

Wikification and Beyond: The Challenges of Entity and Concept Grounding

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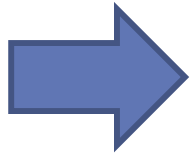
Xiaoman Pan (RPI), Hongzhao Huang (RPI)

<http://nlp.cs.rpi.edu/paper/wikificationtutorial2.pdf> [pptx]



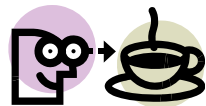
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Outline



Motivation and Definition)

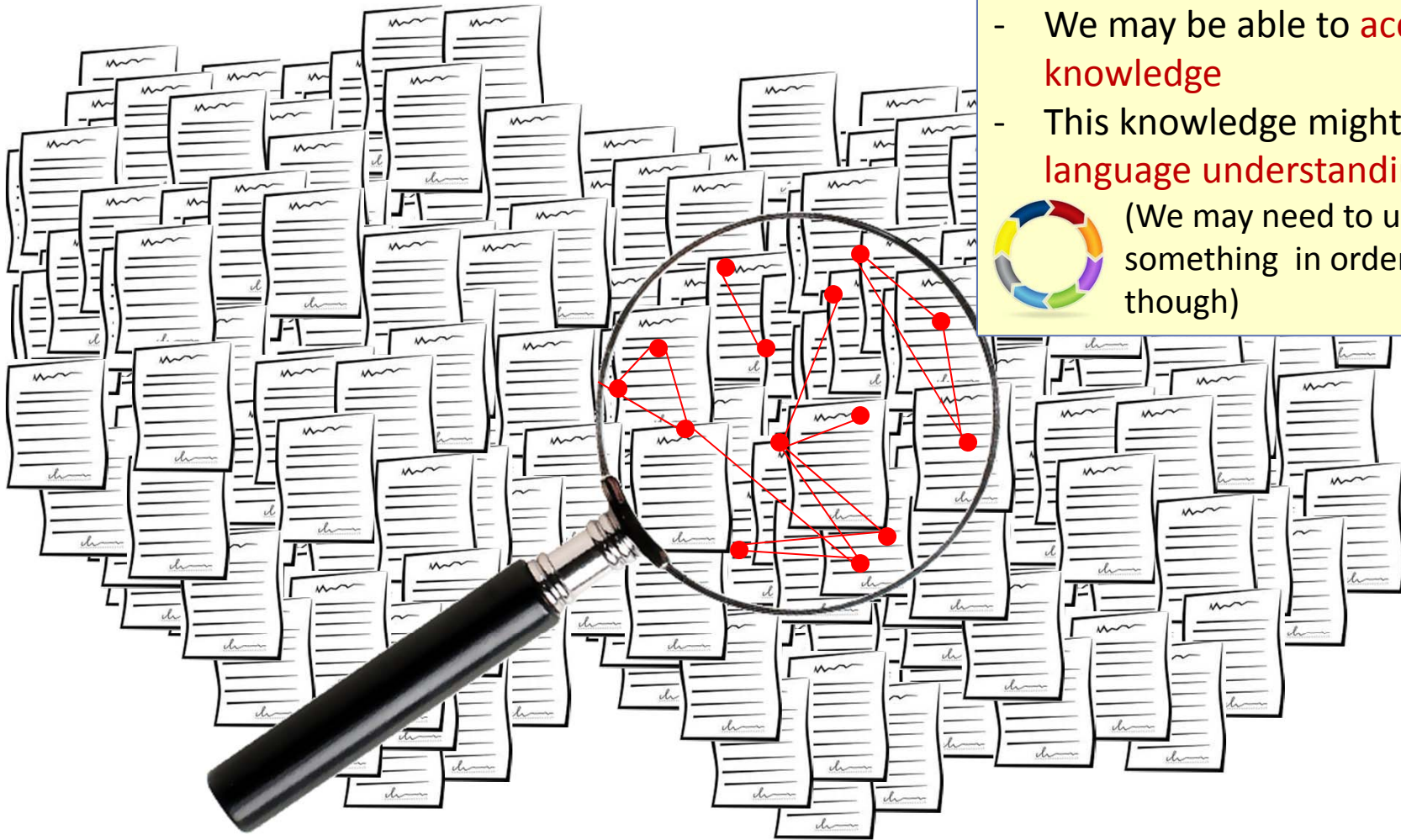
- A Skeletal View of a Wikification System
 - High Level Algorithmic Approach
- Key Challenges



Coffee Break

- Recent Advances
- New Tasks, Trends and Applications
- What's Next?
- Resources, Shared Tasks and Demos

Information overload



Downside:

- We need to deal with a lot of information

Upside:

- We may be able to **acquire knowledge**
- This knowledge might support **language understanding**



(We may need to understand something in order to do it, though)

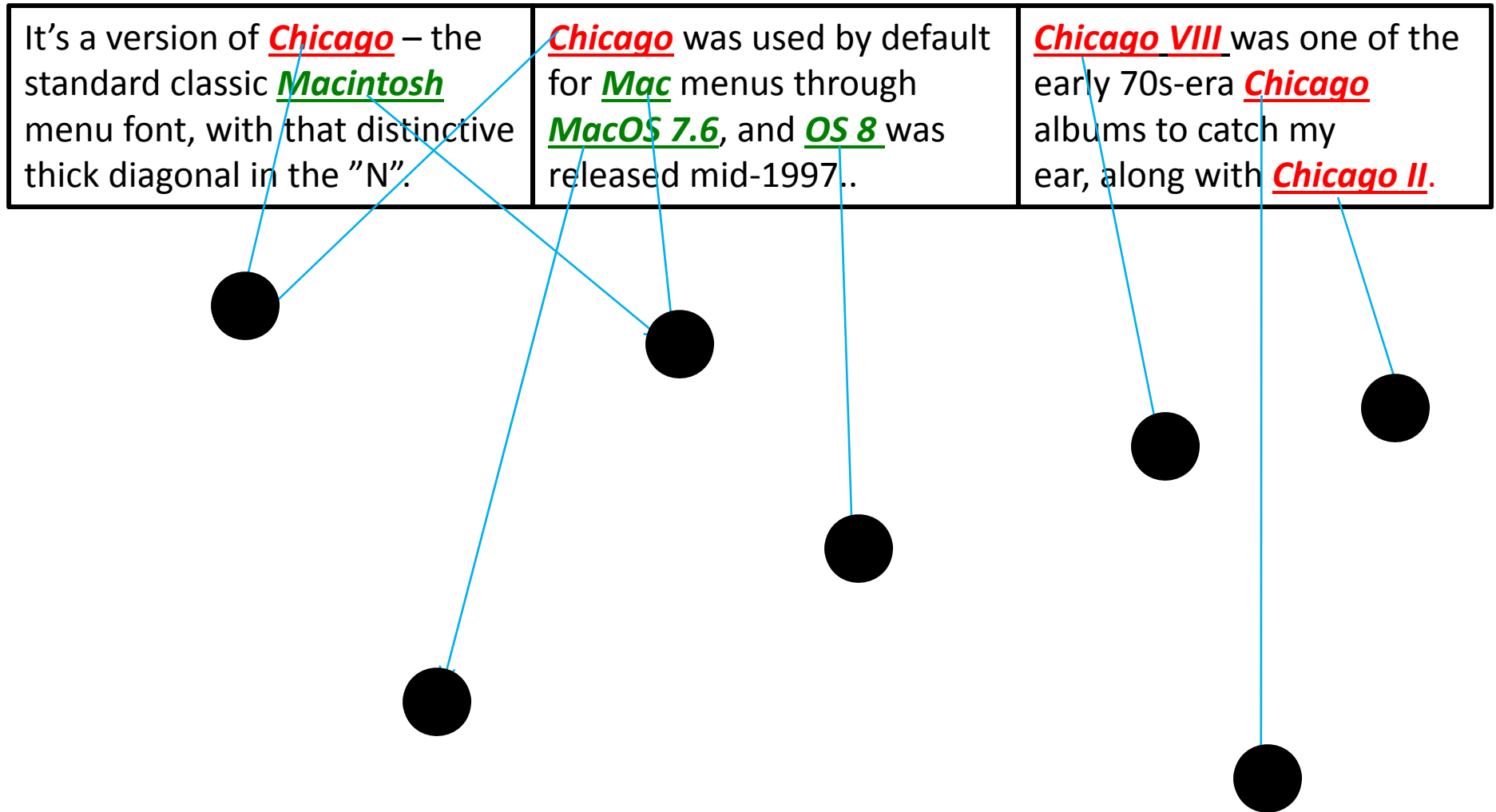
Organizing knowledge

It's a version of Chicago – the standard classic Macintosh menu font, with that distinctive thick diagonal in the "N".

Chicago was used by default for Mac menus through MacOS 7.6, and OS 8 was released mid-1997..

Chicago VIII was one of the early 70s-era Chicago albums to catch my ear, along with Chicago II.

Cross-document co-reference resolution



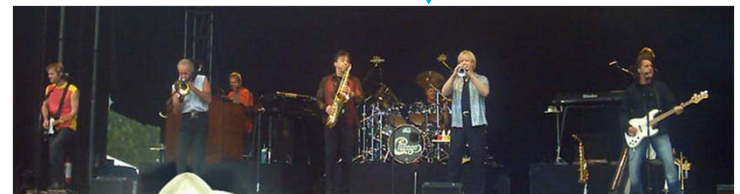
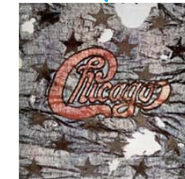
Reference resolution: (disambiguation to

Wikipedia)

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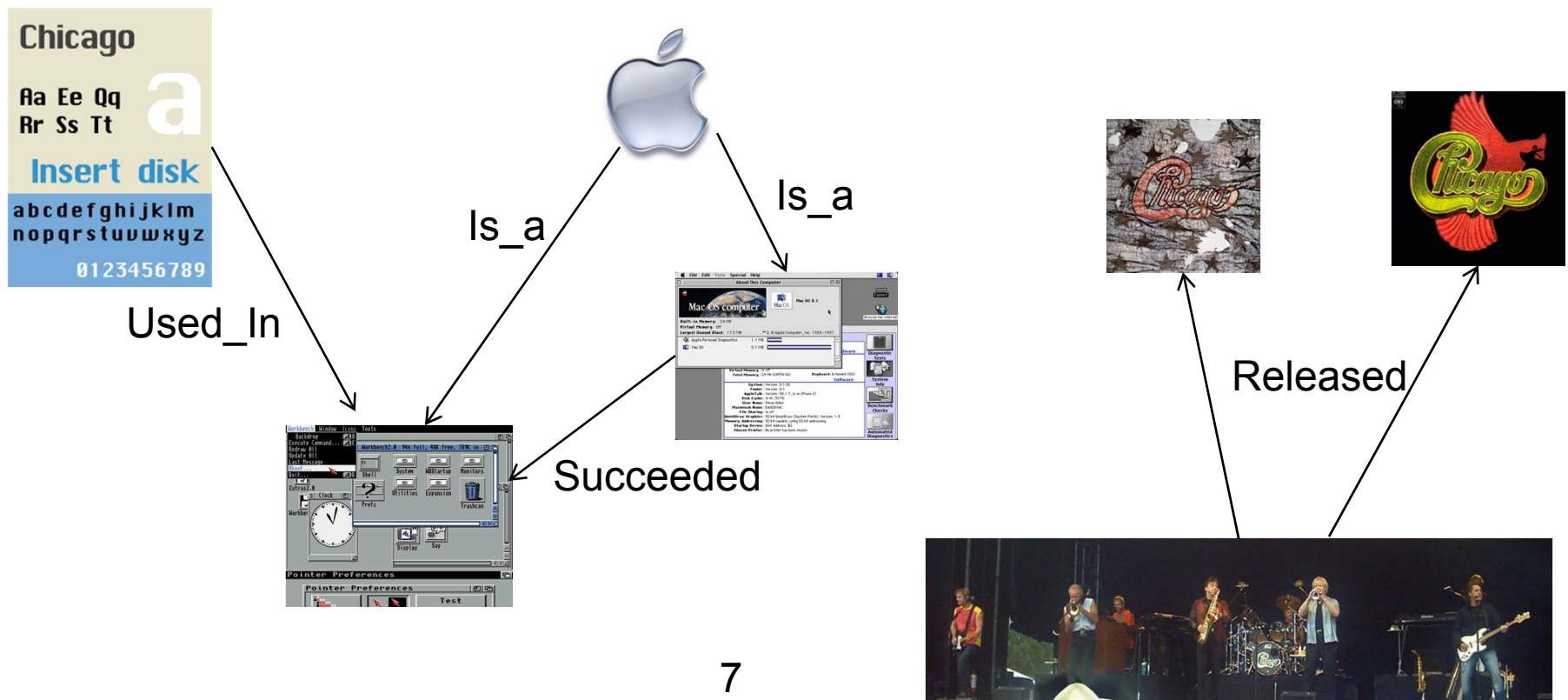


The “Reference” Collection has Structure

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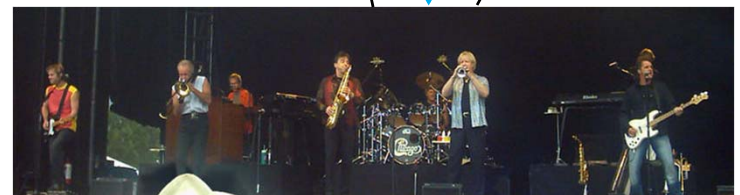
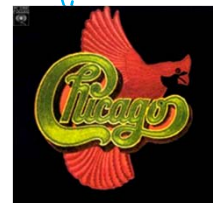
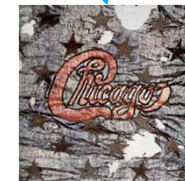


Analysis of Information Networks

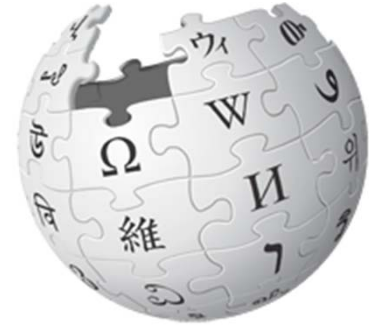
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Chicago VIII was one of the early 70s-era Chicago albums to catch my ear, along with Chicago II.



Here – Wikipedia as a knowledge resource
.... but we can use other resources



Used_In

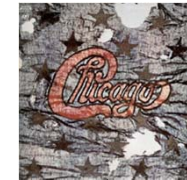


Is_a

Is_a



Succeeded



Released



Wikification: The Reference Problem

Cycles of
Knowledge:
Grounding
for/using
Knowledge



Blumenthal (D) is a candidate for the U.S. Senate seat now held by Christopher Dodd (D), and he has held a commanding lead in the race since he entered it. But the Times report has the potential to fundamentally reshape the contest in the Nutmeg State.



Richard Blumenthal

From Wikipedia, the free encyclopedia

Democratic Party (United States)

From Wikipedia, the free encyclopedia

United States Senate

From Wikipedia, the free encyclopedia

[Blumenthal](#) ([D](#)) is a candidate for the [U.S. Senate](#) seat now held by [Christopher Dodd](#) ([D](#)), and he has held a commanding lead in the race since he entered it. But the [Times](#) report has the potential to fundamentally reshape the contest in [the Nutmeg State](#).

Chris Dodd

From Wikipedia, the free encyclopedia

The New York Times

From Wikipedia, the free encyclopedia

Connecticut

From Wikipedia, the free encyclopedia

Motivation

- Dealing with **Ambiguity** of Natural Language
 - Mentions of entities and concepts could have multiple meanings
- Dealing with **Variability** of Natural Language
 - A given concept could be expressed in many ways
- **Wikification** addresses these two issues in a specific way:
- The Reference Problem
 - What is meant by this concept? (WSD + Grounding)
 - More than just co-reference (within and across documents)

Who is Alex Smith?

Cognitive Computation Group ▶ Demos ▶ Wikifier

Wikifier Demo

fewer concepts more concepts

wiki! clear

* If you wish to cite this work, please cite the following publications: (1) Retinov et. al. and (2) Cheng and Roth.

The Chiefs' **Alex Smith** is a game manager who wouldn't kill their offense. They needed a **quarterback** who knows how to manage the game. What he's done for most of this season: throw the ball. He's necessary and use his **Smith** to throw the ball. These days it's all about **San Diego** -- that he can elevate his game.



Quarterback of the Kansas City Chief

Cognitive Computation Group ▶ Demos ▶ Wikifier

Wikifier Demo

fewer concepts more concepts

the following publications: (1) Retinov et. al. and (2) Cheng and Roth.

Smith tight end **Alex Smith** for the season. The tight end **Smith** had a wrist injury in the third quarter during the regular season. The Bengals head coach Marvin Lewis described the injury as a "wrist injury." In the post-game interview on 700 WLW with Dave Smith, Lewis confirmed an **eventuality**. More will be on declaring him done. On the other hand, Lewis confirmed the tight end **Smith** and Jermaine Gresham for the next game against the Ravens.



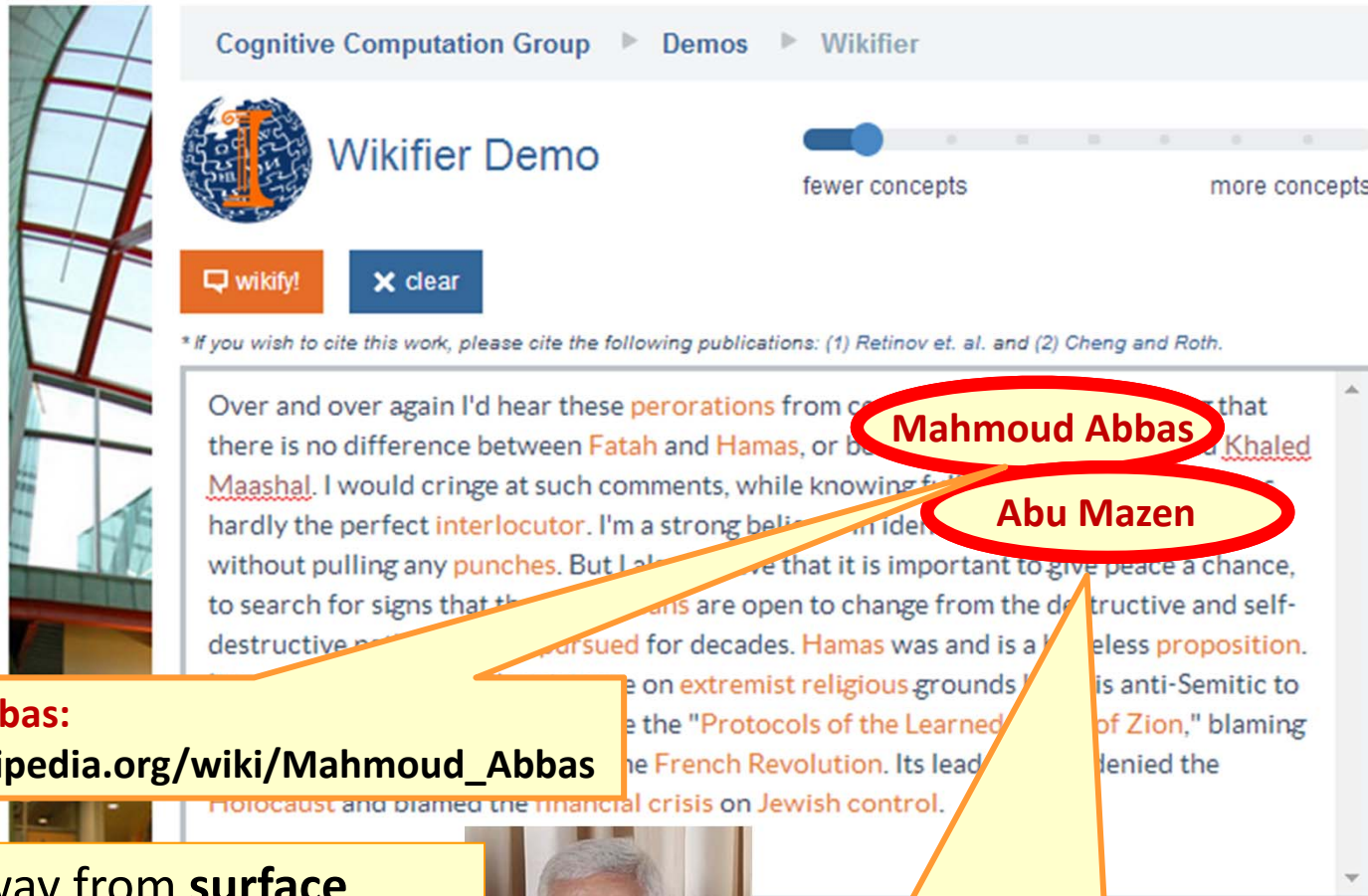
Tight End of the Cincinnati Bengals

San Diego: The San Diego Chargers (A Football team)


Contextual decision on **what is meant** by a given entity or concept. **WSD** with Wikipedia titles as categories.

Ravens: The Baltimore Ravens (A Football team)


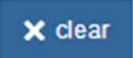
Middle Eastern Politics



Cognitive Computation Group ▶ Demos ▶ Wikifier

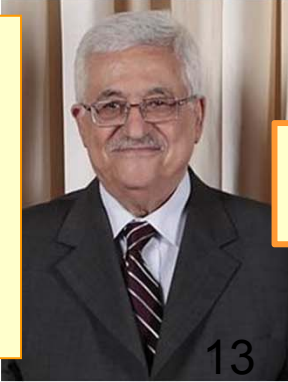
 Wikifier Demo

☐ fewer concepts ☒ more concepts

** If you wish to cite this work, please cite the following publications: (1) Retinov et. al. and (2) Cheng and Roth.*

Over and over again I'd hear these **perorations** from **Mahmoud Abbas** that there is no difference between **Fatah** and **Hamas**, or between **Khaled Maashal**. I would cringe at such comments, while knowing full well that he is hardly the perfect **interlocutor**. I'm a strong believer in identifying the enemy without pulling any **punches**. But I believe that it is important to give peace a chance, to search for signs that the **Ans** are open to change from the destructive and self-destructive path they have pursued for decades. **Hamas** was and is a **useless proposition**. It is based on extremist religious grounds and is anti-Semitic to the core. It is the "Protocols of the Learned Elders of Zion," blaming the French Revolution. Its leadership denied the Holocaust and blamed the financial crisis on Jewish control.



Mahmoud Abbas:

http://en.wikipedia.org/wiki/Mahmoud_Abbas

Getting away from **surface representations**.
Co-reference resolution within and across documents, **with grounding**

Mahmoud Abbas

Abu Mazen

Abu Mazen:

http://en.wikipedia.org/wiki/Mahmoud_Abbas

Navigating Unfamiliar Domains



Cognitive Computation Group ▶ Demos ▶ Wikifier



Wikifier Demo

☒ fewer concepts ☐ more concepts

wikify! ✕ clear

* If you wish to cite this work, please cite the following publications: (1) Retinov et. al. and (2) Cheng and Roth.

Human immunodeficiency virus (HIV) is the primary etiologic agent responsible for the AIDS pandemic. We constructed a fusion of the gp41 membrane-proximal external region (MPER) peptide along with a variable-length (Gly4Ser)x linker (where x is 4 or 8) between the C terminus of the former and N terminus of the latter. The His-tagged recombinant proteins, expressed in BL21(DE3)pLysS cells and purified by immobilized metal affinity chromatography followed by gel filtration, were found to display a nanomolar efficacy in blocking BaL-pseudotyped HIV-1 infection of HOS.T4.R5 cells. This antiviral activity was HIV-1 specific, since it did not inhibit cell infection by vesicular stomatitis virus (VSV). The chimeric proteins were found to release intraviral p24 protein from both BaL-pseudotyped HIV-1 and fully infectious BaL HIV-1 in a dose-dependent manner in the absence of host cells. The addition of either MPER or CVN was found to outcompete this virolytic effect, indicating that both components of the chimera are required for virolysis. The finding that engaging the Env protein spike and membrane using a chimeric ligand can destabilize the virus and lead to inactivation opens up a means to investigate virus particle metastability and to evaluate this approach for inactivation at the earliest stages of exposure to virus and before host cell encounter.

Navigating Unfamiliar Domains

Chimeric Cyano Engineered Pro HIV-1

Mark Contarino^a, Arang Ramalingam Venkat Ka Vamshi Gangupomu^d, I

Author Affiliations

ABSTRACT

Human immunodeficiency the AIDS pandemic. In tl to test the possibility of that simultaneously bini fusion of the **lectin cyan region (MPER)** peptide w between the **C terminus** recombinant proteins, e immobilized metal affini to display a **nanomolar** **HOS.T4.R5** cells. This ar cell infection by **vesicul** virus. Importantly, the c protein from both **BaL-p** dose-dependent manne or **CVN** was found to ou components of the **chim** the **Env protein** spike ar virus and lead to inactiv metastability and to eva exposure to virus and b



Cognitive Computation G

Wikifier De

wikify! clear

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WIKIPEDIA The Free Encyclopedia

Main page Contents Featured content

Article Talk

Fusion protein

From Wikipedia, the free encyclopedia

This article is about chimeric fusion proteins. For proteins involved in memb

Fusion proteins or **chimeric proteins** (literally, made of parts from different so originally coded for separate proteins. Translation of this *fusion gene* results in a

Article Talk

Gp41

From Wikipedia, the free encyclopedia

Gp41 also known as **glycoprotein 41** is a subunit of the envelope protein complex of **retroviruses** *Human immunodeficiency virus* (HIV). Gp41 is a **transmembrane protein** that contains several site ectodomain that are required for infection of host cells.

Article Talk

Affinity chromatography

From Wikipedia, the free encyclopedia

Affinity chromatography is a method of separating **biochemical** mixtures based on **antibody**, **enzyme** and **substrate**, or **receptor** and **ligand**.

Educational Applications: Unfamiliar domains may contain terms unknown to a reader. The Wikifier can supply the necessary background knowledge even when the relevant article titles are not identical to what appears in the text, dealing with both **ambiguity and variability**.

Applications of Wikification

- Knowledge Acquisition (via grounding)
 - Still remains open: how to organize the knowledge in a useful way?
- Co-reference resolution (Ratinov & Roth, 2012)
 - “After the **vessel** suffered a catastrophic torpedo detonation, **Kursk** sank in the waters of Barents Sea...”
 - Knowing Kursk → Russian submarine K-141 Kursk helps system to co-ref “Kursk” and “vessel”
- Document classification
 - Tweets labeled World, US, Science & Technology, Sports, Business, Health, Entertainment (Vitale et. al., 2012)
 - Dataless classification (ESA-based representations; Song & Roth’ 14)
 - Document and concepts are represented via Wikipedia titles
- Visualization: Geo- visualization of News (Gao et. al. CHI’14)

Task Definition

- A formal definition of the task consists of:
 1. A definition of the **mentions** (concepts, entities) to highlight
 2. Determining the target encyclopedic resource (**KB**)
 3. Defining what to point to in the KB (**title**)

1. Mentions

- **A mention**: a phrase used to refer to something in the world
 - Named entity (person, organization), object, substance, event, philosophy, mental state, rule ...
- Task definitions vary across the definition of **mentions**
 - All N-grams (up to a certain size); Dictionary-based selection; Data-driven controlled vocabulary (e.g., all Wikipedia titles); **only named entities.**
- Ideally, one would like to have a mention definition that **adapts** to the application/user

Examples of Mentions (1)

Blumenthal (D) is a candidate for the U.S. Senate seat now held by Christopher Dodd (D), and he has held a commanding lead in the race since he entered it. But the Times report has the potential to fundamentally reshape the contest in the Nutmeg State.



Examples of Mentions (2)



The screenshot shows the Wikifier Demo interface. At the top, it says "Cognitive Computation Group" and "Demos" with a "Wikifier" link. Below this is a "Wikifier Demo" header with a slider between "fewer concepts" and "more concepts". There are "wikify!" and "clear" buttons. A text snippet is displayed with four entities circled in red: "Alex Smith", "offseason", "turnover", and "feet". The text snippet is: "The Chiefs didn't trade for a smart **Alex Smith** because they wanted a smart **game manager** who wouldn't kill their **offseason** offense. They acquired him because they needed a **quarterback** who knows how to **turnover** requires him to do what he's done this season: throw the ball, make the key play when necessary and keep the chains moving when his arm can't get the job done. These days it means **Smith** has to show people more of what he revealed in Sunday's 41-38 loss to **San Diego** -- that he can elevate his game when his team is in dire straits."

Some task definitions insist on dealing only with mentions that are **named entities**

How about: *Hosni Mubarak's wife?*
Both entities have a Wikipedia page

Examples of Mentions (3)



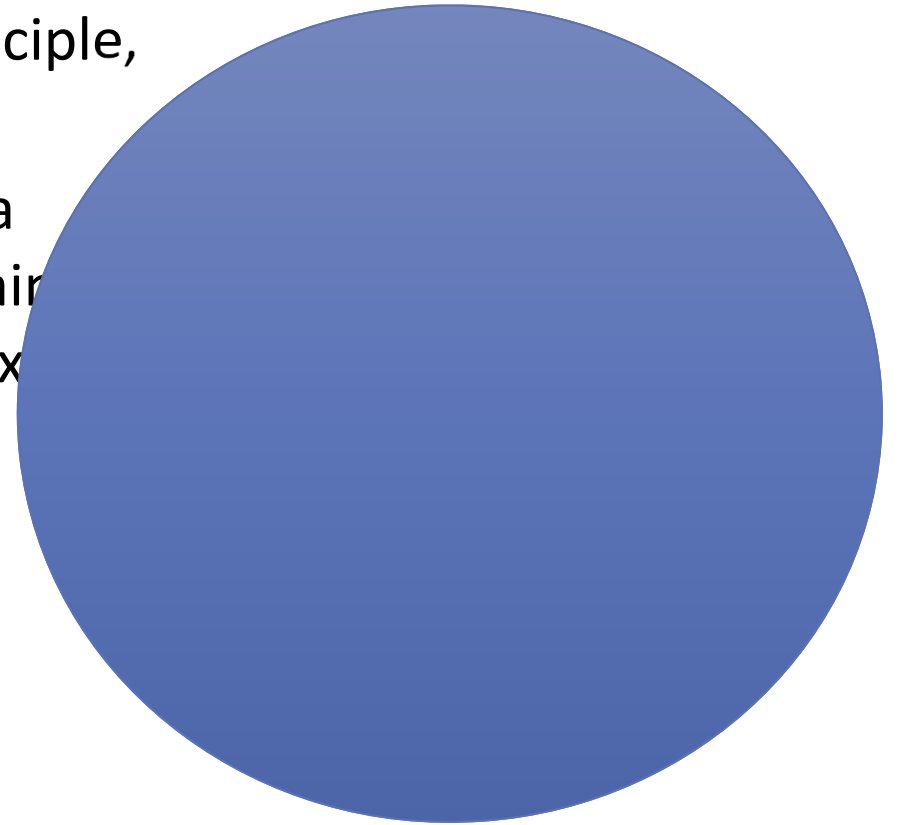
The screenshot shows the Wikifier Demo interface. At the top, there's a navigation bar with "Cognitive Computation Group", "Demos", and "Wikifier". Below this is the "Wikifier Demo" title and a slider control labeled "fewer concepts" and "more concepts". There are two buttons: "wikify!" and "clear". A citation note reads: "* If you wish to cite this work, please cite the following publications: (1) Retinov et. al. and (2) Cheng and Roth." The main text area displays a snippet from a document about HIV. Several terms are highlighted in yellow and circled in red: "HIV", "gp41", "Chimeric proteins", and "virus".

Human immunodeficiency **HIV** agent responsible for the epidemic. We constructed a peptide along with a variable-length (Gly4Ser)_x linker (where x is 4 or 8) the C terminus of the former and N terminus of the latter. The His-tagged **gp41** proteins, expressed in BL21(DE3)pLysS cells and purified by immobilized affinity chromatography followed by gel filtration, were found to display a higher efficacy in blocking BaL-pseudotyped HIV-1 infection of HOS.T4.R5 cells. This activity was HIV-1 dependent. Chimeric proteins that inhibit cell infection by vesicular stomatitis virus (VSV) and to release intraviral p24 protein in BaL-pseudotyped HIV-1 and fully infectious BaL HIV-1 in a dose-dependent manner in the absence of host cells. The addition of either MPER or CVN was found to outcompete this virolytic effect, indicating that both components of the chimera are required for virolysis. The finding that engaging the Env protein spike and membrane using a chimeric ligand can destabilize the virus and lead to inactivation opens up a means to investigate virus partial stability and to evaluate this approach for inactivation at the earliest stages **virus** and before host cell encounter.

Perhaps the definition of which mentions to highlight should depend on the expertise and interests of the users?

2. Concept Inventory (KB)

- Multiple KBs can be used, in principle, as the target KB.
- **Wikipedia** has the advantage of a broad coverage, regularly maintaining a KB, with significant amount of text associated with each title.
 - All type of pages?
 - Content pages
 - Disambiguation pages
 - List pages
- What should happened to mentions that **do not have entries** in the target KB?



3. What to Link to?

- Often, there are multiple sensible links.

The veteran tight end suffered a wrist injury in the third quarter during the regular season finale against Baltimore. Bengals head coach Marvin Lewis described the injury as a "wrist dislocation".

Baltimore Raven: Should the link be any different? **Both?**

Baltimore: The city? Baltimore Raven, the Football team? **Both?**

The veteran tight end suffered a wrist injury in the third quarter during the regular season finale against Baltimore Ravens. Bengals head coach Marvin Lewis described the injury as a "wrist dislocation".

Atmosphere: The general term? Or the most specific one "Earth Atmosphere?"

Earth's biosphere then significantly altered the atmospheric and basic physical conditions, which enabled the proliferation of organisms. The atmosphere is composed of

3. Null Links

- Often, there are multiple sensible links.

Dorothy Byrne, a state coordinator for the Florida Green Party,...

- How to capture the fact that Dorothy Byrne does not refer to any concept in Wikipedia?
- **Wikification:** Simply map Dorothy Byrne → Null
- **Entity Linking:** If multiple mentions in the given document(s) correspond to the same concept, which is outside KB
 - First cluster relevant mentions as representing a single concept
 - Map the cluster to Null

Naming Convention

- Wikification:
 - Map Mentions to KB Titles
 - Map Mentions that are not in the KB to NIL
- Entity Linking:
 - Map Mentions to KB Titles
 - If multiple mentions in correspond to the same Title, which is outside KB:
 - First cluster relevant mentions as representing a single Title
 - Map the cluster to Null
- If the set of target mentions only consists of named entities we call the task: Named Entity [Wikification, Linking]

Evaluation

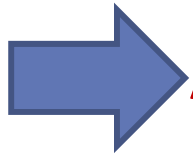
- In principle, evaluation on an application is possible, but hasn't been pursued [with some minor exceptions: NER, Coref]

Factors in Wikification/Entity-Linking Evaluation:

- Mention Selection
 - Are the mentions chosen for linking correct (R/P)
- Linking accuracy
 - Evaluate quality of links chosen per-mention
 - Ranking
 - Accuracy (including NIL)
- NIL clustering
 - Entity Linking: evaluate out-of-KB clustering (co-reference)
- Other (including IR-inspired) metrics
 - E.g. MRR, MAP, R-Precision, Recall, accuracy

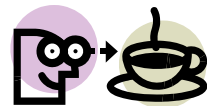
Outline

- Motivation and Definition



A Skeletal View of a Wikification System

- High Level Algorithmic Approach
- Key Challenges



Coffee Break

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Wikification: Subtasks

- Wikification and Entity Linking requires addressing several sub-tasks:
 - Identifying Target Mentions
 - Mentions in the input text that should be Wikified
 - Identifying Candidate Titles
 - Candidate Wikipedia titles that could correspond to each mention
 - Candidate Title Ranking
 - Rank the candidate titles for a given mention
 - NIL Detection and Clustering
 - Identify mentions that do not correspond to a Wikipedia title
 - Entity Linking: cluster NIL mentions that represent the same entity.

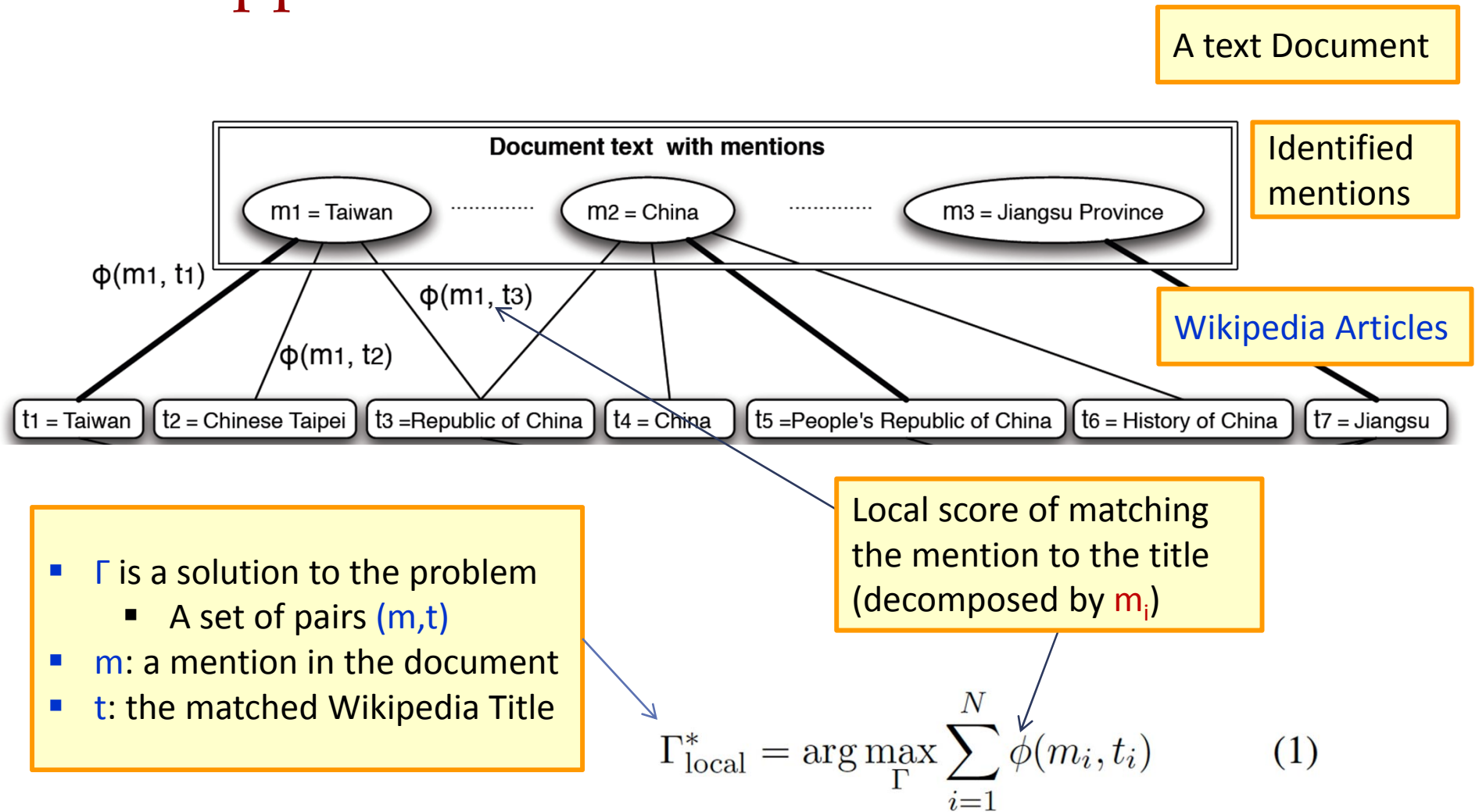
High-level Algorithmic Approach.

- **Input:** A text document d ; **Output:** a set of pairs (m_i, t_i)
 - m_i are mentions in d ; $t_i(m_i)$ are corresponding Wikipedia titles, or NIL.
- (1) Identify mentions m_i in d
- (2) Local Inference
 - For each m_i in d :
 - Identify a set of relevant titles $T(m_i)$
 - Rank titles $t_i \in T(m_i)$

[E.g., consider local statistics of edges $[(m_i, t_i), (m_i, *), \text{and } (*, t_i)]$ occurrences in the Wikipedia graph]
- (3) Global Inference
 - For each document d :
 - Consider all $m_i \in d$; and all $t_i \in T(m_i)$
 - Re-rank titles $t_i \in T(m_i)$

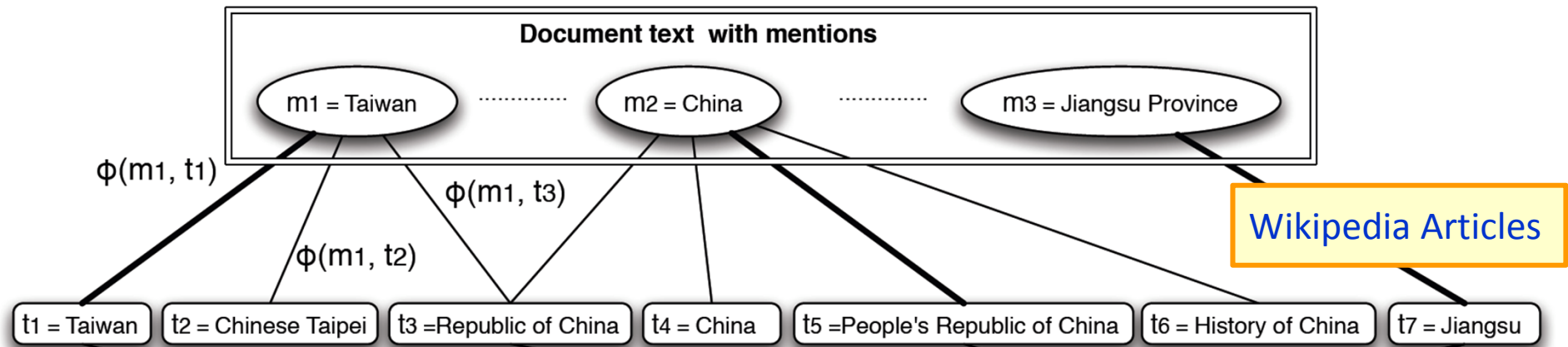
[E.g., if m, m' are related by virtue of being in d , their corresponding titles t, t' may also be related]

Local approach



Global Approach: Using Additional Structure

Text Document(s)—News, Blogs,...



$$\Gamma^* \approx \arg \max_{\Gamma} \sum_{i=1}^N [\phi(m_i, t_i) + \sum_{t_i \in \Gamma, t_j \in \Gamma'} \psi(t_i, t_j)]$$

Adding a “global” term to evaluate how good the **structure** of the solution is.

- Use the local solutions Γ' (each mention considered independently).
- Evaluate the structure based on pairwise coherence scores $\psi(t_i, t_j)$
- Choose those that satisfy **document** coherence conditions.

High-level Algorithmic Approach

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[E.g., if m, m' are related by virtue of being in d , their corresponding titles t, t' should also be related]

Mention Identification

- Highest recall: Each n-gram is a potential concept mention
 - Intractable for larger documents
- Surface form based filtering
 - Shallow parsing (especially NP chunks), NP's augmented with surrounding tokens, capitalized words
 - Remove: single characters, “stop words”, punctuation, etc.
- Classification and statistics based filtering
 - Name tagging (Finkel et al., 2005; Ratnov and Roth, 2009; Li et al., 2012)
 - Mention extraction (Florian et al., 2006, Li and Ji, 2014)
 - Key phrase extraction, independence tests (Mihalcea and Csomai, 2007), common word removal (Mendes et al., 2012;)

Mention Identification (Cont')

- Wikipedia Lexicon Construction based on prior link knowledge
 - Only n-grams linked in training data (prior anchor text) (Ratinov et al., 2011; Davis et al., 2012; Sil et al., 2012; Demartini et al., 2012; Wang et al., 2012; Han and Sun, 2011; Han et al., 2011; Mihalcea and Csomai, 2007; Cucerzan, 2007; Milne and Witten, 2008; Ferragina and Scaiella, 2010)
 - E.g. all n-grams used as anchor text within Wikipedia
 - Only terms that exceed link probability threshold (Bunescu, 2006; Cucerzan, 2007; Fernandez et al., 2010; Chang et al., 2010; Chen et al., 2010; Meij et al., 2012; Bysani et al., 2010; Hachey et al., 2013; Huang et al., 2014)
 - Dictionary-based chunking
 - String matching (n-gram with canonical concept name list)
- Mis-spelling correction and normalization (Yu et al., 2013; Charton et al., 2013)

Mention Identification (Cont')

- Multiple input sources are being used
 - Some build on the given text only, some use external resources.
- Methods used by some popular systems
 - Illinois Wikifier (Ratinov et al., 2011; Cheng and Roth, 2013)
 - NP chunks and substrings, NER (+nesting), prior anchor text
 - TAGME (Ferragina and Scaiella, 2010)
 - Prior anchor text
 - DBPedia Spotlight (Mendes et al., 2011)
 - Dictionary-based chunking with string matching (via DBpedia lexicalization dataset)
 - AIDA (Finkel et al., 2005; Hoffart et al., 2011)
 - Name Tagging
 - RPI Wikifier (Chen and Ji, 2011; Cassidy et al., 2012; Huang et al., 2014)
 - Mention Extraction (Li and Ji, 2014)

Mention Identification (Mendes et al., 2012)

L Dictionary-Based chunking (LingPipe) using DBPedia Lexicalization Dataset (Mendes et al., 2011)

LNP Extends L with simple heuristic to isolate NP's

NPL_{>k} Same as LNP but with Statistical NP Chunker

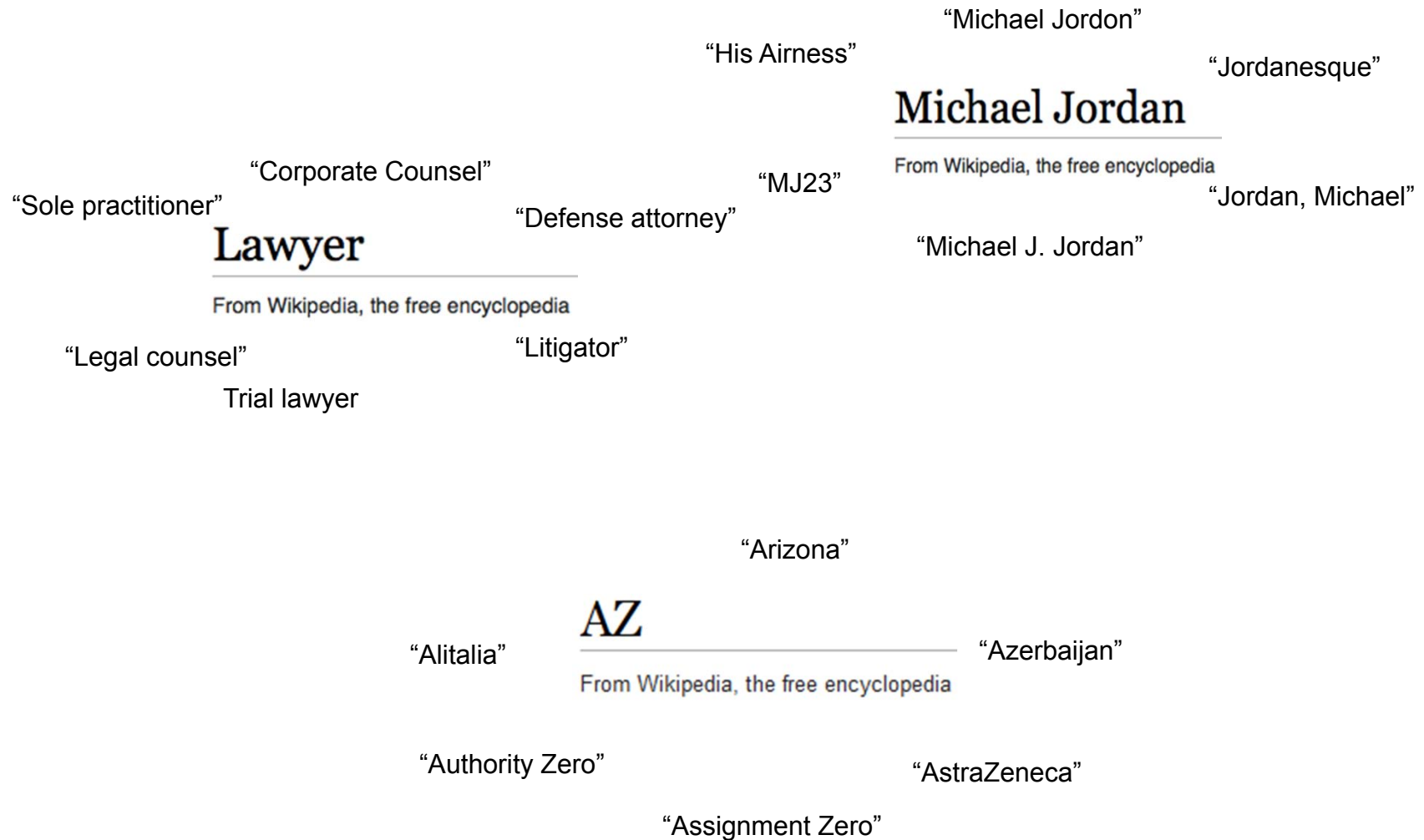
CW Extends L by filtering out common words (Daiber, 2011)

Kea Uses supervised key phrase extraction (Frank et al., 1999)

NER Based on OpenNLP 1.5.1
NER_{UNP} Augments NER with NPL

Method	P	R	Avg Time per mention
L>3	4.89	68.20	.0279
L>10	5.05	66.53	.0246
L>75	5.06	58.00	.0286
LNP*	5.52	57.04	.0331
NPL*>3	6.12	45.40	1.1807
NPL*>10	6.19	44.48	1.1408
NPL*>75	6.17	38.65	1.2969
CW	6.15	42.53	.2516
Kea	1.90	61.53	.0505
NER	4.57	7.03	2.9239
NER \cup NP	1.99	68.30	3.1701

Need Mention Expansion



Need Mention Expansion

- Medical Domain: 33% of abbreviations are ambiguous (Liu et al., 2001), major source of errors in medical NLP (Friedman et al., 2001)

RA	“rheumatoid arthritis”, “tenal artery”, “right atrium”, “right atrial”, “refractory anemia”, “radioactive”, “right arm”, “rheumatic arthritis”, ...
PN	“Penicillin”; “Pneumonia”; “Polyarteritis”; “Nodosa”; “Peripheral neuropathy”; “Peripheral nerve”; “Polyneuropathy”; “Pyelonephritis”; “Polyneuritis”; “Parenteral nutrition”; “Positional Nystagmus”; “Periarteritis nodosa”, ...

- Military Domain
 - *“GA ADT 1, USDA, USAID, ADP, Turkish PRT, and the DAIL staff met to create the Wardak Agricultural Steering Committee. “*
 - *“DST” = “District Stability Team” or “District Sanitation Technician”?*
 - *“ADP” = “Adrian Peterson” (Person) or “Arab Democratic Party” (Organization) or “American Democracy Project” (Initiative)?*

Mention Expansion

- Co-reference resolution
 - Each mention in a co-referential cluster should link to the same concept
 - Canonical names are often less ambiguous
 - Correct types: “*Detroit*” = “*Red Wings*”; “*Newport*” = “*Newport-Gwent Dragons*”
- Known Aliases
 - KB link mining (e.g., Wikipedia “re-direct”) (Nemeskey et al., 2010)
 - Patterns for Nicknames/ Acronym mining (Zhang et al., 2011; Tamang et al., 2012)
“full-name” (acronym) or “acronym (full-name)”, “city, state/country”
- Statistical models such as weighted finite state transducer (Friburger and Maurel, 2004)
 - CCP = “Communist Party of China”; “MINDEF” = “Ministry of Defence”
- Ambiguity drops from 46.3% to 11.2% (Chen and Ji, 2011; Tamang et al., 2012).

High-level Algorithmic Approach

- **Input:** A text document d ; **Output:** a set of pairs (m_i, t_i)
 - m_i are mentions in d ; t_i are corresponding Wikipedia titles, or NIL.
- (1) Identify mentions m_i in d
- ⇒ • (2) Local Inference
 - For each m_i in d :
 - Identify a set of relevant titles $T(m_i)$
 - Rank titles $t_i \in T(m_i)$

[E.g., consider local statistics of edges (m_i, t_i) , $(m_i, *)$, and $(*, t_i)$ occurrences of in the Wikipedia graph]
- (3) Global Inference
 - For each document d :
 - Consider all $m_i \in d$; and all $t_i \in T(m_i)$
 - Re-rank titles $t_i \in T(m_i)$

[E.g., if m, m' are related by virtue of being in d , their corresponding titles t, t' should also be related]

Generating Candidate Titles

- 1. Based on canonical names (e.g. Wikipedia page title)
 - Titles that are a super or substring of the mention
 - Michael Jordan is a candidate for “Jordan”
 - Titles that overlap with the mention
 - “William Jefferson Clinton” → Bill Clinton;
 - “non-alcoholic drink” → Soft Drink
- 2. Based on previously attested references
 - All Titles ever referred to by a given string in training data
 - Using, e.g., Wikipedia-internal hyperlink index
 - More Comprehensive Cross-lingual resource (Spitkovsky & Chang, 2012)

Initial Ranking of Candidate Titles

- Initially rank titles according to...
 - Wikipedia article length
 - Incoming Wikipedia Links (from other titles)
 - Number of inhabitants or the largest area (for geo-location titles)
- More sophisticated measures of prominence
 - Prior link probability
 - Graph based methods

$P(t|m)$: “Commonness”

$$\text{Commonness}(m \Rightarrow t) = \frac{\text{count}(m \rightarrow t)}{\sum_{t' \in W} \text{count}(m \rightarrow t')}$$

Typography

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Airlines and destinations

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The Greatest Show on Earth were a **British rock** band, who recorded two **albums** for **Harvest Records** in 1970.

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$P(\text{Title} | \text{"Chicago"})$

$P(t|m)$: “Commonness”

Rank	t	$P(t \text{“Chicago”})$
1	Chicago	.76
2	Chicago (band)	.041
3	Chicago (2002_film)	.022
20	Chicago Maroons Football	.00186
100	1985 Chicago Whitesox Season	.00023448
505	Chicago Cougars	.0000528
999	Kimbell Art Museum	.00000586

- First used by Medelyan et al. (2008)
- Most popular method for initial candidate ranking

Note on Domain Dependence

- “Commonness” Not robust across domains

Formal Genre

Corpus	Recall
ACE	86.85%
MSNBC	88.67%
AQUAINT	97.83%
Wiki	98.59%

Ratinov et al. (2011)

Tweets

Metric	Score
P1	60.21%
R-Prec	52.71%
Recall	77.75%
MRR	70.80%
MAP	58.53%

Meij et al. (2012)

Graph Based Initial Ranking

- Centrality (Hachey et al., 2011; Hakimov et al., 2012)

$$Centrality(a) = \frac{\partial_a}{\sum_{b \in W} s(a, b)} * in_links(a) * out_links(a) * k$$

- ∂_a : the number of all reachable nodes from a
 - $s(a, b)$: the distance between a and b
- Importance of the title with respect to Wikipedia - Similar to PageRank (Brin & Page, 1998)
 - Hachey et al. (2011) showed tha centrality works slightly better than PageRank

Basic Ranking Methods

- Local: Mention-Concept Context Similarity
 - Use **similarity measure** to compare the **context of the mention** with the **text associated with a candidate title** (the text in the corresponding page)
- Global: Document-wide Conceptual Coherence
 - Use topical/semantic **coherence** measures between the set of referent concepts for all mentions in a document

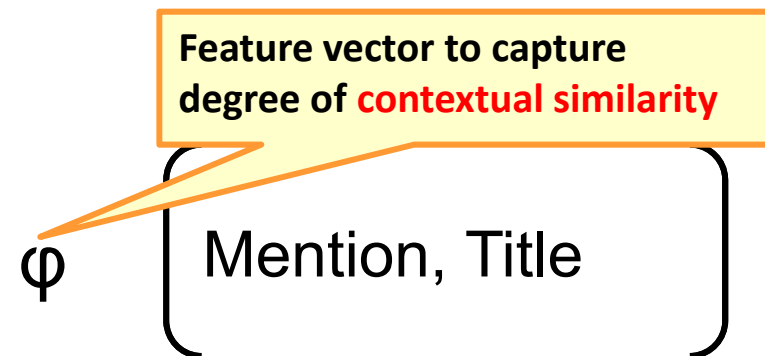
Context Similarity Measures

Determine assignment that maximizes pairwise similarity

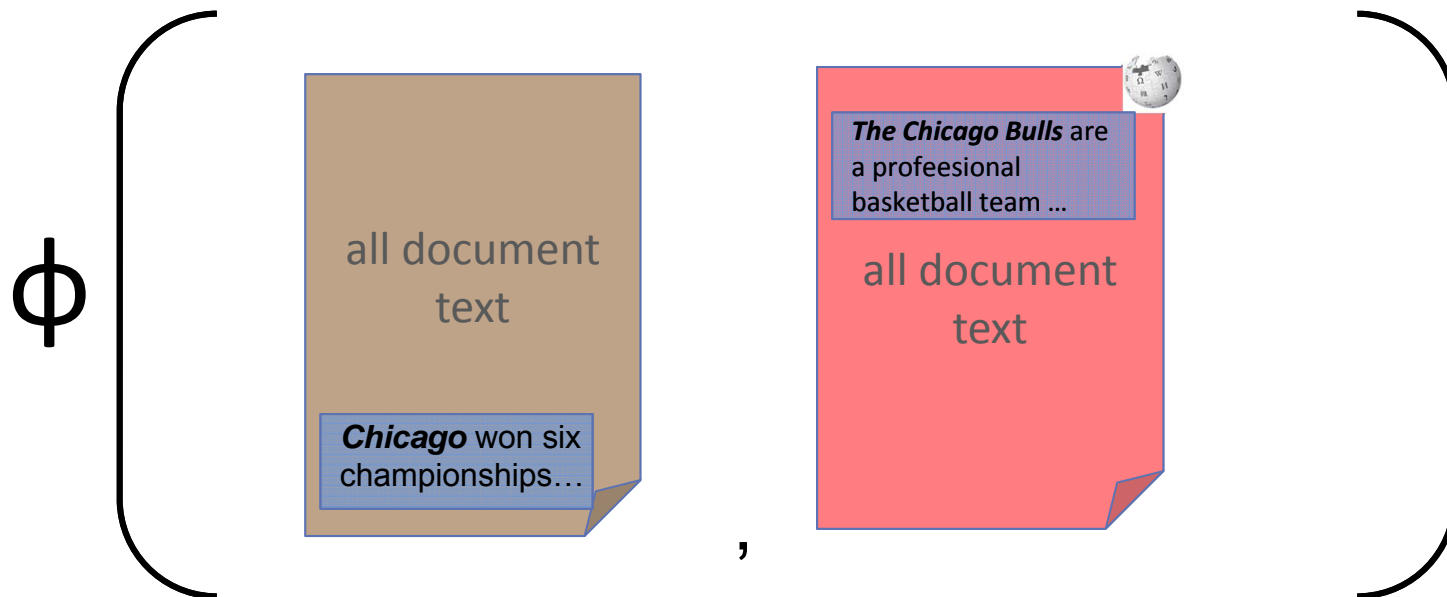
$$\Gamma^* = \operatorname{argmax}_{\Gamma} \sum_i \varphi(m_i, t_i)$$



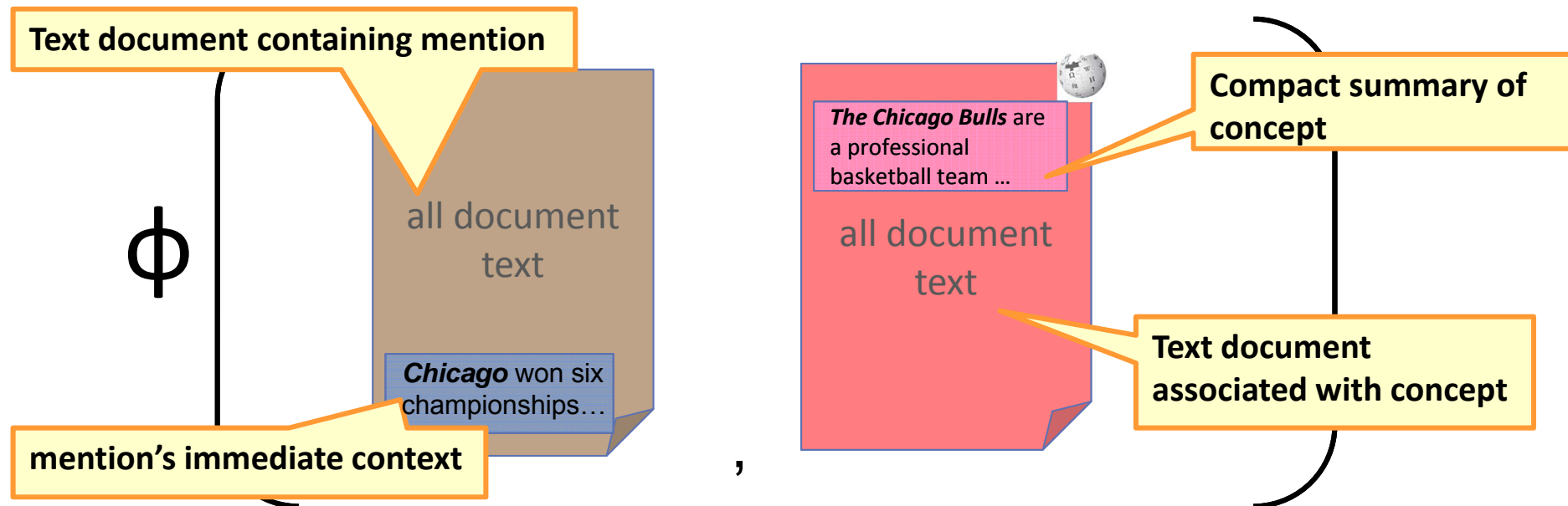
Mapping from mentions to titles



Context Similarity Measures: *Context Source*

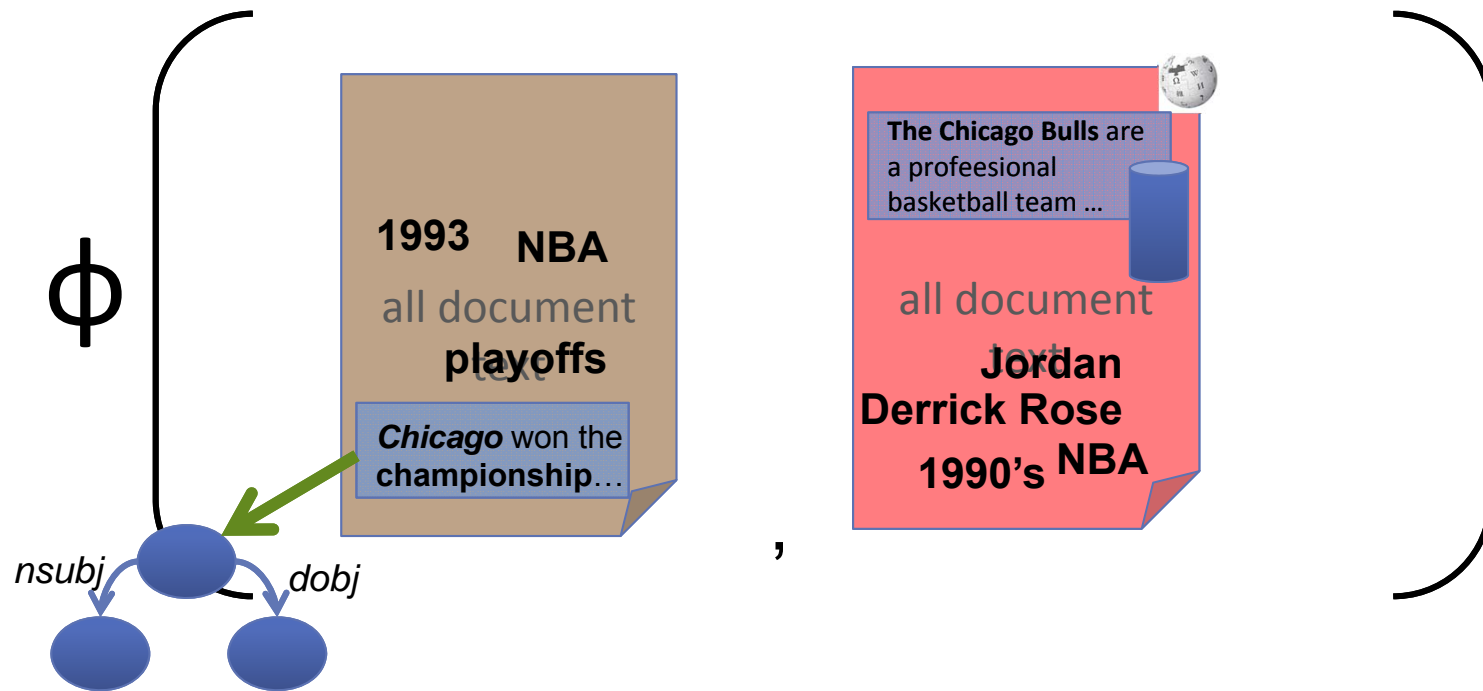


Context Similarity Measures: *Context Source*



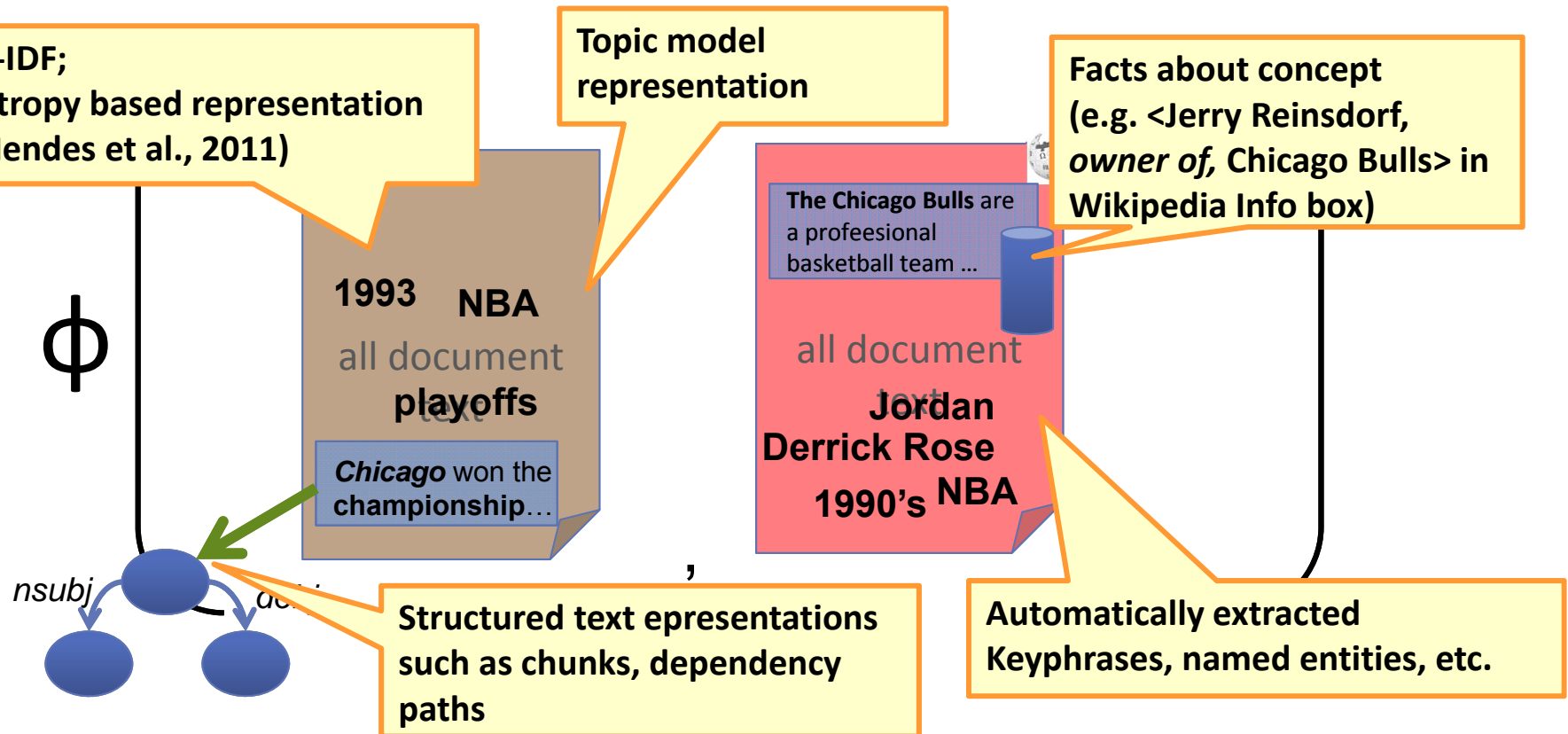
- Varying notion of distance between mention and context tokens
 - Token-level, discourse-level
- Varying granularity of concept description
 - Synopsis, entire document

Context Similarity Measures: *Context Analysis*



- Context is processed and represented in a variety of ways

Context Similarity Measures: *Context Analysis*



- Context is processed and represented in a variety of ways

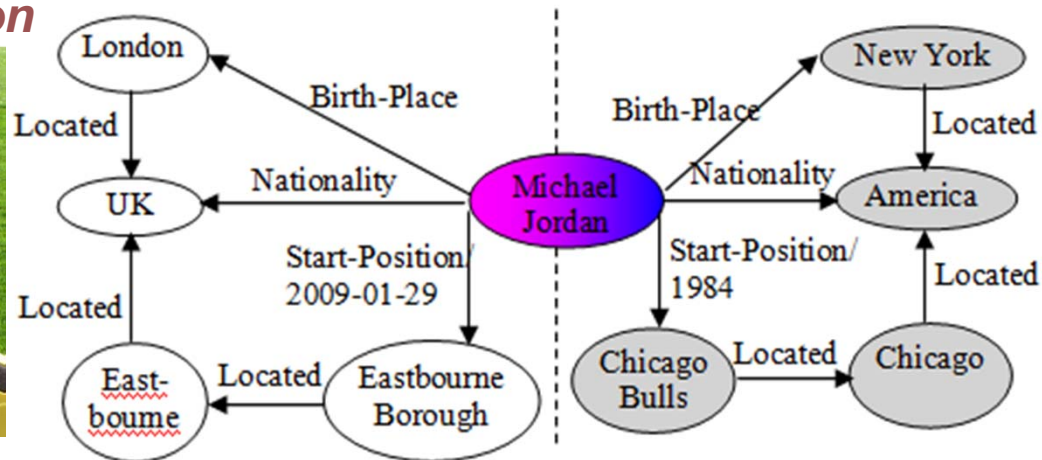
Typical Features for Ranking

Mention/Concept Attribute		Description
Name	Spelling match	Exact string match, acronym match, alias match, string matching...
	KB link mining	Name pairs mined from KB text redirect and disambiguation pages
	Name Gazetteer	Organization and geo-political entity abbreviation gazetteers
Document surface	Lexical	Words in KB facts, KB text, mention name, mention text.
		Tf.idf of words and ngrams
	Position	Mention name appears early in KB text
	Genre	Genre of the mention text (newswire, blog, ...)
	Local Context	Lexical and part-of-speech tags of context words
Entity Context	Type	Mention concept type, subtype
	Relation/Event	Concepts co-occurred, attributes/relations/events with mention
	Coreference	Co-reference links between the source document and the KB text
Profiling		Slot fills of the mention, concept attributes stored in KB infobox
Concept		Ontology extracted from KB text
Topic		Topics (identity and lexical similarity) for the mention text and KB text
KB Link Mining		Attributes extracted from hyperlink graphs of the KB text
Popularity	Web	Top KB text ranked by search engine and its length
	Frequency	Frequency in KB texts

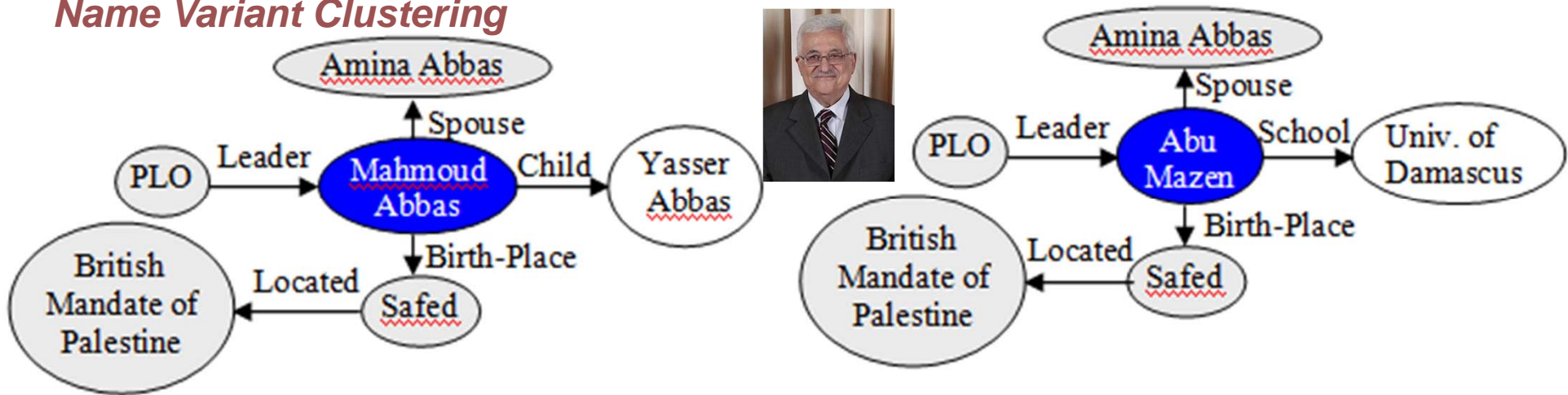
- (Ji et al., 2011; Zheng et al., 2010; Dredze et al., 2010; Anastacio et al., 2011)

Entity Profiling Feature Examples

Disambiguation



Name Variant Clustering



- Deep semantic context exploration and indicative context selection (Gao et al., 2010; Chen et al., 2010; Chen and Ji, 2011; Cassidy et al., 2012)
- Exploit name tagging, Wikipedia infoboxes, synonyms, variants and abbreviations, slot filling results and semantic categories

Topic Feature Example



Li Na

player

tennis

Russia

single

final

gain

half

female

Pakistan

relation

express

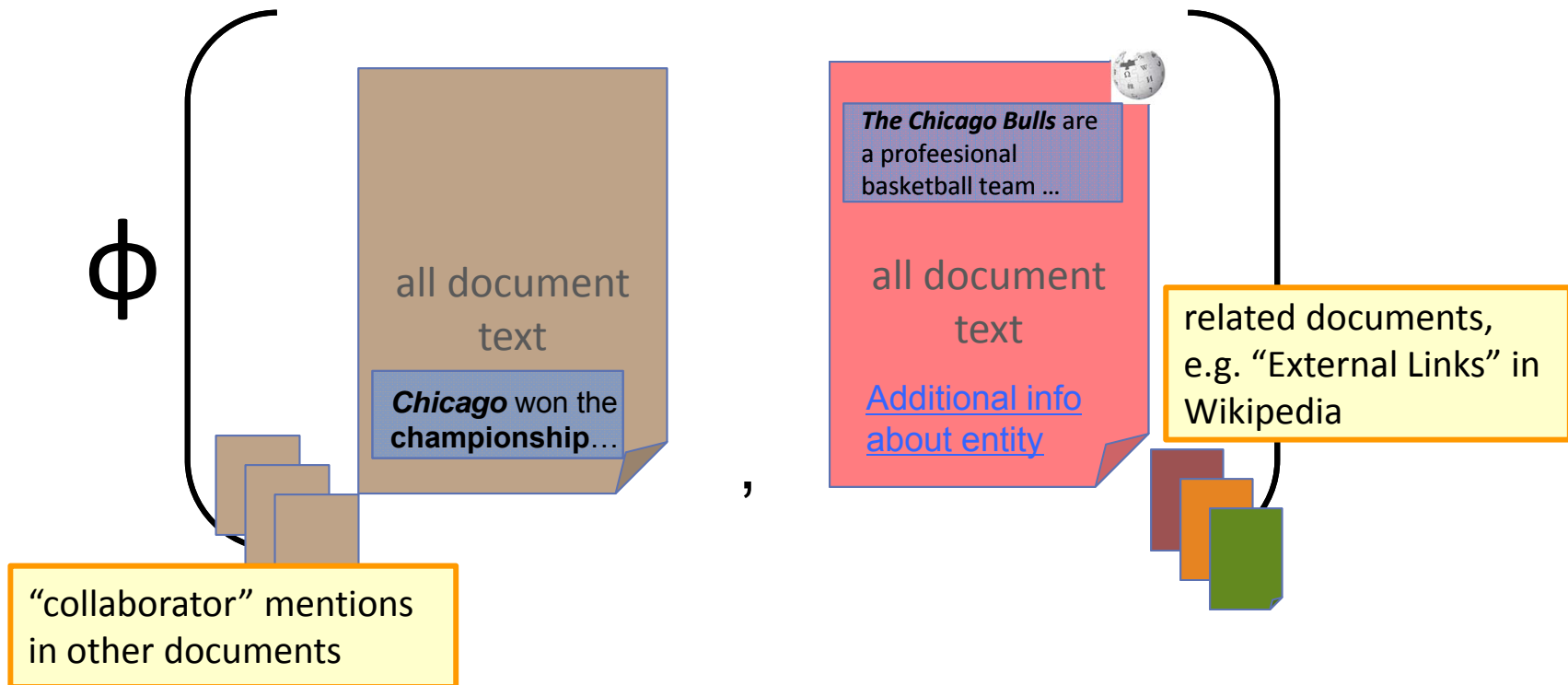
vice president

country

Prime minister

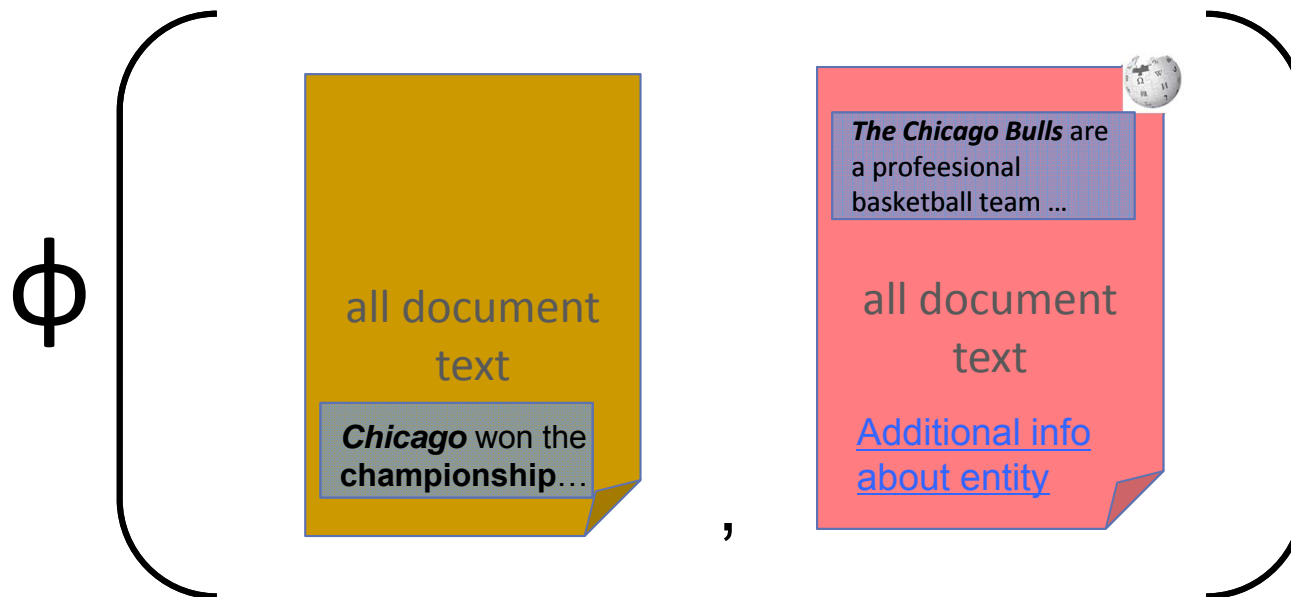
Topical features or topic based document clustering for context expansion (Milne and Witten, 2008; Syed et al., 2008; Srinivasan et al., 2009; Kozareva and Ravi, 2011; Zhang et al., 2011; Anastacio et al., 2011; Cassidy et al., 2011; Pink et al., 2013)

Context Similarity Measures: *Context Expansion*



- Obtain additional documents related to mention
 - Consider mention as information retrieval query
- KB may link to additional, more detailed information

Context Similarity Measures: *Computation*



- Cosine similarity (via TF-IDF)
- Other distance metrics (e.g. Jaccard)
- 2nd order vector composition (Hoffart et al., EMNLP2011)
- Mutual Information

Putting it All Together

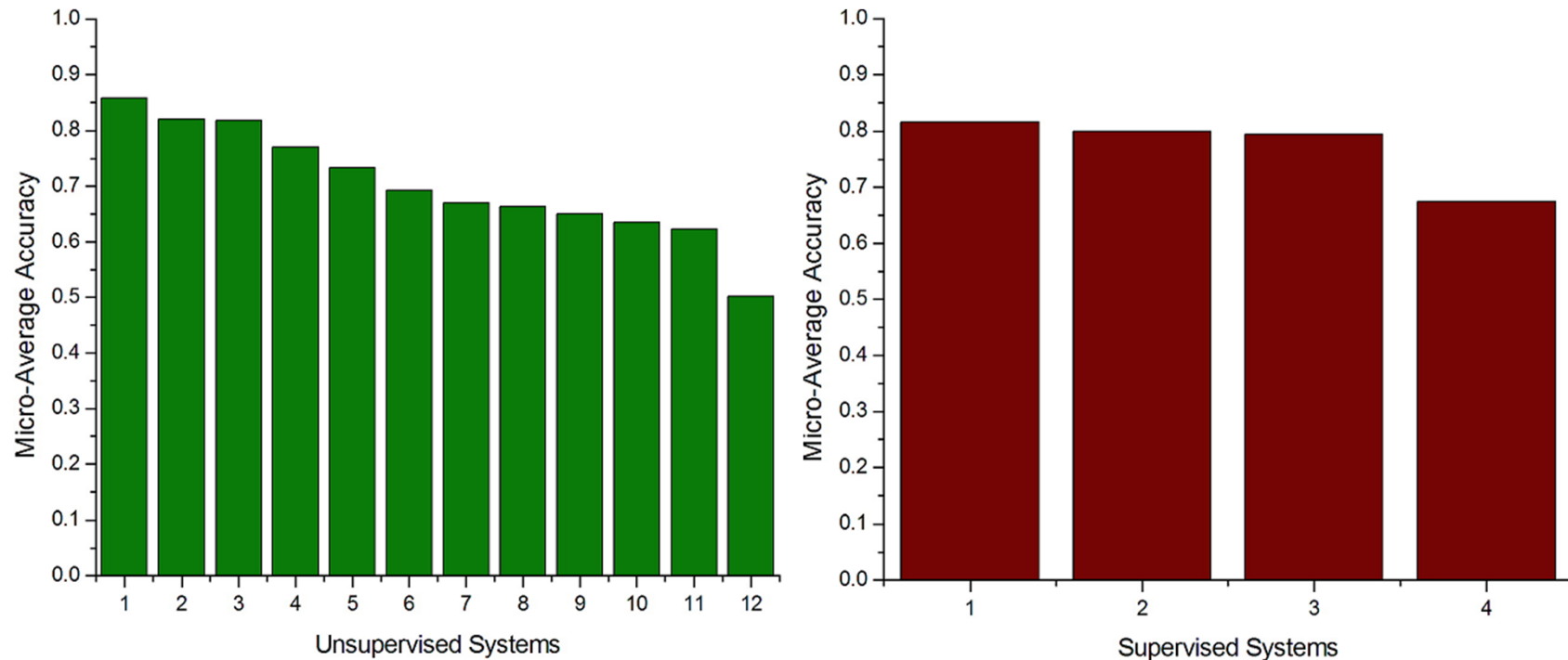
	Score Baseline	Score Context	Score Text
Chicago_city	0.99	0.01	0.03
Chicago_font	0.0001	0.2	0.01
Chicago_band	0.001	0.001	0.02

- Learning to Rank [Ratinov et. al. 2011]
 - Consider all pairs of title candidates
 - Supervision is provided by Wikipedia
 - Train a ranker on the pairs (learn to prefer the correct solution)
 - A Collaborative Ranking approach: outperforms many other learning approaches (Chen and Ji, 2011)

Ranking Approach Comparison

- Unsupervised or weakly-supervised learning (Ferragina and Scaiella, 2010)
 - Annotated data is minimally used to tune thresholds and parameters
 - The similarity measure is largely based on the unlabeled contexts
- Supervised learning (Bunescu and Pasca, 2006; Mihalcea and Csomai, 2007; Milne and Witten, 2008, Lehmann et al., 2010; McNamee, 2010; Chang et al., 2010; Zhang et al., 2010; Pablo-Sanchez et al., 2010, Han and Sun, 2011, Chen and Ji, 2011; Meij et al., 2012)
 - Each <mention, title> pair is a classification instance
 - Learn from annotated training data based on a variety of features
 - ListNet performs the best using the same feature set (Chen and Ji, 2011)
- Graph-based ranking (Gonzalez et al., 2012)
 - context entities are taken into account in order to reach a global optimized solution together with the query entity
- IR approach (Nemeskey et al., 2010)
 - the entire source document is considered as a single query to retrieve the most relevant Wikipedia article

Unsupervised vs. Supervised Ranking



- KBP2010 Entity Linking Systems (Ji et al., 2010)

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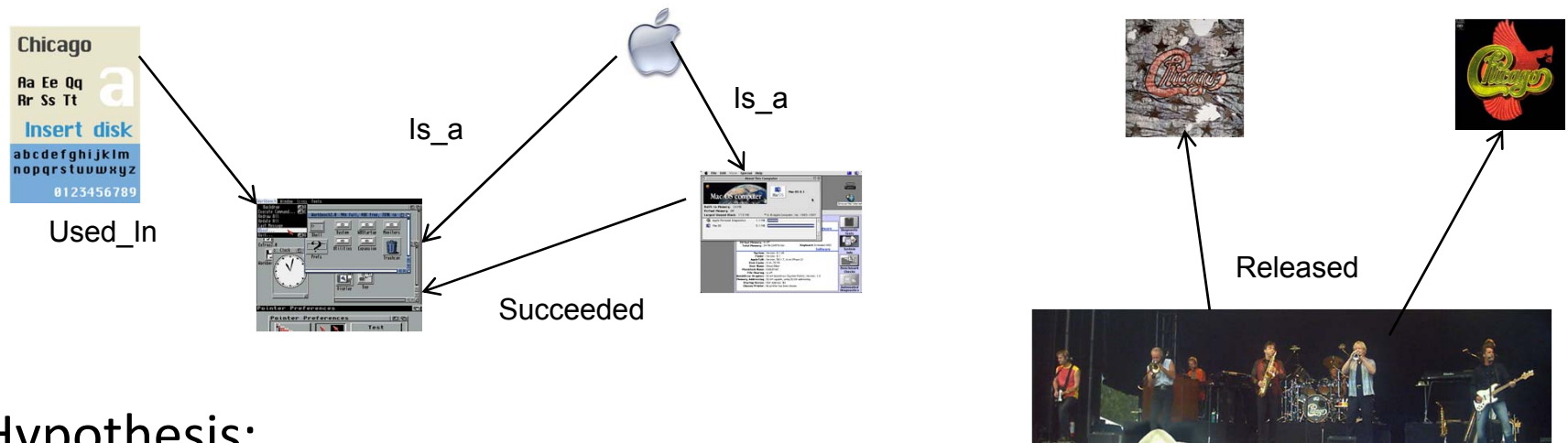
Conceptual Coherence

- Recall: The reference collection (might) have structure.

It's a version of Chicago – the standard classic Macintosh menu font, with that distinctive thick diagonal in the "N".

Chicago was used by default for Mac menus through MacOS 7.6, and OS 8 was released mid-1997..

Chicago VIII was one of the early 70s-era Chicago albums to catch my ear, along with Chicago II.



- Hypothesis:
 - Textual co-occurrence of concepts is reflected in the KB (Wikipedia)
- Incite:
 - Preferred disambiguation Γ contains structurally coherent concepts

Co-occurrence (Title 1, Title 2)

Typography

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Airlines and destinations

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The city senses of Boston and Chicago appear together often.

The Greatest Show on Earth were a **British rock** band, who recorded two **albums** for **Harvest Records** in 1970.

The band had been conceived by Harvest Records in an attempt to create a horn-based rock combo, such as **Blood Sweat & Tears** or **Chicago**.^[1]



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Rock music and albums appear together often

The Greatest Show on Earth were a **British rock** band, who recorded two **albums** for **Harvest Records** in 1970.

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Global Ranking

$$\Gamma^* \approx \arg \max_{\Gamma} \sum_{i=1}^N [\phi(m_i, t_i) + \sum_{t_i \in \Gamma, t_j \in \Gamma'} \psi(t_i, t_j)]$$

- How to approximate the “global semantic context” in the document”?
 - It is possible to only use non-ambiguous mentions as a way to approximate it.
- How to define relatedness between two titles? (What is Ψ ?)

Title Coherence & Relatedness

- Let c, d be a pair of titles ...
- Let C and D be their sets of incoming (or outgoing) links
 - Unlabeled, directed link structure

Introduced by Milne & Witten (2008)
Used by Kulkarni et al. (2009), Ratnov
et al (2011), Hoffart et al (2011),

$$relatedness(c, d) = \frac{\log(\max(|C|, |D|)) - \log(|C \cap D|)}{\log(W) - \log(\min(|C|, |D|))}$$

See García et al.
(JAIR2014) for
variational details

$$PMI(c, d) = \frac{|C \cap D| / |W|}{(|C| / |W|) * (|D| / |W|)}$$

Relatedness Outperforms
Pointwise Mutual Information
(Ratnov et al., 2011)

- Let C and $D \in \{0, 1\}^K$, where K is the set of all categories

$$relatedness(c, d) = \langle C, D \rangle$$

Category based similarity
introduced by Cucerzan (2007)

More Relatedness Measures (Ceccarelli et al., 2013)

Singleton Features	
$P(a)$	probability of a mention to entity a : $P(a) = in(a) / W .$
$H(a)$	entropy of a : $H(a) = -P(a) \log(P(a)) - (1 - P(a)) \log(1 - P(a)).$
Asymmetric Features	
$P(a b)$	conditional probability of the entity a given b : $P(a b) = in(a) \cap in(b) / in(b) .$
$Link(a \rightarrow b)$	equals 1 if a links to b , and 0 otherwise.
$P(a \rightarrow b)$	probability that a links to b : equals $1/ out(a) $ if a links to b , and 0 otherwise.
$Friend(a, b)$	equals 1 if a links to b , and $ out(a) \cap in(b) / out(a) $ otherwise.
$KL(a b)$	Kullback-Leibler divergence: $KL(a b) = \log \frac{P(a)}{P(b)} P(a) + \log \frac{1-P(a)}{1-P(b)} (1 - P(a)).$

More Relatedness Measures (Ceccarelli et al., 2013)

Symmetric Features	
$\rho^{MW}(a, b)$	co-citation based similarity [19].
$J(a, b)$	Jaccard similarity: $J(a, b) = \frac{in(a) \cap in(b)}{in(a) \cup in(b)}$.
$P(a, b)$	joint probability of entities a and b : $P(a, b) = P(a b) \cdot P(b) = P(b a) \cdot P(a)$.
$Link(a \leftrightarrow b)$	equals 1 if a links to b and vice versa, 0 otherwise.
$AvgFr(a, b)$	average friendship: $(Friend(a, b) + Friend(b, a))/2$.
$\rho_{out}^{MW}(a, b)$	ρ^{MW} considering outgoing links.
$\rho_{in-out}^{MW}(a, b)$	ρ^{MW} considering the union of the incoming and outgoing links.
$J_{out}(a, b)$	Jaccard similarity considering the outgoing links.
$J_{in-out}(a, b)$	Jaccard similarity considering the union of the incoming and outgoing links.
$\chi^2(a, b)$	χ^2 statistic: $\chi^2(a, b) = (in(b) \cap in(a) \cdot (W - in(b) \cup in(a)) +$ $- in(b) \setminus in(a) \cdot in(a) \setminus in(b))^2 \cdot$ $\frac{ W }{ in(a) \cdot in(b) (W - in(a)) (W - in(b))}$
$\chi_{out}^2(a, b)$	χ^2 statistic considering the outgoing links.
$\chi_{in-out}^2(a, b)$	χ^2 statistic considering the union of the incoming and outgoing links.
$PMI(a, b)$	point-wise mutual information: $\log \frac{P(b a)}{P(b)} = \log \frac{P(a b)}{P(a)} = \log \frac{ in(b) \cap in(a) W }{ in(b) in(a) }$

More Relatedness Measures (Ceccarelli et al., 2013)

Features	Rank	NDCG@5	NDCG@10	P@5	P@10	MRR
$P(c e)$	1	0.68	0.72	0.47	0.33	0.80
$J(e, c)$	2	0.62	0.66	0.44	0.31	0.75
$\text{Friend}(e, c)$	24	0.59	0.64	0.42	0.31	0.71
$\rho^{\text{MW}}(e, c)$	19	0.59	0.63	0.42	0.31	0.72
$J_{\text{in-out}}(e, c)$	26	0.60	0.63	0.42	0.30	0.74
$\text{AvgFr}(e, c)$	3	0.57	0.62	0.40	0.30	0.69
$P(e, c)$	27	0.56	0.60	0.39	0.28	0.70
$\rho_{\text{in-out}}^{\text{MW}}(a, b)$	9	0.56	0.60	0.40	0.29	0.71
$J_{\text{in-out}}(e, c)$	4	0.54	0.58	0.39	0.28	0.67
$\rho_{\text{out}}^{\text{MW}}(a, b)$	17	0.52	0.55	0.37	0.27	0.65
$\chi^2(e, c)$	25	0.51	0.55	0.37	0.27	0.64
$P(e c)$	22	0.48	0.54	0.36	0.28	0.60
$H(c)$	5	0.48	0.51	0.30	0.20	0.68
$\chi_{\text{out}}^2(e, c)$	16	0.47	0.50	0.34	0.24	0.61
$\text{AvgFr}(c, e)$	21	0.44	0.49	0.33	0.25	0.56
$P(c)$	13	0.47	0.49	0.29	0.19	0.66
$\text{PMI}(e, c)$	23	0.42	0.48	0.32	0.25	0.53
$\chi_{\text{in-out}}^2(e, c)$	11	0.44	0.46	0.33	0.23	0.58
$P(e \rightarrow c)$	18	0.37	0.38	0.24	0.15	0.55
$\text{Link}(e \rightarrow c)$	20	0.37	0.38	0.24	0.15	0.55
$P(c \rightarrow e)$	12	0.35	0.36	0.22	0.14	0.52
$\text{Link}(c \rightarrow e)$	15	0.31	0.33	0.21	0.14	0.46
$KL(c e)$	10	0.32	0.32	0.19	0.12	0.51
$\text{Link}(c \leftrightarrow e)$	14	0.28	0.29	0.17	0.11	0.45
$KL(e c)$	8	0.26	0.28	0.17	0.11	0.44
$P(e)$	6	0.08	0.11	0.06	0.06	0.17
$H(e)$	7	0.08	0.11	0.06	0.06	0.17

Densest Subgraph Heuristic (Moro et al., TACL2014)

- Target KB: **Babelnet** (Navigli & Ponzetto, AI 2012)
 - A **semantic network** of concepts (including named entities), with typed edges for semantic relations, in multiple languages.
- Babelify System
 - 1. Assign weights to and remove labels from edges using *directed triangles*
 - Inspired by (Watts & Strogatz 1998)
 - 2. Create *semantic signature* via Random Walk with Restart (RWR) (Tong et al., 2006) using edge weights for probability
 - SemSign_c – set of concepts most related to c based on RWR
 - 3. Graph - V : (m, c) candidates E : based on SemSign
 - 4. Reduce ambiguity by approximating Densest Subgraph
 - Hypothesis: The best concept for a mention comes from the densest portion of the graph

NIL Detection and Clustering

- The key difference between Wikification and Entity Linking is the way NIL are treated.
- In **Wikification**:
 - Local Processing
 - Each mention m_i that does not correspond to title t_i is mapped to NIL.
- In **Entity Linking**:
 - Global Processing
 - Cluster all mentions m_i that represent the same concept
 - If this cluster does not correspond to a title t_i , map it to NIL.
- Mapping to NIL is challenging in both cases

NIL Detection

1. Augment KB with NIL entry and treat it like any other entry
2. Include general NIL-indicating features

Is it in the KB?



, NIL



KB

Jordan accepted a basketball scholarship to North Carolina, ...

In the 1980's **Jordan** began developing recurrent neural networks.

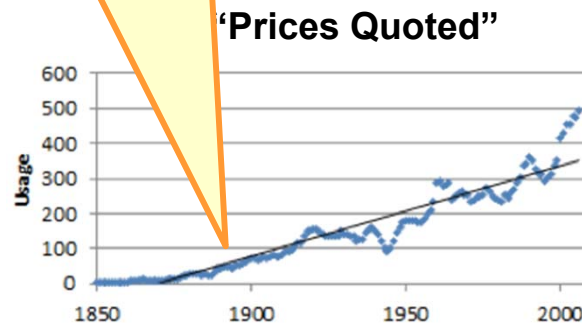
Local man **Michael Jordan** was appointed county coroner ...

1. Binary classification (Within KB vs. NIL)
2. Select NIL cutoff by tuning confidence threshold

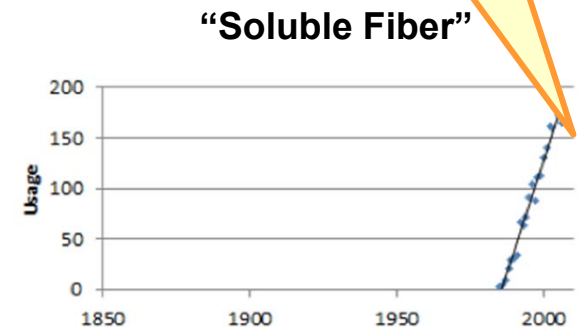
Is it an *entity*?

- Concept Mention Identification (above)
- Not all NP's are linkable

No spike: **Not an entity**



Sudden Google Books frequency spike: **Entity**



NIL Detection: Main Challenges

- Wikipedia's hyperlinks offer a wealth of disambiguated mentions that can be leveraged to train a Wikification system.
- However, relative to mentions from general text, Wikipedia mentions are disproportionately likely to have corresponding Wikipedia pages
- Accounting for this bias from statistical models requires more than simply training a Wikification system on a moderate number of examples from non-Wikipedia text
- Applying distinct semi-supervised and active learning approaches to the task is a primary area of future work
- More advanced selectional preference methods should be applied to solve the cases when the correct referent is ranked very low by statistical models, and combine multi-dimensional clues

NIL Clustering

“All in one”

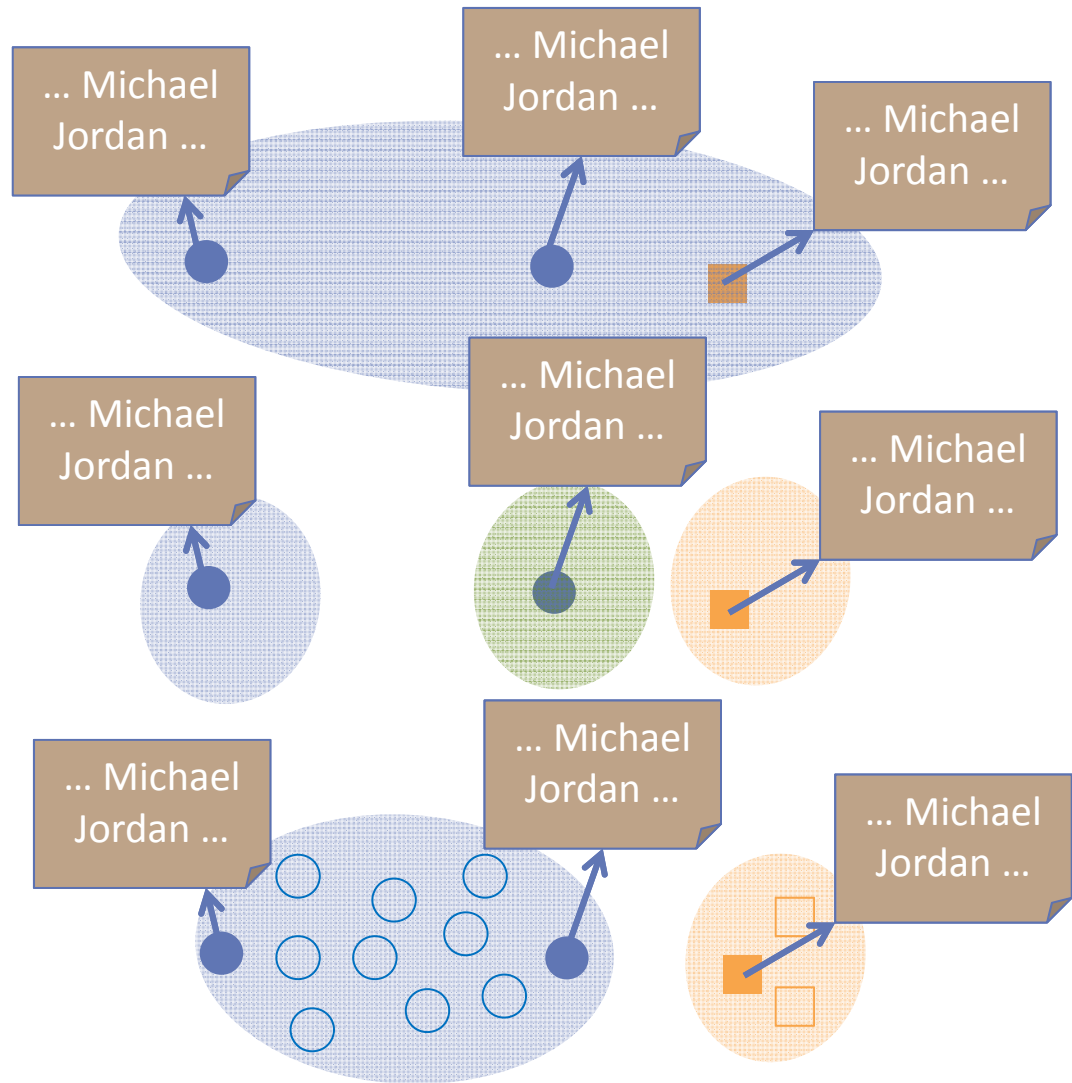
Simple string matching

“One in one”

Often difficult to beat!

Collaborative Clustering

**Most effective when
ambiguity is high**



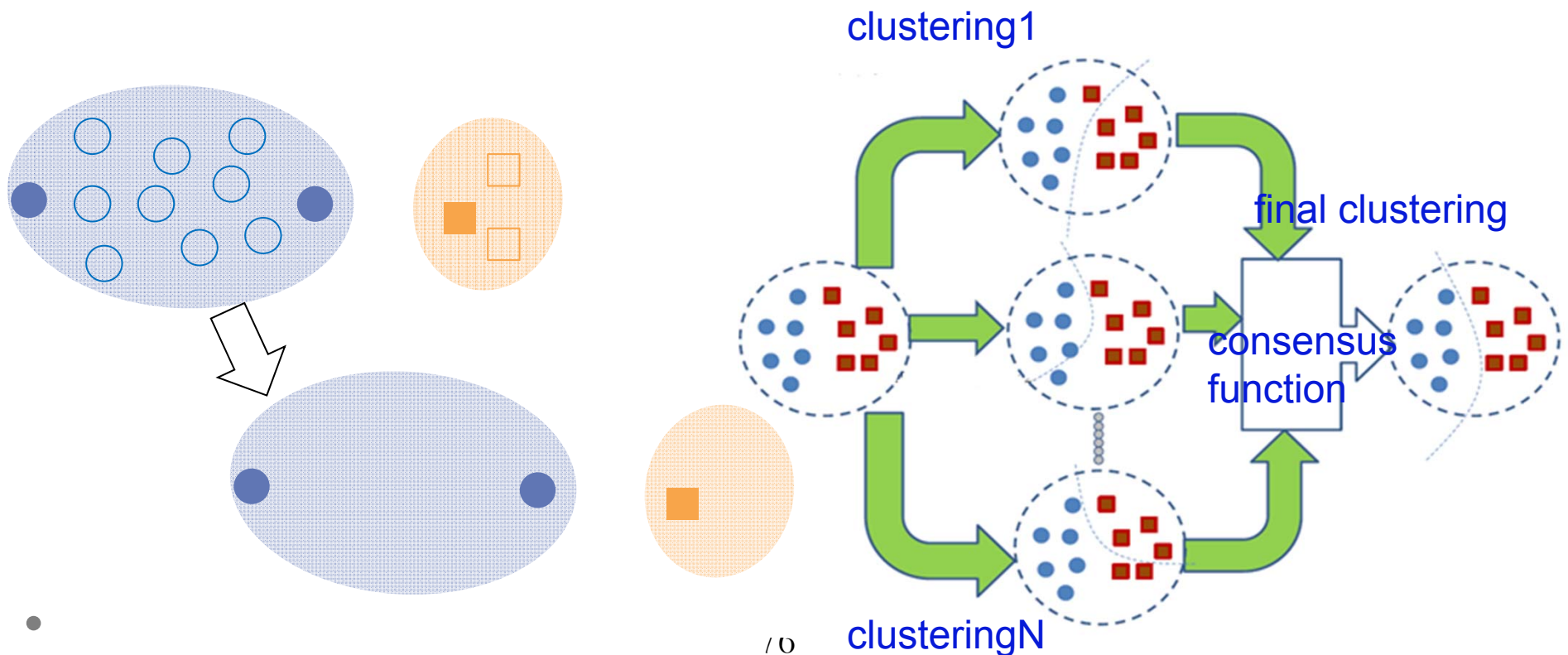
NIL Clustering Methods Comparison (Chen and Ji, 2011; Tamang et al., 2012)

Algorithms		B-cubed+ F-Measure	Complexity
Agglomerative clustering	3 linkage based algorithms (single linkage, complete linkage, average linkage) (Manning et al., 2008)	85.4%-85.8%	$O(n^2)$ $O(n^2 \log n)$ n: the number of mentions
	6 algorithms optimizing internal measures cohesion and separation	85.6%-86.6%	$O(n^2 \log n)$ $O(n^3)$
Partitioning Clustering	6 repeated bisection algorithms optimizing internal measures	85.4%-86.1%	$O(NNZ \times k + m \times k)$ NNZ: the number of non-zeroes in the input matrix M: dimension of feature vector for each mention k: the number of clusters
	6 direct k-way algorithms optimizing internal measures (Zhao and Karypis, 2002)	85.5%-86.9%	$O(NNZ \times \log k)$

- **Co-reference methods** were also used to address NIL Clustering (E.g., Cheng et. al 2013): L^3M Latent Left Linking jointly learn metric and clusters mentions

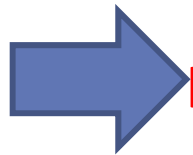
Collaborative Clustering (Chen and Ji, 2011; Tamang et al., 2012)

- Consensus functions
 - Co-association matrix (Fred and Jain, 2002)
 - Graph formulations (Strehl and Ghosh, 2002; Fern and Brodley, 2004): instance-based; cluster-based; hybrid bipartite
- 12% gain over the best individual clustering algorithm

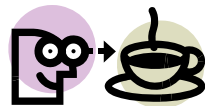


Outline

- Motivation and Definition
- A Skeletal View of a Wikification System
 - High Level Algorithmic Approach



Key Challenges



Coffee Break

- Recent Advances
- New Tasks, Trends and Applications
- What's Next?
- Resources, Shared Tasks and Demos

General Challenges

[Blumenthal](#) ([D](#)) is a candidate for the [U.S. Senate](#) seat now held by [Christopher Dodd](#) (D), and he has held a commanding lead in the race since he entered it. But the [Times](#) report has the potential to fundamentally reshape the contest in [the Nutmeg State](#).

- Ambiguity

[Times](#)  [The New York Times](#)
[The Times](#)
•
•
•

- Concepts outside of Wikipedia (NIL)
 - [Blumenthal](#) ?

- Variability

[The Nutmeg State](#)  [CT](#) [Connecticut](#)
•
•
•

- Scale
 - Millions of labels

General Challenges

- A few researchers focused on efficiency of Wikification (e.g. stacking (He et al., 2013) and distributional hierarchical clustering (Bekkerman et al., 2005; Singh et al. 2011)); most others focus on improving quality

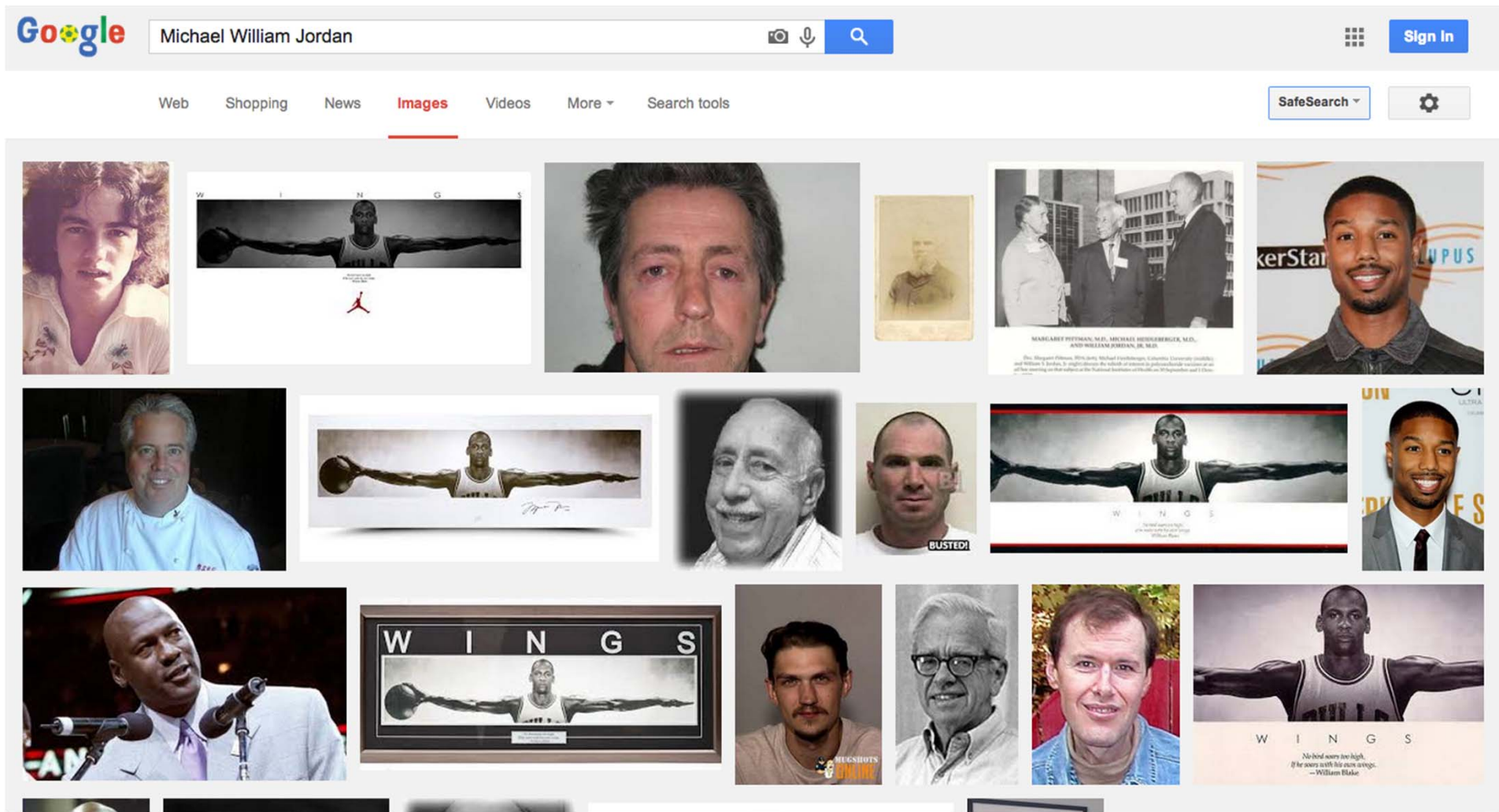
[Blumenthal](#) ([D](#)) is a candidate for the [U.S. Senate](#) seat now held by [Christopher Dodd](#) (D), and he has held a commanding lead in the race since he entered it. But the [Times](#) report has the potential to fundamentally reshape the contest in [the Nutmeg State](#).

- State-of-the-art systems (Ratinov et al. 2011) can achieve the above with local and global statistical features
 - Reaches bottleneck around 70%~ 85% F1 on non-wiki datasets
 - What is missing?

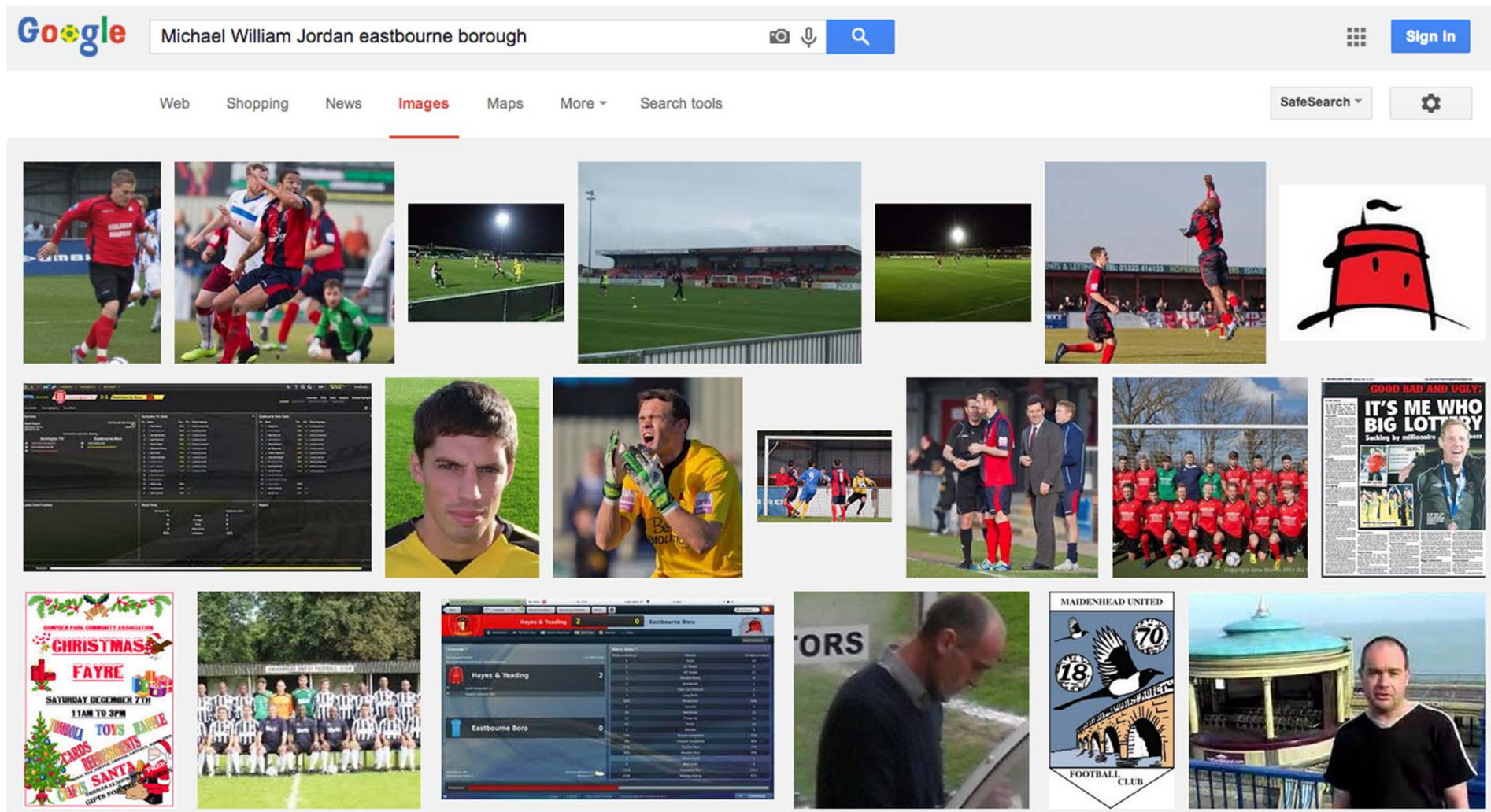
Challenges

- Dealing with Popularity Bias
- Exploiting Semantic Knowledge to Improve Wikification
 - Relational Information in the text
- Recovering from gaps in background knowledge
 - Mostly when dealing with short texts and social media
- Exploiting common sense knowledge

Popularity Bias: If you are called Michael Jordan...



A Little Better...



Deep Semantic Knowledge

Local **OWS** activists were part of this **protest**.



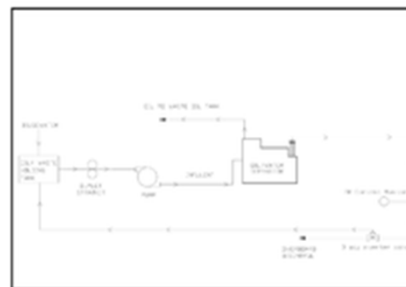
Order of World Scouts



Occupy Wall Street



Oily Water Separator



Overhead Weapon Station



Open Window School



Open Geospatial Consortium



Deep Semantic Knowledge

- An Australian jury found that an Uzbekistan **Olympic** boxing official was defamed in a book about alleged **Olympic** corruption in which he was depicted as a major international heroin dealer and racketeer.
- Rakhimov was also said to have bribed members of the **International Boxing Federation** in the vote for the Federation Presidency.



International Boxing Association
(amateur), **olympic**-style

International Boxing Association
(professional body), organization that
sanctions professional boxing

Deep Semantic Knowledge

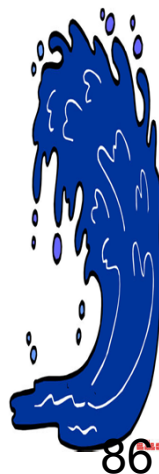
- It was a pool **report** typo. Here is exact **Rhodes** quote: "this is not gonna be a couple of weeks. It will be a period of days."
- At a **WH briefing** here in Santiago, **NSA** spox **Rhodes** came with a litany of pushback on idea **WH** didn't consult with **Congress**.
- **Rhodes** singled out a **Senate** resolution that passed on March 1st which denounced **Khaddafy's** atrocities. **WH** says **UN** rez incorporates it



Ben Rhodes
(Speech Writer)

Knowledge Gap between Source and KB

Source: breaking news/new information/rumor	KB: bio, summary, snapshot of life
According to Darwin it is the Males who do the vamping.	Charles Robert Darwin , was an English naturalist and geologist best known for his contributions to evolutionary theory .
I had no idea the victim in the Jackson cases was publicized.	In the summer of 1993, Jackson was accused of child sexual abuse by a 13-year-old boy named Jordan Chandler and his father, Dr. Evan Chandler, a dentist.
I went to youtube and checked out the Gulf oil crisis : all of the posts are one month old, or older...	On April 20, 2010, the Deepwater Horizon oil platform, located in the Mississippi Canyon about 40 miles (64 km) off the Louisiana coast, suffered a catastrophic explosion ; it sank a day-and-a-half later



Fill in the Gap with Background Knowledge

Source: breaking news/new information/rumors	KB: bio, summary, snapshot of life
Christies denial of marriage privledges to gays will alienate independents and his "I wanted to have the people vote on it" will ring hollow.	Christie has said that he favoured New Jersey's law allowing same-sex couples to form civil unions, but would veto any bill legalizing same-sex marriage in New Jersey
Translation out of hype-speak: some kook made threatening noises at Brownback and go arrested	Samuel Dale "Sam" Brownback (born September 12, 1956) is an American politician, the 46th and current Governor of Kansas.



Connect/Sort
Background Knowledge



87

Man Accused Of Making **Threatening**
Phone Call To Kansas **Gov. Sam**
Brownback May Face Felony Charge



Background Knowledge

Making **pesto**! I had to soak my nuts for 3 hours



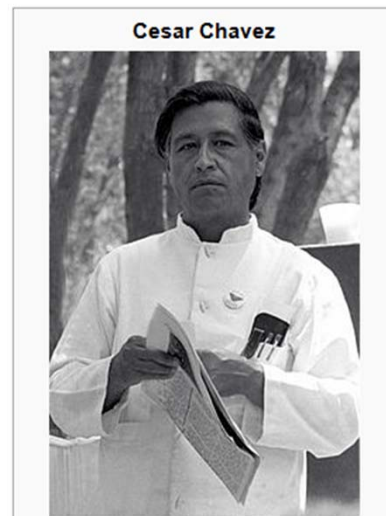
Background Knowledge

Awesome post from wolflitzerCNN: Behind the scenes on **Clinton**'s Mideast trip -
URL - #cnn



Background Knowledge

Iran and **Russia** will be the next war along with **Chavez** if we do not create a successful **democracy** in **Iraq**.



- Chavez's opposition to Zionism and close relations with **Iran**, have led to accusations of antisemitism
- Soon after this speech, in August Chávez announced that his government would nationalize Venezuela's gold industry,... to banks in Venezuela's political allies like **Russia**, China and Brazil.
- The CD and other opponents of Chávez's Bolivarian government accused it of trying to turn Venezuela from a **democracy** into a dictatorship by...

Background Knowledge

2005-06-05

Taiwan (TW)

International; weapons

Taiwan successfully fired its first cruise missile.

This will enable Taiwan to hit major military targets in southeast China.

The China Times reported that Taiwan has successfully test fired the **Hsiung Feng** its first cruise missile enabling Taiwan to hit major military targets in southeast China.

Hsiung Feng

From Wikipedia, the free encyclopedia

Hsiung Feng can refer to:

- Hsiung Feng I
- Hsiung Feng II
- Hsiung Feng IIE
- Hsiung Feng III



Hsiung Feng IIE

Background Knowledge

1995-12-18

Germany (DE)

International; weapons; war and conflict

There are huge obstacles to achieving peace and cooperation among combatants in the former **Yugoslavia**.

German Foreign Minister Klaus Kinkel said in opening remarks at the one-day meeting that there can be no peace in the former **Yugoslavia** if some parties to the conflict remain heavily armed and others try to catch up.

1918-1929: *Kingdom of Serbs, Croats and Slovenes*

1929-1941: Kingdom of Yugoslavia

1945-1946: Yugoslavia Democratic Union

1946-1963: Federal People's Republic of Yugoslavia

1963-1992: Socialist Federal Republic of Yugoslavia

1992-2003: Federal Republic of Yugoslavia

2003-2006: Serbia and Montenegro

...

Commonsense Knowledge

2008-07-26

During talks in Geneva attended by **William J. Burns** Iran refused to respond to Solana's offers.



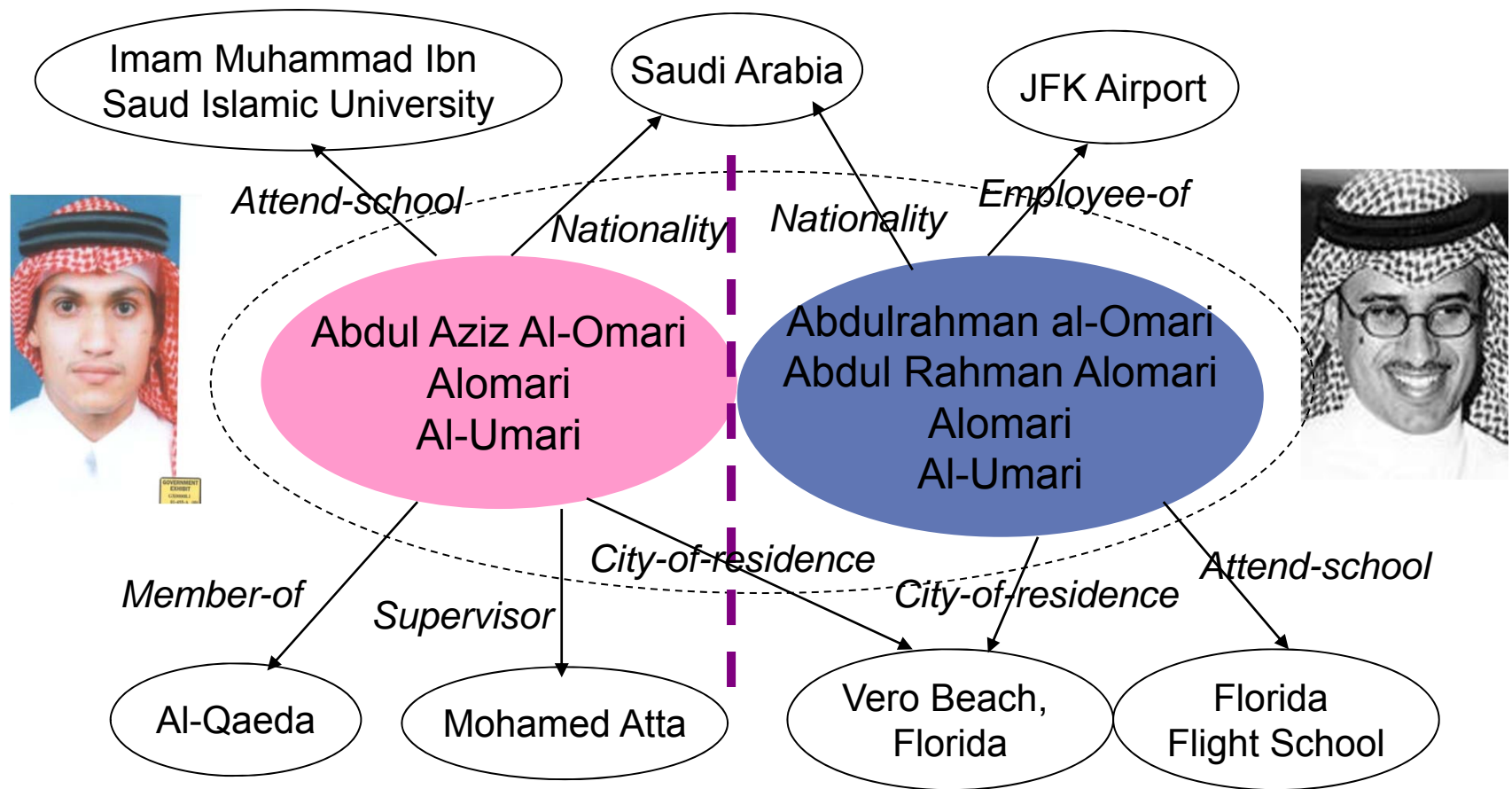
William_J._Burns (1861-1932)



William_Joseph_Burns (1956-)



Rich Context (Information Networks)



Rich Context

- “Supreme Court” (in Japan, China, U.S., Macedonia, etc.)
- “LDP (Liberty and Democracy Party)” (in Australia, Japan, etc.)
- “Newcastle University” can be located in UK or Australia
- Many person entities share the same common names such as “Albert”, “Pasha”, etc.
- “Ji county” can be located in “Shanxi” or “Tianjin”

Rich Context: Coreferential Mentions

Brazilian government and **Abbott Laboratories** agree on lower price for AIDS drug Kaletra in response to Brazilian threat to violate the patent.

According to WHO studies the price of the drug was exorbitant and the Brazilian government demanded that **Abbot** lower the price.



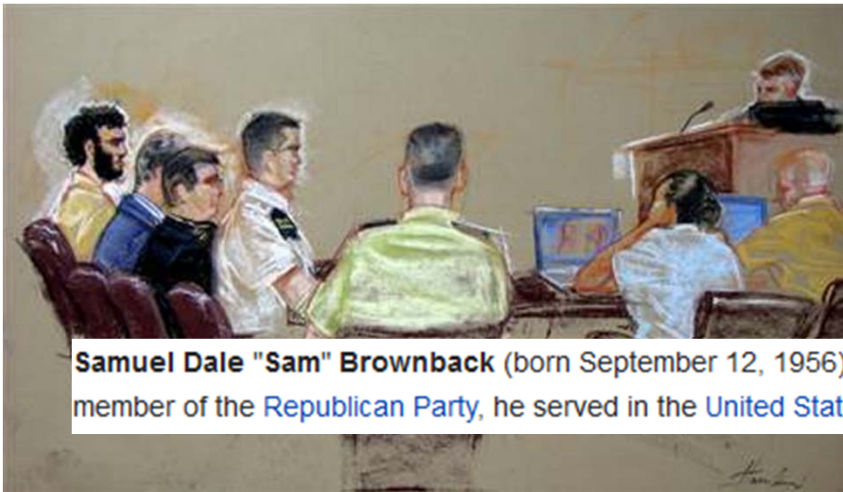
- Finding collaborators based cross-document entity clustering (Chen and Ji, 2011)

Rich Context: Related Employer

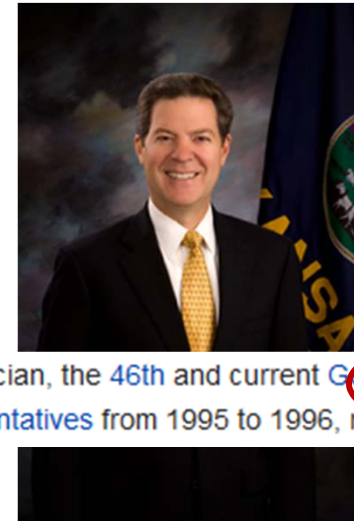
Hundreds of protesters from various groups converged on the state capitol in **Topeka, Kansas** today...

Second, I have a really hard time believing that there were any ACTUAL “explosives” since the news story they link to talks about one guy getting arrested for THREATENING Governor **Brownback**.

Peter Brownback



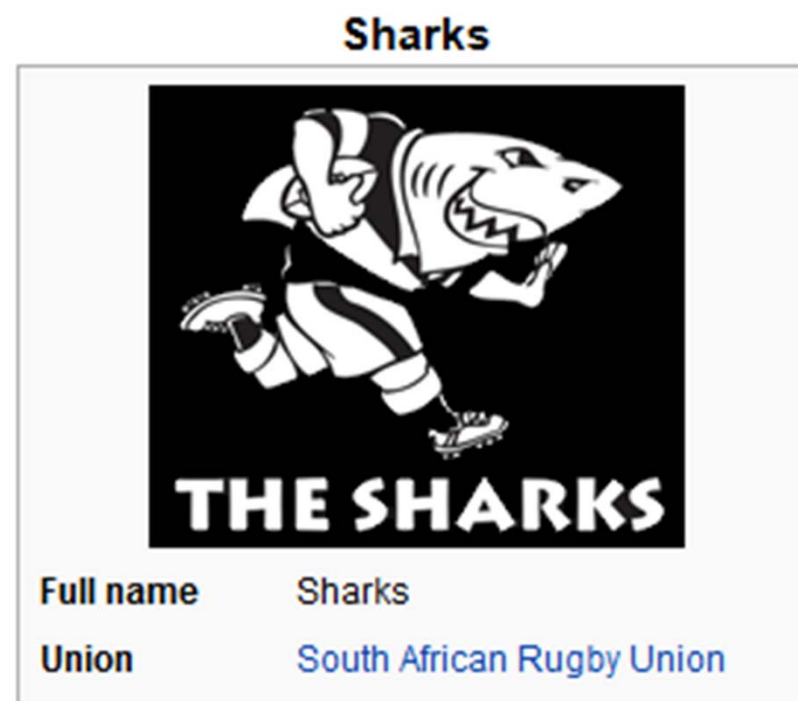
Sam Brownback



Samuel Dale "Sam" Brownback (born September 12, 1956) is an American politician, the 46th and current Governor of Kansas. A member of the Republican Party, he served in the United States House of Representatives from 1995 to 1996, representing Kansas's

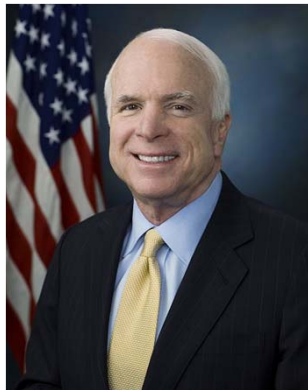
Rich Context: Related Employees

*I check the numbers, and am shocked to learn the Sharks have over 10 million in available cap room. **Antropov** would fit in great with the **Sharks**, while **McCabe** would be the big shot (you will remember last year how much they pursued **Souray**).*



Rich Context: Related Colleagues

Where would **McCain** be without **Sarah**?



Alaska Governor **Sarah Palin** was revealed as McCain's surprise choice for running mate on August 29, 2008. ^[234]

Sarah Louise Palin (^[1][/ˈpeɪlɪn/](#); née **Heath**; born February 11, 1964) is an **American** politician, commentator and author who served as the ninth **Governor of Alaska**, from 2006 to 2009. As the **Republican Party** nominee for **Vice President** in the **2008 presidential election** alongside **Arizona Senator John McCain**, she was the first **Alaskan** on the national ticket of a major party and first Republican

Rich Context: Related Colleagues

No matter what, he never should have given **Michael Jackson** that propofol. He seems to think a “proper” court would have let **Murray** go free.



The trial of Conrad Murray was the American criminal trial of **Michael Jackson's** personal physician, **Conrad Murray**.

Rich Context: Related Family Members

Mubarak, the wife of deposed Egyptian President Hosni Mubarak,

...



wife



Outline

- Motivation and Definition
- A Skeletal View of a Wikification System
 - High Level Algorithmic Approach
- Key Challenges

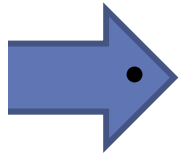


Recent Advances

- New Tasks, Trends and Applications
- What's Next?
- Resources, Shared Tasks and Demos

Recent Advances

Improving Wikification by



- Acquiring Rich Knowledge
 - Better Meaning Representation
 - Collaborative Title Collection
- Global Inference Using the Additional Knowledge
 - Joint Mention Extraction and Linking
 - Collective Inference

Semantic Relations and Event Extraction

- Co-occurrence
 - Two pilots had their wedding in **Spain** on 15th, and so they became the first homosexual couple who got married in Spanish troops. The wedding was held in **Sevilla** city hall.
 - The assistant of **Bosnia** Premier Taqik said ...two **Democratic Progressive Party** members who held important duties in the central government...
- Part-whole Relation
 - Verizon coverage in **WV** is good along the interstates and in the major cities like Charleston, Clarksburg, **Fairmont**, Morgantown, Huntington, and Parkersburg.-
 - **Manchester** (**New Hampshire**)

Semantic Relations and Event Extraction (Cont')

- Employer/Title
 - **Milton**, the senior **representative** of **Brazil** government
 - **Milton**, the **Governor** of **Pichincha Province, Ecuador**
- Affiliation
 - **Bulgarian National Medicines Agency**
- Located Relation
 - **Fine Chemical Plant** in Wuhu City
- Event
 - The leader of **Chilean** Fencing Federation **Ertl** was **elected** as the new **chairman** of this country's **Olympic Committee** tonight.

Another Challenging Example

- I am cautiously anticipating the **GOP** nominee in 2012 not to be **Mitt Romney**.
- When **Romney** was the Governor of **Massachusetts**, he helped develop health care law. I appreciate his work.
- I think **Newt** is going to be the last of the "Not **Romneys**".
- **Romney** is the great-great-grandson of a **Mormon pioneer**, from being a Mormon to having taken so many positions in the past that annoy conservatives.
- I don't think **Republican candidates** like **Romney**, **Newt**, and **Johnson** have a real chance for the election.

Candidates from Popularity Ranking

- **Mitt Romney**
- George W. Romney
- George Romney (painter)
- Marion G. Romney
- Ann Romney
- G. Scott Romney
- Lenore Romney
- George S. Romney
- Val Romney
- G. Ott Romney



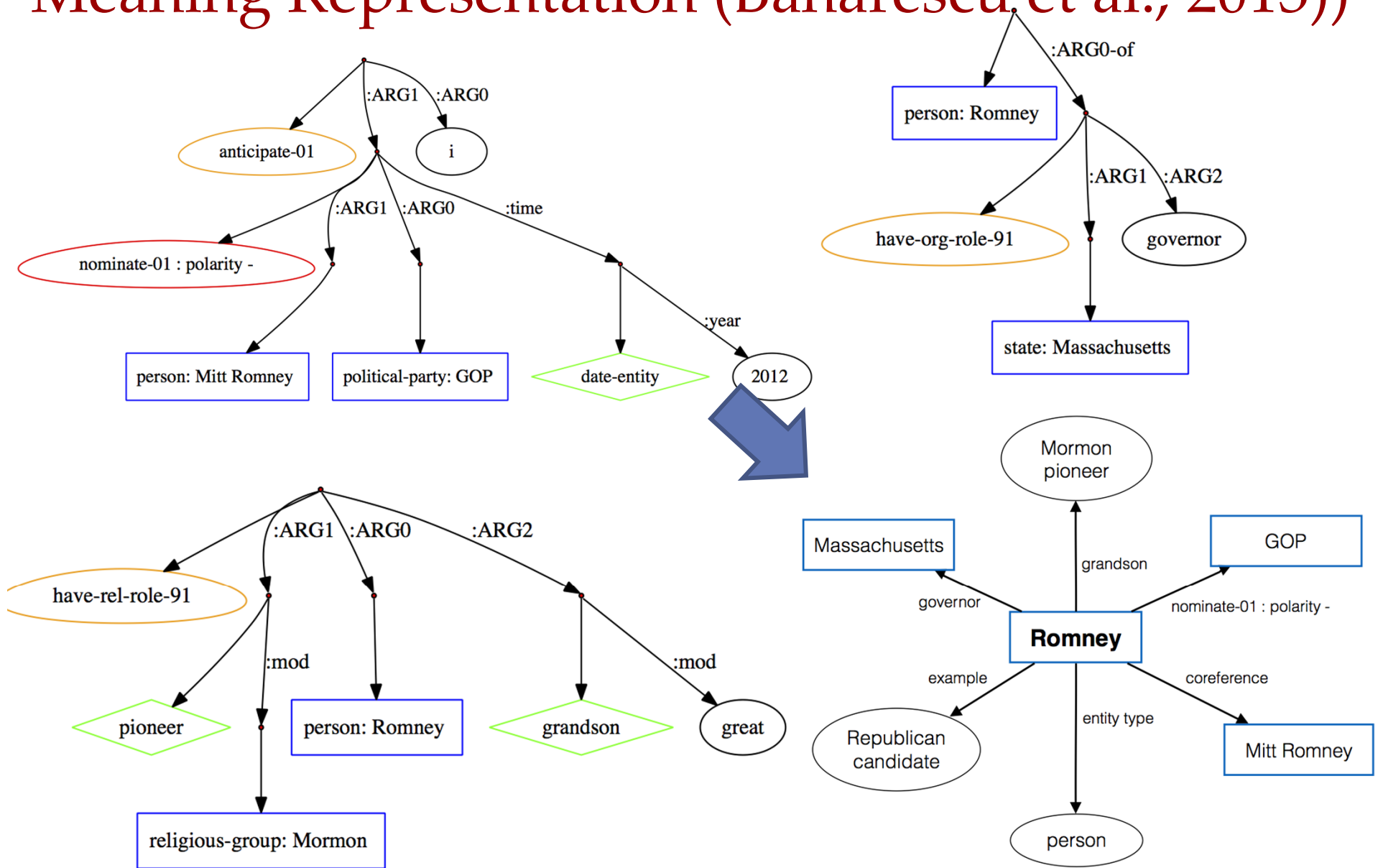
- Newt
- **Newt Gingrich**
- Newt (programming library)
- Eastern newt
- California newt
- Rough-skinned newt
- Alpine newt
- Iberian ribbed newt
- Kaiser's spotted newt
- Newt Allen



- Johnson & Johnson
- Johnson
- Lyndon B. Johnson
- Samuel Johnson
- Andrew Johnson
- B. S. Johnson
- Magic Johnson
- Robert Johnson
- **Gary Johnson**
- Randy Johnson



Better Semantic Representations (e.g., Abstract Meaning Representation (Banarescu et al., 2013))



Acquiring Rich Knowledge from KBs

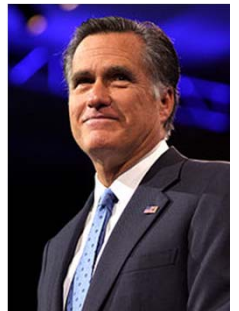
- Wikipedia (Han and Zhao, 2009)
 - Wikipedia titles and their surface forms
 - Associative relation (internal page links), hierarchical relation and equivalence relation between concepts
 - Polysemy (disambiguation page) and synonymy (redirect page) between key terms
 - Templates (Zheng et al., 2014)
- DBPedia (Zheng et al., 2014)
 - Rich relational structures and hierarchies, fine-grained types

Matching Rich Semantic Knowledge in KB

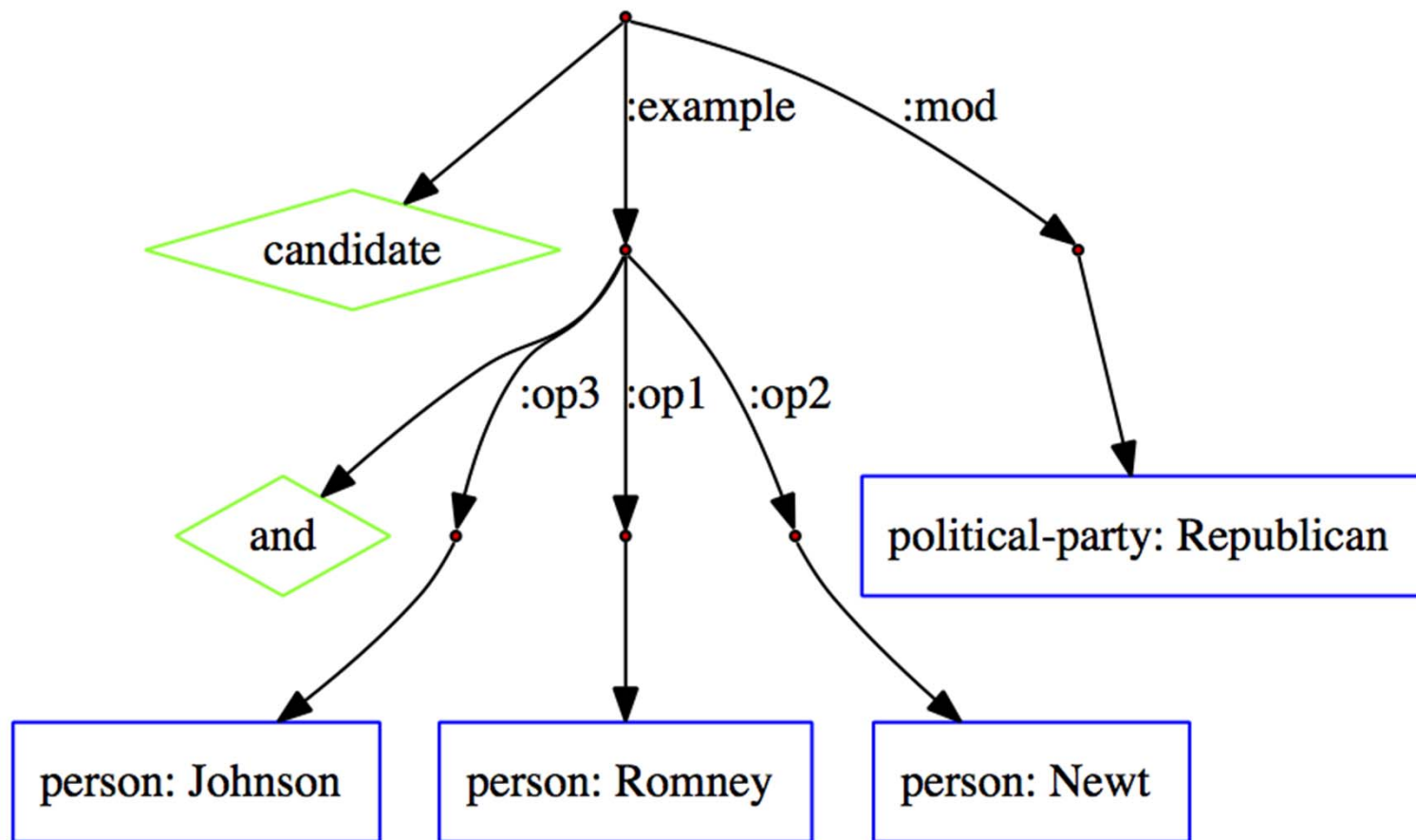
Willard Mitt Romney (born March 12, 1947) is an American businessman who was the [*Republican Party's*](#) nominee for [*President of the United States*](#) in the [*2012 election*](#). Before his presidential bid, he served as the [*70th Governor of Massachusetts*](#) from 2003 to 2007.

Religion The Church of Jesus Christ of
Latter-day Saints (Mormon)

Political party Republican

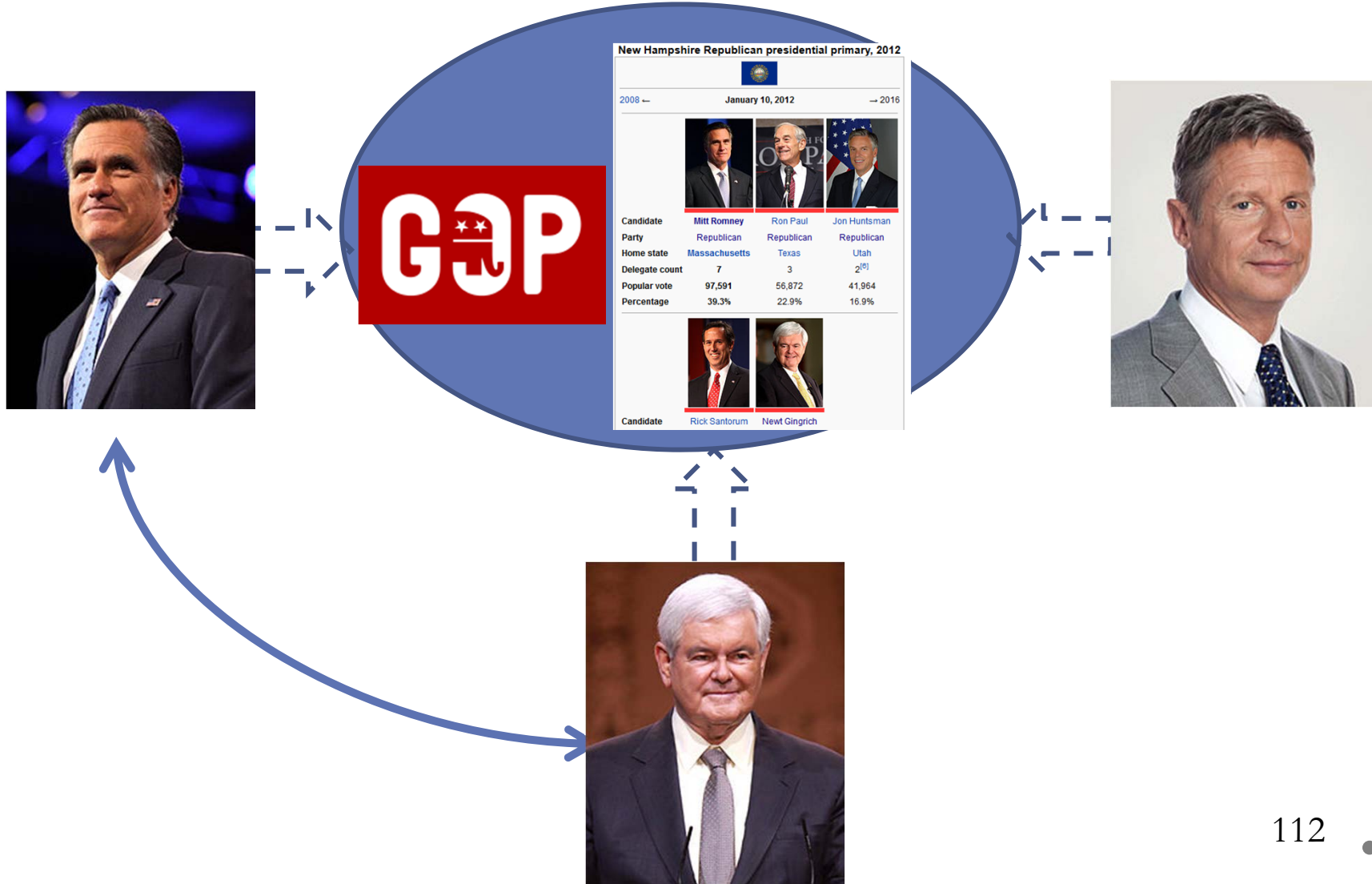


Collaborative Title Collection on Source



Collaborative Title Collection on KB

- Explicit inlinks / outlinks
- Implicit semantic relatedness: overlapped hyperlinks in Wikipedia titles, articles, infoboxes, concept categories and external links



Collaborative Title Collection on KB

- Go beyond Wikipedia: Exploit rich structures in DBPedia, Freebase, YAGO, Ontologies
- Google Knowledge base: “people also search for”



John McCain
United States Senator

John Sidney McCain III is the senior United States Senator from Arizona. He was the Republican presidential nominee in the 2008 United States election. [Wikipedia](#)

Born: August 29, 1936 (age 77), [Coco Solo](#)

Office: Senator ([AZ](#)) since 1987

Previous office: Representative ([AZ 1st District](#)) 1983–1987

Spouse: [Cindy McCain](#) (m. 1980), [Carol McCain](#) (m. 1965–1980)

Parents: [John S. McCain, Jr.](#), [Roberta McCain](#)

Children: [Meghan McCain](#), [Bridget McCain](#), [More](#)

People also search for



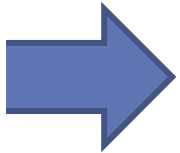
[Sarah Palin](#) [Hillary Rodham Clinton](#) [Mitt Romney](#) [Joe Biden](#) [George W. Bush](#)

[Feedback / More info](#)

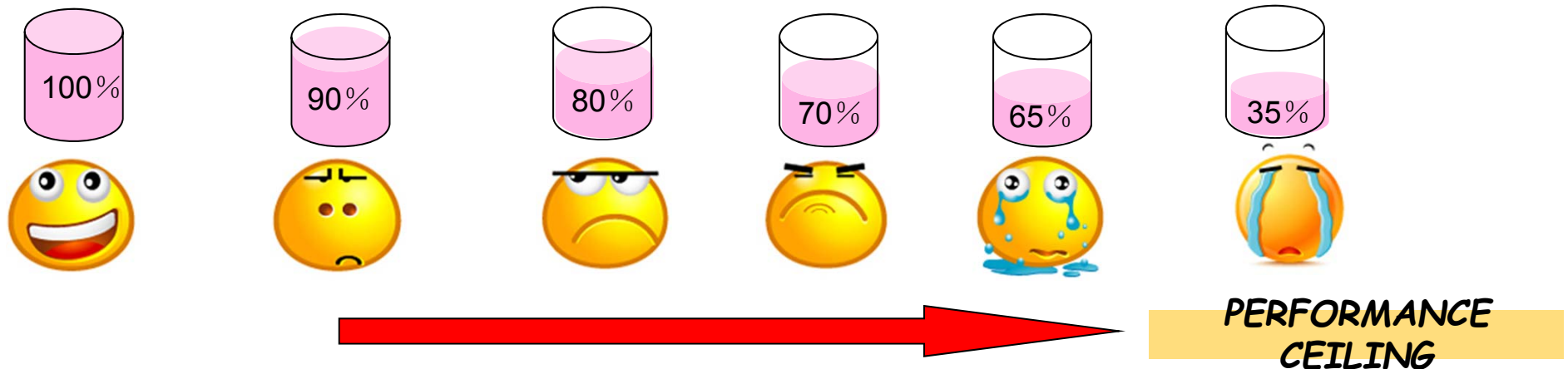
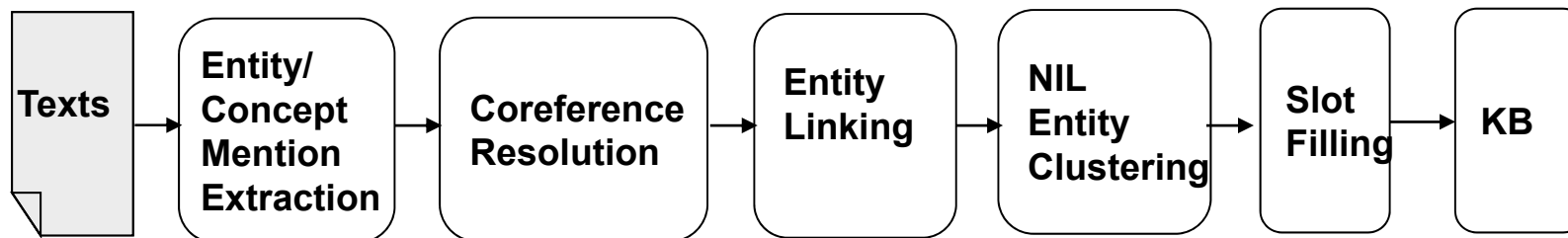
Recent Advances

Improving Wikification by

- Acquiring Rich Knowledge
 - Better Meaning Representation
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 - Joint Mention Extraction and Linking
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End-to-end Wikification: Traditional Pipeline Approach

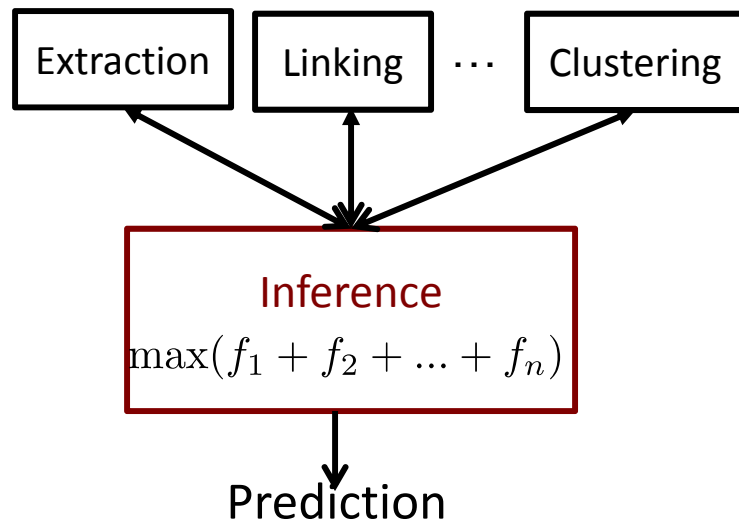


- Errors are compounded from stage to stage
- No interaction between individual predictions
- Incapable of dealing with global dependencies

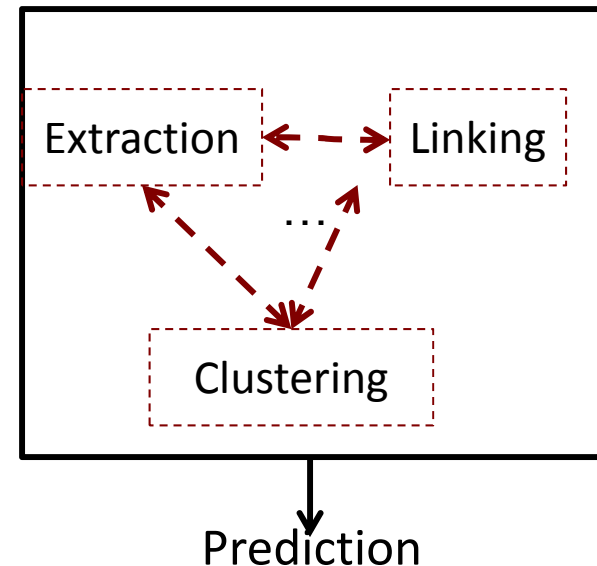
Solution: Joint Extraction and Linking

- [Blue Cross]_{ORG} and [Blue Shield of Alabama]_{ORG}
- [Blue Cross and Blue Shield of Alabama]_{ORG} → BCBS of Alabama

Joint Inference



Joint Modeling

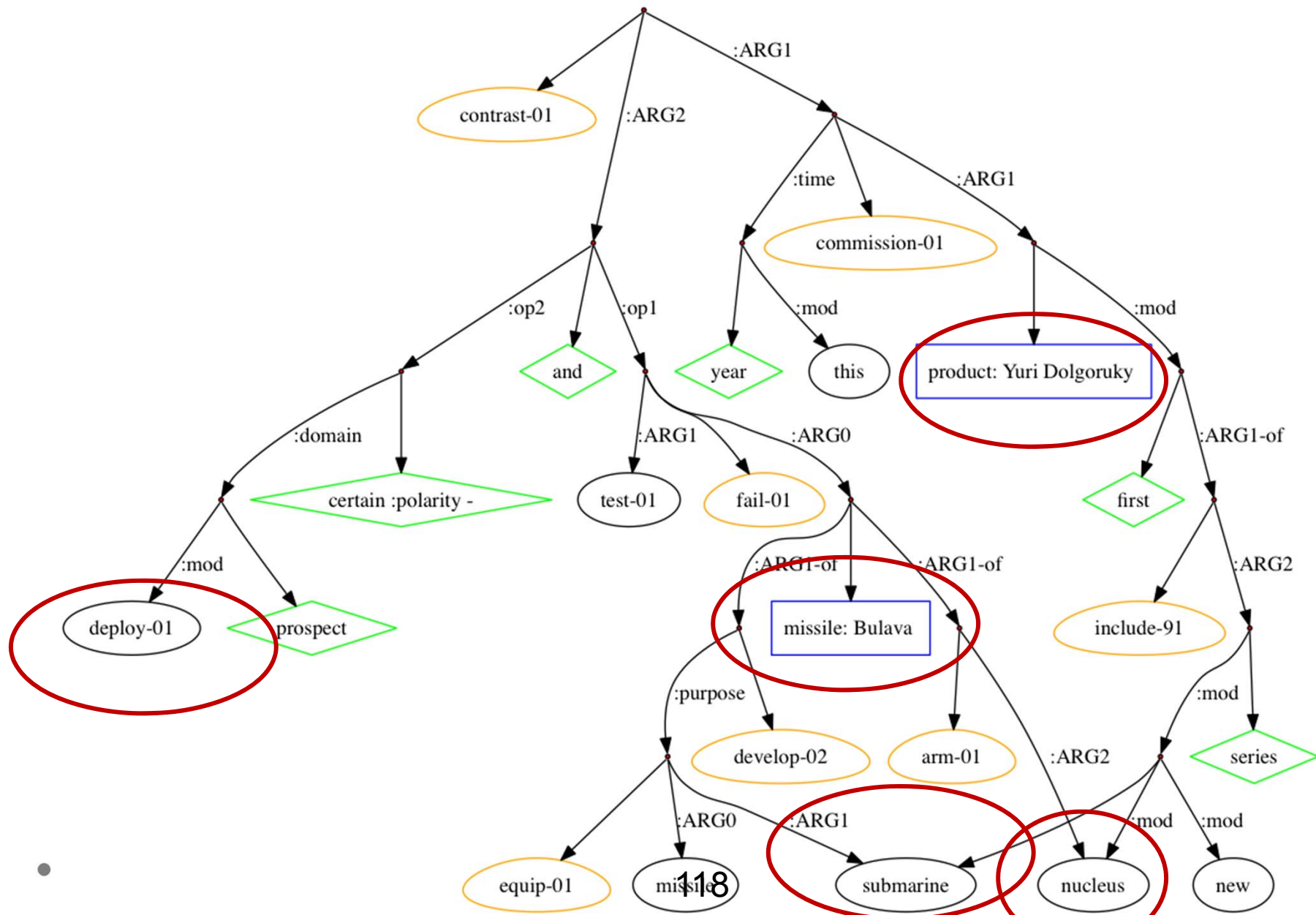


- Constrained Conditional Models, ILP [Roth2004, Punyakanok2005, Roth2007, Chang2012, Yang2013]
- Re-ranking [Sil2013, Ji2005, McClosky2011]
- Dual decomposition [Rush2010]
- Probabilistic Graphical Models [Sutton2004, Wick2012, **Wick2013**, Singh2013]
- Markov logic networks [Poon2007, Poon2010, Kiddon2012]
- Linking for extraction [**Meij2012, Guo2013, Fahrni2013, Huang2014**]

Joint Extraction and Linking

The **Yuri dolgoruky** is the first in a series of new nuclear submarines to be commissioned this year but the bulava nuclear-armed missile developed to equip the submarine has failed tests and the deployment prospects are uncertain.





Joint Extraction and Linking

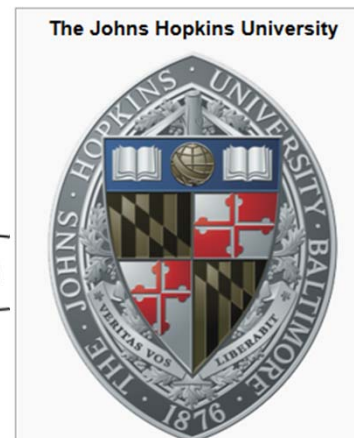
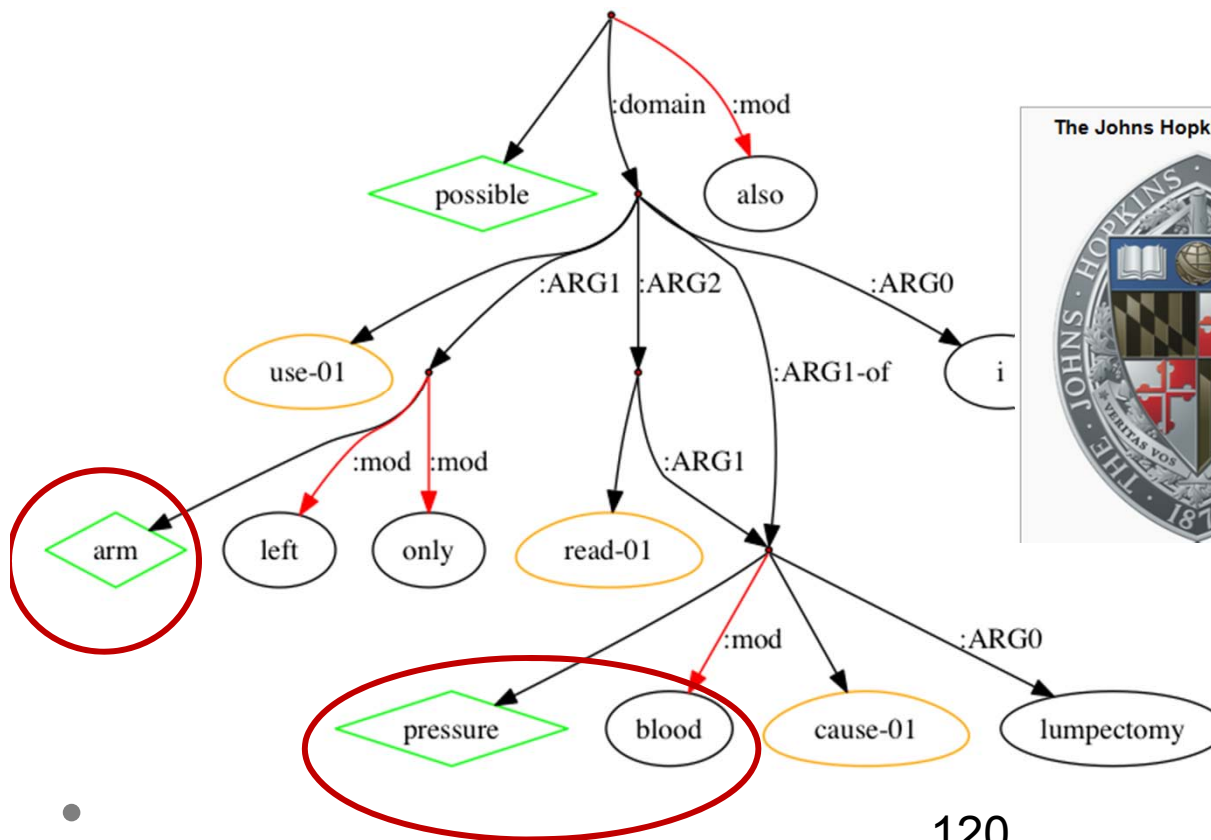
The **Yuri dolgoruky** is the first in a series of new nuclear submarines to be commissioned this year but the bulava nuclear-armed missile developed to equip the submarine has failed tests and the deployment prospects are uncertain.



Acquiring Rich Knowledge

I had it done three years ago at **Johns Hopkins**.

Also, because of a lumpectomy I can only use my left **arm** for **B. P.** readings.



Global Interaction Feature: Distinct-Links-Per-Mention (Sil and Yates, 2013)

- **Objective:** Penalize over-segmented phrases

- **Example:**


[Home] [Depot]

↓ ↓

Home_Depot Home_Depot

Indicates **over-segmentation**

#distinct Entities = 1
#mentions = 2
=> Feature Value= 0.5




[Home Depot]

↓

Home_Depot

Indicates **correct segmentation**

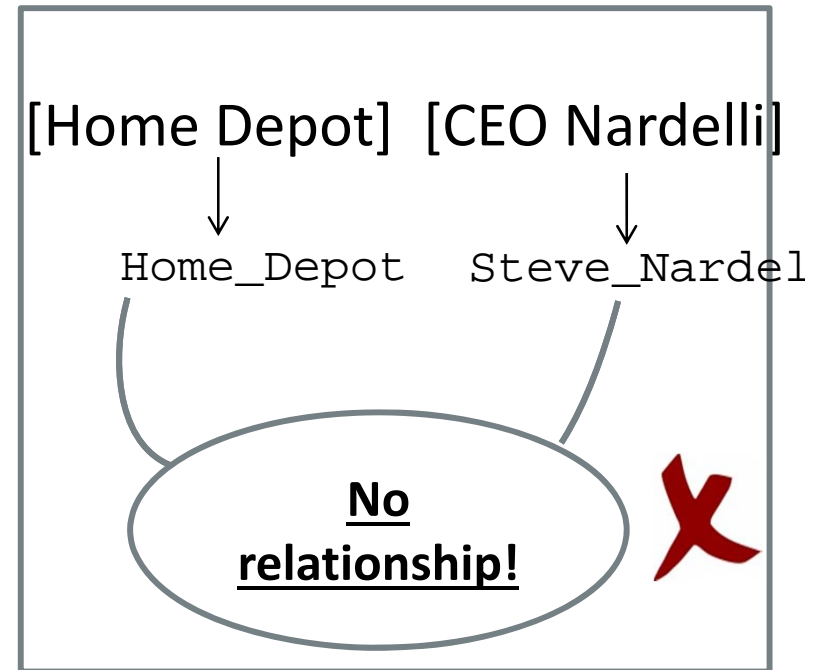
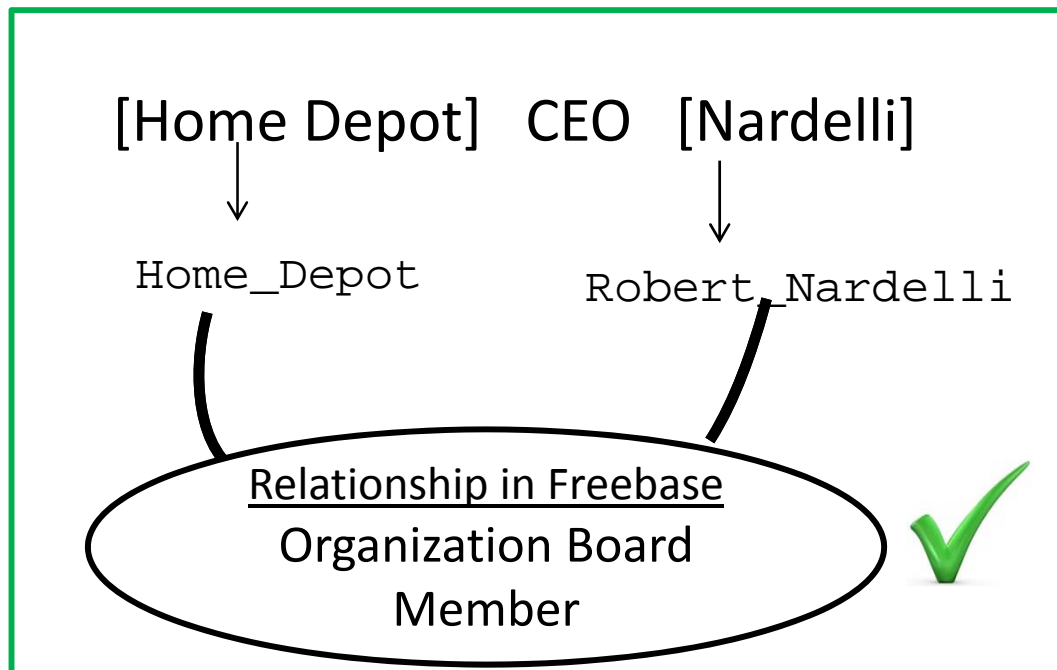
#distinct Entities = 1
#mentions = 1
=> Feature Value= 1



Global Interaction Feature: Binary Relation Count (Sil and Yates, 2013)

- Use Binary Relations between entities in Freebase

- **Example:**



Indicates: Under-segmentation

Global Interaction Feature: Entity Type PMI (Sil and Yates, 2013)

- Find patterns of entities appearing close to each other

$$PMI(T(e_1), T(e_2)) = \frac{\sum_{(e, e') \in T} 1[T(e_1) = T(e) \wedge T(e_2) = T(e')]}{\sum_{e \in T} 1[T(e_1) = T(e)] \times \sum_{e \in T} 1[T(e_2) = T(e)]}$$

- Example:**

[Home Depot] CEO [Nardelli]

↓
Home_Depot
🏠 **Type:**
Organization

↓
Robert_Nardelli
🏠 **Type:**
Org_Leader



123

[Home Depot] [CEO Nardelli]

↓
Home_Depot
🏠 **Type:**
Organization

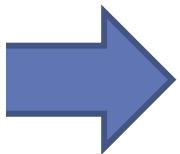
↓
Steve_Nardel
🏠 **Type:**
Music_Artist



Recent Advances

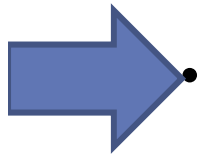
Improving Wikification by

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 - Joint Concept Extraction and Linking
 - Collective Inference



From Non-collective to Collective

- Intuition: Promote semantically coherent pairs of titles



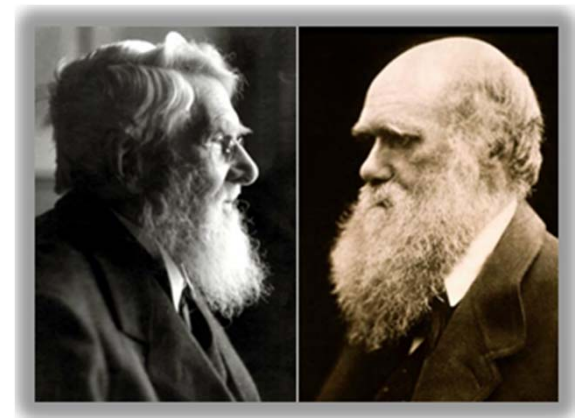
- (1) Enrich text with external KB knowledge
 - Use graph metrics (as described earlier)
- (2) Enrich text with (some) gold titles
 - Use graph propagation algorithms
- (3) Enrich Text with (local) relational information
 - Use global inference methods



Collaborative Learning



Collective Animal Behavior



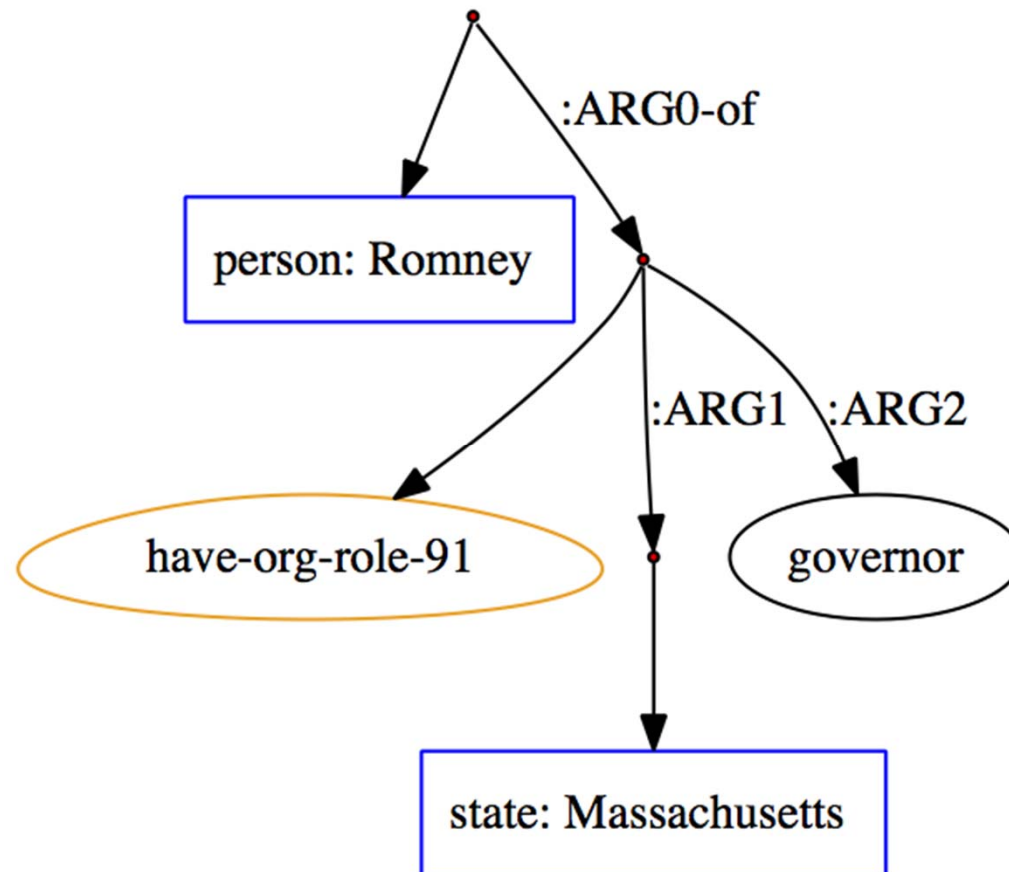
Great Minds Think Alike

(1) Collective Inference: Basic Idea

- Construct a Knowledge Graph from Source
- Construct a Knowledge Graph from KBs
- Each Knowledge Graph contains a thematically homogeneous coherent story/context
- Semantic Matches of Knowledge Graphs using Graph based Measures to Match Three Criteria:
 - Ideally we want to align two graphs directly (Yan and Han, 2002), current simplified solutions→
 - **Similarity:** The mention and the concept should have high similarity
 - **Salience:** The concept should be salient and popular in KB
 - **Coherence:** The concept and its collaborators decided by the mention's collaborators should be strongly connected in KB

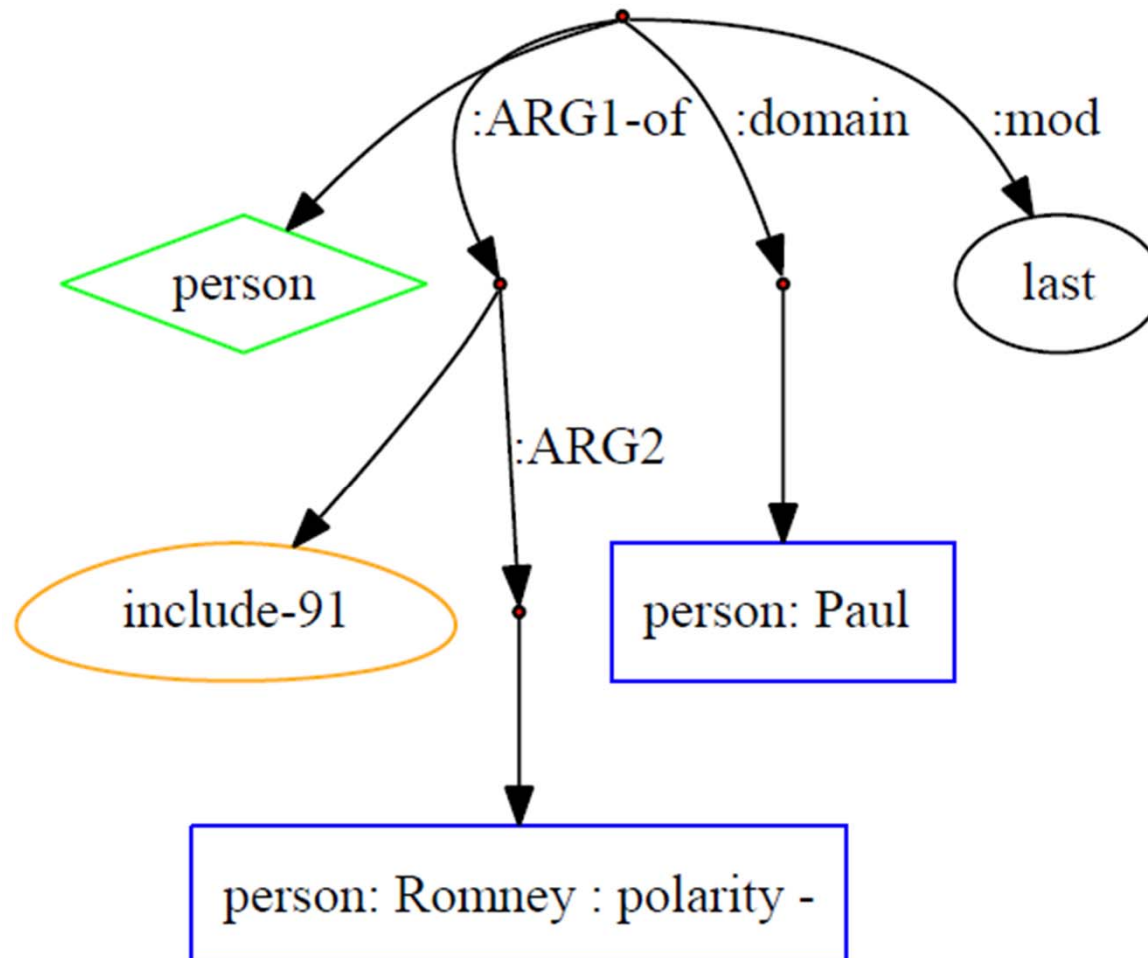
Abstract Meaning Representation

- When **Romney** was the Governor of Massachusetts ...



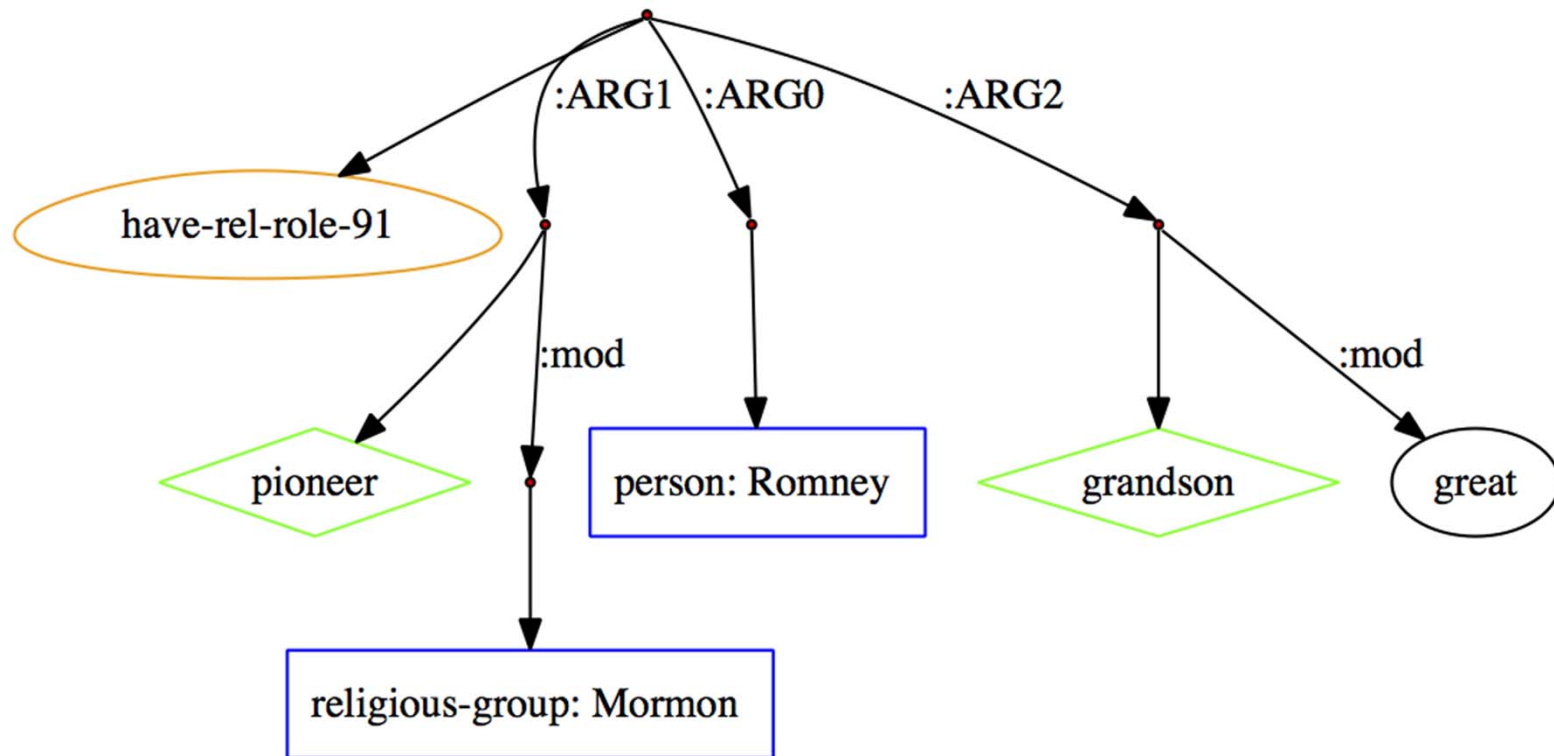
Abstract Meaning Representation

- I think **Paul** is going to be the last of the "Not **Romneys**".



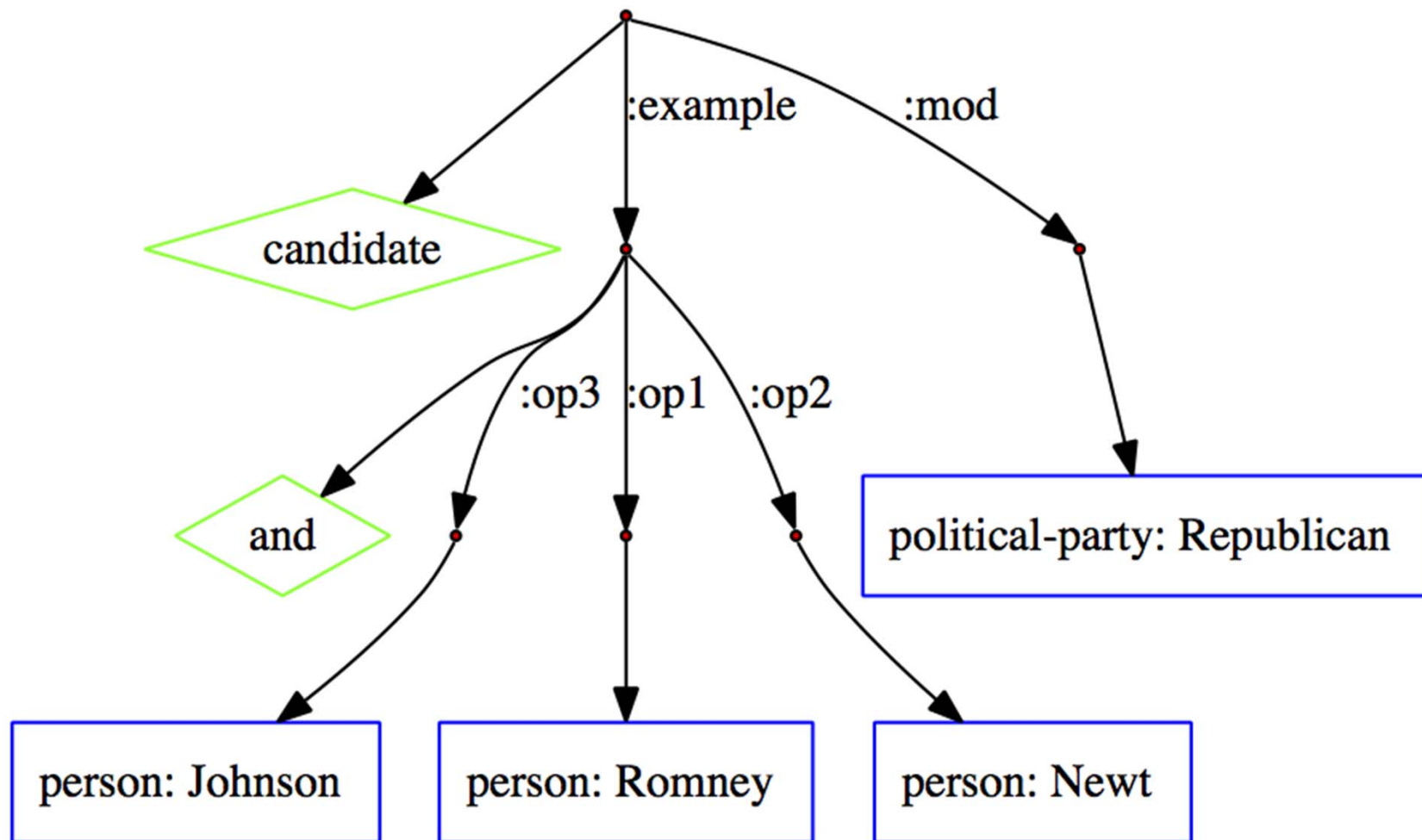
Abstract Meaning Representation

- **Romney** is the great-great-grandson of a **Mormon** pioneer.



Abstract Meaning Representation

- Republican candidates like **Romney**, **Newt**, and **Johnson** ...



Basic Idea: Collective Inference

- Construct a Knowledge Graph from Source
- Construct a Knowledge Graph from KBs
- Each Knowledge Graph contains a thematically homogeneous coherent story/context
- Semantic Matches of Knowledge Graphs using Graph based Measures to Match Three Criteria:
 - Ideally we want to align two graphs directly (Yan and Han, 2002), current simplified solutions→
 - **Similarity:** The mention and the concept should have high similarity
 - **Salience:** The concept should be salient and popular in KB
 - **Coherence:** The concept and its collaborators decided by the mention's collaborators should be strongly connected in KB

Constructing Knowledge Network from Source: Entity Nodes

- 8 main types: Person, Organization, Location, Facility, Event, Product, Publication, Natural object, Other
- Hundreds of fine-grained subtypes
 - e.g., Organization subtypes: company, government organization, military, criminal organization, political party, school, university, research institute, team and league
- Use AMR entity node annotation for Entity Linking
 - Name Expansion
 - Name Classification

Constructing Knowledge Network from Source: Roles

- Basic idea: use all other nodes which played the following roles in the same events as neighbors for the target entity mention
- Propbank/Nombank/Ontonotes Type Core Roles
 - Did Palin apologize to Giffords? He needs to conduct a beer summit between Palin and NBC.
 - Construct “Giffords” and “NBC” as neighbors for “Palin” because they are core roles involved in the “apologize” and “summit” events
- Special Roles
 - “ARG2” of “have-org-role-9” which indicates the title of the office held, such as President and Governor
 - “ARG2” and “ARG3” of “have-rel-role-91” are used to describe two entities with the same type, such as family and friendship relations
- Non-core Roles
 - domain, mod, cause, concession, condition, consist-of, extent, part, purpose, degree, manner, medium, instrument, ord, poss, quant, subevent, subset, topic

Constructing Knowledge Network from Source: Frames & Senses

Ok, my answer is no one and **Obama** wins the **GE**.
I think **Romney** wins big today and obviously stays in.
Santorum gets enough of a boost to do the **Huckabee** hangs around.
I think **Gingrich**'s sole win in **GA** is enough to hang it up and go back to making millions in the private sector.
I think **Mitt** drops out...
The only one with any reason to will be **Newt**, but I don't think that he will.

```
<inventory lemma="win-v">  
<sense group="1" n="1" name="beat, prevail or triumph" type="">  
<commentary>  
  NP WIN PP  
  NP WIN NP [competition,activity,event]  
</commentary>
```

General Electric

United States presidential election, 2012

Constructing Knowledge Network from Source: Time & Location

- AMR Event Time
 - time, year, month, day

Billy moved to the US in **1976**.



KB (Billy Thorpe): Thorpe also performed as a solo artist; he relocated to the United States from **1976** to 1996.

- AMR Event Location
 - Source, destination, path, location

I-55 will be closed in both directions between **Carondelet** and the 4500 block

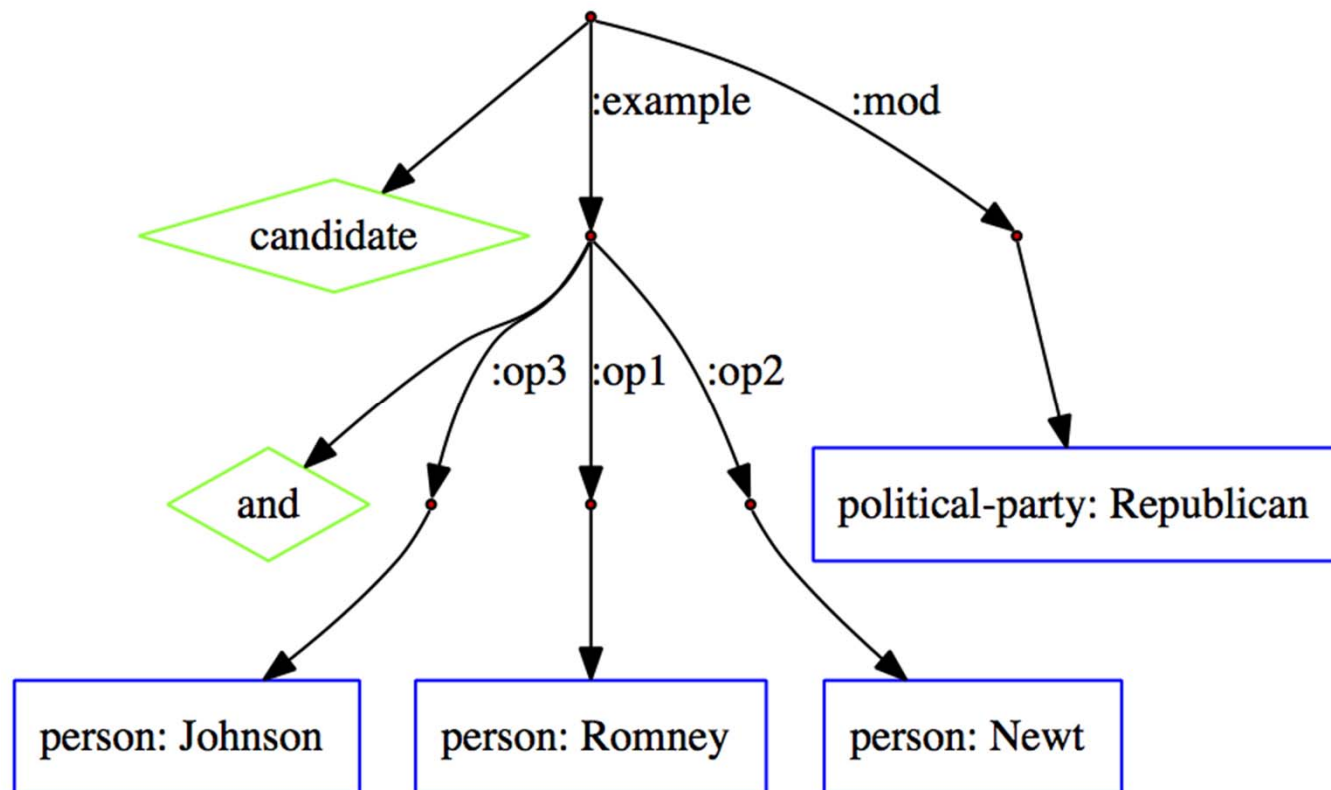
Carondelet is a neighborhood in the extreme southeastern portion of St. Louis, Missouri.

Interstate 55

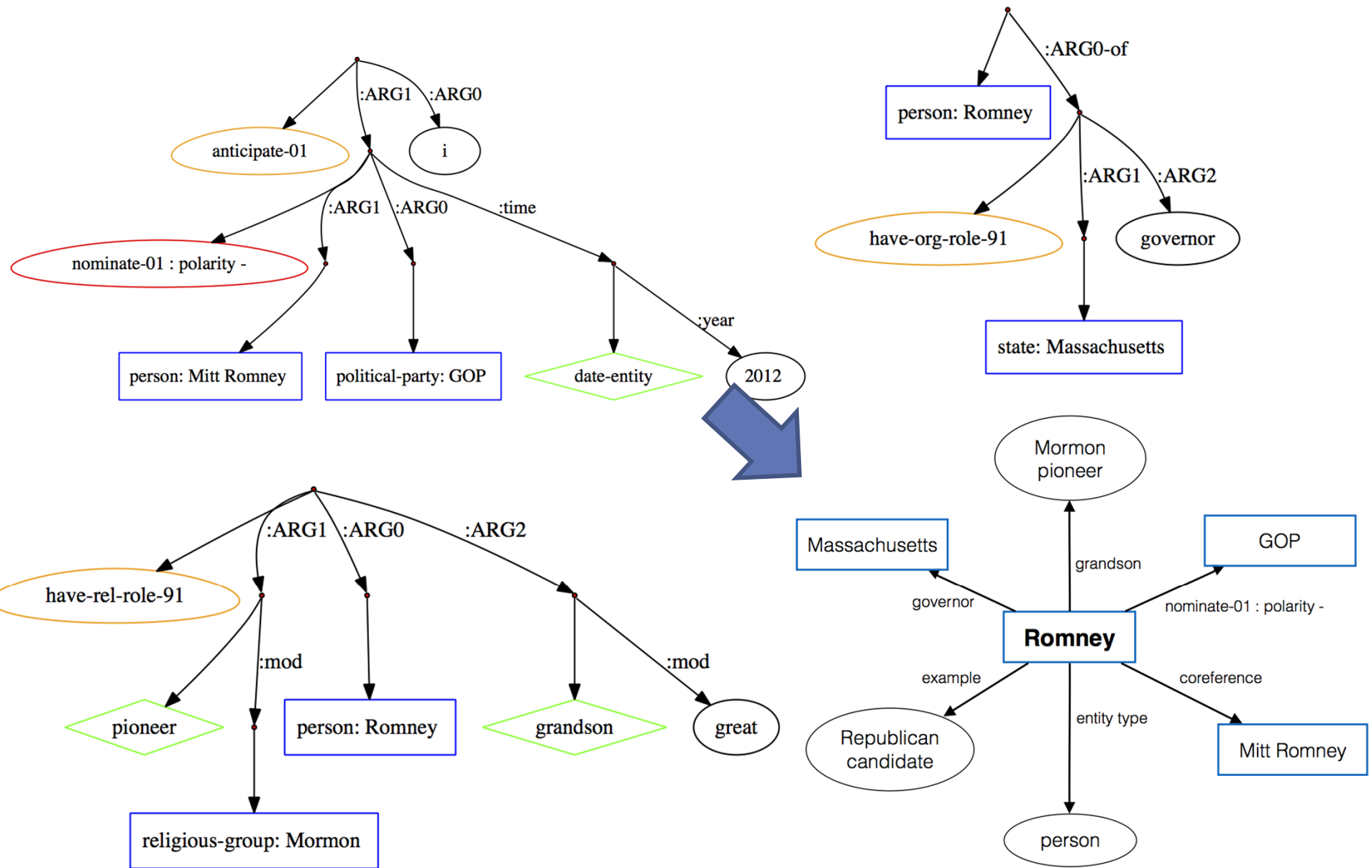
KB: Interstate 55 in Missouri

Collective Inference based on AMR

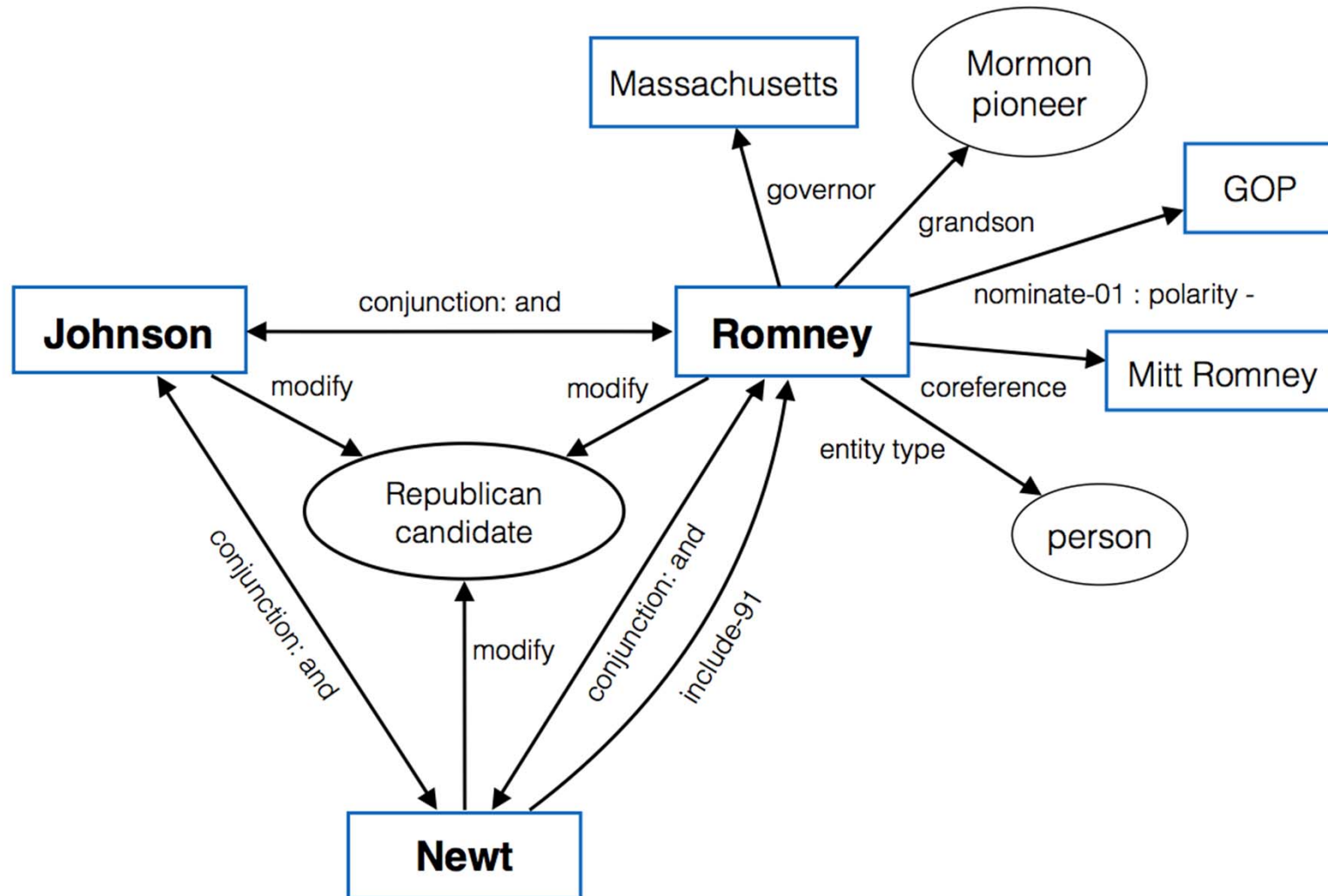
- Entity mentions involved in AMR conjunction relations should be linked jointly to KB; their candidates in KB should also be strongly connected to each other with high semantic relatedness
 - “and”, “or”, “contrast-01”, “either”, “compared to”, “prep along with”, “neither”, “slash”, “between” and “both”



Put Everything Together



Put Everything Together



Construct Knowledge Networks of Entity Candidates and their Collaborators in KB

- Wikipedia (Han and Zhao, 2009)
 - Wikipedia titles and their surface forms
 - Associative relation (internal page links), hierarchical relation and equivalence relation between concepts
 - Polysemy (disambiguation page) and synonymy (redirect page) between key terms
 - Templates (Zheng et al., 2014)
- DBPedia (Zheng et al., 2014)
 - Rich relational structures and hierarchies, fine-grained types

Willard Mitt Romney (born March 12, 1947) is an American businessman who was the [Republican Party's](#) nominee for [President of the United States](#) in the [2012 election](#). Before his presidential bid, he served as the [70th Governor of Massachusetts](#) from 2003 to 2007.

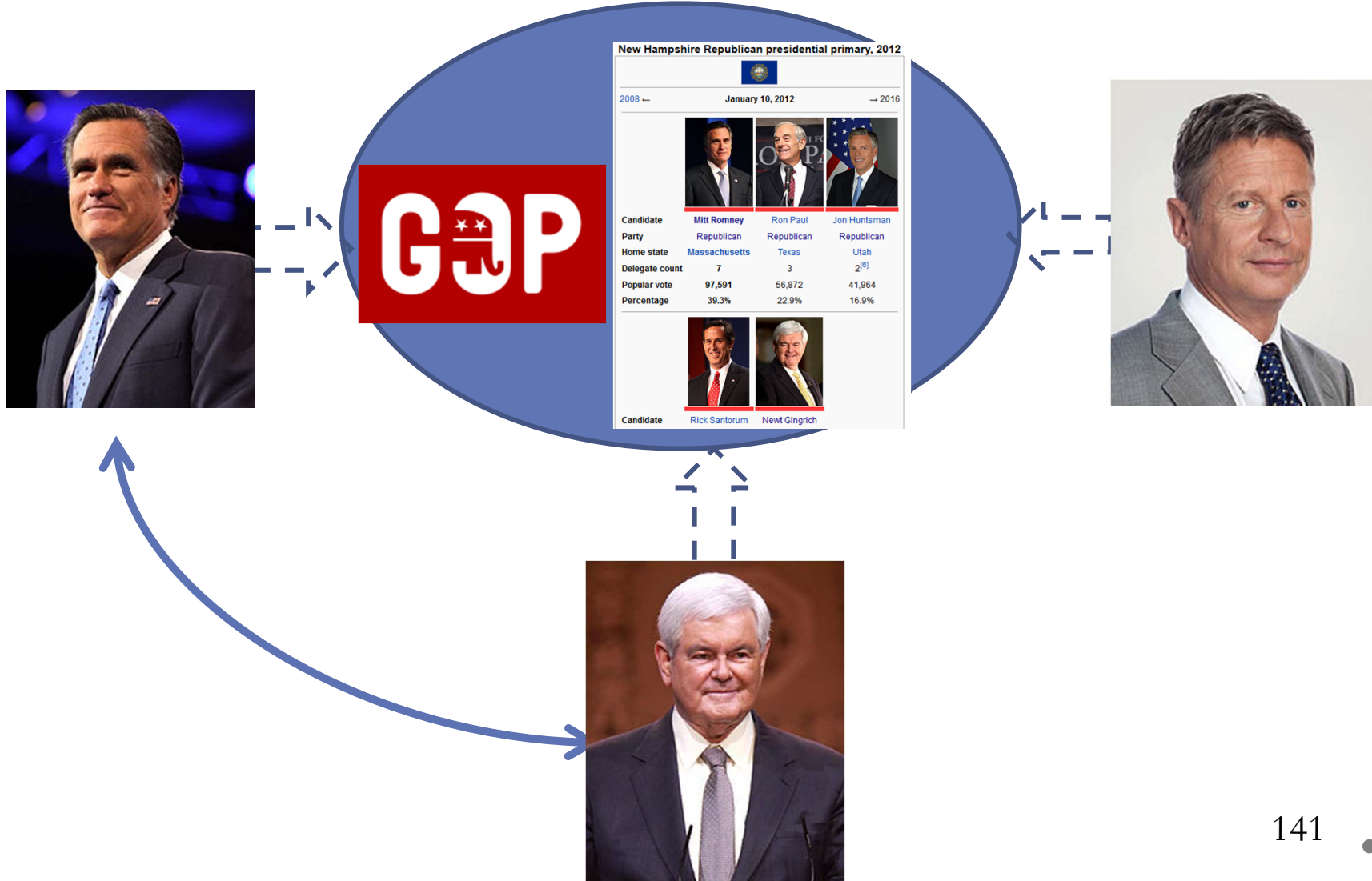
Religion [The Church of Jesus Christ of Latter-day Saints \(Mormon\)](#)

Political party

[Republican](#)

Collaborators in KB

- Explicit inlinks / outlinks
- Implicit semantic relatedness: overlapped hyperlinks in Wikipedia titles, articles, infoboxes, concept categories and external links



Collaborators in KB

- Go beyond Wikipedia: Exploit rich structures in DBPedia, Freebase, YAGO, Ontologies
- Google Knowledge base: “people also search for”



John McCain
United States Senator

John Sidney McCain III is the senior United States Senator from Arizona. He was the Republican presidential nominee in the 2008 United States election. [Wikipedia](#)

Born: August 29, 1936 (age 77), [Coco Solo](#)

Office: Senator ([AZ](#)) since 1987

Previous office: Representative ([AZ 1st District](#)) 1983–1987

Spouse: [Cindy McCain](#) (m. 1980), [Carol McCain](#) (m. 1965–1980)

Parents: [John S. McCain, Jr.](#), [Roberta McCain](#)

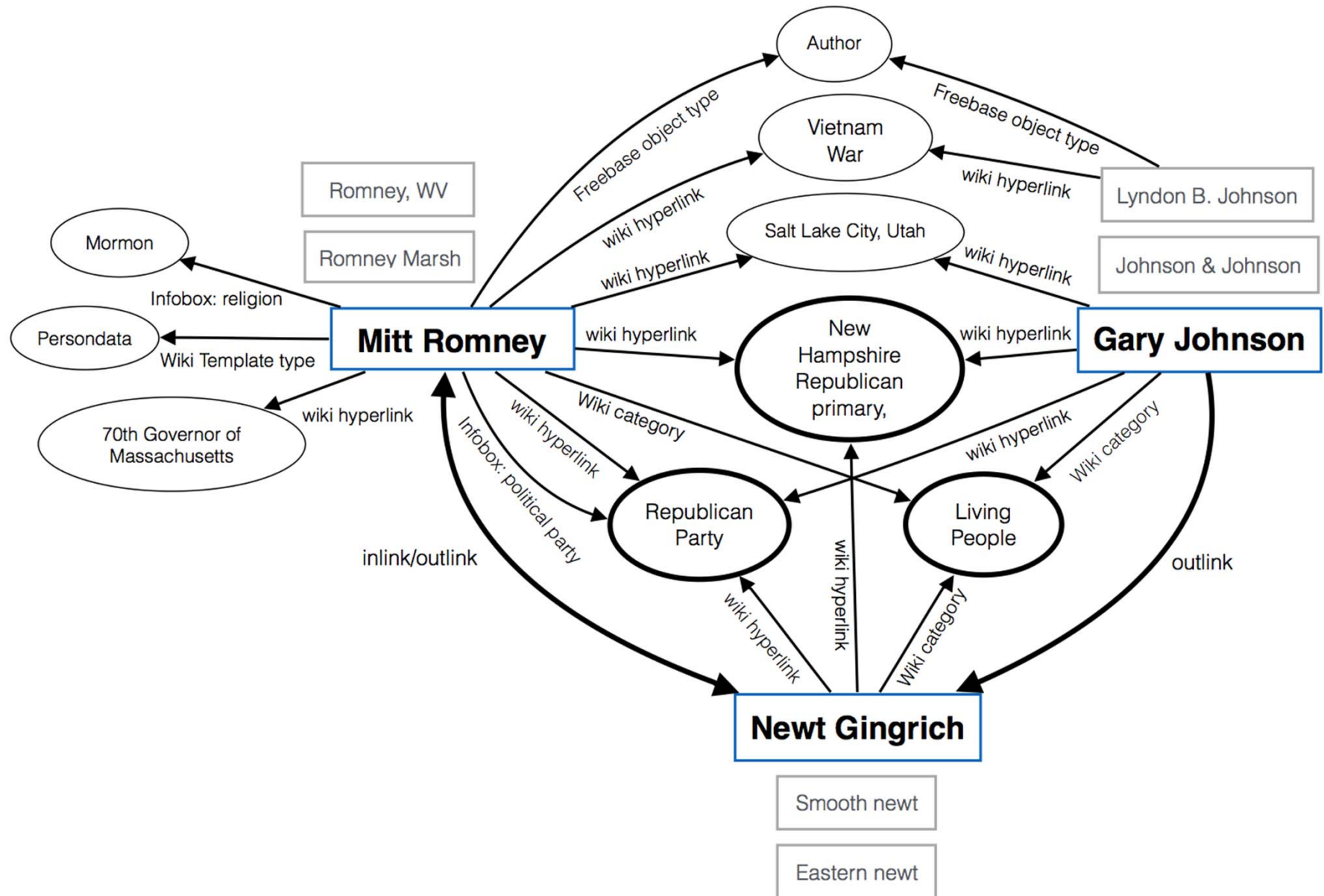
Children: [Meghan McCain](#), [Bridget McCain](#), [More](#)

People also search for

				
Sarah Palin	Hillary Rodham Clinton	Mitt Romney	Joe Biden	George W. Bush

[Feedback / More info](#)

Construct Knowledge Networks of Entity Candidates and their Collaborators in KB



Saliency

$$\text{Commonness}(m \Rightarrow t) = \frac{\text{count}(m \rightarrow t)}{\sum_{t' \in W} \text{count}(m \rightarrow t')}$$



Typography

By default, a font called **Charcoal** is used to replace the similar **Chicago** typeface. Additional system fonts are also provided including **Capitals**, **Gadget**, **Sand**, **Teal**. The operating system needs to be provided, such as the **Command key** symbol, **⌘**.

Airlines and destinations

Although the population of Iceland is only about 300,000, there are scheduled flights to and from seven locations in the United States (**Boston**, **Chicago**, **Minneapolis**, **New York**, **Orlando**, **Seattle**, and **Washington**), three in Canada (**Halifax**, **Toronto** and **Winnipeg**) and 30 cities across Europe. The largest carriers at Keflavík are Icelandair and Iceland Express.

P(Title | "Chicago")

The Greatest Show on Earth were a **British rock** band, who recorded two **albums** for **Harvest Records** in 1970.

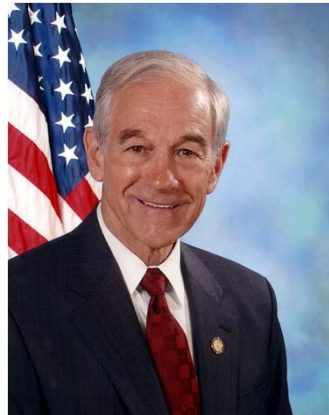
The band had been conceived by Harvest Records in an attempt to create a horn-based rock combo, such as **Blood Sweat & Tears** or **Chicago**.^[1]

Salience based Ranking

- **Mitt Romney**
- Mitt Romney Presidential campaign, 2012
- George W. Romney
- Romney, West Virginia
- New Romney
- George Romney (painter)
- HMS Romney (1708)
- Romney family
- Romney Expedition
- Old Romney



- Paul McCartney
- **Ron Paul**
- Paul the Apostle
- St Paul's Cathedral
- Paul Martin
- Paul Klee
- Paul Allen
- Chris Paul
- Pauline epistles
- Paul I of Russia



- Lyndon B. Johnson
- Andrew Johnson
- Samuel Johnson
- Magic Johnson
- Jimmie Johnson
- Boris Johnson
- Randy Johnson
- Johnson & Johnson
- **Gary Johnson**
- Robert Johnson



Similarity and Coherence

- Similarity
 - M: entity mention m's neighbors
 - C: the neighbors of candidate entity c in KB
 - Compute similarity between M and C based on Jaccard Index

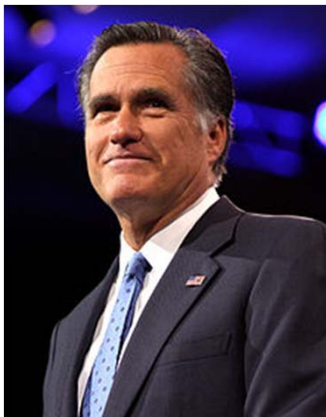
$$J(M, C) = \frac{M \cap C}{M \cup C}$$

- Coherence
 - C1: the neighbors of candidate entity c1 in KB
 - C2: the neighbors of candidate entity c2 in KB
 - Compute similarity between C1 and C2 based on Jaccard Index

Similarity based Re-Ranking

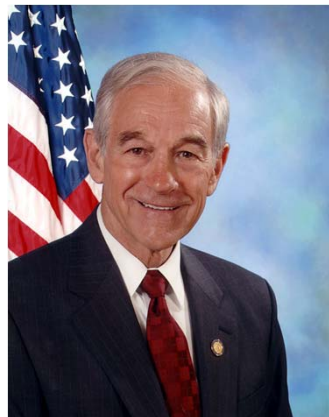
- **Mitt Romney**

- George W. Romney
- Mitt Romney Presidential campaign, 2012
- Romney family
- George Romney (painter)
- Romney, West Virginia
- HMS Romney (1762)
- New Romney
- HMS Romney (1708)
- Old Romney



- **Ron Paul**

- Paul McCartney
- Paul the Apostle
- Paul Martin
- Paul Klee
- Paul Allen
- Chris Paul
- Paul I of Russia
- Paul
- Paul of Greece



- Andrew Johnson

- **Gary Johnson**

- Samuel Johnson
- Magic Johnson
- Jimmie Johnson
- Boris Johnson
- Randy Johnson
- Robert Johnson
- Jack Johnson (boxer)



Coherence based Re-Ranking

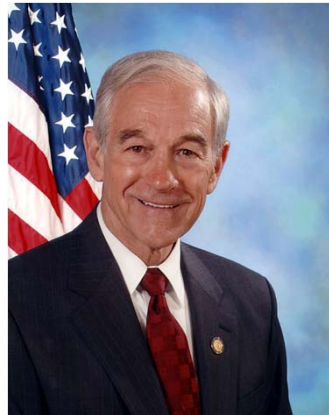
- **Mitt Romney**

- Mitt Romney Presidential campaign, 2012
- George W. Romney
- Romney, West Virginia
- New Romney
- George Romney (painter)
- HMS Romney (1708)
- Romney family
- Romney Expedition
- Old Romney



- **Ron Paul**

- Paul McCartney
- Paul Martin
- Paul Allen
- Chris Paul
- Paul of Greece
- Paul I of Russia
- Gregory S. Paul
- Paul Klee
- Paul the Apostle



- **Gary Johnson**

- Lyndon B. Johnson
- Andrew Johnson
- Boris Johnson
- Magic Johnson
- Samuel Johnson
- B. S. Johnson
- Jimmie Johnson
- Robert Johnson
- Lawrence Alexander Sidney Johnson



Linking Accuracy on AMR Corpus

(Pan et al., 2014 submission; collaboration with ISI)

- Tested on 1,613 entity mentions (394 persons, 316 organizations, 903 geo-political entities)
- Ranked top 2 in KBP2014; the top 1 system is fully supervised system trained from 20K queries, 5+ years feature engineering

Method		Acc@1
Popularity	Commonness	82.01%
	Google Search	83.7%
Supervised (trained from 20,000 entity mentions)	Ground-truth was created based on correcting output from this model	94.25%
Unsupervised	Human AMR (perfect nodes + perfect links)	93.69%
	perfect nodes + system links	91.49%
	System AMR (system nodes + system links)	88.41%
	Human Ontonotes-type Core-role Semantic Role Labeling	85.75%

From Non-collective to Collective

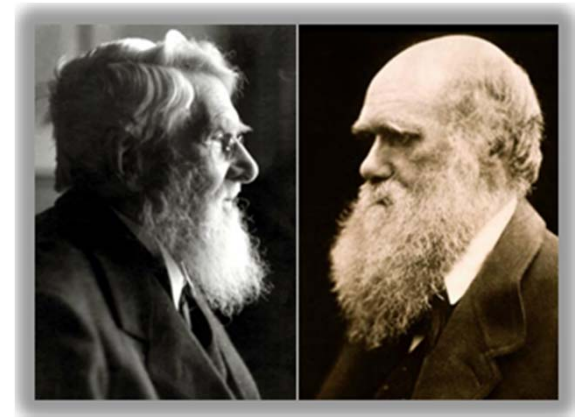
- Intuition: Promote semantically coherent pairs of titles
 - (1) Enrich text with external KB knowledge
 - Use graph metrics (as described earlier)
 - ➔ • (2) Enrich text with (some) gold titles
 - Use graph propagation algorithms
 - (3) Enrich Text with (local) relational information
 - Use global inference methods



Collaborative Learning



Collective Animal Behavior



Great Minds Think Alike

Enrichment with (some) Gold Titles:

Inference with Graph Regularization (Huang et al., 2014)

- Relational Graph Construction with semantic relations
 - Perform collective inference to identify and link a set of semantically related mentions
 - Make use of manifold (cluster) structure and need less training data
- Semi-supervised Graph Regularization
 - Loss Function: ensure the refined labels is not too far from the initial labels
 - Regularizer: smooth the refined labels over the constructed graph
 - Both closed and iterative form solutions exist

$$\mathcal{Q}(\mathcal{Y}) = \underbrace{\mu \sum_{i=l+1}^n (y_i - y_i^0)^2}_{\text{Loss Function}} + \underbrace{\frac{1}{2} \sum_{i,j} W_{ij} (y_i - y_j)^2}_{\text{Regularizer}}.$$

Collective Inference with Social Relations

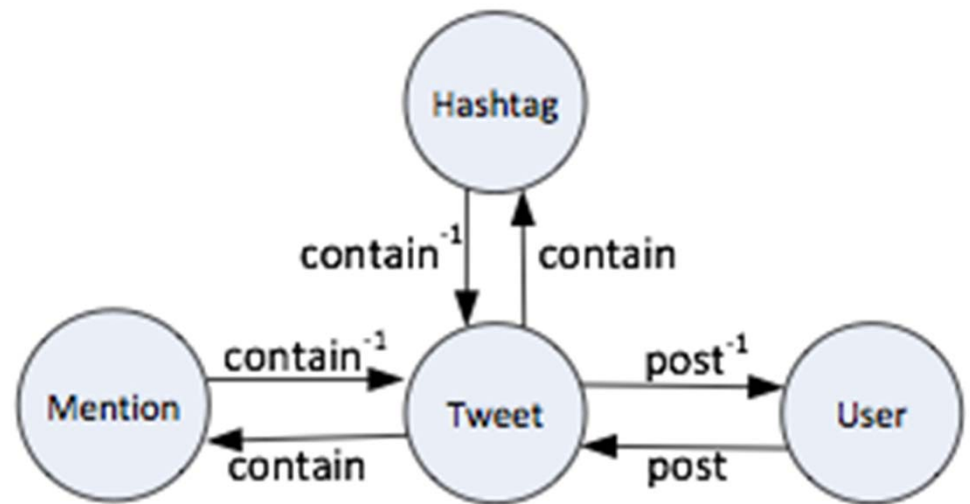


■ Stay up **Hawk Fans**.
■ We are going through a **slump**,
■ but we have to stay positive. Go **Hawks!**



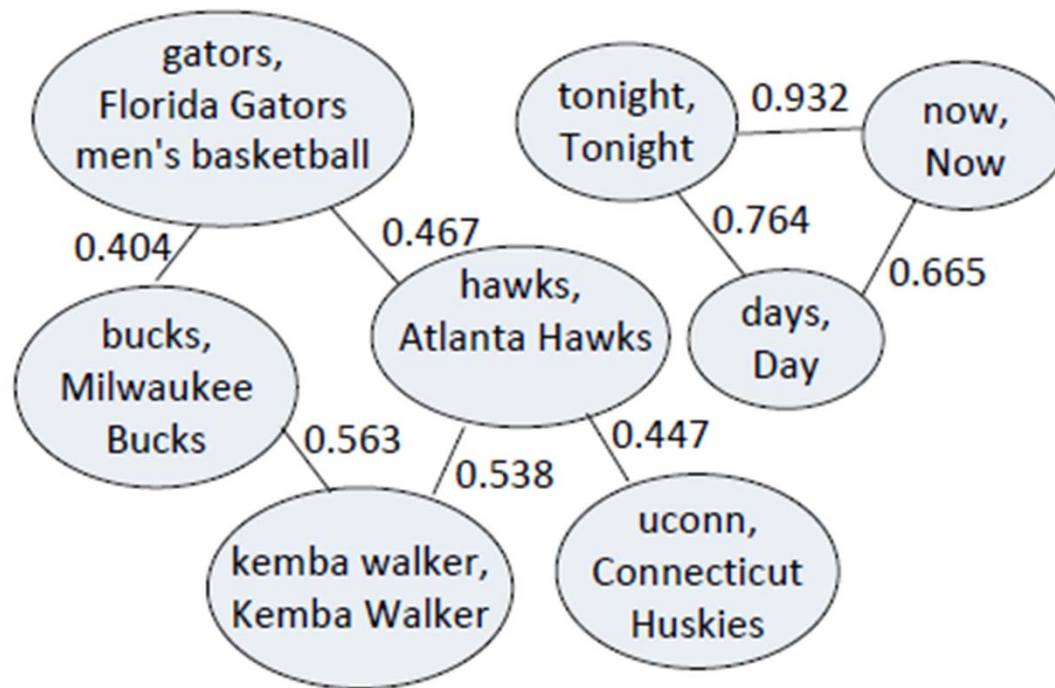
Meta Path

- A meta-path is a path defined over a network and composed of a sequence of relations between different object types (Sun et al., 2011)
- Meta paths between mentions
 - M-T-M
 - M-T-U-T-M
 - M-T-H-T-M
 - M-T-U-T-M-T-H-T-M
 - M-T-H-T-M-T-U-T-M

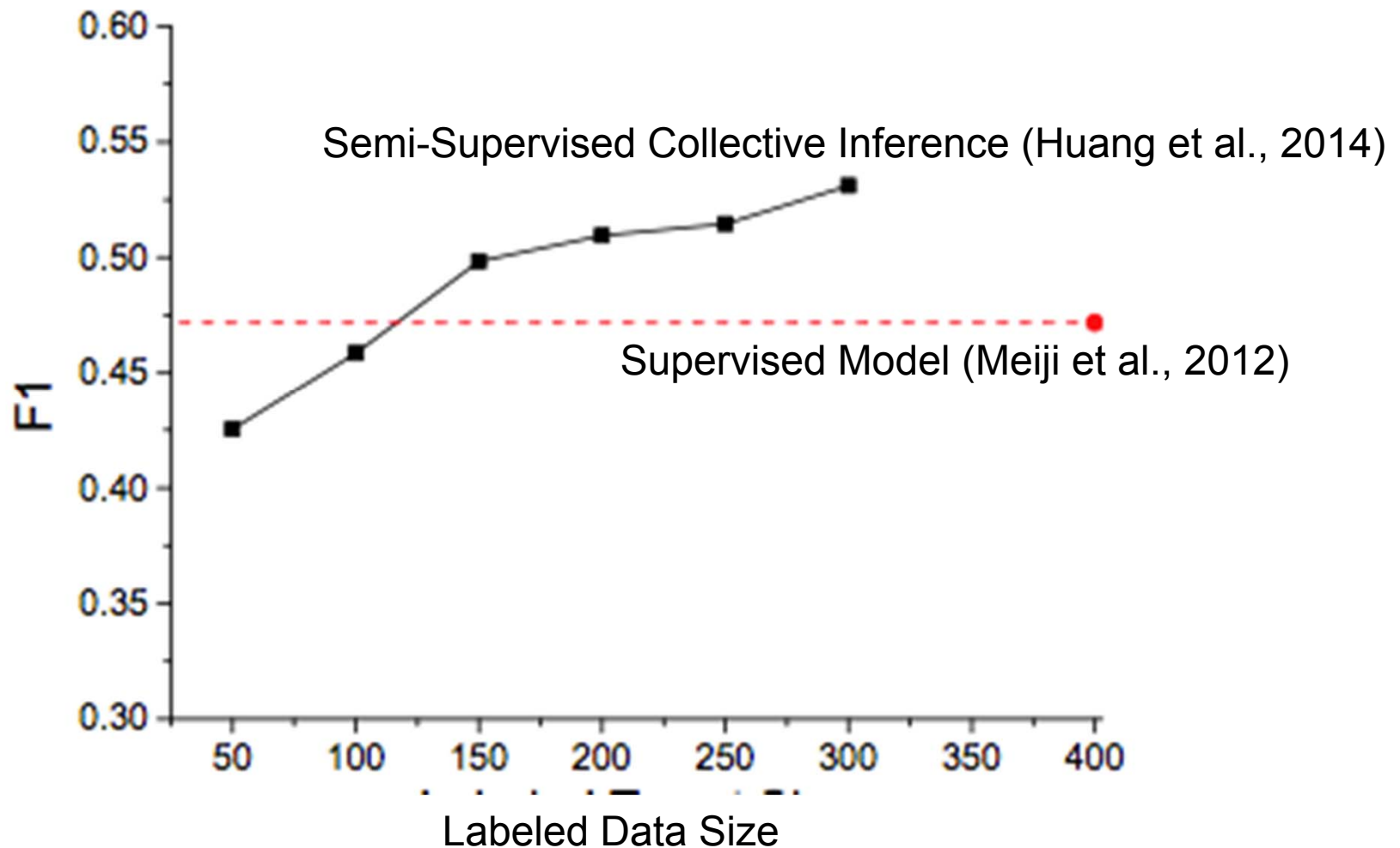


Relational Graph

- Each pair of mention m and concept c as a node
 - m is linkable, and c is the correct concept, $\langle m, c \rangle$ should be assigned label 1, otherwise 0



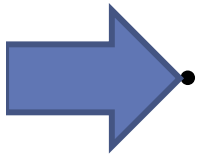
Performance Comparison



Semi-supervised collective inference with 30% labeled data achieves comparable performance with the state-of-the-art supervised model

From Non-collective to Collective

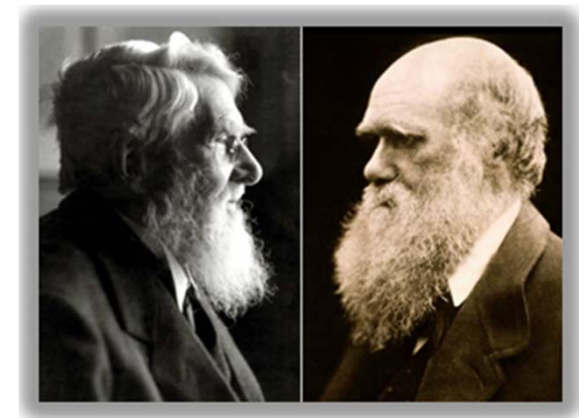
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Collaborative Learning



Collective Animal Behavior



Great Minds Think Alike

General Challenges

- A few researchers focused on efficiency of Wikification (e.g. stacking (He et al., 2013) and distributional hierarchical clustering (Bekkerman et al., 2005; Singh et al. 2011)); most others focus on improving quality

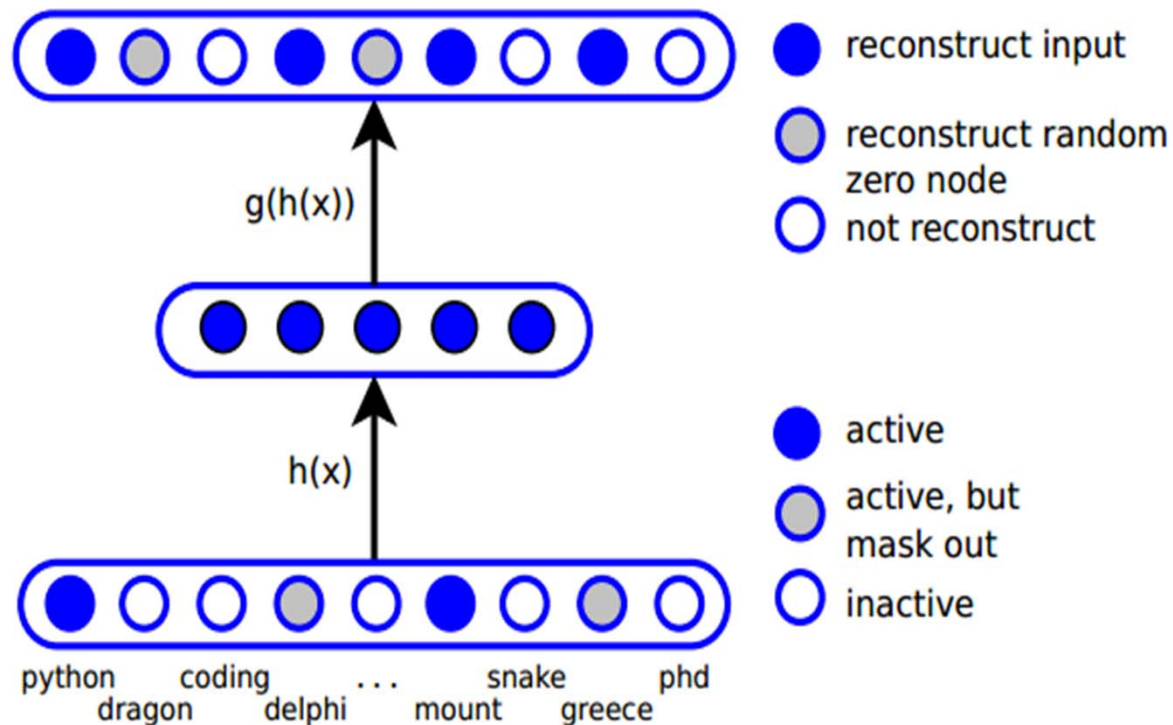
[Blumenthal](#) ([D](#)) is a candidate for the [U.S. Senate](#) seat now held by [Christopher Dodd](#) (D), and he has held a commanding lead in the race since he entered it. But the [Times](#) report has the potential to fundamentally reshape the contest in [the Nutmeg State](#).

- State-of-the-art systems (Ratinov et al. 2011) can achieve the above with local and global statistical features
 - Reaches bottleneck around 70%~ 85% F1 on non-wiki datasets
 - **What is missing?**

Modeling Local Mention-Entity Similarity

(He et al., 2013)

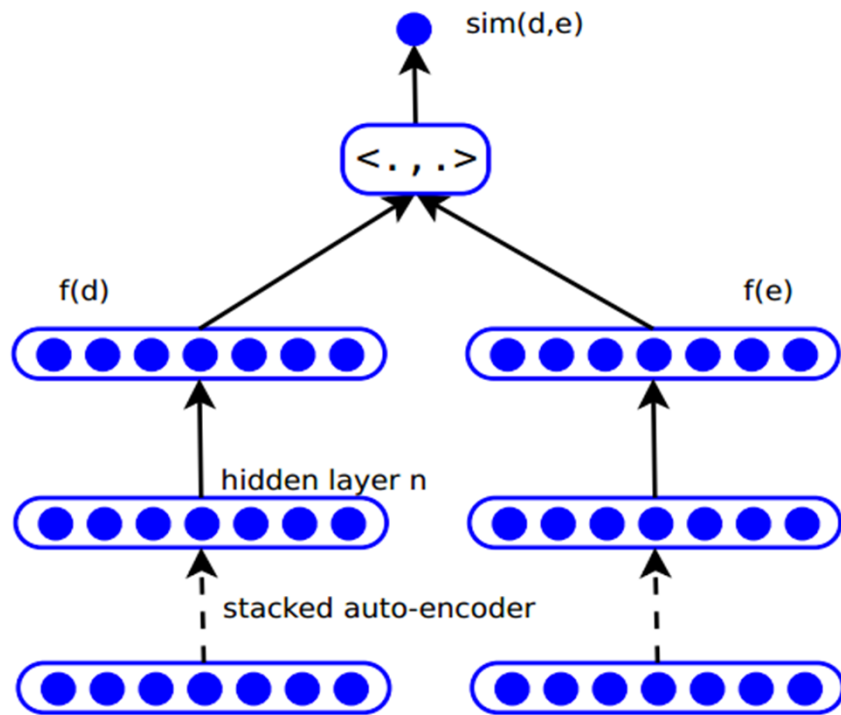
- Unsupervised pre-training with Stacked auto-encoder



Modeling Local Mention-Entity Similarity

(He et al., 2013) (con't)

- Supervised fine-tuning with deep neural networks (DNN)
 - Optimize an objective function with respect to the similarity of a mention and an entity



Methods	micro P@1	macro P@1
TAC 2010 eval		
Lcc (2010) (top1, noweb)	79.22	-
Siel 2010 (top2, noweb)	71.57	-
our best	80.97	-
AIDA dataset (collective approaches)		
AIDA (2011)	82.29	82.02
Shirakawa et al. (2011)	81.40	83.57
Kulkarni et al. (2009)	72.87	76.74
wordsim (cosine)	48.38	37.30
Han (2011) + wordsim	78.97	75.77
our best (non-collective)	84.82	83.37
Han (2011) + our best	85.62	83.95

Modeling Topical Coherence with DNN and KGs (Huang & Heck, MSR-TR-2014-108, 2014)

- State-of-the-art Approaches
Relatedness

- (Milne and Witten, 2008):
method

$$SR(c_i, c_j) = 1 - \frac{\log \max(|C|, |C_i|, |C_j|)}{\log(|C|)}$$

- C : the set of entities in W
- C_i : the set of incoming links to c_i

- Supervised Method (Ceccarelli et al., 2013)

- Formulate as a learning-to-rank problem
- Explore a set of link-based features


Limitation I: Fail to capture deep semantics of entities (e.g., $SR(\text{NBA}, \text{Chicago Bull}) = 0.59 < SR(\text{NBA}, \text{Chicago}) = 0.83$)

Limitation II: Ignore the knowledge from the rich Knowledge Graphs

Limitation III: what if we don't have anchor links?

Semantic Knowledge Graphs


Topic

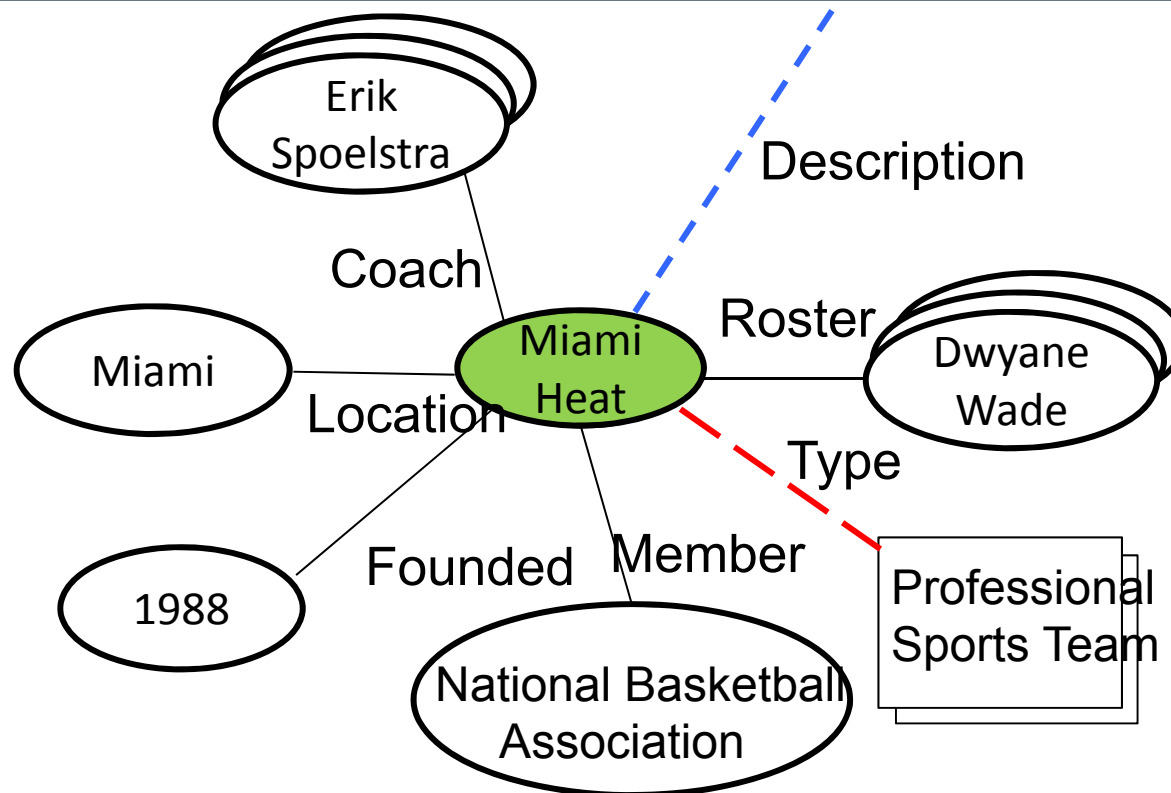


Miami Heat^{en}

mid: /m/0jm2v notable type: /sports/professional_sports_team notable for: /sports/professional_sports_team on the web: [wikipedia.org](https://en.wikipedia.org/wiki/Miami_Heat)

The Miami Heat are a professional basketball team based in Miami, Florida, United States. The team is a member of the Southeast Division in the Eastern Conference of the National Basketball Association. They play their home games at the American Airlines Arena in Downtown Miami. The team owner is Micky Arison, who also owns cruise-ship giant Carnival Corporation. The team president and de facto general manager is Pat Riley, and the head coach is Erik Spoelstra. The mascot of the team is Burnie, an anthropomorphic fireball. Formed in 1988 as one of the NBA's four expansion franchises, the Heat have won three league championships, five conference titles and 11 division titles. From February 3 to March 27, 2013, the Heat won 27 games in a row, the second-longest streak in NBA history. In 2013,

 Created by metaweb on 10/22/2006



A Deep Semantic Relatedness Model

Semantic relatedness
(cosine similarity)

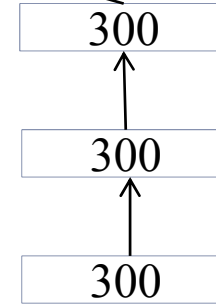
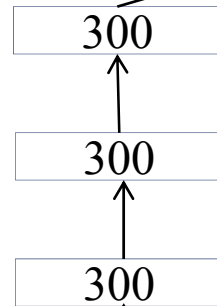
Semantic Layer y

Multi-layer non-linear projections

Word Hashing Layer

Feature Vector x

$$SR(e_i, e_j)$$



105k (50k + 50k + 3.2k + 1.6k)

105k (50k + 50k + 3.2k + 1.6k)

1m
 D_i

4m
 E_i

3.2k
 R_i

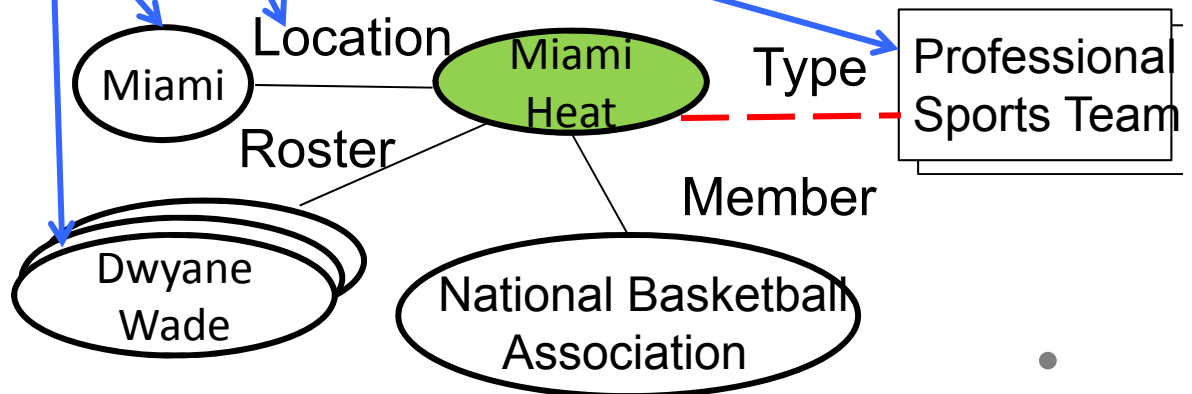
1.6k
 ET_i

1m
 D_j

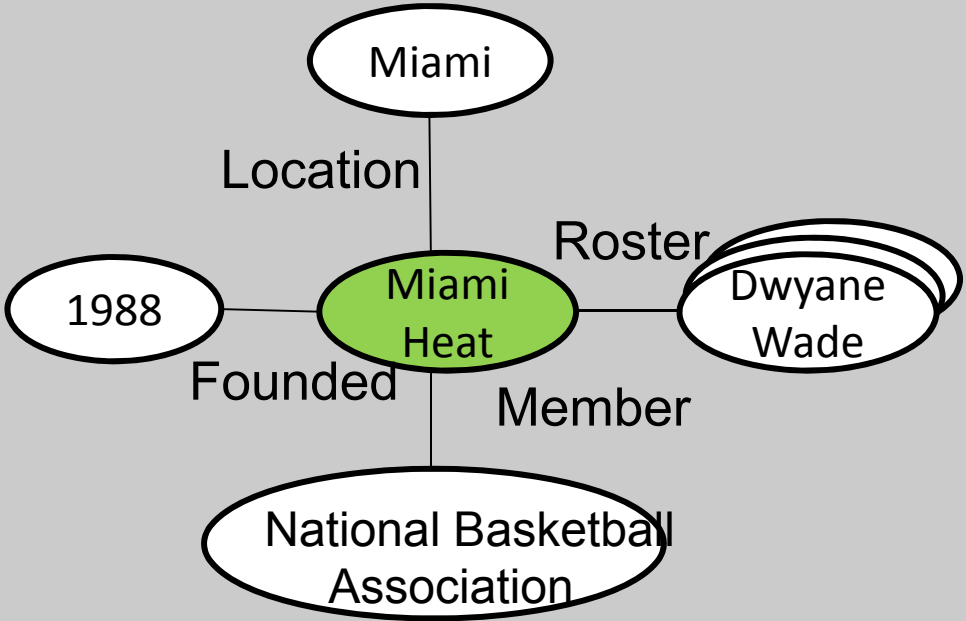
4m
 E_j

3.2k
 R_j

1.6k
 ET_j



Encoding Knowledge from KGs

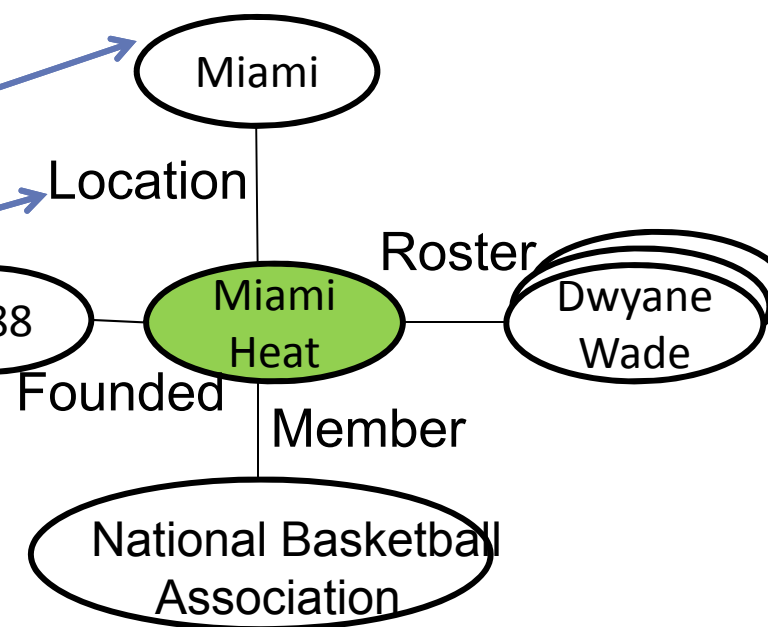
Knowledge	Representation	Example
Description	Letter tri-gram vector	dog = <#do, dog, og#> <0,...,1,1,...,0,1,...,0>
Entity Type	1-of-V vector	<0,...,0,...,1,...,0,...>
Subgraph	1-of-V vector for relation Letter tri-gram for entities	 <pre> graph TD Miami([Miami]) --- Location -- Location --- MiamiHeat([Miami Heat]) 1988([1988]) --- Founded -- Founded --- MiamiHeat NBA([National Basketball Association]) --- Member -- Member --- MiamiHeat Wade([Dwyane Wade]) --- Roster -- Roster --- MiamiHeat style MiamiHeat fill:#90EE90 style Wade stroke-width:4px </pre>

Models for Comparison

- For news documents
 - **Kul_sp**: A collective inference approach with rounding integer linear programs (Kulkarni et al., 2009).
 - **Shirak**: A naive Bayes probabilistic model with a probabilistic taxonomy (Shirakawa et al., 2011).
 - **AIDA**: A graph-based collective inference approach based on dense subgraph finding (Hoffart et al., 2011).
- For Tweets
 - **TagMe**: an unsupervised model based on prior popularity and semantic relatedness of a single message (Ferragina and Scaiella, 2010)
 - **Meij**: the state-of-the-art supervised approach based on the random forest model (Meij et al., 2012)

Overall Performance on News Documents

Method	Micro P@1	Macro P@1
Kul_sp	72.87%	76.74%
Shirak	81.40%	83.57%
AIDA	82.29%	82.02
GraphRegu + (Milne and Witten, 2008)	82.23%	81.10%
GraphRegu + DSRM + Connected Entities	84.17%	83.30%
+ Relations	85.33%	83.94%
+ Entity Type (e.g., film)	84.91%	83.56%
+ Entity Descriptions	85.82%	84.41%



- 20% error rate reduction over AIDA
- 20% error rate reduction over the standard method to compute semantic relatedness (Milne and Witten, 2008)

Overall Performance on Tweets

Method	Micro P@1	Macro P@1
TagMe (unsupervised)	61.03%	60.46%
Meiji (5 fold cross-validation)	68.33%	69.19%
GraphRegu + (Milne and Witten, 2008)	65.13%	66.20%
GraphRegu + DSRM + Connected Entities	69.19%	69.04%
+ Relations	70.22%	69.61%
+ Entity Type (e.g., film)	71.50%	70.92%
+ Entity Descriptions	71.89%	71.72%

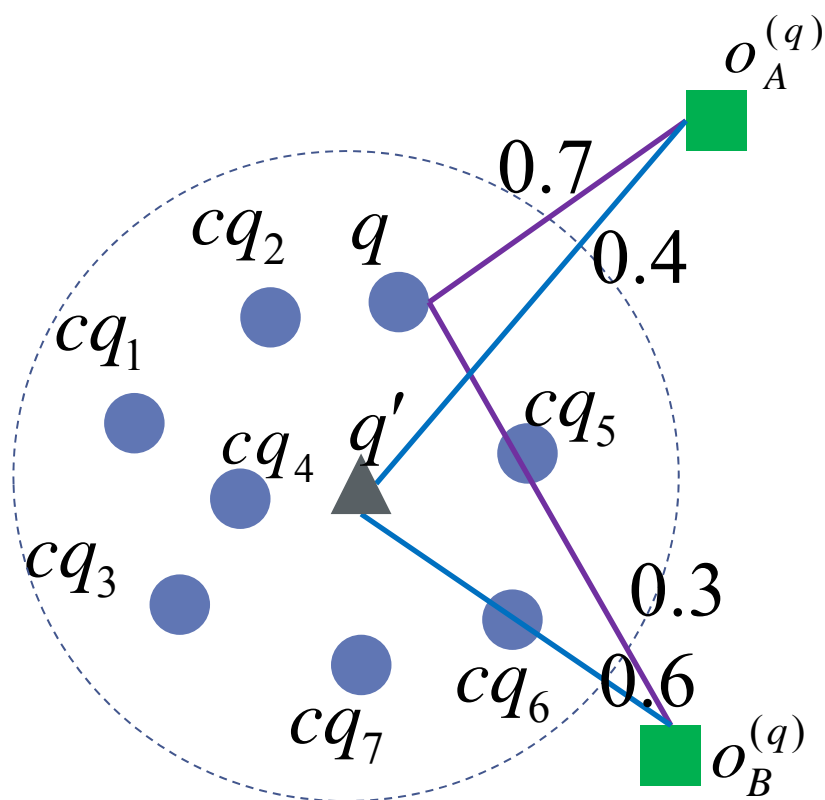
- 28% error rate reduction over TagMe
- 19% error rate reduction over the standard method to compute semantic relatedness (Milne and Witten, 2008)

Comparison of Semantic Relatedness Methods

Method	M&W	DSRM
New York City	0.92	0.22
New York Knicks	0.78	0.79
Washington, D.C.	0.80	0.30
Washington Wizards	0.60	0.85
Atlanta	0.71	0.39
Atlanta Hawks	0.53	0.83
Houston	0.55	0.37
Houston Rockets	0.49	0.80

Semantic relatedness scores between a sample of entities and the entity "**National Basketball Association**" in *sports* domain.

Other Inference Approaches (mostly, local information)



correct rank : $A < B$

$$f(q, o_A^{(q)}) = 0.7, f(q, o_B^{(q)}) = 0.3, A > B$$

$$\Rightarrow g_1(\cdot_A) = 0.4, g_2(\cdot_B) = 0.6, A < B$$

■ Relational Inference (Chan and Roth, 2013)
■ Collaborative Ranking and Collaborative Clustering (Chen and Ji, 2011)

- Construct a collaborative network for the target entity based on graph-based clustering
- Rank multiple decisions from collaborative entities (micro) and algorithms (macro)
- 7% absolute improvement

■ Disambiguate all entities in the contexts with PageRank

- (Fernandez et al., 2010; Pink et al., 2013; Radford et al., 2010; Cucerzan, 2011; Guo et al., 2011; Han and Sun, 2011; Han et al., 2011; Kozareva et al., 2011; Fahrni et al., 2012; Shen et al., 2013; Liu et al., 2013; Dalton and Dietz, 2013)

■ Re-formulate mentions using contexts (Gottipati and Jiang, 2010)

- "Cambridge" → "Cambridge, Massachusetts, the United States"
- "Cambridge" → "Cambridge, Ontario, Canada"

■ Model contexts using Wikipedia page concepts, and computed linkability scores iteratively (Lehmann et al., 2010, Ploch et al., 2011; Moro et al., 2014)

Outline

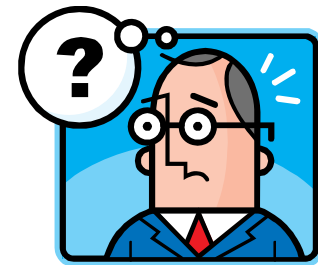
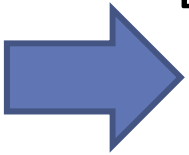
- Motivation and Definition
- A Skeletal View of a Wikification System
 - High Level Algorithmic Approach
- Key Challenges



- Recent Advances
- ➔ New Tasks, Trends and Applications
- What's Next?
- Resources, Shared Tasks and Demos

New Trends

- Wikification Until now: Solving Wikification Problems in
 - Standard settings; Long documents
- Extending the Wikification task to new settings
 - Social media Wikification
 - Cross-lingual Entity Linking
 - Linking to general KB and ontologies



Morphs in Social Media



=



“Conquer West King”
(平西王)

“Bo Xilai”
(薄熙来)



=



“Baby”
(宝宝)

“Wen Jiabao”
(温家宝)



Chris Christie → the Hutt

Morph Decoding

- Goal: automatically determine which term is used as a morph, and resolve it to its true target

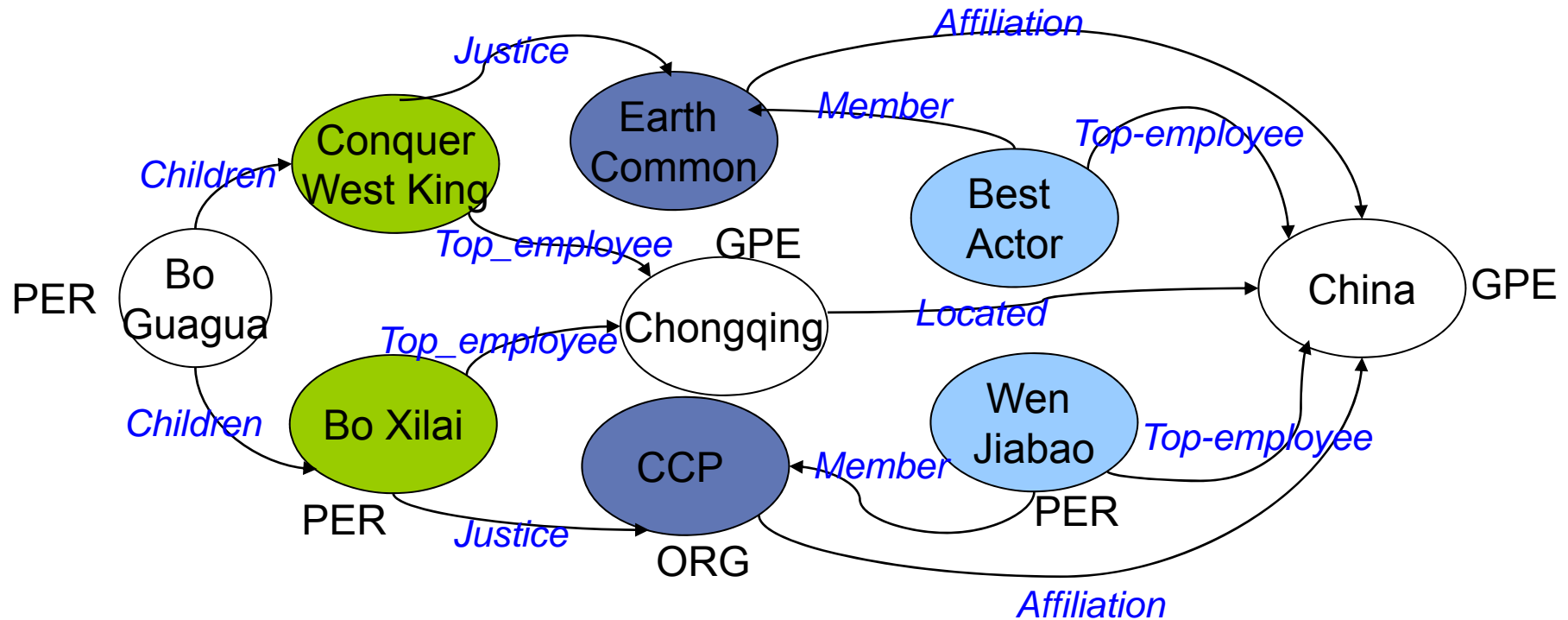
- Then *Wu Sangui* helped the *army of Qing dynasty* invaded China, and became *Conquer West King*.



- *Conquer West King* from *Chongqing* fell from power, still need to *sing red songs*?



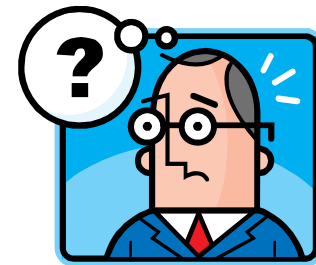
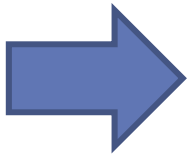
Morph Linking based on Information Networks Construction (Huang et al., 2013)



- Each node is an entity mention
- An edge: a semantic relation, event, sentiment, semantic role, dependency relation or co-occurrence, associated with confidence values
- Meta-path: a meta-level description of a existing or concatenated path between two object types (Sun et al., 2012)

New Trends

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 - Cross-lingual Entity Linking
 - Linking to general KB and ontologies
 - Fuzzy matching for candidates



Cross-lingual Entity Linking (CLEL)



<query id="SF114">
<name>李安</name>
<docid>XIN20030616.0130.0053</docid>
</query>



李安 - 简介

[纠错](#) | [编辑本段](#)

Parent: Li Sheng

李安，台湾著名导演，祖籍江西省九江市德安县，生于台湾屏东县，父亲李升。李安高中就读台南二中，后转学考进了台南第一志愿——台南一中。对于读书，李安一点兴趣都没有，心里只想着当导演。大学考试落榜两次，后来准备专科考试，进了国立台湾艺专（今国立台湾艺术大学）影剧科，从此改变了李安的一生。

Birth-place: Taiwan Pingdong City

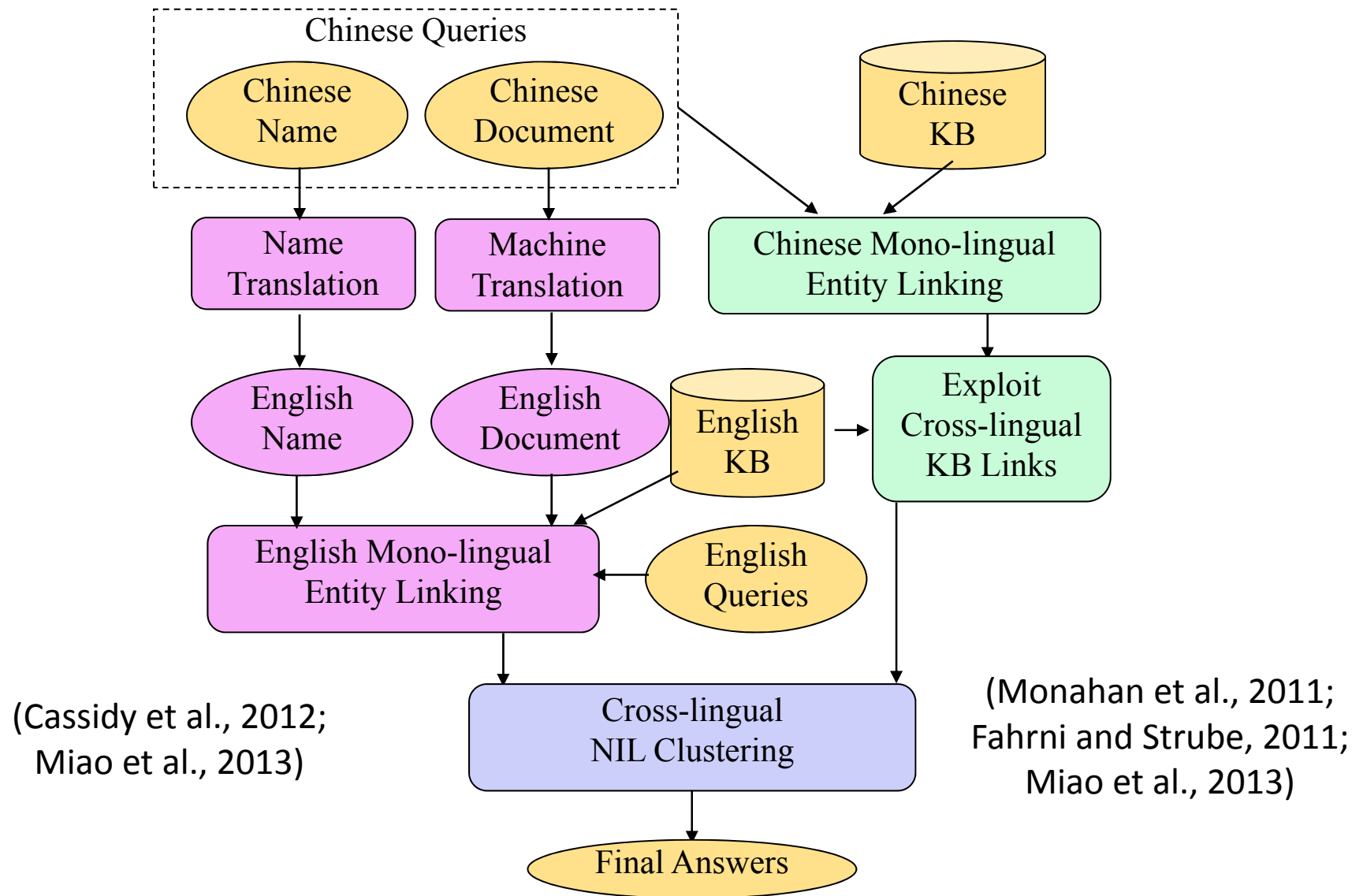
Residence: Hua Lian

李安曾言，住在花莲的八年，乃其北上就读艺专前最快乐的一段学习岁月。十岁之前的李安在花莲念了两所小学，接受的是美式开放教育，来到台南，又念了两所小学，面对语言习惯不同国语一台语，头一次经验到文化冲击。

Attended-School: NYU

李安于1979年赴美就读伊利诺大学香槟分校戏剧系取得学士学位，后于1981年至纽约大学就读电影制作研究所，取得硕士学位。李安的妻子林惠嘉是伊利诺大学香槟分校生物学博士，现任纽约医学院病理学研究员。

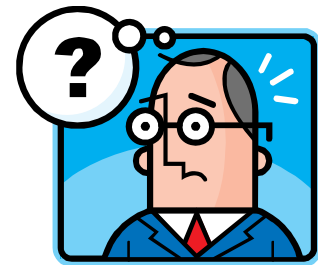
General CLEL System Architecture



- Major Challenge: Name Translation (Ji et al., 2011)

New Trends

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Link to General Database

- Many entities are not in Wikipedia
 - In “The Great Gatsby” movie
 - 8 characters listed; only one has a Wikipedia page
 - Many movies are missing
- Question: How can we link open-ended Databases?
 - Challenge: no new labeled data for the new knowledge base
 - Similarity-based features are domain independent [Sil, et. al 12]:
 - Train on the labeled examples based on a sports database
 - Test on the documents with a movie database
 - Very simple approach. Outperform the oracle wikifier on the movie domain

Link to Ontologies

- Wikification as a “Reading Assistant” for Scientific Literature

KB1	nuclear factor kappa-light-chain-enhancer of activated B cells		
KB2	nuclear factor of kappa light polypeptide gene enhancer in B-cells inhibitor	KB2-1	alpha
		KB2-2	beta
		KB2-3	eta
		KB2-4	gamma
KB3	B-cell lymphoma 3-encoded protein		
KB4	carboxyl-terminus		

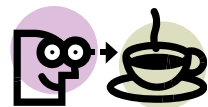
In resting cells, **p50–65 heterodimers** [**KB1**] (referred herein as **NF-kB** [**KB1**]) are sequestered in the cytoplasm by association with members of another family of proteins called **IkB** [**KB2**]: This family of proteins includes **IkBα** [**KB2-1**]; **IkBβ** [**KB2-2**]; **IkBε** [**KB2-3**] **IkBγ** [**KB2-4**] and **Bcl-3** [**KB3**], but also **p105** [**NIL1**] and **p100** [**NIL2**], due to their **C-terminal** [**KB4**] ankyrin-repeat regions have homologous functions to **IkB** [**KB2**].

Link to Biomedical Ontologies

- Wikipedia is not enough
 - Wikification trained only from news and Wikipedia
 - ➔ 20% end-to-end extraction and linking F-measure
- We can take advantage of the structures of the ontologies
 - Semantic relations among concepts in the ontologies (e.g. subClassOf) + collective inference technologies ➔ 84.5% (Zheng et al., 2014)
- Another approach:
 - Wikification: Wikipedia + Ontologies

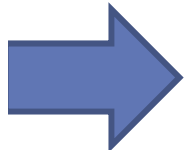
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Coffee Break

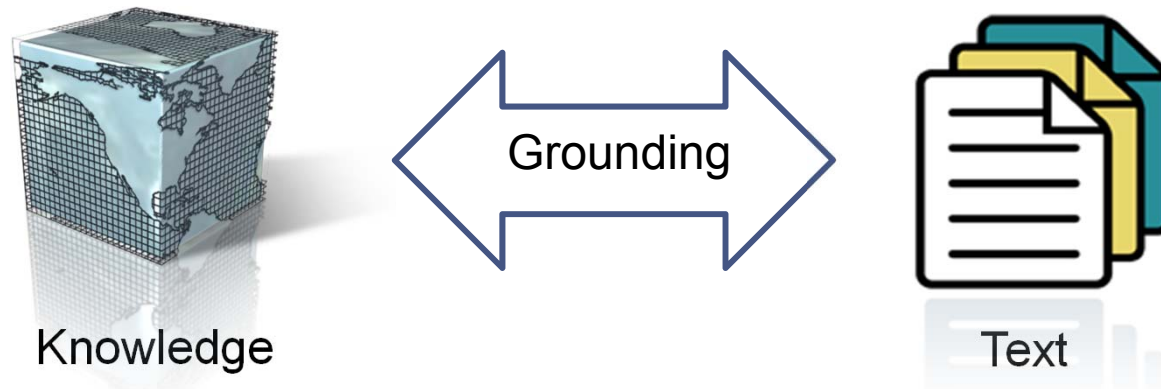
- Recent Advances
- New Tasks, Trends and Applications



What's Next?

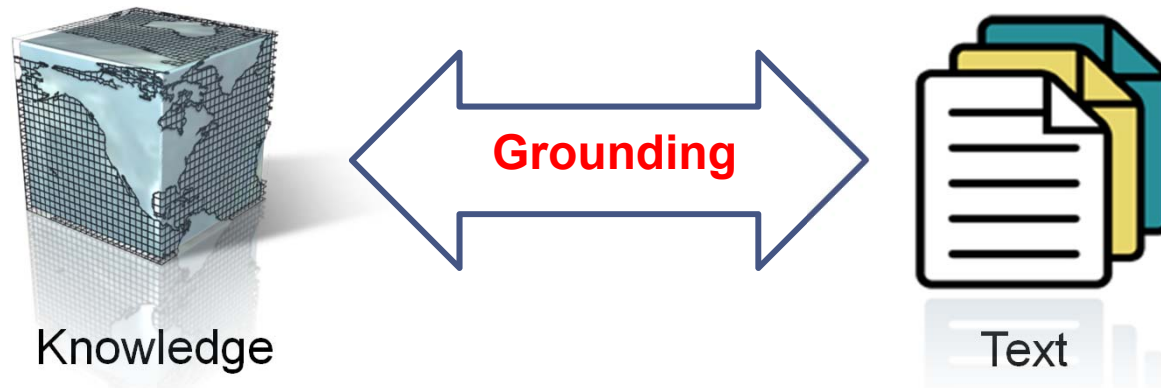
- Resources, Shared Tasks and Demos

What's Next? Now..



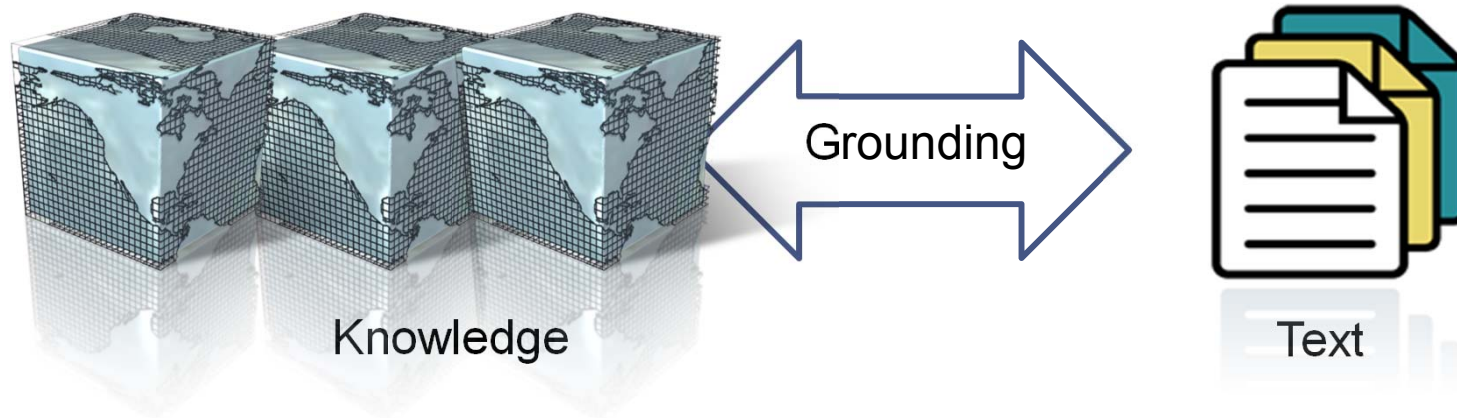
- Wikification & Entity Linking
 - Understand the semantic of text by “linking/grounding”
- Right now:
 - Knowledge = (almost) Wikipedia entities
 - Text = Text-based Documents; News Documents
- How can we bring text understanding to the next level?

Entity Grounding to Knowledge Grounding



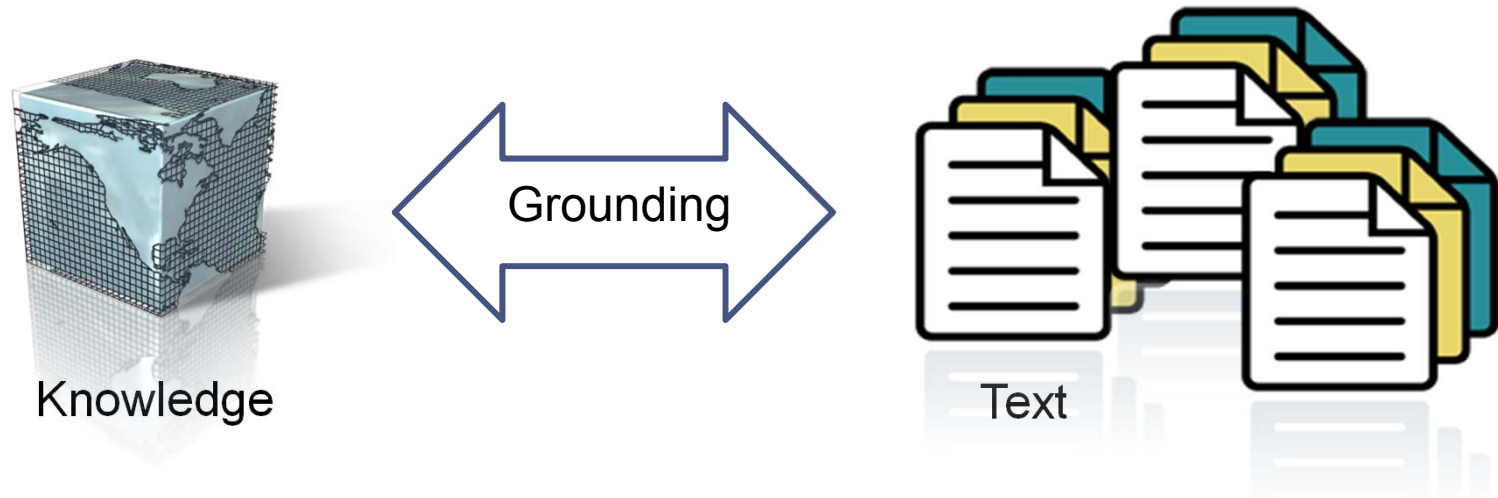
- Knowledge does not only contain entities
 - Relations: Freebase or Dbpedia
- Large scale semantic parsing
 - Semantic parsing + Entity Linking?
 - Which university did Obama go to? [Berant, et. al, ACL 14]
 - The lexical matching problem in semantic parsing is entity linking
- Should we jointly ground entities and relations?

Multiple Knowledge Resources



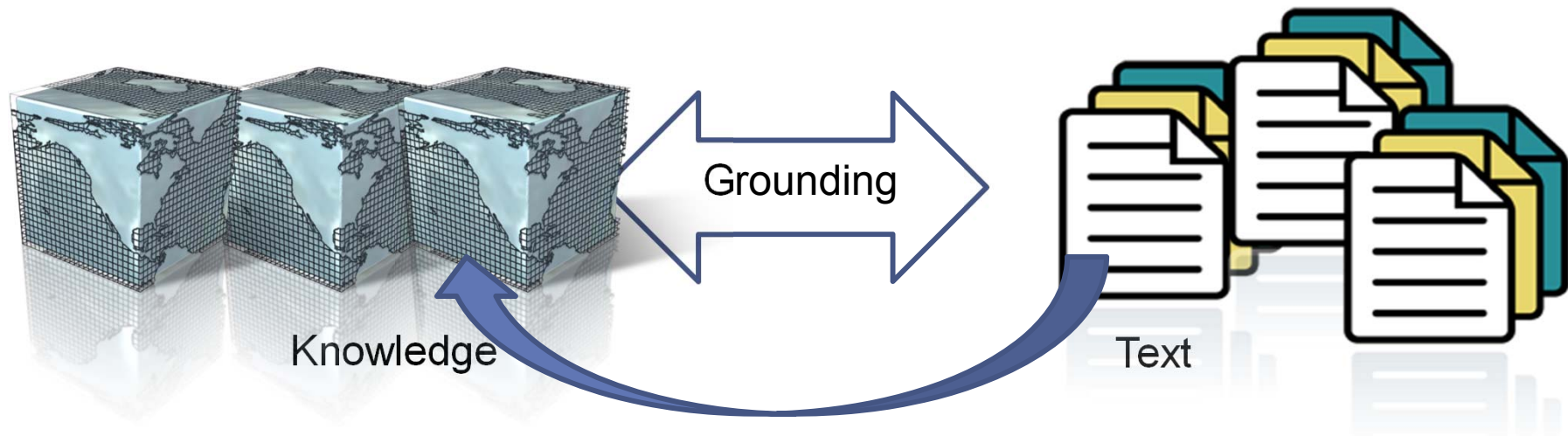
- We have: Wikipedia; Freebase; Customized databases; IMDB...
- How can we have one unified id for all databases?
 - Entity Linking is related to DB Integration
- Different Knowledge bases contain different resources
 - How to utilized them for better grounding?
- How can we use Wikipedia together with another knowledge base?

Handling Various Types of Documents



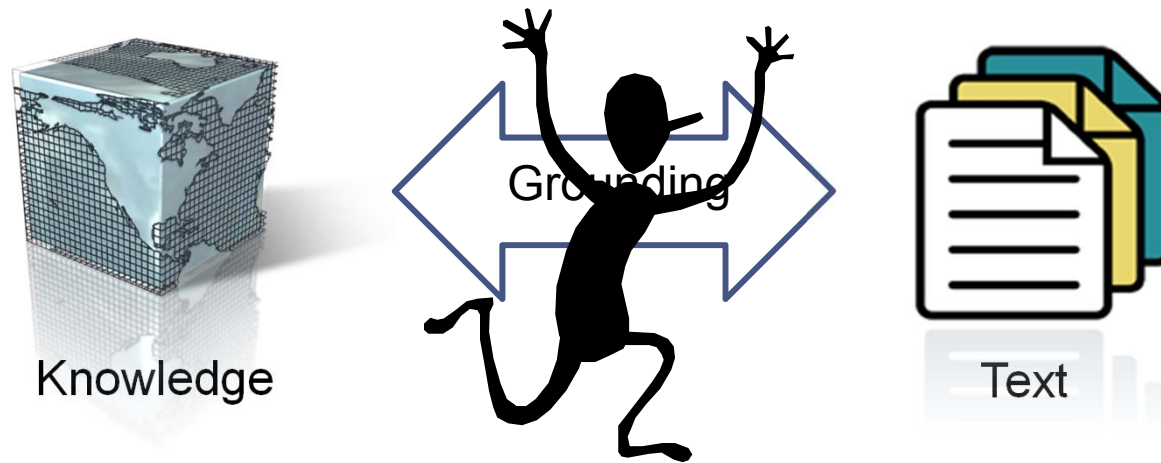
- It is not only text
 - Webpage, queries, tweets, All with meta information
 - How can we make use of the meta information?
- Noise
 - How can we develop robust linking techniques on noisy text?
 - Tweet, table + text, broken format, html
- Text in different languages

Machine Reading



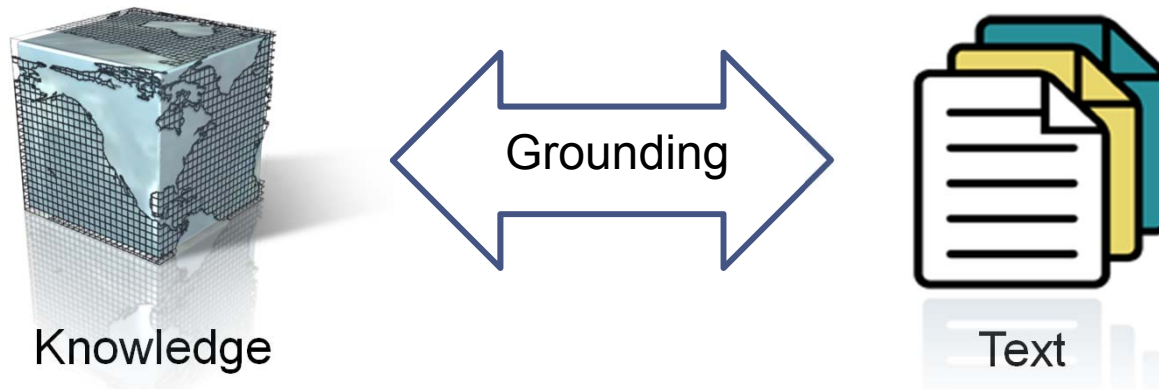
- Can we automatically extract large amounts of knowledge by reading text?
- Grounding should play an important role
 - Grounding → Better understanding of Text → Better Extraction
- How to put it back? Trustworthiness [Dong, et. Al 2014]
- How to handle probabilistic knowledge bases?

Getting Human in the Loop



- How can we apply knowledge grounding to better help human?
 - To understand text better?
 - To query knowledge bases in a better way?
 - Personalize assistant? Educational purposes?

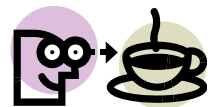
Knowledge Grounding



- Exciting time
 - We only touched the surface of an emerging field
 - Machines can do a much better job remembering knowledge
 - Machines should really be our assistant
 - Research + Engineering (Speed, Scale, Accuracy)

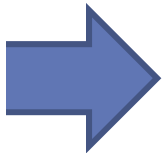
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Coffee Break

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Resources, Shared Tasks and Demos

Dataset

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Dataset – Long Text

- KBP Evaluations (can obtain all data sets after registration)
 - <http://nlp.cs.rpi.edu/kbp/2014/>
- CoNLL Dataset
 - <http://www.mpi-inf.mpg.de/departments/databases-and-information-systems/research/yago-naga/aida/downloads/>
- Emerging Entity Recognition
 - <http://www.mpi-inf.mpg.de/departments/databases-and-information-systems/research/yago-naga/aida/downloads/>

Dataset - Short Text

- Micropost Challenge
 - <http://www.scc.lancs.ac.uk/microposts2014/challenge/index.html>
- Dataset for “Adding semantics to microblog posts”
 - <http://edgar.meij.pro/dataset-adding-semantics-microblog-posts/>
- Dataset for “Entity Linking on Microblogs with Spatial and Temporal Signals”
 - <http://research.microsoft.com/en-us/downloads/84ac9d88-c353-4059-97a4-87d129db0464/>
- Query Entity Linking
 - <http://edgar.meij.pro/linking-queries-entities/>

Dataset Summary Angela Fahrni (2014)

Data Set	Task	Language Information		Mention Information		Corpus Information		Inventory	Annotation Information		Usage
Name		Setting	Lang.	Definition	Tokens	Source	Texts	Version	Strategy	Agreement	Shared Task
ACE 2005 Bentivogli et al. (2010)	concept and entity disambiguation, recognition of NILs	monolingual	en	ACE mentions (common and proper nouns)	29,300 92.8% in KE 7.2% NILs	broadcast news, newspapers, newswire reports, internet sources, transcribed audio data	597	Online version of Wikipedia 2010 (February - April; August)	Annotated by humans, partly by two annotators	0.85 (Dice coefficient with respect to annotated concepts and entities; before reconciliation)	no
ACE 2004 Ratinov et al. (2011)	concept and entity disambiguation, recognition of NILs	monolingual	en	ACE mentions (common and proper nouns)	306 (84.0% in KE, 16% NILs)	newswire, broadcast news	36	Wikipedia 2011 (?)	mechanical turk, only first mention in coreference chain is annotated	0.85 (agreement, then corrected)	no
ITB Kulkarni et al. (2009)	concept and entity disambiguation, recognition of NILs	monolingual	en	as much as possible, identified by people (including common and proper nouns)	17,200 (60% in KE; 40% NILs)	collection of web pages (sports, entertainment, science and technology, health)	107	Wikipedia dump from August 2008	annotated by humans, partly by two annotators; candidate mentions and tokens were suggested by the system	0.80 (agreement)	no
NewsSc Turdakov & Lizorkin (2009)	concept and entity disambiguation, recognition of NILs	monolingual	en	identified by humans (as many as possible, including common and proper nouns)	8,236 (80.6% in KE, 19.4% NILs)	news articles, scientific papers	131	Wikipedia dump from October 2008	annotated by humans	n.a.	no
MSNBC Cucerzan (2007)	entity disambiguation, recognition of NILs	monolingual	en	proper nouns recognized by a system	756 (83.2% in KE, 16.8% NILs)	MSNBC news (Business, US politics, Entertainment, Health, Sports, Tech & Science, Travel TV news, U.S. News, World News)	20	Wikipedia version from the 11.9.2006	post-hoc evaluation of system output	n.a.	no

Resources

- Reading List
 - <http://nlp.cs.rpi.edu/kbp/2014/elreading.html>
- Tool List
 - <http://nlp.cs.rpi.edu/kbp/2014/tools.html>
- Shared Tasks
 - KBP 2014
 - <http://nlp.cs.rpi.edu/kbp/2014/>
 - ERD 2014
 - <http://web-ngram.research.microsoft.com/erd2014>
 - #Micropost Challenge (for tweets)
 - <http://www.scc.lancs.ac.uk/microposts2014/challenge/index.html>
 - Chinese Entity Linking Task at NLPCC2014
 - <http://tcci.ccf.org.cn/conference/2014/dldoc/evatask3.pdf>

Task and Evaluation

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ERD 2014

- Given a document, recognize all of the mentions and the entities;
 - No target mention is given
- An entity snapshot is given
 - Intersection of Freebase and Wikipedia
- Input: Webpages
- Output: Byte-offset based predictions
- Webservice-driven; Leaderboard

NIST TAC Knowledge Base Population (KBP)

- KBP2009-2010 Entity Linking(Ji et al., 2010)
 - Entity mentions are given, Link to KB or NIL, Mono-lingual
- KBP2011-2013 (Ji et al., 2011)
 - Added NIL clustering and cross-lingual tracks
- KBP2014 Entity Discovery and Linking (Evaluation: September)
 - <http://nlp.cs.rpi.edu/kbp/2014/>
 - Given a document source collection (from newswire, web documents and discussion forums), an EDL system is required to automatically extract (identify and classify) entity mentions (“queries”), link them to the KB, and cluster NIL mentions
 - English Mono-lingual track
 - Chinese-to-English Cross-lingual track
 - Spanish-to-English Cross-lingual track

Evaluation Metrics

- Concept/Entity Extraction
 - F-Measure, Clustering
- Linking
 - Accuracy @ K (K=1, 5, 10...)
- End-to-end Concept/Entity Extraction + Linking + NIL Clustering
 - B-cubed
 - CEAF
 - Graph Edit Distance
- How should we handle the mention boundary?
 - KBP2014 Rules: Extraction for Population
 - Fuzzy F1-Measure (ERD 2014)
 - Full credit if the predicted boundary overlaps with the gold boundary

Demo

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Demos

- UIUC Wikification Demo
 - <http://cogcomp.cs.illinois.edu/demo/wikify/?id=25>
- RPI Wikification Demo
 - Entity Discovery and Linking:
 - <http://orion.tw.rpi.edu/~zhengj3/wod/wikify.php>
 - AMR based Entity Linker:
 - <http://blender02.cs.rpi.edu:3300/>