

Part I

Entity Linking

Outline

- Entity Linking
 - introduction
 - methods
 - evaluation
 - test collections
 - toolkits
 - open challenges

Introduction

article discussion edit this page history

You're running!

Plant

From Wikipedia, the free encyclopedia

For other uses, see Plant (disambiguation).

Plants are a major group of living things including familiar organisms such as trees, flowers, herbs, ferns, and mosses.

About 350,000 species of plants, defined as seed plants, bryophytes, ferns and fern allies, have been estimated to exist. As of 2004, some 287,655 species had been identified, of which 258,650 are flowering and 15,000 bryophytes.

Tree

From Wikipedia, the free encyclopedia

For other senses of the word, see tree (disambiguation)

A tree is a large, perennial, woody plant. Though there is no set definition regarding minimum size, the term generally applies to plants at least 6 m (20 ft) high at maturity and, more importantly, having



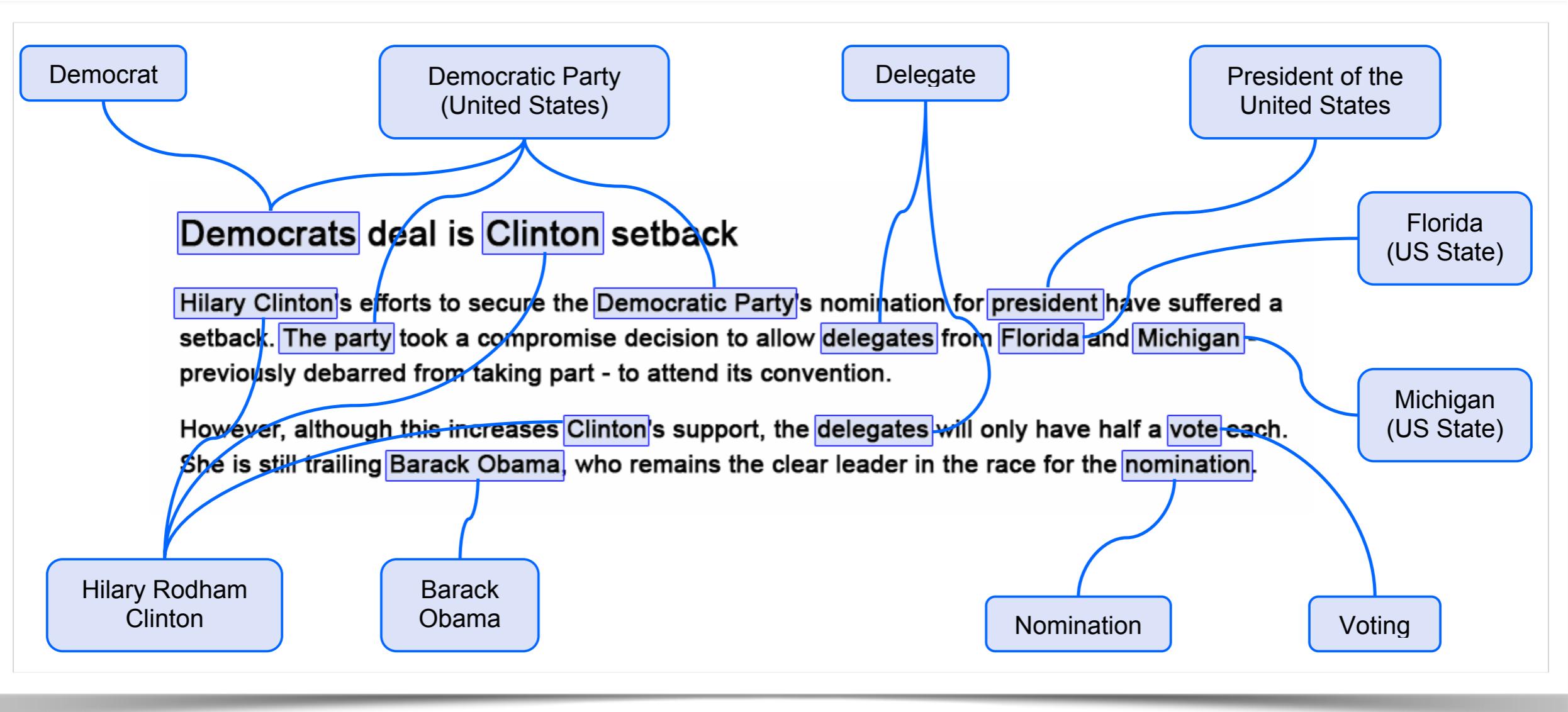
Fossil range: Middle-Late Ordovician - Recent

Species

From Wikipedia, the free encyclopedia

This article is about biology. For the movie, see Species (film). In biology, a species is one of the basic units of biodiversity. In classification, a species is assigned a two-part name, first the genus is listed first (with its leading letter capitalized), followed by the species. For example, humans belong to the genus *Homo*, and species *Homo sapiens*. The name of the species is the whole name, not just the second term (which may be called [specific epithet](#)).

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



**Let's learn something about
Spin-Optical Metamaterial**

REPORT

Spin–Optical Metamaterial Route to Spin–Controlled Photonics

Nir Shitrit, Igor Yulevich, Elhanan Maguid, Dror Ozeri, Dekel Veksler, Vladimir Kleiner, Erez Hasman*

 Author Affiliations

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ABSTRACT EDITOR'S SUMMARY

Spin optics provides a route to control light, whereby the photon helicity (spin angular momentum) degeneracy is removed due to a geometric gradient onto a metasurface. The alliance of spin optics and metamaterials offers the dispersion engineering of a structured matter in a polarization helicity-dependent manner. We show that polarization-controlled optical modes of metamaterials arise where the spatial inversion symmetry is violated. The emerged spin-split dispersion of spontaneous emission originates from the spin-orbit interaction of light, generating a selection rule based on symmetry restrictions in a spin-optical metamaterial. The inversion asymmetric metasurface is obtained via anisotropic optical antenna patterns. This type of metamaterial provides a route for spin-controlled nanophotonic applications based on the design of the metasurface symmetry properties.

Received for publication 7 January 2013.



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MICROSOFT EDGE

Degenerate energy levels – Wikipedia, the free encyclopedia

W en.wikipedia.org/wiki/Degenerate_energy_level

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Input Text

Italiano English

momentum) degeneracy of spin optical modes of matter in a polarized interaction of light optical metamaterials optical antenna pads nanophotonic applications

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Tagged text Topics

Spin optics provides momentum) degeneracy of spin optical modes of matter in a polarized interaction of light optical metamaterials optical antenna pads nanophotonic applications

Article Talk Read Edit View history

Degenerate energy levels

From Wikipedia, the free encyclopedia
(Redirected from Degenerate energy level)

This article is about different quantum states having the same energy. For other uses, see Degeneracy.
"Quantum degeneracy" redirects here. It sometimes refers to a degenerate matter.

 This article needs additional citations for verification. Please help improve this article by adding citations to reliable sources. Unsourced material may be challenged and removed. (February 2009)

In quantum mechanics, a branch of physics, two or more different states of a system are said to be degenerate if they are all at the same energy level. It is represented mathematically by the system having more than one linearly independent eigenstate with the same eigenvalue. Conversely, an energy level is said to be degenerate if it contains two or more different states at a particular energy level is called the level's degeneracy, and this phenomenon is generally known as a quantum degeneracy.

From the perspective of quantum statistical mechanics, several degenerate states at the same level are all equally probable of being filled.

Contents [hide]

- 1 Mathematics
- 2 Examples
- 3 Perturbation
- 4 See also
- 5 Further reading

Mathematics

The term comes from the fact that, for a point spectrum Hamiltonian H , degenerate eigenstates correspond to identical eigenvalues. Since eigenvalues correspond to roots of the characteristic polynomial, the degeneracy here has the same meaning as the common mathematical usage of the word.

The eigenvalue λ is called nondegenerate (or simple) when its corresponding eigenvector is unique up to a constant factor, or, the same, the corresponding eigenspace is one-dimensional. Indeed, the eigenspace $\{|\psi\rangle : H|\psi\rangle = \lambda|\psi\rangle\}$ (in bra-ket notation) is not necessarily one-dimensional. If there exist at least two linearly independent ket-vectors in it, then this eigenvalue is called degenerate. Its degree of degeneracy is then the dimension of the eigenspace, which is the same as the number of distinct (linearly independent) quantum states associated with it.

Examples

In atomic physics, electron's energy levels are often degenerate, where different possible occupation states for particles may be related by symmetry. For example, in the hydrogen atom, for a given principal quantum number n , there exist several states which have that energy, but differ in the eigenvalues of angular momentum L^2 , spin component S_z and so on. The eigenvalue of an operator \hat{O} for a degenerate state is called a quantum number.

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- + Creating smart tags and settings

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Smart tagged text in Word

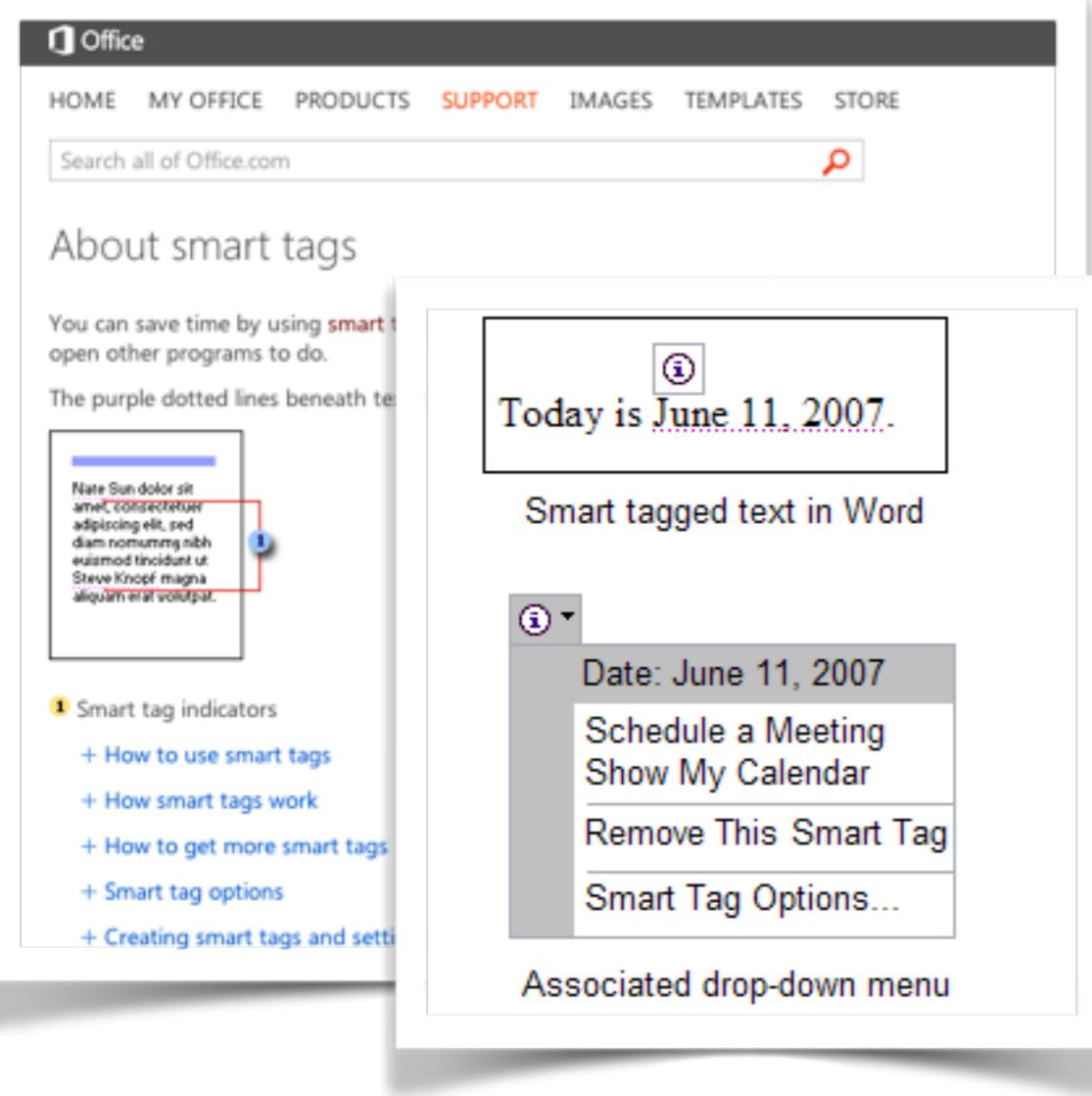
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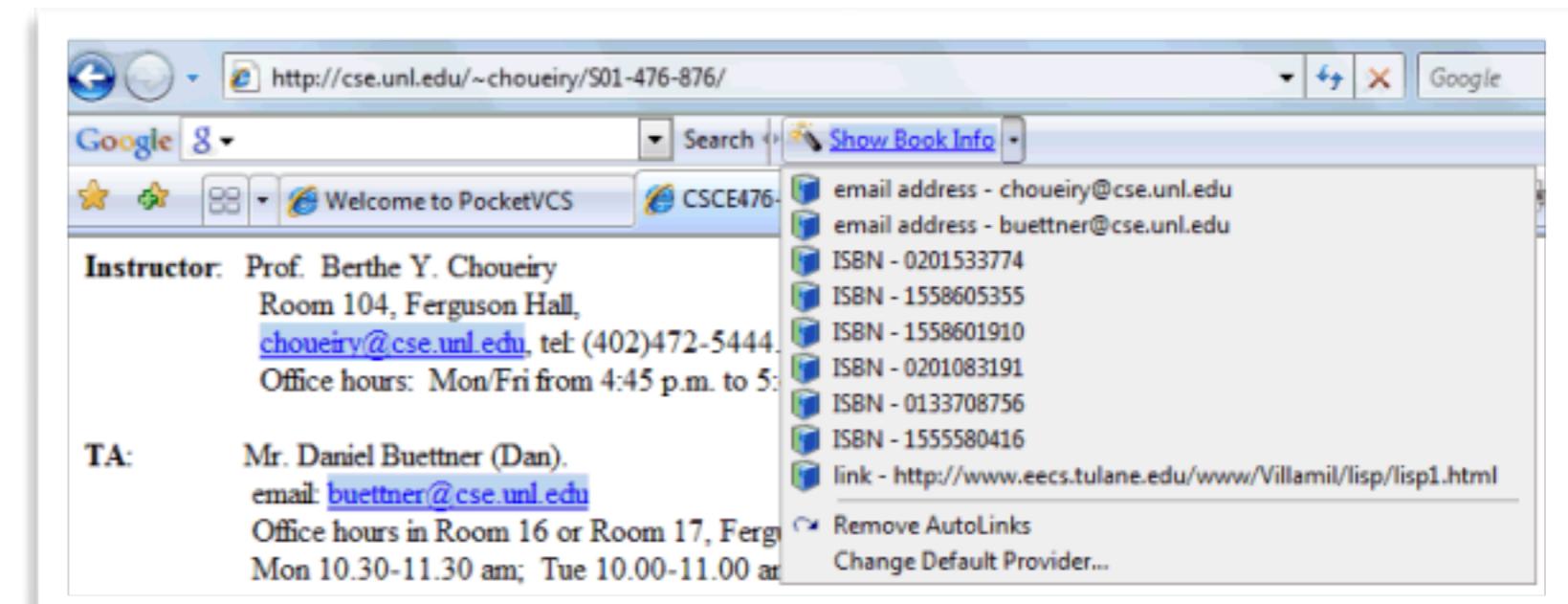
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Instructor: Prof. Berthe Y. Choueiry
Room 104, Ferguson Hall,
choueiry@cse.unl.edu, tel: (402)472-5444.
Office hours: Mon/Fri from 4:45 p.m. to 5:30 p.m.

TA: Mr. Daniel Buettner (Dan).
email: bueettner@cse.unl.edu
Office hours in Room 16 or Room 17, Ferguson Hall
Mon 10.30-11.30 am; Tue 10.00-11.00 am

- email address - choueiry@cse.unl.edu
- email address - buettner@cse.unl.edu
- ISBN - 0201533774
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Google toolbar

A screenshot of the WolframAlpha website. The background is a vibrant green patterned with numerous small, white, semi-transparent icons representing various subjects like science, technology, and culture. At the top, there's a navigation bar with standard browser controls (back, forward, search, etc.) and the URL www.wolframalpha.com. A red banner at the top left says "New: Practice math problems and more online with Wolfram Problem Generator." On the right side of the header, there are links for "Sign in", "Reader", and a color palette. Below the header, a green banner encourages users to "Try our new background colors" with a small upward arrow icon.

The main content area features the WolframAlpha logo with its tagline "computational knowledge engine". Below the logo is a search bar with the placeholder text "Enter what you want to calculate or know about:". A dropdown menu is open over the search bar, showing suggestions for "montreal": "montreal weather", "montreal population", "montreal vs toronto", "montreal temperature", "montreal canada", and "montreal to boston". At the bottom of this menu are five small, semi-transparent icons representing different types of data or analysis.

At the bottom of the page, there's a footer with links to "About", "Pro", "Products", "Mobile Apps", "Business Solutions", "For Developers", "Resources & Tools", "Blog", "Community", "Participate", "Contact", "Connect" (with links to social media), and "Privacy". There's also a copyright notice: "© 2014 Wolfram Alpha LLC—A Wolfram Research Company | Terms | Privacy". A "Display a menu" button is located at the very bottom left.

www.wolframalpha.com/input/?i=montreal

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WolframAlpha computational knowledge engine

montreal

Assuming Montreal (Canada) | Use Montreal (United States) or more instead

Input interpretation: Montreal, Quebec, Canada

Populations:

city population	1.65 million people (country rank: 2 nd) (2011 estimate)
metro area population	3.764 million people (Montreal metro area) (2007 estimate)

Location:

World map Show coordinates

Satellite image >

Local map: 70 miles across Metric

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Montreal is a city in the Canadian province of Quebec. It is the largest city in the province, the second-largest in Canada and the 8th-largest in North America ...
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www.tourisme-montreal.org ▾
Information about local hotels, restaurants, attractions, festivals and services for the tourism industry.
What To Do · Hotels and Booking · Travel Information · Packages

[Map of Montreal, Quebec, Canada](#)
bing.com/maps



Show traffic

Display a menu

Montreal

 Montreal is a city in the Canadian province of Quebec. It is the largest city in the province, the second-largest in Canada and the 8th-largest in North America. Originally called Ville-Marie, or "City of Mary", it is named after Mount Royal... +
en.wikipedia.org

Local time: 5:22 PM 6/15/2014
Population: 1.65 million (2011)
Colleges and universities: McGill University · Concordia University · Université de Montréal · Université du Québec à Montréal +
Host of: 1976 Summer Olympics
Nearby airport: Montréal–Pierre Elliott Trudeau International Airport
Mayor: Denis Coderre

Weather

 73 °F Clear
H 76 °F · L 52 °F

Points of interest

     
Mount Royal Old Montreal Bell Centre Montreal Biodome Montreal Botanical ...

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Tourism Montreal: Traveller
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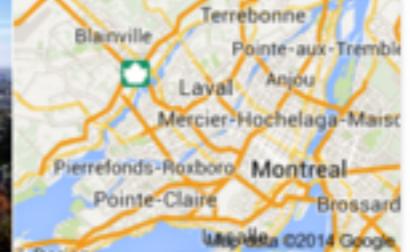
RAW: Sinkhole on De La Montagne
CBC.ca - 2 hours ago
A sinkhole big enough to swallow a person opened up right in the middle of downtown Montreal on De La Montagne Street on Saturday ...

Towns in Montreal celebrate 10 demerged years
CBC.ca - 1 hour ago

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Montreal
City in Canada

Montreal is a city in the Canadian province of Quebec. It is the largest city in the province, the second-largest in Canada and the 8th-largest in North America. [Wikipedia](#)

Area: 141 sq miles (365.1 km²)
Weather: 85°F (29°C), Wind SE at 3 mph (5 km/h), 11% Humidity
Local time: Sunday 5:22 PM
Population: 1.621 million (2006) [UNdata](#)
Province: Québec

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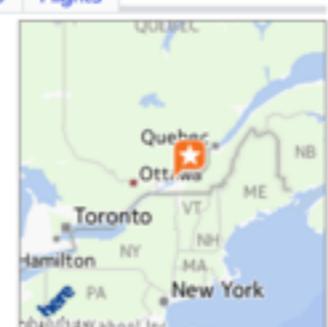
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Montreal, Canada
travel.yahoo.com
Sun Jun 15 5:23 pm EDT Mostly Cloudy, 73°F

Montreal is a city in the Canadian province of Quebec. It is the largest city in the province, the second-largest in Canada and the 8th-largest in North America. Originally called Ville-Marie, or "City of Mary", it is named after Mount Royal, the triple-peaked hill in the heart of the city. The city is ... [Wikipedia](#)



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Ben Affleck Steps Out Looking Buff With New Batman Bod

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Yahoo Celebrity

Legendary radio broadcaster Casey Kasem dead at 82

Casey Kasem, the legendary radio broadcaster whose style set the benchmark for Top 40 shows, has died. Danny Deraney, publicist for Kasem's daughter, Kerri, says Kasem died Sunday morning. "We are confirming that Casey Kasem passed away at Fox News from RSS 27 mins ago

Former NFL RB Thomas dies at 41

Former NFL running back Rodney Thomas died on Saturday. He was 41.

The SportsXchange

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3 Riders relieved Philadelphia rail strike is over
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Barcelona 22°C Partly Cloudy

Today 24° 19° Tomorrow 24° 19° Tuesday 25° 18°

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NASDAQ Composite	4,310.65	↑	0.30%
Dow Jones Indust...	16,775.74	↑	0.25%
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Legendary radio broadcaster Casey Kasem dead at 82

Casey Kasem... the legendary radio broadcaster whose voice cut the benchmark for

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Ben Affleck Steps Out Looking Buff With New Batman Bod

Y | + | X

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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
 - classification; retrieval; word sense disambiguation; semantic similarity;...
 - dimensionality reduction (e.g., term vectors)

A little bit of history

- Text classification
- NER
- WSD
- NED/NEN
 - {person name, geo, movie name, ...} disambiguation
 - (Cross-document) coreference resolution
 - Automatic link generation
- Entity linking

Entity linking?

- NE normalization / canonicalization / sense disambiguation
- DB record linkage / schema mapping
 - (not the focus here, but see [\[Demartini et al. 2013\]](#))
- Knowledge base population
- Entity linking
 - D2W
 - Wikification
 - Semantic linking

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
 - ...

Common steps

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

Input Text

Italiano English

momentum) degeneracy is removed due to a geometric gradient onto a metasurface. The alliance of spin optics and metamaterials offers the dispersion engineering of a structured matter in a polarization helicity-dependent manner. We show that polarization-controlled optical modes of [metamaterials](#) arise where the spatial inversion symmetry is violated. The emerged spin-split dispersion of spontaneous emission originates from the spin-orbit interaction of light, generating a selection rule based on symmetry restrictions in a spin-optical metamaterial. The inversion asymmetric metasurface is obtained via anisotropic optical antenna patterns. This type of metamaterial provides a route for spin-controlled nanophotonic applications based on the design of the metasurface symmetry properties.

Many links

Few links

Reset

TAGME!

Tagged text

Topics

Spin [optics](#) provides a route to [control light](#), whereby the [photon helicity](#) (spin [angular momentum](#)) [degeneracy](#) is removed due to a [geometric gradient](#) onto a metasurface. The alliance of sp

Degenerate energy levels

[matter in a p](#)
[optical modes](#):
emerged spir
[interaction of](#)
optical [metar](#)

In physics, two or more different quantum states are said to be degenerate if they are all at the same energy level. Statistically this means that they are all equally probable of being filled, and in... e dispersion engineering of a structured matter. We show that polarization-controlled spatial inversion symmetry is violated. The emission originates from the spin-orbit based on symmetry restrictions in a spin-metasurface is obtained via anisotropic

MD



... degeneracy is removed ...

LG

Q ... degeneracy ...

The screenshot shows a web browser window with four tabs open, each displaying a different Wikipedia page:

- Degeneracy (mathematics)**: A page about the concept in mathematics, mentioning its relation to graph theory and quantum mechanics.
- Degeneracy (biology)**: A page about biological systems where components perform similar functions under certain conditions.
- Degeneracy (graph theory)**: A page about the property of a graph where multiple vertices have the same degree.
- Degenerate energy levels**: A page about quantum mechanics, explaining degeneracy as having the same energy level.

The browser interface includes a sidebar with navigation links like Main page, Contents, and Recent changes, and a bottom bar with tabs for Article, Talk, Read, Edit, View history, and Search.

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The browser interface includes a sidebar with navigation links like Main page, Contents, and Recent changes, and a bottom bar with tabs for Article, Talk, Read, Edit, View history, and Search.

DA

Q ... degeneracy ...

The screenshot shows three separate browser windows side-by-side, each displaying a different Wikipedia page. The top window is titled "Degeneracy (mathematics)" and contains text about the concept in mathematics. The middle window is titled "Degeneracy (biology)" and contains text about the concept in biology, noting it is often used to mean functionally redundant components. The bottom window is titled "Degeneracy (graph theory)" and contains text about the concept in graph theory. All three pages include standard Wikipedia navigation bars at the top.

This screenshot shows four browser windows arranged in a grid. The top-left window is identical to the one in the first screenshot. The top-right window is also identical. The bottom-left window is titled "Degeneracy (graph theory)" and contains text about the concept in graph theory. The bottom-right window is titled "Degenerate energy levels" and contains text about quantum mechanics, stating that an energy level is degenerate if it corresponds to multiple states with the same energy. A green rectangular highlight surrounds the top-right and bottom-right windows, indicating they are the same page viewed in different contexts.

Methods



Preliminaries

- Knowledge bases...
- Wikipedia-based methods
 - commonness
 - relatedness
 - keyphraseness

Wikipedia

- 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]]



Disambiguation pages

- Senses of an ambiguous phrase
- Short description
- (Possible) categorization
- Non-exhaustive

The screenshot shows a web browser window with the title bar "New York (disambiguation) -". The main content area displays the "New York (disambiguation)" page from Wikipedia. The page starts with a short description: "New York is a state in the United States of America." It then lists "New York may also refer to:" followed by several categories: "Places" (with links to "England" and "United States"), "Black Sea", "Media and entertainment", "Film", and "Literature". A sidebar on the left contains a navigation menu with links like "Main page", "Contents", "Featured content", and "Interaction". Below the menu is a "Languages" section with links to various Wikipedia editions in different languages.

Some statistics

- WordNet
 - 80k “entity” definitions
 - 115k surface forms
 - 142k senses (entity - surface form combinations)
- Wikipedia (only)
 - ~4M entity definitions
 - ~12M surface forms
 - ~24M senses

Wikipedia-based methods

Wikipedia-based methods

- keyphraseness(w_l) [Mihalcea & Csomai 2007]

$$\frac{\text{CF}(w_l)}{\text{CF}(w)} \longrightarrow \begin{array}{l} \textbf{Collection frequency} \\ \text{term } w_l \text{ as a link to another} \\ \text{Wikipedia article} \end{array}$$



Collection frequency
term w

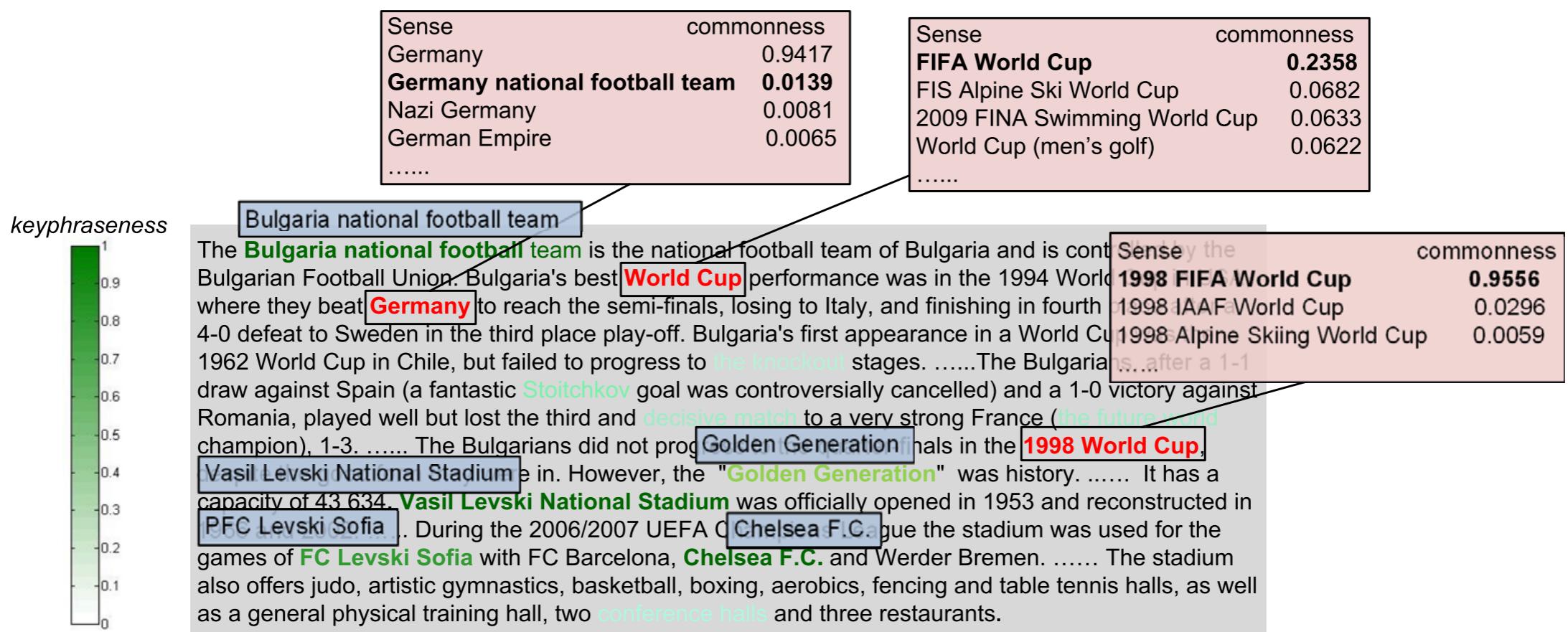
Wikipedia-based methods

- commonness(w, c) [Medelyan et al. 2008]

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


Number of links
with target c' and anchor text w

Commonness and keyphraseness



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
 - click logs **[Pantel et al. 2011]**

Baseline methods



Recall the steps

- 1. mention detection – MD**
- 2. link generation – LG**
- 3. (disambiguation) – DA**

Wikify!

[Mihalcea & Csomai 2007]

- First paper on actual entity linking
- Identifies two steps
 1. identify important concepts in the text
 - ~ “keyword extraction” (**MD**)
 2. link these to corresponding Wikipedia pages
 - ~ “word sense disambiguation” (**LG/DA**)

Wikify!

[Mihalcea & Csomai 2007]

- MD
 - tf.idf, χ^2 , keyphraseness
- LG/DA
 1. Overlap between definition (Wikipedia page) and context (paragraph) [Lesk 1986]
 2. Naive Bayes [Mihalcea 2007]
 - context, POS, entity-specific terms
 3. Voting between (1) and (2)

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%
...	

Wikipedia-based measures

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

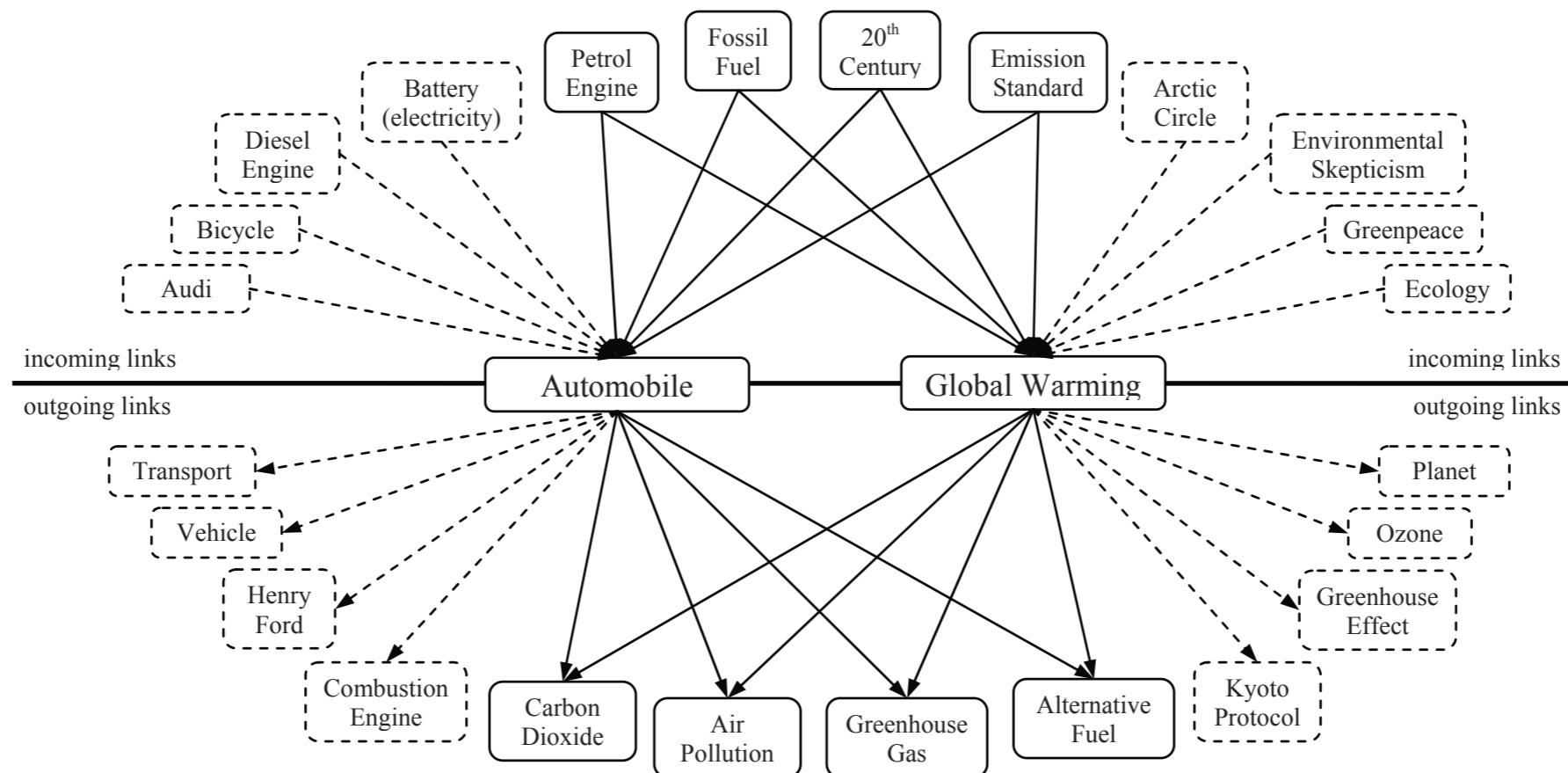


Image taken from Milne and Witten (2008a). An Effective, Low-Cost Measure of Semantic Relatedness Obtained from Wikipedia Links. In AAAI WikiAI Workshop.

Wikipedia-based measures

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

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

Number of links
with target c

Intersection of inlinks
with target c and c'

Total number of
Wikipedia articles

The diagram illustrates the formula for relatedness. At the bottom, there is a downward-pointing arrow above the text "Total number of Wikipedia articles". Above it, there are two upward-pointing arrows, one pointing to the term "Number of links with target c" and another pointing to the term "Intersection of inlinks with target c and c'". These two terms are enclosed in a brace at the top, indicating they are being subtracted from each other in the numerator of the formula.

Learning to Link with Wikipedia

[Milne & Witten 2008b]

- MD
 - ...
- LG
 - Machine learning
 - keyphraseness, average relatedness, sum of average weights

Learning to Link with Wikipedia

[Milne & Witten 2008b]

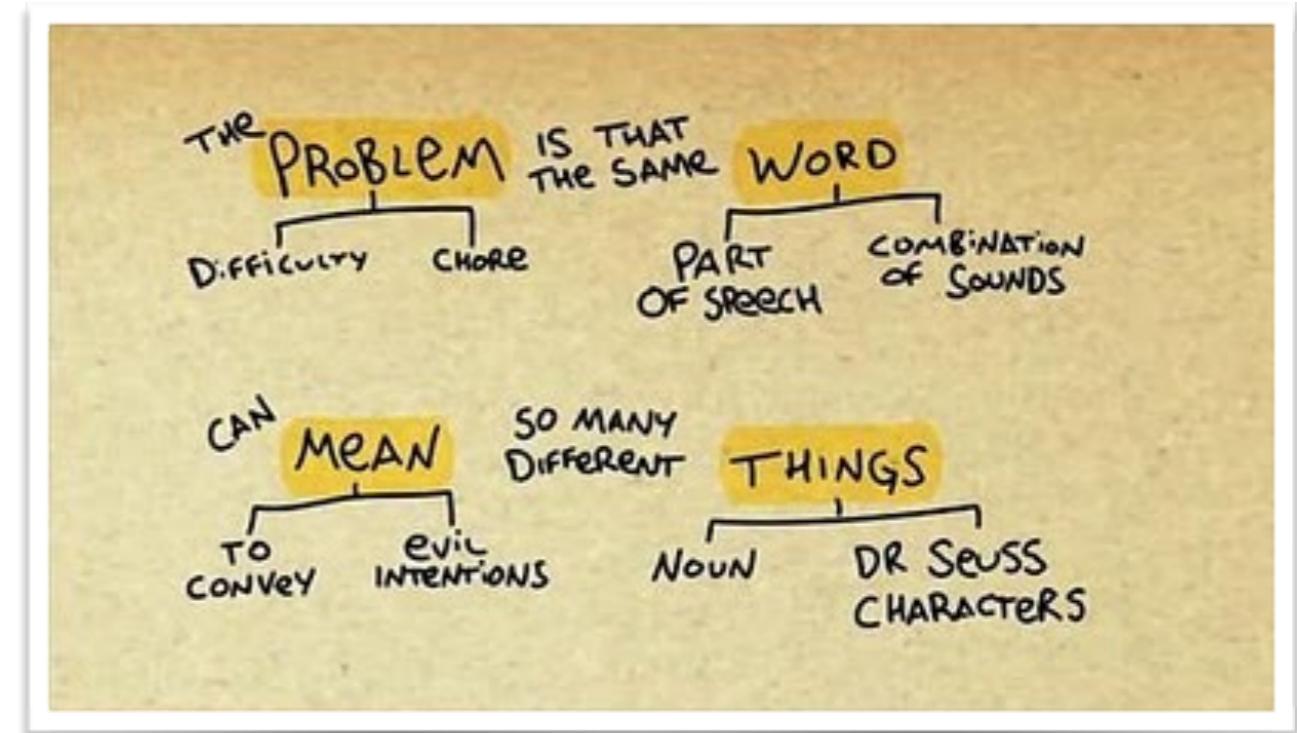
- MD
 - Machine learning
 - link probability, relatedness, **confidence of LG**, generality, frequency, location, spread
- LG
 - Machine learning
 - keyphraseness, average relatedness, sum of average weights

Learning to Link with Wikipedia

[Milne & Witten 2008b]

- Some heuristics
 - filter non-informative, non-ambiguous candidates (e.g., “the”)
 - based on keyphraseness, i.e., link probability
 - filter non-central candidates
 - based on average relatedness to all other context senses

Context



Main intuition

- Leverage “context” as signal for disambiguation
 - query
 - history; session; interests; ...
 - phrase
 - sentence; paragraph; document; ...
- But also candidate entity context
 - e.g., most central entities in the candidate entity graph, relatedness, ...

Local versus global context

- “Global”
 - i.e., disambiguation of the 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]**

Collective annotation of Wikipedia entities in web text

[Kulkarni et al. 2009]

- Contribution
 - determine a collective score based on trade-off between local compatibility and global topical coherence between candidate entities
 - use ILP or Hill-climbing (ILP beats HC, but is slower)
- Also
 - new test collection (web pages), including NILs

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}
- (Apply another round of machine learning) – LG

TAGME: On-the-fly Annotation of Short Text Fragments

[Ferragina & Scaiella 2010]

- MD
 - keyphraseness [Mihalcea & Csomai 2007]
- LG
 - use “local” approach to generate a disambiguation context, very similar to [Ratinov et al. 2011]
 - Heavy pruning
 - mentions; candidate links; coherence
- Accessible at <http://tagme.di.unipi.it>

Graph-based named entity linking with Wikipedia

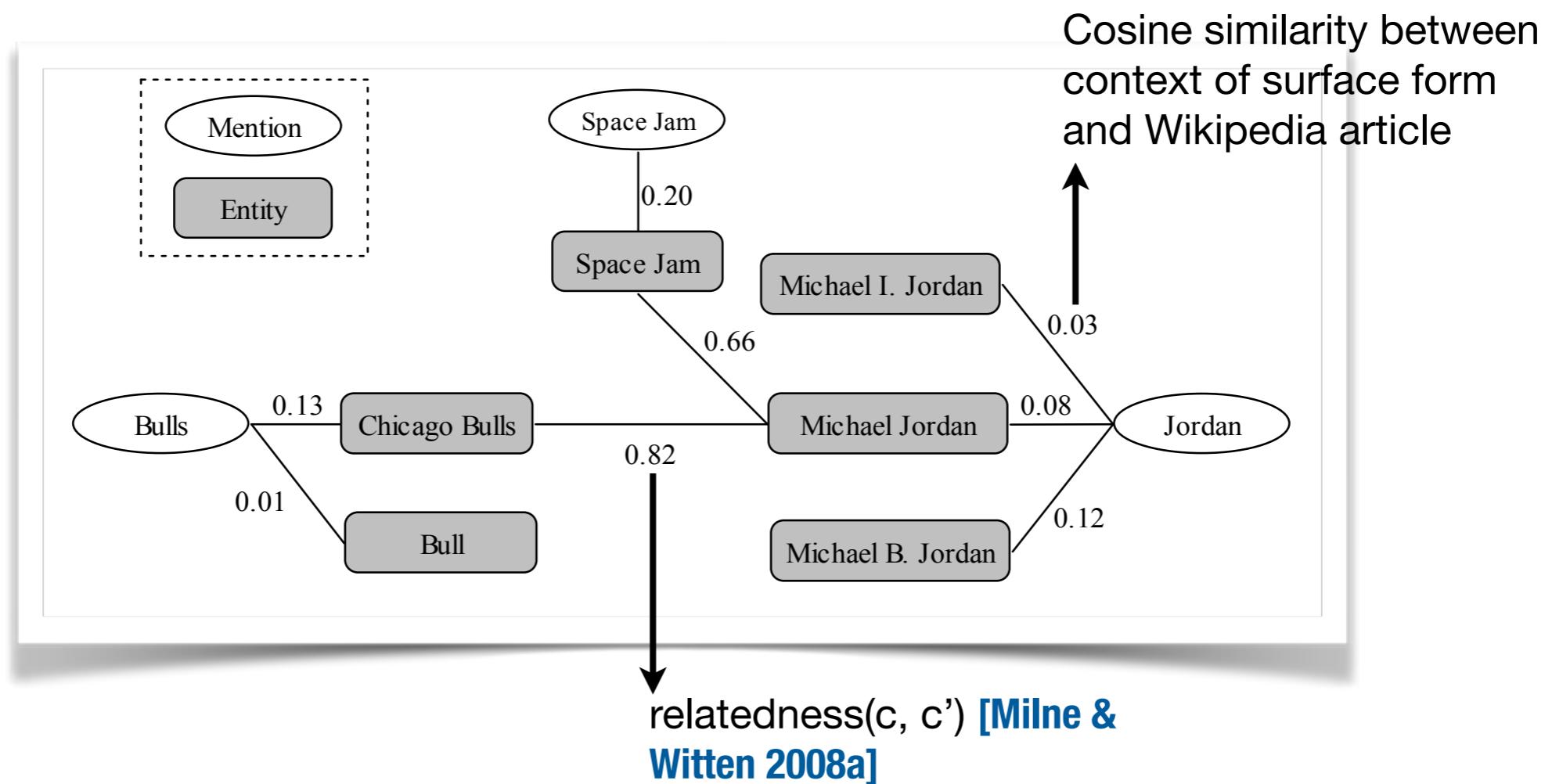
[Hachey et al. 2011]

- MD
 - generate disambiguation context
 - based on unambiguous entity links
 - edges defined by wikilinks (articles & categories)
 - max step size: 2 (articles), 3 (categories)
- LG
 - use degree centrality and PageRank to reweigh cosine-based similarity scores
- Evaluation on TAC KBP

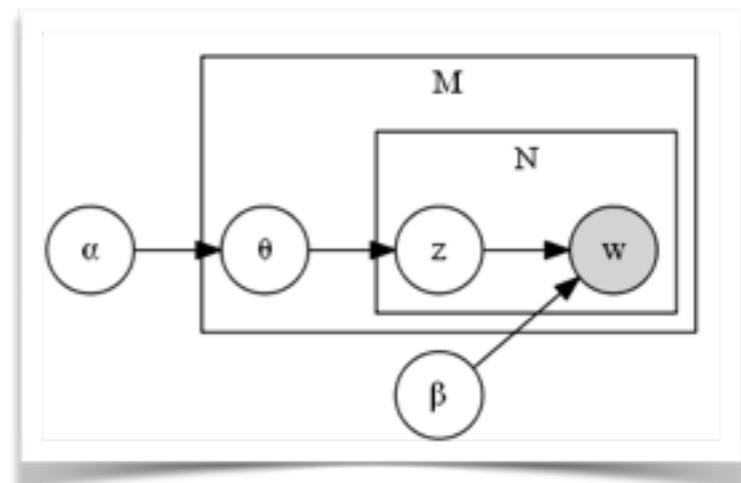
Collective Entity Linking in Web Text: A Graph-Based Method

[Han et al. 2011]

- Global approach, main contribution
 - random walk on the *referent graph*, defined by the intra-Wikipedia links



Topic modeling methods



From Names to Entities using Thematic Context Distance

[Pilz et al. 2011]

- Main contribution
 - “extend” previous BOW approaches for disambiguation with LDA topics
 - compare topic distributions of source document with candidate entities

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, baltimore maryland, new hampshire, 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, ...

Recap

- Essential ingredients
 - MD
 - commonness
 - keyphraseness
 - LG
 - commonness
 - machine learning
 - DA
 - relatedness
 - machine learning
 - topic modeling
 - graph-based methods

Outline

- Part 1 – Entity Linking
 - introduction
 - methods
 - evaluation
 - test collections
 - toolkits
 - open challenges

Evaluation



Entity linking evaluation

- Ingredients
 - knowledge base
 - document(s)
 - gold-standard annotations
 - evaluation metrics

Knowledge bases

DBpedia

- Extract structured information from Wikipedia
 - infoboxes, categories, and more
 - crowd-sourced community effort
- Open source
 - written in Scala, Java and VSP
 - Virtuoso Universal Server Operating system
- See <http://dbpedia.org/About>

Freebase

- Initially seeded from high-quality open data
 - now composed mainly by community
 - harvested from many sources
 - Wikipedia, MusicBrainz, and others.
- Acquired by Google in 2010 (GKG)
- See <http://www.freebase.com/>

Wikipedia vs Freebase

- Freebase 5x larger than Wikipedia
(in terms of the number of entities)
- Geared towards entertainment
- For 85% of Freebase entities there's no text...
 - but, there are Wikipedia-Freebase links
(for some entities)
 - initial work trying to ameliorate this problem **[Zheng et al. 2012]**

YAGO

- Accuracy manually evaluated
 - confirmed accuracy of 95%
 - relation is annotated with its confidence value.
- Anchored in Time and Space
 - Thematic domains (e.g. "music" or "science")
- Includes WordNet
- See <http://www.mpi-inf.mpg.de/yago-naga/yago/>

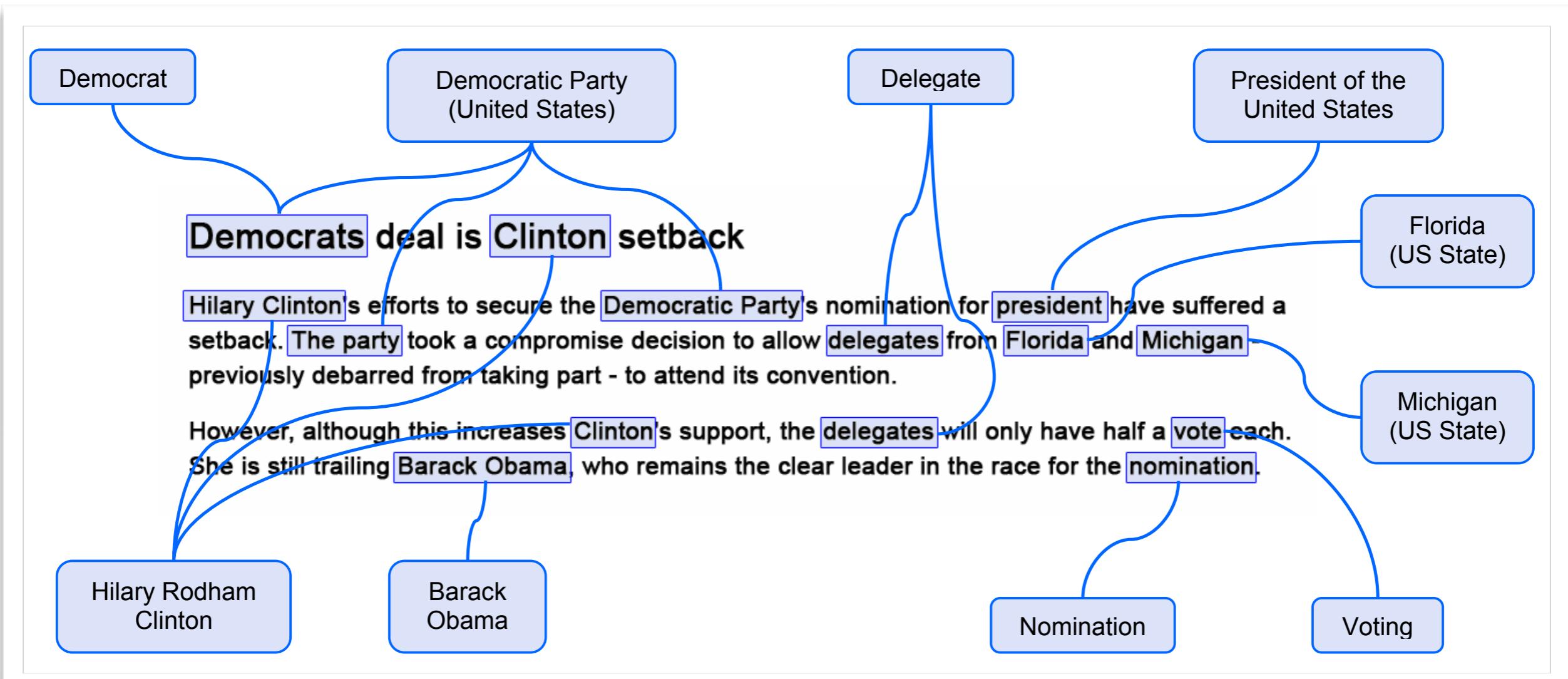
Sense of Scale

- YAGO: 10 million entities and 120 million facts
- Freebase: 37 million topics, 1,998 types, and more than 30,000 properties
- DBpedia: 3.77 million things
 - 2.35 million classified in Ontology, including:
 - 764,000 persons, 573,000 places,
 - 333,000 creative works, 192,000 organizations,
 - 202,000 species and 5,500 diseases.
 - 111 languages, together 20.8 million things

Evaluation metrics

Evaluation metrics

- ## - What is the task?



Evaluation metrics

- Compounded problem
 - tagging/spanning – **MG**
 - 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 anchor phrase
 - 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)

Wikipedia (for evaluation)

- Widely used
- Pros
 - cheap and easy; the links are already provided
- Cons
 - biased (style guides!)
 - specific scenario
 - unbalanced

TAC

[McNamee et al. 2010]

- Target: KB – from Wikipedia (~800k instances)
 - infoboxes; article text; type
- “Query”
 - document ID (news, web, blog)
 - mention string (occurring at least once in that doc)
- Focus on ambiguous mentions
 - collected by cherry-picking ‘interesting’ mentions, rather than systematically annotating all mentions
- Explicit NILs (> 50% of the queries)

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...

Meta-evaluations

- [Hachey et al. 2013]
- [Cornolti et al. 2013]

Evaluating Entity Linking with Wikipedia

[Hachey et al. 2013]

- Named entity linking, a.k.a., “NEL”
 - include NILs
 - Wikipedia articles not always named entities
- Explicit focus on separating “search” (LG) and “disambiguation” (DA)
- Reimplement and evaluate three NEL systems
 - [Bunescu & Pasă 2006]
 - [Cucerzan 2007]
 - [Varna et al. 2009] (TAC system paper)

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

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]

- Benchmarking framework
- Introduces “fuzzy” evaluation measures
- Main findings
 - different systems perform well in different scenarios
 - AIDA and TagMe seem to be the winners overall

DIY Entity Linking – footnotes

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

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

Outline

- Entity Linking
 - introduction
 - methods
 - evaluation
 - test collections
 - toolkits
 - open challenges

Toolkits



Public Toolkits and Web Services for Entity Linking

- Wikipedia Miner
- TagMe
- DBpedia Spotlight
- Illinios Wikifier
- AIDA
- (OpenCalais)

	Programming Language	Service	Available Languages	Open Source
Wikipedia Miner	Java	Web API, Application	any WP	✓
TagMe	Java	Web API	EN, IT	✗
DBpedia Spotlight	Java	Web API, Application	EN + any WP	✓
Illinois Wikifier	Java	Application	EN	✓
AIDA	Java	Web API	EN	✓
OpenCalais	?	Web API	EN, FR, SP	✗

	Matching	Target KB	Context	Comment
Wikipedia Miner	Lexical	Wikipedia	ML on Relatedness	
TagMe	Lexical	Wikipedia	Vote on Relatedness	Focus on Short texts
DBpedia Spotlight	Lexical?	DBpedia	Cosine Similarity	Structure
Illinois Wikifier	NER	Wikipedia	Global Coherence	
AIDA	NER	YAGO2	Multiple	Structure
OpenCalais	?	Calais	?	

Open challenges



Open challenges

- Difficulty prediction
 - similar to ambiguity, but not the same
 - dependent on context, candidate links, ...
- Multi/Cross-lingual entity linking
 - **[Wang et al. 2013]**
 - CrossLink-2 (NTCIR-9), CJK - EN **[Tang et al. 2013]**
 - TAC...
- Cross-KB entity linking (“Freebase”)
 - directly? use Wikipedia as pivot?

Open challenges

- Generic test collections
 - What's the task? User model? Evaluation?
 - TAC? set-based? ranking? known-item finding? top- k ?
 - exhaustive linking? first mention only?
 - "aboutness"
- Moving beyond entities
 - events/news, concepts, relations
- Moving beyond "ad hoc" entity linking:
 - incorporate contextual evidence in the task (and evaluation)
 - {users, history, profile, social, trending, ...}

Follow-up reading

- Detecting **unlinkable** entities [Lin et al. 2012a]
- Linking entities to **any database** [Sil et al. 2012]
- Hyperlinking for **multimedia** data [Eskevich et al. 2013]
- Automatically generating **Wikipedia articles** [Sauper & Barzilay 2009]
- **Scaling up** to the web [Lin et al. 2012b]
- Serendipitous **suggestions** based on **personalized** entity links [Bordino et al. 2013]
- **Actionable** entities/queries [Lin et al. 2012]

Outline

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 - open challenges

References – Entity linking

The screenshot shows a web browser window displaying a Mendeley group page. The title of the group is "Entity Linking and Retrieval". The page includes a sidebar with navigation links like "Get Mendeley", "What is Mendeley?", "Papers", "Groups", and a "Feedback" button. The main content area shows a list of papers tagged with "entity linking". The first paper listed is "ZenCrowd" by Gianluca Demartini, Djellel Eddine Difallah, Philippe Cudré-Mauroux in Proceedings of the 21st international conference on World Wide Web - WWW '12 (2012). The second paper is "Relational Inference for Wikification" by Cheng Xiao, Dan Roth in EMNLP '13 (2013). The third paper is "Re-ranking for Joint Named-Entity Recognition and Linking" by Avirup Sil, Alexander Yates in CIKM '13 (2013). The fourth paper is "Wikimantic: Toward effective disambiguation and expansion of queries" by Christopher Boston, Hui Fang, Sandra Carberry, Hao Wu, Xitong Liu in Data & Knowledge Engineering (2013). On the right side of the page, there is a "Top tags in this group" section showing various terms related to entity linking and retrieval.

<http://www.mendeley.com/groups/3339761/entity-linking-and-retrieval-tutorial/papers/added/0/tag/entity+linking/>