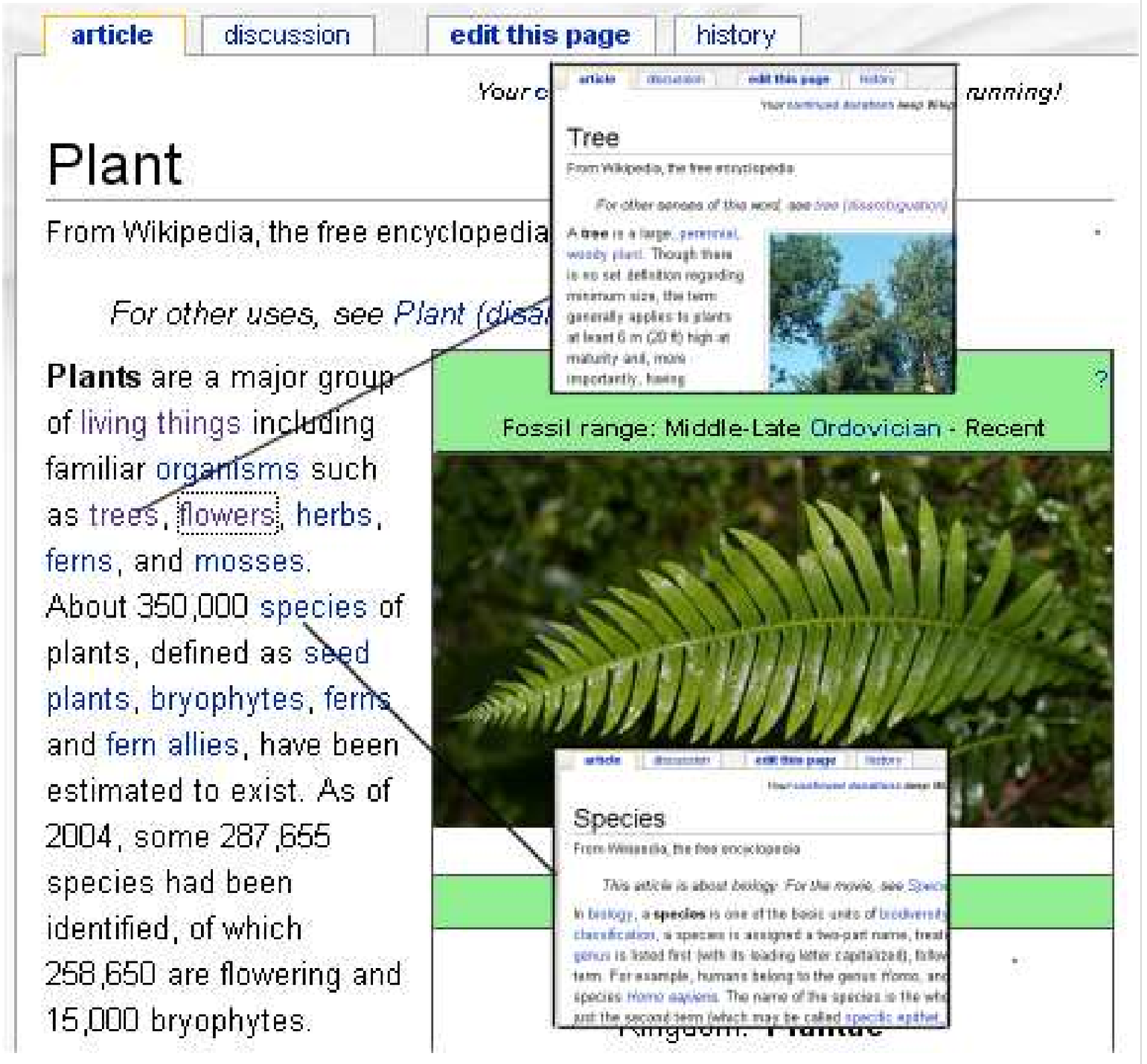

Image taken from Mihalcea and Csomai (2007). Wikify!: linking documents to encyclopedic knowledge. In CIKM '07.

Why do we need entity linking?

- Enable
  - semantic search
  - advanced UI/UX
  - automatic document enrichment; go-read-here
  - inline annotations (microformats, RDFa)
  - ontology learning, KB population
- “Use as feature”
  - to improve
    - end-to-end retrieval, classification, word sense disambiguation, semantic similarity, …
  - dimensionality reduction (e.g., term vectors)

Main problem

Main problem

- Linking free text to entities
  - Any piece of text
    - news documents
    - blog posts
    - tweets
    - queries
    - ...
  - Entities: typically taken from a knowledge base
    - Wikipedia
    - Freebase
    - ...

Methods

Common steps

1. Determine “linkable” phrases
   - mention detection – **MD**
2. Identify candidate entities for each mention
   - link generation – **LG**
   - may include NILs (null values, i.e., no target in KB)
3. (Use “context” to disambiguate/filter/improve)
   - disambiguation – **DA**

Wikipedia-based methods

Wikipedia-based methods

- Basic element: article proper
- But also
  - redirect pages
  - disambiguation pages
  - category/template pages
  - admin pages
- Hyperlinks
  - use “unique identifiers” (URLs)
    - [[United States]] or [[United States|American]]
    - [[United States (TV series)]] or [[United States (TV series)|TV show]]

Wikipedia-based methods

- keyphraseness(w) **[Mihalcea & Csomai 2007]**
  - "What's the likelihood of mention w_l being a link?"

$$\frac{\mathrm{CF}(w_l)}{\mathrm{CF}(w)}$$

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Collection frequency
phrase w as a link to another Wikipedia article

Collection frequency
phrase w

Wikipedia-based methods

- commonness(w,c) **[Medelyan et al. 2008]**
  - "What's the likelihood of *c* being the target of *w*?"

$$\frac{|L_{w,c}|}{\sum_{c'} |L_{w,c'}|}$$

Number of links
with target c' and anchor text w

Wikipedia-based methods

- Of course, these can also be based on other data, e.g.,
  - (focused) web crawls, with anchor text in the links to Wikipedia articles **[Chisholm & Hachey 2015]**
  - click logs **[Pantel et al. 2011]**

Commonness and keyphraseness

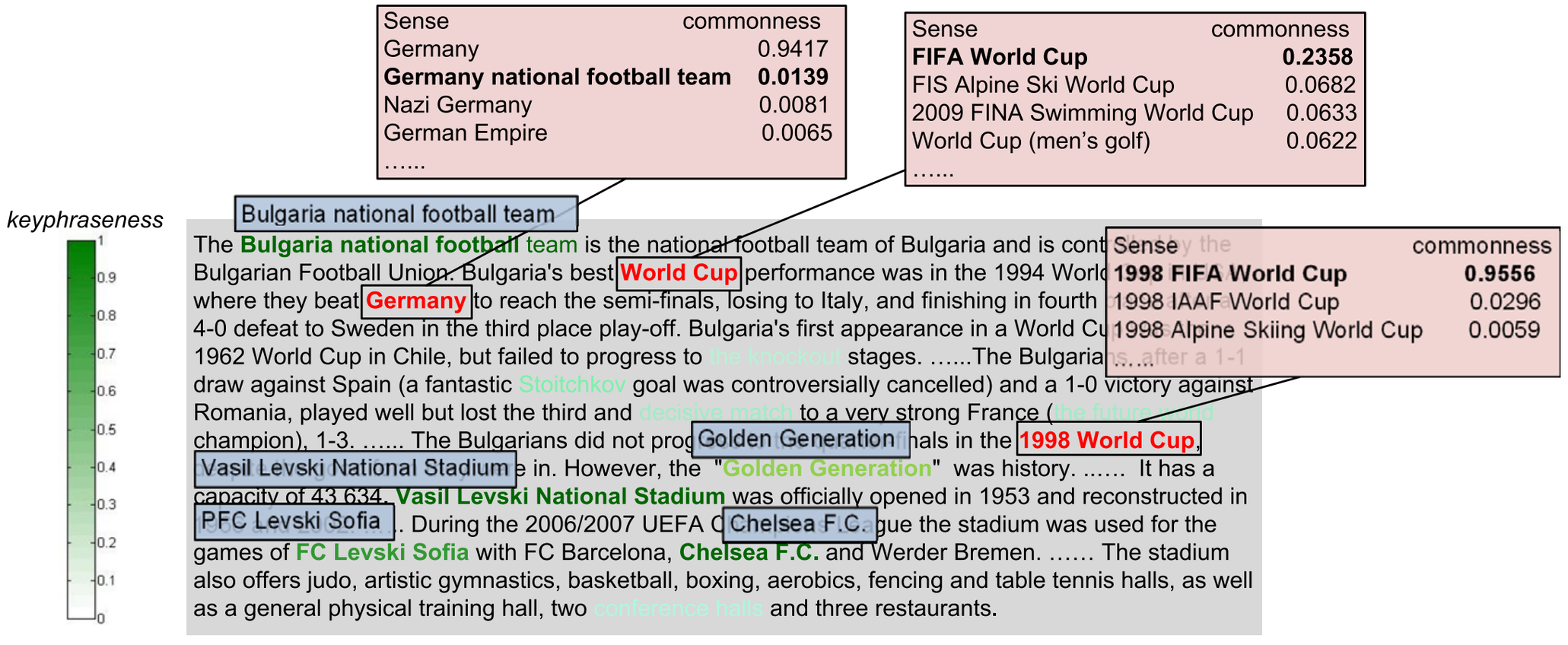


Image taken from Li et al. (2013). TSDW: Two-stage word sense disambiguation using Wikipedia. In JASIST 2013.

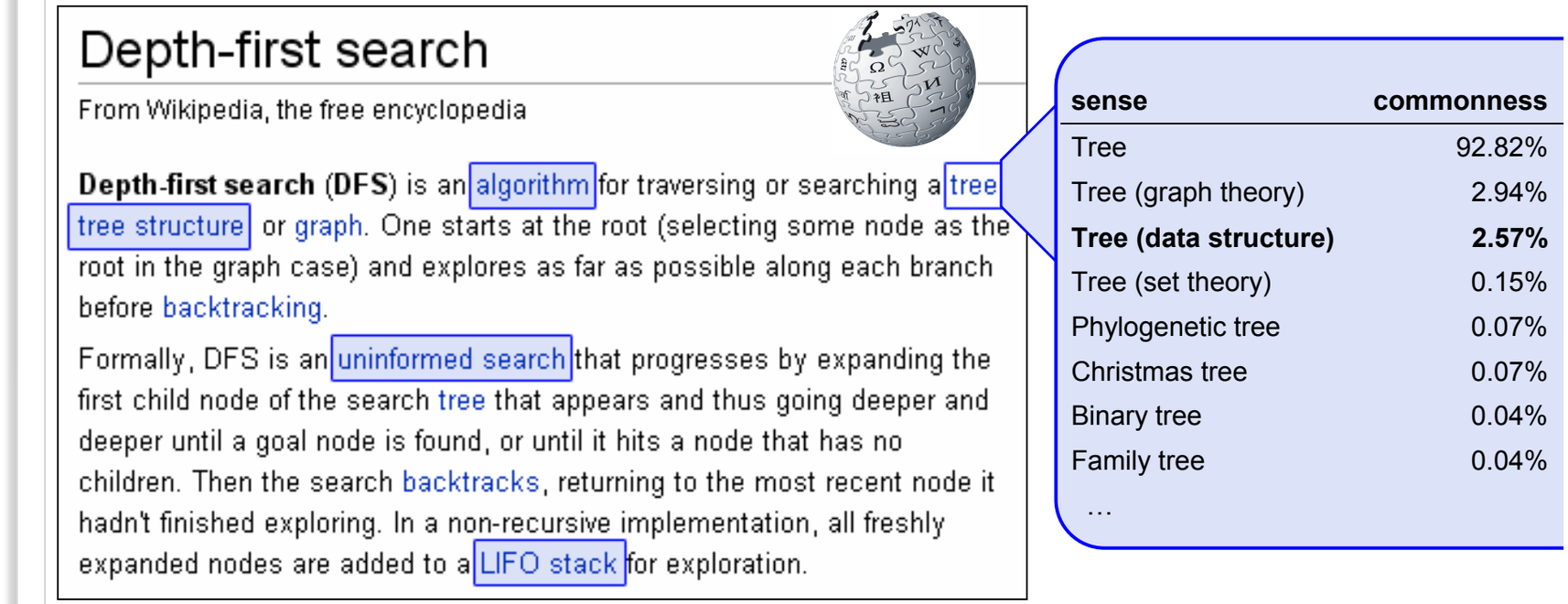
Learning to Link with Wikipedia

[Milne & Witten 2008b]

- Key idea: disambiguation informs detection
  - start with unambiguous senses
  - compare each possible sense with its *relatedness* to the context sense candidates
  - So, first LG, then base MD on these results

Learning to Link with Wikipedia

[Milne & Witten 2008b]



Depth-first search

From Wikipedia, the free encyclopedia

Depth-first search (**DFS**) is an algorithm for traversing or searching a tree tree structure or graph. One starts at the root (selecting some node as the root in the graph case) and explores as far as possible along each branch before backtracking.

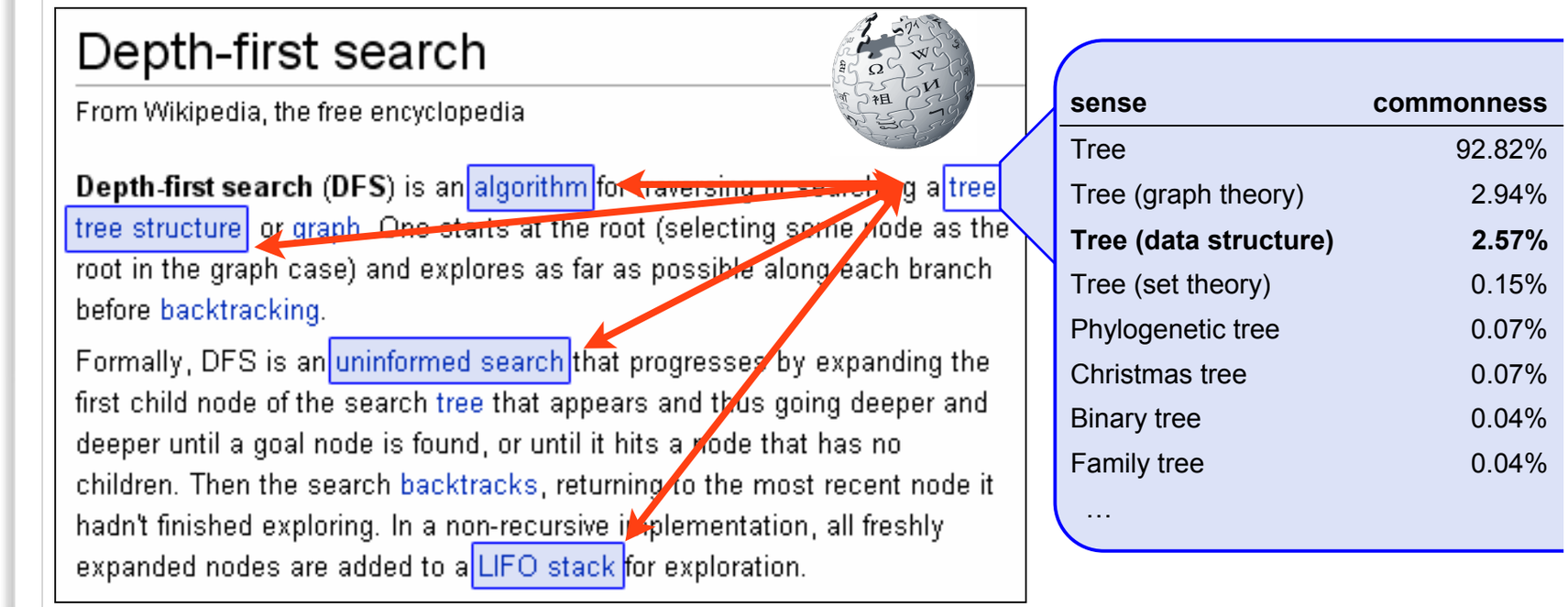
Formally, DFS is an uninformed search that progresses by expanding the first child node of the search tree that appears and thus going deeper and deeper until a goal node is found, or until it hits a node that has no children. Then the search backtracks, returning to the most recent node it hadn't finished exploring. In a non-recursive implementation, all freshly expanded nodes are added to a LIFO stack for exploration.

sense	commonness
Tree	92.82%
Tree (graph theory)	2.94%
Tree (data structure)	**2.57%**
Tree (set theory)	0.15%
Phylogenetic tree	0.07%
Christmas tree	0.07%
Binary tree	0.04%
Family tree	0.04%
…	

Image taken from Milne and Witten (2008b). Learning to Link with Wikipedia. In CIKM '08.

Learning to Link with Wikipedia

[Milne & Witten 2008b]



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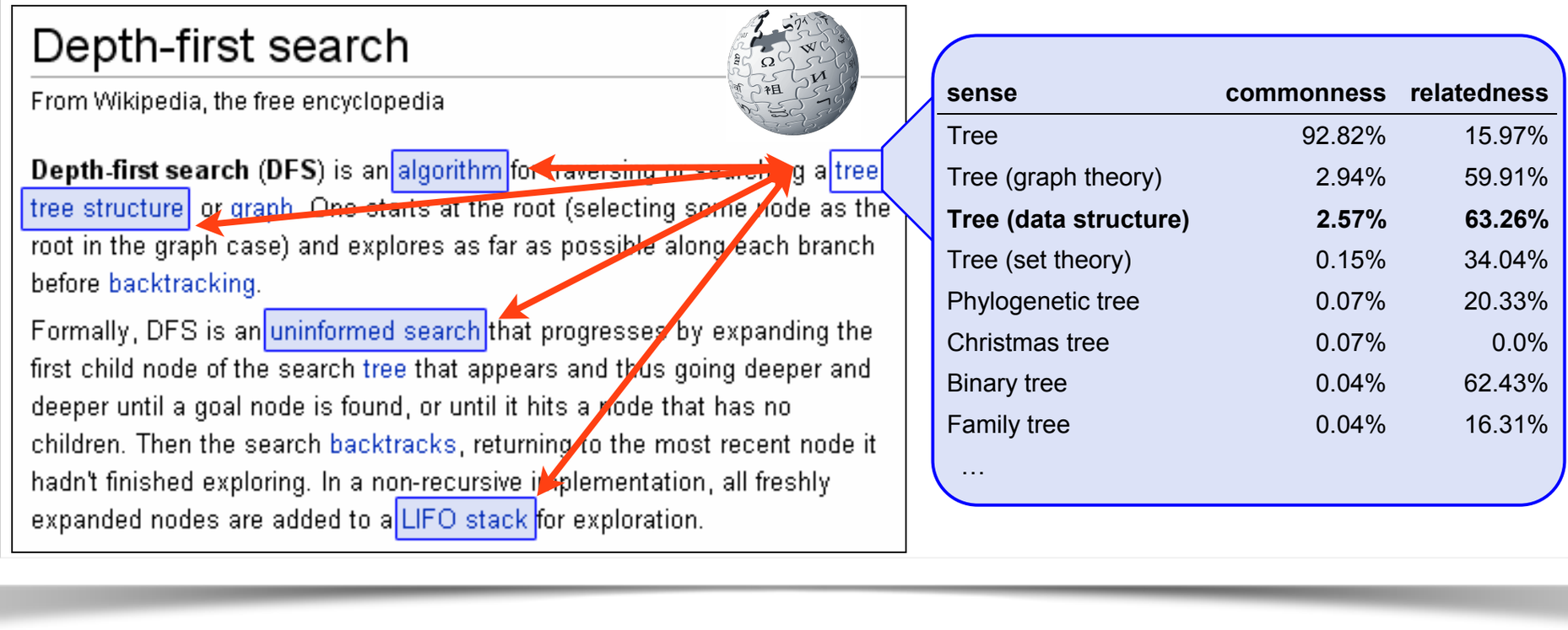

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Entity relatedness

- relatedness(c, c') **[Milne & Witten 2008a]**
  - "How related are *c* and *c'*?"

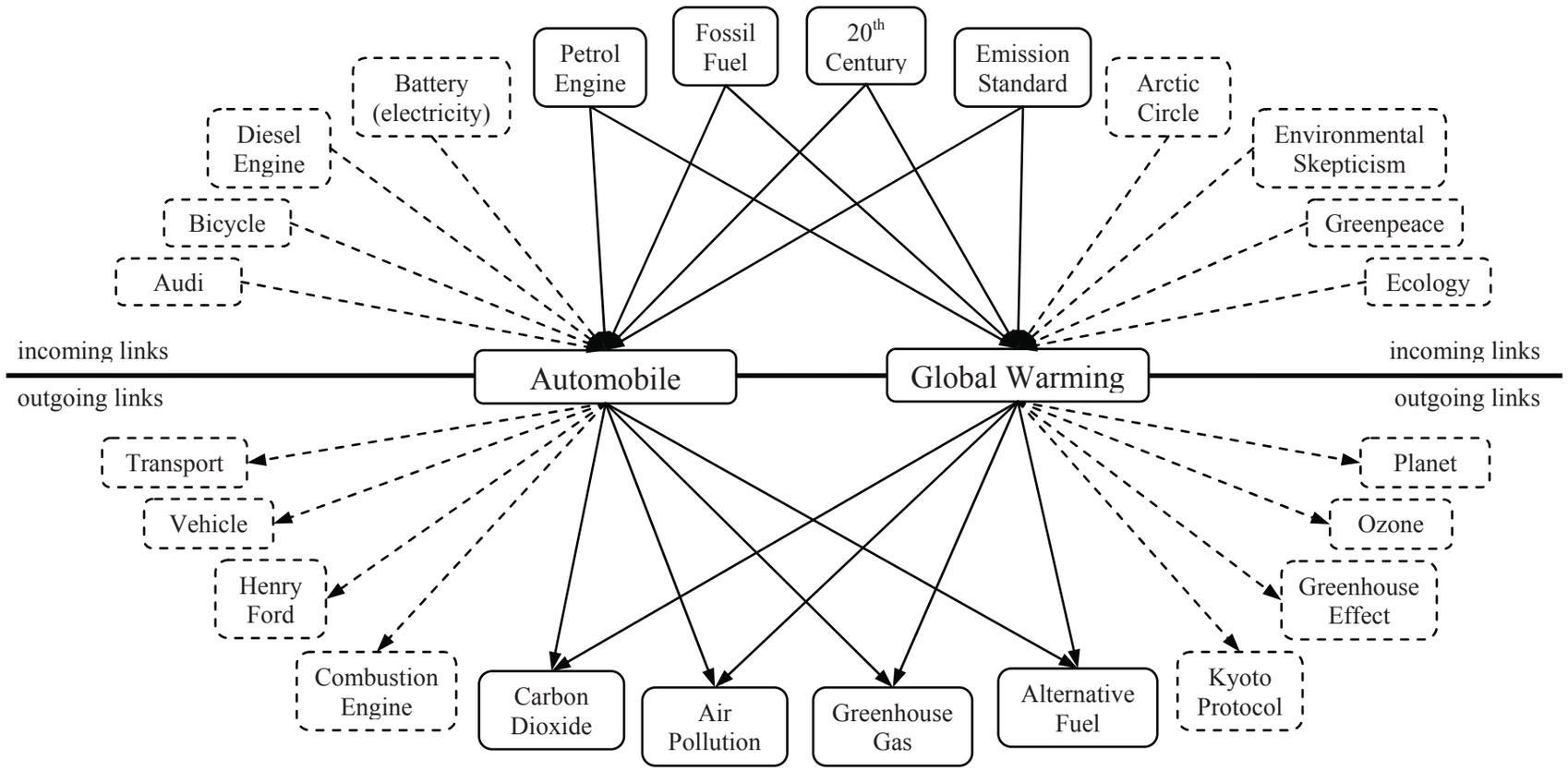

Image taken from Milne and Witten (2008a). An Effective, Low-Cost Measure of Semantic Relatedness Obtained from Wikipedia Links. In AAAI WikiAI Workshop.

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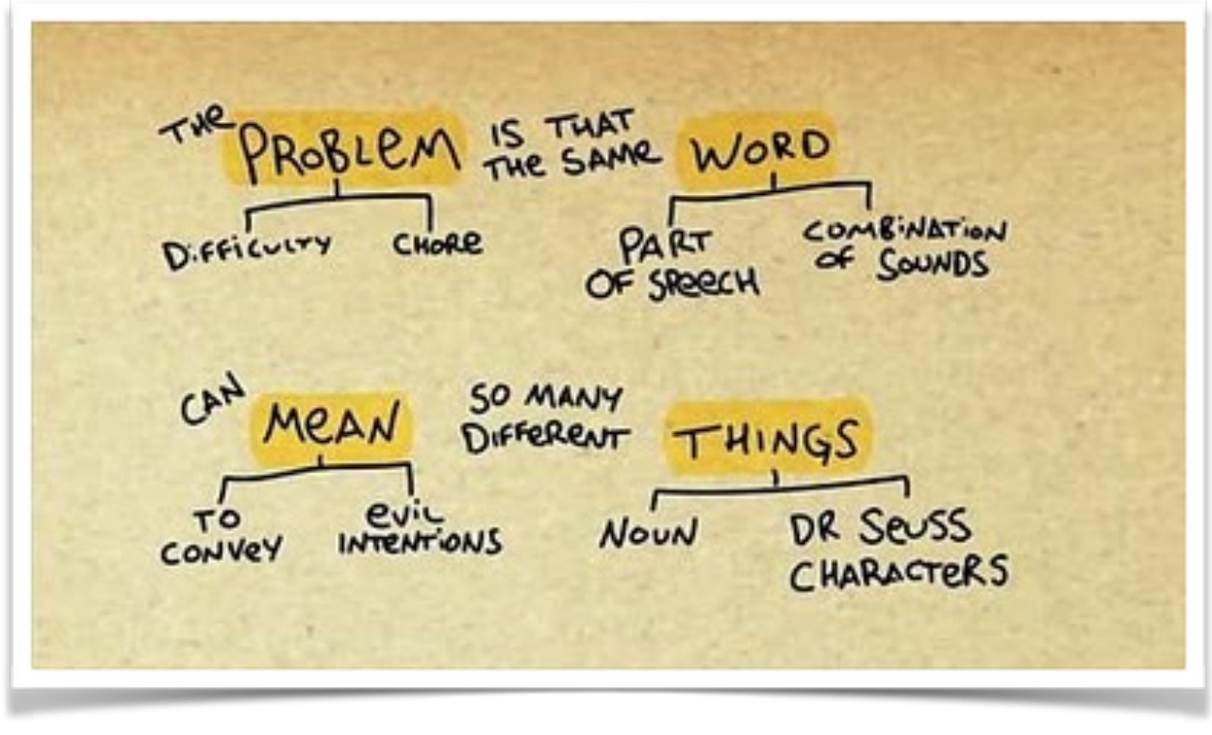
Number of links with target c

Intersection of inlinks with target c and c'

$$\frac{\log(\max(|L_c|, |L_{c'}|)) - \log(|L_c \cap L_{c'}|)}{\log(|WP|) - \log(\min(|L_c|, |L_{c'}|))}$$

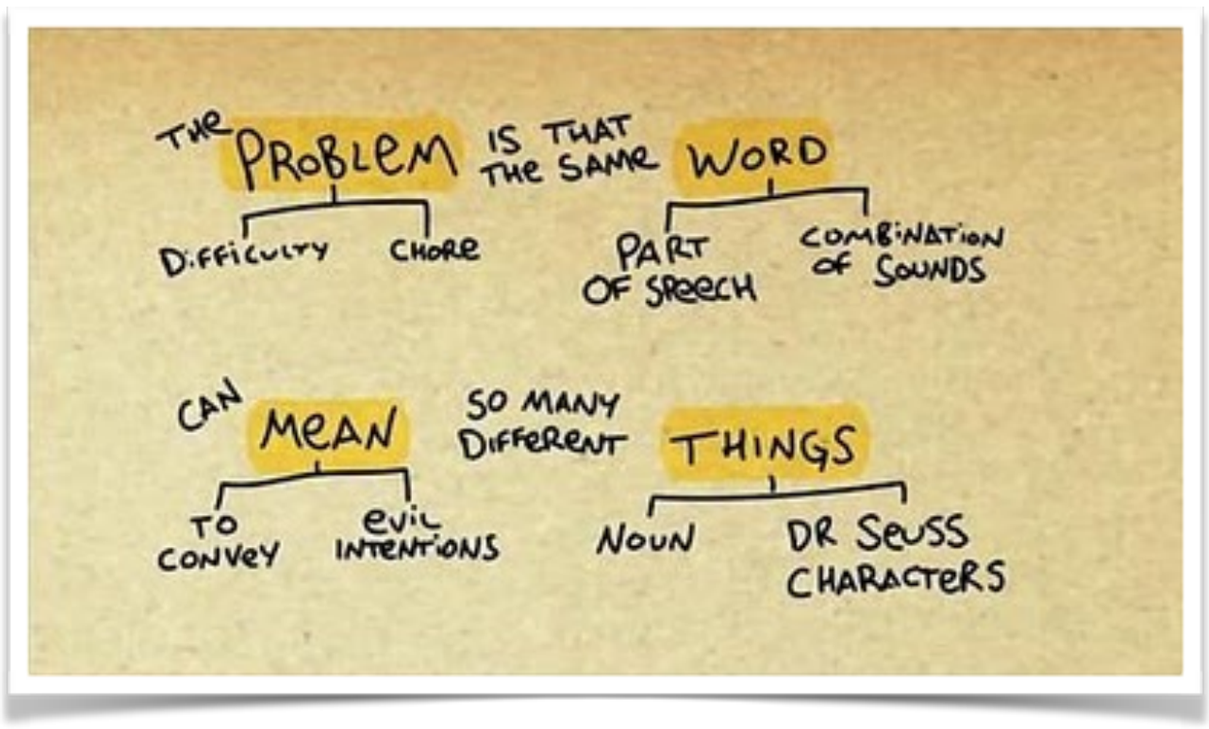
Total number of Wikipedia articles

Context


THE PROBLEM IS THAT THE SAME WORD
DIFFICULTY
CHORE
PART OF SPEECH
COMBINATION OF SOUNDS
CAN MEAN SO MANY DIFFERENT THINGS
TO CONVEY
EVIL INTENTIONS
NOUN
DR SEUSS CHARACTERS

Main intuition

- Leverage “context” as disambiguation signal
  - query: history, session, interests; …
  - phrase: sentence, paragraph, document, …
- But also candidate entity context
  - e.g., KG, candidate entity graph, relatedness, …



Local versus global context

- "Global"
  - i.e., disambiguation of the whole candidate entity graph
  - NP-hard
- Optimization
  - reduce the search space to a "disambiguation context"
    - all plausible (reciprocal) disambiguations **[Cucerzan 2007]**
    - unambiguous surface forms, pair-wise comparisons, and/or averages **[Milne & Witten 2008b]**
    - hill-climbing, integer linear programs **[Kulkarni et al. 2009]**
    - hybrid + ML **[Ratinov et al. 2011, Ferragina & Scaiella 2010]**

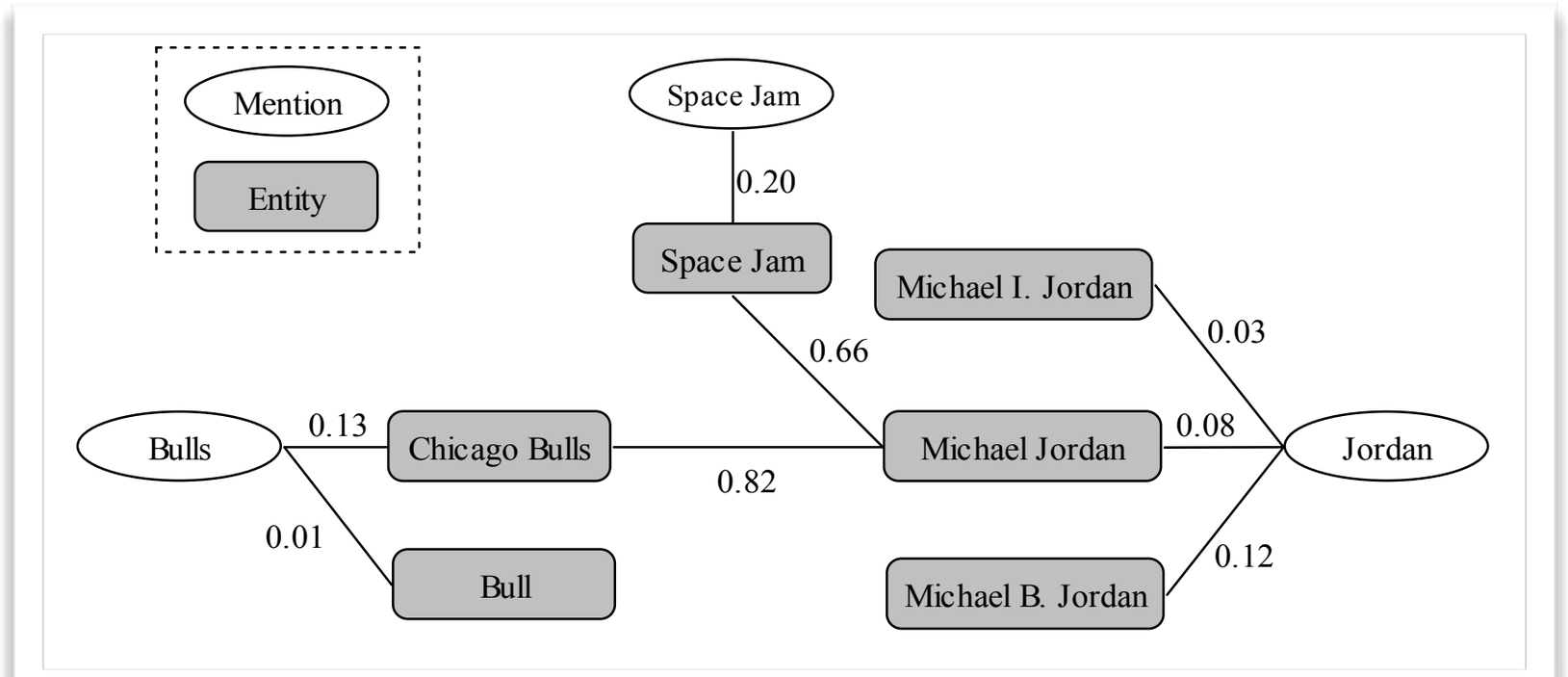
Local and Global Algorithms for Disambiguation to Wikipedia

[Ratinov et al. 2011]

- Main contribution, in steps – MD + DA
1. use “local” approach (e.g., commonness) to generate a disambiguation context
2. apply “global” machine learning approach on pairs
   - relatedness, PMI
     - {inlinks, outlinks} in various combinations (c and c’)
     - {avg, max}

Graph-based approaches

- Random walk with restarts **[Guo & Barbosa 2014]**
- Random walk on a graph defined by the intra-Wikipedia links **[Han et al. 2011]**



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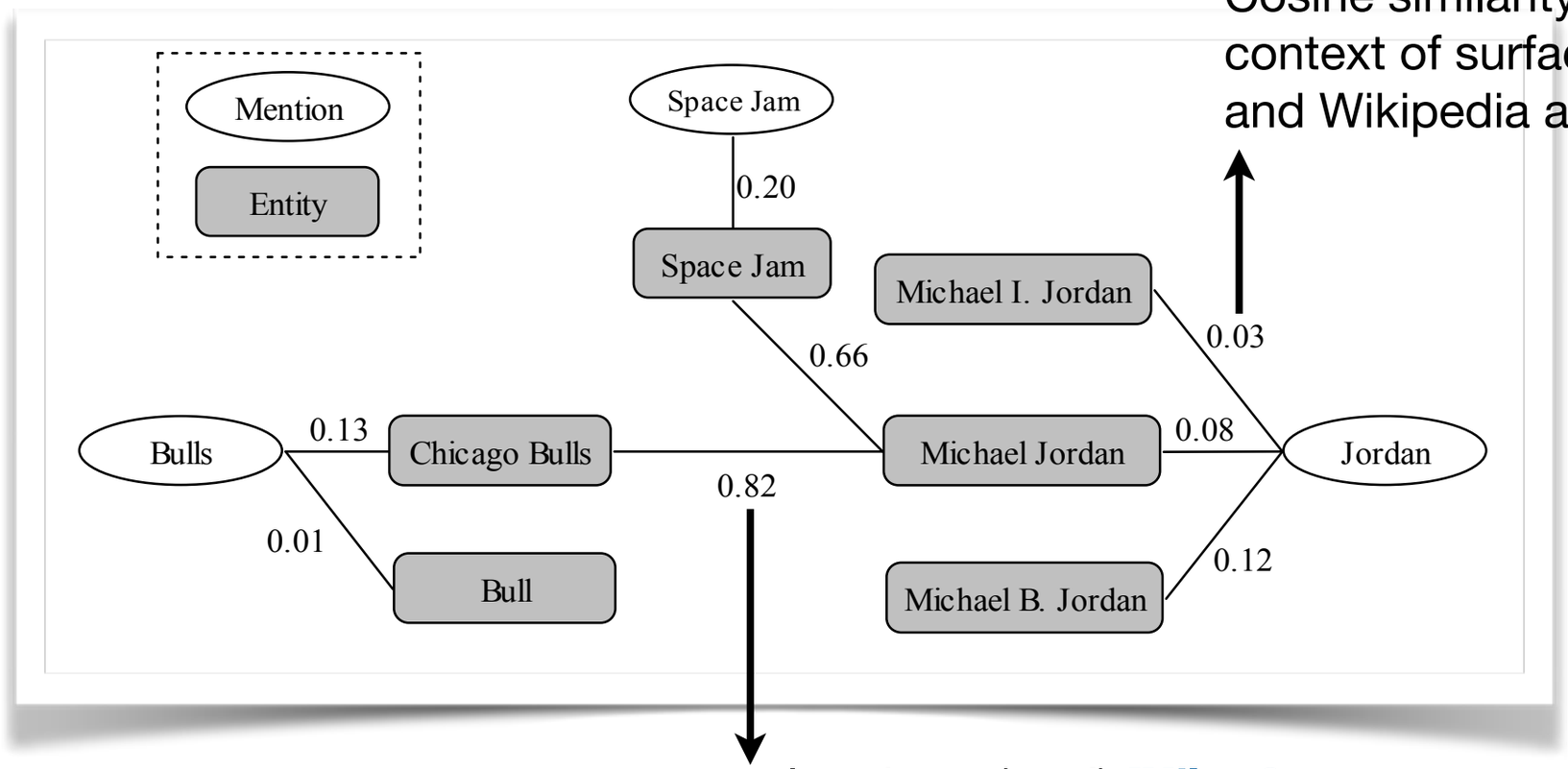


Cosine similarity between context of surface form and Wikipedia article

relatedness(c, c') **[Milne & Witten 2008a]**

Topic modeling approaches

- "Extend" BOW approaches to include disambiguation with LDA topics **[Han & Sun 2012]**
  - compare topic distributions of source document with candidate entities **[Pilz et al. 2011]**

Table 1: Topics for entities with name *John Taylor* (excerpt) with associated probability value

disambiguation term	i	p(t_i)	Important words (titles) of the topics
South Carolina governor	109	0.3805	unit state, state senat, lieuten governor, hous repres, elect governor, ...
	120	0.2477	north carolina, south carolina, unit state, west virginia, civil war, ...
athlete	80	0.4190	summer olymp, gold medal, world record, silver medal, world championship, ...
	135	0.1047	unit state, rhode island, baltimor maryland, new hampshir, georg washington, ...
racing driver	129	0.7407	grand prix, race driver, motor race, formula, race team, sport car, ...
jazz	141	0.5781	jazz musician, big band, new york, duke ellington, jazz band, ...
bass guitarist	18	0.2964	rock band, solo album, play guitar, band member, rock roll, ...
	70	0.1594	album releas, studio album, debut album, record label, music video, ...

Topic modeling approaches

- "Extend" BOW approaches to include disambiguation with LDA topics **[Han & Sun 2012]**
  - compare topic distributions of source document with candidate entities **[Pilz et al. 2011]**
- Associate each entity with a latent topic
  - Semi-supervised **[Kataria 2011]** or using sparse Gibbs sampling **[Houlsby & Ciaramita 2014]**

Word embeddings

- Jointly embedding words and entities, using anchors as “bridge”
  - **[Wang et al. 2014]**
- PageRank on an “embeddings graph”
  - **[Zwicklbauer et al. 2016]**
- Disambiguation
  - **[He et al. 2013, Blanco et al. 2015]**

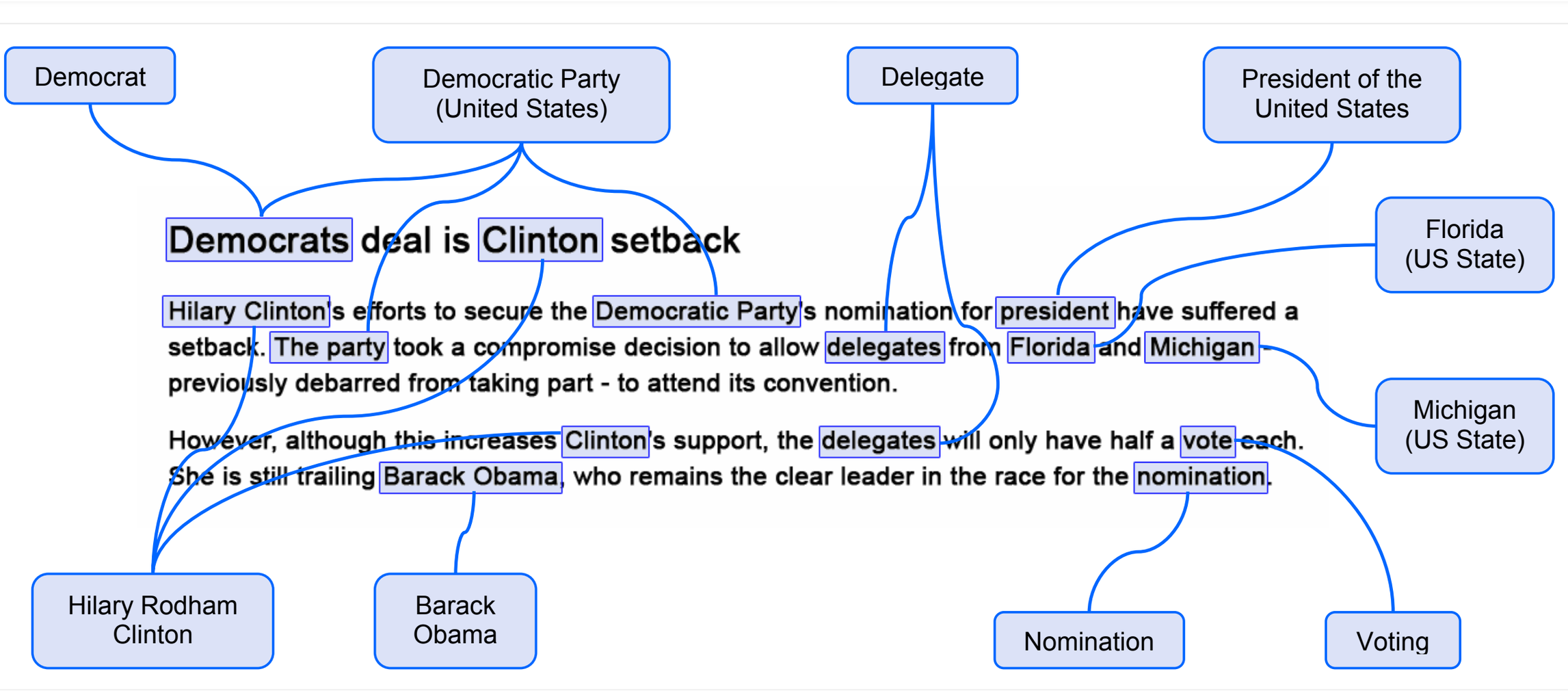
Evaluation

Entity linking evaluation

- Ingredients
- knowledge base
- input texts
- gold-standard annotations
- evaluation metrics

Evaluation metrics

- What is the task?



Evaluation metrics

- Compounded problem
  - tagging/spanning – **MD**
  - entity linking – **LG**/**DA**

Evaluation metrics

- Set-based (similar to WSD)
  - "How many correct links were retrieved?"
    - precision, recall, F-measure
- Rank-based
  - "Was the correct link(s) retrieved with a high score?"
    - precision@k, recall@k, P1, R-prec, MRR, MAP, etc.
- macro/micro
  - per mention
  - per tweet, query, sentence, document

Test collections

Gold-standard annotations

- Human annotators, labeling or judging links from input “documents” to entities in the KB

Entity linking test collections

- Wikipedia
- MSNBC
- AQUAINT
- ACE
- Twitter
- AIDA (CoNLL)
- IITB (web data)
- INEX link-the-wiki
- TREC knowledge base acceleration (KBA)
- TAC knowledge base population (KBP)
- Yahoo Webscope: web search queries (in sessions)
- ERD 2014: http://web-ngram.research.microsoft.com/ERD2014/
- …

Evaluation - recap

- Even with so many test collections to choose from, there's still quite some variation
- People create their own "extracts" from WP
- Same method, same test collection, but different results in different papers
  - tokenization, normalization, ...
- We need meta-evaluations…
  - **[Hachey et al. 2013], [Cornolti et al. 2013]**

A Framework for Benchmarking Entity-Annotation Systems

[Cornolti et al. 2013]

- Compare five publicly available entity linkers
  - **[Hoffart et al. 2007]** (AIDA)
  - **[Ratinov et al. 2011]**
  - **[Ferragina & Scaiella 2010]** (TAGME)
  - **[Milne & Witten 2008]** (wikipedia-miner)
  - DBpedia Spotlight
- And also investigate parameter/cut-off settings

See http://acube.di.unipi.it/bat-framework/ and https://github.com/marcocor/bat-framework/.

A Framework for Benchmarking Entity-Annotation Systems

[Cornolti et al. 2013]

- On five publicly available test collections
  - AIDA **[Hoffart et al. 2007]**
    - based on CoNLL 2003: noun annotations
    - 1393 Reuters newswire articles
    - hand-annotated all nouns with entities in YAGO2
  - AQUAINT **[Milne & Witten 2008]**
  - MSNBC **[Cucerzan 2007]**
  - IITB **[Kulkarni et al. 2010]** (web data)
  - Twitter **[Meij et al. 2012]**

A Framework for Benchmarking Entity-Annotation Systems

[Cornolti et al. 2013]

- Main findings
  - different systems perform well in different scenarios
  - AIDA and TagMe seem to be the winners overall

GERBIL – General Entity Annotator Benchmarking Framework

[Usbeck et al. 2015]

- REST-based platform for entity linking using uniform measuring approaches
  - Systems: Wikipedia Miner, Illinois Wikifier, DBpedia Spotlight, TagMe 2, KEA, WAT, AGDISTIS, Babelfy, NERD-ML, AIDA, entityclassifier.eu, FREME e-Entity
  - Data sets: AIDA/CoNLL, AQUAINT, DBpedia Spotlight, IITB, KORE50, MSNBC, Microposts, N3-RSS-500, N3-Reuters-128, OKE 2015

See http://aksw.org/Projects/GERBIL.html.

GERBIL – General Entity Annotator Benchmarking Framework

[Usbeck et al. 2015]

- Provides linkable experiments, e.g.,

gerbil.aksw.org/gerbil/experiment?id=201510160026

Home | Configure Experiment | Experiment Overview | About Us

GERBIL Experiment

Experiment URI: http://gerbil.aksw.org/gerbil/experiment?id=201510160026 and http://w3id.org/gerbil/experiment?id=201510160026
Type: D2KB
Matching: Ma - strong annotation match

Annotator	Dataset	Micro F1	Micro Precision	Micro Recall	Macro F1	Macro Precision	Macro Recall	Error Count	Timestamp	GERBIL version
AGDISTIS	ACE2004	0.6583	0.696	0.6245	0.7763	0.801	0.7583	0	2015-10-14 11:24:23	1.1.4
AGDISTIS	AIDA/CoNLL-Complete	0.6027	0.6513	0.5608	0.5697	0.6355	0.5311	0	2015-10-16 16:11:17	1.1.4
AGDISTIS	AIDA/CoNLL-TestA	0.5906	0.6393	0.5487	0.5336	0.5912	0.4981	0	2015-10-16 15:59:50	1.1.4
AGDISTIS	AIDA/CoNLL-TestB	0.5832	0.63	0.5429	0.5803	0.6442	0.5449	0	2015-10-16 15:59:57	1.1.4
AGDISTIS	AIDA/CoNLL-Training	0.6105	0.6595	0.5682	0.5753	0.6434	0.5353	0	2015-10-16 16:06:43	1.1.4

DIY Entity Linking – footnotes

- ClueWeb annotated with Freebase (FACC1)
- wiki-links
- Dictionaries for Linking Text, Entities and Ideas

concept:	“***soccer***”		
	football *and* Football		
	Soccer *and* soccer		
	Association football	サッカー	piłkarz
	fútbol *and* Fútbol	축구	voetbalclub
	footballer	footballeur	**ฟุตบอล**
	Futbol *and* futbol	Fußballspieler	bóng đá
	Fußball	sepak bola	voetbal
	futebol	足球	Foutbaal
	futbolista	فوتبال	futebolista
		футболист	لعبة كرة القدم
		כדורגל	fotbal

Entity linking for end-to-end IR

Entity linking for end-to-end IR

[Raviv et al. 2016]

- Approach
  - entity linking on queries and documents
    - (they use Tagme and Wikifier)
    - output: mentions, entity IDs, and confidence levels in [0,1]
  - retrieval model over a "token space" that is defined by the union of terms and entities
  - leverage notion of "pseudo counts" and "pseudo lengths"

Entity linking for end-to-end IR

[Raviv et al. 2016]

- Thresholding on confidence levels
  - two variants
    - hard thresholding (HT): all mentions above a fixed level will be replaced by the entity, everything below will be kept as terms
    - soft thresholding (ST): incorporate confidence levels.
    - both: add term level interpolation to obtain pseudo counts
  - ranking using cross-entropy between LM(q) and LM(d) in the token space
  - alternative: no interpolation at the term level but data fusion of the components (F-HT and S-HT)
    - similar performance to HT/ST

Recap

- Entity Linking
  - introduction
  - methods
  - evaluation

Q: UK EU relationships

Q: UK EU relationships

Entity linking would give you the following entities:

- enwiki:United_Kingdom
- enwiki:European_Union
- enwiki:Relationship

Q: UK EU relationships

Entity linking would give you the following entities:

- enwiki:United_Kingdom
- enwiki:European_Union
- enwiki:Relationship
- (maybe) enwiki:Foreign_relations_of_the_United_Kingdom
- (maybe) enwiki:Foreign_relations_of_the_United_Kingdom#Europe
- (maybe) enwiki:Politics_of_the_United_Kingdom
- (maybe) enwiki:Politics_of_the_United_Kingdom#European_Union
- (maybe) enwiki:Euroscepticism_in_the_United_Kingdom
- (maybe) enwiki:Brexit
- (maybe) enwiki:Theresa_May