

# Entities, Graphs, and Crowdsourcing for better Web Search

Gianluca Demartini

eXascale Infolab

University of Fribourg, Switzerland

[gianlucademartini.net](http://gianlucademartini.net)

[exascale.info](http://exascale.info)

# Gianluca Demartini



demartini@exascale.info

- M.Sc. at University of Udine, Italy
- Ph.D. at University of Hannover, Germany
  - Entity Retrieval
- Worked for UC Berkeley (on Crowdsourcing), Yahoo! Research (Spain), L3S Research Center (Germany)
- Post-doc at the **eXascale Infolab**, Uni Fribourg, Switzerland.
- Lecturer for *Social Computing* in Fribourg
- Tutorial on Entity Search at ECIR 2012, on Crowdsourcing at ESWC 2013 and ISWC 2013
- Research Interests
  - Information Retrieval, Semantic Web, Crowdsourcing

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6 personal results. 188,000,000 other results.

### [Tom Cruise - IMDb](#)

[www.imdb.com/name/nm0000129/](http://www.imdb.com/name/nm0000129/) ▾

**Tom Cruise**, Actor: Top Gun. If you had told 14 year old Franciscan seminary student Thomas Cruise Mapother IV that one day in the not too distant future he ...

Filmography by year - Biography - Rock of Ages - All You Need Is Kill

### [Tom Cruise - Wikipedia, the free encyclopedia](#)

[https://en.wikipedia.org/wiki/Tom\\_Cruise](https://en.wikipedia.org/wiki/Tom_Cruise) ▾

Thomas Cruise Mapother IV (/ˈtoʊməs ˈkruːz ˈmeɪpoʊθər/; born July 3, 1962), widely known as **Tom Cruise**, is an American film actor and producer. He has ...

Tom Cruise filmography - Katie Holmes - Mimi Rogers - List of awards and ...

### [Official Tom Cruise: Oblivion, Movies, Video, Biography, News ...](#)

[www.tomcruise.com/](http://www.tomcruise.com/) ▾

Official **Tom Cruise** site: Get the latest Rock of Ages trailer, info & downloads! Watch career movie trailers, videos, and retrospective. Read the **Tom Cruise** ...

### [TomCruise.com \(TomCruise\) on Twitter](#)

<https://twitter.com/TomCruise> ▾

The latest from **TomCruise.com** (@TomCruise). Official <http://TomCruise.com> TeamTC tweets. Does Tom Tweet? Sometimes between family & movies & its ...

### [Tom Cruise | Facebook](#)

<https://www.facebook.com/officialtomcruise> ▾

**Tom Cruise**. 3883109 likes · 76956 talking about this. Welcome to the Official [www.TomCruise.com](http://www.TomCruise.com) team Facebook page! **Tom Cruise** news, events, pics & video ...



## Tom Cruise

[Follow](#)

Actor

Thomas Cruise Mapother IV, widely known as Tom Cruise, is an American film actor and producer. He has been nominated for three Academy Awards and has won three Golden Globe Awards. He started his career at age 19 in the 1981 film Taps. [Wikipedia](#)

**Born:** July 3, 1962 (age 50), [Syracuse, New York, United States](#)

**Height:** 5' 7" (1.70 m)

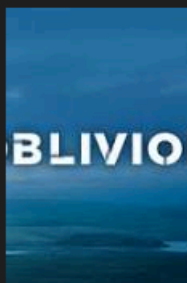
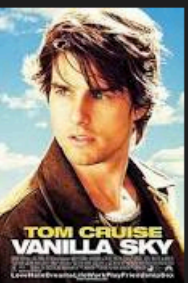
**Upcoming movie:** [All You Need Is Kill](#)

**Spouse:** [Katie Holmes](#) (m. 2006–2012), [Nicole Kidman](#) (m. 1990–2001), [Mimi Rogers](#) (m. 1987–1990)

**Children:** [Suri Cruise](#), [Connor Cruise](#), [Isabella Jane Cruise](#)



## Tom Cruise movies

Oblivion  
2013Jack Reacher  
2012Mission:  
Impossible – G...  
2011Rock of Ages  
2012Top Gun  
1986Knight and Day  
2010Minority Report  
2002Eyes Wide Shut  
1999Vanilla Sky  
2001[Tom Cruise - IMDb](#)[www.imdb.com/name/nm0000129/](http://www.imdb.com/name/nm0000129/) ▾

**Tom Cruise**, Actor: **Top Gun**. ... **Movies**. In Theaters; Top 250; US Box Office; Coming Soon; Trailer Gallery; Watch Now on AIV; On DVD ... **Tom Cruise** and Olga Kurylenko at event of **Oblivion** Still of **Tom Cruise** and Mia Sara in Legend Tom ...

[Filmography by year](#) - [Biography](#) - [Rock of Ages](#) - [All You Need Is Kill](#)

[Tom Cruise filmography - Wikipedia, the free encyclopedia](#)[en.wikipedia.org/wiki/Tom\\_Cruise\\_filmography](http://en.wikipedia.org/wiki/Tom_Cruise_filmography) ▾

**Tom Cruise** is an American **film** actor and producer. The following is a ... 1981, Endless Love, Billy, Tom plays a boy who jokingly tells about committing arson.

[Filmography](#) - [See also](#) - [References](#) - [External links](#)

[Official Tom Cruise: Oblivion, Movies, Video, Biography, News ...](#)[www.tomcruise.com/](http://www.tomcruise.com/) ▾

Official **Tom Cruise** site: Get the latest **Rock of Ages** trailer, info & downloads! Watch career **movie** trailers, videos, and retrospective. Read the **Tom Cruise** ...

[Tom Cruise | Movies and Biography - Yahoo! Movies](#)[movies.yahoo.com/person/tom-cruise/](http://movies.yahoo.com/person/tom-cruise/) ▾

**Movies**. The biggest star in the world for 20 years, **Tom Cruise** stood atop the ...

## Tom Cruise

Actor

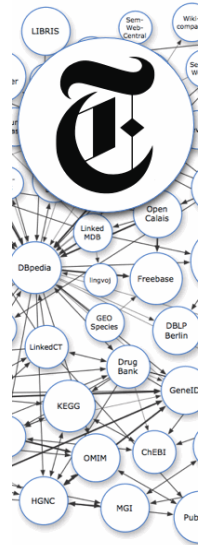
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**Born:** July 3, 1962 (age 50), Syracuse, New York, United States**Height:** 5' 7" (1.70 m)**Upcoming movie:** [All You Need Is Kill](#)**Spouse:** [Katie Holmes](#) (m. 2006–2012), [Nicole Kidman](#) (m. 1990–2001), [Mimi Rogers](#) (m. 1987–1990)**Children:** [Suri Cruise](#), [Connor Cruise](#), [Isabella Jane Cruise](#)

# Web of Data

- Freebase
  - Acquired by Google in July 2010.
  - Knowledge Graph launched in May 2012.
- Schema.org
  - Driven by major search engine companies
  - Machine-readable annotations of Web pages
- Linked Open Data
  - 31 billion triples, Sept. 2011





# Linked Open Data

## LOD cloud



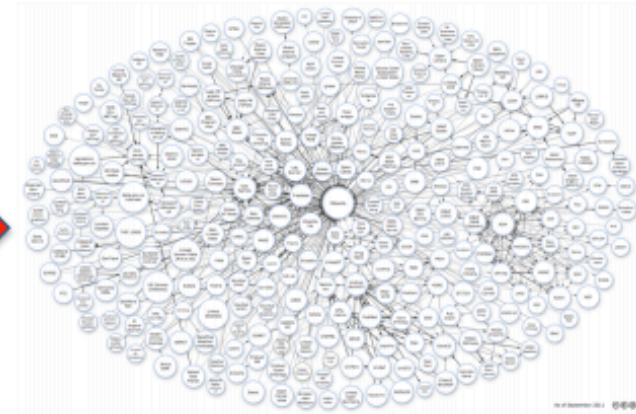
2007



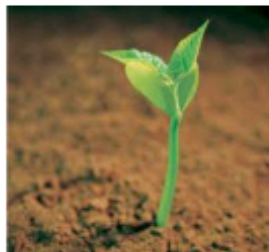
2008



2009



2011



# I will talk about

- Entity Linking/Disambiguation
  - On the Web using crowdsourcing
  - For Data Integration / For Entity Type Ranking
- Ad-hoc Object Retrieval (Entity Ranking)
  - Using IR and graphs
- Crowdsourced Query Understanding

# Disclaimer

- No efficiency evaluation
  - Approaches not distributed
  - But designed to scale out
- No user studies
  - Goal: Obtain high quality data
  - Only TREC-like evaluation on effectiveness



# Entity Linking/Disambiguation

# Facebook Buys Instagram for \$1 Billion

BY EVELYN M. RUSLI

2:02 p.m. | Updated

Facebook is not waiting for its initial public offering to make its first big purchase.

In its largest acquisition to date, the social network has purchased Instagram the popular photo-sharing application, for about \$1 billion in cash and stock, the company said Monday.



<http://dbpedia.org/resource/Facebook>

HTML:

<p>Facebook is not waiting for its initial public offering to make its first big purchase.</p><p>In its largest acquisition to date, the social network has purchased Instagram, the popular photo-sharing application, for about \$1 billion in cash and stock, the company said Monday.</p>

<http://dbpedia.org/resource/Instagram>

owl:sameAs

fbase:Instagram

RDFa  
enrichment

<p><span about="http://dbpedia.org/resource/Facebook"><cite property="rdfs:label">Facebook</cite> is not waiting for its initial public offering to make its first big purchase.</span></p><p><span about="http://dbpedia.org/resource/Instagram">In its largest acquisition to date, the social network has purchased <cite property="rdfs:label">Instagram</cite>, the popular photo-sharing application, for about \$1 billion in cash and stock, the company said Monday.</span></p>

CNET > News > Mobile

## Instagram for Android is now available

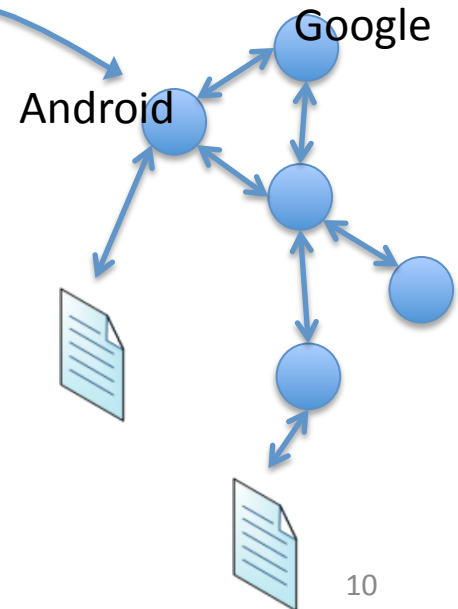
At long last, Instagram finally releases the Android version of its app.



by Jason Cipriani | April 3, 2012 10:07 AM PDT

Follow

Instagram has been around since 2010, available only to iOS devices. Android users have been waiting patiently, with repeated promises of an Android version arriving soon.





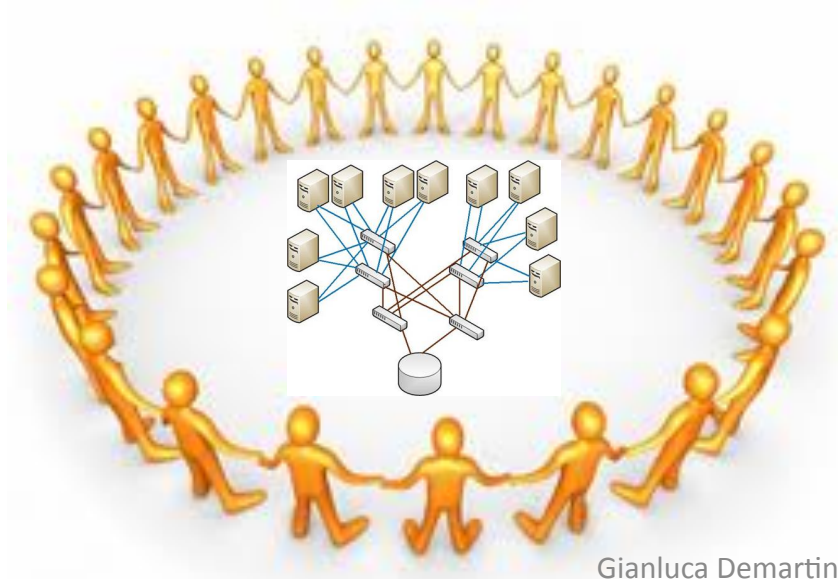
# Crowdsourcing

- Exploit human intelligence to solve
  - Tasks simple for humans, complex for machines
  - With a large number of humans (the Crowd)
  - Small problems: micro-tasks (Amazon MTurk)
- Examples
  - Wikipedia, Image tagging
- Incentives
  - Financial, fun, visibility

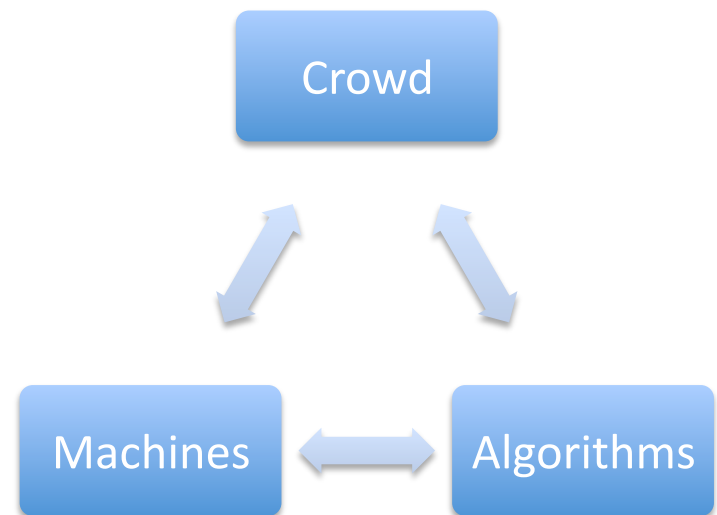


# ZenCrowd

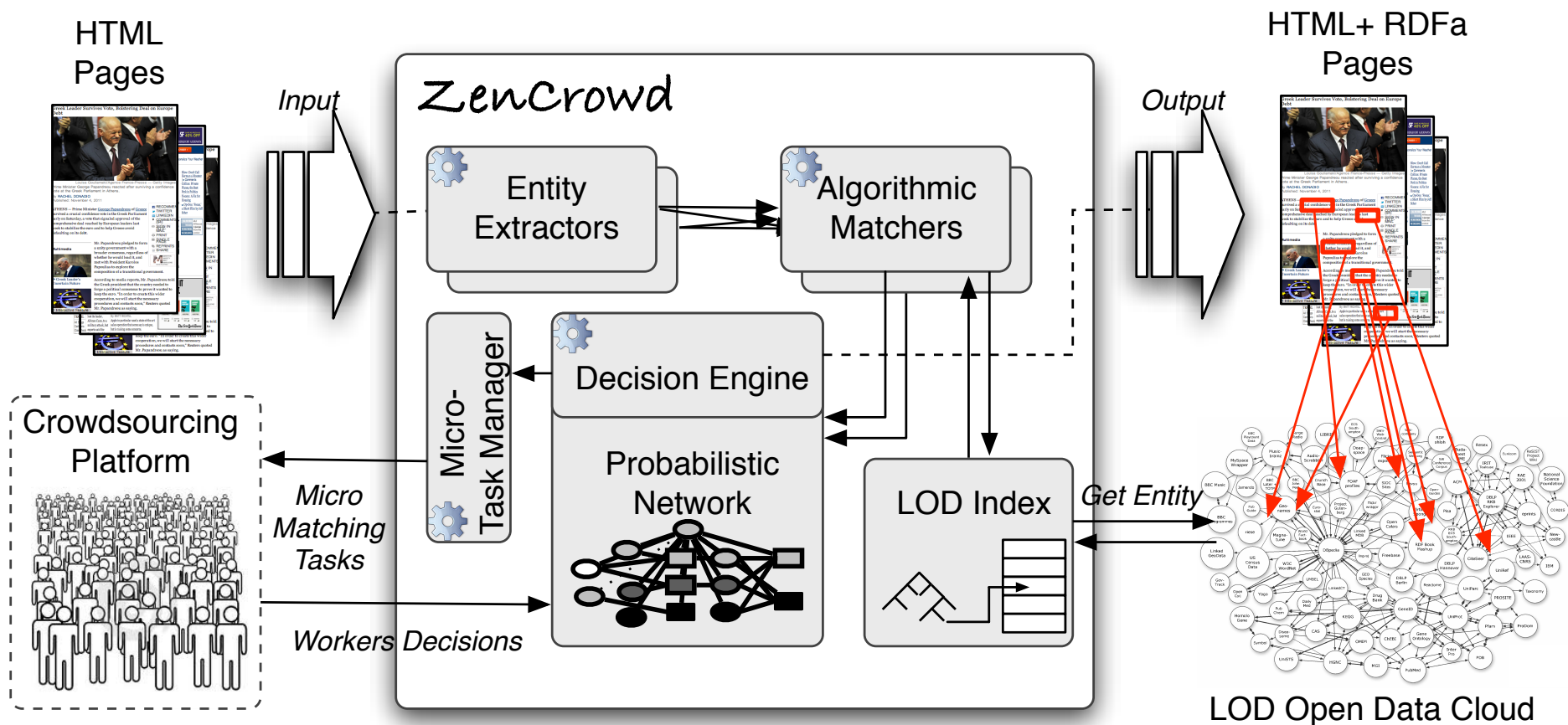
- Combine both algorithmic and manual linking
- Automate manual linking via crowdsourcing
- Dynamically assess human workers with a probabilistic reasoning framework



Gianluca Demartini



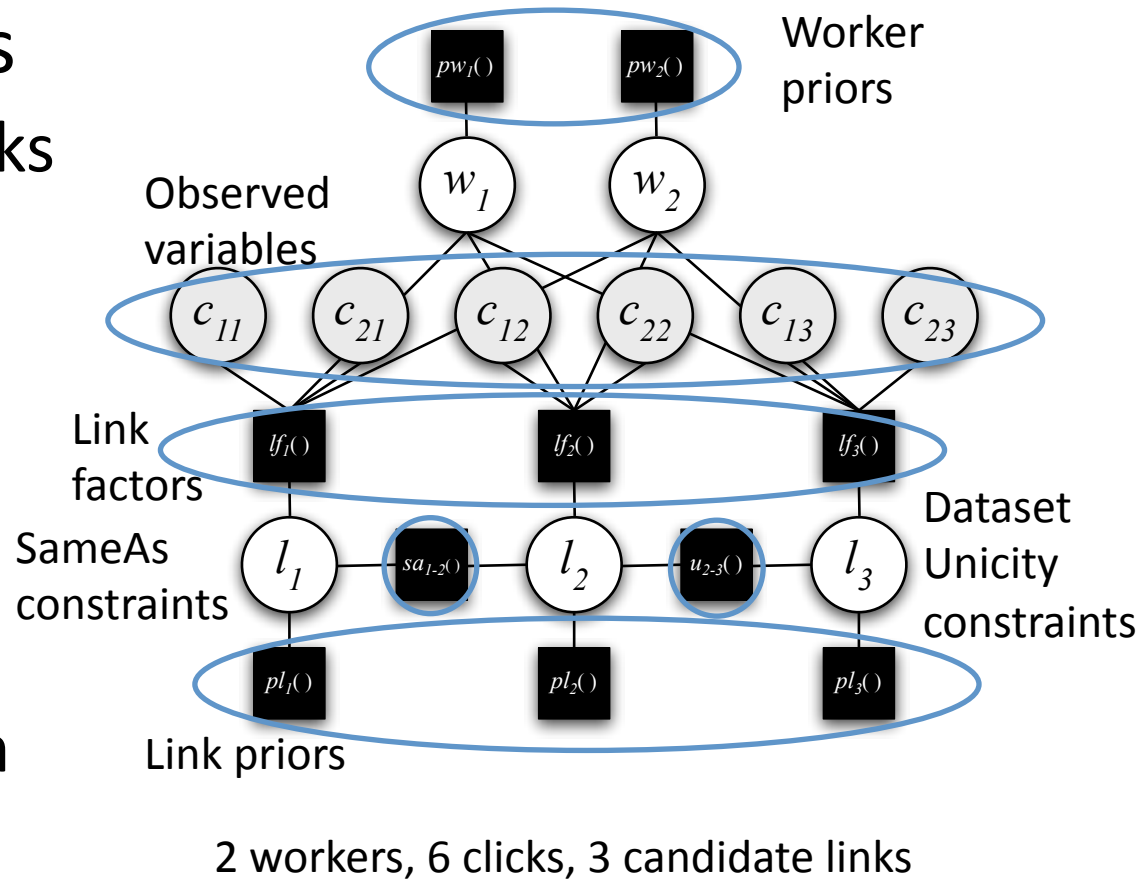
# ZenCrowd Architecture



Gianluca Demartini, Djellel Eddine Difallah, and Philippe Cudré-Mauroux. ZenCrowd: Leveraging Probabilistic Reasoning and Crowdsourcing Techniques for Large-Scale Entity Linking. In: 21st International Conference on World Wide Web (**WWW 2012**).

# Entity Factor Graphs

- Graph components
  - Workers, links, clicks
  - Prior probabilities
  - Link Factors
  - Constraints
- Probabilistic Inference
  - Select all links with posterior prob  $> \tau$





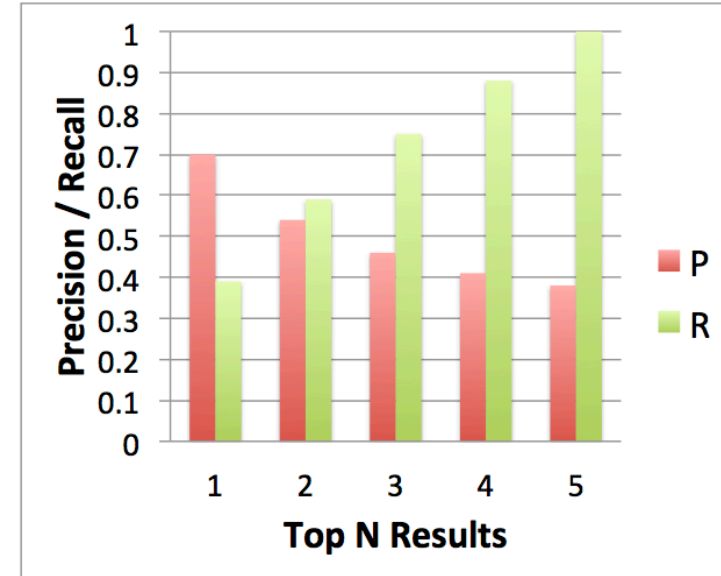
# Experimental Evaluation

- Datasets

- 25 news articles from

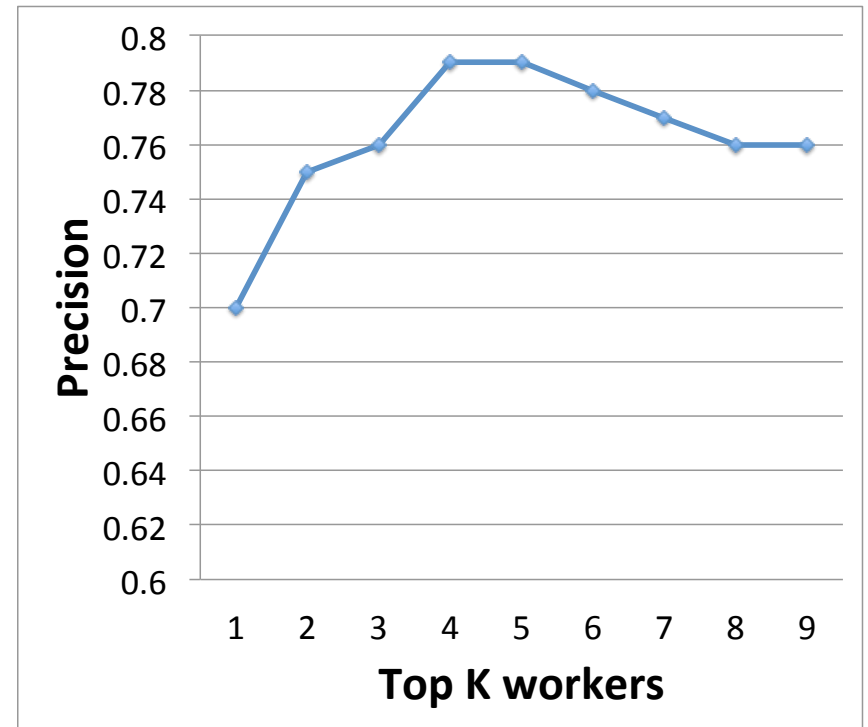
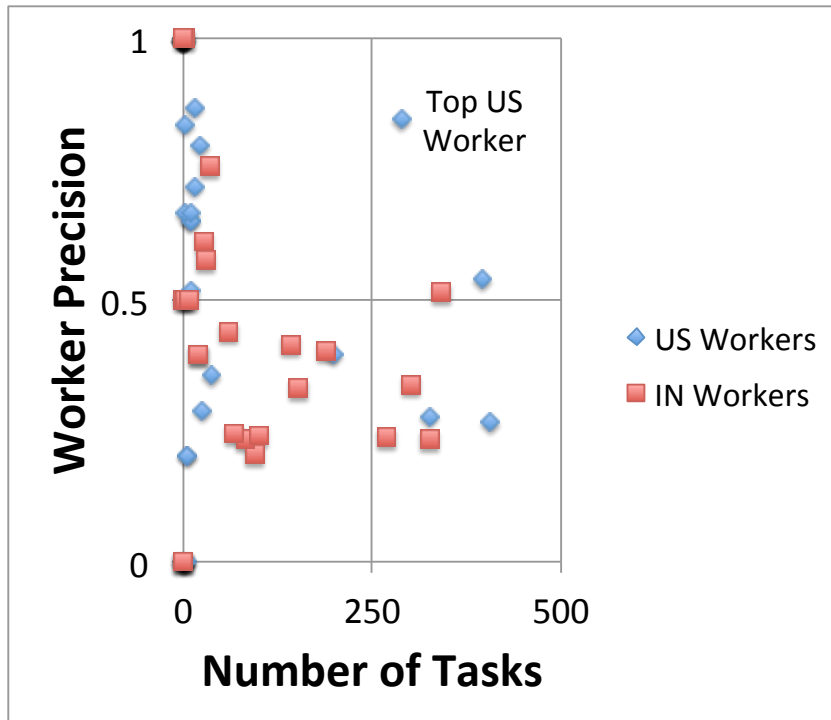
- CNN.com (Global news)
    - NYTimes.com (Global news)
    - Washington-post.com (US local news)
    - Timesofindia.indiatimes.com (India news)
    - Swissinfo.com (Switzerland local news)

- 40M entities (Freebase, DBPedia, Geonames, NYT)



	US Workers			Indian Workers		
	P	R	A	P	R	A
GL News	0.84	0.87	0.90	0.67	0.64	0.78
US News	0.64	0.68	0.78	0.55	0.63	0.71
IN News	0.84	0.82	0.89	0.75	0.77	0.80
SW News	0.72	0.80	0.85	0.61	0.62	0.73
All News	0.80	0.81	0.88	0.64	0.62	0.76

# Worker Selection

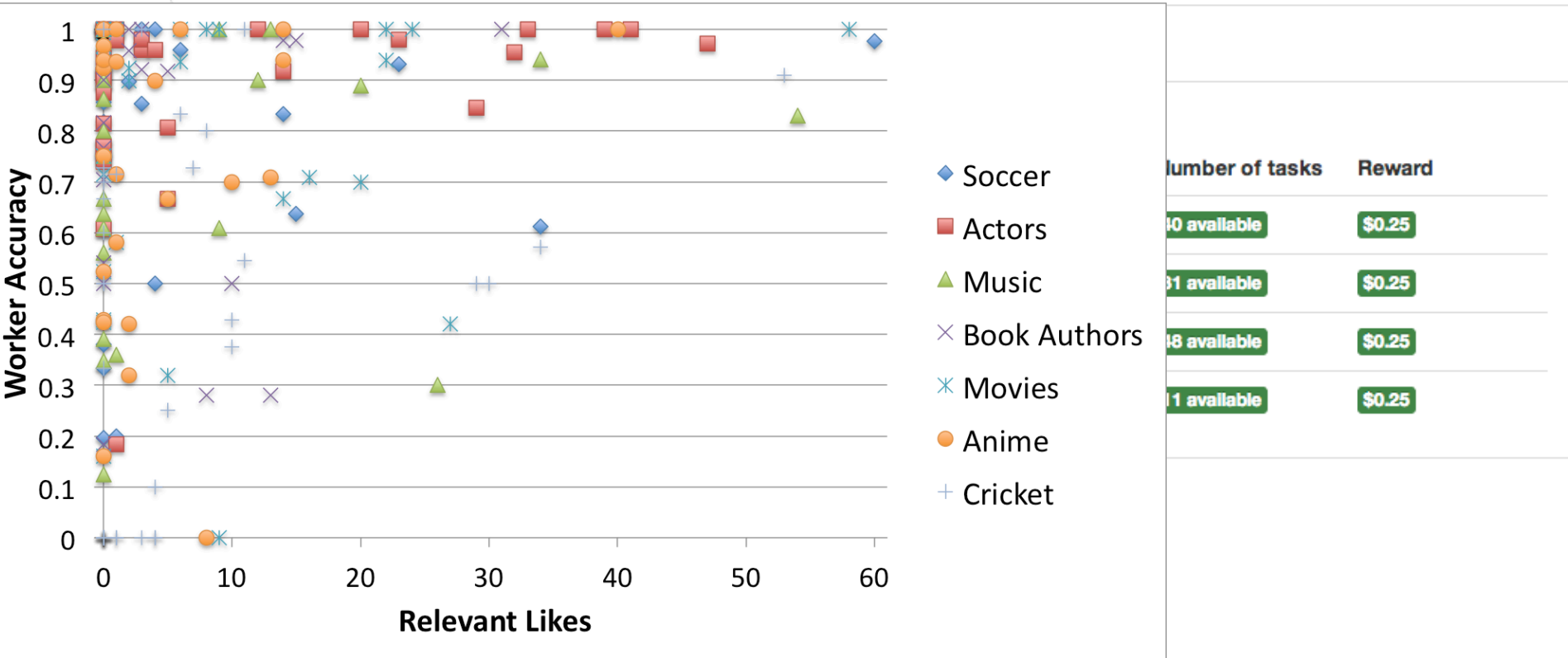


# Lessons Learnt

- Crowdsourcing + Prob reasoning works!
- But
  - Different worker communities perform differently
  - Many low quality workers
  - Completion time may vary (based on reward)
- Need to find the right workers for your task (see WWW13 paper)

### My customized list of batches:

Batch			
Batch description	Challenge	Number of tasks	Reward
Football players identifications	Recommend	5	Completed\$0.25
What movie is this scene from?	Recommend	931 available	\$0.25
Comics, mangas and characters	Recommend	541 available	For Fun



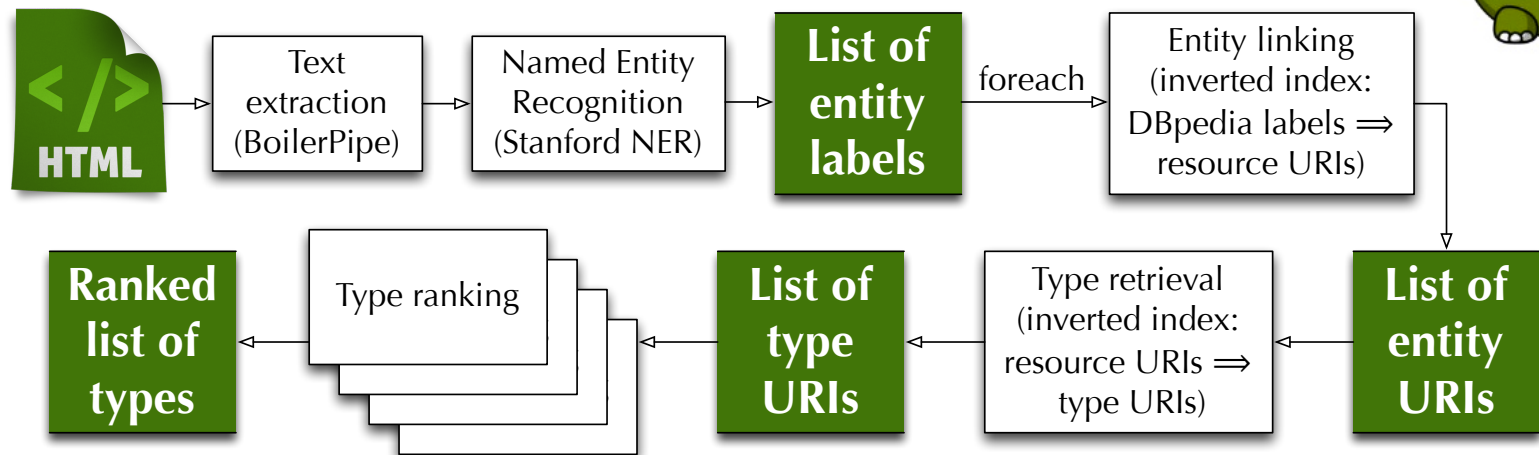
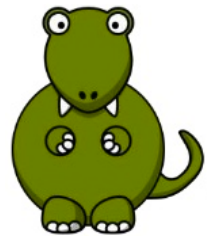
# ZenCrowd Summary

- ZenCrowd: Probabilistic reasoning over automatic and crowdsourcing methods for entity linking
- Standard crowdsourcing improves 6% over automatic
- 4% - 35% improvement over standard crowdsourcing
- 14% average improvement over automatic approaches

<http://exascale.info/zencrowd/>

# On top of Entity Linking

- Follow-up works:
  - Also used for instance matching across datasets
  - Ranking Entity *Types*: see TRank at ISWC13, nominated for best paper award





# Three-stage blocking with the Crowd for Data Integration

- 1. Cheap clustering/inverted index selection of candidates
- 2. Expensive similarity measure
- 3. Crowdsourced low confidence matches

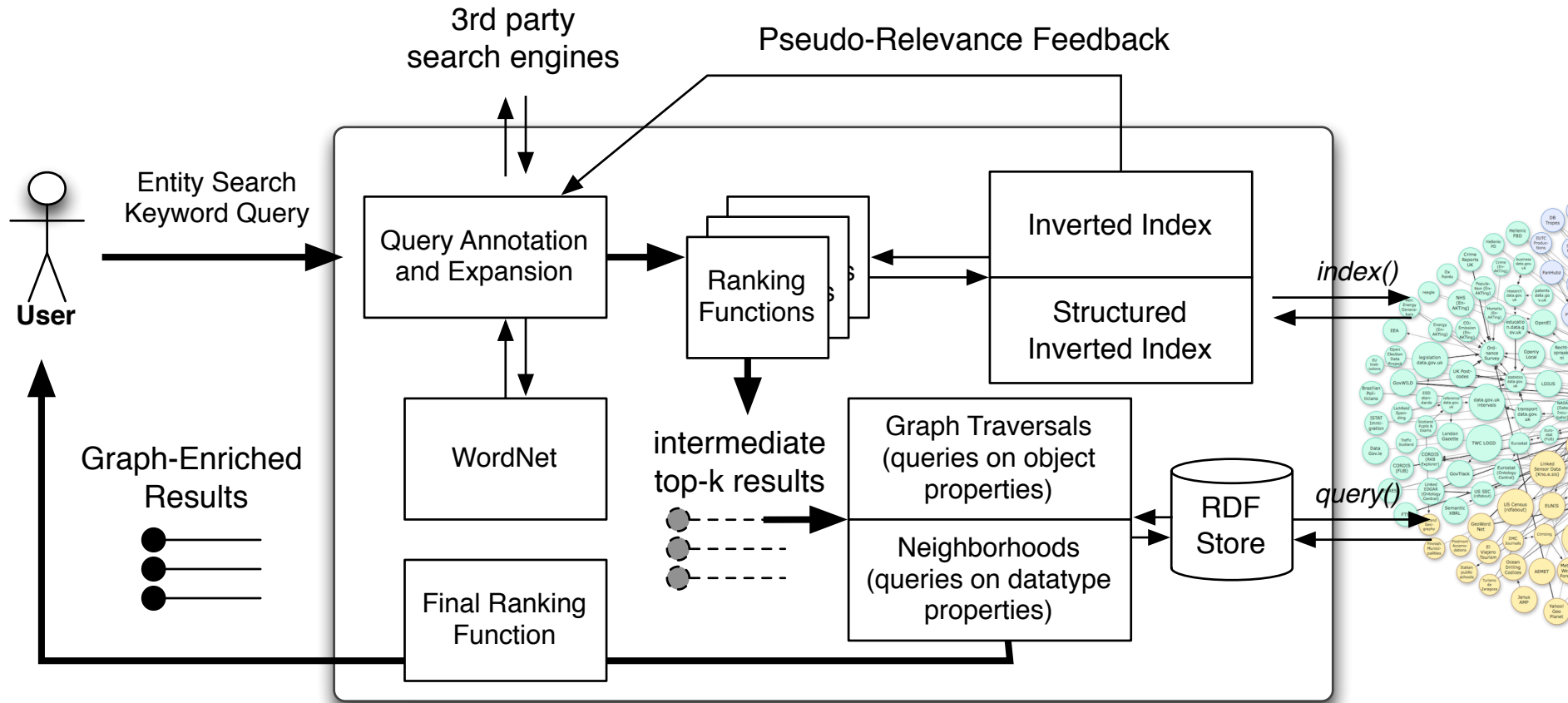
Gianluca Demartini, Djellel Eddine Difallah, and Philippe Cudré-Mauroux. Large-Scale Linked Data Integration Using Probabilistic Reasoning and Crowdsourcing. In: **VLDB Journal**, Volume 22, Issue 5 (2013), Page 665-687, Special issue on Structured, Social and Crowd-sourced Data on the Web. October 2013.

# Entity Ranking

# Ad-hoc Object Retrieval

- Once entities have been identified...
- We want to rank them as answer to a query
- AOR
  - Given the description of an entity
  - give me back its identifier
  - Input: query  $q$ , data graph  $G$
  - Output: ranked list of URIs from  $G$

# An Hybrid Approach to AOR



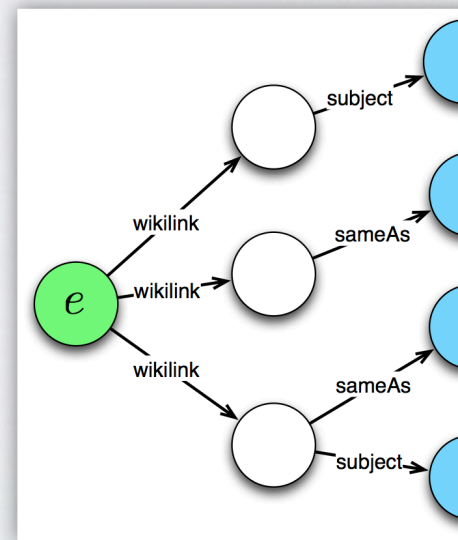
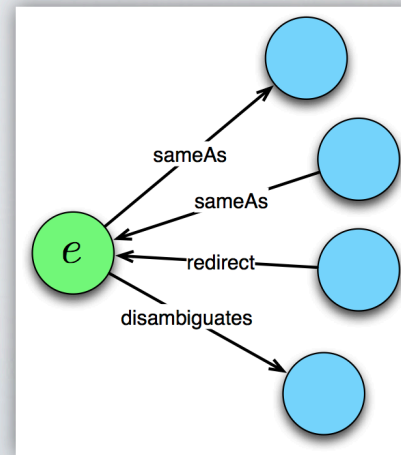
Alberto Tonon, Gianluca Demartini, and Philippe Cudré-Mauroux. Combining Inverted Indices and Structured Search for Ad-hoc Object Retrieval. In: 35th Annual ACM SIGIR Conference (**SIGIR 2012**).

# AOR Evaluation

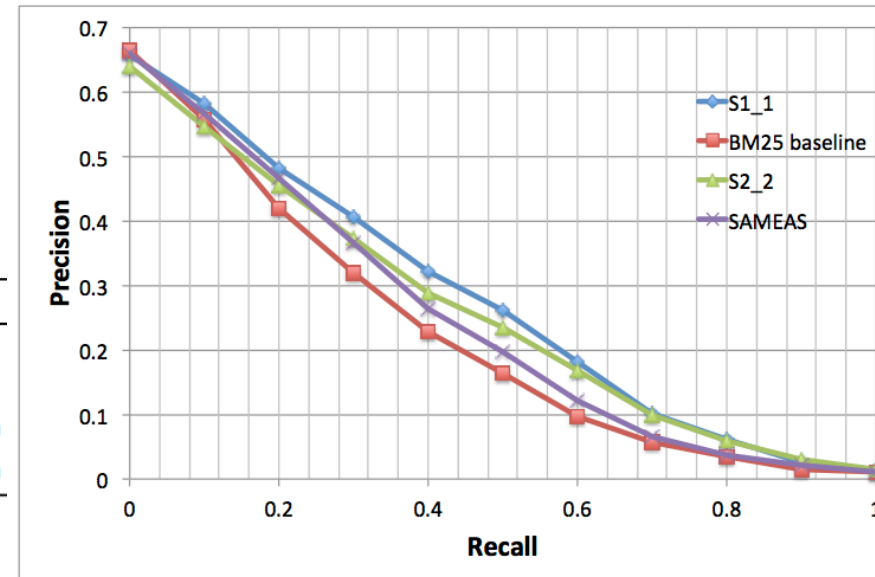
- 1.3 billions RDF triples from LOD cloud
- 92 and 50 queries
- Crowdsourced relevance judgments
- [semsearch.yahoo.com](http://semsearch.yahoo.com)

# Evaluation Results

	2010 Collection	
	MAP	P10
BM25	0.2070	0.3348
SAMEAS	0.2293* (+11%)	0.363* (+8%)
S1_1	<b>0.2586*</b> (+25%)	<b>0.3848*</b> (+15%)
S1_2	0.2305* (+11%)	0.3217 (-4%)
S1_3	0.2306* (+11%)	0.3217 (-4%)
S2_1	0.2118 (+2%)	0.3370 (+1%)
S2_2	0.2118 (+2%)	0.3370 (+1%)
S2_3	0.2113 (+2%)	0.3402 (+2%)



Approach	IR time	RDF time	Total time
BM25 Baseline	285	-	285
Extension	580	-	580 (+104%)
Query Autoc.	1447	-	1447 (+408%)
PRF3	2670	-	2670 (+837%)
SAMEAS	285	30	315 (+11%)
S1_1	285	48	333 (+17%)
S1_2	285	84	369 (+29%)
S1_3	285	86	371 (+30%)
S2_1	285	1746	2031 (+613%)
S2_2	285	2192	2477 (+769%)
S2_3	285	105	390 (+37%)





# Summary

- AOR = *“Given the description of an entity, give me back its identifier”*
- Combining classic IR techniques + structured database storing graph data
- Significantly better results (up to +25% MAP over BM25 baseline).
- Overhead caused from the graph traversal part is limited

<http://exascale.info/AOR/>

# CrowdQ: Crowdsourced Query Understanding

# birthdate of mayor of capital city of france



The image is a screenshot of a Google search results page. At the top, the Google logo is on the left, and a search bar contains the text "birthdate of mayor of capital city of france". To the right of the search bar is a microphone icon and a blue search button with a magnifying glass. Below the search bar, there are tabs for "Web", "Images", "Maps", "Shopping", "More", and "Search tools". The "Web" tab is selected and underlined. Below the tabs, it says "About 13,800,000 results (0.20 seconds)". The first search result is titled "France Cities Map, Major Cities of France" in blue, with the URL "www.mapsofworld.com > France > Facts" in green. The snippet below it says "Dec 21, 2012 – Paris is the **capital** of **France**, as well as the largest **city** in the country with a population of over 2 million, and a metropolitan area population of ...". The second search result is titled "Nice - Wikipedia, the free encyclopedia" in blue, with the URL "en.wikipedia.org/wiki/Nice" in green. The snippet below it says "Giuseppe Garibaldi, **born** in Nice, strongly opposed the cession to **France** (arguing ... Two men dominated this period: Jean Médecin, **mayor** for 33 years from 1928 ... However, it is also the largest **city** in **France** that is not a regional **capital**; the ...". The third search result is titled "Rouen - Wikipedia, the free encyclopedia" in blue, with the URL "en.wikipedia.org/wiki/Rouen" in green. The snippet below it says "In the 14th century urban strife threatened the city: in 1291, the **mayor** was ... Rouen became the **capital city** of English power in occupied **France** and when the duke .... Isaac Oliver (c.1560–1617), French-**born** English portrait miniature painter ...".

Google

birthdate of mayor of capital city of france

Web Images Maps Shopping More Search tools

About 13,800,000 results (0.20 seconds)

[France Cities Map, Major Cities of France](#)  
[www.mapsofworld.com > France > Facts](#)  
Dec 21, 2012 – Paris is the **capital** of **France**, as well as the largest **city** in the country with a population of over 2 million, and a metropolitan area population of ...

[Nice - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Nice](#)  
Giuseppe Garibaldi, **born** in Nice, strongly opposed the cession to **France** (arguing ...  
Two men dominated this period: Jean Médecin, **mayor** for 33 years from 1928 ...  
However, it is also the largest **city** in **France** that is not a regional **capital**; the ...

[Rouen - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Rouen](#)  
In the 14th century urban strife threatened the city: in 1291, the **mayor** was ... Rouen became the **capital city** of English power in occupied **France** and when the duke .... Isaac Oliver (c.1560–1617), French-**born** English portrait miniature painter ...

# capital city of france

Google

capital city of france

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## Paris

France, Capital

[Paris - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Paris](http://en.wikipedia.org/wiki/Paris)  
Coordinates: 48°51′24″N 2°21′03″E﻿ / ﻿48.8567°N 2.3508°E﻿ / 48.8567; 2.3508. **Paris** is the **capital** and largest **city of France**. It is situated on the river ...  
[List of tourist attractions in Paris](#) - [History of Paris](#) - [Demographics of Paris](#) - [Paris FC](#)




[France facts, capital city, currency, flag, language, landforms, land ...](#)  
[www.worldatlas.com](http://www.worldatlas.com) > [Europe](#) > [France](#)  
Name: **France** (long form) French Republic; **Capital City**: **Paris** (2,193,031 pop.) ( 44,826,870 metro); **France Population**: (2010 est.) **World Populations** (all



## Paris

Paris is the capital and largest city of France. It is situated on the river Seine, in northern France, at the heart of the Île-de-France region. The city of Paris, within its administrative limits, has a population of about 2,230,000. [Wikipedia](#)

# mayor of paris

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About 98,900,000 results (0.20 seconds)

## Bertrand Delanoë

Paris, Mayor

[List of mayors of Paris - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/List\\_of\\_mayors\\_of\\_Paris](http://en.wikipedia.org/wiki/List_of_mayors_of_Paris)  
Before the French Revolution, the municipality of **Paris** was headed by the provost of the merchants (prévôt des marchands). On 14 July 1789, at the end of the ...

[Bertrand Delanoë - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Bertrand\\_Delanoë](http://en.wikipedia.org/wiki/Bertrand_Delanoë)  
Delanoë has been **mayor of Paris** since 18 March 2001, when control of the city council ... Delanoë won the **mayorship of Paris**, at the head of a coalition of Socialists, .... City Mayors: **Bertrand Delanoë – Mayor of Paris**; ^ "Psychiatric tests for ...  
[Early life](#) - [Career](#) - [Personal life](#) - [Political career](#)






[Letter to the mayor of Paris, re: No skyscrapers! | Architecture Here ...](#)  
[blogs.providencejournal.com/.../letter-to-the-mayor-of-paris-re-no-...](http://blogs.providencejournal.com/.../letter-to-the-mayor-of-paris-re-no-...)  
Nov 24, 2012 – Anyway, here is my letter: Nov. 24, 2012. Mr. **Bertrand Delanoë Mayor of Paris** Place de l'Hotel de Ville Paris, France 75004. Dear Mr. Delanoë: ...

## Bertrand Delanoë

Bertrand Delanoë is a French politician, and has been the mayor of Paris since 2001. He is member of the Socialist Party. Delanoë was born in Tunis, Tunisia to a French-Tunisian father and a French mother. [Wikipedia](#)




**Born:** May 30, 1950 (age 62), [Tunis](#)  
**Party:** Socialist Party

People also search for

 <a href="#">Martine Aubry</a>	 <a href="#">Jacques Chirac</a>	 <a href="#">Jean Tiberi</a>	 <a href="#">Ségolène Royal</a>	 <a href="#">Lionel Jospin</a>
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[Feedback](#) / [More info](#)

# birthdate of Bertrand Delanoë

 birthdate of Bertrand Delanoë  

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About 1,800,000 results (0.14 seconds)

## May 30, 1950 (age 62 years)

Bertrand Delanoë, Date of birth


[Bertrand Delanoë - Wikipedia, the free encyclopedia](#)  
[en.wikipedia.org/wiki/Bertrand\\_Delanoë](http://en.wikipedia.org/wiki/Bertrand_Delanoë)  
Bertrand Delanoë was born 30 May 1950 in Tunis, to an atheist father (a land ... At the age of 11, Delanoë witnessed the Battle of Bizerte between France and ...

[Bertrand Delanoë - Wikipédia](#)  
[fr.wikipedia.org/wiki/Bertrand\\_Delanoë](http://fr.wikipedia.org/wiki/Bertrand_Delanoë) - Translate this page  
Bertrand Delanoë, né le 30 mai 1950 à Tunis (Tunisie, alors sous protectorat français), est un homme politique français. Membre du Parti socialiste, conseiller ...

[Quel âge a Bertrand Delanoë ? - Age des Célébrités](#)  
[www.age-des-celebrites.com/age-de-bertrand-dela...](http://www.age-des-celebrites.com/age-de-bertrand-dela...) - Translate this page  
Age de Bertrand Delanoë Date de naissance de Bertrand Delanoë

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Ads ⓘ

[Looking for a Birthday?](#)  
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Find **Birthday** by Name or Phone.  
Get Phone, Address, Age Instantly.

[Date Of Birth](#)  
[www.ask.com/Date+Of+Birth](http://www.ask.com/Date+Of+Birth)  
Search for **Date Of Birth**.  
Find Answers on Ask.com.

[Free Birth Records](#)



# Motivation

- Web Search Engines can answer simple factual queries directly on the result page
- Users with complex information needs are often unsatisfied
- Purely automatic techniques are not enough
- We want to solve it with Crowdsourcing!

# CrowdQ

- CrowdQ is the first system that uses crowdsourcing to
  - *Understand* the intended meaning
  - *Build* a structured query template
  - *Answer* the query over Linked Open Data

Gianluca Demartini, Beth Trushkowsky, Tim Kraska, and Michael Franklin. CrowdQ: Crowdsourced Query Understanding. In: 6th Biennial Conference on Innovative Data Systems Research (**CIDR 2013**).

# Hybrid Human-Machine Pipeline

Q= birthdate of actors of forrest gump

Query annotation

Noun

Noun

Named entity

Verification

Is forrest gump this entity in the query?

Entity Relations

Which is the relation between: actors and forrest gump → starring

Schema element

Starring → <dbpedia-owl:starring>

Verification

Is the relation between:  
**Indiana Jones – Harrison Ford**  
**Back to the Future – Michael J. Fox**  
of the same type as  
**Forrest Gump - actors**

# Structured query generation

Q= birthdate of actors of fo

MOVIE

SELECT ?y ?x

WHERE { ?y <dbpedia-owl:birthdate> ?x .

?z <dbpedia-owl:starring> ?y .

?z <rdfs:label> 'Fo

MOVIE

Results from BTC09:

```
<http://dbpedia.org/resource/Robin_Wright_Penn> 1966-04-08  
<http://dbpedia.org/resource/Tom_Hanks> 1956-07-09  
<http://dbpedia.org/resource/Sally_Field> 1946-11-06  
<http://dbpedia.org/resource/Gary_Sinise> 1955-03-17  
<http://dbpedia.org/resource/Mykelti_Williamson> 1960-03-04
```

# Conclusions

- Structured Data make Web Search better
- Exploit the best out of structured and unstructured data (Hybrid AOR)
- Crowd can help in understanding semantics
- Hybrid human-machine systems (ZenCrowd)
- Exploit Human Intelligence at Scale (CrowdQ)