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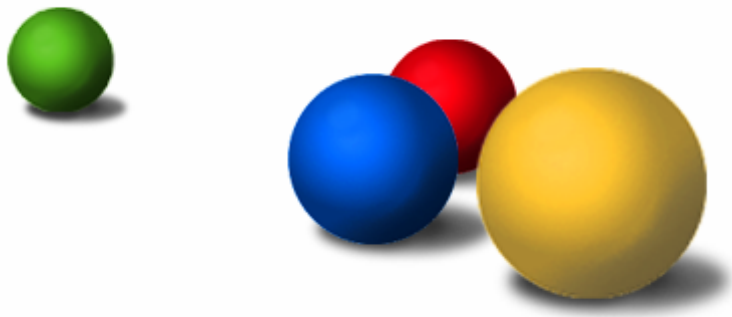
Low-Pass Semantics

Fernando Pereira
with
William Cohen*, Rahul Gupta, Ni Lao*, Slav Petrov, Michael Ringgaard, and Amar Subramanya

*CMU



An “easy” query…

painkillers that don't thin blood ✕ Search

painkillers that don't **thin blood**
painkillers that don't **cause constipation**
painkillers that don't **cause nausea**
painkillers that don't **upset stomach**
painkillers that don't

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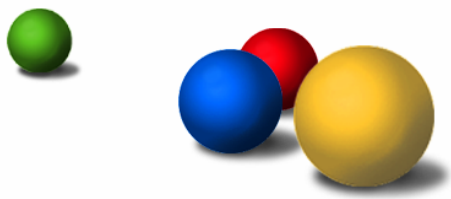

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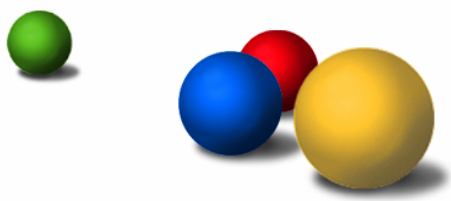

painkillers that don't upset stomach ✕ Search

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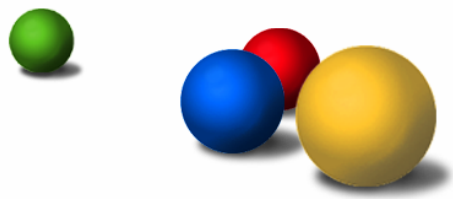

negation

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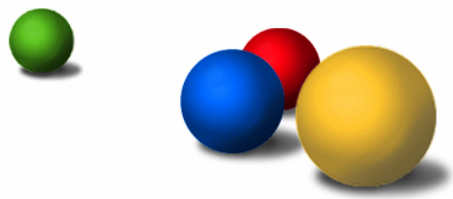

class negation

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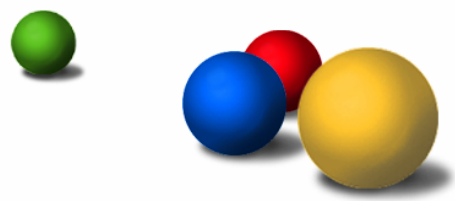

class negation synonyms

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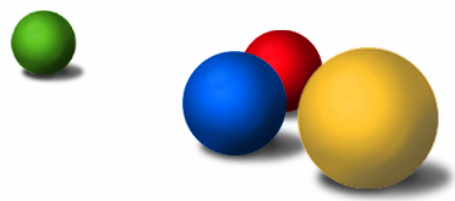

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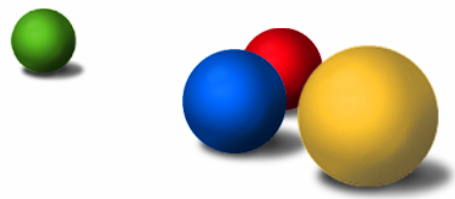

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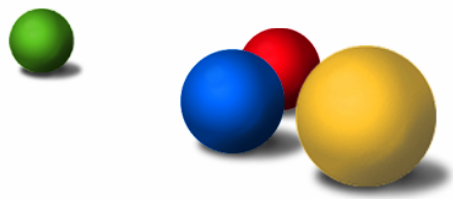

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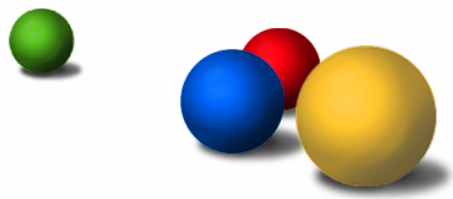
tylenol ⇒ painkiller



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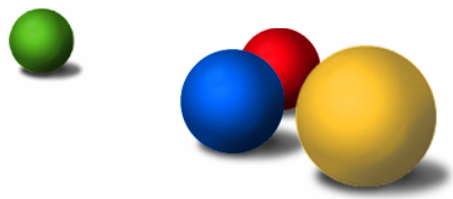

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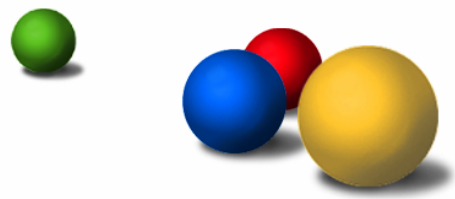

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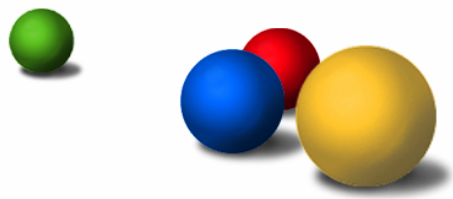
upset stomach ⇒ adverse effect (on stomach)



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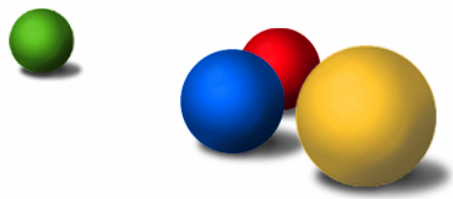

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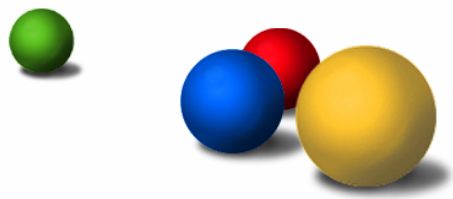

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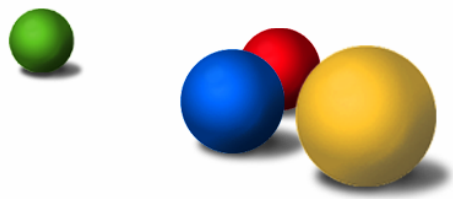

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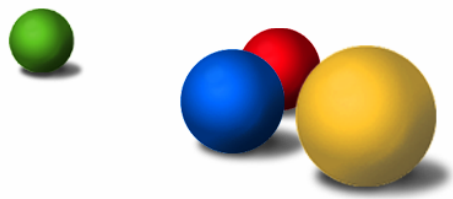
⇒ no upset stomach



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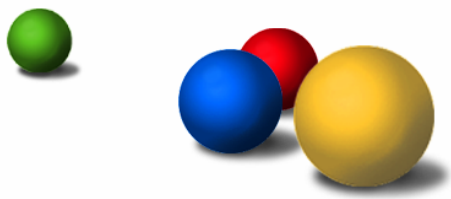
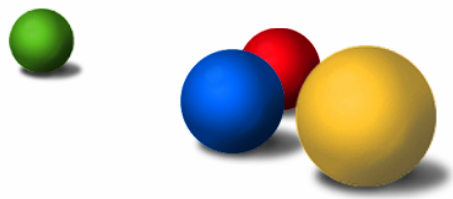


From search to inference

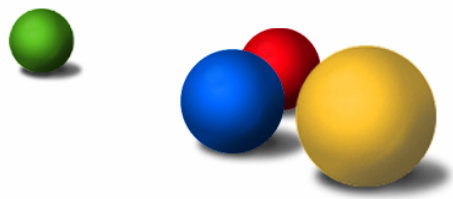
painkiller



From search to inference

painkiller

upset



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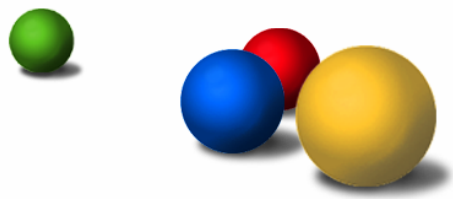
painkiller upset stomach



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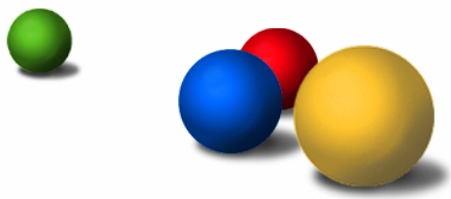
upset

stomach

is-a



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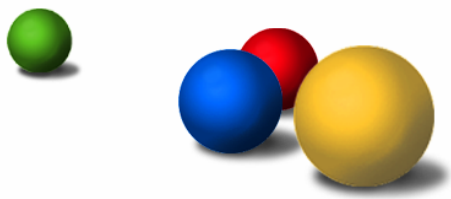
tylenol



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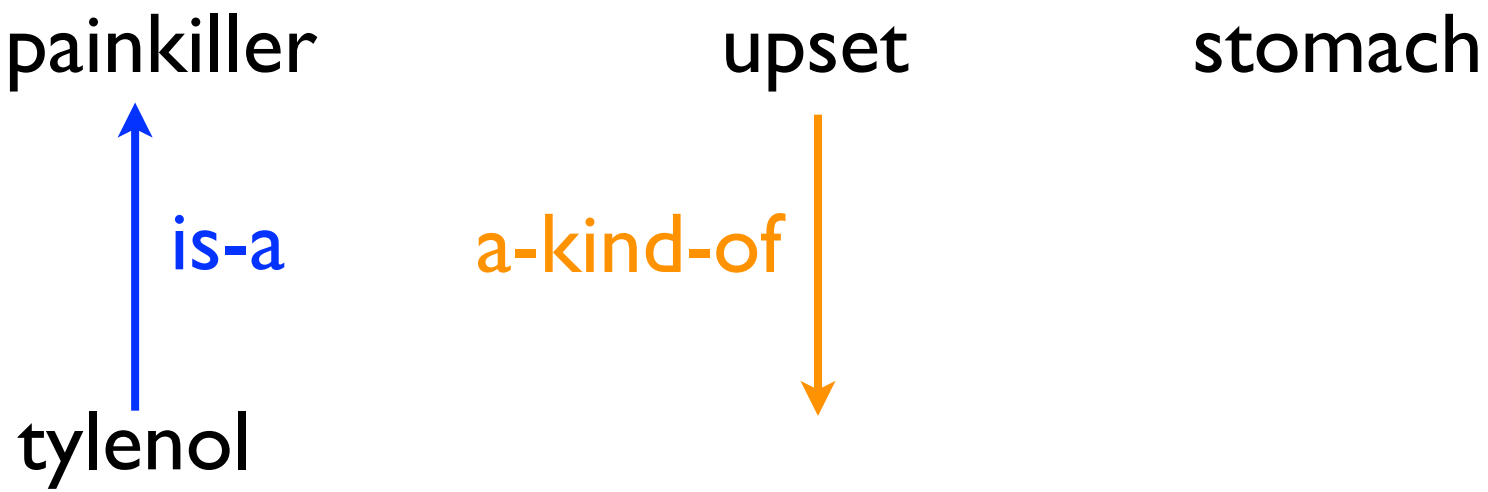

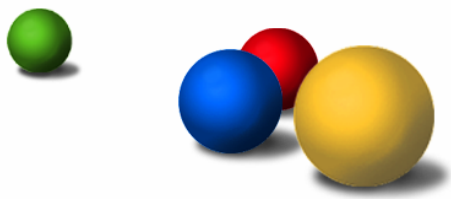

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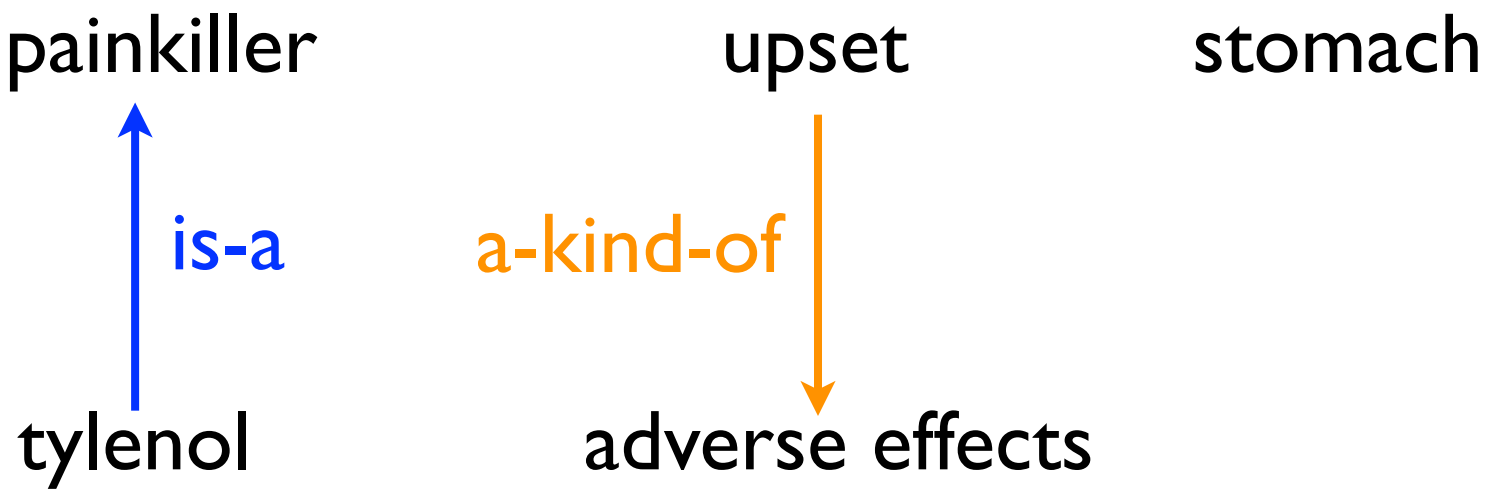

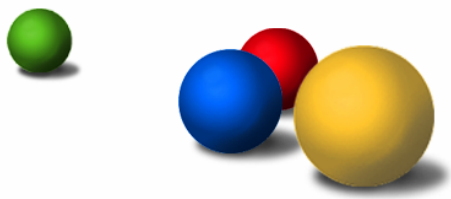

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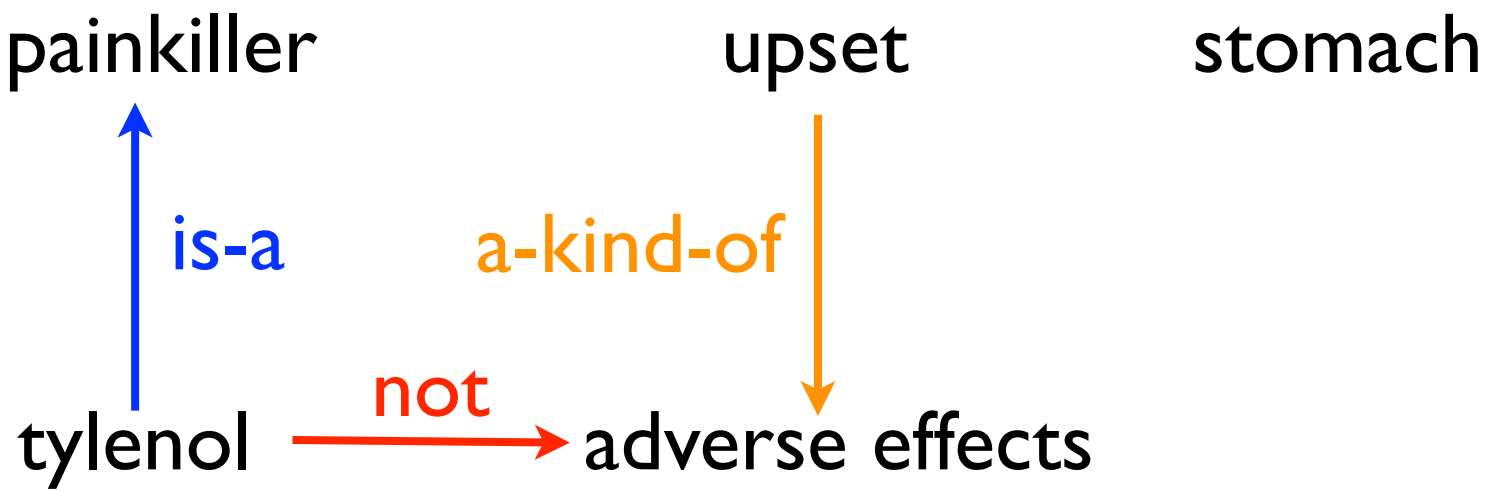

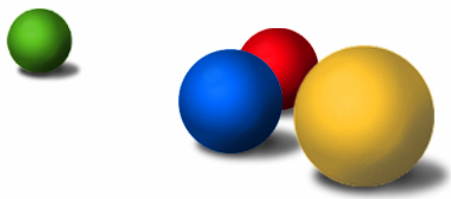

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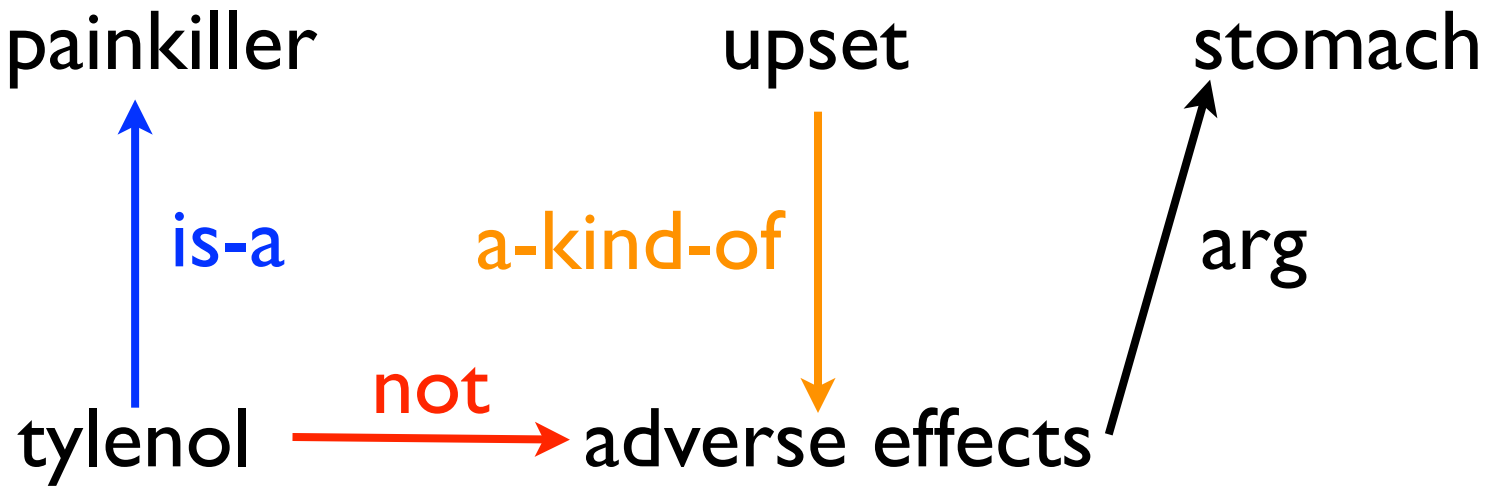

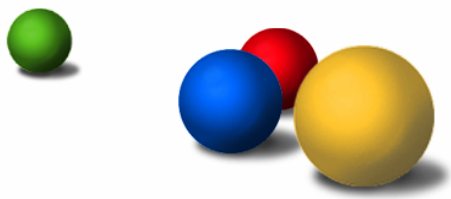

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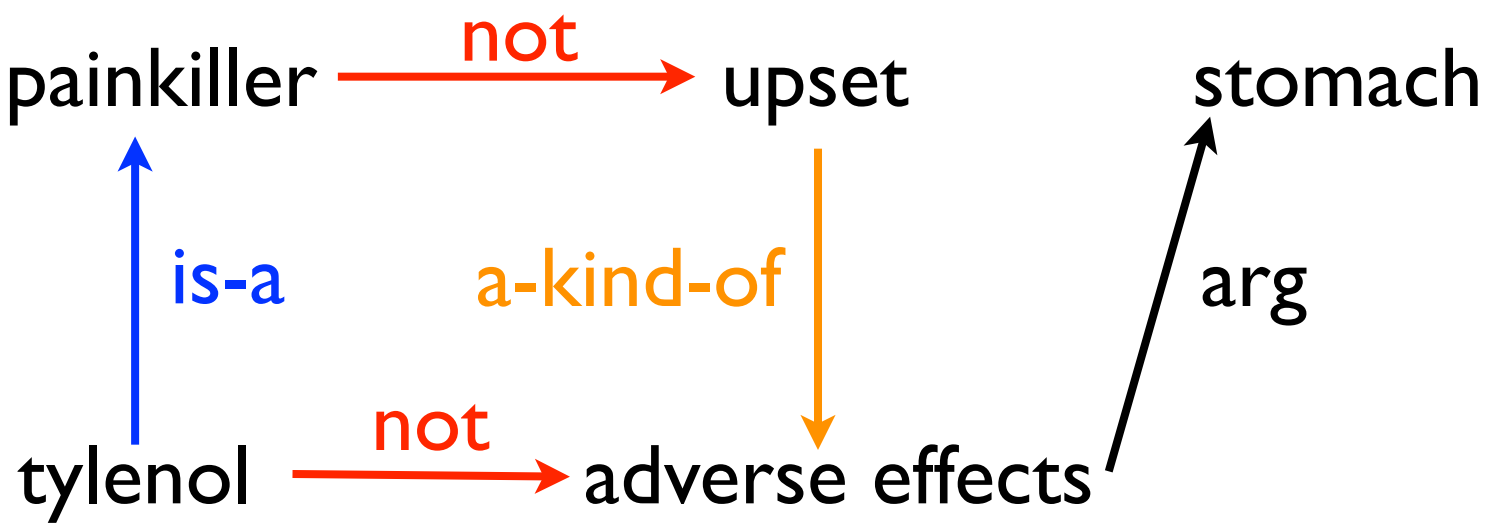

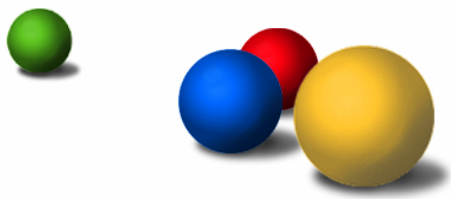

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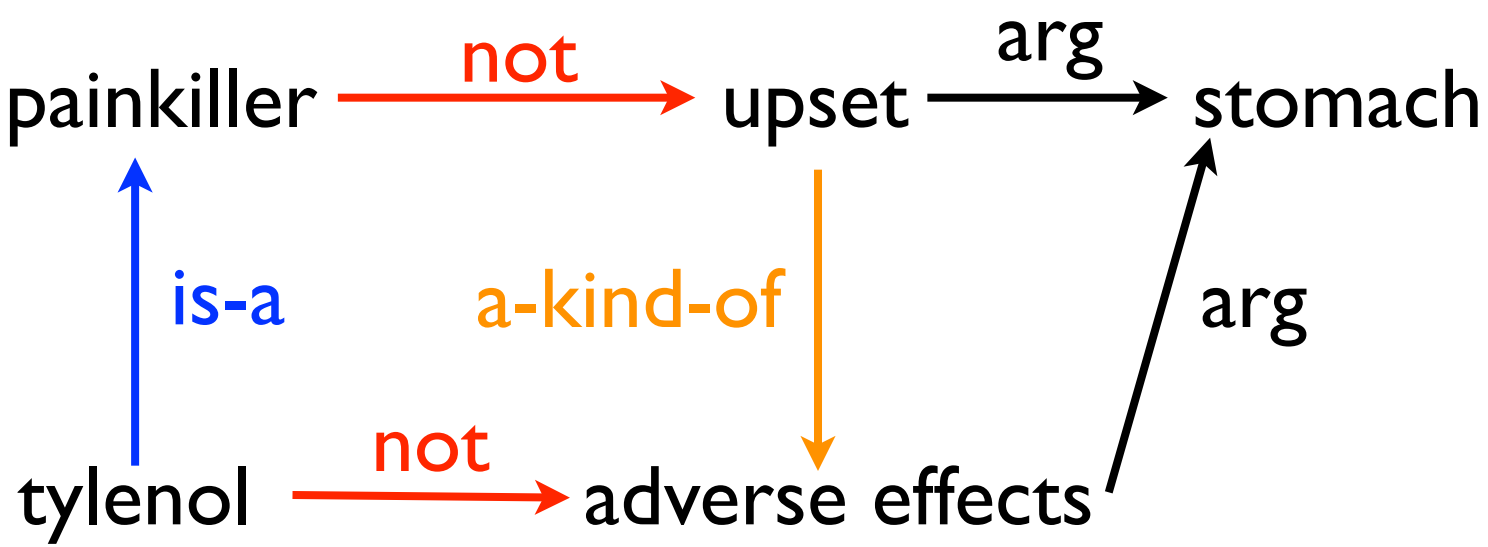
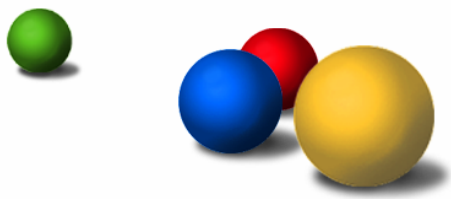
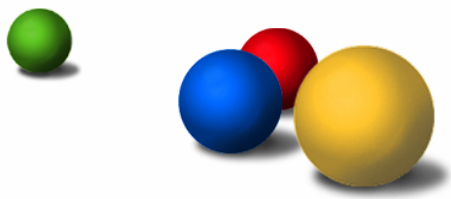


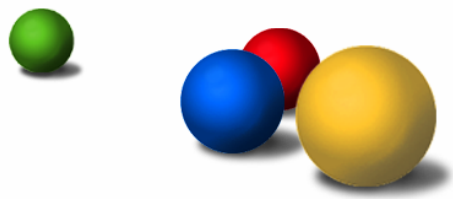


“Things, not strings”



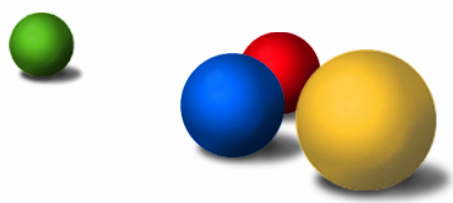
“Things, not strings”

From	To	Requires



“Things, not strings”

From	To	Requires
Term	Concept	Parsing, disambiguation, coreference



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From	To	Requires
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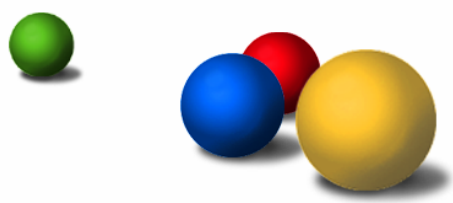
Term identity	Entailment	Concept relations



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From	To	Requires
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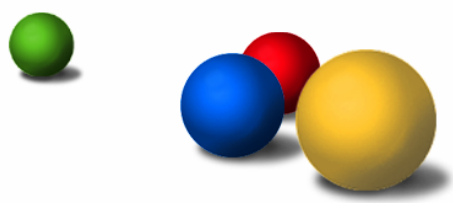
Co-occurrence	Syntactic relation	Document structure, parsing



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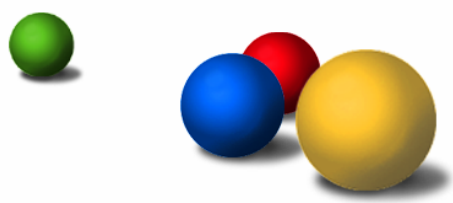
Co-occurrence	Syntactic relation	Document structure, parsing
Term index	Semantic index	Concept disambiguation, inference



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Mount Shasta (Úytaahkoo in Karuk or "White Mountain": the origin of the name " Shasta" is vague, perhaps from Russian (Чистая, means "white, clean, pure" or ...
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Images for mount shasta - Report images

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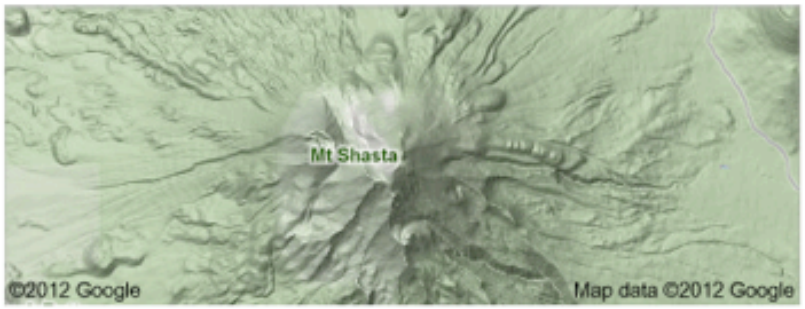
Mount Shasta



summitpost.org

Mount Shasta is located at the southern end of the Cascade Range in Siskiyou County, California and at 14,179 feet is the second highest peak in the Cascades and the fifth highest in California.
Wikipedia

Elevation: 14,180 feet (4,322 m)
Last eruption: 1786
First ascent: 1854
Prominence: 9,823 feet (2,994 m)
First ascender: E. D. Pearce
Mountain range: Cascade Range

People also search for

Lassen Peak

Mount Rainier

Mount Whitney

Mount Hood

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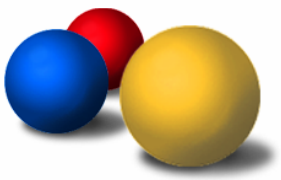

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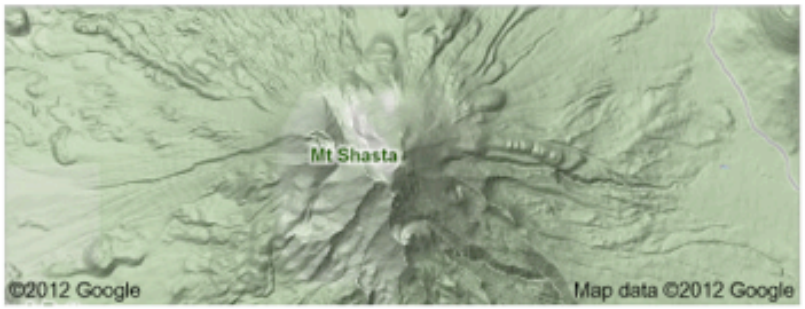

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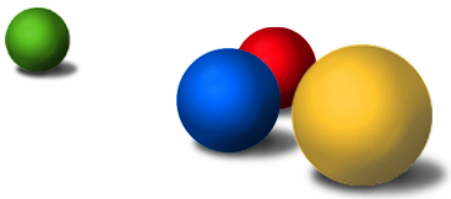

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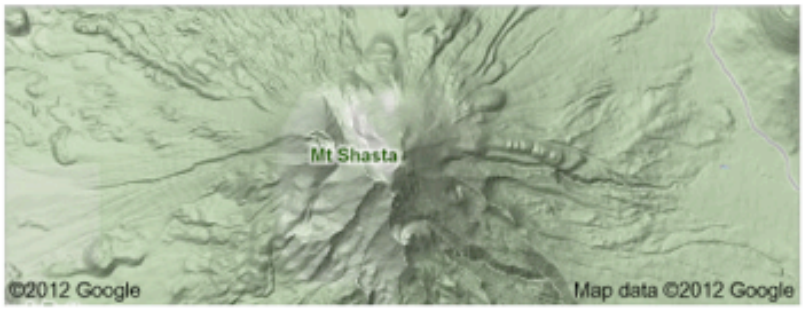

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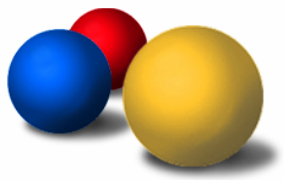
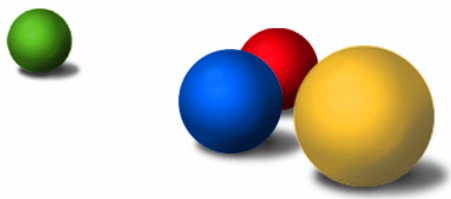
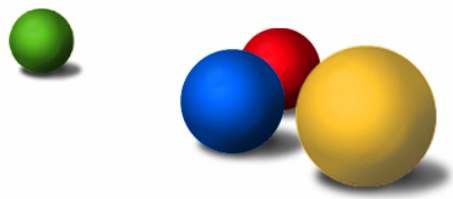


Hypotheses



Hypotheses

- *Web understanding will arise from machine learning of relationships implicit in Web content and use*



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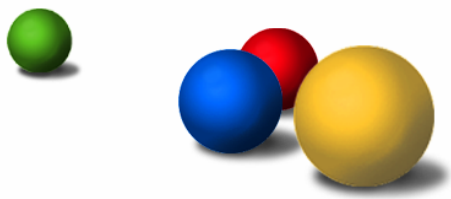

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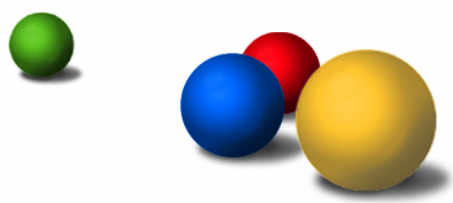

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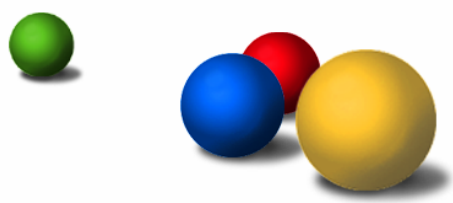

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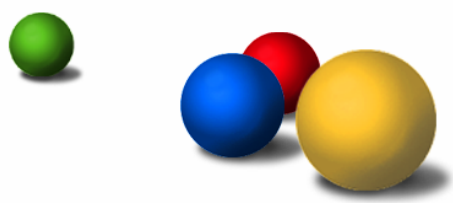
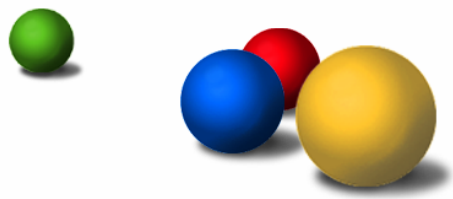


Knowledge Bases?



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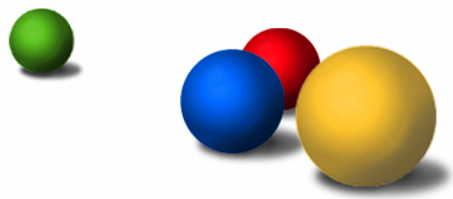
- Curated, disambiguated “text”



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- Curated, disambiguated “text”
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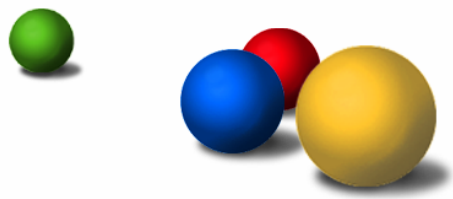

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- Curated, disambiguated “text”
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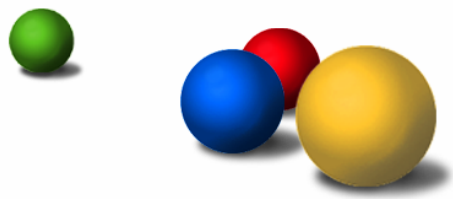

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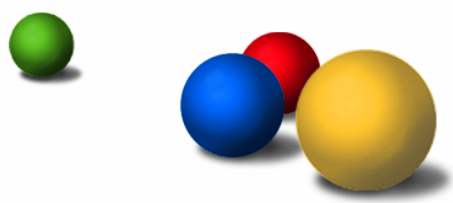
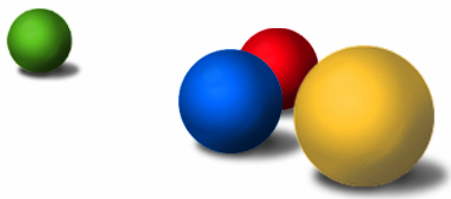
- *Join keys*

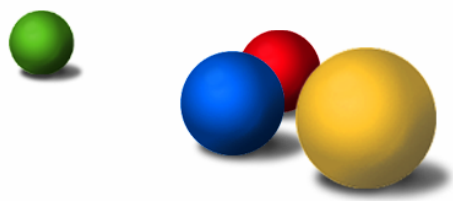


Layers of meaning



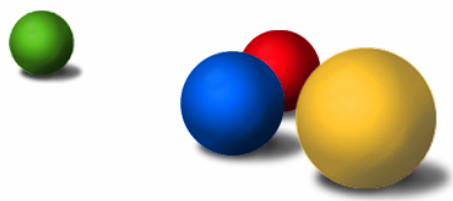
Layers of meaning

- Grammatical structure (parsing)



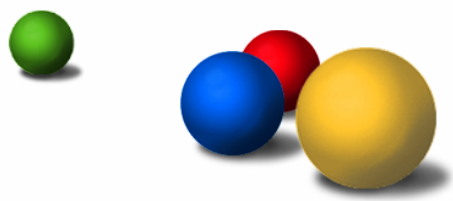
Layers of meaning

- Grammatical structure (parsing)
- Referring expression classification



Layers of meaning

- Grammatical structure (parsing)
- Referring expression classification
- Within-document coreference



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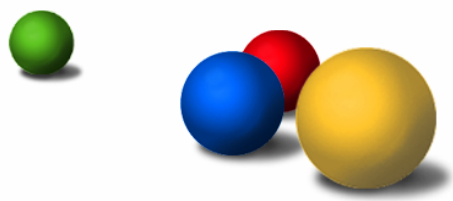

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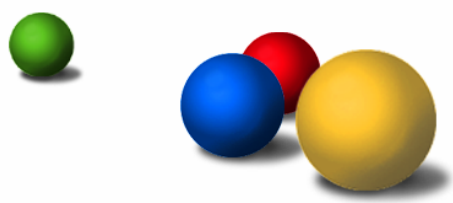

Putting it all together

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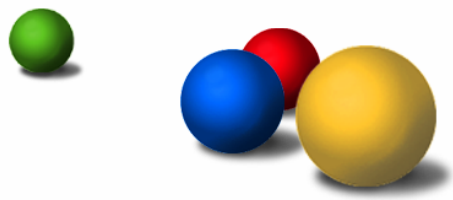

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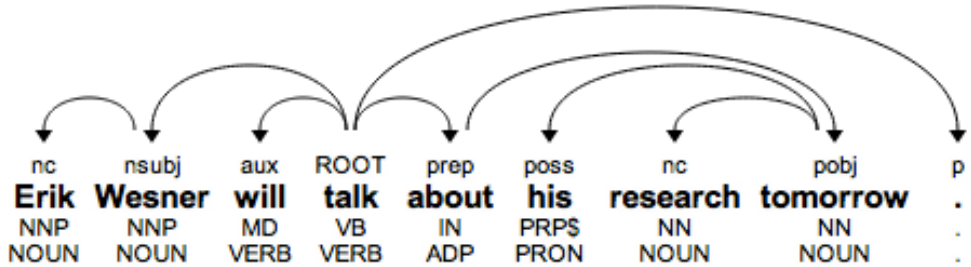

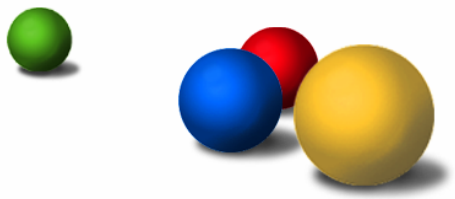

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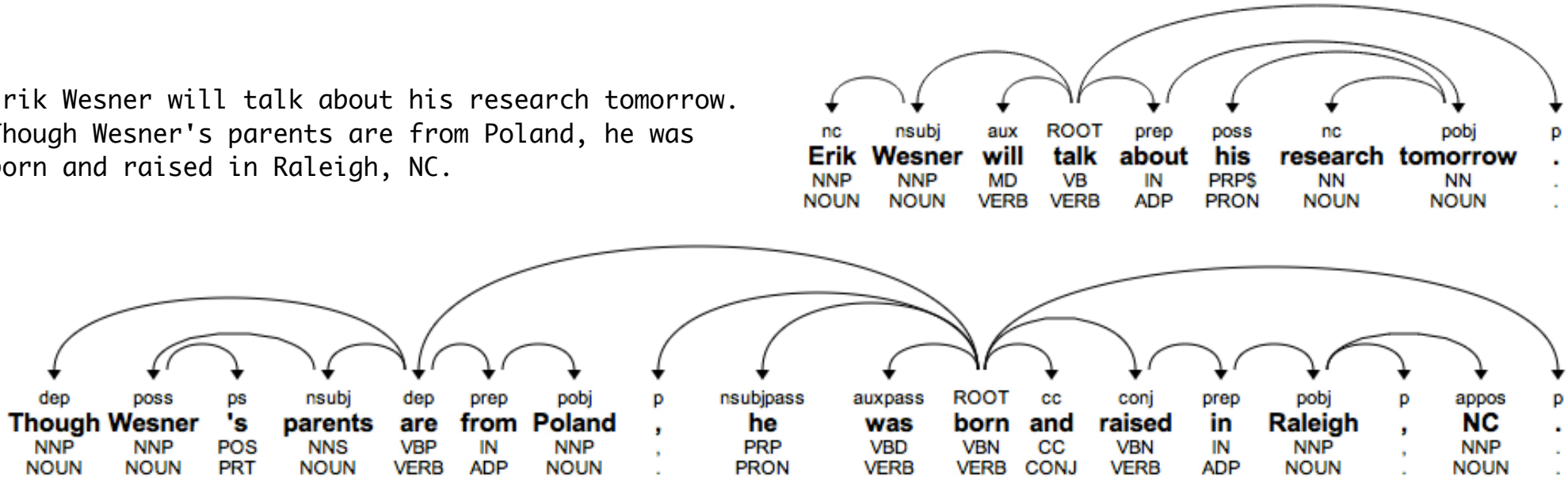

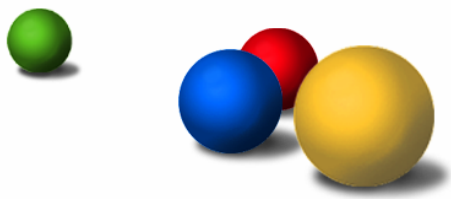

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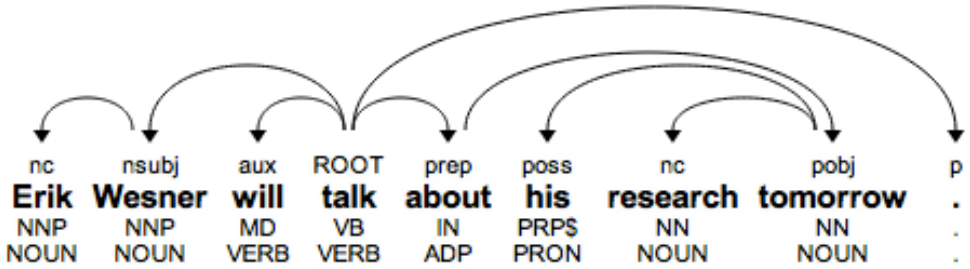

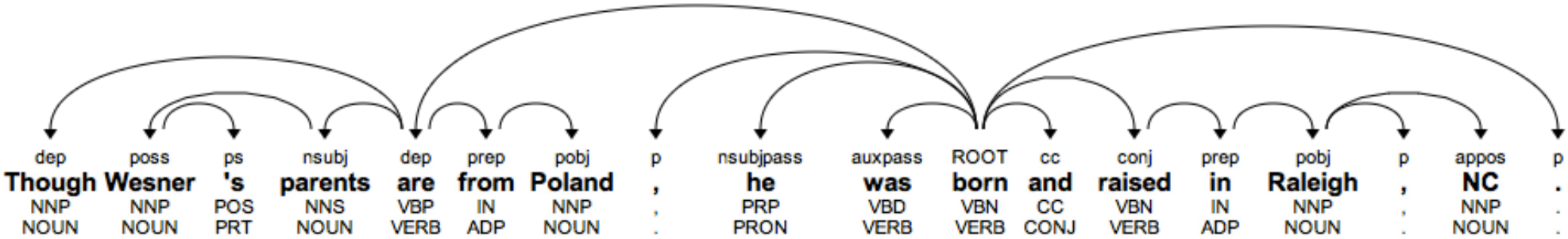

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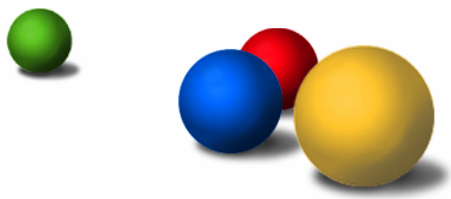

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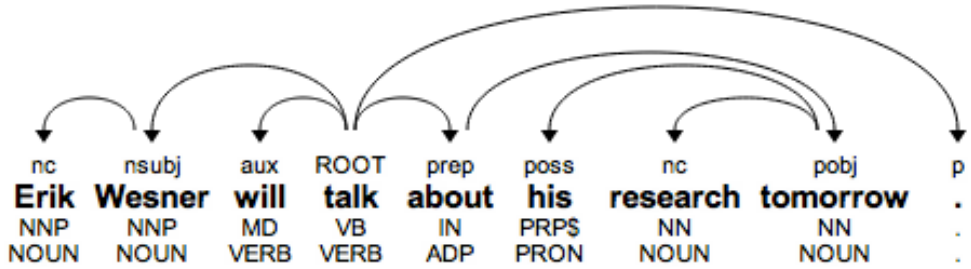

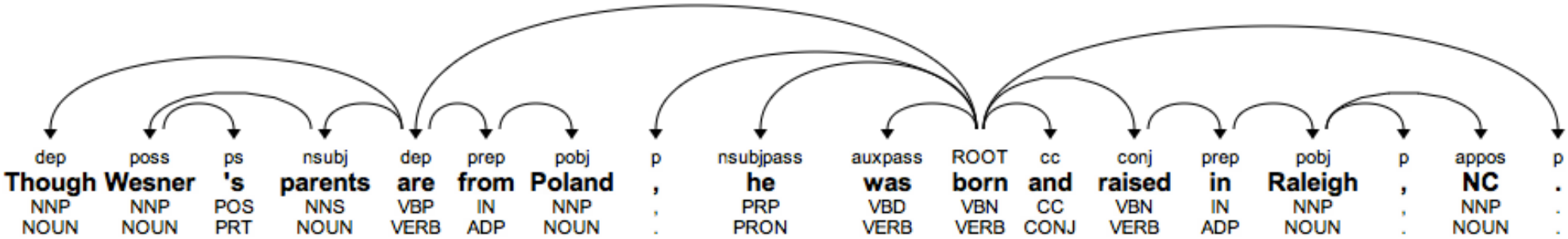

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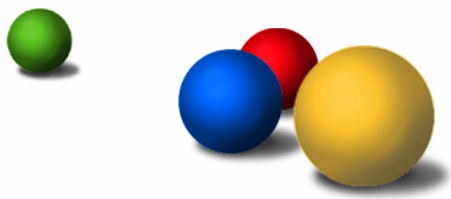
Though [Wesner]$_1$'s [parents]$_3$ are from [Poland]$_5$, [he]$_1$ was born and raised in [Raleigh, NC]$_6$.

Entity	Type	Gender	Name	Description
E#1	PER	MASCULINE	Erik Wesner	mentions: Erik Wesner, Wesner, he, his
E#3	PER		parents	mentions: parents
E#5	LOC		Poland	profile: Poland mentions: Poland
E#6	LOC		Raleigh, NC	profile: Raleigh, North Carolina mentions: Raleigh, NC



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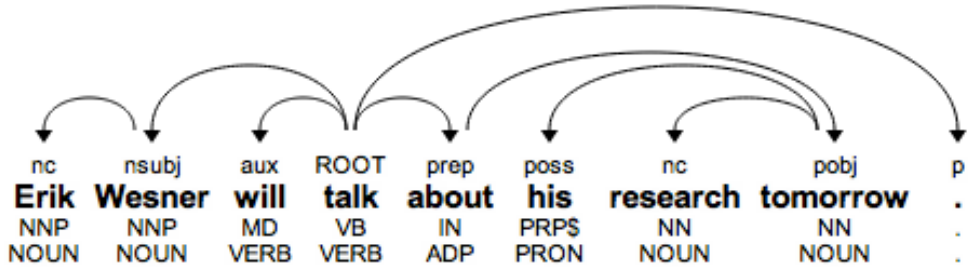

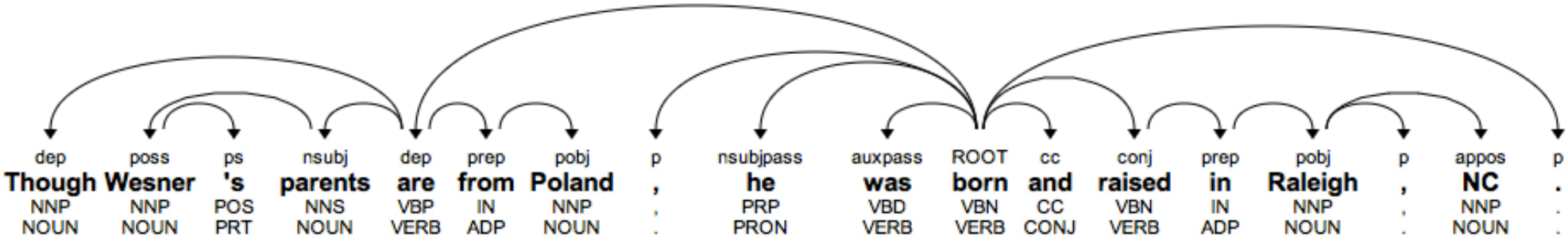

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1. **Erik Wesner**, place_of_birth, **Raleigh, NC**.
   PARSE_PATH: PRON <nsubjpass born/VERB conj> raised/VERB prep> in/ADP pobj> NOUN
   LINEAR_PATH: /PRON was born and raised in /NOUN

Entity	Type	Gender	Name	Description
E#1	PER	MASCULINE	Erik Wesner	mentions: Erik Wesner, Wesner, he, his
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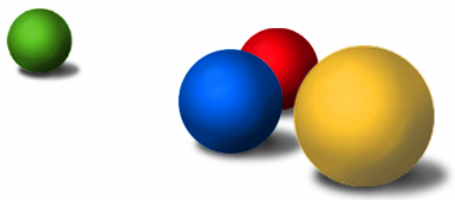


Linguistic analysis matters

Relation extraction quality

+ *examples*

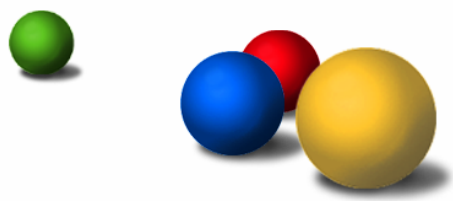
patterns

relations

known triples

(likely) correct triples

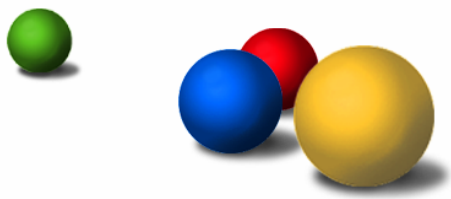
LAS



Linguistic analysis matters

Relation extraction quality

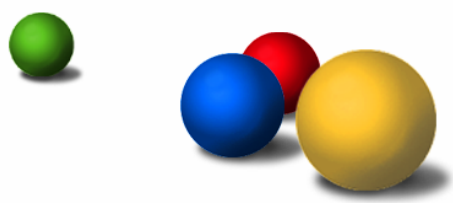
	text
+ examples	*580k*
patterns	*187*
relations	*24*
known triples	*69k*
(likely) correct triples	*67k*
LAS	



Linguistic analysis matters

Relation extraction quality

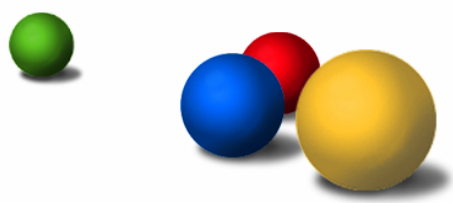
	text	*text slow parse*
+ examples	*580k*	*580k*
patterns	*187*	*478*
relations	*24*	*32*
known triples	*69k*	*191k*
(likely) correct triples	*67k*	*198k*
LAS		*86.49*



Linguistic analysis matters

Relation extraction quality

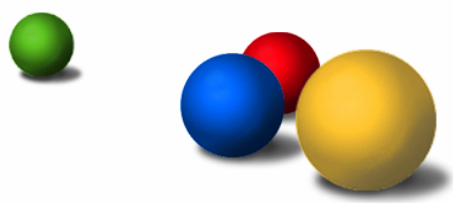
	text	*text slow parse*	*text slow parse coref*
+ examples	*580k*	*580k*	*935k*
patterns	*187*	*478*	*1023*
relations	*24*	*32*	*38*
known triples	*69k*	*191k*	*281k*
(likely) correct triples	*67k*	*198k*	*478k*
LAS		*86.49*	*86.49*



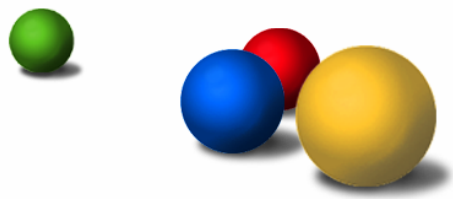
Linguistic analysis matters

Relation extraction quality

	text	*text slow parse*	*text slow parse coref*	*text fast parse coref*
+ examples	*580k*	*580k*	*935k*	*941k*
patterns	*187*	*478*	*1023*	*1013*
relations	*24*	*32*	*38*	*38*
known triples	*69k*	*191k*	*281k*	*270k*
(likely) correct triples	*67k*	*198k*	*478k*	*454k*
LAS		*86.49*	*86.49*	*82.72*

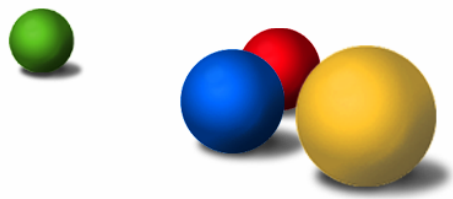


Unifying idea: graph inference



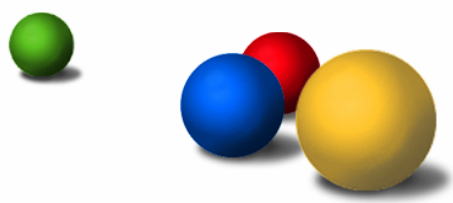
Unifying idea: graph inference

- *Nodes*: objects of interest



Unifying idea: graph inference

- *Nodes*: objects of interest
- *Edges*: distributional, syntactic, semantic relationships
  - *Edge weights*: relationship strength



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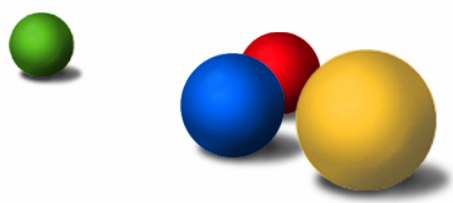

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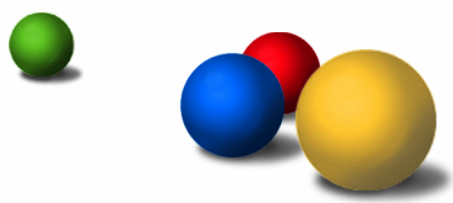
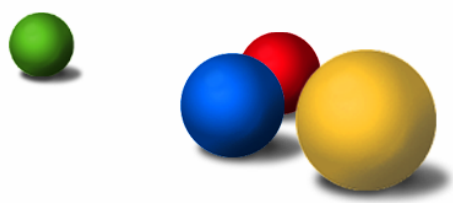
- *Outputs*: node interpretations, new edges



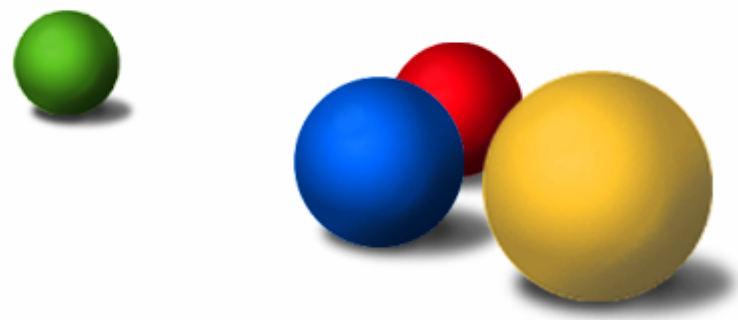
Unifying idea: graph inference

- *Nodes*: objects of interest
- *Edges*: distributional, syntactic, semantic relationships
  - *Edge weights*: relationship strength
- Curated seed subgraph
- *Outputs*: node interpretations, new edges
- Naturally (almost) parallel algorithms

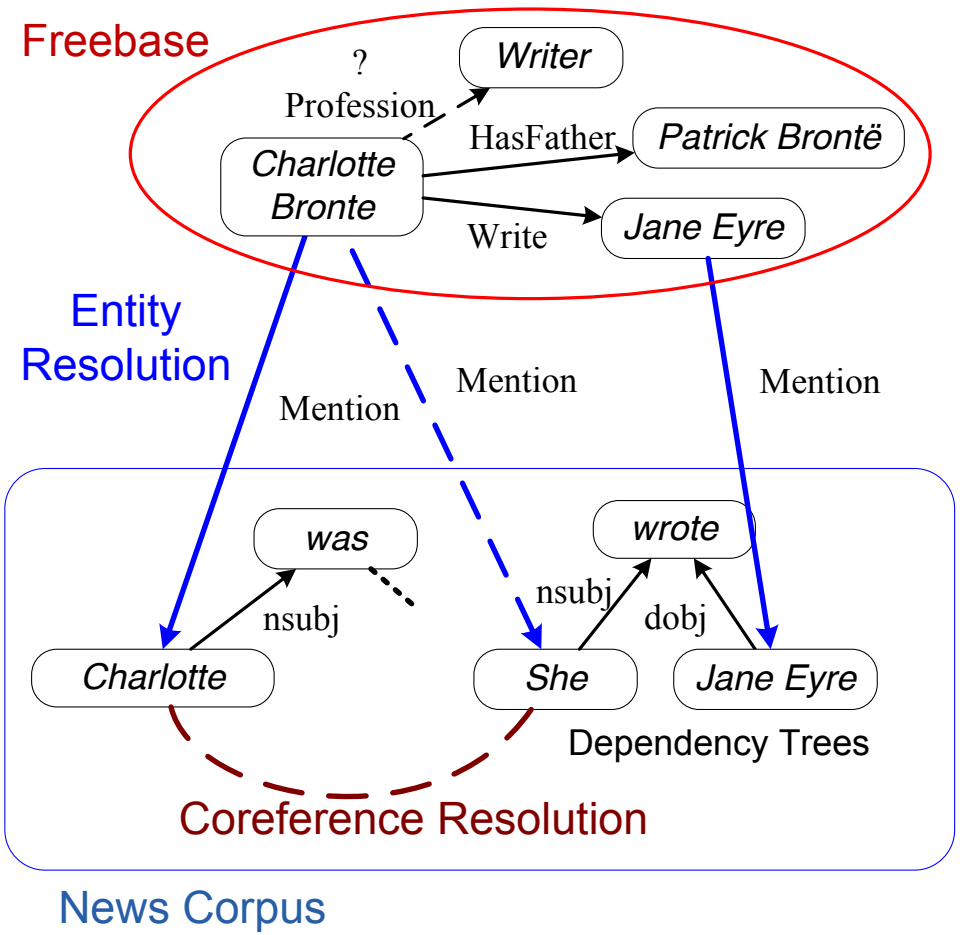


Entities ⇒ relations

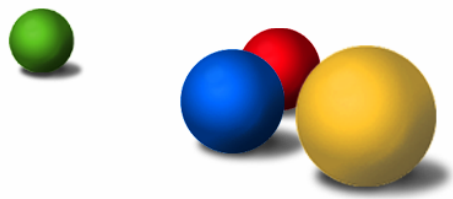
N. Lao, A. Subramanya, F. Pereira, W. Cohen *EMNLP* 2012



Joint KB+text inference



Path ranking algorithm (PRA): Lao and Cohen, *Machine Learning*, 2010



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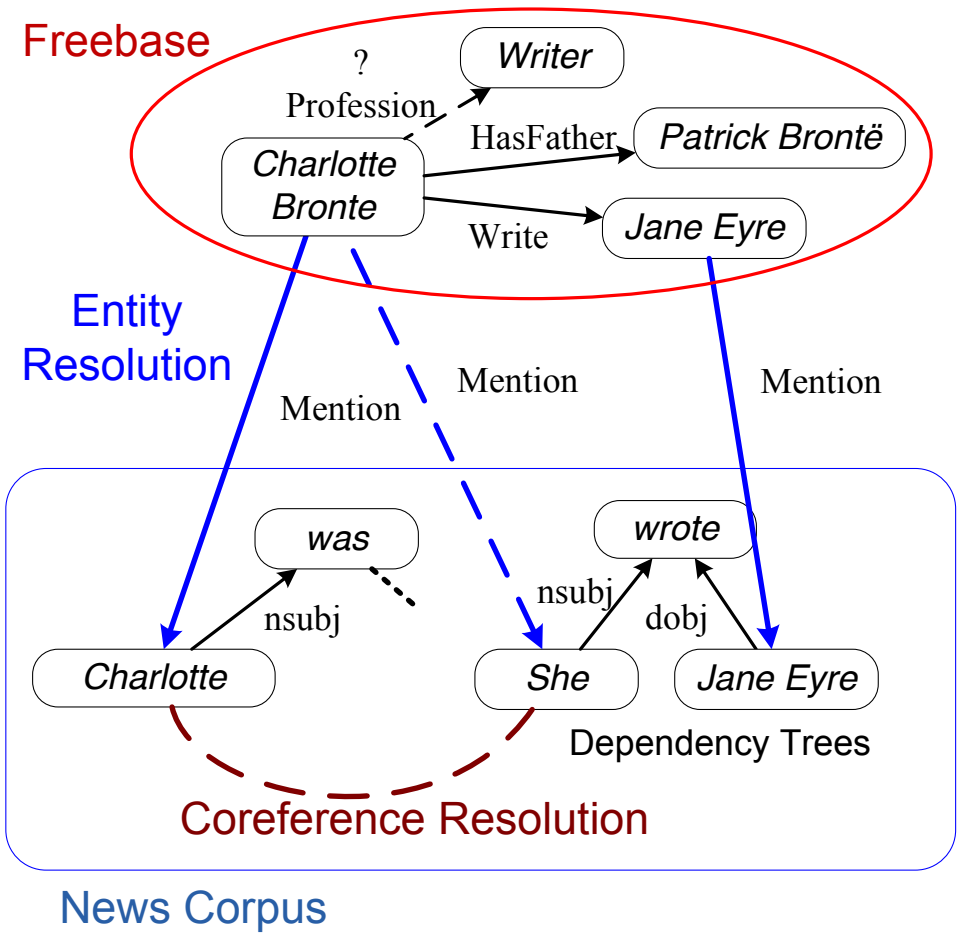

$$score(s,t) = \sum_{\pi \in B} P(s \rightarrow t; \pi)\theta_\pi$$

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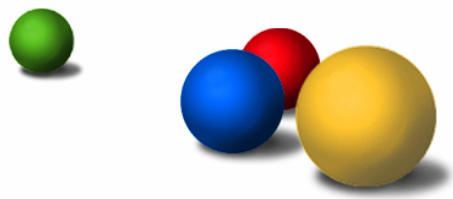

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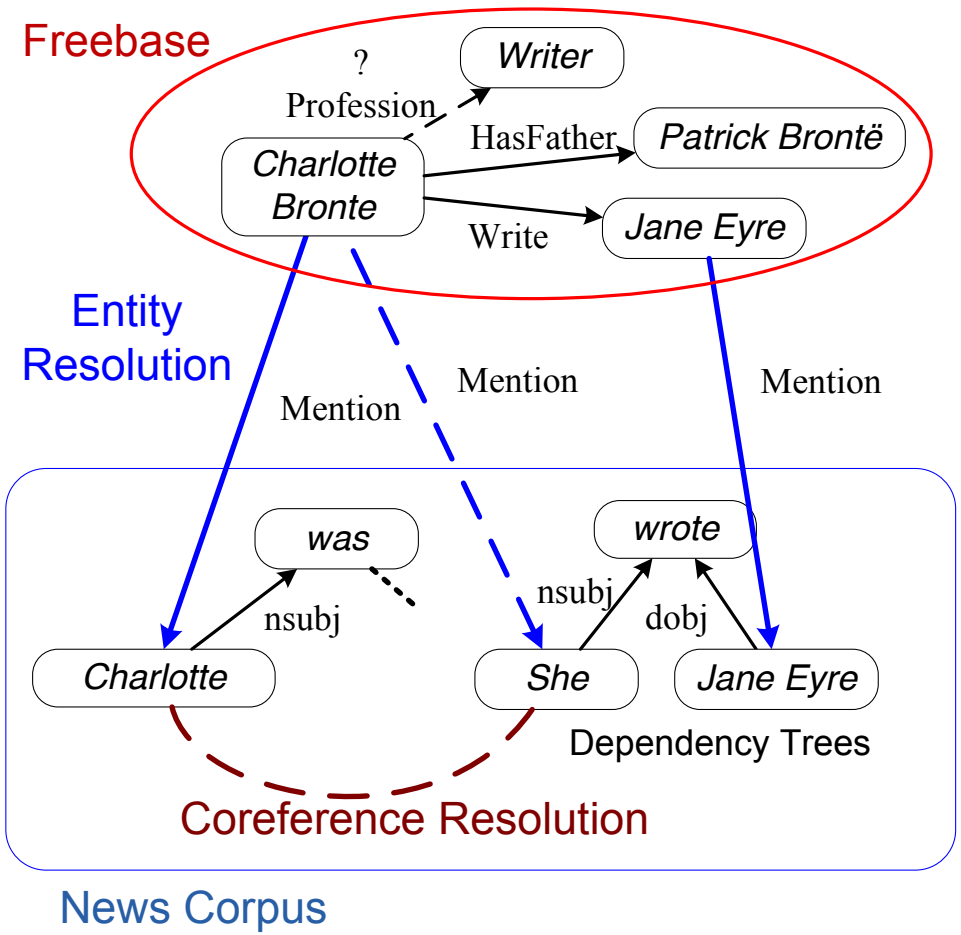

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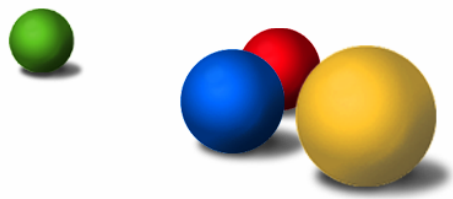

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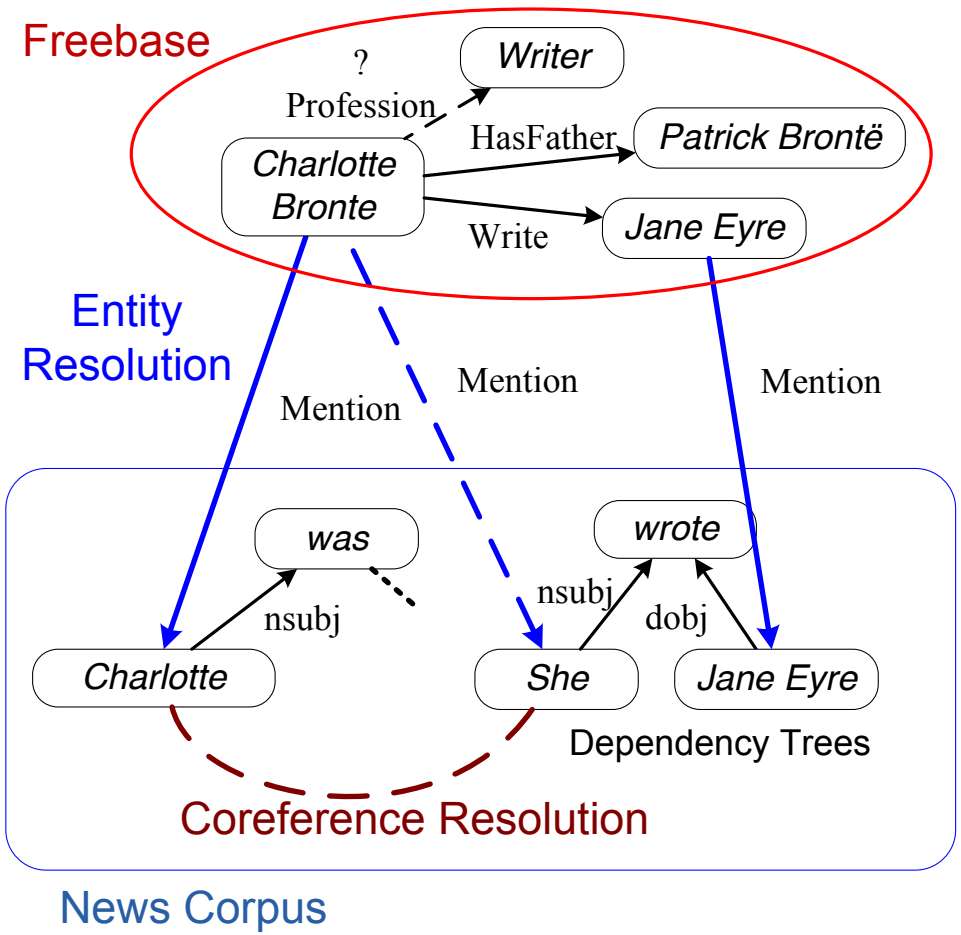

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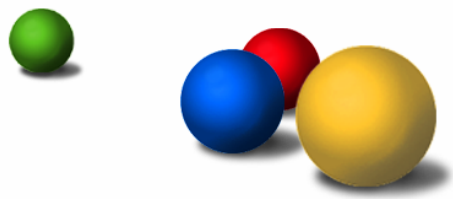

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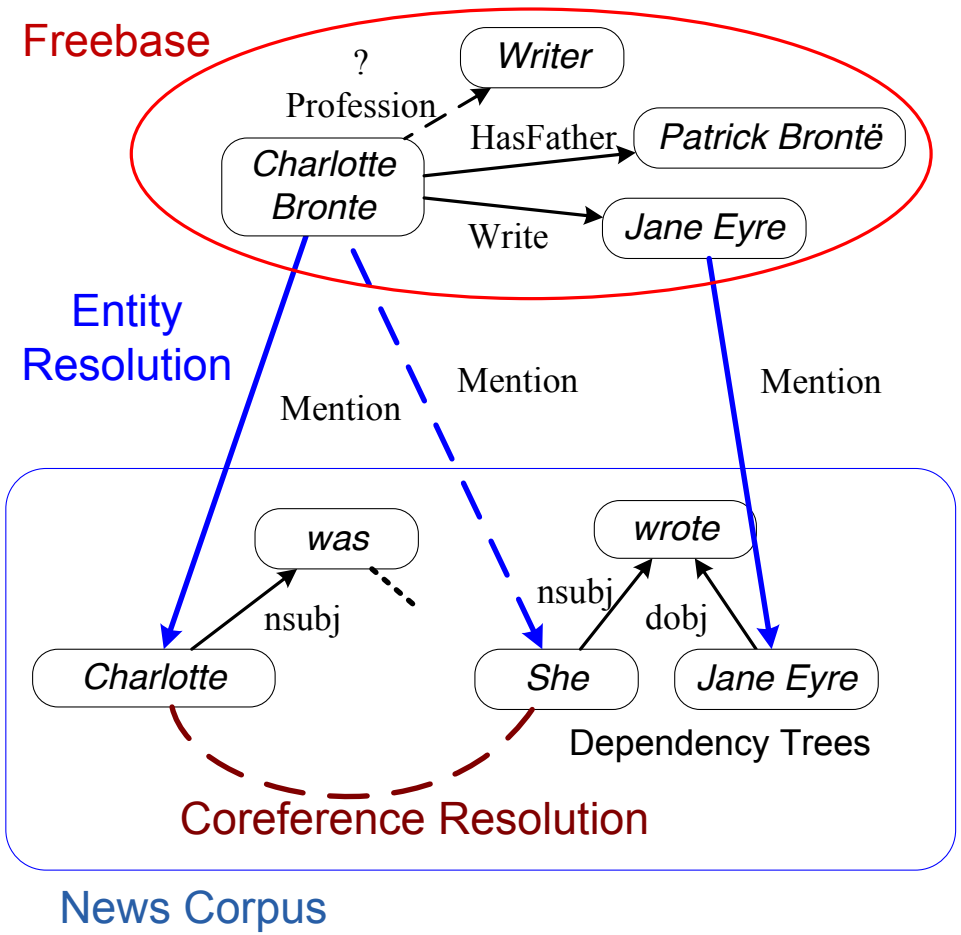

$$score(s,t) = \sum_{\pi \in B} P(s \to t; \pi)\theta_\pi$$

- Path types π: edge label sequences
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- Weights θ_π learned by logistic regression

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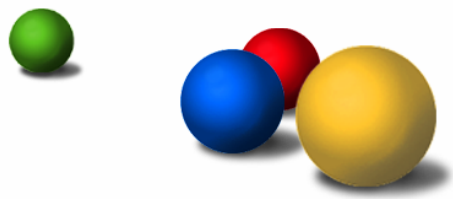
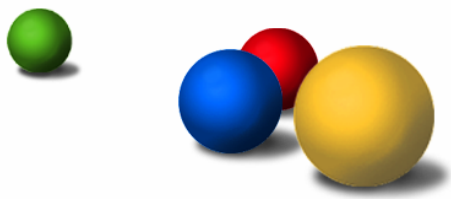
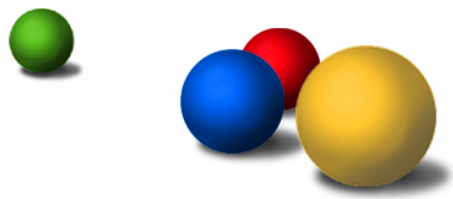


Case study: extending Freebase



Case study: extending Freebase

- Freebase: 21M concepts, 70M edges



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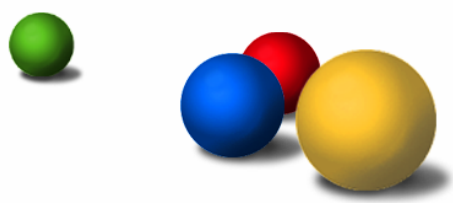

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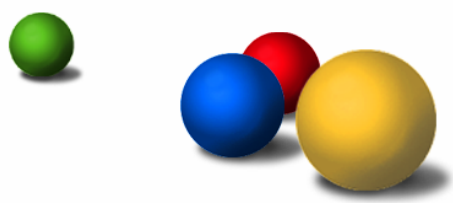

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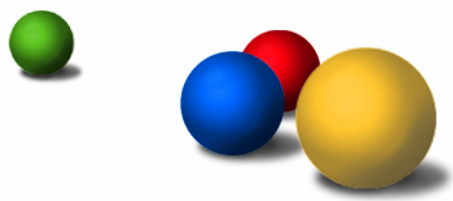

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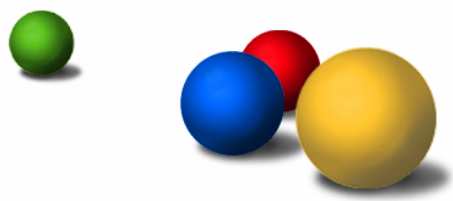

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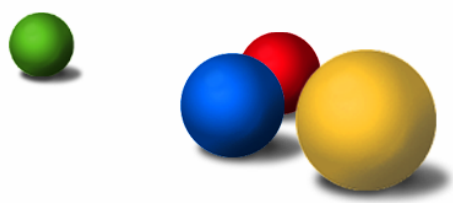
  - 2M people in Freebase



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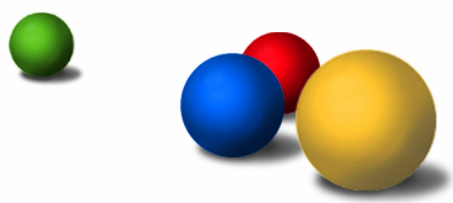
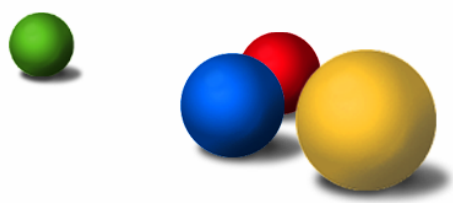
  - 2M people in Freebase
  - 0.3M have a recorded profession

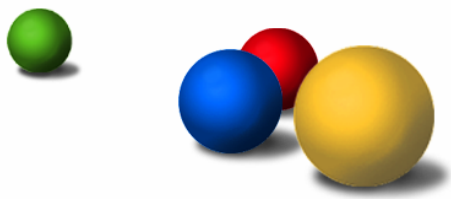


Case study: extending Freebase

- Freebase: 21M concepts, 70M edges
- 60M Web pages mention Freebase concepts relevant to this study
- Study relations: *profession, nationality, parent*
- Simplified entity resolution: most likely concept for named mentions in coref cluster
- *Profession* stats:
  - 2M people in Freebase
  - 0.3M have a recorded profession
  - Biased data (0.24M politicians, actors)

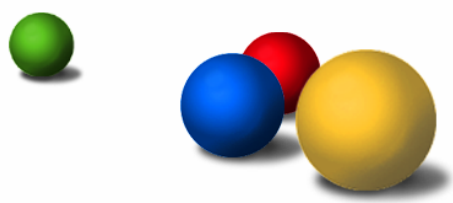


Selecting training data



Selecting training data

$$s \xrightarrow{\pi} t, |\pi| \leq 4$$



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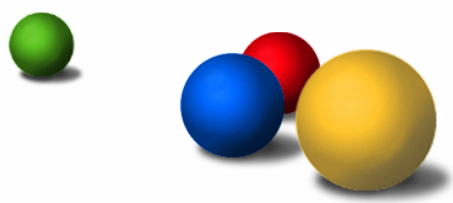
Positive: $r(s,t)$, downsample for popular s,t



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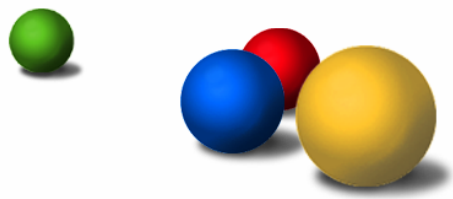

Selecting training data

$$s \xrightarrow{\pi} t, |\pi| \leq 4$$

Positive: $r(s,t)$, downsample for popular s,t

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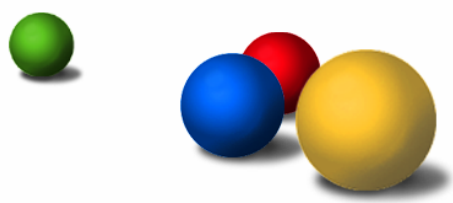
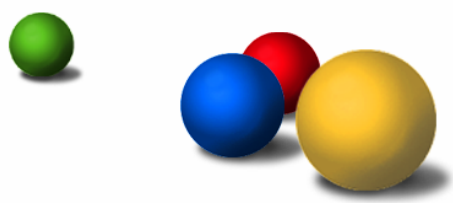
Task	Training Set	Test Set
Profession	22,829	15,219
Nationality	14,431	9,620
Parents	21,232	14,155



A Learned path for *profession*

$$\langle M, conj, M^{-1}, Profession \rangle$$



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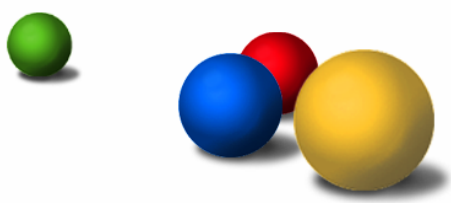

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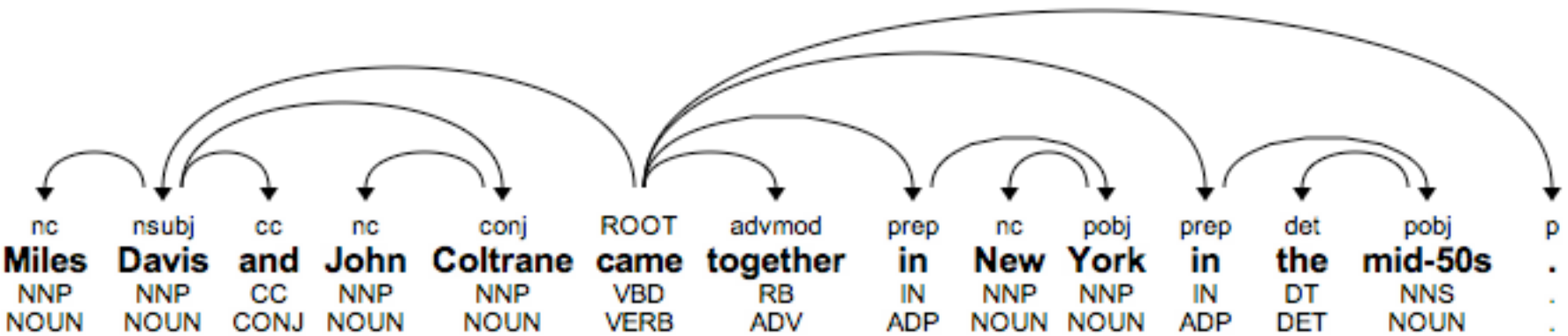

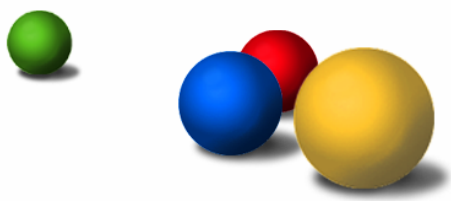

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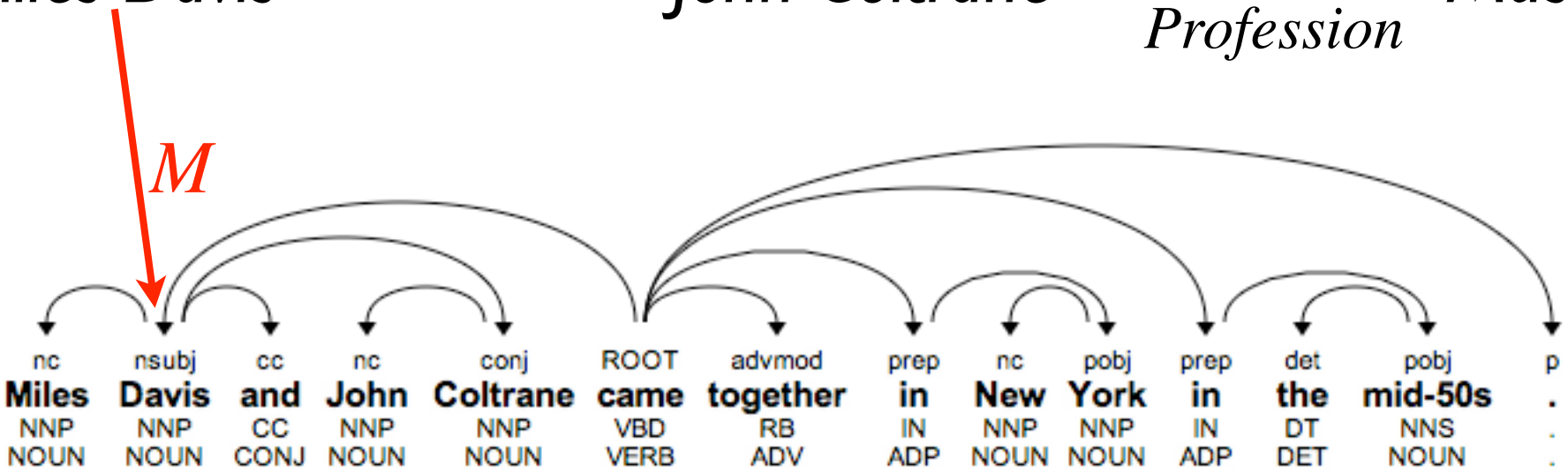
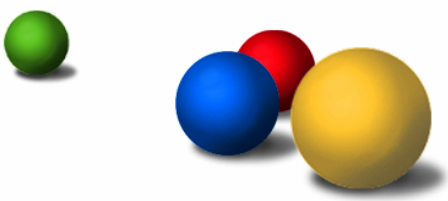
Profession





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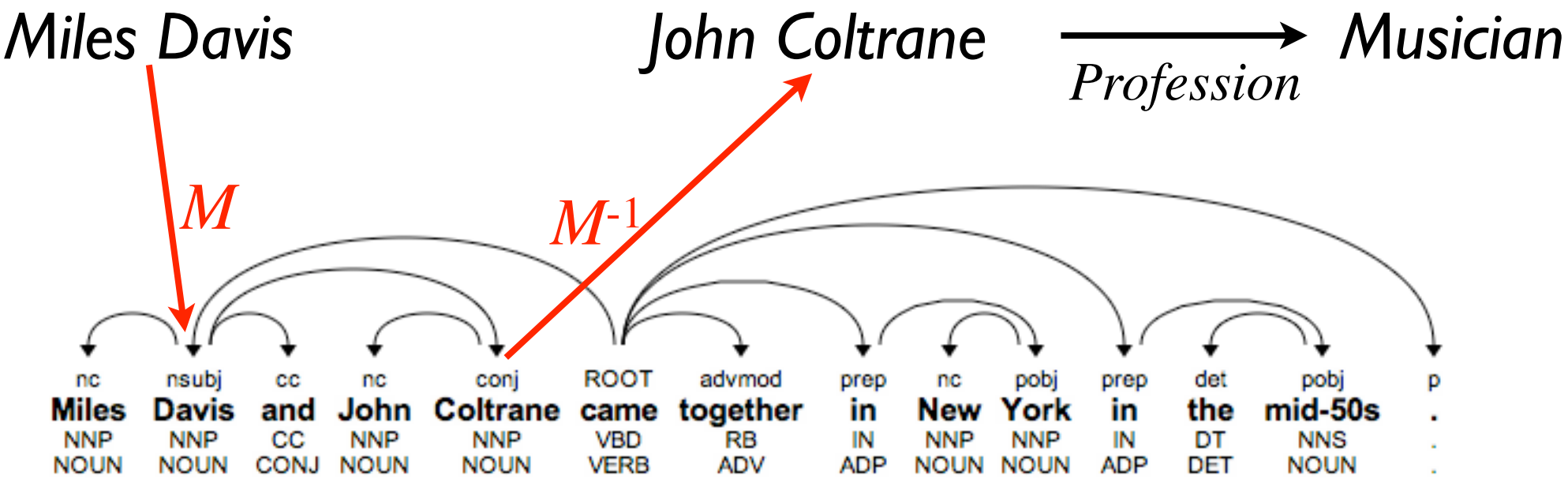
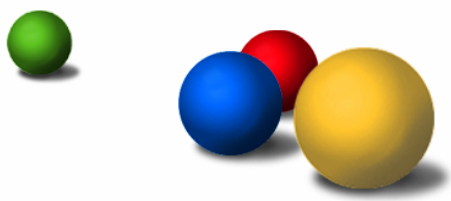
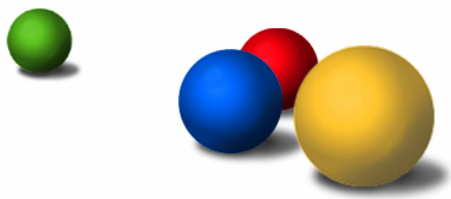




Relation extraction results

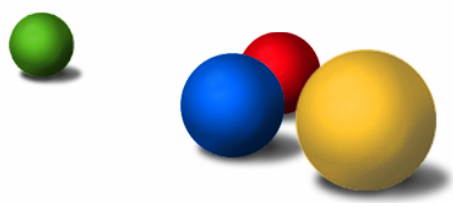


Relation extraction results

Known triples

Task	KB	Text	KB+Text	KB+Text[b]
Profession	0.532	0.516	**0.583**	0.453
Nationality	0.734	0.729	**0.812**	0.693
Parents	0.329	0.332	**0.392**	0.319

$$\text{MRR} = \frac{1}{|Q|} \sum_{q \in Q} \frac{1}{\text{rank of } q\text{'s first correct answer}}$$



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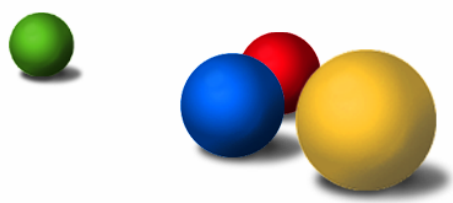
Human evaluation

Task	p@100	p@1k	p@10k
Profession	0.97	0.92	0.84
Nationality	0.98	0.97	0.90
Parents	0.86	0.81	0.79



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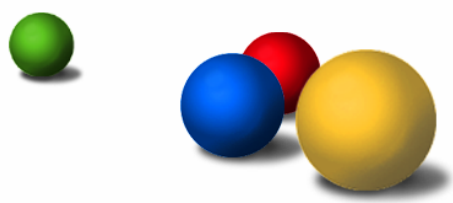
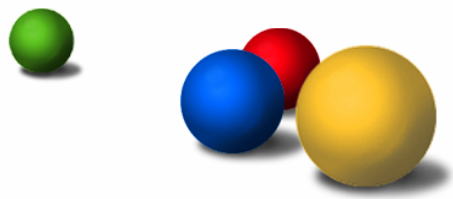
Coverage

Profession triples	People
1,000	970
10,000	8,726
100,000	79,885

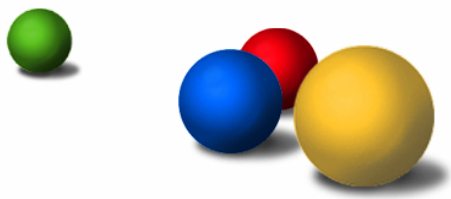


Scaling up

- Index text graph by entity mentions
- Explore short paths in parallel
- Aggregate path types with MapReduce

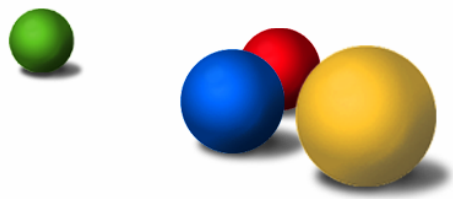


Better inference and learning



Better inference and learning

- Interactions between interpretation layers
  - entity knowledge helps parsing



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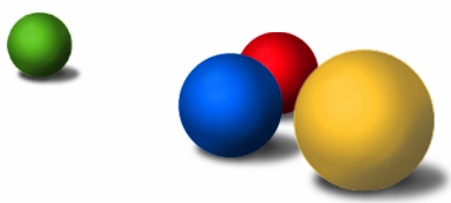

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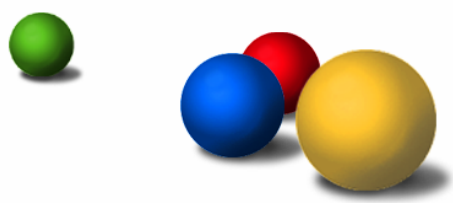
- Learn from mistakes
  - predict Wikipedia/Freebase edits



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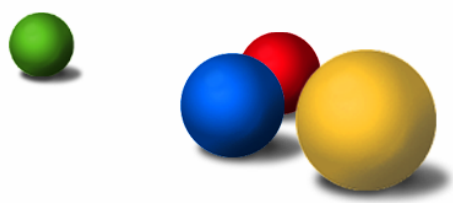
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  - most terms are just a few interpretations
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  - predict Wikipedia/Freebase edits
- Better generalization through latent features
  - unreliable context evidence for rare entities