



24TH INTERNATIONAL
WORLD WIDE WEB CONFERENCE

Florence 18 - 22 May 2015

An Introduction to Entity Recommendation and Understanding

Hao Ma and Yan Ke

Microsoft

The contents and opinions described in this tutorial do not necessarily reflect the opinions of Microsoft.

Technologies mentioned might or might not be in actual use.

Motivation

Database?

NLP?



Application?

Goals of this Tutorial

- Help identify many interesting applications in the field of Entity Recommendation and Understanding
- Present the current state of research on related topics
- Pinpoint challenging research problems



Outline

- Introduction to Entity and Knowledge
- Demonstration of Microsoft's Entity Experience
- Entity Recommendation and Understanding
 - $P(\textit{entity}|\textit{entity})$
 - $P(\textit{entity}|\textit{user})$
 - $P(\textit{entity}|\textit{query})$
- Summary

Outline

- Introduction to Entity and Knowledge
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 - $P(\text{entity}|\text{query})$
- Summary

Introduction to Entity and Knowledge

Why “Entities”

bing MS Beta

florence

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46,100,000 RESULTS Any time ▾

[Florence - Wikipedia, the free encyclopedia](#)

en.wikipedia.org/wiki/Florence ▾

Florence is the capital city of the Italian region of Tuscany and of the province of Florence. It is the most populous city in Tuscany, with approximately 380,000 ...

[History](#) · [Geography](#) · [Government](#) · [Main sights](#) · [Demographics](#) · [Economy](#)

[TripAdvisor Florence - Travel & Tourism for Florence, Italy](#)

www.tripadvisor.com > ... > Italy > Tuscany > Province of Florence ▾

Florence Tourism: TripAdvisor has 585,444 reviews of Florence Hotels, Attractions, and Restaurants making it your best Florence resource.

[Florence, Italy: Tourist Travel Guide for Holidays in ...](#)

www.visitflorence.com ▾

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[Florence Welch broke her foot at Coachella](#)

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Florence Welch of Florence + the Machine performs at the 2015 Coachella festival. (Photo: Scott Roth, Invision/AP) Captivating the Coachella crowd can cost...

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florence places to go

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[Best Places to Visit in Florence, Italy | The Duomo ...](#)

www.thereareplaces.com/newguidebook/pdest/itflonpts.htm ▾

The Best Places to Visit in Florence described above include the most popular tourist attractions in Firenze. Florence offers great restaurants, yummy gelato shops ...

[Top Sights and Attractions in Florence, Italy](#)

goitaly.about.com > ... > What to See in Florence ▾

Here are the top must-see places and tourist attractions in Florence. Find out what to see and do on your visit to Florence, Italy.

[Places to visit in Florence - Andreea Francu](#)

andreea.francu.com/travel/florence.vr/places.vr ▾

Places to visit in Florence. ... in the front of the church is a good place for taking a break. Rest on the steps in front of Dante's statue and watch the world go by.

[Top 19 Places to Visit in Florence: Check out Florence ...](#)

www.tripadvisor.in > ... > South Carolina (SC) > Florence ▾

Top 19 places to visit in Florence, South Carolina: See TripAdvisor's 109 traveller reviews and photos of Florence attractions.

[The Shoals, Alabama - Places To Go, Restaurants and ...](#)

alabama.travel/places-to-go/the-shoals ▾

The Shoals area of Alabama is the birthplace of some of America's most influential music. Explore Florence, Muscle Shoals and Helen Keller's childhood...

[Things to do in Florence with kids - KY on FAMILYdaysOUT ...](#)

www.familydaysout.com/kids-things-to-do-usa/florence/ky ▾

Fun things to do in Florence for kids - Kentucky - all colour coded by category - great places to go with children and family attractions to visit - preschoolers play

anding, F

Why “Entities”



florence nearby cities

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[Cities near Florence, Italy - Travelmath](#)

www.travelmath.com/cities-near/Florence ▾

What are some other cities, towns, and suburbs near Florence, Italy? Find the closest city and explore the surrounding area.

[11 Reviews of Cities Not to Miss Near Florence in Florence](#)

www.virtualltourist.com > ... > Italy > Tuscany > Florence > Favorites ▾

Cities Not to Miss Near Florence Florence tips from real travelers and locals in Florence, Italy

[Cities near Florence , Kentucky - Travelmath](#)

www.travelmath.com/cities-near/Florence, KY ▾

What are some other cities, towns, and suburbs near Florence, KY? Find the closest city and explore the surrounding area.

[List of Cities near Florence in Toscana, Italy - GoMapper](#)

www.gomapper.com/travel/list-of-cities-near/florence-toscana.html ▾

The closest cities, towns, suburbs/localities and places to Florence in Toscana, Italy are listed below in order of increasing distance.

[Cities and Towns near Florence | MyTravelGuide.com](#)

www.mytravelguide.com > Attractions ▾

Cities and towns near Florence - MYTravelGuide - Reviews and research on all Hotels Restaurants and more. Plan your next trip at MyTravelGuide.



florence oregon

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Also try: [Florence Oregon Weather](#) · [Florence Oregon Lodging](#) · [Florence Oregon ...](#)

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[Florence Oregon coast tourism vacations hotels travel ...](#)

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For business, relocation, or vacation - you will find the Florence Oregon Coast to be the perfect setting for tranquility, relaxation ...

[Attractions](#)

Local Within An Hour . Oregon Dunes
40 miles of dunes, many ...

[Relocation](#)

Relocation information for Florence
Oregon on the Oregon coast. ...

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Florence Oregon Hotel Reviews. Park
Motel ... FLORENCE : Fish ...

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www.ci.florence.or.us ▾

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Why “Entities”



florence

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Florence is the capital city of the Italian region of Tuscany and of the province of Florence. It is the most populous city in Tuscany, with approximately 380,000 ...
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Visit Florence, one of the most beautiful cities in Italy and center of Italian Renaissance. Our travel guide helps you plan your holidays in Florence, Italy.

[News about Florence](#)

bing.com/news



[Florence Welch broke her foot at Coachella](#)

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Florence Welch of Florence + the Machine performs at the 2015 Coachella festival. (Photo: Scott Roth, Invision/AP) Captivating the Coachella crowd can cost...

[Florence Welch breaks her foot after jumping off Coachella stage](#)

[New York Daily News](#) · 2 hours ago

[Florence Welch Breaks Foot At Coachella, 'Strips Back' Performances](#)

[The Inquisitr](#) · 21 hours ago



Florence

City

Florence is the capital city of the Italian region of Tuscany and of the province of Florence. It is the most populous city in Tuscany, with approximately 380,000 inhabitants, expanding to over 1,520,000 in the metropolitan area.

en.wikipedia.org

Local time: 9:12 PM 4/16/2015

Population: 370,092 (2010)

Area: 39.54 sq miles (102.41 km²)

Explore area: [Florence](#) · [Tuscany](#) · [Italy](#)

Travel tip: Everyone's heard the Doors of Paradise, the Duomo, +

Colleges and universities: [University of Florence](#) · [Accademia di Belle Arti di Firenze](#) · [European University Institute](#) · [Accademia italiana](#) +

Weather

59 °F Patchy fog
H 79 °F · L 59 °F

Points of interest

[See all \(10+\)](#)



Florence Cathedral



Uffizi Gallery



Ponte Vecchio



David



Palazzo Vecchio

People also search for

[See all \(10+\)](#)



Venice



Rome



Milan



Pisa



Naples

ing, Florenc

Why “Entities”



Florence photos

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Florence Cathedral



Uffizi Gallery



Ponte Vecchio



David



Palazzo Vecchio

People also search for

[See all \(10+\)](#)



Venice



Rome



Milan



Pisa



Naples

Time in florence

Florence population

What's the weather in florence

Florence places to go

Cities similar to florence

How big is florence

Florence travel tips

Popular schools in florence

One single Entity Pane can answer many user queries and satisfy users' diverse information needs

Why "Entities"

bing MS Beta

Search: florence

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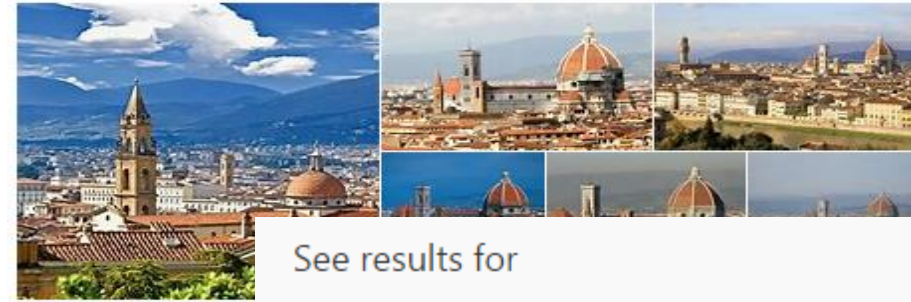
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en.wikipedia.org

Local time: 9:12

Population: 370,000

Area: 39.54 sq mi

Explore area: Florence

Travel tip: Every

Colleges and universities: [Belle Arti di Firenze](#)
[italiana](#) +

See results for

Florence

Oregon

Florence is a city in Lane County, Oregon, United States. As of the 2010 census, the city had a total population of approximately 10,000.



Florence

South Carolina

Florence is a city located in Florence County, South Carolina, United States. The city is the county seat of Florence County.



Florence

Kentucky

Florence is a home rule-class city in Boone County, Kentucky, in the United States. Florence is part of the Boone County, Kentucky micropolitan area.



Florence

New Jersey

Florence Township is a township in Burlington County, New Jersey, United States. As of the 2010 United States census, the township had a population of 10,000.



Florence

Arizona

Florence is a town in and the county seat of Pinal County, Arizona, United States. The population was 25,000 as of the 2010 census.



Why “Entities”



florence oregon

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Florence, Oregon - Official Site

www.ci.florence.or.us ▾

Offers information on city government, services, business development, and departments. Includes news, events, calendar, city code, meeting minutes, and resource links.

Jobs

Contact Ann Steward, HR Manager, at 541-902-2589 or e-mail ann ...

Planning

The Florence Environmental Management Advisory Committee ...

Florence Events Center

Florence -- the one spot on the Oregon Coast that boasts a rare ...

[See results only from ci.florence.or.us](#)

Calendar

Florence Event Center Calendar. Council, Boards, and ...

City of Florence Newsle...

The May issue of "Focus on Florence," the City of Florence ...

Public Works

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Florence Oregon coast tourism vacations hotels travel ...

www.florenceoregon.net ▾

For business, relocation, or vacation - you will find the Florence Oregon Coast to be the perfect setting for tranquility, relaxation, and ...

Home Page | Florence Oregon Chamber of Commerce

www.florencechamber.com ▾

Visitor, business and relocation information for the city of Florence. Includes events, membership information, recreational activities and maps.

Florence, Oregon - Wikipedia, the free encyclopedia

en.wikipedia.org/wiki/Florence,_Oregon ▾

Florence is a city in Lane County, Oregon, United States. As of the 2010 census, the city had a total population of 8,466. Contents 1 History 2 Geography 3 ...

[History](#) · [Geography](#) · [Demographics](#) · [Economy](#) · [Arts and culture](#)



Florence

Oregon

Florence is a city in Lane County, Oregon, United States. As of the 2010 census, the city had a total population of 8,466. The Florence area was originally inhabited by the Siuslaw tribe of Native Americans. Some state that the city was named for state senator A. B. Florence, who represented Lane County from 1858–1860; another notion is that F... +

en.wikipedia.org

Local time: 9:46 PM 5/12/2015

Population: 8,466 (2013)

Area: 5.50 sq miles (14.24 km²)

Points of interest: [Sea Lion Caves](#)

Weather

 50 °F Cloudy
H 50 °F · L 48 °F

People also search for

[See all \(10+\)](#)



Newport



Coos Bay



Brookings



Eugene



Reedsport

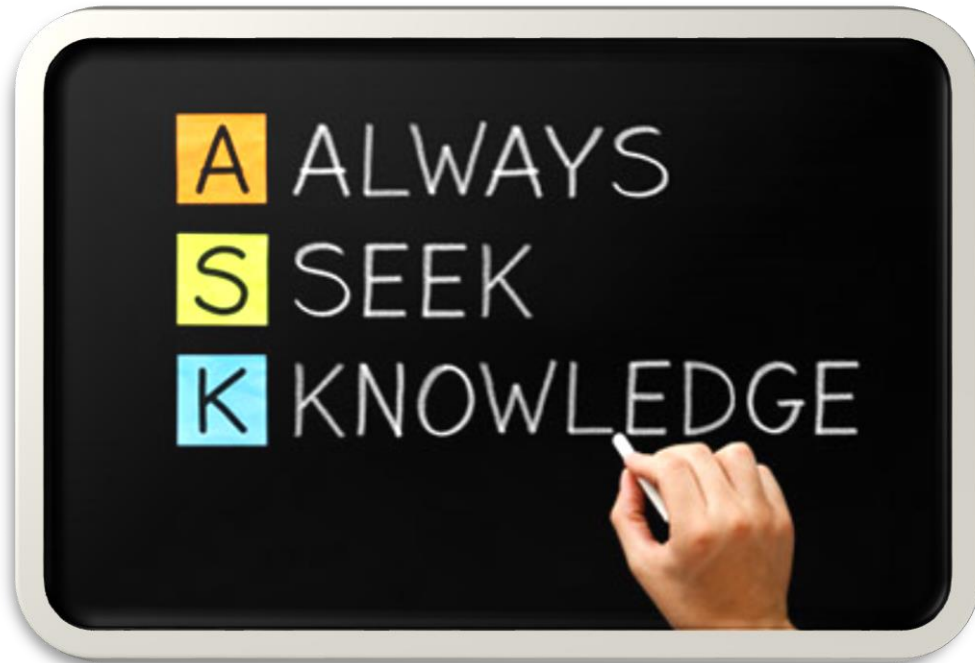
Because Entities are Surrounded by Knowledge



Why People Search?



Our Job



Florence

City

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en.wikipedia.org

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Weather

59 °F Patchy fog
H 79 °F · L 59 °F

Points of interest

[See all \(10+\)](#)



People also search for

[See all \(10+\)](#)



Entity Graphs



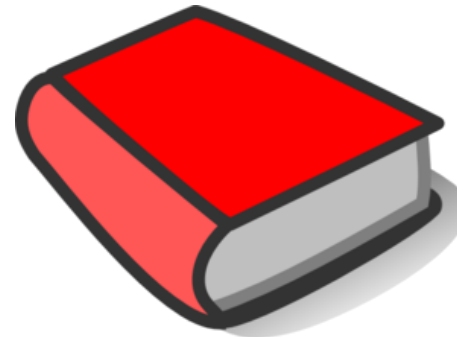
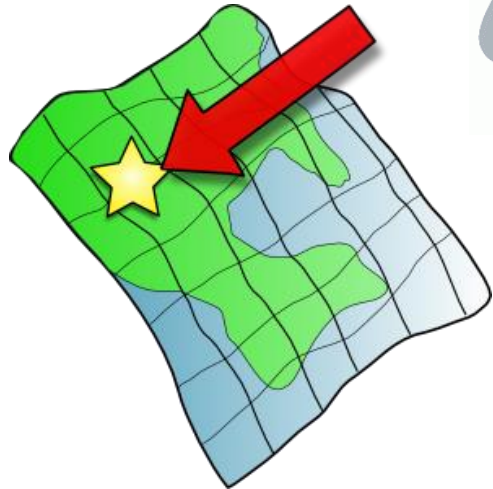
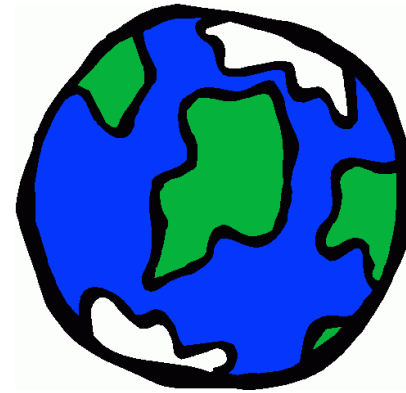
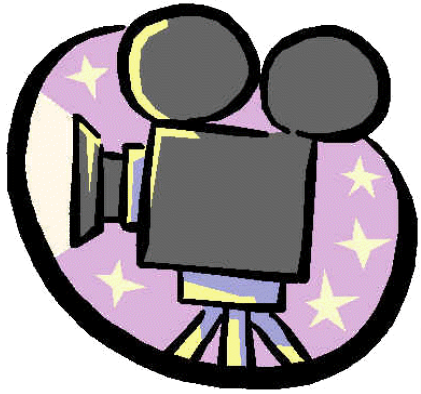
Knowledge Graph



Satori Knowledge Base



Entity Definition



Knowledge Definition



Address: 400 Broad St, Seattle, 98109
Phone: (800) 937-9582
Opened: Apr 21, 1962
Height: 605 feet (184.41 m)
Floors: 6



NFL championships: 2013
Head coach: Pete Carroll
Founded: 1976
Division: NFC West

Home Field

Location

Seattle

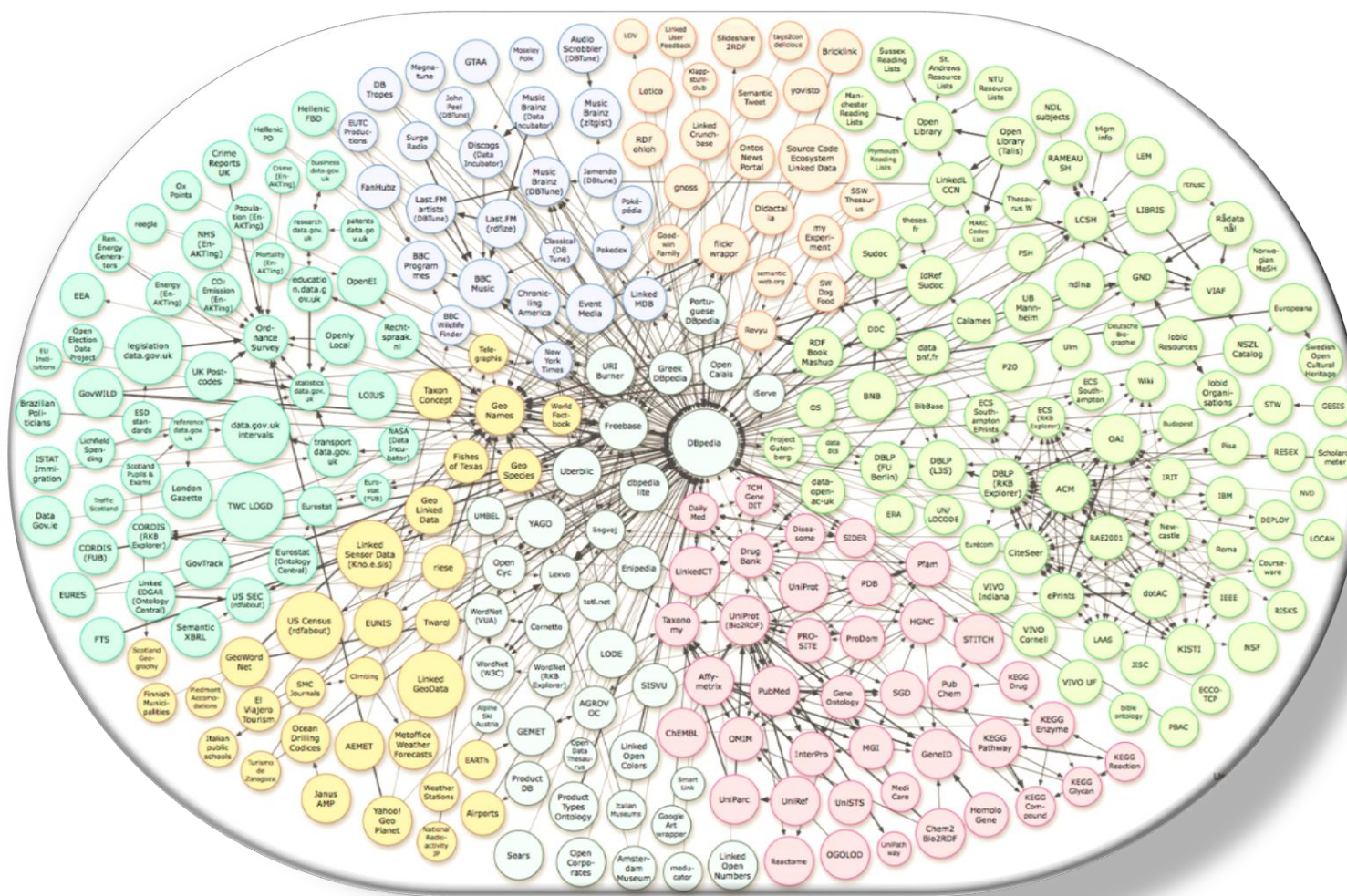
Population: 652,405 (2013)
Area: 142.55 sq miles (369.20 km²)
Mayor: Ed Murray



Headquarters

Founded: Mar 30, 1971 · Pike Place Market
Customer service: +1 800-782-7282
CEO: Howard Schultz
Founders: Jerry Baldwin · Zev Siegl · Gordon Bowker

Entity Graphs



Why “Entity Recommendation”

- Information Explosion



Why “Entity Recommendation”



47,558,128

Topics
(and counting)

2,899,191,441

Facts
(and counting)



4,580,000

Topics
(and counting)

580,000,000

Facts
(and counting)

Why “Entity Recommendation”

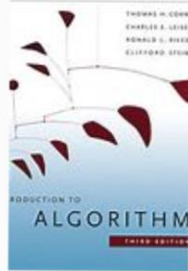
- Information Overload



**Help Explore the
Knowledge Base**

Why “Entity Recommendation”

Introduction to Algorithms
Book



[Amazon](#) 4.3/5 ★★★★★

Introduction to Algorithms is a book by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein. It is used as the textbook for algorithms courses at many universities and is ... +
en.wikipedia.org

en.wikipedia.org

First published: 1990


Authors: Thomas H. Cormen · Charles E. Leiserson · Ronald Rivest · Clifford Stein

Genres: Computers · Languages · Programming · Mathematics

Introduction to Algorithms - People also search for





									
The Art of Computer Programming	Computers and Intractability	Artificial Intelligence: A Modern App...	Computer Graphics: Principles a...	Operating System Concepts	Introduction to Automata Theory, Lan...	Modern Operating Systems	Concrete Mathematics	Introduction to the Theory of Computation	Database System Concepts

Why “Entity Recommendation”








Leonardo DiCaprio
American Actor

Leonardo Wilhelm DiCaprio is an American actor and film producer. He has been nominated for ten Golden Globe Awards, winning two, and five Academy Awards. DiCaprio began his career by appearing in television commercials, after which he had recurring roles in TV series such as the soap opera Santa Barbara and the sitcom Growing Pains in th... +
en.wikipedia.org






   
Wikipedia IMDb Twitter Facebook

Born: Nov 11, 1974 (age 40) · Los Angeles, California
Height: 6' 0" (1.83 m)
Partner: Gisele Bündchen (2000 - 2005)
Upcoming movies: [The Revenant](#)
Parents: [George DiCaprio](#) · [Irmelin Indenbirken](#)
Nominations: [Academy Award for Best Actor \(2005, 2007, 2014\)](#) · [Academy Award for Best Picture \(2014\)](#) +






Movies and TV shows [See all \(10+\)](#)

 The Wolf of Wall Street 2013	 Titanic 1997	 The Great Gatsby 2013	 Inception 2010	 The Departed 2006
---	---	--	---	--

Romance [See all \(5+\)](#)

 Toni Garm	 Bar Refaeli	 Blake Lively	 Gisele Bündchen	 Monica Hansen
---	---	--	---	---

People also search for [See all \(10+\)](#)

 Kate Winslet	 Jordan Belfort	 Margot Robbie	 Johnny Depp	 Brad Pitt
--	--	---	---	---

Why “Entity Recommendation”

bing machine learning

Machine learning



Machine learning is a subfield of computer science that evolved from the study of pattern recognition and computational learning theory in artificial intelligence. Machine learning explores the construction and study of algorithms that can ... [en.wikipedia.org](#)

Subdisciplines of: [Artificial intelligence](#) · [Computer Science](#)

Subdisciplines: [Supervised learning](#) · [Deep learning](#)

Academic conferences: [AAAI 2016](#) · [NIPS 2015](#) · [ICML 2015](#) · [IJCAI-15](#) · [KDD 2015](#) · [CVPR 2015](#) · [ICASSP 2016](#) · [ICDM 2015](#) +

Related people

[See all \(10+\)](#)



[Andrew Ng](#)



[Arthur Samuel](#)



[Michael I. Jordan](#)



[Geoffrey Hinton](#)



[Tom M. Mitchell](#)

People also search for

[Data mining](#)

[Artificial neural network](#)

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[Pattern recognition](#)

[Deep learning](#)

[Unsupervised learning](#)

bing www 2015

WWW 2015

Dates: May 20 - 22, 2015

Location: [Florence](#)

Website: [WWW 2015](#)

Abstracts due: Nov 03, 2014

Submissions due: Nov 10, 2014

Notification date: Jan 17, 2015

Final version due: Mar 08, 2015

People also search for

[CIKM 2015](#) (Oct 19, 2015)

[AAAI 2016](#) (Feb 12, 2016)

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[KDD 2015](#) (Aug 10, 2015)

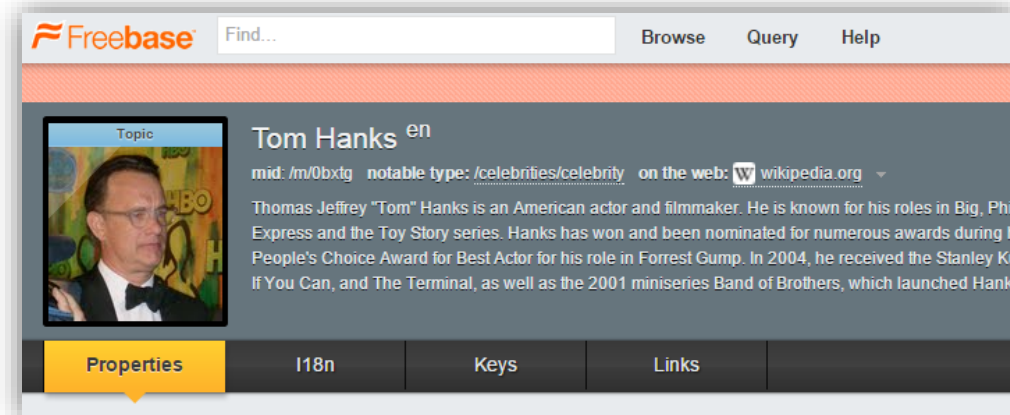
[VLDB 2015](#) (Aug 31, 2015)

[IJCAI-15](#) (Jul 25, 2015)

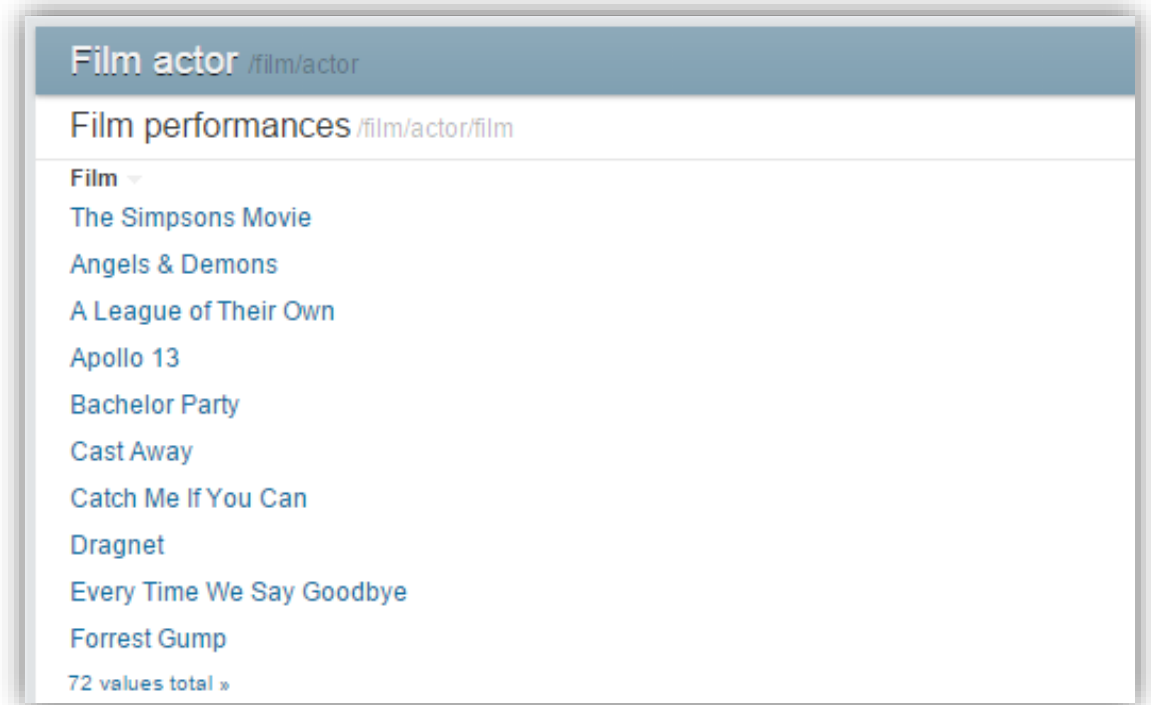
[ICDE 2015](#) (Apr 13, 2015)

Why “Entity Understanding”

- Knowledge Bases are just an unordered list of facts



The screenshot shows the Freebase website interface. At the top, there is a search bar with the text "Find..." and navigation links for "Browse", "Query", and "Help". Below the search bar, the profile for "Tom Hanks" is displayed. The profile includes a small image of Tom Hanks, his name "Tom Hanks" with a language code "en", and a brief biographical description. Below the description, there are tabs for "Properties", "I18n", "Keys", and "Links".



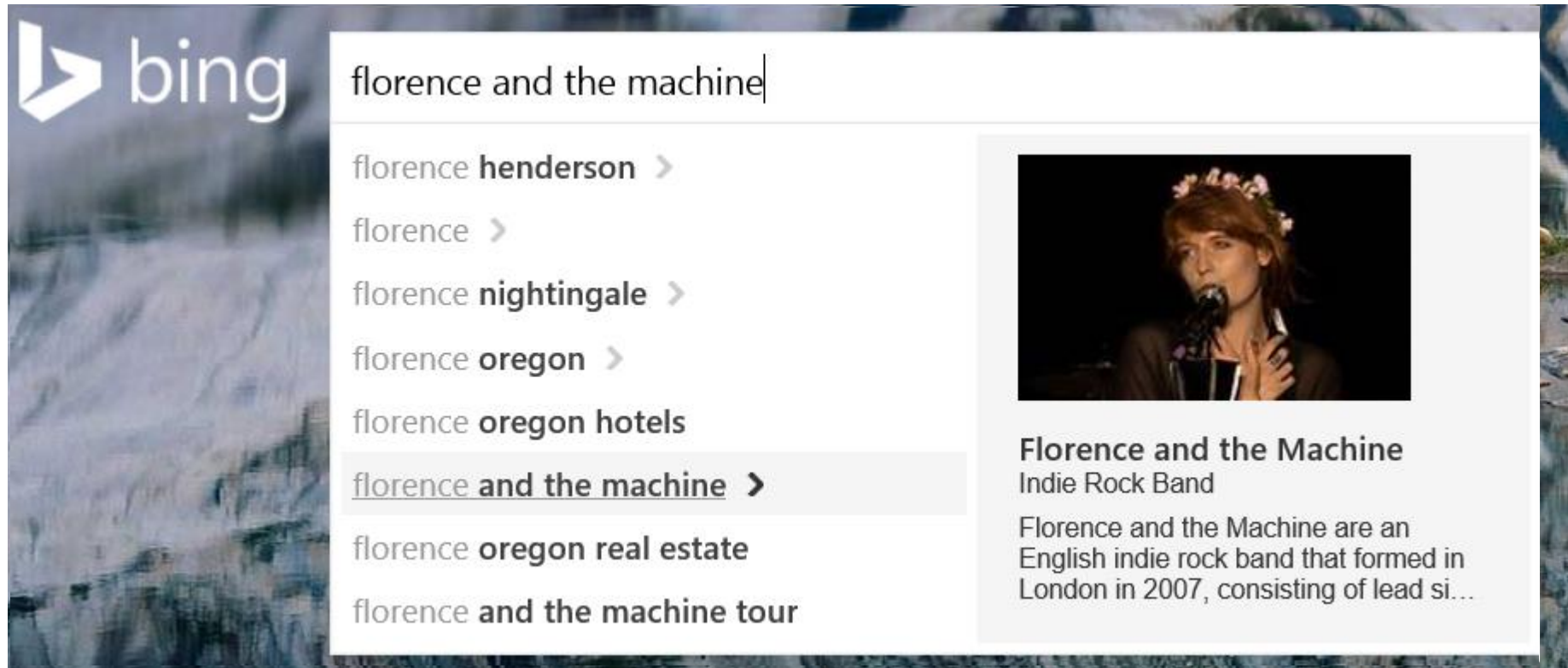
The screenshot shows a detailed view of the "Film actor" entity in Freebase. The page has a blue header with the text "Film actor /film/actor". Below the header, there is a section titled "Film performances /film/actor/film". Under this section, a list of film titles is displayed, including "The Simpsons Movie", "Angels & Demons", "A League of Their Own", "Apollo 13", "Bachelor Party", "Cast Away", "Catch Me If You Can", "Dragnet", "Every Time We Say Goodbye", and "Forrest Gump". At the bottom of the list, it says "72 values total »".

Why “Entity Understanding”

- Knowledge Bases are just an unordered list of facts
- Understanding is
 - Ranking facts
 - Creating connections between entities
 - Connecting entities and facts to queries and documents

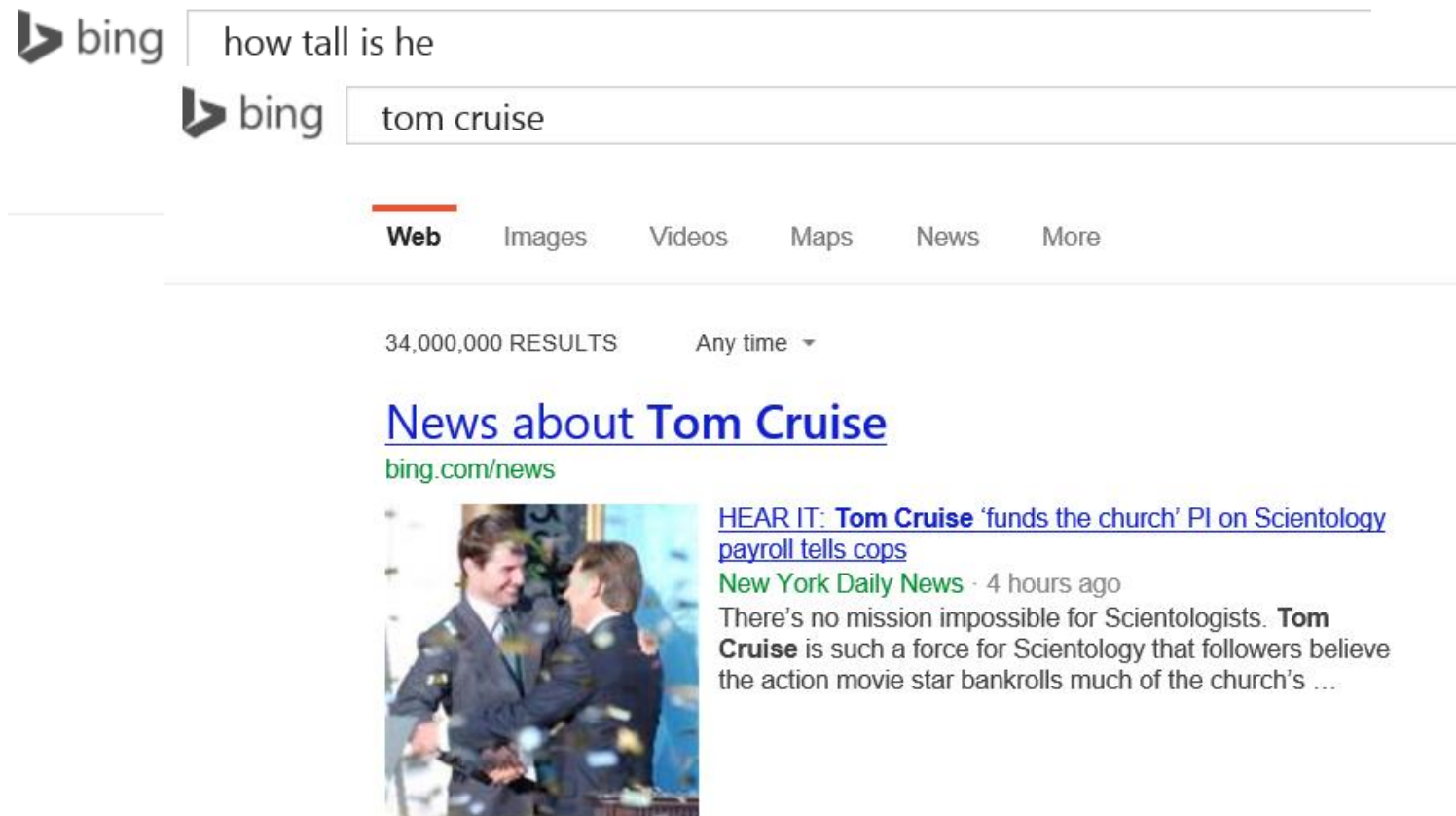
Why “Entity Understanding”

- When a user typed “Florence”, how do you know which “Florence”?



Why “Entity Understanding”

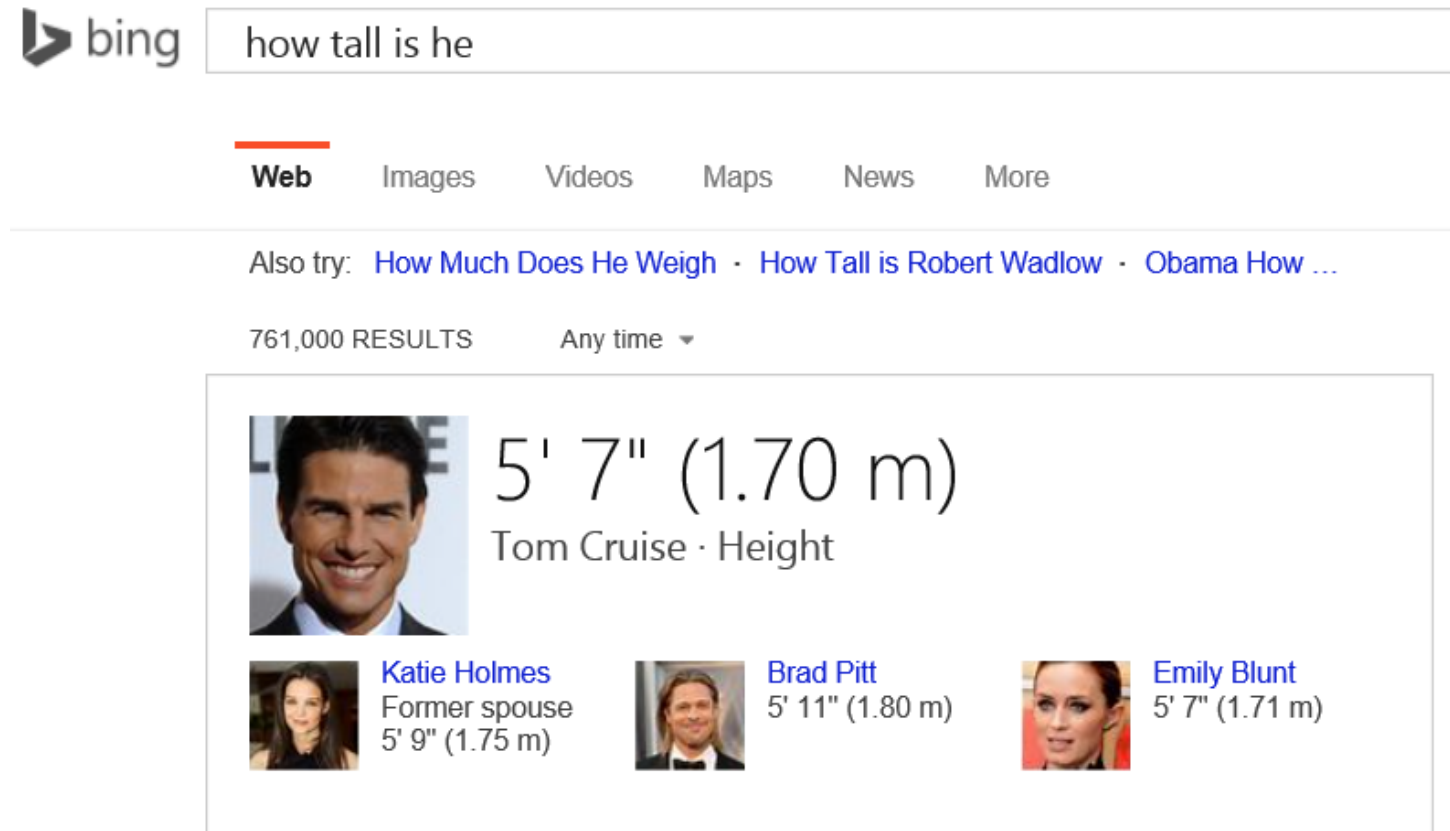
- When a user typed “how tall is he”, how do you know who is “he”?



The image shows a Bing search engine interface. At the top, there are two search input boxes. The first box contains the text "how tall is he" and the Bing logo. The second box contains the text "tom cruise" and the Bing logo. Below the search boxes, there are navigation tabs for "Web", "Images", "Videos", "Maps", "News", and "More". The "Web" tab is selected. Below the tabs, it shows "34,000,000 RESULTS" and "Any time" with a dropdown arrow. The main result is titled "News about Tom Cruise" in blue text, with a link to "bing.com/news" in green. Below the title is a small image of Tom Cruise in a suit, and a news snippet from the "New York Daily News" dated "4 hours ago". The snippet text reads: "HEAR IT: **Tom Cruise** 'funds the church' PI on Scientology payroll tells cops. There's no mission impossible for Scientologists. **Tom Cruise** is such a force for Scientology that followers believe the action movie star bankrolls much of the church's ..."

Why “Entity Understanding”

- When a user typed “how tall is he”, how do you know who is “he”?



The image shows a Bing search interface. The search bar contains the text "how tall is he". Below the search bar, there are navigation tabs for "Web", "Images", "Videos", "Maps", "News", and "More". Underneath the tabs, there are suggestions: "Also try: [How Much Does He Weigh](#) · [How Tall is Robert Wadlow](#) · [Obama How ...](#)". Below the suggestions, it says "761,000 RESULTS" and "Any time ▾". The main result is a card for Tom Cruise's height, showing a photo of Tom Cruise, the text "5' 7" (1.70 m)", and "Tom Cruise · Height". Below this card are three smaller cards for Katie Holmes (Former spouse, 5' 9" (1.75 m)), Brad Pitt (5' 11" (1.80 m)), and Emily Blunt (5' 7" (1.71 m)).

Why “Entity Understanding”

- When a user clicked a few Web pages, how do you know what kind of entities this user is interested in?



Technologies

- Natural Language Processing
- Machine Learning
- Information Retrieval
- Recommender Systems
- Text and Log Mining
-

Data Sources

- Wikipedia
 - Semi-structured free Internet encyclopedia, contributed by community members
- Freebase
 - Structured data composed mainly by its community members
 - Acquired by Google on July 2010, and will be retired on June 2015
 - Data will be ported to WikiData
- WikiData
 - a collaboratively edited knowledge base
- DBPedia
 - Extracted structured information from Wikipedia
- Yago
 - a knowledge base automatically extracted from Wikipedia and other sources
 - Accuracy 95.02% based on manual evaluation
- Web Documents
- Queries and Search Click Log

Applications

- Entity Pane Experiences
- Entity Recommendation
 - Recommendation and Ranking
 - Interpretation
 - Exploration
 - Personalization
- Factoid Answers
- Graph Search
- Conversational Question and Answering
- Natural Language Question and Answering
-

Outline

- Introduction to Entity and Knowledge
- **Demonstration of Microsoft's Entity Experience**
- Entity Recommendation and Understanding
 - $P(\textit{entity}|\textit{entity})$
 - $P(\textit{entity}|\textit{user})$
 - $P(\textit{entity}|\textit{query})$
- Summary

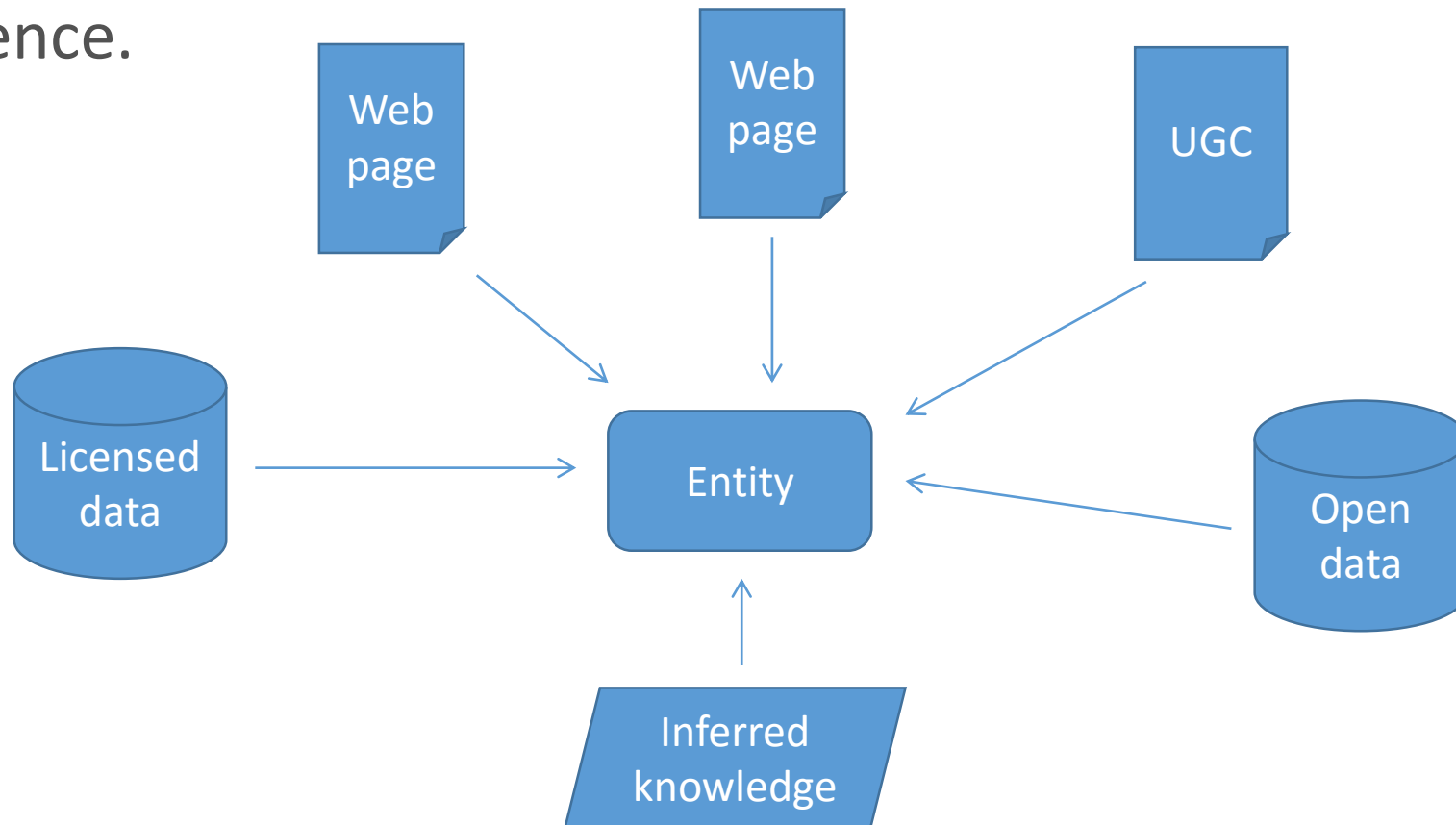
Demonstration of Microsoft's Entity Experience

Entities are deeply integrated

- Bing
 - SERP, Images, Videos, Maps, ...
- Office
- Windows
- Edge Browser
- Phone
- Xbox

Integrated Entity Experiences

- Combine data from many sources for an entity to build a rich user experience.





U2 / Top songs / With or Without You



Top songs

With or Without You	4:49	Vertigo	3:14	New Year's Day	5:35	All I Want Is You	9:51	Walk On	4:56
I Still Haven't Found What I...	4:29	One	4:36	Stuck in a Moment You Can'...	3:41	Bullet the Blue Sky	4:32	Sometimes You Can't Make I...	5:08
Beautiful Day	4:07	Sunday Bloody Sunday	4:39	Mysterious Ways	4:03	Desire	2:59	In God's Country	2:57
Where the Streets Have No N...	4:35	Pride (In the Name of Love)	3:50	Elevation	3:47	City of Blinding Lights	5:20	Running to Stand Still	4:17

Songs of Innocence
2014

Videos of u2 with or without you

bing.com/videos[See more songs by U2](#)

Lyrics

See the stone set in your eyes
 See the thorn twist in your side
 I wait for you
 Sleight of hand and twist of fate
 On a bed of nails she makes me wait
 And I wait, without you

With or without you
 With or without you

Through the storm we reach the shore
 You give it all but I want more
 And I'm waiting for you

[VIDEO] U2 - With Or Without You - YouTube

www.youtube.com/watch?v=XmSdT9kaiQ

By U2VEVO · 5 min · 105,897,210 views · Added Oct 05, 2009

Music video by U2 performing **With Or Without You**. 1987 Universal-Island Records Ltd. under exclusive licence to Mercury Records Limited[The Police](#) · [Try Something New](#) · [Google Play](#) · [Hoobastank](#) · [Sinéad O'Connor](#)

With or Without You



"With or Without You" is a song by the Irish rock band U2. It is the third track from their fifth studio album, The Joshua Tree, and was released as the album's lead single on 21 March 1987. The song was the group's most successful single at th... [+](#)

U2 - With Or Without You

4:51

YouTube · 104,687,000+ views

See more songs by U2

[VIDEO] U2 - With Or Without You - YouTube

www.youtube.com/watch?v=XmSdT9kaiQ

By U2VEVO · 5 min · 104,667,422 views · Added Oct 05, 2009

Music video by **U2** performing **With Or Without You**. 1987 Universal-Island Records Ltd. under exclusive licence to Mercury Records Limited

With or Without You - Wikipedia, the free encyclopedia

en.wikipedia.org/wiki/With_or_Without_You

"**With or Without You**" is a song by the Irish rock band **U2**. It is the third track from their fifth studio album, **The Joshua Tree** (1987), and was released as the album ...

Writing and recording · Composition · Release and chart ... · Live performances

With Or Without You Lyrics - U2 - LyricsFreak.com

www.lyricsfreak.com · U2

Lyrics to **With Or Without** by **U2**: See the stone set in your eyes / See the thorn twist in your side / I'll wait for **you** / Sleight of hand

U2 - With Or Without You Lyrics | MetroLyrics

www.metrolyrics.com/with-or-without-you-lyrics-u2.html

"**With Or Without You**" is track #4 on the album U218 Singles. It was written by Adam Clayton, Dave Evans, Paul Hewson, Larry Mullen. (No other information is available ...)

Related searches for u2 with or without you

U2 All I Want Is You

With or Without You Lyrics

U2 Greatest Hits

U2 Sunday Bloody Sunday

With or Without You U2 YouTube

With or Without You Song

U2 - With or Without You Lyrics | SongMeanings

songmeanings.com · Artists - U

You give it all but I want more

And I'm waiting for you

With or Without You



"With or Without You" is a song by the Irish rock band U2. It is the third track from their fifth studio album, *The Joshua Tree*, and was released as the album's lead single on 21 March 1987. The song was the group's most successful single at th... +

en.wikipedia.org

Album: *The Joshua Tree*

Artist: U2

Duration: 4:49

Genre: Rock, Mainstream Rock

Listen or buy

Xbox Music

iTunes

Amazon MP3

Also appears on



U218
Singles



The Best Of
1980 - 1990



Please

Data from: [Xbox Music](#) · [LyricFind](#) · [Freebase](#)

[Feedback](#)



Bill Gates

Co-Founder of Microsoft

William Henry "Bill" Gates III is an American business magnate, philanthropist, investor, computer programmer, and inventor. Gates originally established his reputation as the co-founder of Microsoft, the world's largest PC software company, with Paul Allen. During his career at Microsoft, Gates held the positions of chairman, CEO and chief ...



Wikipedia



Twitter



Facebook

Born: Oct 28, 1955 (age 59) · Seattle, WA

Net worth: \$79 billion USD (2015)

Spouse: Melinda Gates (Since 1994)

Founded: Microsoft · Bill & Melinda Gates Foundation · Cascade Investment · Corbis · bgC3 · Microsoft Research

Parents: William H. Gates, Sr. · Mary Maxwell Gates

Education: Lakeside School (1968 - 1973) · Harvard College (1973 - 1975)

TED talks

- Teachers need real feedback
- Mosquitos, malaria and education
- How state budgets are breaking US schools
- Why giving away our wealth has been the most satisf...

Timeline

1973: Gates enrolled in Harvard College where he met Steve Ballmer who would later succeed him as a CEO of Microsoft. In college, Gates did not have a proper study plan, used most of his time using the school's computer and demonstrated potential for solving hard problems. He left eventually two years later to start a company.

1975: What started as a project for demonstrating Altair emulator, Microsoft was formed as a partnership between Paul Allen and Bill Gates and had their first office located in Albuquerque.

1985: Under Gates, MS launches Microsoft Windows which became the dominant OS, in the next few years, Microsoft Office was launched which was eventually used by over a billion people. These two product lines largely defined the success of Microsoft and Bill Gates as a CEO.

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Teachers need real feedback



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Why giving away our wealth has been the most satisf...

<http://blogs.bing.com/search/2013/12/12/expand-your-understanding-with-bing/>



Bill Gates

Co-Founder of Microsoft

William Henry "Bill" Gates III is an American business magnate, philanthropist, investor, computer programmer, and inventor. Gates originally established his reputation as the co-founder of Microsoft, the world's largest PC software company, with Paul Allen. During his career at Microsoft, Gates held the positions of chairman, CEO and chief ...



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Steve Jobs



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Timeline

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1985: Under Gates, MS launches Microsoft Windows which became the dominant OS. In the next few years, Microsoft Office was launched which was eventually used by over a billion people. These two product lines largely defined the success of Microsoft and Bill Gates as a CEO.

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<http://blogs.bing.com/search/2014/02/21/timeline-understanding-important-events-in-peoples-lives/>

Online Courses

Stanford University

University



Stanford University is a private research university in Stanford, California, and one of the world's most prestigious institutions, with the highest undergraduate selectivity and the top position in numerous surveys and measures in the Unite... +
en.wikipedia.org

Address: 450 Serra Mall, Stanford, CA 94305

Ranking: #4 National University (2015)

Undergraduates: 7,063 (2015)

Acceptance rate: 5.70% (2015)

Tuition: \$43,245 USD (2015)

Founded: Oct 01, 1891

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Physics



Physics is the natural science that involves the study of matter and its motion through space and time, along with related concepts such as energy and force. More broadly, it is the general analysis of nature, conducted in order to understand h... +

en.wikipedia.org

Subdiscipline of: [Natural science](#)

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- ▶ [Relationship between angular velocity and speed](#)
- ▶ [Displacement from time and velocity example](#)
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[Astronomy](#)



[Quantum mechanics](#)



[Mechanics](#)




[Nuclear physics](#)



[Particle physics](#)

Long tail of interconnected entities

Richard Qian



[LinkedIn](#)

Current: Corporate Vice President at Microsoft
Location: Greater Seattle Area

Experience

Corporate Vice President
Microsoft · 2015 - Present

Partner Development Manager - Web Indexing & Knowledge
Microsoft · 2008 - 2014

Principal Development Manager - Multimedia & News Search
Microsoft · 2006 - 2008

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Education


University of Illinois at Urbana-Champaign
Ph.D., Electrical & Computer Engineering · 1992 - 1996

University of Illinois at Urbana-Champaign
M.S., Electrical & Computer Engineering · 1991 - 1992

Tsinghua University
B.S., Computer Science · 1981 - 1986

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12160 168th Ct NE, Redmond, WA 98052



Beautiful Murray Franklyn home in Prescott. The Woodland floor plan has 4 bdrms/2.75 baths and bonus room. Upgraded throughout including slab granite, designer backsplash, Kitchen Aid appliances, & pendant lighting. Huge master ... [+](#)
www.zillow.com


[Directions](#) [Zillow](#)

Address: 12160 168th Ct NE,, Redmond, WA 98052
Floors: 2
Zestimate: \$770,081
Year built: 2011
Price: \$750,000
Rooms: 4 beds, 2.75 baths

Assigned schools

School	Distance	Rating
Albert Einstein Elementary School	1.20 miles	6/10
Evergreen Junior High School	4.20 miles	10/10
Redmond High School	1 miles	8/10

People also search for



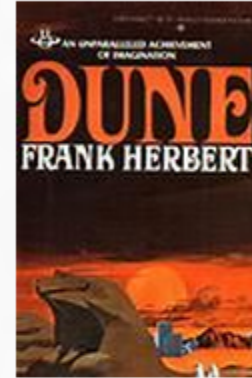
[17260 NE 123rd Way](#) [17250 NE 123rd Way](#) [16829 NE 121st St](#) [17215 NE 117th Way](#) [17419 NE 123rd Way](#)

<http://blogs.bing.com/search/2014/03/31/150-million-more-reasons-to-love-bing-everyday/>

Actions – facilitate task completion

Dune

Novel



[Amazon](#)

4.4/5 ★★★★★

[Barnes and Noble](#)

4.6/5 ★★★★★

Dune is a 1965 epic science fiction novel by Frank Herbert. It won the Hugo Award in 1966, and the inaugural Nebula Award for Best Novel. Dune is the world's best-selling science fiction novel and is ... [+](#)

en.wikipedia.org

First published: 1965

Author: [Frank Herbert](#)

Adaptations: [Dune \(1984\)](#) · [Frank Herbert's Dune \(2000\)](#) · [Dune](#)

Followed by: [Dune Messiah](#)


Characters: [Paul Atreides](#) · [Vladimir Harkonnen](#) · [Princess Irulan](#) · [Duncan Idaho](#) · [Chani](#) · [Feyd-Rautha](#) · [Lady Jessica](#) · [Leto Atreides I](#) [+](#)

Awards: [Hugo Award for Best Novel](#) · [Nebula Award for Best Novel](#)

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 [Seattle Public Library](#)



The Avengers

PG-13 · 2hr 23min · Sci-Fi

[IMDb](#)

8.2/10 ★★★★★

[Rotten Tomatoes](#)

92% ★★★★★

"Marvel's The Avengers"-the Super Hero team up of a lifetime, featuring iconic Marvel Super Heroes Iron Man, The Incredible Hulk, Thor, Captain America, Hawkeye and Black Widow. When an unexpected enemy emerges that threatens global safety and security, Nick Fury, Director of the international peacekeeping agency known as S.H.I.E.L.D., finds himself in need of a t... +

Estimated budget: \$220 million USD

Release date: May 04, 2012

Director: [Joss Whedon](#)

Sequel: [Avengers: Age of Ultron](#)

Production company: [Marvel Studios](#)

Story by: [Joss Whedon](#) · [Zak Penn](#)

Watch now

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[Xbox Video](#)

[Watch trailer on IMDb](#)

Songs of Innocence (2014)



Songs of Innocence is the thirteenth studio album by Irish rock band U2. Released on 9 September 2014, it was produced by Danger Mouse, with additional production from Paul Epworth, Ryan Tedder, Declan Gaffney and Flood. The albu... +

en.wikipedia.org

Genre: Rock, Mainstream Rock

Label: Interscope

Release year: 2014

Artist: [U2](#)

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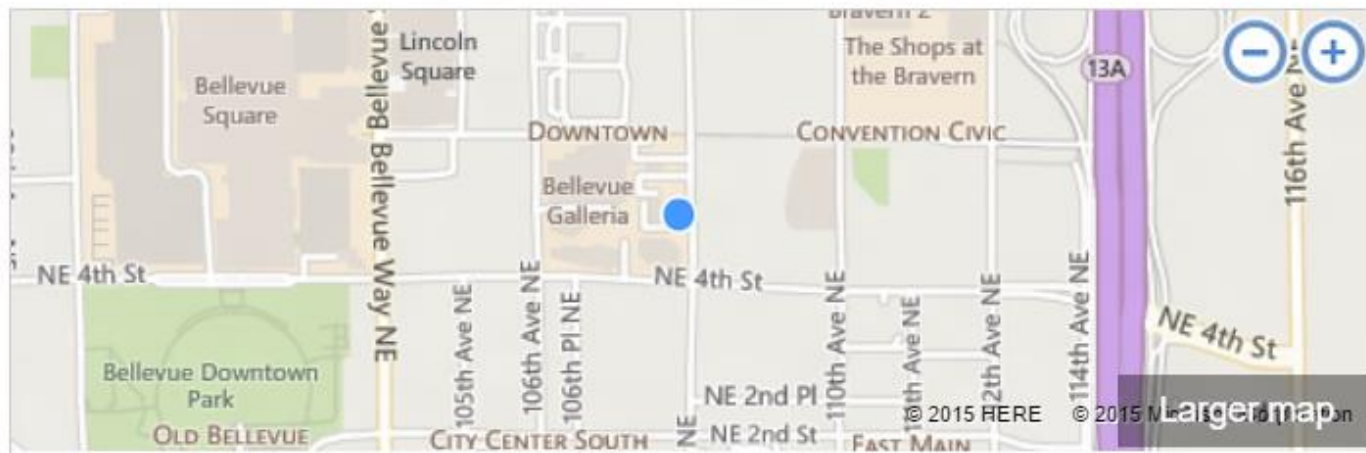
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elgaucho.com

450 108th Avenue NE, Bellevue, WA 98004 - 6.31 mi

(425) 455-2715

Open 11:30 AM - 10:00 PM

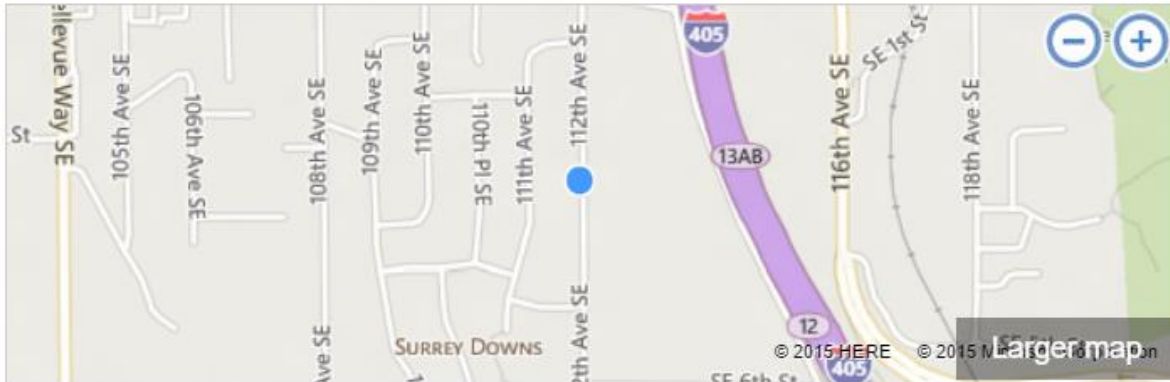
★★★★★ 347 Yelp reviews · \$\$\$\$\$

Directions

Menu

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Hilton Bellevue

www3.hilton.com

300 112th Ave Se, Bellevue, WA 98004 · 6.51 mi

(425) 455-1300

★★★★☆ 596 TripAdvisor reviews

Directions

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Bellevue Hotel - Hilton Bellevue - Hotels in Bellevue WA

www.bellevuehilton.com ▾

Official **Hilton Bellevue** Hotel Website - Just minutes from Seattle and close to popular **Bellevue** businesses, we're one of the best hotels in **Bellevue**, WA.



More about Hilton Bellevue

Reservations

Avg. rate \$212

Check in

Check out

5/29/2015



5/31/2015



Find rate

Powered by [TripAdvisor](#)

Reviews

★★★★☆ TripAdvisor (596)



Demonstration of Microsoft's Entity Experience

Question Answering



tom hanks movies



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Tom Hanks - movies

All genres

Popular first



Captain Phillips
(2013)
★★★★☆



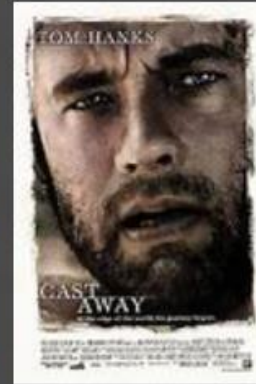
Saving Mr.
Banks (2013)
★★★★☆



Forrest Gump
(1994)
★★★★★



A Hologram for
the King (2015)



Cast Away
(2000)
★★★★☆



Big (1988)
★★★★☆



The Green Mile
(1999)
★★★★☆



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Also try: [Joe Versus the Volcano](#) · [Tom Hanks Meg Ryan Movies Together](#) · [All ...](#)

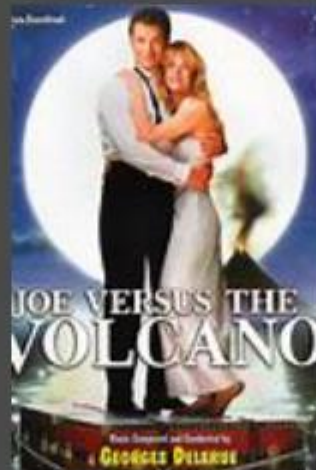
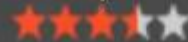
Movies of Tom Hanks starring Meg Ryan



Sleepless in Seattle (1993)



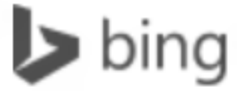
You've Got Mail (1998)



Joe Versus the Volcano (1990)



Hope for Haiti Now: A Global Benefit for E...



tom hanks first movie with meg ryan

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First movie of Tom Hanks starring Meg Ryan

Joe Versus the Volcano
(1990)



director of tom hanks first movie with meg ryan

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Director of first movie of Tom Hanks starring Meg Ryan

[John Patrick Shanley](#)



[Joe Versus the Volcano \(1990\) - IMDb](#)

www.imdb.com/title/tt0099892 ▾

★★★☆☆ Rating: 5.7/10 · 25,640 ratings · Comedy/Romance · PG · 102 min

Joe Versus the Volcano PG ... **Director: John Patrick Shanley**. **Writer: John Patrick Shanley**. **Stars: Tom Hanks, Meg Ryan, Lloyd Bridges** | [See full cast and crew »](#)

[Meg Ryan Reteams With Tom Hanks for Ithaca , Actress Set ...](#)

www.eonline.com/news/505216/meg-ryan-reteams-with-tom-hanks-for... ▾

Jan 29, 2014 · **Meg Ryan** and **Tom Hanks** are teaming ... latest to step into the role of **director**. ... and was instrumental in making the **first film** such a ...

Conversational Question Answering

bing tom cruise

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Tom Cruise - Official Site
www.tomcruise.com
OFFICIAL TOM CRUISE SITE: View the latest EDGE OF TOMORROW trailer! Watch career movie trailers, videos, and retrospective. Read the **Tom Cruise biography** or ...

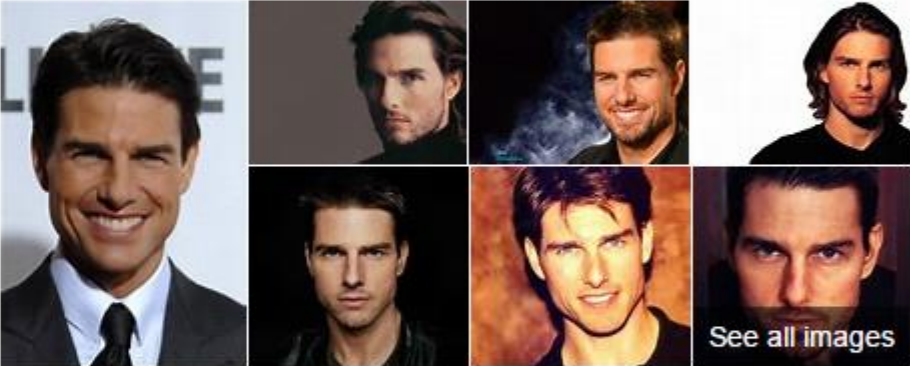
Official Tom Cruise Blog
Official Tom Cruise Blog: Read the latest Tom Cruise news, ...

Tom Cruise on WhoSay
Tom Cruise's WhoSay Celebrity Profile - Check out the latest Tom ...

[See results only from tomcruise.com](#)

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TomCruise.com Contact Us - Official Tom Cruise: Edge Of ...

News about Tom Cruise
bing.com/news
 **Tom Cruise Has Been Distancing Himself From Scientology, But Why?**
The Inquisitr - 3 days ago



Tom Cruise
American Actor

Tom Cruise is an American actor and filmmaker. Cruise 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 Endless Love. After portraying supporting roles in Taps and The Outsiders, his first leading role was in the romantic comedy Risky Business, release... +

<http://blogs.bing.com/search/2014/08/13/lets-have-a-conversation/>



who was he married to

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Tom Cruise spouse

Katie Holmes

(m. 2006-2012)

Nicole Kidman

(m. 1990-2001)

Mimi Rogers

(m. 1987-1990)

Find out more on: [wikipedia](#)

how tall are they

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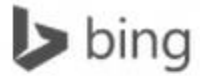
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Katie Holmes height: 5 feet 9 inches
(1.75 meters)

Nicole Kidman height: 5 feet 11 inches
(1.80 meters)

Mimi Rogers height: 5 feet 9 inches
(1.74 meters)

Find out more on: [IMDb](#)



how old is katie

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36 years old

Born Dec 18, 1978

Katie Holmes · Age



Tom Cruise
Former spouse
52 years old



Joshua Jackson
36 years old



Chris Klein
36 years old

Data from: [IMDb](#)



how about nicole

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47 years old

Born Jun 20, 1967

Nicole Kidman · Age



Keith Urban
Spouse
47 years old



Jimmy Fallon
40 years old



Angelina Jolie
39 years old

Data from: [Wikipedia](#)

544,000 RESULTS

Any time ▾



Honolulu, HI

Nicole Kidman · Birthplace

Data from: [Wikipedia](#)

Nicole Kidman - Biography - IMDb

www.imdb.com/name/nm0000173/bio ▾

48 years old · [News](#)

Elegant redhead **Nicole Kidman**, known as one of Hollywood's top Australian imports, was actually **born** in **Honolulu, Hawaii**. Kidman is the daughter of ...

[Awards](#) · [Films](#)

Nicole Kidman - Biography - Film Actress - Biography.com

www.biography.com/people/nicole-kidman-9364474 ▾

Meet Academy Award-winning actress **Nicole Kidman** at **Biography.com**. **She** is best known for movies like Moulin Rouge and her ten-year marriage to Tom Cruise.

Demonstration of Microsoft's Entity Experience

Diversity of entity collections



19th-century writers frequently mentioned on the web



Mark Twain
1835 - 1910



George Eliot
1819 - 1880



Emily Dickinson
1830 - 1886



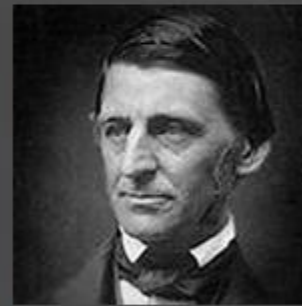
Jane Austen
1775 - 1817



Edgar Allan Poe
1809 - 1849



Charles Dickens
1812 - 1870



Ralph Waldo
Emerson
1803 - 1882



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Types of Butterflies



Monarch butterfly



Swallowtail butterfly



Morpho



Papilio glaucus



Papilio polyxenes



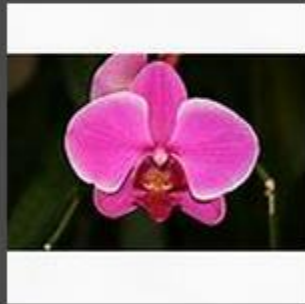
Pieris rapae



Limenitis Arthemis



Types of Orchidaceae



Phalaenopsis



Cattleya



Showy Lady's
Slipper



Dendrobium



Vanilla



Orchis italica



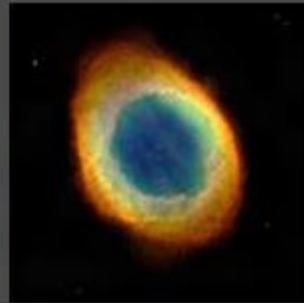
Cypripedium
acaule



Famous Nebulae



Orion Nebula



Ring Nebula



Crab Nebula



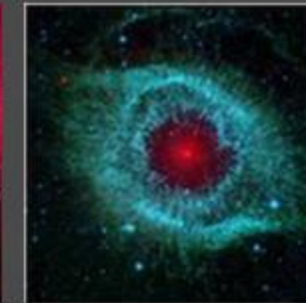
Eagle Nebula



Heart Nebula



Horsehead Nebula



Helix Nebula



Republican Party United States President



Abraham Lincoln
1861 - 1865



Theodore Roosevelt
1901 - 1909



George W. Bush
2001 - 2009



Dwight D. Eisenhower
1953 - 1961



Richard Nixon
1969 - 1974



George H. W. Bush
1989 - 1993



Ulysses S. Grant
1869 - 1877



Ivy league schools



Brown University



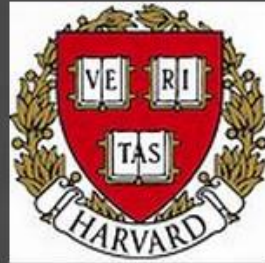
Columbia University



Cornell University



Dartmouth College



Harvard University



Princeton University



University of Pennsylvania



Yale University








Segment-specific entity rankings

bing famous actors

Web Images Videos Maps News More

1416

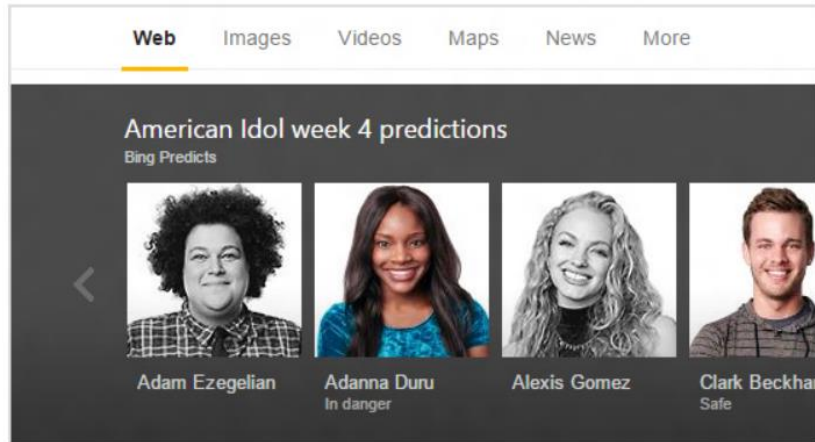
Famous Actors

						
Robin Williams 1951 - 2014	Mark Wahlberg Since 1971	Philip Seymour Hoffman 1967 - 2014	Jennifer Lawrence Since 1990	Matthew McConaughey Since 1969	Bradley Cooper Since 1975	Scarlett Johansson Since 1984

Demonstration of Microsoft's Entity Experience

Entities in the platform

Bing Predicts



American Idol

Search for "American Idol predictions" to find out who Bing predicts will be eliminated and who'll be safe.

Try it >

Dancing with the Stars

Search for "Dancing with the Stars predictions" to see who Bing predicts will make it to the next round and who won't.

Try it >

A screenshot of the Bing Predicts interface for "Dancing with the Stars predictions". The interface shows a navigation bar with "Web" selected, and tabs for "Images", "Videos", "Maps", "News", and "More". Below the navigation bar, the title "Dancing with the Stars predictions" is displayed, followed by "Bing Predicts". A horizontal carousel of four contestant portraits is shown. From left to right: Charlotte McKinney (Will be eliminated), Nastia Liukin (Top), Rumer Willis (Top), and Suzanne Somers (In danger). A left-pointing arrow is visible on the far left of the carousel.

<https://www.bing.com/explore/predicts>

Bing Predicts



March Madness

Prediction accuracy: 73 percent



American Idol

Prediction accuracy: 90 percent



Dancing with the Stars

Prediction accuracy: 95 percent



The Voice

Prediction accuracy: 85 percent



Academy Awards

Prediction accuracy: 84 percent



Golden Globe Awards

Prediction accuracy: 83 percent

Bing Widget API

The screenshot shows a web browser window with the address bar displaying `http://www.daioscovecrete.com/`. The page content includes a navigation menu with items like GALLERY, LOCATION, ROOMS & SUITES, VILLAS, DINING & BARS, SPA, FACILITIES, EVENTS, HONEYMOON, and EXPERIENCE. The main content area features a large image of lavender flowers and text that reads "Welcome to Daios Cove" and "Luxury Resort in Crete".

Overlaid on the right side of the browser is a Bing widget. The widget's search bar contains the text "agios nikolaos crete". Below the search bar, there are several image thumbnails. A map shows the location of Agios Nikolaos on the island of Crete, with labels for nearby towns like Mália, Neápolis, Skopi, and Kritsa. Below the map, the widget displays the following information:

- Agios Nikolaos**
Crete
- Agios Nikolaos or Aghios Nikolaos is a coastal town on the Greek island of Crete, lying east of the island's capital Heraklion, north of the town of Ierapetra and west of the town of Sitia. In the year 2011, the Municipality of Agios Nikolaos, which takes in part of the surrounding village...
- [en.wikipedia.org](#)
- Local time:** 12:01 AM 5/16/2015
- Area:** 197.68 sq miles (511.99 km²)
- Points of interest:** Lake Voulismeni

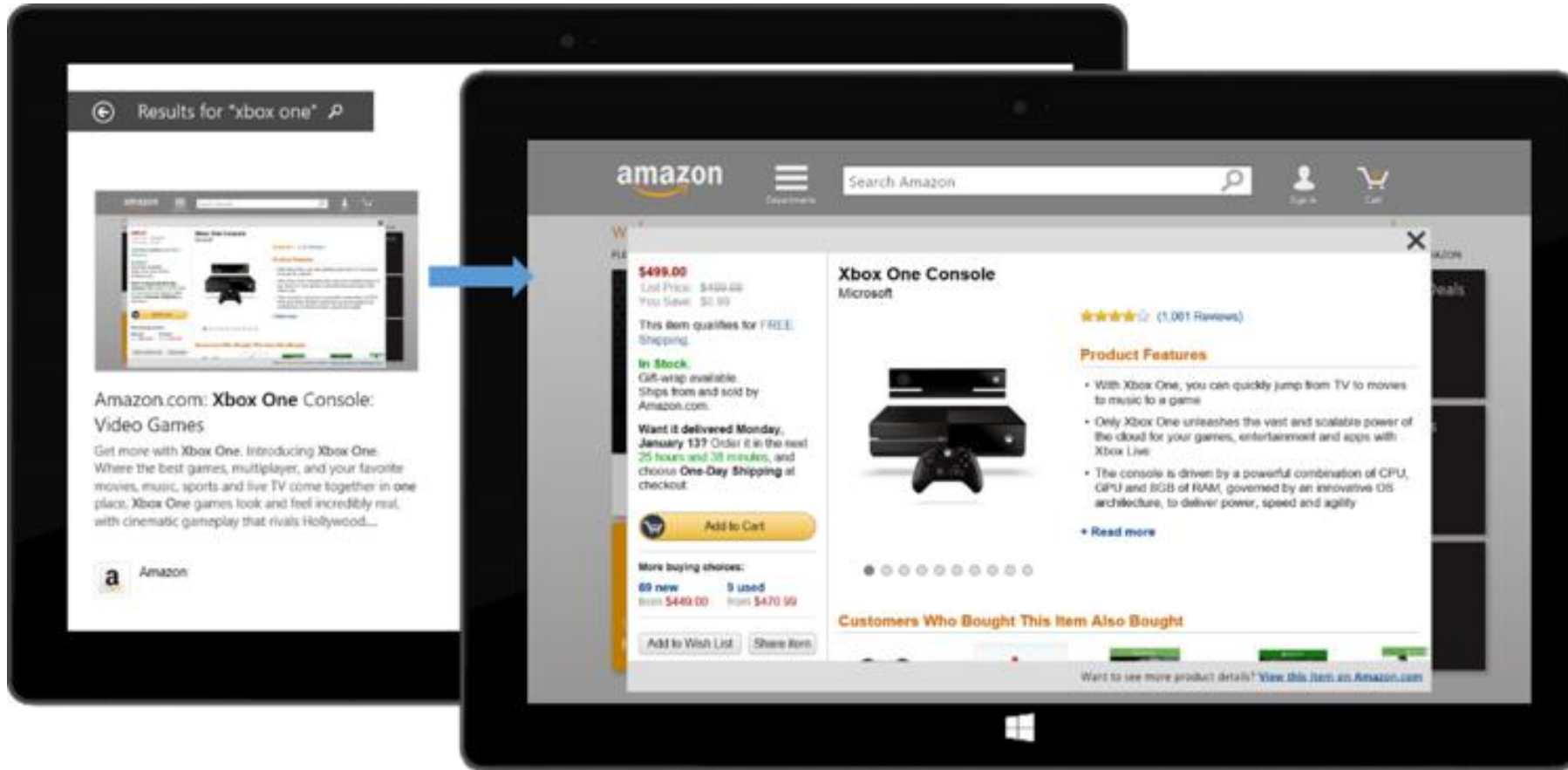
Below this information is a "Weather" section showing a moon icon, "63 °F Mostly Clear", and "H 80 °F · L 63 °F". At the bottom, there is a "People also search for" section with a "See all (10+)" link and four image thumbnails labeled Heraklion, Sitia, Chania, and Rethymno.

<http://blogs.bing.com/webmaster/2014/01/03/bringing-the-power-of-bing-knowledge-to-webmasters/>

<http://blogs.bing.com/webmaster/2014/06/19/bing-knowledge-comes-to-webmaster-tools/>

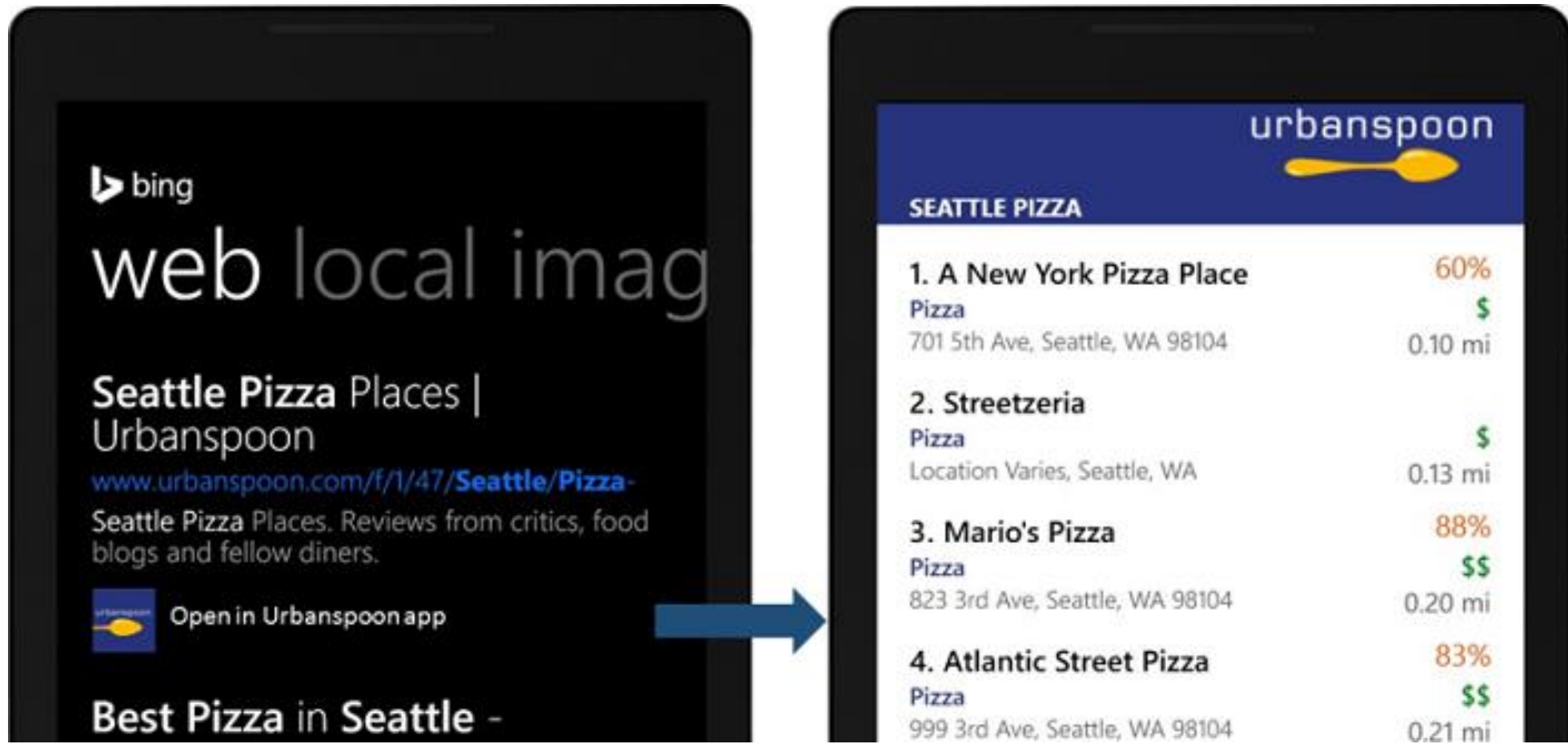
<http://blogs.bing.com/webmaster/2014/05/15/mark-it-up/>

App Linking

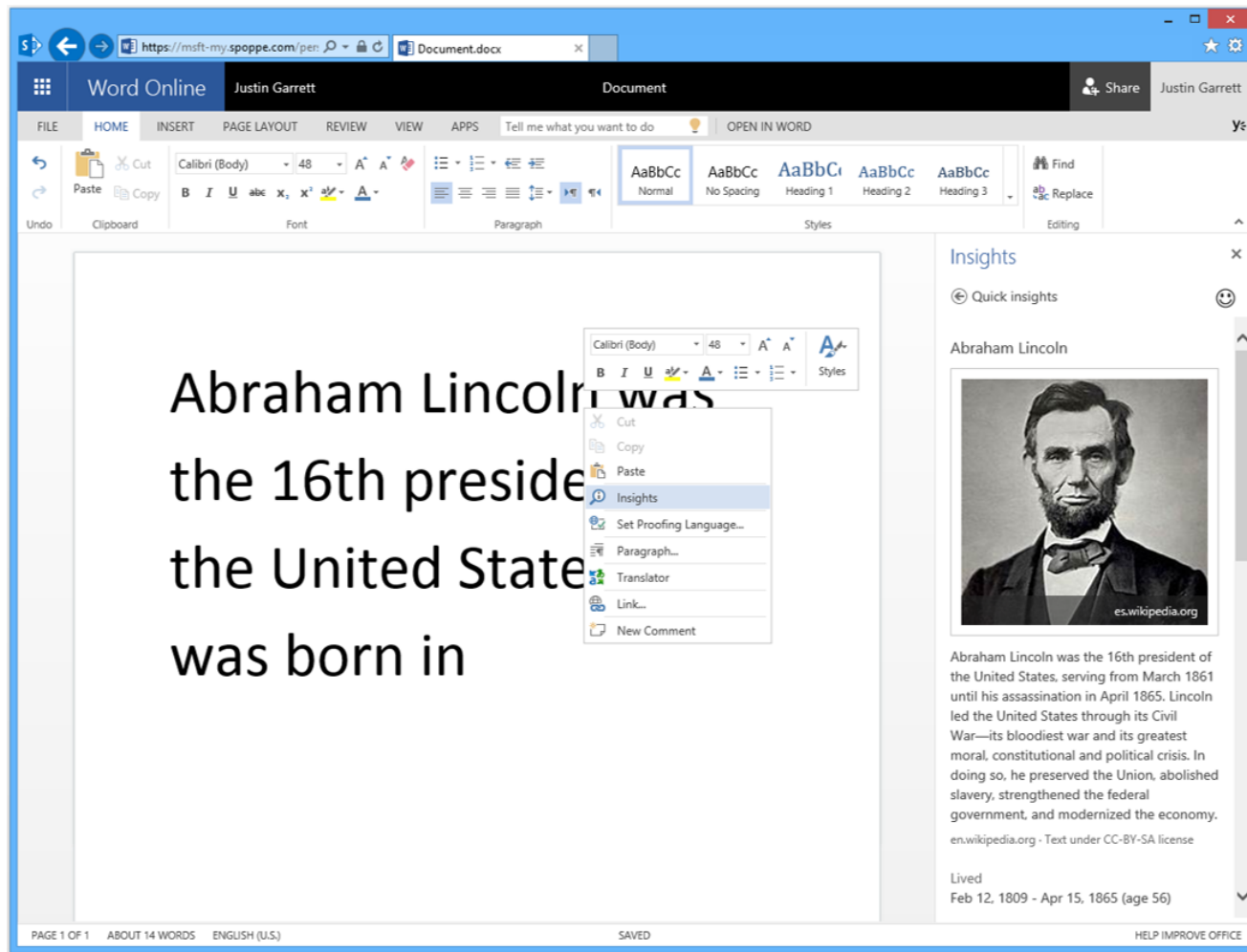


<http://blogs.bing.com/webmaster/2014/04/02/announcing-bing-knowledge-widget-app-linking/>
<http://www.bing.com/webmaster/help/app-linking-09399b4b>

App Linking



Office Insights



<http://blogs.bing.com/search/2014/12/10/bing-brings-the-worlds-knowledge-straight-to-you-with-insights-for-office/>

<http://blogs.office.com/2014/12/11/first-look-insights-office-word-online-bringing-knowledge-web-document/>

<http://blogs.office.com/2014/12/10/whats-new-office-online/>

Office Insights

FILE HOME INSERT PAGE LAYOUT REVIEW VIEW Tell me what you want to do OPEN IN WORD

Undo Clipboard Font Paragraph Styles Editing

Calibri (Body) 11 A⁺ A⁻ A

Paste Copy Cut

B I U abc x₂ x² ab A


AaBbCc Normal AaBbCc No Spacing AaBbCc Heading 1 AaBbCc Heading 2 AaBbCc Heading 3

Find Replace

Insights

Explore Define

Missouri



en.wikipedia.org

Missouri is a U.S. state located in the Midwestern United States. Missouri is the

Office Insights

The screenshot displays the Microsoft Word ribbon with the following sections: FILE, HOME, INSERT, PAGE LAYOUT, REVIEW, VIEW, Tell me what you want to do (with a lightbulb icon), and OPEN IN WORD. The ribbon includes icons for Undo, Paste, Copy, Cut, Font (Calibri (Body), 11, A+, A-, A), Paragraph (bulleted list, numbered list, left-align, right-align, center-align, justify-align, decrease indent, increase indent), Styles (Normal, No Spacing, Heading 1, Heading 2, Heading 3), Find, and Replace.

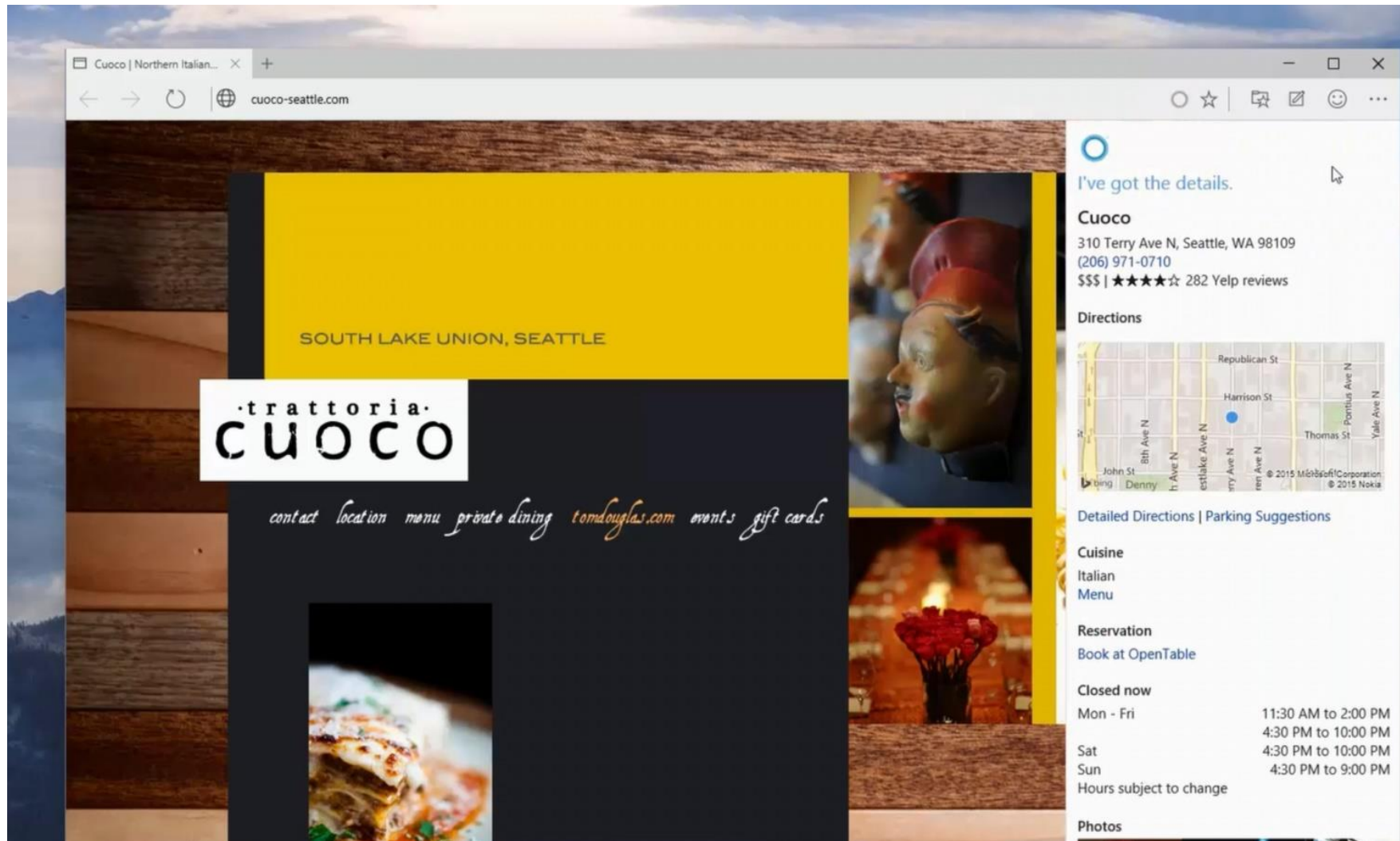
The main document area contains the following text:

The Corps of Discovery departed from Camp Dubois at 4 pm on May 14, 1804, and met up with Lewis in St. Charles, Missouri, a short time later, marking the beginning of the voyage to the Pacific coast. The Corps followed the Missouri River westward. Soon, they passed La Charrette, the last Euro-American settlement on the **Missouri** River.

(Source: http://en.wikipedia.org/wiki/Lewis_and_Clark_Expedition)

The Insights sidebar on the right shows the title "Insights" with a close button (X) and a smiley face icon. It has two tabs: "Explore" (selected) and "Define". Below the tabs is the heading "Missouri River" and a photograph of a wide river valley with green trees in the foreground and a blue sky with white clouds. The photo is credited to "en.wikipedia.org". Below the photo is the text: "The Missouri River is the longest river in North America. Rising in the Rocky".

Edge Browser




<http://windows.microsoft.com/en-us/windows/preview-microsoft-edge-pc>

Is the Seahawk a Real Bi... x +

blog.nwf.org/2014/01/is-the-seahawk-a-real-bird

NWF ADOPT SHOP KIDS

 *Inspiring Americans to protect wildlife for our children's future*

WHO WE ARE WHAT WE DO WHERE WE WORK HOW TO HELP

WILDLIFE PROMISE
BLOGS FROM AROUND THE FEDERATION


BLOG HOME TOPICS NWF BLOGGERS ABOUT WILDLIFE PROMISE SUBSCRIBE

WILDLIFE
Is the Seahawk a Real Bird?


25 1/31/2014 // By Dani Tinker

My hometown is Portland, Oregon. We do not have a professional football team. I've always for the Seahawks, but it took me an embarrassingly long time to figure out that they are really commonly known as ospreys, these are truly awe-inspiring predators to see in person. I want to share their majesty, and have compiled facts, photos and video in a shameless attempt to get fans before a very popular football competition this Sunday. Some people may say this is biased, but they would be correct.


Fish make up 99% of their diet.
I'm pretty sure the other 1% is bronco.



I've gathered this together.



See all images



Osprey

The osprey, sometimes known as the fish eagle, sea hawk, river hawk, or fish hawk, is a diurnal, fish-eating bird of prey. It is a large raptor, reaching more than 60 cm in length and 180 cm across the wings. It is brown on the upperparts and predominantly greyish on the head and underparts.

en.wikipedia.org

Scientific name: *Pandion haliaetus*

Biological classification: [Species](#)

Belongs to: [Falconiformes](#)

People also search for

<http://blog.nwf.org/2014/01/is-the-seahawk-a-real-bird/>

The screenshot shows a web browser window with the address bar displaying blog.nwf.org/2014/01/is-the-seahawk-a-real-bird. The page features the National Wildlife Federation logo and navigation links. The main content is a blog post titled "Is the Seahawk a Real Bird?" by Dani Tinker, dated 1/31/2014. The text discusses the confusion between seahawks and ospreys. A sidebar on the right provides information about the Seattle Seahawks, including their founding year (1976), coach (Pete Carroll), and a list of players.

NATIONAL WILDLIFE FEDERATION
Inspiring Americans to protect wildlife for our children's future

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WILDLIFE
Is the Seahawk a Real Bird?
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I'm pretty sure the other 1% is bronco.

Seattle Seahawks
The Seattle Seahawks are a professional American football franchise in the National Football League based in Seattle, Washington and the reigning Super Bowl champions. They are members of the NFC West division of the National Football Conference.

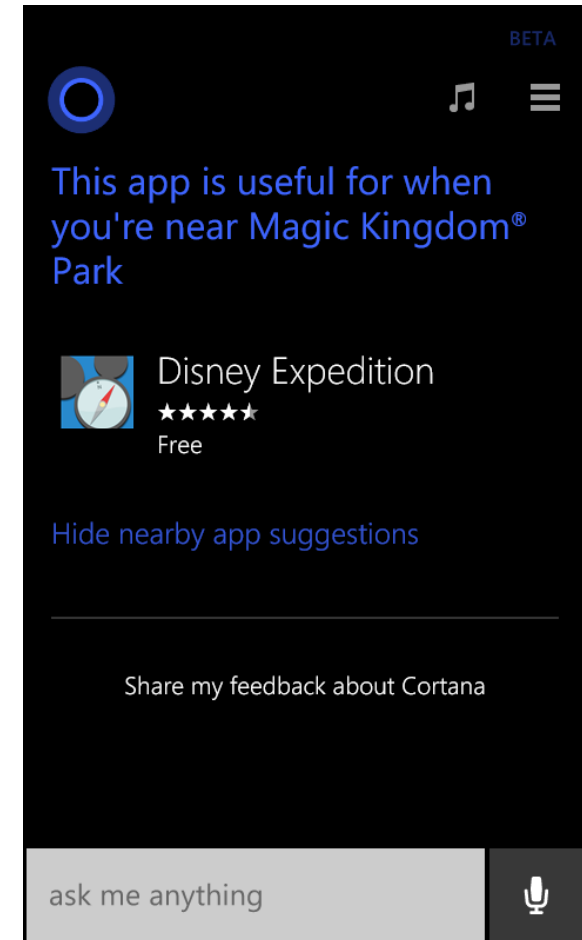
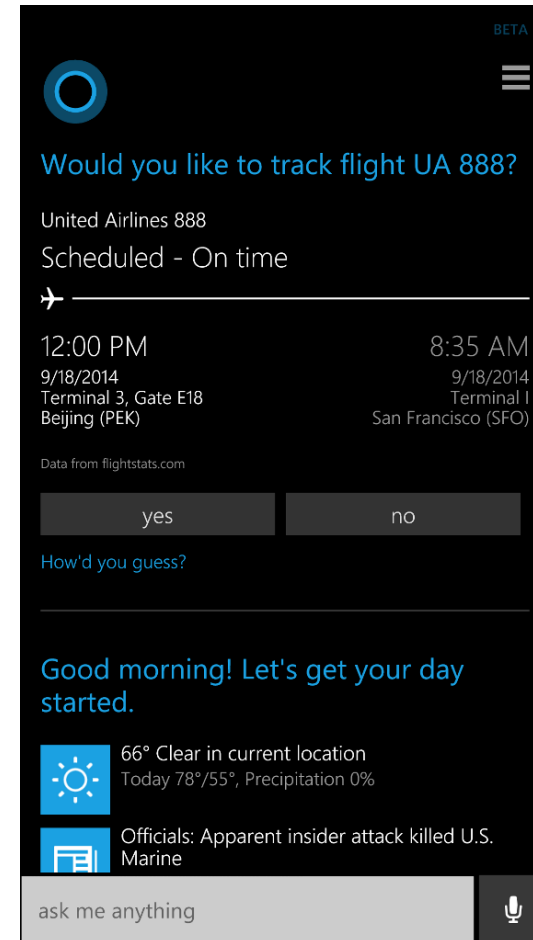
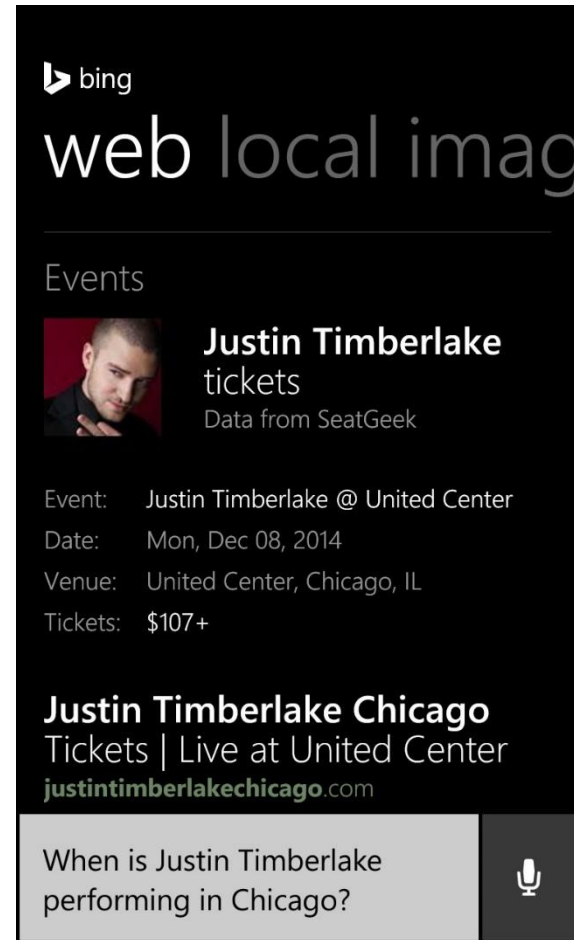
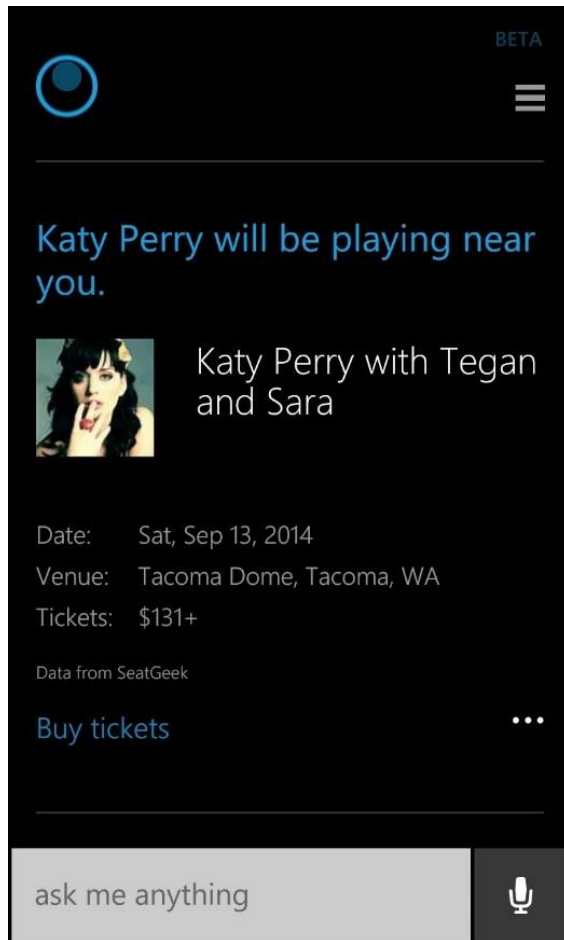
Founded: 1976
Coach: Pete Carroll
Championships: Super Bowl XLVIII · 2014 NFC Championship Game
Owners: Paul Allen · Paul G. Allen Family Foundation
Venue: CenturyLink Field
Location: Seattle

Roster

3	Russell Wilson	Quarterback
24	Marshawn Lynch	Running back
89	Doug Baldwin	Wide Receiver
15	Jermaine Kearse	Wide Receiver
88	Jimmy Graham	Tight End

<http://blog.nwf.org/2014/01/is-the-seahawk-a-real-bird/>

Phone / Cortana



<http://www.windowsphone.com/en-us/how-to/wp8/cortana/what-can-i-say-to-cortana>

<http://blogs.bing.com/search/2014/10/17/bing-adds-smarts-to-cortana/>

Windows

← Results for "san diego" 🔍

72°F ☀️
Sunny

1.33 million (2011)
Population

📍 View on map
Maps

➔ Explore city
Travel

☰ Read about
Wikipedia

Attractions >

- Balboa Park
- San Diego Zoo
- SeaWorld San Diego
- San Diego Zoo Safari Park
- San Diego Bay Marina

San Diego

Data from: Accuweather · Wikipedia · Freebase

<http://blogs.bing.com/search/2013/10/18/unwrapping-windows-8-1-bing-smart-search/>

Windows

Results for "daft punk" ↻

Electronic / Dance
Genre

Dance
Subgenre

Daft Punk is a French electronic music duo consisting of musicians Guy-Manuel de Homem-Christo and Thomas Bangalter. Daft Punk reached significant popularity in the late 1990s house...

[Play top songs](#)
Xbox Music

[Read about](#)
Wikipedia

Songs

- Get Lucky (feat. Pharrel...) 6:07
- Give Life Back to Music 4:34
- Lose Yourself to Dance... 5:53
- The Game of Love 5:21
- Giorgio by Moroder 9:04
- Instant Crush (feat. Juli... 5:37
- Within 3:48
- Beyond 4:50

Albums

- Random Access Me...
- TRON: Legacy
- Discovery

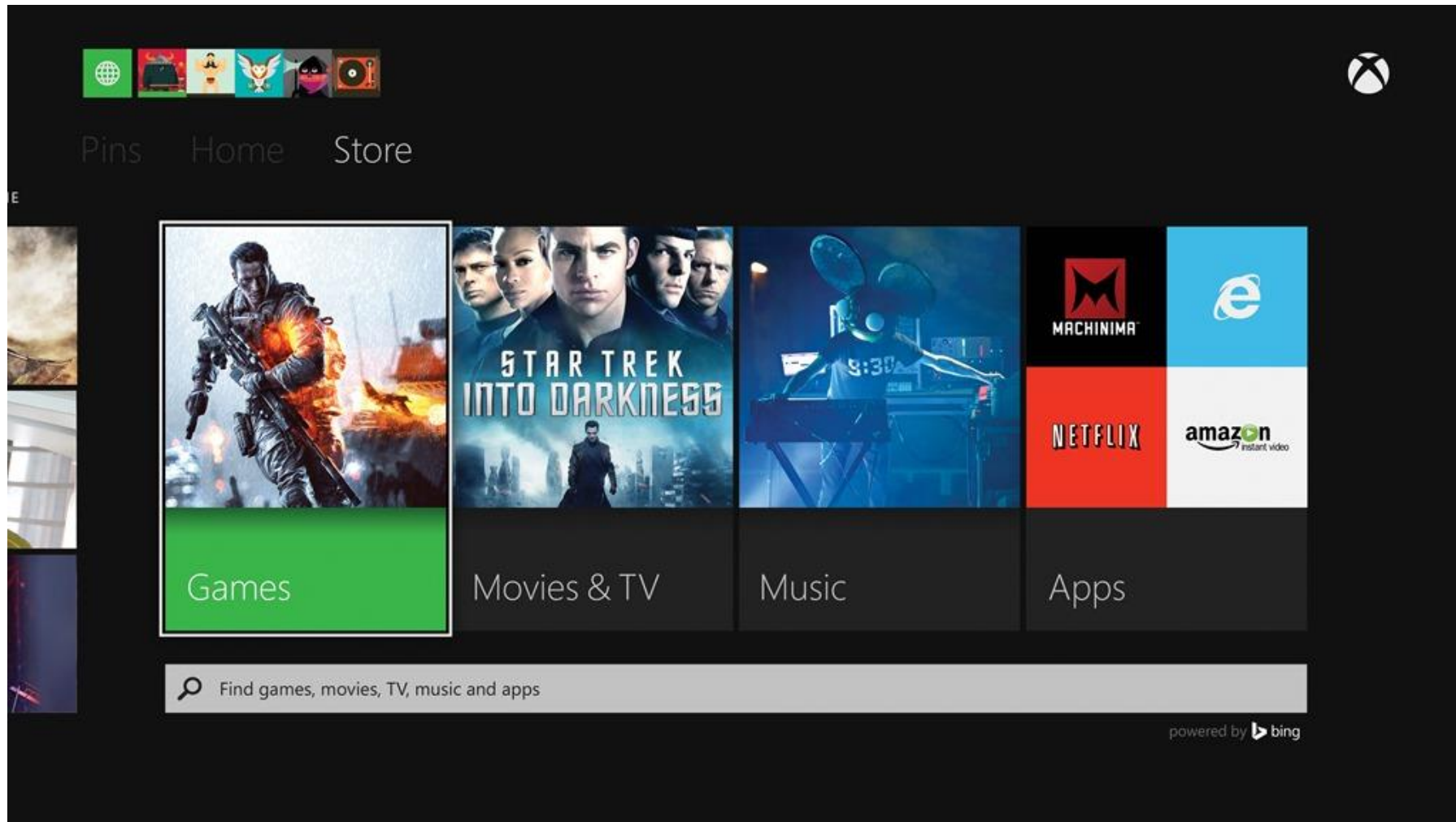
Videos

- Daft Punk - Around The... YouTube (4:03)
- Daft Punk - One More Time YouTube (5:21)

Daft Punk

Data from: Xbox Music · wikipedia · freebase

Xbox



<http://blogs.bing.com/search/2013/11/19/xbox-bing-deliver-me-a-whole-new-way-to-search/>

Challenges


- Speed – entity search can't slow down web search.
- Size – serve hundreds of millions of entities online.
- Generalize to tail – how to retrieval and recommend tail entities when there are no popularity signals.
- Ambiguity – how to ask users to clarify intent.

Outline

- Introduction to Entity and Knowledge
- Demonstration of Microsoft's Entity Experience
- Entity Recommendation and Understanding
 - $P(\text{entity}|\text{entity})$
 - $P(\text{entity}|\text{user})$
 - $P(\text{entity}|\text{query})$
- Summary

Entity Recommendation and Understanding

Traditional Recommender Systems




Today's Recommendations For You

Here's a daily sample of items recommended for you. Click here to [see all recommendations](#). Page 1 of 25



Invincible ~ Michael Jackson
★★★★☆ (880) \$7.99



In Search of Sunrise, Vol. 7: Asia
 ~ DJ Tiesto
★★★★☆ (53) \$15.99



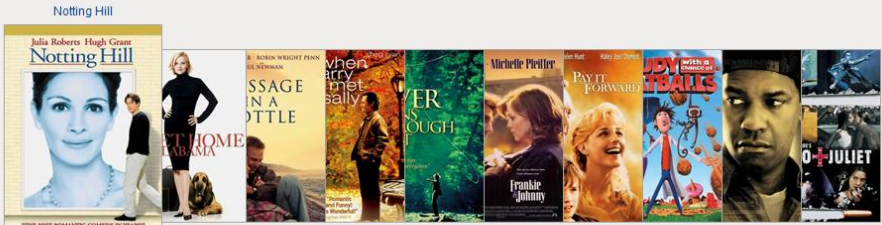
Fallen ~ Evanescence
★★★★☆ (2,447) \$8.99



Amar Es Combatir ~ Maná
★★★★☆ (55) \$8.49



Top Picks for You [How these are chosen for you.](#)



Notting Hill
Julia Roberts Hugh Grant
Notting Hill
"THE BEST ROMANTIC COMEDY BY YEARS"
★★★★☆

Rome
Ben Barnes
Rome
★★★★☆

When Harry Met Sally...
Billy Crystal Sally Field
When Harry Met Sally...
★★★★☆

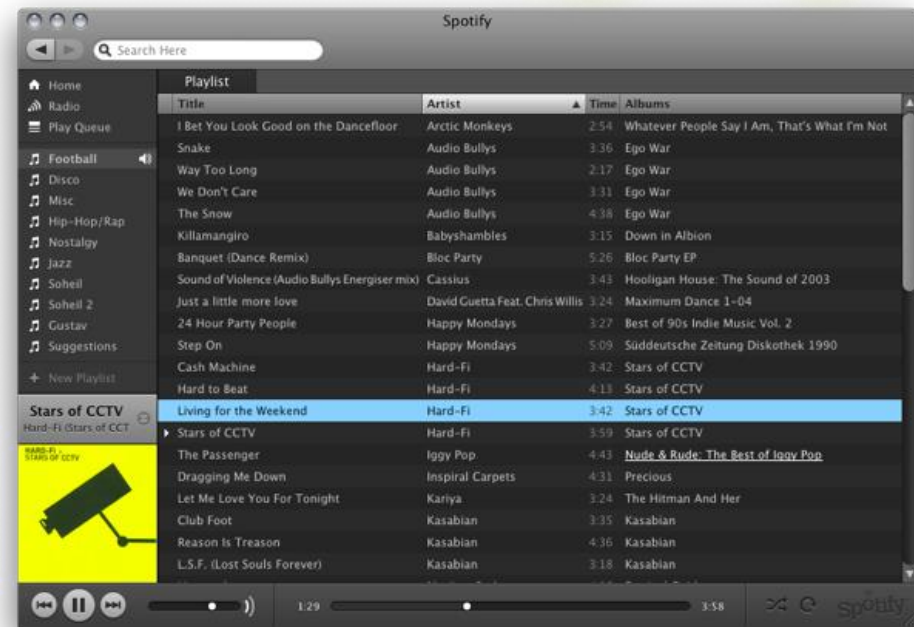
Frankie & Johnny
Michelle Pfeiffer
Frankie & Johnny
★★★★☆

Pay It Forward
Kevin Spacey
Pay It Forward
★★★★☆

Juicy Balls
Wesley Snipes
Juicy Balls
★★★★☆

0-7 JULIET
Lance Reddick
0-7 JULIET
★★★★☆

Play
Not Interested



Spotify

Search Here

Home Radio Play Queue Football Disco Misc Hip-Hop/Rap Nostalgia Jazz Soheil Soheil 2 Gustav Suggestions

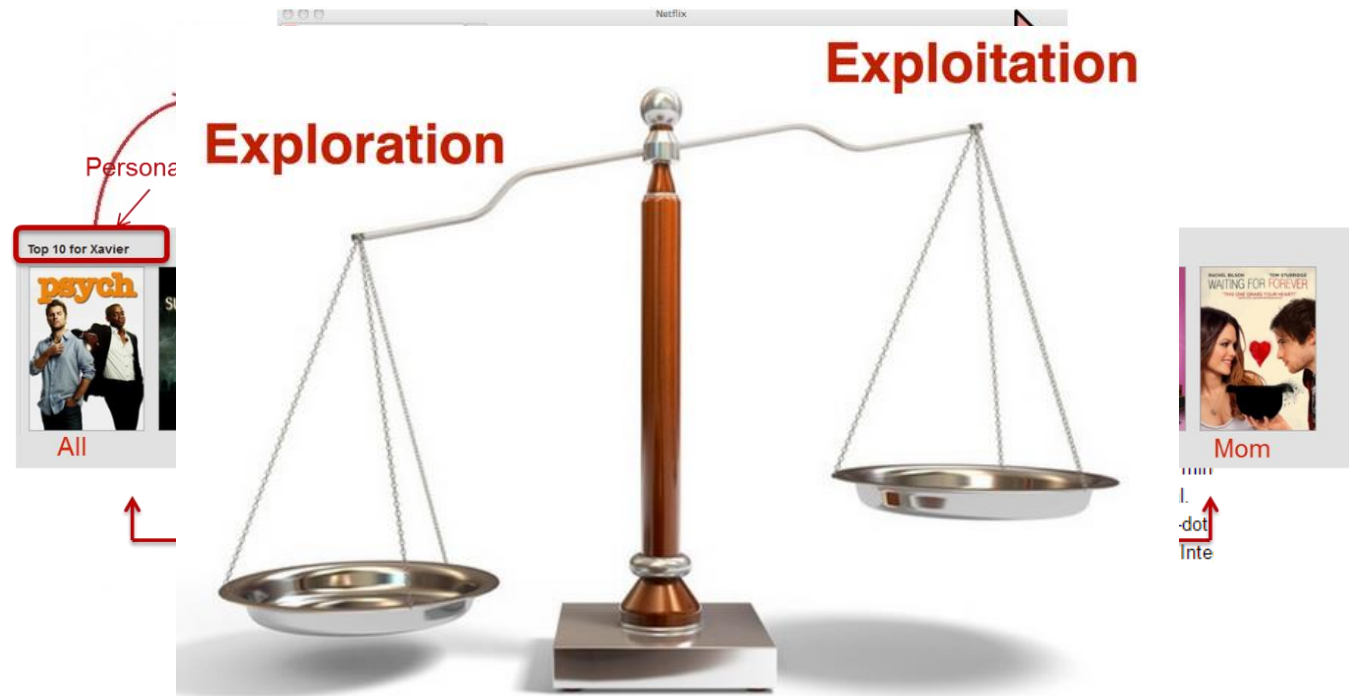
New Playlist

Title	Artist	Time	Albums
I Bet You Look Good on the Dancefloor	Arctic Monkeys	2:54	Whatever People Say I Am, That's What I'm Not
Snake	Audio Bullys	3:36	Ego War
Way Too Long	Audio Bullys	2:17	Ego War
We Don't Care	Audio Bullys	3:31	Ego War
The Snow	Audio Bullys	4:38	Ego War
Killamangiro	Babyshambles	3:15	Down in Albion
Banquet (Dance Remix)	Bloc Party	5:26	Bloc Party EP
Sound of Violence (Audio Bullys Energiser mix)	Cassius	3:43	Hooligan House: The Sound of 2003
Just a little more love	David Guetta Feat. Chris Willis	3:24	Maximum Dance 1-04
24 Hour Party People	Happy Mondays	3:27	Best of 90s Indie Music Vol. 2
Step On	Happy Mondays	5:09	Süddeutsche Zeitung Diskothek 1990
Cash Machine	Hard-Fi	3:42	Stars of CCTV
Hard to Beat	Hard-Fi	4:13	Stars of CCTV
Stars of CCTV	Living for the Weekend	3:42	Stars of CCTV
Stars of CCTV	Hard-Fi	3:59	Stars of CCTV
The Passenger	Iggy Pop	4:43	Nude & Ruie: The Best of Iggy Pop
Dragging Me Down	Inspirational Carpets	4:31	Precious
Let Me Love You For Tonight	Kariya	3:24	The Hitman And Her
Club Foot	Kasabian	3:35	Kasabian
Reason Is Treason	Kasabian	4:36	Kasabian
L.S.F. (Lost Souls Forever)	Kasabian	3:18	Kasabian

1:29 3:58

Traditional Recommender Systems

- Recommender Systems have been well studied from many aspects
 - Collaborative filtering
 - Content-based
 - Context-aware
 - Rating-based
 - Learning to Rank
 - Diversity
 - Serendipity
 - Social-Aware
 - Temporal
 - Explore/Exploit
 -



Traditional Recommender Systems

- Majority of the algorithms is focusing on Personalization
 - $P(item|user)$
 - User-Item Matrix

	v_1	v_2	v_3	v_4	v_5
u_1	1		2	3	
u_2		3			1
u_3		4		5	
u_4	5			4	
u_5		2	5		4

	v_1	v_2	v_3	v_4	v_5	v_6
u_1		1	1		1	
u_2	1			1		1
u_3			1			1
u_4	1			1		
u_5		1	1			1

Entity Recommender Systems

- Entity Graph
 - Heterogeneous Graph
 - Freebase
 - 2K+ commonly used types
 - 30K+ commonly used properties



Entity Recommender Systems

- Entity Graph
 - High Size
Freebase
47M+ topics
2.9B+ facts



Entity Recommender Systems

- Non-Personalized
 - $P(item|item)$
 - $P(item|query)$

Collaborative filtering

Collaborative filtering is a technique used by some recommender systems. Collaborative filtering has two senses, a narrow one and a more general one. In general, filtering for information or pattern collaboration among multiple

en.wikipedia.org

People also search for

[Recommender system](#)

[Cosine similarity](#)

[Cold start](#)

[Learning to rank](#)

[Collective intelligence](#)

[See more](#) ▾



www 2015 date

Web

Images

Videos

Maps

News

More

1,440,000,000 RESULTS

Any time ▾

2015 WWW Conference start date

May 20, 2015

[Data from WWW2015](#)

Entity Recommender Systems

- Personalization
 - $P(item|user)$




Entity Recommender Systems in Search

- Recommendation & Ranking
- Interpretation
- Entity Collection Recommendation
- Exploration
- Personalization

Recommendation & Ranking

Tom Cruise



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 Endless Love. After portraying supp... +
en.wikipedia.org

www.imdb.com

Born: Jul 3, 1962 (age 51) · Syracuse, New York

Height: 5' 7" (1.70 m)






Spouse: [Katie Holmes \(2006 - 2012\)](#) · [Nicole Kidman \(1990 - 2001\)](#) · [Mimi Rogers \(1987 - 1990\)](#)

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






Upcoming movies: [Edge of Tomorrow](#)

Siblings: [Lee Ann Mapother](#) · [Marian Mapother](#) · [Cass Mapother](#)


Movies

 Oblivion 2013	 Jack Reacher 2012	 Edge of Tomorrow 2014	 Rock of Ages 2012	 Mission: Impossible... 2011
--	--	--	--	---

People also search for

 Brad Pitt	 Leonardo DiCaprio	 Tom Hanks	 Bruce Willis	 Johnny Depp
--	--	--	---	---

Hao Ma





I worked on many interesting problems in both
... and ...

Concrete Mathematics

[Amazon](#) 4.5/5 ★★★★★

Bellevue Square








en.wikipedia.org

Bellevue Square is a shopping center in Bellevue, Washington. The mall has 180 retail stores, with anchors JCPenney, Macy's, and Nordstrom, and specialty stores such as Tiffany's, Hugo Boss, Armani Exchange, Lego, Victorinox Swiss Army, and the Microsoft Store. Restaurants include P.F. Chang's, The Cheesecake Factory, Red Robin, and R... +
en.wikipedia.org

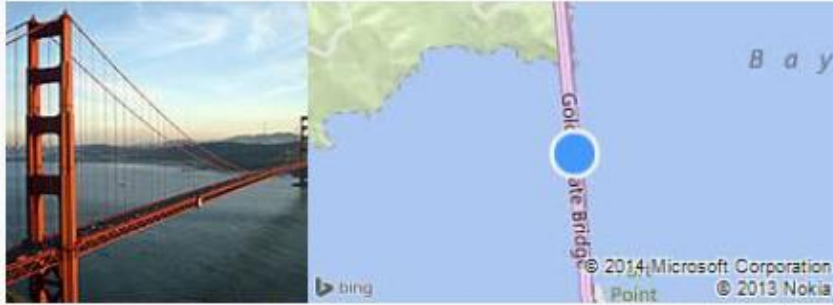
Built: 1946

People also search for

 Lincoln Square	 Westfield Southcenter	 Bellevue Arts Muse...	 The Outlet Collection ...	 Meydenbaue r Center
---	--	--	--	--

Interpretation

Golden Gate Bridge



en.wikipedia.org

The Golden Gate Bridge is a suspension bridge spanning the Golden Gate strait, the mile-wide, three-mile-long channel between San Francisco Bay and the Pacific Ocean. The structure links the U.S. city of San Francisco, on the northern tip of the San Francisco Peninsula, to Marin County, bridging both U.S. Route 101 and California State R... +

en.wikipedia.org

Built: 1937

Length: 8,980 feet (2,737 m)

Height: 746 feet (227.40 m)

Architects: [Joseph Strauss](#) · [Charles Alton Ellis](#) · [Irving Morrow](#)

Location: [San Francisco](#) · [Marin County](#)

Crosses: [Golden Gate](#)

Bridge type: [Suspension bridge](#) · [Truss bridge](#) · [Truss arch bridge](#)

Charles Alton Ellis was a professor, structural engineer and mathematician who was chiefly responsible for the structural design of the Golden Gate Bridge.



[Joseph Strauss](#)
Architect



[Charles Alton Ellis](#)
Architect



[Irving Morrow](#)
Architect



[Amadeo Giannini](#)



[Leon Moisseiff](#)

Harvard University



www.harvard.edu

Harvard University is a private Ivy League research university in Cambridge, Massachusetts, whose history, influence and wealth have made it one of the most prestigious universities in the world. Established in 1636 by the Massachusetts legislature and soon thereafter named for John Harvard, Harvard is the United States' o... +

en.wikipedia.org

Address: 1350 Massachusetts Ave, Cambridge, MA, 02138 · [Directions](#)

Ranking: #2 National University (2014)

Undergraduates: 6,658 (2014)

Acceptance rate: 6% (2014)

Tuition: \$42,292 USD (2014)

Founder: [John Harvard](#)

School color: [Crimson](#)

Mascot: [Harvard University John Harvard](#)

Born in Honolulu, Hawaii, Barack Obama is a graduate of Columbia University and Harvard Law School, where he was president of the Harvard Law Review.

Related people



[John Harvard](#)
Founder



[Drew Gilpin Faust](#)



[Mark Zuckerberg](#)
Alumni



[Barack Obama](#)
Alumni



[Bill Gates](#)
Alumni

Entity Collection Recommendation










bing MS Beta

pop musicians

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Pop musicians frequently mentioned on the web

								
Michael Jackson 1958 - 2009	Katy Perry	Taylor Swift	Lady Gaga	Elvis Presley 1935 - 1977	Britney Spears	Justin Bieber	Justin Timberlake	Miley Cyrus

bing MS Beta











basketball movies

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Basketball - Movies

Popular first

									
Space Jam (1996) ★★★★☆	He Got Game (1998) ★★★★☆	White Men Can't Jump (1992) ★★★★☆	Coach Carter (2005) ★★★★☆	Like Mike (2002) ★★★★☆	Blue Chips (1994) ★★★★☆	Glory Road (2006) ★★★★☆	Hoosiers (1987) ★★★★☆	Finding Forrester (2001) ★★★★☆	BASEketball (1998) ★★★★☆

Entity Collection Recommendation

bing MS Beta




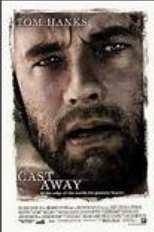






tom hanks drama movies

Web Images Videos Maps News More

262 Sign in

Tom Hanks - Drama movies

Drama Popular first

									
Captain Phillips (2013) ★★★★★	Saving Mr. Banks (2013) ★★★★★	Forrest Gump (1994) ★★★★★	Cast Away (2000) ★★★★★	The Green Mile (1999) ★★★★★	Saving Private Ryan (1998) ★★★★★	Larry Crowne (2011) ★★★★★	Philadelphia (1994) ★★★★★	Cloud Atlas (2012) ★★★★★	Sleepless in Seattle (1993) ★★★★★

bing MS Beta





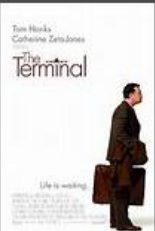





tom hanks romance movies

Web Images Videos Maps News More

262 Sign in

Tom Hanks - Romance movies

Romance Popular first

									
Forrest Gump (1994) ★★★★★	Big (1988) ★★★★★	Larry Crowne (2011) ★★★★★	Sleepless in Seattle (1993) ★★★★★	The Terminal (2004) ★★★★★	You've Got a Mail (1998) ★★★★★	Splash (1984) ★★★★★	Joe Versus the Volcano (1990) ★★★★★	My Big Fat Greek Wedding (2002) ★★★★★	Mamma Mia! (2008) ★★★★★

Die Hard (1988)



Die Hard is a 1988 American action film directed by John McTiernan and written by Steve de Souza and Jeb Stuart, based on the 1979 novel Nothing Lasts Forever by Roderick Thorp. Die Hard follows off-duty New York City Police Department offi... +

en.wikipedia.org

en.wikipedia.org

Summary: R · 2hr 11min · Action/Adventure

Release date: Jul 15, 1988

Director: John McTiernan

Sequel: Die Hard 2

Story by: Roderick Thorp

Music by: Michael Kamen

Watch movie

Reviews

★★★★★ (993,662)

Explore more

Die Hard movies

Bruce Willis movies

Action movies (Ranked at #6)

Movies about Christmas (Ranked at #5)

Movies about terrorism (Ranked at #3)

Cast



Bruce Willis
John
McClane



Alan
Rickman
Hans Gruber



Reginald
VelJohnson
Sgt. Al
Powell (a...



Bonnie
Bedelia
Holly
Gennaro ...

Exploration



die hard movies



MS Beta

50,500,000 RESULTS

Any time

[Die Hard film series - movies](#)



christmas movies



MS Beta

125,000,000 RESULTS

Any time

Christmas - Movies



terrorism movies



MS Beta

15,000,000 RESULTS

Any time

movies



Entity Recommendation & Understanding Taxonomy

- $P(item|item)$
 - Recommendations given an item
- $P(item|user)$
 - Recommendations given a user
- $P(item|query)$
 - Recommendations given a query

Entity Recommendation & Understanding Taxonomy

- $P(\text{entity}|\text{entity})$
 - Recommendations given an entity
- $P(\text{entity}|\text{user})$
 - Recommendations given a user
- $P(\text{entity}|\text{query})$
 - Recommendations given a query



$P(\text{entity}|\text{entity})$

- $P(\text{Florence}|\text{Italy}) = \frac{\text{Freq}(\text{Florence}, \text{Italy})}{\text{Freq}(\text{Italy})}$

Co-occurrence

- $P(\text{Florence}|\text{Italy}) = \frac{\text{Sim}(\text{Florence}, \text{Italy})}{\sum \text{Sim}(*, \text{Italy})}$

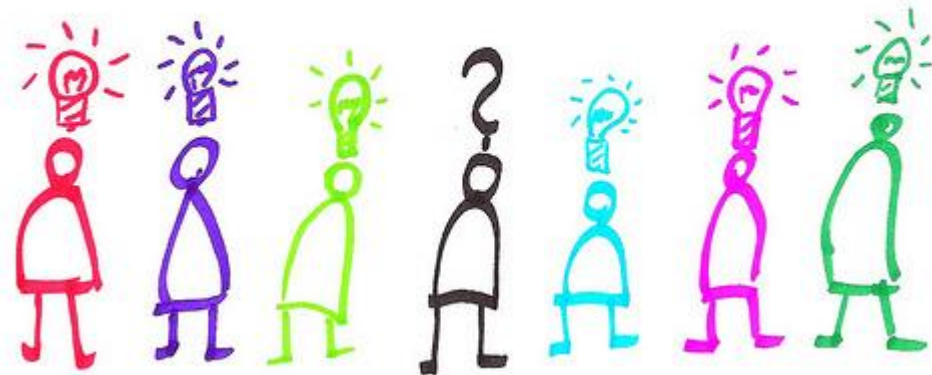
Cosine Similarity

Item-Based Top-N Recommendation Algorithms [Mukund Deshpande, et al., ACM TOIS 2004]

$P(\text{entity}|\text{entity})$ – Co-occurrence

- Sources
 - Within Queries
 - Across Queries
 - User Url Clicks
 - Wikipedia Pages
 - Wikipedia Categories/Templates
 - Wikipedia Revision Histories
 - Web documents
 -

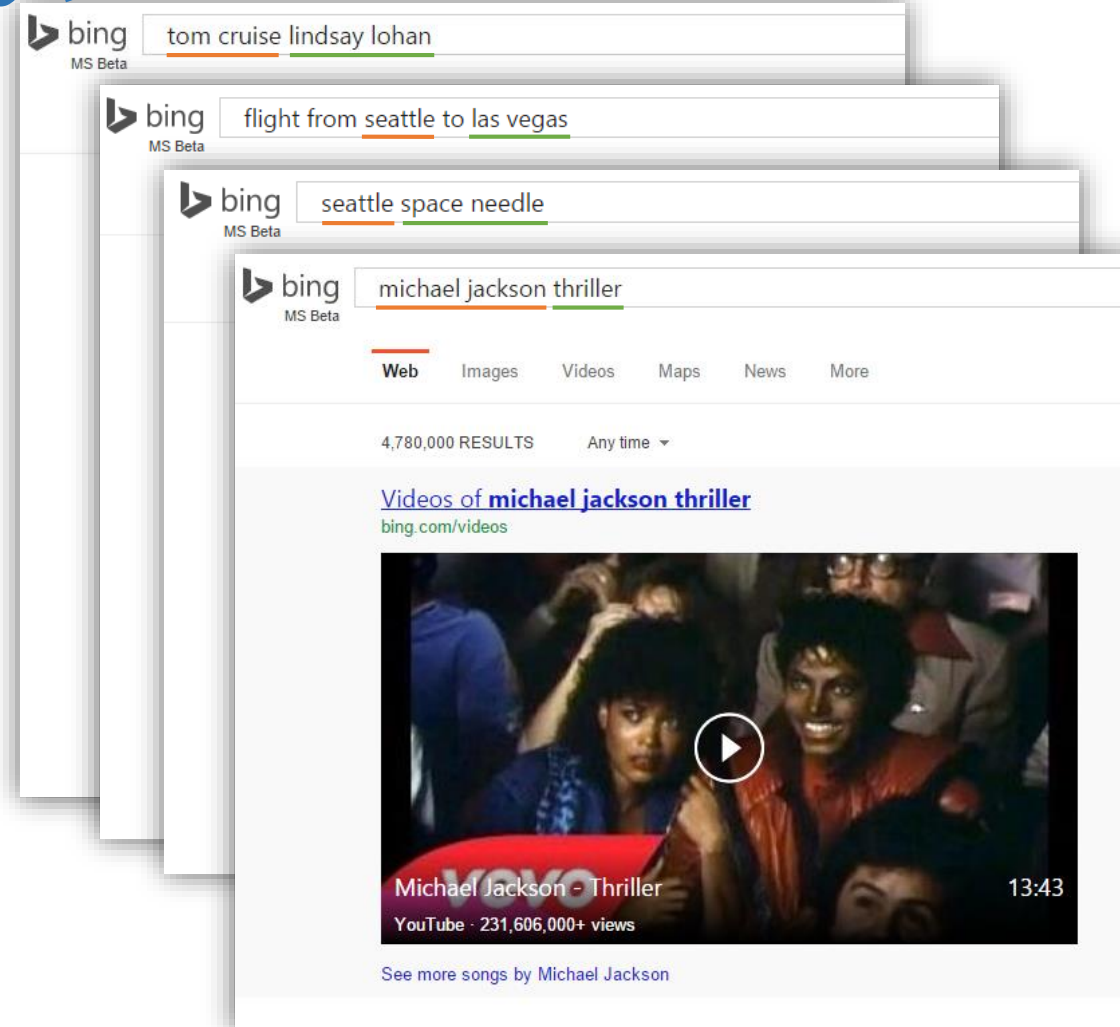
The Wisdom of Crowds



$P(\text{entity}|\text{entity})$ – Co-occurrence

- Within Queries

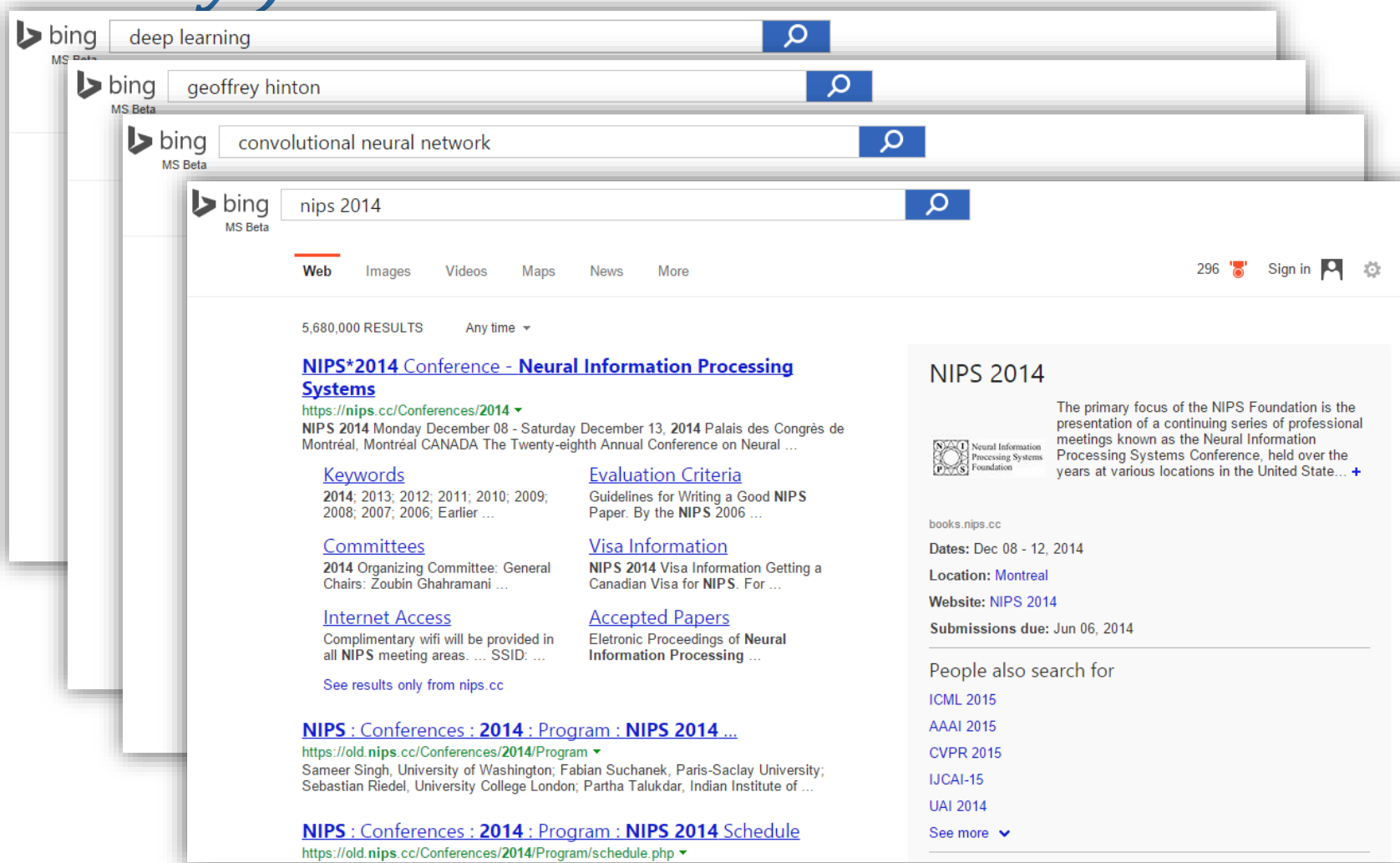
How to extract those entities?



Entity Recommendations in Web Search [Roi Blanco, et al., ISWC 2013]

$P(\text{entity}|\text{entity})$ – Co-occurrence

- Across Queries



The image shows a stack of four Bing search results pages. The top page is for the query 'nips 2014'. The search results include:

- 5,680,000 RESULTS** Any time ▾
- [NIPS*2014 Conference - Neural Information Processing Systems](#)**
<https://nips.cc/Conferences/2014> ▾
NIPS 2014 Monday December 08 - Saturday December 13, 2014 Palais des Congrès de Montréal, Montréal CANADA The Twenty-eighth Annual Conference on Neural ...
- Keywords**
2014; 2013; 2012; 2011; 2010; 2009; 2008; 2007; 2006; Earlier ...
- Evaluation Criteria**
Guidelines for Writing a Good NIPS Paper. By the NIPS 2006 ...
- Committees**
2014 Organizing Committee: General Chairs: Zoubin Ghahramani ...
- Visa Information**
NIPS 2014 Visa Information Getting a Canadian Visa for NIPS. For ...
- Internet Access**
Complimentary wifi will be provided in all NIPS meeting areas. ... SSID: ...
- Accepted Papers**
Electronic Proceedings of Neural Information Processing ...
- See results only from nips.cc**
- [NIPS : Conferences : 2014 : Program : NIPS 2014 ...](#)**
<https://old.nips.cc/Conferences/2014/Program> ▾
Sameer Singh, University of Washington; Fabian Suchanek, Paris-Saclay University; Sebastian Riedel, University College London; Partha Talukdar, Indian Institute of ...
- [NIPS : Conferences : 2014 : Program : NIPS 2014 Schedule](#)**
<https://old.nips.cc/Conferences/2014/Program/schedule.php> ▾

On the right side of the search results, there is a summary for NIPS 2014:

- NIPS 2014**
- The primary focus of the NIPS Foundation is the presentation of a continuing series of professional meetings known as the Neural Information Processing Systems Conference, held over the years at various locations in the United State... +
- books.nips.cc
- Dates:** Dec 08 - 12, 2014
- Location:** Montreal
- Website:** NIPS 2014
- Submissions due:** Jun 06, 2014
- People also search for
 - ICML 2015
 - AAAI 2015
 - CVPR 2015
 - IJCAI-15
 - UAI 2014
 - See more ▾

Entity Recommendations in Web Search [Roi Blanco, et al., ISWC 2013]

$P(\text{entity}|\text{entity})$ – Co-occurrence



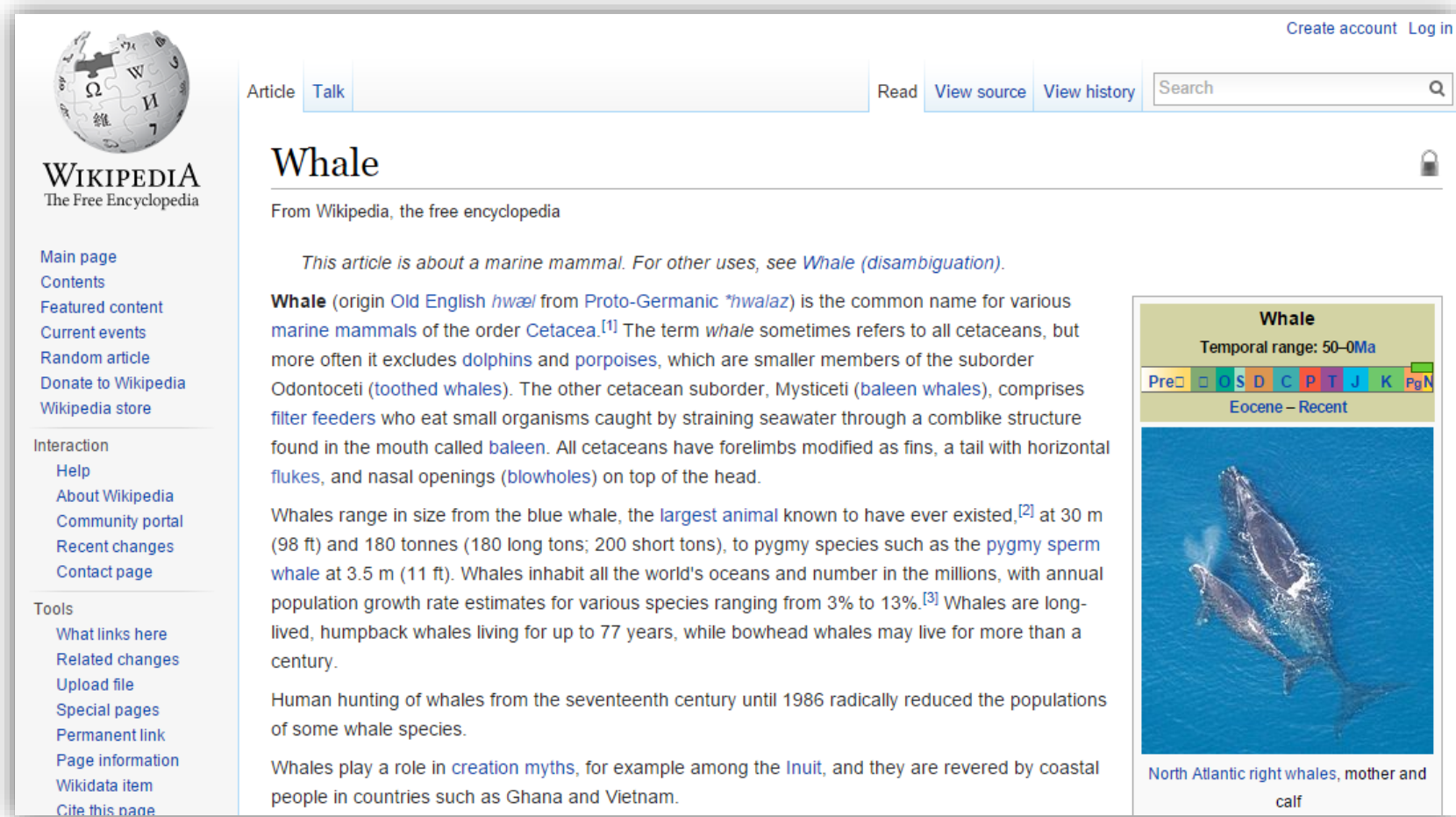
– User Url Clicks

The image displays three side-by-side screenshots of Bing search results, each with a hand cursor icon pointing to a specific result, illustrating user clicks on search results.

- Search 1: "sherlock holmes 2009"**
 - Results: 2,560,000 RESULTS
 - Clicked result: **Sherlock Holmes (2009)** - en.wikipedia.org/wiki/Sherlock_Holmes
 - Other result: **Sherlock Holmes (2009)** - www.imdb.com/title/tt0988016
- Search 2: "iron man 3"**
 - Results: 77,000,000 RESULTS
 - Clicked result: **Iron Man 3 (2013)** - www.imdb.com/title/tt1344299
 - Other result: **Iron Man 3 - Wikipedia** - en.wikipedia.org/wiki/Iron_Man_3
- Search 3: "robert downey"**
 - Results: 4,550,000 RESULTS
 - Clicked result: **Robert Downey Jr. - Wikipedia** - en.wikipedia.org/wiki/Robert_Downey,_Jr.
 - Other result: **Robert Downey Sr. - Wikipedia** - en.wikipedia.org/wiki/Robert_Downey,_Sr.

$P(\text{entity}|\text{entity})$ – Co-occurrence

– Wikipedia Pages



The image is a screenshot of the Wikipedia article for "Whale". The page layout includes a left sidebar with navigation links, a main content area with text and a table, and a right sidebar with a timeline and an image.

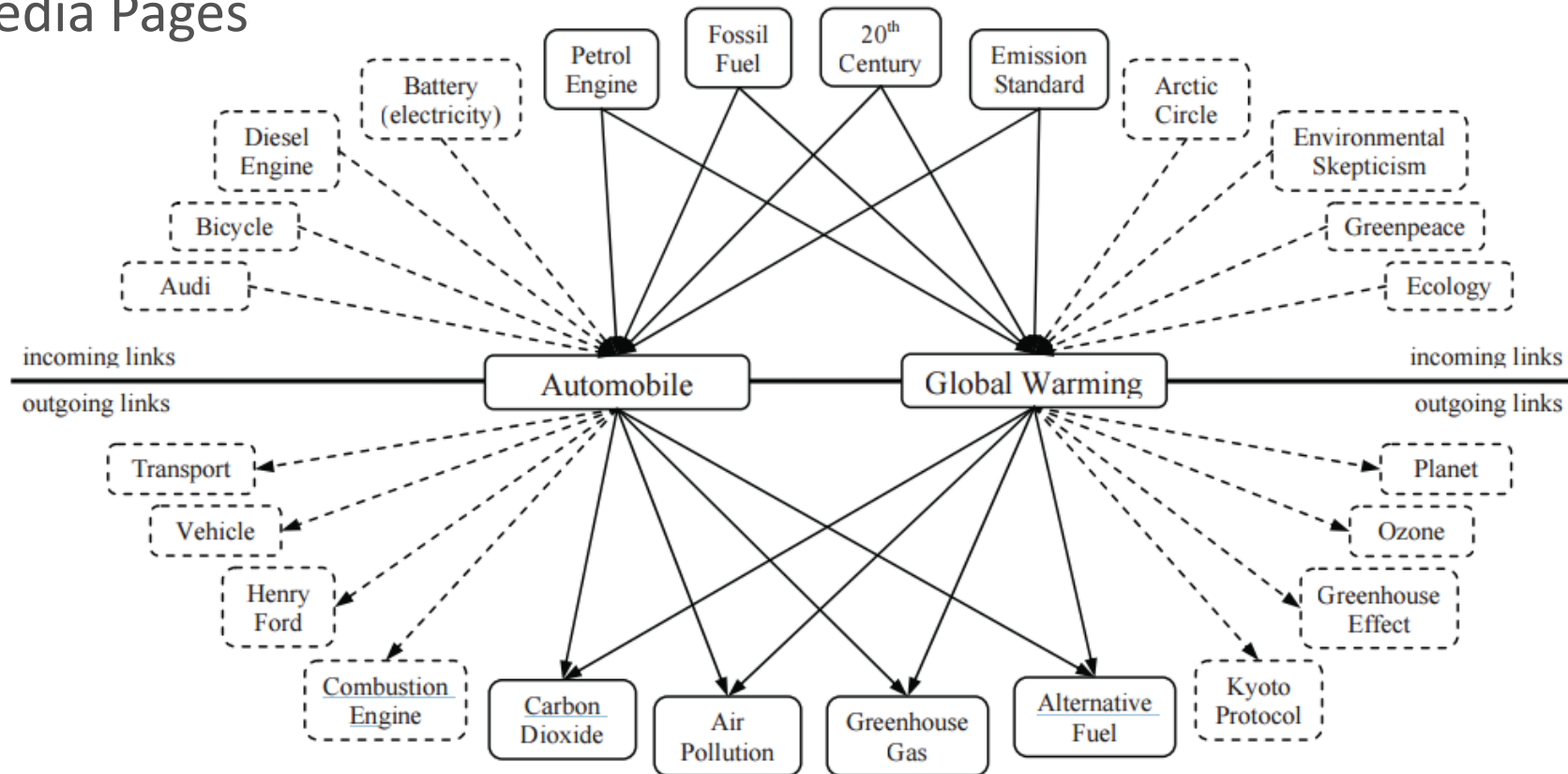
Left Sidebar: Features the Wikipedia logo and the text "WIKIPEDIA The Free Encyclopedia". Below this are sections for "Main page", "Contents", "Featured content", "Current events", "Random article", "Donate to Wikipedia", and "Wikipedia store". There is also an "Interaction" section with links for "Help", "About Wikipedia", "Community portal", "Recent changes", and "Contact page". A "Tools" section includes links for "What links here", "Related changes", "Upload file", "Special pages", "Permanent link", "Page information", "Wikidata item", and "Cite this page".

Main Content Area: The title "Whale" is at the top, followed by the sub-header "From Wikipedia, the free encyclopedia". A note states: "This article is about a marine mammal. For other uses, see *Whale (disambiguation)*." The main text begins: "Whale (origin Old English *hwæl* from Proto-Germanic **hwalaz*) is the common name for various marine mammals of the order Cetacea.^[1] The term *whale* sometimes refers to all cetaceans, but more often it excludes dolphins and porpoises, which are smaller members of the suborder Odontoceti (toothed whales). The other cetacean suborder, Mysticeti (baleen whales), comprises filter feeders who eat small organisms caught by straining seawater through a comblike structure found in the mouth called baleen. All cetaceans have forelimbs modified as fins, a tail with horizontal flukes, and nasal openings (blowholes) on top of the head." A second paragraph states: "Whales range in size from the blue whale, the largest animal known to have ever existed,^[2] at 30 m (98 ft) and 180 tonnes (180 long tons; 200 short tons), to pygmy species such as the pygmy sperm whale at 3.5 m (11 ft). Whales inhabit all the world's oceans and number in the millions, with annual population growth rate estimates for various species ranging from 3% to 13%.^[3] Whales are long-lived, humpback whales living for up to 77 years, while bowhead whales may live for more than a century." A third paragraph states: "Human hunting of whales from the seventeenth century until 1986 radically reduced the populations of some whale species." The final paragraph states: "Whales play a role in creation myths, for example among the Inuit, and they are revered by coastal people in countries such as Ghana and Vietnam."

Right Sidebar: Contains a "Whale" section with a "Temporal range: 50–0Ma" label and a geological time scale diagram showing the Eocene to Recent periods. Below this is an image of a North Atlantic right whale, mother and calf, with the caption "North Atlantic right whales, mother and calf".

$P(entity|entity)$ – Co-occurrence

– Wikipedia Pages

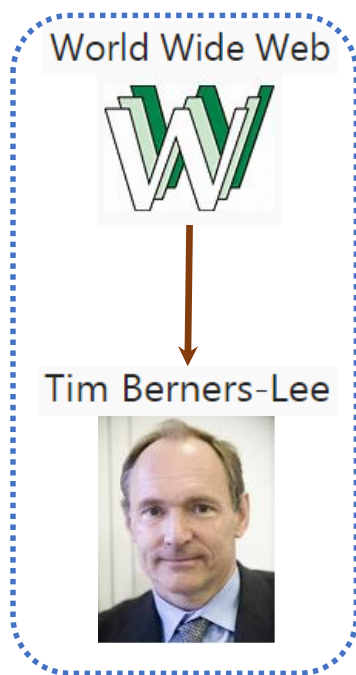


An Effective, Low-Cost Measure of Semantic Relatedness Obtained from Wikipedia Links [David Milne, et al., AAAI 2008]

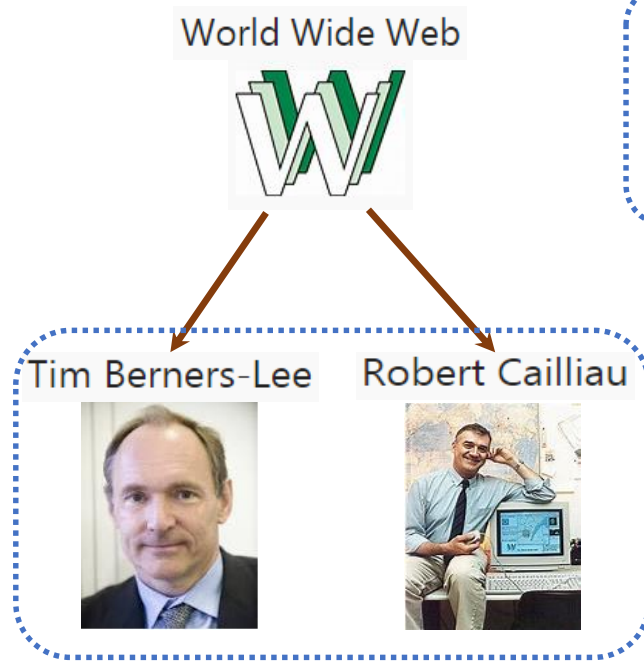
$P(entity|entity)$ – Co-occurrence

– Wikipedia Pages

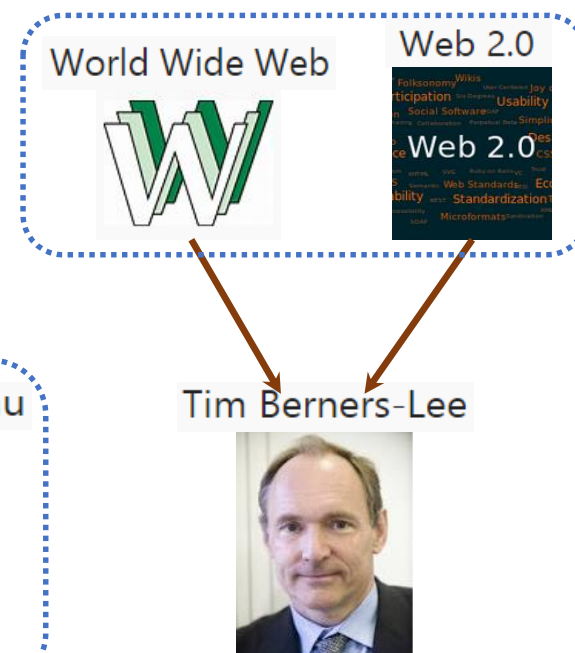
Direct Link



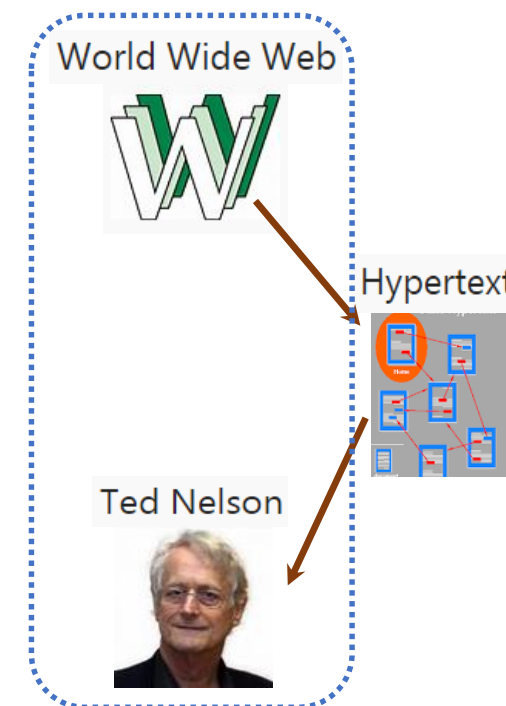
Shared Link



Shared Backlink



Directed Path



Exploratory Recommendations Using Wikipedia's Linking Structure [Adrian M. Kentsch, et al., Benelearn 2011]

$P(\text{entity}|\text{entity})$ – Co-occurrence

– Wikipedia Categories & Templates

The screenshot shows the Wikipedia page for the category "Computer science books". The page includes a sidebar with navigation links, a main content area with subcategories and a list of pages, and a top navigation bar. The sidebar contains sections for "Main page", "Interaction", "Tools", "Print/export", and "Languages". The main content area is titled "Category:Computer science books" and includes a search bar, a "Talk" tab, and a list of subcategories and pages. The list of pages is organized by letter (A, B, C, I, L, R, S, T) and includes titles such as "The Hacker Ethic and the Spirit of the Information Age", "Lecture Notes in Computer Science", "Algorithms + Data Structures = Programs", "The Art of Computer Programming", "Artificial Intelligence: A Modern Approach", "Artificial Minds", "BeBop to the Boolean Boogie", "The Cathedral and the Bazaar", "Compilers: Principles, Techniques, and Tools", "Computer Graphics: Principles and Practice", "The Hacker's Delight", "Handbook of Automated Reasoning", "Homesteading the Noosphere", "How to Design Programs", "Information and Communication Technology for CCEA GCSE", "Introduction to Algorithms", "Introduction to Automata Theory, Languages, and Computation", "Introduction to the Theory of Computation", "Lions' Commentary on UNIX 6th Edition, with Source Code", "Paradigms of AI Programming: Case Studies in Common Lisp", "The Pattern on the Stone", "Perceptrons (book)", "Prentice Hall International Series in Computer Science", "Principles of Compiler Design", "Programming Languages: Application and Interpretation", "Programming the Universe", "The Rootkit Arsenal: Escape and Evasion in the Dark Corners of the System", and "Structure and Interpretation of Computer Programs".

WikiRelate! Computing Semantic Relatedness Using Wikipedia [Michael Strube, et al., AAAI 2006]

$P(entity|entity)$ – Co-occurrence

- Wikipedia Revision History

The image shows three overlapping screenshots of Wikipedia pages. The top screenshot is the main article for 'Susan Dumais'. The middle screenshot is the 'Revision history' page for 'Susan Dumais', showing a list of revisions with the user 'Waacstats' highlighted in a red box. The bottom screenshot is the 'Revision history' page for 'Gerard Salton', showing a list of revisions with the user 'Waacstats' also highlighted in a red box. The 'Waacstats' user name is highlighted in both revision lists, indicating co-occurrence.

Susan Dumais: Revision history

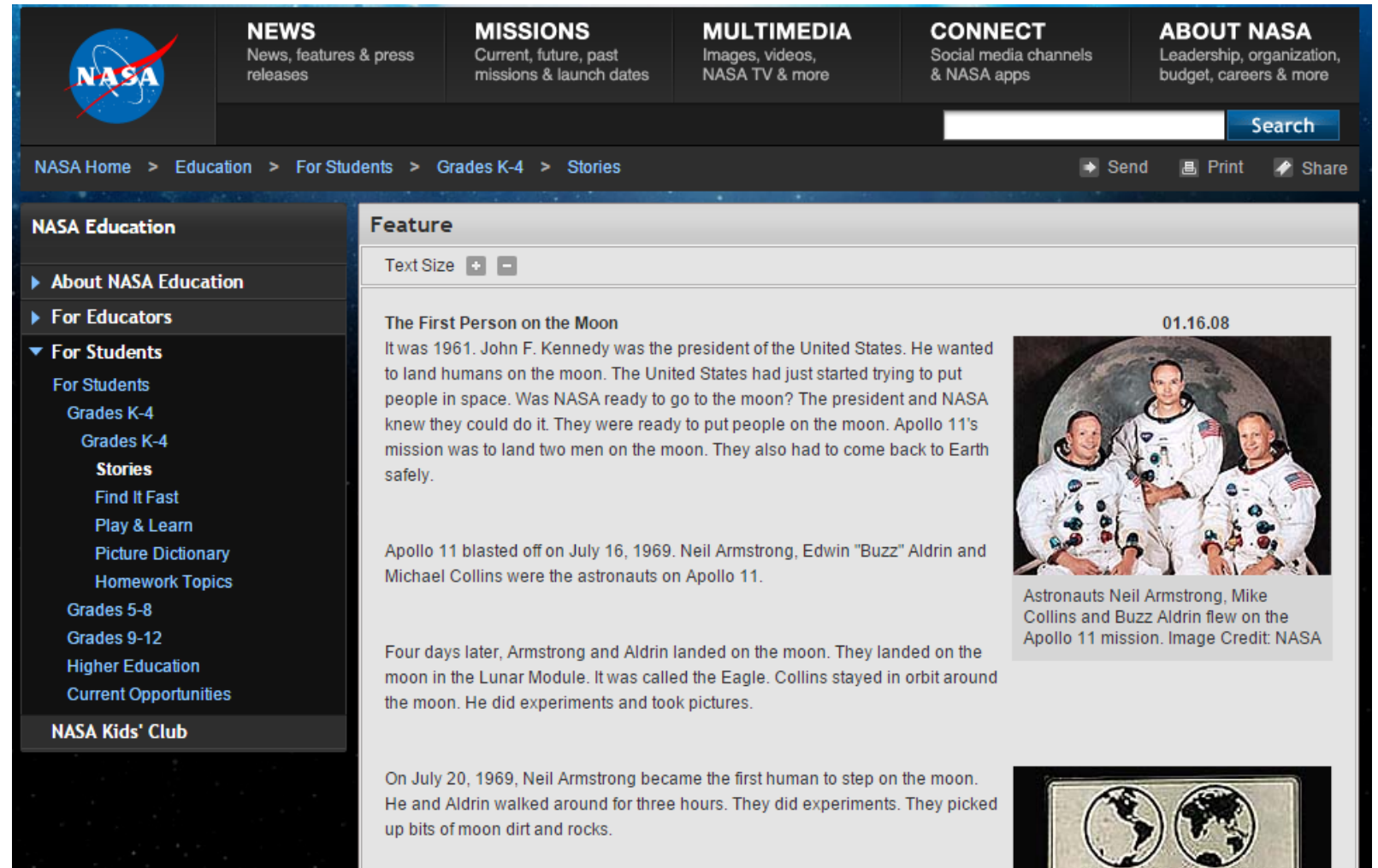
Revision	Date	User	Size	Change
(cur prev)	21:54, 17 November 2014	Waacstats	(talk contribs)	
(cur prev)	09:42, 17 September 2014	Jussi Karlgren	(talk contribs)	
(cur prev)	17:06, 30 April 2014	Yobot	(talk contribs)	m . . (3,670 bytes) (-2) . . (WP:CHECKWIKI error fixes using AWB (10900)) (undo)
(cur prev)	16:08, 28 April 2014	207.236.147.203	(talk)	. . (3,670 bytes) (+1) . . (undo)
(cur prev)	22:10, 5 January 2014	BG19bot	(talk contribs)	m . . (3,670 bytes) (+1) . . (undo)
(cur prev)	20:24, 2 December 2013	Cydebot	(talk contribs)	(undo)
(cur prev)	05:10, 14 November 2013	Ottawahitech	(talk contribs)	
(cur prev)	05:04, 14 November 2013	Ottawahitech	(talk contribs)	
(cur prev)	19:56, 27 September 2013	2001:4898:80e0:ee43::		
(cur prev)	01:00, 4 November 2012	Missvain	(talk contribs)	
(cur prev)	12:10, 11 August 2012	Magioladitis	(talk contribs)	
(cur prev)	09:57, 6 May 2012	Cydebot	(talk contribs)	m . . (3,670 bytes) (+1) . . (Wikipedia:Categories for discussion/Log/2012 April 21.) (undo)

Gerard Salton: Revision history

Revision	Date	User	Size	Change
(cur prev)	08:31, 8 April 2015	Yobot	(talk contribs)	m . . (6,870 bytes) (-2) . . (WP:CHECKWIKI error fixes using AWB (10900)) (undo)
(cur prev)	11:43, 10 March 2015	Velvel2	(talk contribs)	m . . (6,872 bytes) (+820) . . (father of information retrieval) (undo)
(cur prev)	04:45, 23 October 2014	Flyer22	(talk contribs)	m . . (6,052 bytes) (-6) . . (Reverted 1 edit by 128.84.124.43 identified by Yobot) (undo)
(cur prev)	20:31, 22 October 2014	128.84.124.43	(talk)	. . (6,058 bytes) (+6) . . (undo)
(cur prev)	09:32, 27 August 2014	RjwilmsiBot	(talk contribs)	m . . (6,052 bytes) (+14) . . (→External links: Adding/Updating Persondata) (undo)
(cur prev)	09:07, 7 February 2014	Gareth Jones	(talk contribs)	. . (6,038 bytes) (+65) . . (undo)
(cur prev)	09:04, 7 February 2014	Gareth Jones	(talk contribs)	. . (5,973 bytes) (+574) . . (add infobox) (undo)
(cur prev)	07:22, 13 December 2013	Osloom	(talk contribs)	. . (5,399 bytes) (+46) . . (→External links) (undo)
(cur prev)	23:41, 14 September 2013	AManWithNoPlan	(talk contribs)	. . (5,353 bytes) (+92) . . (Filling in 1 references using Reftools) (undo)
(cur prev)	10:41, 12 September 2013	Gareth Jones	(talk contribs)	. . (5,261 bytes) (0) . . (typo) (undo)
(cur prev)	22:54, 11 September 2013	Gareth Jones	(talk contribs)	. . (5,261 bytes) (-101) . . (use template for ref) (undo)
(cur prev)	22:53, 11 September 2013	Gareth Jones	(talk contribs)	. . (5,362 bytes) (-463) . . (use templates for references) (undo)
(cur prev)	22:38, 11 September 2013	Gareth Jones	(talk contribs)	m . . (5,825 bytes) (-18) . . (capitalisation) (undo)
(cur prev)	05:27, 4 June 2013	Cydebot	(talk contribs)	m . . (5,843 bytes) (-31) . . (Robot - Removing category Computer pioneer) (undo)
(cur prev)	06:07, 28 February 2013	Addbot	(talk contribs)	m . . (5,874 bytes) (-85) . . (Bot: Migrating 4 interwiki links, now providing interwiki links) (undo)
(cur prev)	21:53, 3 February 2013	Waacstats	(talk contribs)	m . . (5,959 bytes) (+28) . . (Persondata) (undo)
(cur prev)	10:06, 9 December 2012	Welsh	(talk contribs)	m . . (5,931 bytes) (0) . . (fix link) (undo)

$P(\text{entity}|\text{entity})$ – Co-occurrence

- Web documents
 - Moon
 - John F. Kennedy
 - United States
 - NASA
 - Apollo 11
 - Neil Armstrong
 - Edwin “Buzz” Aldrin
 - Michael Collins
 - Astronauts



The screenshot shows the NASA website's navigation bar with categories: NEWS, MISSIONS, MULTIMEDIA, CONNECT, and ABOUT NASA. The breadcrumb trail is: NASA Home > Education > For Students > Grades K-4 > Stories. The left sidebar lists 'NASA Education' with sub-sections for 'About NASA Education', 'For Educators', and 'For Students' (including 'Grades K-4', 'Grades 5-8', 'Grades 9-12', 'Higher Education', and 'Current Opportunities'). The main content area features a 'Feature' section with a 'Text Size' control. The article is titled 'The First Person on the Moon' and dated '01.16.08'. It contains text about the Apollo 11 mission, including a photo of the three astronauts (Neil Armstrong, Michael Collins, and Buzz Aldrin) and a small image of the Earth from space.

TimeMachine:Timeline Generation for Knowledge-Base Entities [Tim Althoff, et al., arXiv:1502.04662, 2015]

$P(\text{entity}|\text{entity})$ – Co-occurrence

- Entity Recommendations based on Wikipedia Co-occurrence

Whale	Susan Dumais	Tom Cruise
Dolphin	C. J. van Rijsbergen	Nicole Kidman
Pinniped	W. Bruce Croft	Brad Pitt
Shark	Eric Horvitz	Steven Spielberg
Killer whale	George Furnas	Tom Hanks
Humpback whale	Thomas Landauer	John Travolta

Susan Dumais
Latent semantic analysis
Information retrieval
Gerard Salton Award
SIGIR
Singular value decomposition

Entity Linking

- How to extract entities from Queries and Documents?
 - Through Entity Linking!

Entity linking

In natural language processing, entity linking, named entity disambiguation, named entity recognition and disambiguation or named entity normalization is the task of determining the identity of entities mentioned in text. It is distinct from named entity recognition in that it identifies not the occurrence of names, but their reference.

en.wikipedia.org

Academic conferences: [AAAI 2016](#) · [ACL 2015](#) · [CIKM 2015](#) · [WWW 2015](#) · [SIGIR 2015](#) · [COLING 2014](#) · [IJCAI-15](#) · [EMNLP 2015](#) +

People also search for

[Information extraction](#)

[Question answering](#)

[Natural language processing](#)

[Explicit semantic analysis](#)

[Automatic summarization](#)

[See more](#) ▼

Entity Linking



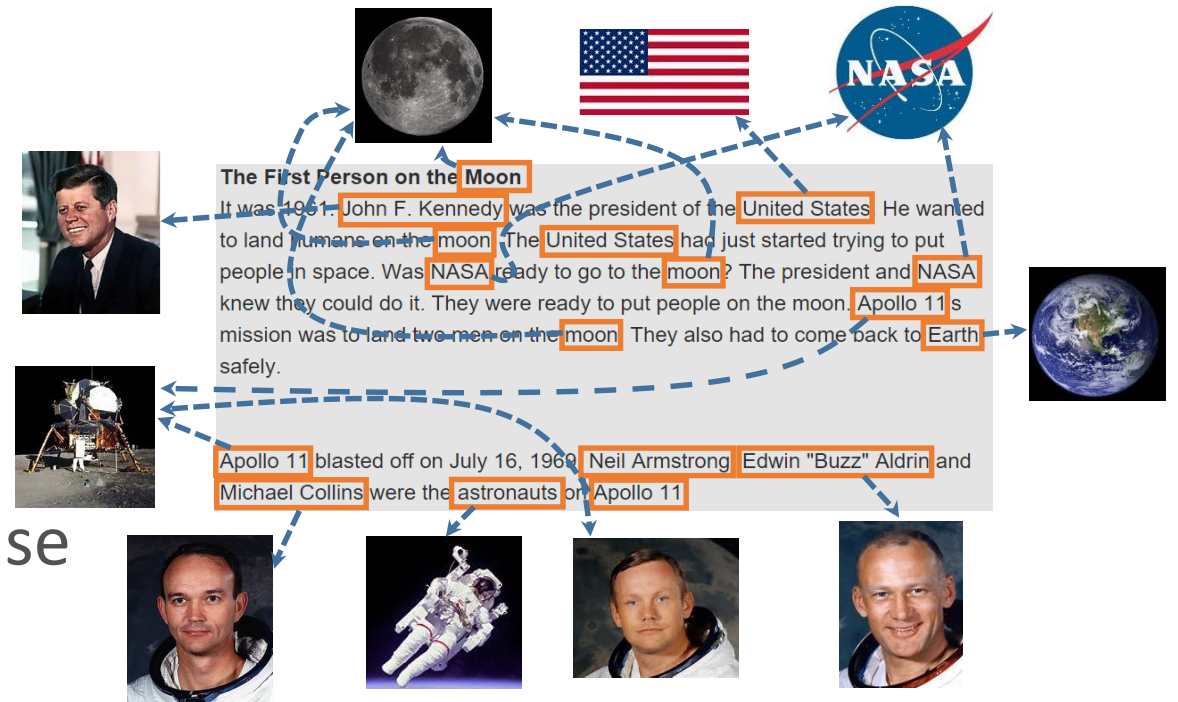
Entity Linking - Main Problem

- Linking free text to entities

- Any piece of text
 - News document
 - Blog posts
 - Tweets
 - Queries
 - ...

- Entities taken from a knowledge base

- Freebase
- Wikipedia
- ...



Entity Linking and Retrieval for Semantic Search [Edgar Meij, et al., WSDM 2014]

Entity Linking - Common Steps

- Determine “linkable” phrases
 - Mention detection
- Select candidate entity links
 - Link generation
 - May include NILs (null values, i.e., no target in KB)
- Use “context” to disambiguate/filter/improve
 - Disambiguation

Entity Linking and Retrieval for Semantic Search [Edgar Meij, et al., WSDM 2014]

Entity Linking

- An Example

Depth-first search
From Wikipedia, the free encyclopedia

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

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

sense	commonness	relatedness
Tree	92.82%	15.97%
Tree (graph theory)	2.94%	59.91%
Tree (data structure)	2.57%	63.26%
Tree (set theory)	0.15%	34.04%
Phylogenetic tree	0.07%	20.33%
Christmas tree	0.07%	0.0%
Binary tree	0.04%	62.43%
Family tree	0.04%	16.31%
...		

Learning to Link with Wikipedia [David Milne, et al., CIKM 2008]

Public Toolkits for Entity Linking

- Wikipedia Miner
- TagMe
- DBpedia Spotlight
- Illinios Wikifier
- AIDA
- RPI Entity Linking System

Entity Linking and Retrieval for Semantic Search [Edgar Meij, et al., WSDM 2014]

$P(\textit{entity}|\textit{entity})$ - Recap

- Co-occurrence
 - Within Queries
 - Across Queries
 - User Url Clicks
 - Wikipedia Pages
 - Wikipedia Categories/Templates
 - Wikipedia Revision Histories
 - Web documents
- Entity Linking
- Similarity

$P(\text{entity}|\text{entity})$ – Similarity

- TF*IDF scores based on Wikipedia Corpus

Florence

From Wikipedia, the free encyclopedia

"Firenze" and "Florentine" redirect here. For other uses, see [Florence \(disambiguation\)](#), [Florentin \(disambiguation\)](#) ([disambiguation](#)).

Florence (/ˈflɒrəns/; Italian: *Firenze* [fiˈrɛntʃe] ⓘ listen), alternative obsolete form: *Fiorenza*; Latin: *Florentia*) is the capital city of the Italian region of [Tuscany](#) and of the [province of Florence](#). It is the most populous city in Tuscany, with approximately 380,000 inhabitants, expanding to over 1,520,000 in the metropolitan area.^[2]

Florence is famous for its history: a centre of [medieval European](#) trade and finance and one of the wealthiest cities of the time,^[3] it is considered the birthplace of the [Renaissance](#), and has been called "the *Athens of the Middle Ages*".^[4] A turbulent political history includes periods of rule by the powerful [Medici](#) family, and numerous religious and republican revolutions.^[5] From 1865 to 1871 the city was the capital of the recently established [Kingdom of Italy](#).

The [Historic Centre of Florence](#) attracts millions of tourists each year, and [Euromonitor International](#) ranked the city as the world's 89th most visited in 2012, with 1.8 million visitors.^[6] It was declared a [World Heritage Site](#) by UNESCO in 1982. The city is noted for its culture, [Renaissance art and architecture](#) and monuments.^[7] The city also contains numerous museums and art galleries, such as the [Uffizi Gallery](#) and the [Palazzo Pitti](#), and still exerts an influence in the fields of art, culture and politics.^[8] Due to Florence's artistic and architectural heritage, it has been ranked by *Forbes* as one of the most beautiful cities in the world.^[9]

Rome

From Wikipedia, the free encyclopedia

This article is about the city in Italy. For the civilization of classical antiquity, see [Ancient Rome](#). For other uses

Rome (/ˈroʊm/, Italian: *Roma* [ˈroːma] ⓘ listen), Latin: *Rōma*) is a city and special *comune* (named "Roma Capitale") in Italy. Rome is the capital of Italy and [region of Lazio](#). With 2.9 million residents in 1,285 km² (496.1 sq mi), it is also the country's largest and most populated *comune* and [fourth-most populous city](#) in the European Union by population within city limits. The [Metropolitan City of Rome](#) has a population of 4.3 million residents.^[2] The city is located in the central-western portion of the [Italian Peninsula](#), within Lazio (Latium), along the shores of [Tiber river](#). [Vatican City](#) is an independent country within the city boundaries of Rome, the only existing example of a country within a city: for this reason Rome has been often defined as capital of two states.^{[3][4]}

Rome's history spans more than two and a half thousand years. While [Roman mythology](#) dates the founding of Rome at only around 753 BC, the site has been inhabited for much longer, making it one of the oldest continuously occupied cities in Europe.^[5] The city's early population originated from a mix of [Latins](#), [Etruscans](#) and [Sabines](#). Eventually, the city successively became the capital of the [Roman Kingdom](#), the [Roman Republic](#) and the [Roman Empire](#), and is regarded as one of the birthplaces of [Western civilization](#). It is referred to as "Roma Aeterna" (The Eternal City)^[6] and "[Caput Mundi](#)" (Capital of the World), two central notions in ancient Roman culture.

$P(entity|entity)$ – Similarity

- Entity Recommendations based on Wikipedia textual similarity

Whale	Susan Dumais	Tom Cruise
Beluga whale	C. J. van Rijsbergen	Leonardo DiCaprio
Toothed whale	W. Bruce Croft	Nicole Kidman
Killer whale	Harry Shum	Clint Eastwood
Pygmy killer whale	Gerard Salton	Mark Rathbun
Humpback whale	Jaime Teevan	L. Ron Hubbard

$P(\textit{entity}|\textit{entity})$ – Similarity

- Challenges

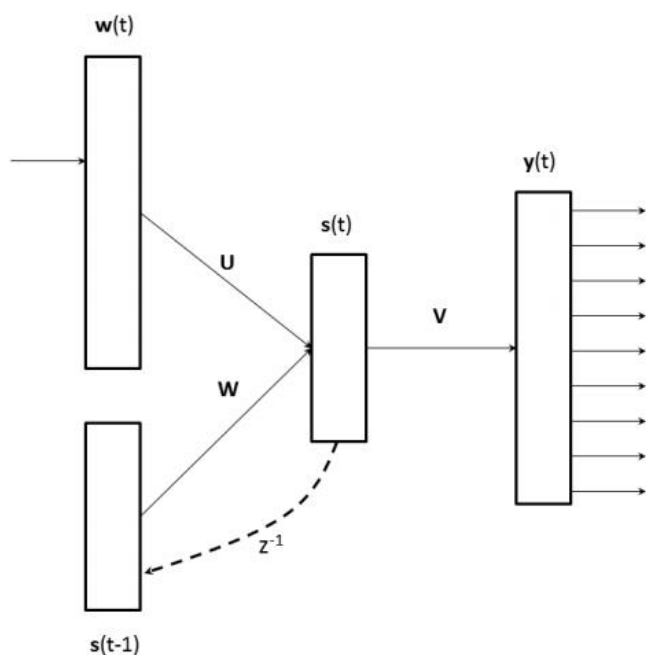
- Textual Similarity suffers the vocabulary mismatch problem
 - “USA” and “United States of America” are semantically equivalent, yet share no terms in common

- Solution

- Project entities into latent space that can semantically represent the entities

$P(\text{entity}|\text{entity})$ – Word Embedding

- Word Embedding



$$\mathbf{s}(t) = f(\mathbf{U}\mathbf{w}(t) + \mathbf{W}\mathbf{s}(t-1))$$

$$\mathbf{y}(t) = g(\mathbf{V}\mathbf{s}(t))$$

$$f(z) = \frac{1}{1 + e^{-z}}, \quad g(z_m) = \frac{e^{z_m}}{\sum_k e^{z_k}}$$

Figure 1: Recurrent Neural Network Language Model.

Linguistic Regularities in Continuous Space Word Representations [Tomas Mikolov, et al., ACL 2013]

$P(entity|entity)$ – Word Embedding

- Word Embedding

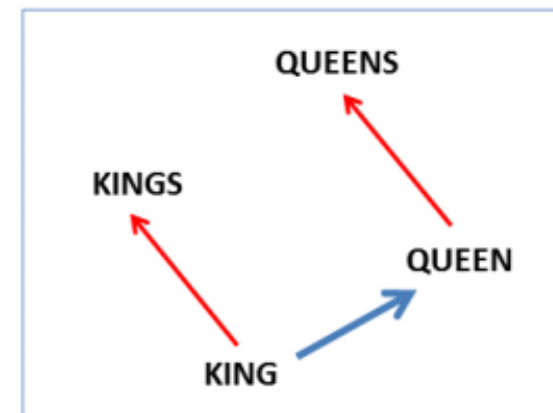
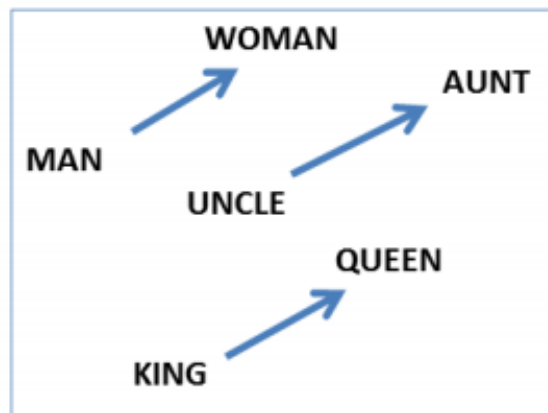
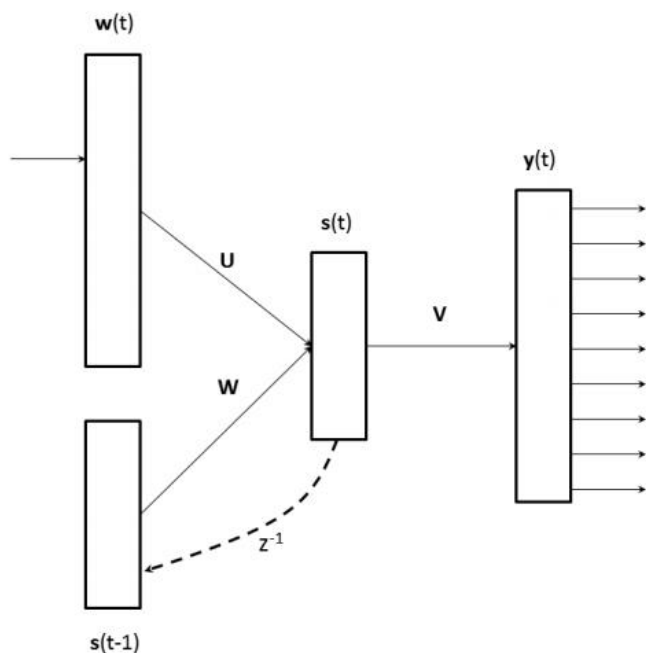
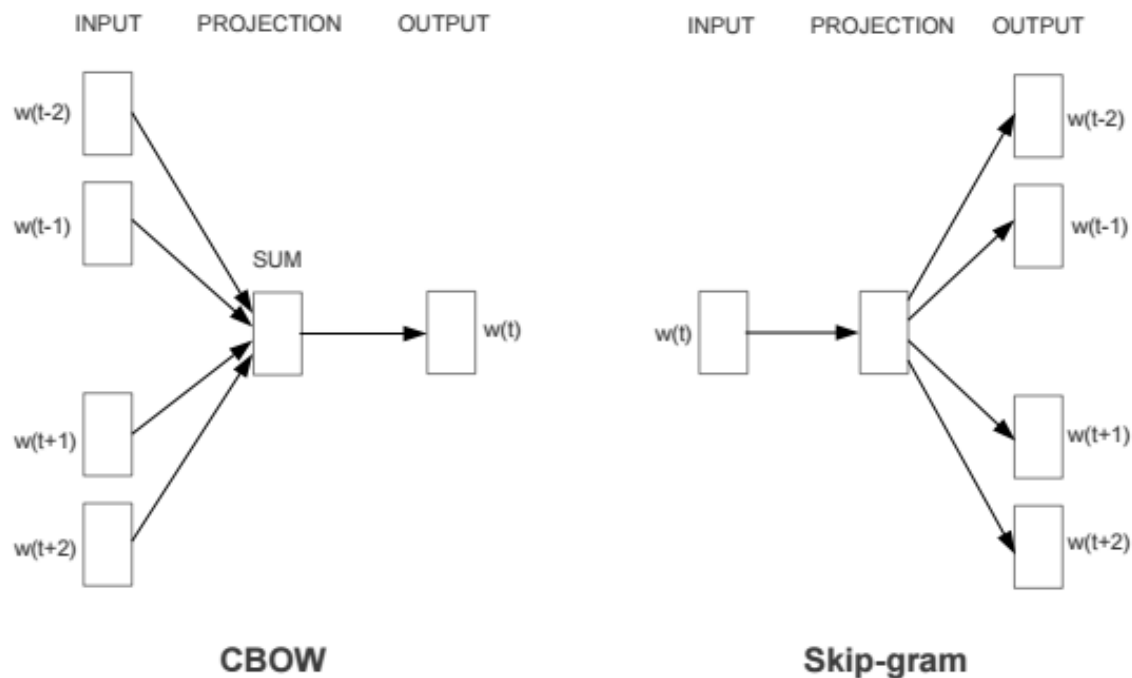


Figure 1: Recurrent Neural Network Language Model.

Linguistic Regularities in Continuous Space Word Representations [Tomas Mikolov, et al., ACL 2013]

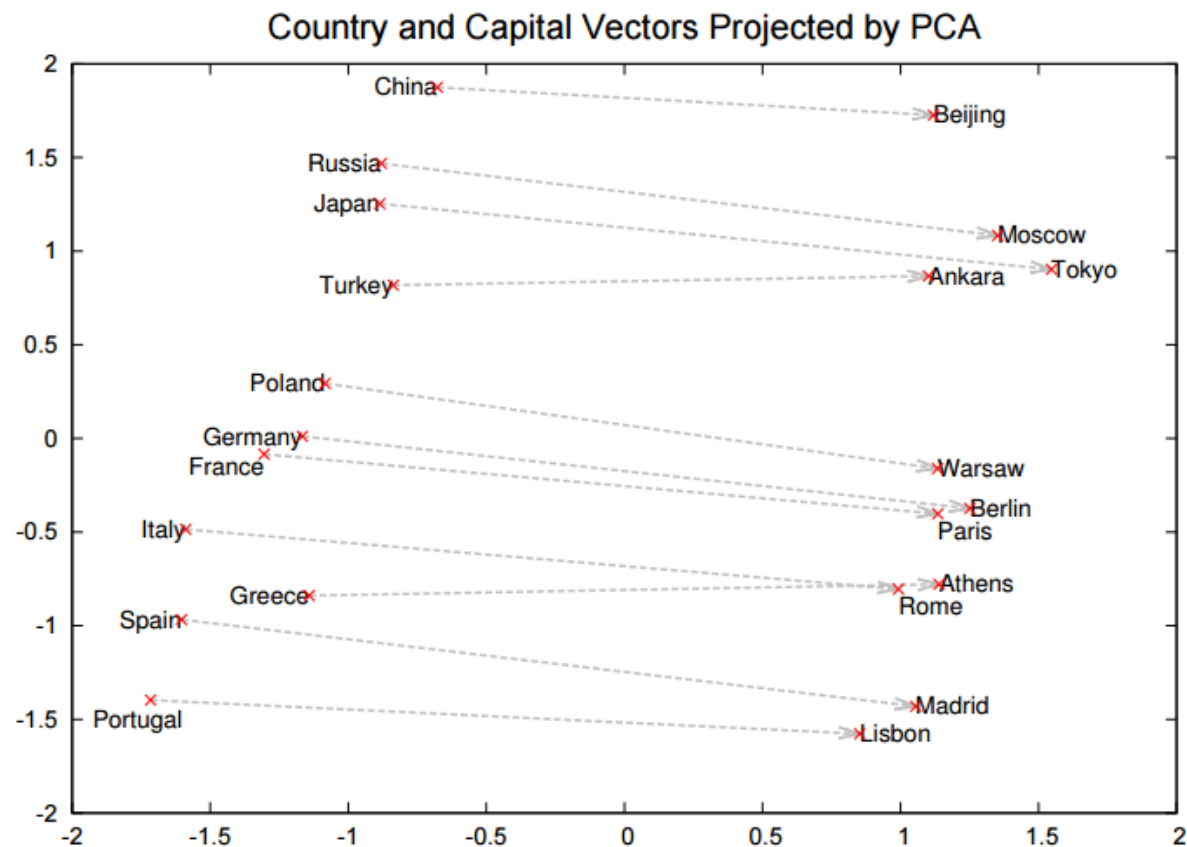
$P(\text{entity}|\text{entity})$ – Word Embedding

- Word Embedding



Efficient Estimation of Word Representations in Vector Space [Tomas Mikolov, et al., ICLR 2013]

$P(\text{entity}|\text{entity})$ – Word Embedding



Distributed Representations of Words and Phrases and their Compositionality [Tomas Mikolov, et al., NIPS 2013]

$P(entity|entity)$ – Word Embedding

Relationship	Example 1	Example 2	Example 3
France - Paris	Italy: Rome	Japan: Tokyo	Florida: Tallahassee
big - bigger	small: larger	cold: colder	quick: quicker
Miami - Florida	Baltimore: Maryland	Dallas: Texas	Kona: Hawaii
Einstein - scientist	Messi: midfielder	Mozart: violinist	Picasso: painter
Sarkozy - France	Berlusconi: Italy	Merkel: Germany	Koizumi: Japan
copper - Cu	zinc: Zn	gold: Au	uranium: plutonium
Berlusconi - Silvio	Sarkozy: Nicolas	Putin: Medvedev	Obama: Barack
Microsoft - Windows	Google: Android	IBM: Linux	Apple: iPhone
Microsoft - Ballmer	Google: Yahoo	IBM: McNealy	Apple: Jobs
Japan - sushi	Germany: bratwurst	France: tapas	USA: pizza

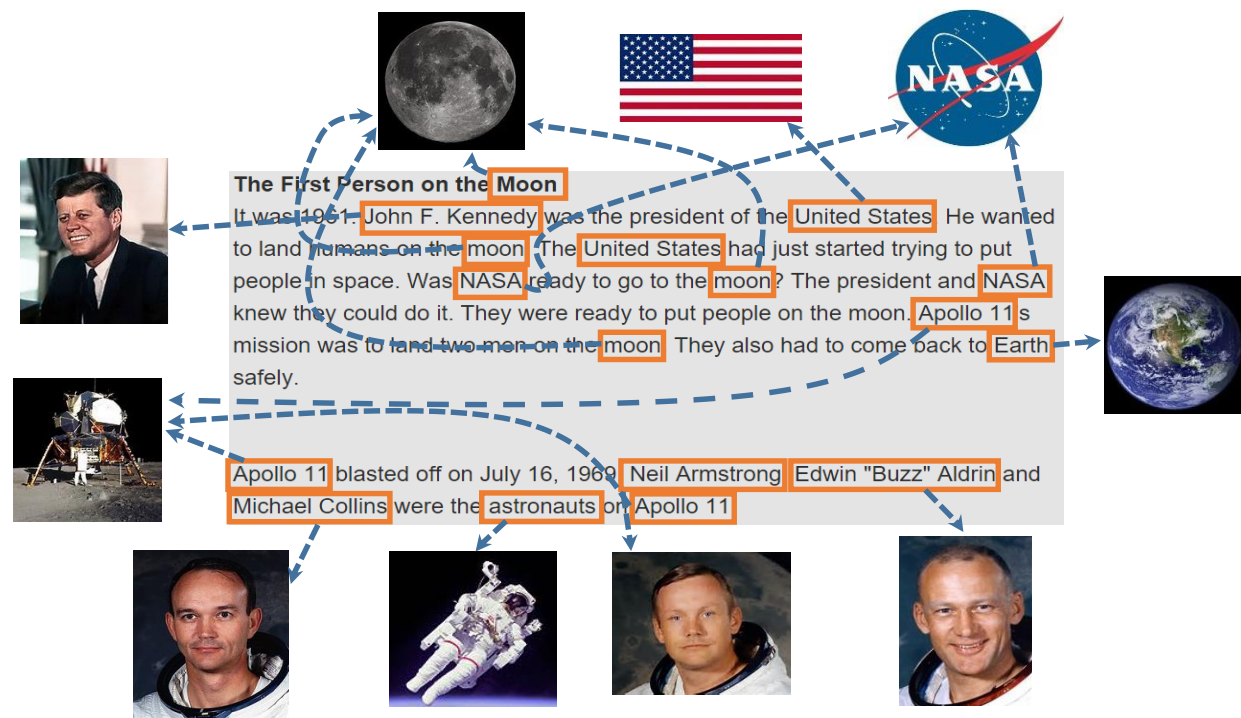
$$y = x_b - x_a + x_c$$

$$w^* = \operatorname{argmax}_w \frac{x_w y}{\|x_w\| \|y\|}$$

Efficient Estimation of Word Representations in Vector Space [Tomas Mikolov, et al., ICLR 2013]

$P(\text{entity}|\text{entity})$ – Word Embedding

- How to apply Word Embedding in Entities?
 - Perform entity linking on documents
 - Treat each entity as a single word
 - Learning the representation



Word2Vec [Tomas Mikolov, et al., ICLR 2013]

$P(\text{entity}|\text{entity})$ – Word Embedding

- Entity Recommendations based on Word Embedding (Skip-gram)
- Trained on 100M Google News Articles

Whale	Susan Dumais	Tom Cruise
Penguin	Gary William Flake	Katie Holmes
Humpback whale	Andrei Broder	Suri Cruise
Killer whale	Bill Buxton	Nicole Kidman
Turtle	Harry Bruce	Cameron Diaz
Rat	Richard Rashid	Connor Antony

Word2Vec [Tomas Mikolov, et al., ICLR 2013]

$P(\text{entity}|\text{entity})$

- Co-occurrence and Textual Similarity methods work well
- Textual Similarity method is very topic- or genre-related
- Word Embedding might not always work (depend on training data)

Co-occurrence

Whale	Susan Dumais	Tom Cruise
Dolphin	C. J. van Rijsbergen	Nicole Kidman
Pinniped	W. Bruce Croft	Brad Pitt
Shark	Eric Horvitz	Steven Spielberg
Killer whale	George Furnas	Tom Hanks
Humpback whale	Thomas Landauer	John Travolta

Textual Similarity

Whale	Susan Dumais	Tom Cruise
Beluga whale	C. J. van Rijsbergen	Leonardo DiCaprio
Toothed whale	W. Bruce Croft	Nicole Kidman
Killer whale	Harry Shum	Clint Eastwood
Pygmy killer whale	Gerard Salton	Mark Rathbun
Humpback whale	Jaime Teevan	L. Ron Hubbard

Word Embedding

Whale	Susan Dumais	Tom Cruise
Penguin	Gary William Flake	Katie Holmes
Humpback whale	Andrei Broder	Suri Cruise
Killer whale	Bill Buxton	Nicole Kidman
Turtle	Harry Bruce	Cameron Diaz
Rat	Richard Rashid	Connor Antony

$P(\textit{entity}|\textit{entity})$ - Recap

- Co-occurrence
 - Within Queries
 - Across Queries
 - User Url Clicks
 - Wikipedia Pages
 - Wikipedia Categories/Templates
 - Wikipedia Revision Histories
 - Web documents
- Entity Linking
- Similarity
 - Textual Similarity
 - Word Embedding
- Interpretation

$P(\text{entity}|\text{entity})$

Florence Cathedral

Church



The Cattedrale di Santa Maria del Fiore is the main church of Florence, Italy. Il Duomo di Firenze, as it is ordinarily called, was begun in 1296 in the Gothic style to the design of Arnolfo di Cambio and completed structurally in 1436 with the dome ... +

en.wikipedia.org

Opened: Mar 25, 1436

Height: 376 feet (114.50 m)

Architects: Filippo Brunelleschi · Giotto · Arnolfo di Cambio · Francesco Talenti

Architectural styles: Renaissance architecture · Gothic architecture · Italian Gothic architecture · Gothic Revival architecture

Categories: Basilica · Cathedral · Minor basilica · Church

Burials: Filippo Brunelleschi · Conrad II of Italy · Niccolò da Tolentino

Related people

[See all \(10+\)](#)



Filippo
Brunelleschi
Architect



Michelang...



Donatello



Giotto
Architect



Arnolfo di
Cambio
Architect

Why are they related to
“Florence Cathedral”?

$P(entity|entity)$ - Interpretation

Florence Cathedral

Church



en.wikipedia.org

The Cattedrale di Santa Maria del Fiore is the main church of Florence, Italy. Il Duomo di Firenze, as it is ordinarily called, was begun in 1296 in the Gothic style to the design of Arnolfo di Cambio and completed structurally in 1436 with the dome ... +

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Categories: [Basilica](#) · [Cathedral](#) · [Minor basilica](#) · [Church](#)

Burials: [Filippo Brunelleschi](#) · [Conrad II of Italy](#) · [Niccolò da Tolentino](#)

Related people



[Filippo Brunelleschi](#)
Architect



[Michelangelo](#)



[Donatello](#)



[Giotto](#)
Architect



[Arnolfo di Cambio](#)
Architect

That Giotto painted the Arena Chapel and that Giotto was chosen by the Comune of Florence in 1334 to design the new campanile of the Florence Cathedral are among the few certainties of his biography.

Hyatt

Company



Hyatt Hotels Corporation is an American international company and operator of hotels. The Hyatt Corporation came into being upon purchase of the Hyatt House, at Los Angeles International Airport, on September 27, 1957. In 2014, Fort... +

en.wikipedia.org

Founded: 1957

CEO: [Mark Hoplemazian](#)

Founders: [Jack D. Crouch](#) · [Hyatt von Dehn](#)

Headquarters: [Chicago, IL](#)

Related people



[Jay Pritzker](#)



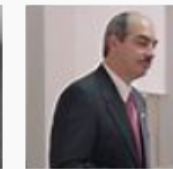
[Thomas Pritzker](#)



[Mark Hoplemazian](#)
CEO



[Liesel Pritzker Simmons](#)



[Jack D. Crouch](#)
Founder

Liesel Pritzker Simmons, stage name Liesel Matthews, is an American former child actress, heiress to the Hyatt Hotels fortune, and philanthropist.

$P(\textit{entity}|\textit{entity})$ - Interpretation

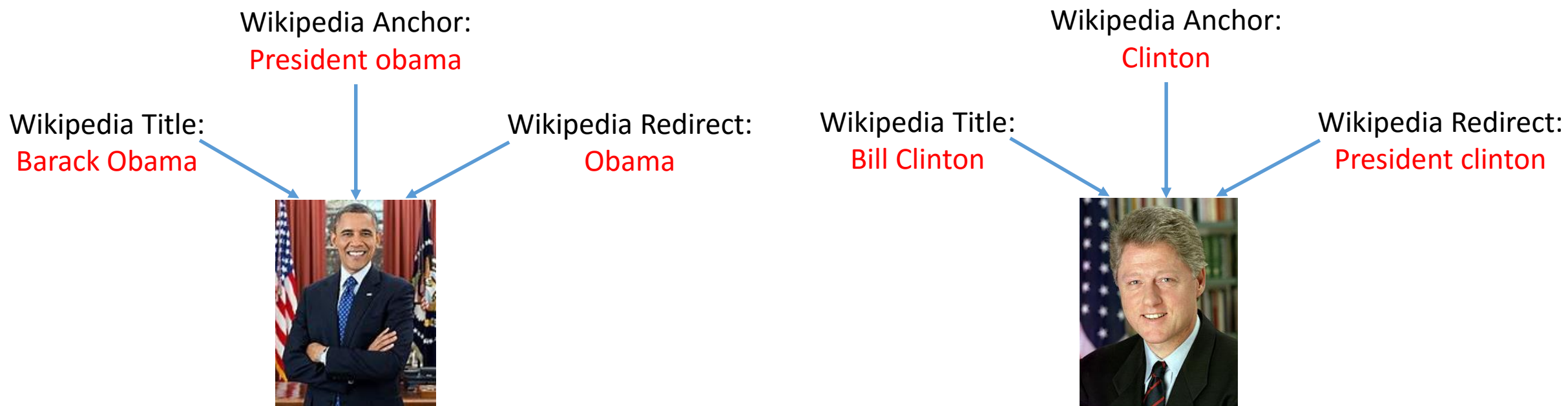
- Problem definition

	Notation	Explanation
Input	e_a	the first entity of the entity pair.
	e_b	the second entity of the entity pair.
	r	the relation of interest between e_a and e_b .
Output	S	a set of candidate sentences possibly referring to e_a and e_b .

Explaining Relationships Between Entities [Nikos Voskarides]

$P(entity|entity)$ - Interpretation

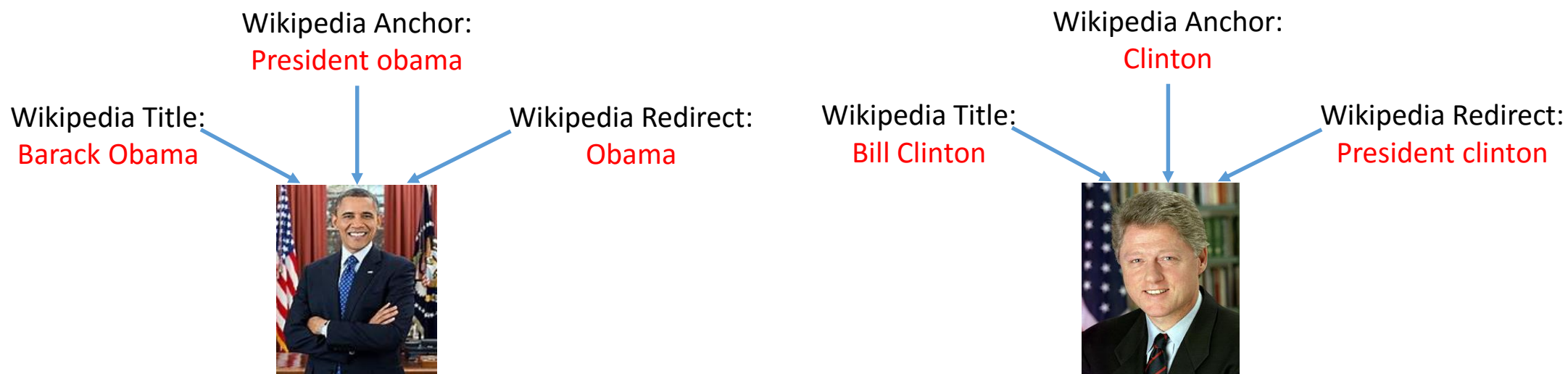
- Entity text representation



Explaining Relationships Between Entities [Nikos Voskarides]

$P(entity|entity)$ - Interpretation

- Candidate Sentences
 - On the wiki pages of “Barack Obama” and “Bill Clinton”
 - Keep those sentences that contains at least one entity’s text representations



Explaining Relationships Between Entities [Nikos Voskarides]

$P(\textit{entity}|\textit{entity})$ - Interpretation

- Sentences enrichment
 - Perform Co-reference resolution
 - Replace detected strings with the entity text representations
 - Examples:
 - “He” → Barack Obama
 - “The company” → Toyota
 - “The film” → Titanic

Explaining Relationships Between Entities [Nikos Voskarides]

$P(\textit{entity}|\textit{entity})$ - Interpretation

- Sentences enrichment
 - Perform Entity Linking on Wikipedia articles

In response to the [2010 Haiti earthquake](#), U.S. President [Barack Obama](#) announced that [Clinton](#) and [George W. Bush](#) would coordinate efforts to raise funds for Haiti's recovery.

Explaining Relationships Between Entities [Nikos Voskarides]

$P(\text{entity}|\text{entity})$ - Interpretation

- Ranking sentences
 - Generate features and using Learning to Rank algorithms to rank sentences
- Features
 - **Text features:** Average IDF of terms of s in Wikipedia; Number of terms in s ; Part of Speech distribution of s ; etc.
 - **Entity features:** Number of entities in s ; Whether s contains links to both e_a and e_b ; Distance between e_a and e_b in s ; Number of entities between e_a and e_b ; etc.
 - **Relation features:** Whether s contains any term of r (binary); Average score of phrases in $\text{word2vec}(r)$ that are matched in s ; etc.
 - **Source features:** Position of s in document d ; etc.

Explaining Relationships Between Entities [Nikos Voskarides]

$P(\text{entity}|\text{entity})$ - Interpretation

(#1) Ben Affleck - Bruce Willis (MovieActor_CoCastsWith_MovieActor)

Affleck starred in "Armageddon" (1998) opposite Bruce Willis.

(#2) Hugh Jackman - Kate Winslet (MovieActor_CoCastsWith_MovieActor)

Katie Finneran's most recent film was "Movie 43" in which she played Angie and also appeared alongside Hugh Jackman and Kate Winslet.

(#3) Bryan Singer - Tom Cruise (MovieDirector_Directs_MovieActor)

The film stars Tom Cruise and is directed by Bryan Singer.

(#4) Cameron Diaz - Tom Cruise (MovieActor_CoCastsWith_MovieActor)

The following year Cruise starred in the romantic thriller "Vanilla Sky" (2001) with Cameron Diaz and Penélope Cruz.

(#5) Cristiano Ronaldo - Karim Benzema (Athlete_PlaysSameSportTeamAs_Athlete)


Karim Benzema was also shortlisted by the French magazine France Football for the 2008 Ballon d'Or award, won by Cristiano Ronaldo.

Explaining Relationships Between Entities [Nikos Voskarides]

$P(\text{entity}|\text{entity})$ - Interpretation

- Challenges
 - Relationships are missing or unknown in the real world scenarios

Artificial intelligence








Artificial intelligence is the intelligence exhibited by machines or software. It is also the name of the academic field of study which studies how to create computers and computer software that are capable of intelligent behavior. Major AI resea... +
en.wikipedia.org

Subdisciplines: [Machine learning](#) · [Cognitive artificial intelligence](#)

John McCarthy, who coined the term in 1955, defines Artificial intelligence as "the science and engineering of making intelligent machines".

related people

[See all \(10+\)](#)

				
John McCarthy	Alan Turing	Stephen Hawking	Ray Kurzweil	Isaac Asimov

$P(\textit{entity}|\textit{entity})$ - Interpretation

- Challenges

- The selected sentences should be more “interesting” instead of just replicating the relationships

(#1) Ben Affleck - Bruce Willis (MovieActor_CoCastsWith_MovieActor)

Affleck starred in “Armageddon” (1998) opposite Bruce Willis.

Entity Recommendation & Understanding Taxonomy

- $P(\textit{entity}|\textit{entity})$
 - Recommendations given an entity
 - Co-occurrence
 - Similarity
 - Entity Linking
 - Interpretation
- $P(\textit{entity}|\textit{user})$
 - Recommendations given a user
- $P(\textit{entity}|\textit{query})$
 - Recommendations given a query

Entity Recommendation & Understanding Taxonomy

- $P(\textit{entity}|\textit{entity})$
 - Recommendations given an entity
 - Co-occurrence
 - Similarity
 - Entity Linking
 - Interpretation
- $P(\textit{entity}|\textit{user})$
 - Recommendations given a user
- $P(\textit{entity}|\textit{query})$
 - Recommendations given a query

Personalized Recommender Systems

- Problem definition
 - User-Item Matrix

	Rating/Frequency				
	v_1	v_2	v_3	v_4	v_5
u_1	1		2	3	
u_2		3			1
u_3		4		5	
u_4	5			4	
u_5		2	5		4

	Implicit/One-class					
	v_1	v_2	v_3	v_4	v_5	v_6
u_1		1	1		1	
u_2	1			1		1
u_3			1			1
u_4	1			1		
u_5		1	1			1

Personalized Recommender Systems

- Memory-based methods
 - Pearson Correlation Coefficient
 - Vector Space Similarity/Cosine Similarity
- Model-based methods
 - Matrix Factorization
 - Probabilistic models
 - Clustering
 - Classification
 - ...

Personalized Recommender Systems

- Memory-based methods
 - Pearson Correlation Coefficient
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- Model-based methods
 - Matrix Factorization
 - Probabilistic models
 - Clustering
 - Classification
 - ...

Personalized Recommender Systems

- Memory-based methods

Items

	1	2	3	4	5	6	7	8	9	10	11	12
Users												
U ₁												
U ₂	1	3		4		2		5			3	4
U ₃												
U ₄		3		4			3	4		3	4	4
U ₅												
U ₆	1			3	5	2		4	1			3

Personalized Recommender Systems

- Memory-based methods

Items

Users

U ₁													
U ₂	1	3		4		2		5			3	4	
U ₃													
U ₄		3		4			3	4		3	4		4
U ₅													
U ₆	1			3	5	2		4	1			3	

Personalized Recommender Systems

- Memory-based methods

Items

Users

U ₁												
U ₂	1	3	4		2		5			3	4	
U ₃												
U ₄		3	4			3	4		3	4		4
U ₅												
U ₆	1		3	5	2		4	1			3	

Personalized Recommender Systems

- Memory-based methods

Items

Users

U ₁												
U ₂	1	3	4	2	5			3	4			
U ₃												
U ₄		3	4		3	4		3	4		4	
U ₅												
U ₆	1		3	5	2	4	1			3		

Personalized Recommender Systems

- Memory-based methods

Items

Users

u ₁													
u ₂	1	3	4		2		5			3	4		
u ₃													
u ₄		3	4			3	4		3	4		4	
u ₅													
u ₆	1		3	5	2		4	1			3		

Personalized Recommender Systems

- Memory-based methods

Items

Users

U ₁													
U ₂	1	3	4		2		5			3	4		
U ₃													
U ₄		3	4			3	4		3	4		4	
U ₅													
U ₆	1		3	5	2		4	1			3		

Personalized Recommender Systems

- Pearson Correlation Coefficient

$$Sim(a, u) = \frac{\sum_{i \in I(a) \cap I(u)} (r_{a,i} - \bar{r}_a) \cdot (r_{u,i} - \bar{r}_u)}{\sqrt{\sum_{i \in I(a) \cap I(u)} (r_{a,i} - \bar{r}_a)^2} \cdot \sqrt{\sum_{i \in I(a) \cap I(u)} (r_{u,i} - \bar{r}_u)^2}}$$

GroupLens: an open architecture for collaborative filtering of netnews [Paul Resnick, et al., CSCW 1994]

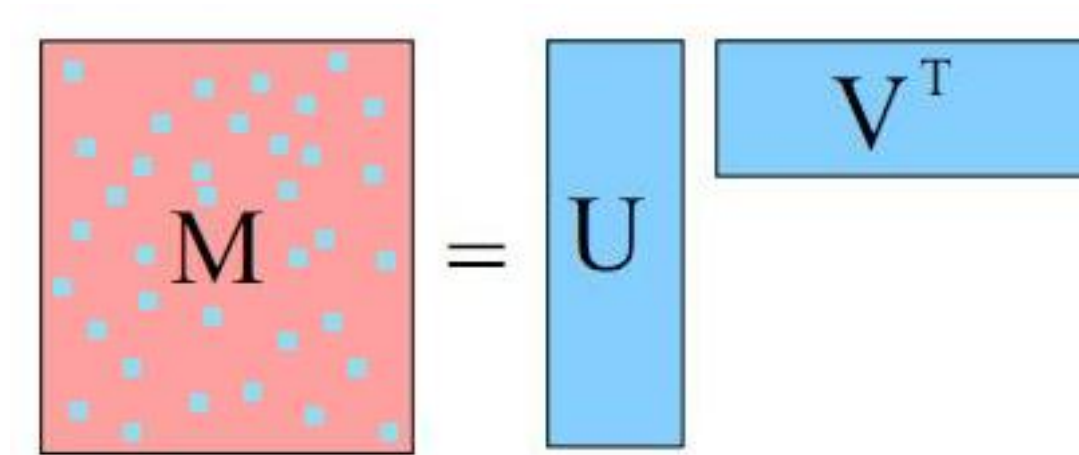
Personalized Recommender Systems

- Challenges on using Memory-based methods
 - Sparsity issue
 - User-item matrix is normally very sparse, and the density is normally under 1%
 - The sparsity issue will make estimating user similarity difficult and inaccurate
 - Scalability
 - Finding nearest neighbors require computation that grows with both the number of users and the number of items

Personalized Recommender Systems

- Matrix Factorization

$$M_{[m \times n]} = U_{[m \times r]} V^T_{[n \times r]}$$



Personalized Recommender Systems

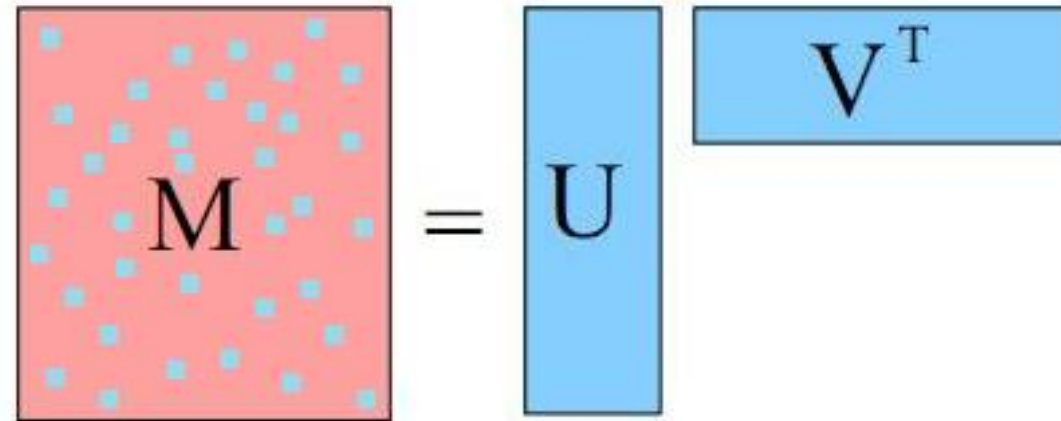
- Matrix Factorization

- Adding bias

- $b_{ij} = \mu + b_i + b_j$

- Predicting rating as

- $r_{ij} = b_{ij} + u_i v_j^T$

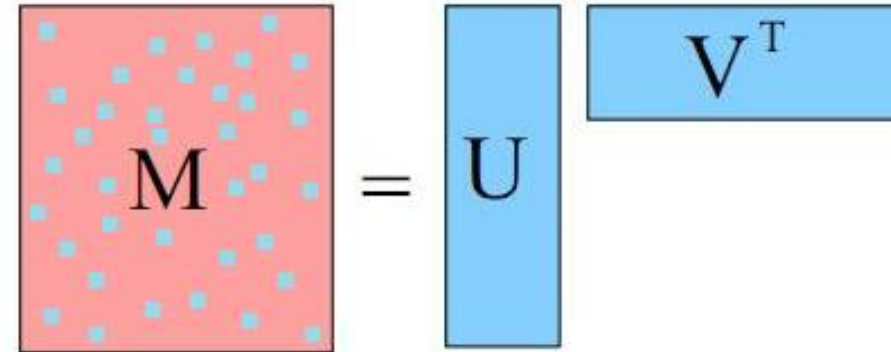


- Matrix factorization method is the single most effective method in the Netflix 1M prize challenge

The Recommender Problem Revisited [Xavier Amatriain, et al., KDD 2014]

Personalized Recommender Systems

- Matrix Factorization
 - What about implicit user-item matrix?
 - Negative Sampling



Implicit/One-class

	v_1	v_2	v_3	v_4	v_5	v_6
u_1		1	1		1	
u_2	1			1		1
u_3			1			1
u_4	1			1		
u_5		1	1			1

Negative Sampling

	v_1	v_2	v_3	v_4	v_5	v_6
u_1	0	1	1		1	
u_2	1	0		1		1
u_3			1		0	1
u_4	1		0	1		
u_5	0	1	1	0		1

One-Class Collaborative Filtering [Rong Pan, et al., ICDM 2008]

An Incomplete List of Academic Papers on RS

- Breese et al. “Empirical analysis of predictive algorithms for collaborative filtering.” UAI-1998.
- Deshpande et al. “Item-based top-n recommendation.” ACM TOIS-2004.
- Herlocker et al. “An algorithmic framework for performing collaborative filtering.” SIGIR-2009.
- Hofmann et al. “Collaborative filtering via gaussian probabilistic latent semantic analysis.” SIGIR-2003.
- Koren et al. “Factorization meets the neighborhood: a multifaceted collaborative filtering model.” KDD-2008.
- Koren et al. “Collaborative filtering with temporal dynamics.” KDD-2009.
- Koren et al. “Matrix factorization techniques for recommender systems.” IEEE Computer-2009.
- Linden et al. “Amazon.com recommendations: Item-to-item collaborative filtering.” Internet Computing-2003.
- Rennie et al. “Fast maximum margin matrix factorization for collaborative prediction.” ICML-2005.
- Salakhutdinov et al. “Probabilistic matrix factorization.” NIPS-2007.
- Salakhutdinov et al. “Bayesian probabilistic matrix factorization using markov chain monte carlo.” ICML-2008.
- Sarwar et al. “Item-based collaborative filtering recommendation algorithms.” WWW-2001.
- Si et al. “Flexible mixture model for collaborative filtering.” ICML-2003.
- Srebro et al. “Weighted low-rank approximations.” ICML-2003.

Why is Entity Recommender System different?

- The problem definition for traditional recommender systems is clearer than entity recommender systems since most of the time **user-item matrix is given**

Rating/Frequency

	v_1	v_2	v_3	v_4	v_5
u_1	1		2	3	
u_2		3			1
u_3		4		5	
u_4	5			4	
u_5		2	5		4

Implicit/One-class

	v_1	v_2	v_3	v_4	v_5	v_6
u_1		1	1		1	
u_2	1			1		1
u_3			1			1
u_4	1			1		
u_5		1	1			1

Why is Entity Recommender System different?

- Entity recommender systems are embedded within searching process, users' preferences on entities are more difficult to observe

Users



Queries



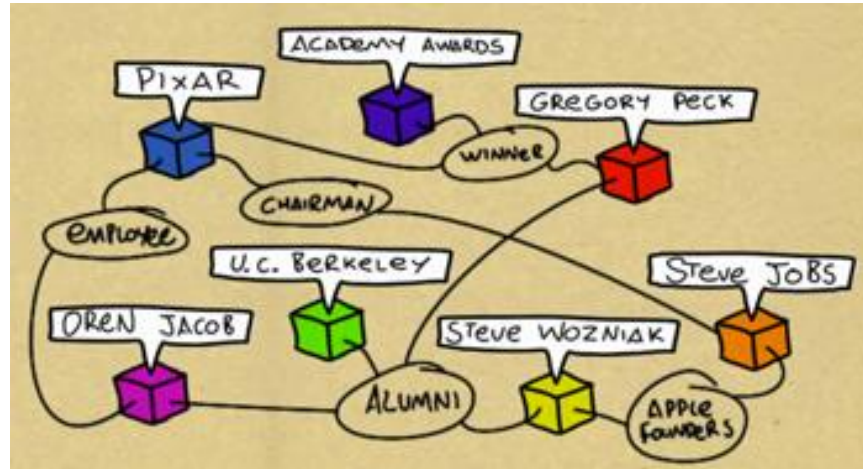
Clicks



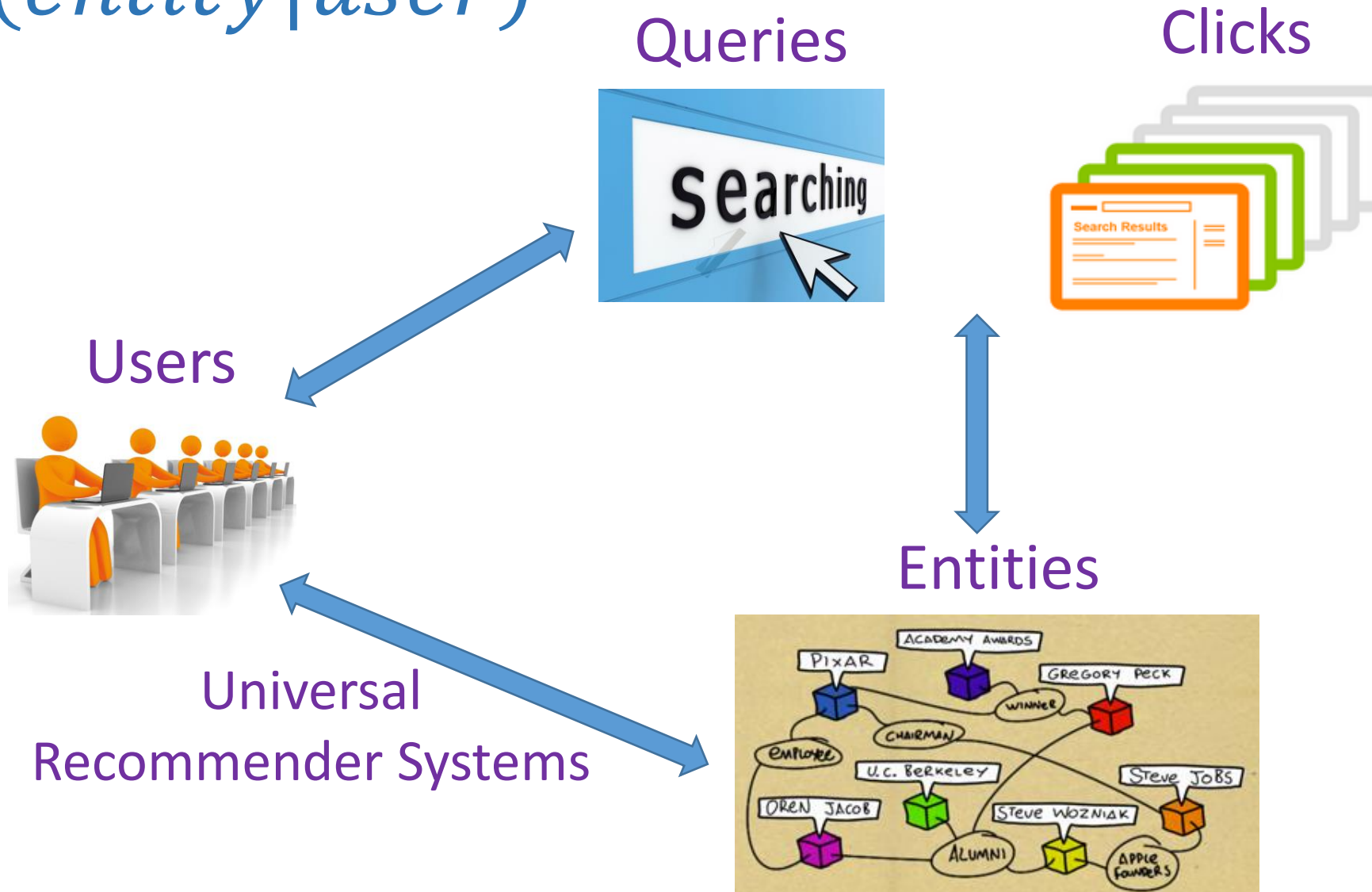
Why is Entity Recommender System different?

- The huge Entity Graph with knowledge makes entity recommender systems more **challenging** and also **appealing**

Entities



$P(\text{entity}|\text{user})$

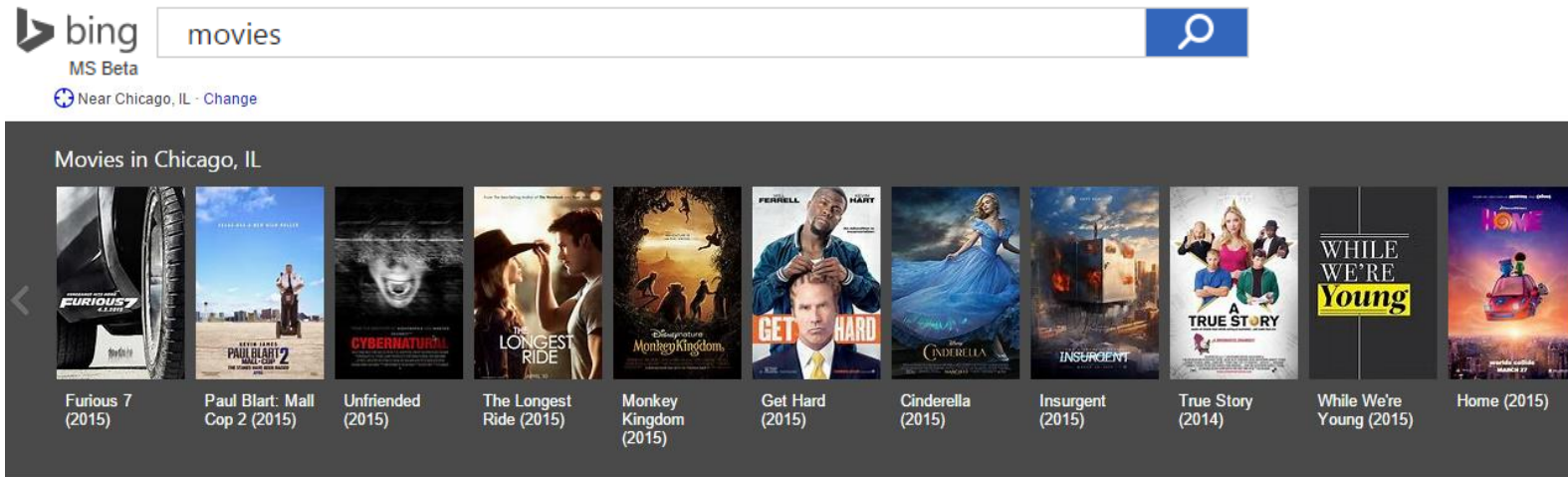


Current Entity Experience

bing MS Beta
Near Chicago, IL · Change

movies

Movies in Chicago, IL

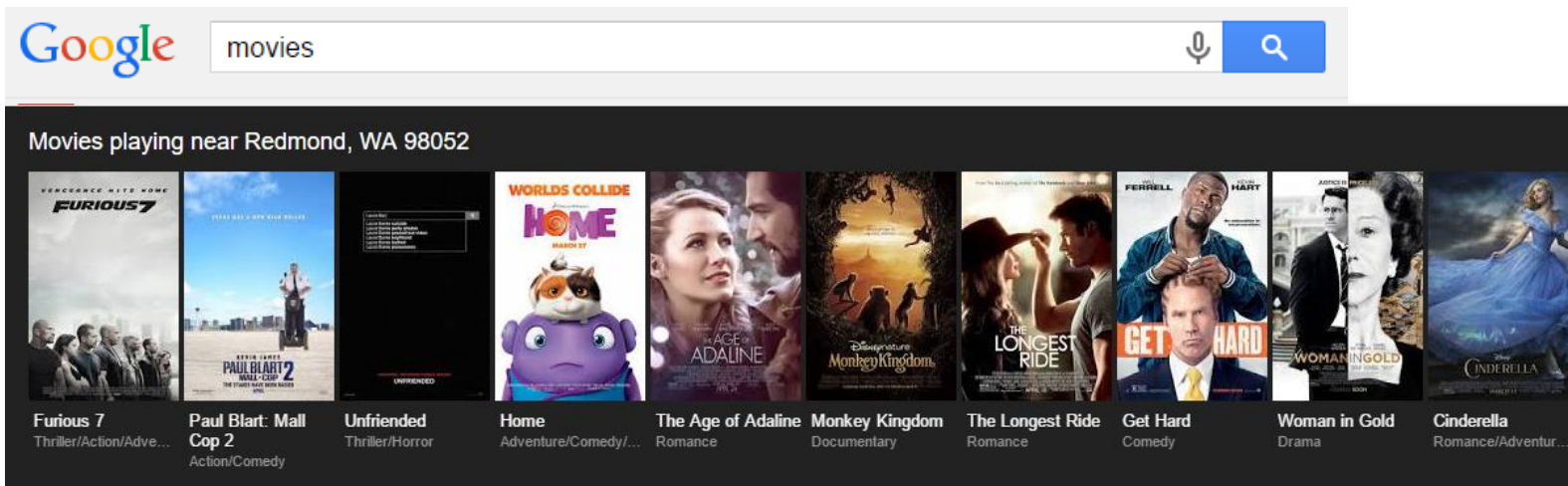


Movie Title	Year
Furious 7	2015
Paul Blart: Mall Cop 2	2015
Unfriended	2015
The Longest Ride	2015
Monkey Kingdom	2015
Get Hard	2015
Cinderella	2015
Insurgent	2015
True Story	2014
While We're Young	2015
Home	2015

Google

movies

Movies playing near Redmond, WA 98052



Movie Title	Genre
Furious 7	Thriller/Action/Adventure
Paul Blart: Mall Cop 2	Action/Comedy
Unfriended	Thriller/Horror
Home	Adventure/Comedy/...
The Age of Adaline	Romance
Monkey Kingdom	Documentary
The Longest Ride	Romance
Get Hard	Comedy
Woman in Gold	Drama
Cinderella	Romance/Adventure

Current Entity Experience

bing MS Beta

restaurants

Near Chicago, IL · Change

restaurants Chicago, Illinois

Restaurant	Rating	Price Range	Yelp Reviews	Address
XOCO	★★★★★	\$\$\$\$\$	2657	449 N Clark St, Chicago
Purple Pig	★★★★★	\$\$\$\$\$	3019	500 N Michigan Ave, Chicago
Portillo's Hot Dogs	★★★★★	\$\$\$\$\$	2156	100 W Ontario St
Signature Room at the 95th	★★★★★	\$\$\$\$\$	824	875 N Michigan Ave
Quartino	★★★★★	\$\$\$\$\$	2528	626 N State St, Chicago
Girl & the Goat	★★★★★	\$\$\$\$\$	3679	809 W Randolph St, Chicago
Wildfire	★★★★★	\$\$\$\$\$	744	159 W Erie St, Chicago
Carmine's	★★★★★	\$\$\$\$\$	473	1043 N Rush St, Chicago
Bandera	★★★★★	\$\$\$\$\$	1066	535 N Michigan Ave, Chicago
Mercadito	★★★★★	\$\$\$\$\$	1310	108 W Kinzie St, Chicago

$P(\text{entity}|\text{user})$

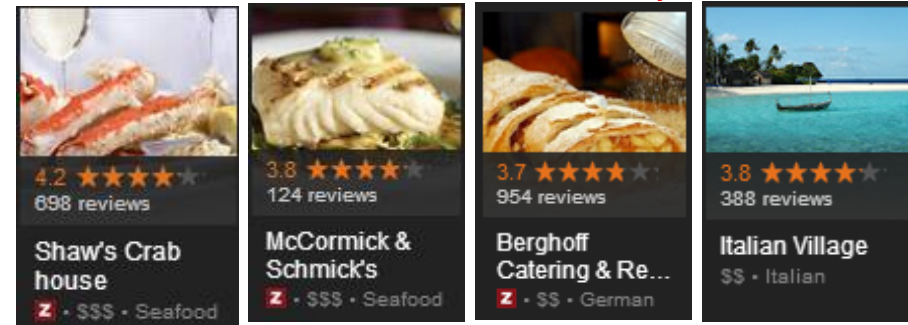
bing movies

Movie recommendation for you



bing restaurants

Restaurant recommendation for you



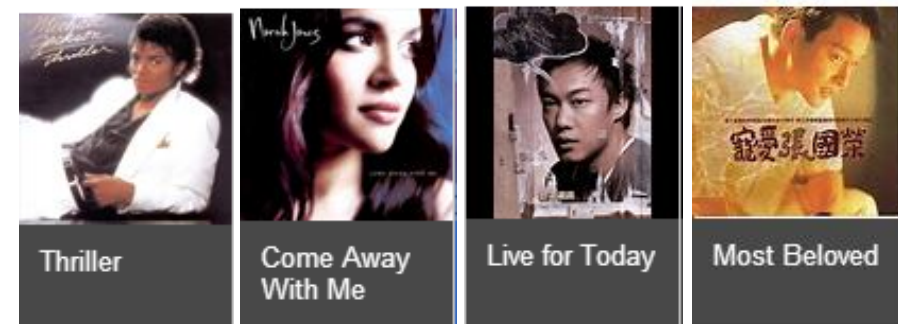
bing books

Book recommendation for you



bing music albums

Music album recommendation for you



$P(entity|user)$



movie recommendation **for you**



restaurant recommendation **for you**



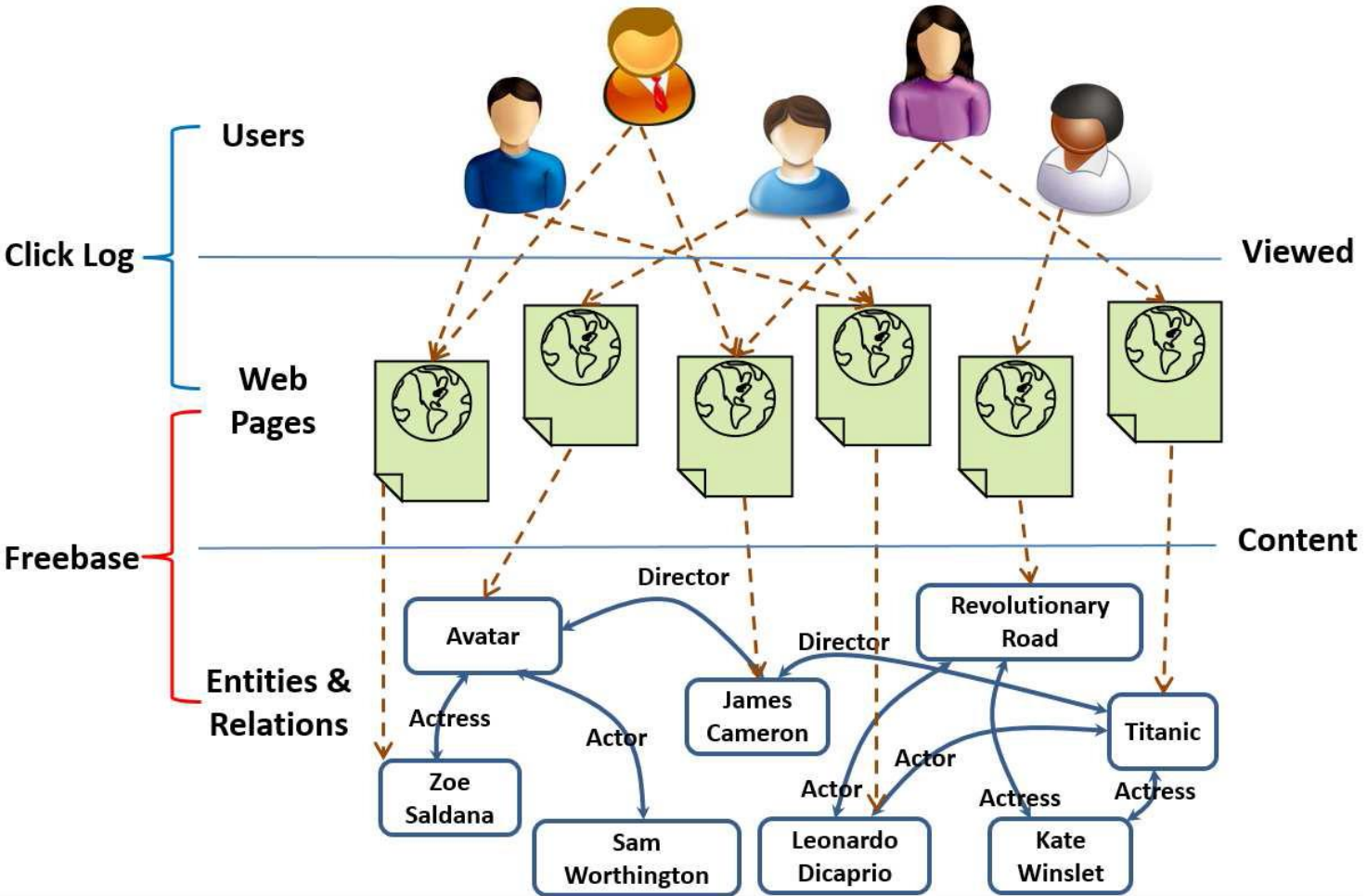
point of interest recommendation **for you**



event recommendation **for you**



User Logs and Entity Graph



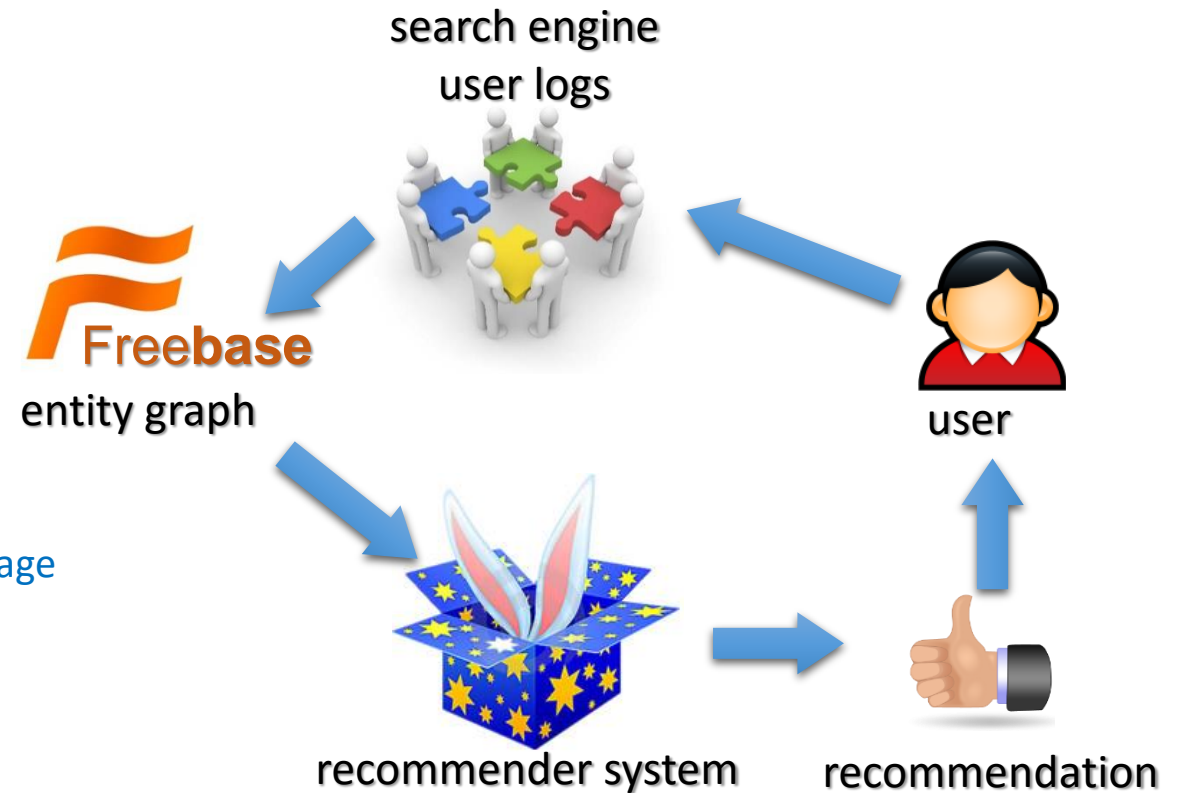
On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Problem Definition

- Consider entity related web pages
- User log sequence, sorted by timestamp

$\langle \underline{e_1^u}, \underline{e_2^u}, \dots, \underline{e_t^u}, \dots, \underline{e_{T-1}^u}, \textcircled{e_T^u} \rangle$ target entity page
user log sequence before T, denotes as L_T^u

- Use L_T^u to predict e_T^u



On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Benefits in Using User Logs and Entity Graph

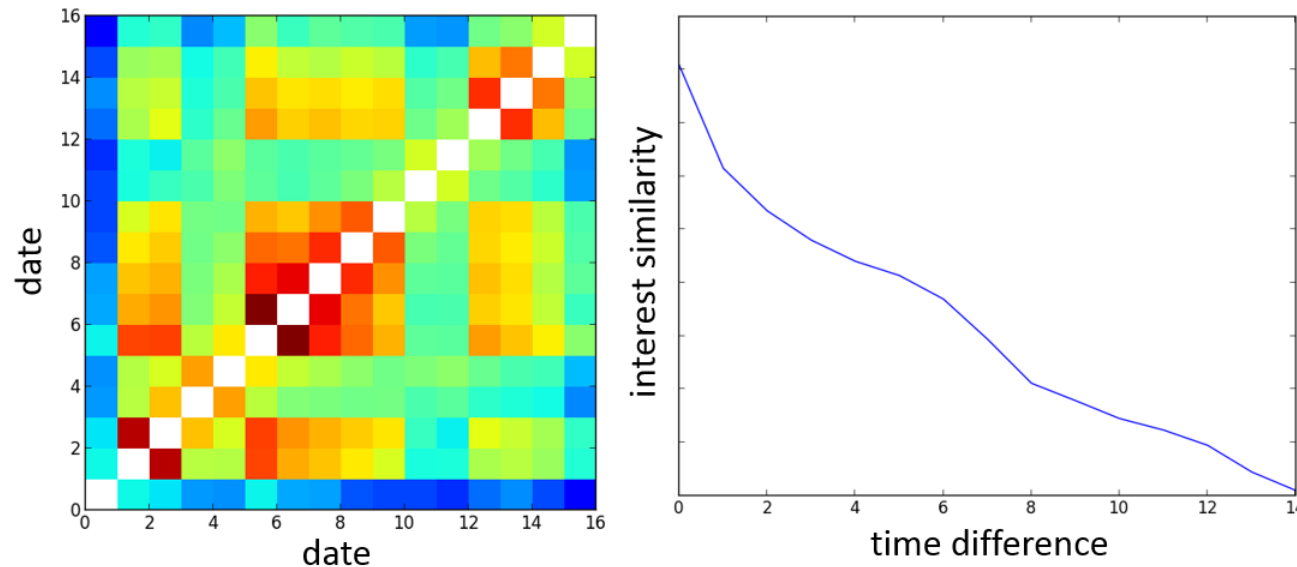
- Besides implicit feedback, user log also has
 - e.g., timestamp, dwell time, user country or region, time of day ...
- Cross domain user log events
 - Which movies will foxnews.com readers like?
- Besides entity relationship, entity graph also has
 - e.g., **movie** release date, tagline, running time, gross revenue, budget, MPAA rating, text description, number of ratings, ...

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Exploring data - User interests drift

User interests are consistent within a short time period but drift over time

The longer the time interval is, the less similar users' interests are



Left: accumulated user interest similarity for two weeks

Right: averaged user interest similarity with relative time difference (number of day)

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Exploring data - Cross Domain Correlation

comicbookresources.com

(comic books)

The Avengers

Spider-Man

The Dark Knight Rises

Prometheus

Men In Black 3

Iron Man 2

Superman: The Man Of Steel

Thor

Snow White & Huntsman

Battleship

ruelala.com

(women shopping)

Magic Mike

The Avengers

Prometheus

Moonrise Kingdom

Ted

Snow White & Huntsman

Savages

Hunger Games

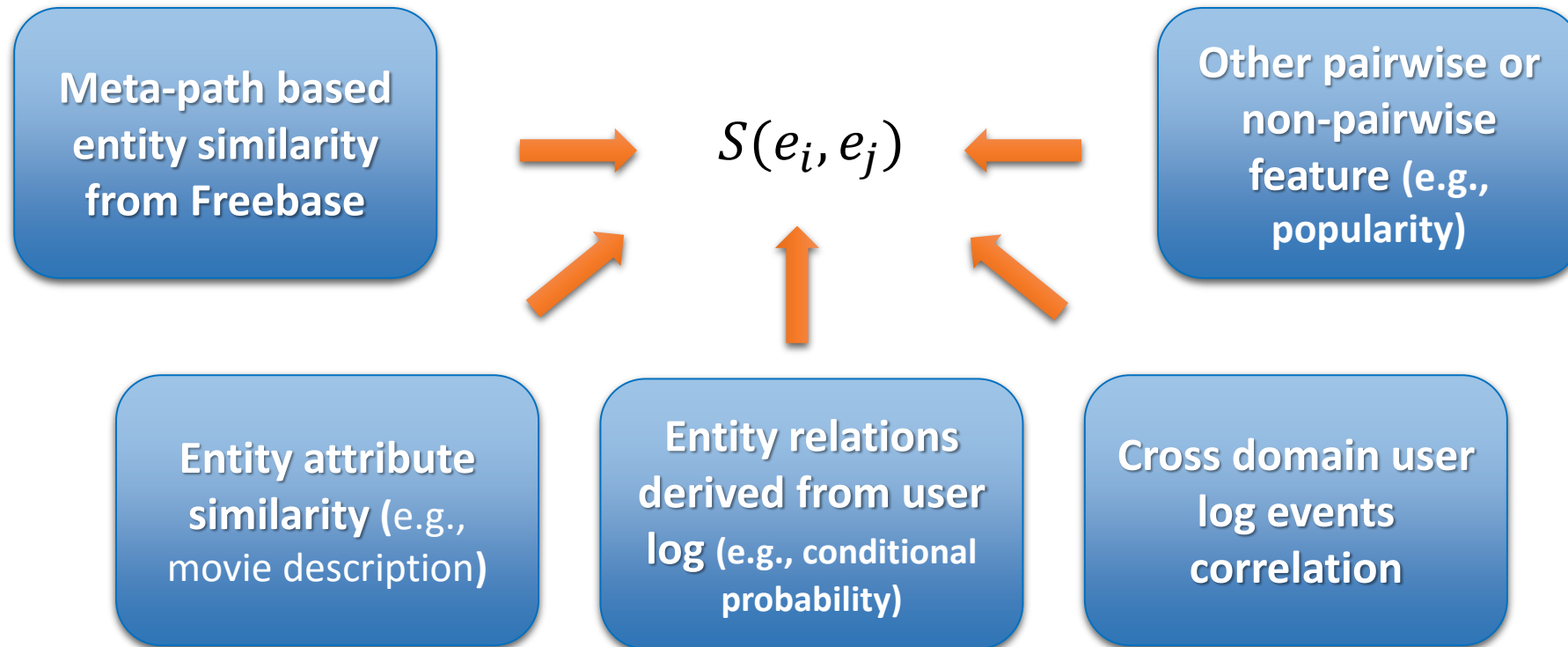
Rock of Ages

The Best Exotic Marigold Hotel

Top 10 most viewed
movies estimated using
cross domain correlation

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Entity Pairwise Features



On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Entity Pairwise Features

Representative Features

Entity Graph Path Features	
movie-actor-movie	movies with the same actors
movie-director-movie	movies with the same directors
movie-producer-movie	movies with the same producers
movie-star-movie	movies with the same stars
movie-writer-movie	movies with the same writers
movie-genre-movie	movies with the same genres
movie-language-movie	movies with the same language
Entity Graph Binary Features	
is_prequel	<i>movie1</i> is a prequel of <i>movie2</i>
is_sequel	<i>movie1</i> is a sequel of <i>movie2</i>
actor-movie	actor appears in the movie
director-movie	director directs the movie
producer-movie	producer produces the movie
Entity Graph Content Features	
release date	two movie with close release dates
description similarity	text similarity in movie descriptions
User Log Features	
co-click	conditional probability between entities
global popularity	movie popularity of all time
local popularity	movie popularity today
cross-domain	cross-domain correlation

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Recommendation Models

- Global recommendation model

entity at timestamp T

$$r(\hat{e}_T^u; L_T^u, \theta) = \sum_{e_t^u \in L_T^u} w_t(\hat{e}_T^u, e_t^u) \sum_k \theta_k S_k(\hat{e}_T^u, e_t^u)$$

events happened before T
 $L_T^u = \langle e_1^u, e_2^u, \dots, e_t^u, \dots, e_{T-1}^u \rangle$

time decay function
 $w_t(e_T, e_t) = \beta e^{-\alpha(T-t)}$

pairwise features

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Recommendation Models

- Personalized recommendation model (PRM)

$$r(\hat{e}_T^u; L_T^u, \theta_T^u) = \sum_{e_t^u \in L_T^u} w_t(\hat{e}_T^u, e_t^u) \sum_k S_k(\hat{e}_T^u, e_t^u) \theta_{T,k}^u$$

for each user at target
timestamp T

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Recommendation Models

- Personalized Recommendation with K-NN (**PRM+KNN**)

$$r_n(\hat{e}_t^u; L_T^u, \theta_T^u) = r(\hat{e}_t^u; L_T^u, \theta_T^u) + \lambda_1 \sum_{L_{T'}^{u'} \in N(L_T^u)} w_u(L_{T'}^{u'}, L_T^u) r(\hat{e}_t^u; L_{T'}^{u'}, \theta_{T'}^{u'})$$

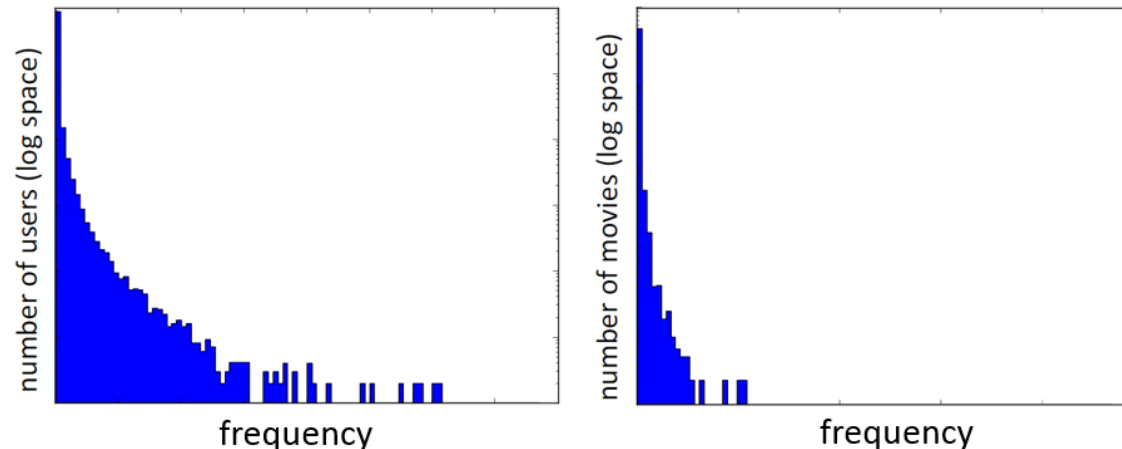
neighbor subsequences neighbor similarity

Collaborative filtering

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Experiment Setup

- **Movie** recommendation with **search engine user log** and movie related **freebase knowledge graph**
 - Sampled 1+ million users with at least one movie entity
 - 2+ million movie related entities with attributes and relationships, including movies, actors/actresses, directors, producers, etc.



On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Evaluation

- Top 10 Mean Reciprocal Rank (MRR) as evaluation metric

$$MRR = \frac{1}{|Test|} \sum_{i=1}^{|Test|} \frac{1}{rank_i}$$

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Comparison

Comparison Method	Description
Global Popularity	Frequently visited movies in 3 months
Local Popularity	Frequently visited movies in short time period
Domain Co-Click	Recommend based on non-movie related events
Matrix Factorization	Implicit feedback factorization
Co-Click with Time Decay	Conditional probability of events

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Performance

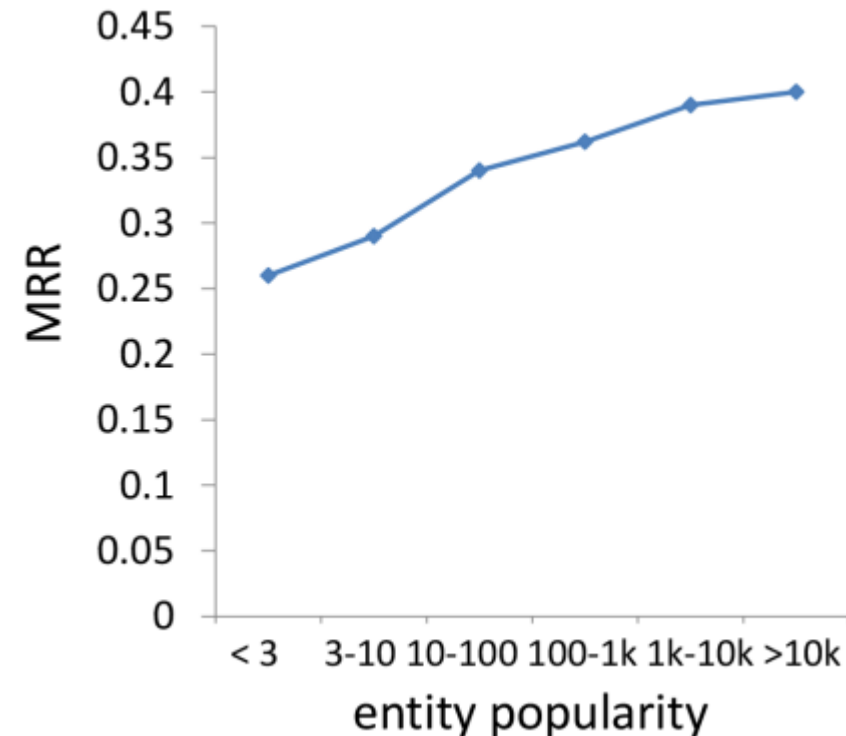
	Method	MRR
comparison methods	Global Popularity	0.024
	Local Popularity	0.043
	Domain Co-click	0.039
	Matrix Factorization	0.160
	Co-Click Time Decay	0.340
proposed methods	Global Model	0.354
	PRM	0.361
	PRM+KNN	0.451

- **PRM+KNN** utilizes neighbor information when recommending (CF)

On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Analysis – Entity Popularity

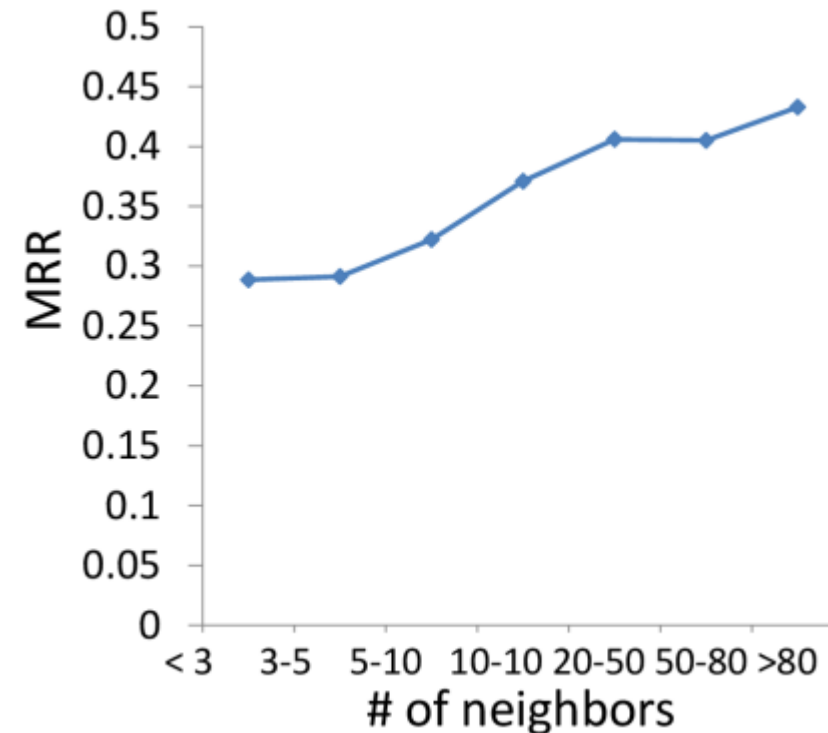
- Popular movies are easier to predict than other movies
 - Features in recommendation models favor popular movies, e.g., global and local popularity
 - With sufficient training data for popular movies, high quality recommendation models can be learned in such scenarios



On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Analysis – Number of Neighbors

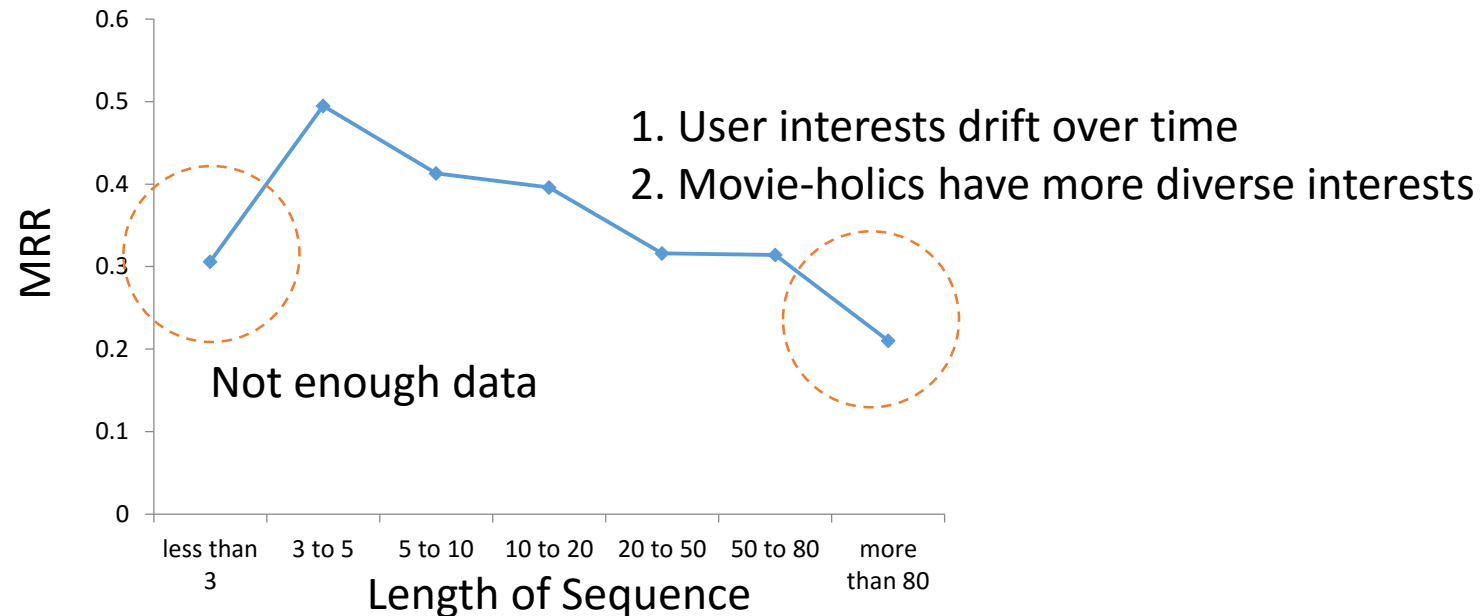
- The more neighbors each user log sequence has, the better the results
 - More neighbors indicate more data during parameter estimation
 - User log sequences with more neighbors, are usually associated with popular movie entities



On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

Analysis – Length of User Log Sequence

- Performance varies with sequence length



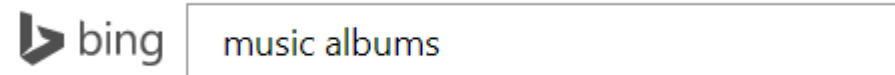
On Building Entity Recommender Systems Using User Click Log and Freebase Knowledge [Xiao Yu, et al., WSDM 2014]

$P(\textit{entity}|\textit{user})$ – Conclusion

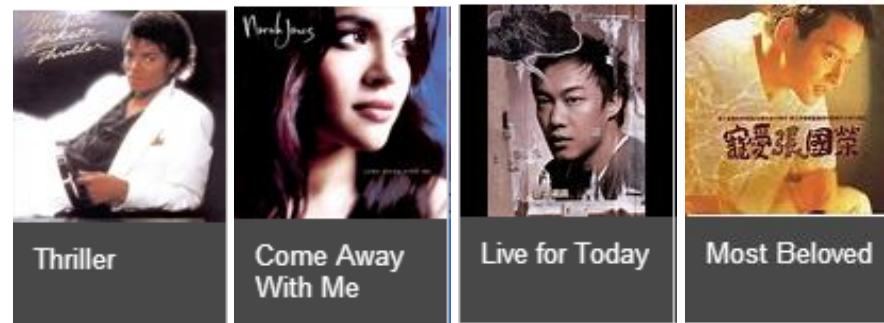
- It is possible to build a universal recommender system on top of any search engines
- The heterogeneous information in the entity graph can be very helpful in improving the recommendation results

Entity Personalization

- Entity recommender systems - $P(entity|user)$



Music album recommendation **for you**



- What are other possible entity personalization experiences that are fundamentally different

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Definitions



A User

Tom Hanks



Thomas Jeffrey "Tom" Hanks is an American actor, producer, writer, and director. Hanks is best known for his roles in Big, A League of Their Own, Sleepless in Seattle, Forrest Gump, Apollo 13, Saving Private Ryan, You've Got Mail, The Gr... +
en.wikipedia.org

www.imdb.com



Born: Jul 9, 1956 (age 57) · Concord, California

Net worth: \$350 million USD (2012)

Spouse: [Rita Wilson](#) (1988) · [Samantha Lewes](#) (1978 - 1987)

Children: [Colin Hanks](#) · [Elizabeth Hanks](#) · [Chet Hanks](#) · [Truman Theodore Hanks](#)

Awards: [Academy Award for Best Actor](#) · [Golden Globe Award for Best Actor – Motion Picture – Musical or Comedy](#) +

Siblings: [Jim Hanks](#) · [Sandra Hanks](#) · [Larry Hanks](#)

Movies and TV shows



[Captain Phillips](#)
2013



[Saving Mr. Banks](#)
2013



[Forrest Gump](#)
1994



[Cloud Atlas](#)
2012



[Cast Away](#)
2000

People also search for



[Rita Wilson](#)
Spouse



[Leonardo DiCaprio](#)



[Tom Cruise](#)



[Brad Pitt](#)



[Johnny Depp](#)

Main
Entity

Related
Entities

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Related Entities

- Current recommender:
 - $P(\text{entity}|\text{entity})$
 - $P(\text{Other Movies}|\text{Lincoln})$
- User-specific information is completely ignored

Lincoln (2012)

PG-13 · 2hr 30min · Biography


[IMDb](#) 7.4/10 ★★★★★
[Rotten Tomatoes](#) 90% ★★★★★

Lincoln is a 2012 American epic historical drama film directed by Steven Spielberg, starring Daniel Day-Lewis as United States President Abraham Lincoln and Sally Field as Mary Todd Lincoln. The screenplay by Tony Kushner was based in par... +

www.imdb.com en.wikipedia.org

Estimated budget: \$65 million USD (2012)
Release date: Nov 09, 2012
Director: Steven Spielberg
Awards: Academy Award for Best Actor · Golden Globe Award for Best Actor – Motion Picture – Drama +
Music by: John Williams
Production companies: DreamWorks · Amblin Entertainment · Touchstone Pictures · 20th Century Fox · Reliance Entertainment +

Related movies



There Will Be Blood 12 Years a Slave War Horse Abraham Lincoln: V... Avengers: Age of Ultron

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

User's information needs are diverse

- Given “Lincoln” movie, a user may be interested in
 - Movies directed by “Steven Spielberg”, or
 - Movies starred by “Daniel Day-Lewis”, or
 - Movies related to “Abraham Lincoln”, or
 - Biographical movies, or
 - Civil War movies, or
 -

Lincoln (2012)

 **PG-13** · 2hr 30min · Biography

[IMDb](#) 7.4/10 ★★★★★

[Rotten Tomatoes](#) 90% ★★★★★

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www.imdb.com en.wikipedia.org

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Related movies

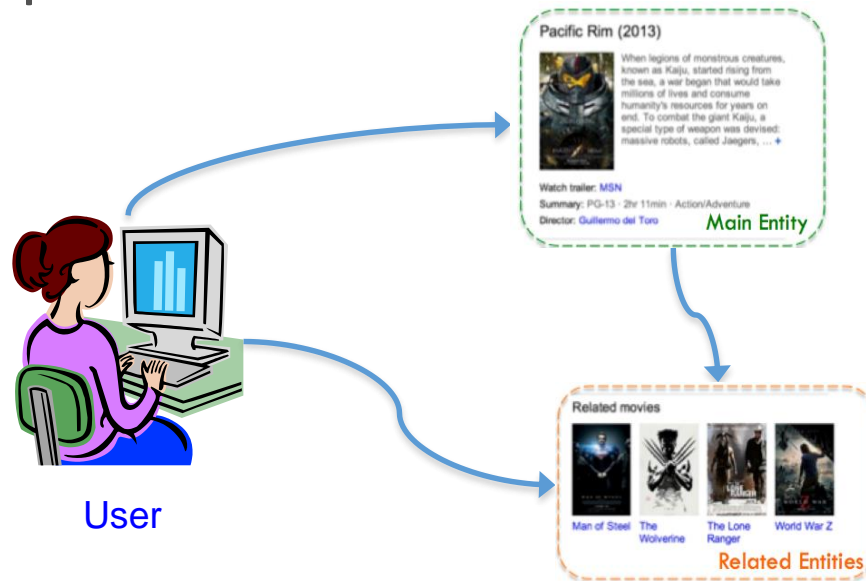
There Will Be Blood 12 Years a Slave War Horse Abraham Lincoln: V... Avengers: Age of Ultron

Personalizing
Related Entities

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Related entity personalization

- **Goal:** Given a **main entity**, we aim to recommend a list of **related entities** based on the search **user's interest**.
- Three important dimensions are involved:



New Paradigm of
Recommender Systems
 $P(\text{entity}|\text{user}, \text{entity})$

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

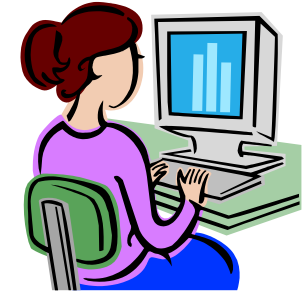
User dimension

- User interest patterns can be mined through users' interactions with the search engine
- Two sources:
 - Search click log
 - Entity pane log



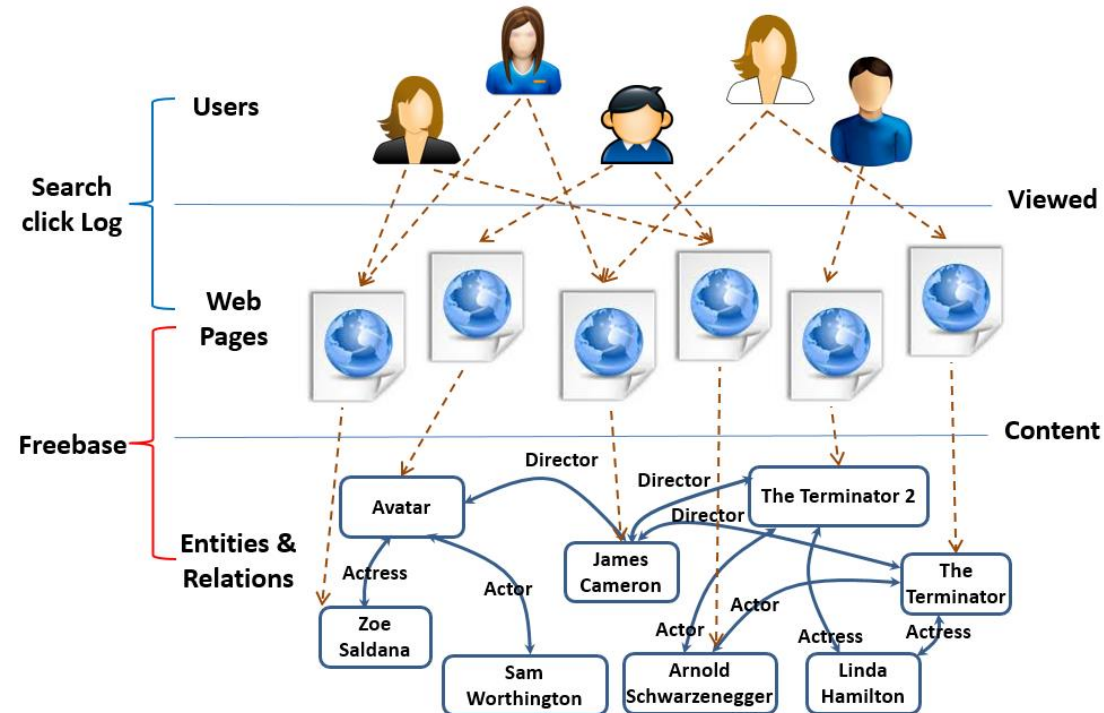
Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

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Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

User dimension



- User interest patterns can be mined through users' interactions with the search engine

- Two sources:
 - Search click log
 - **Entity pane log**

Entity pane log

User ID	Time	Main entity	Related entity	Rank	Click
32	7/9/2013 10:32:26	Pacific Rim	Man of Steel	1	0
32	7/9/2013 10:32:26	Pacific Rim	The Wolverine	2	0
32	7/9/2013 10:32:26	Pacific Rim	The Lone Ranger	3	1
498	6/16/2013 15:16:41	Leonardo DiCaprio	Kate Winslet	1	0
498	6/16/2013 15:16:41	Leonardo DiCaprio	Johnny Depp	2	1

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]



User dimension

- User interest patterns can be mined through users' interactions with the search engine
- Two sources:
 - Search click log
 - Entity pane log
- Each user is represented as a vector of features: \mathbf{x}

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Main entity



- Reflects the user's current search interest
- Ignoring main entities leads to inferior performance
 - If related entities are obtained based purely on the user's past interest, they will be completely independent of her information need
- Each main entity is represented as a feature vector: y

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

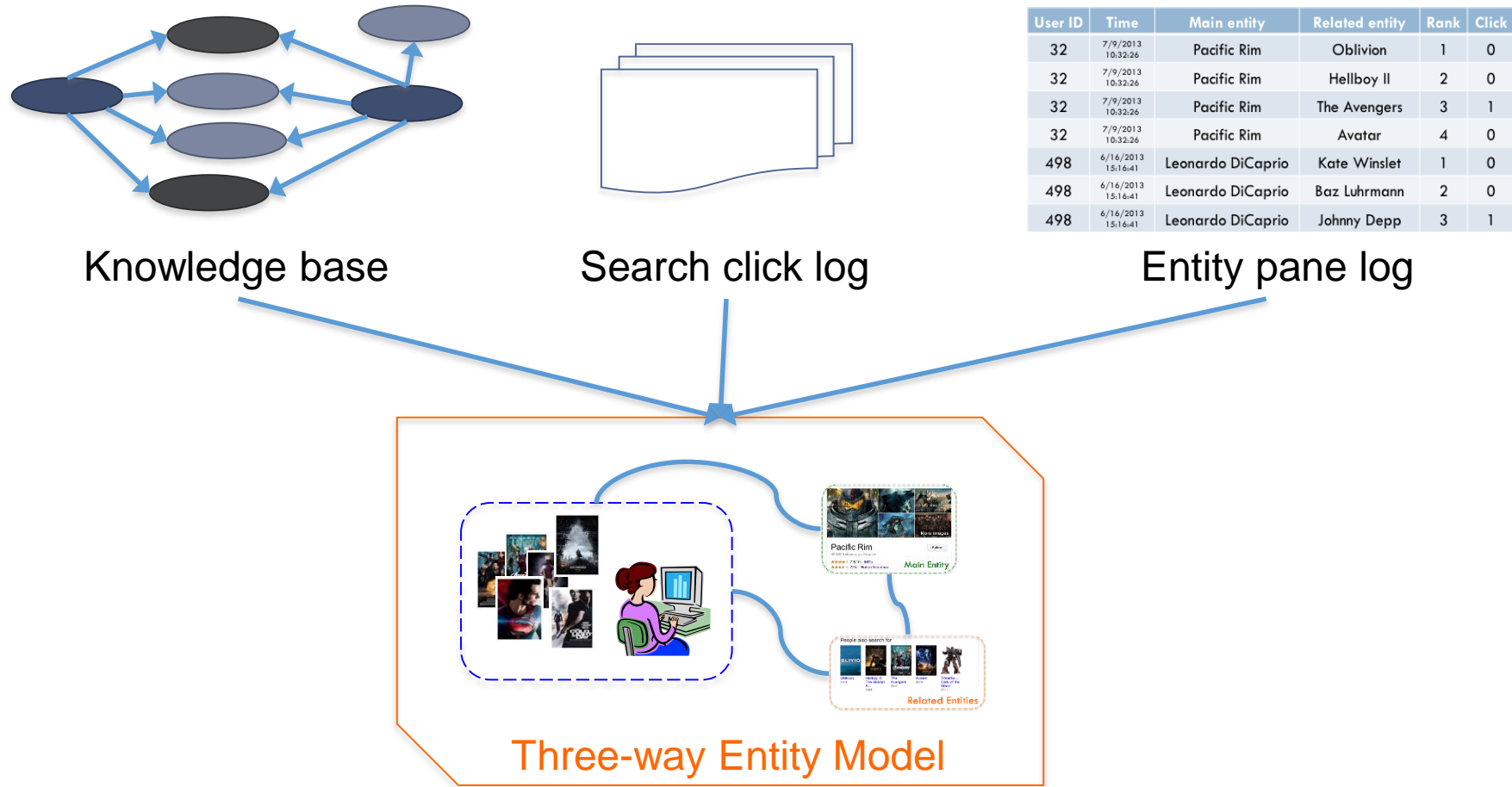
Related entity



- A user may click a related entity, when it is aligned with both her interest pattern and current need
- Clicks on related entities specify user interests in certain facets of the main entities
- Each related entity is represented as a feature vector: \vec{z}

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Goal



Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Three-way Entity Model (TEM)

- Trilinear function:

$$\Phi_{umr}(\eta) = \sum_{i=0}^I \sum_{j=0}^J \sum_{k=0}^K \eta_{ijk} [x_{ui} || y_{mj} || z_{rk}]$$

i-th feature of related entity r

- Weights h capture the associations among users, main entities and related entities

- Feature vectors:

$$\mathbf{x}_u = [1, x_{u1}, x_{u2}, \dots, x_{uI}]^T,$$

$$\mathbf{y}_m = [1, y_{m1}, y_{m2}, \dots, y_{mJ}]^T,$$

$$\mathbf{z}_r = [1, z_{r1}, z_{r2}, \dots, z_{rK}]^T.$$

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

CTR incorporation

- Trilinear function contributes an important indicator to entity recommendation, especially for rare/new entities
- To further enhance recommendation on popular entities:
 - $\text{CTR}(r)$: CTRs on related entities
 - $\text{CTR}(m,r)$: CTRs on related entities specific to main entity m
 - $\text{CTR}(u,m,r)$: CTRs on related entities specific to user u & main entity m
- Integration:

$$\Psi_{umr}(\eta, \beta) = \sum_{i=0}^I \sum_{j=0}^J \sum_{k=0}^K \eta_{ijk} \cdot x_{ui} \cdot y_{mj} \cdot z_{rk} + \underbrace{\beta}_{\text{weight}} \underbrace{\|V_{\text{CTR}}\|}_{\text{CTR feature vector}}$$

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Learning from entity pane log


- Clicks on entity pane
 - Positive feedback from users
- Negative feedback is missing
 - Users didn't click recommended entities for different reasons
- **Solution:** we use entity pairs as training data instead of individual entities

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Constructing training data

- Assumption
 - Users prefer the related entities they clicked over all the other suggestions

User ID	Time	Main entity	Related entity	Rank	Click
32	7/9/2013 10:32:26	Pacific Rim	Man of Steel	1	0
32	7/9/2013 10:32:26	Pacific Rim	The Wolverine	2	0
32	7/9/2013 10:32:26	Pacific Rim	The Lone Ranger	3	1
32	7/9/2013 10:32:26	Pacific Rim	World War Z	4	0
498	6/16/2013 15:16:41	Leonardo DiCaprio	Kate Winslet	1	0
498	6/16/2013 15:16:41	Leonardo DiCaprio	Baz Luhrmann	2	0
498	6/16/2013 15:16:41	Leonardo DiCaprio	Johnny Depp	3	1



Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Likelihood function

- Likelihood function relating Ψ_{umr} values to pairwise preferences:

$$p(r_i \succ r_j | \Psi_{umr_i}, \Psi_{umr_j}) = \frac{1}{1 + e^{-g_{r_i r_j} (\Psi_{umr_i} - \Psi_{umr_j})}} \quad g_{r_i r_j} \in \{-1, 1\}$$

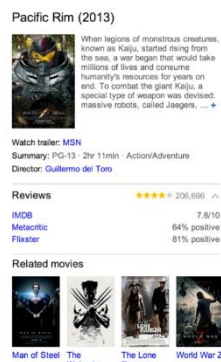
- Likelihood of all preference observations:

$$\begin{aligned} p(\mathcal{D} | \Psi) &= \prod_{(u, m, r_i, r_j) \in \mathcal{D}} p(r_i \succ r_j | \Psi_{umr_i}, \Psi_{umr_j}) \\ &= \prod_{(u, m, r_i, r_j) \in \mathcal{D}} \frac{1}{1 + e^{-g_{r_i r_j} (\Psi_{umr_i} - \Psi_{umr_j})}} \end{aligned}$$

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Experiments

- Two tasks: **Movie recommendation**



- **Celebrity recommendation**



- Data (3/2013 ~ 7/2013)

Dataset	#users	#entities	#instances
Movie	36,641	15,409	224,567
Celebrity	26,371	2,016	1,450,609

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Features used for movie & celebrity recommendation

Movie recommendation		Celebrity recommendation	
User dimension	Main & related movie	User dimension	Main & related movie
Viewed entities		Viewed entities	Profession
Types of viewed entities	Actors	Types of viewed entities	Movie acted
Viewed movie's actors	Directors	Attributes of viewed entities	Movie directed
Viewed movie's directors	Genres	Viewed pop singers	Book written
Viewed movie's genres	Country of origin	Viewed business leaders	Music genre
Viewed movie's country	Language	Viewed writers	Organization
Viewed movie's language	Producers	Viewed musicians	Spouse
Viewed movie's producers	Series	Viewed actors	Nationality
Viewed movie's series	Story	Viewed film directors	Language
Viewed movie's story	Subject		Types
Viewed movie's subject	Music	
Viewed movie's music		
.....			

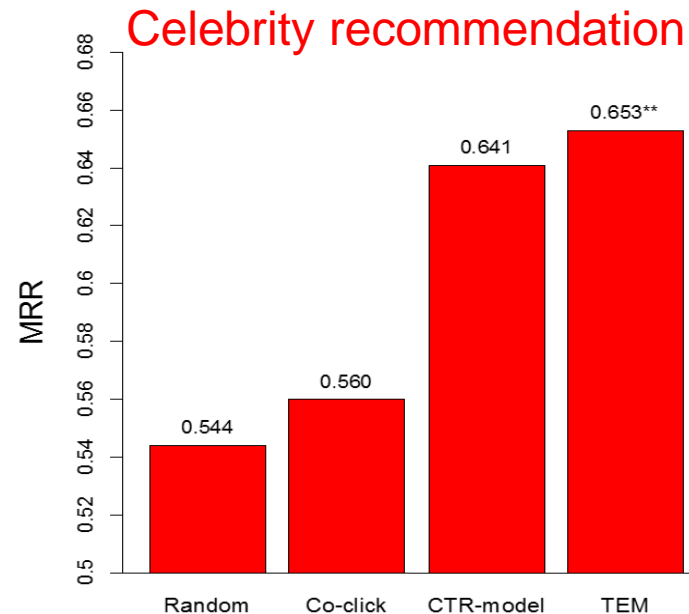
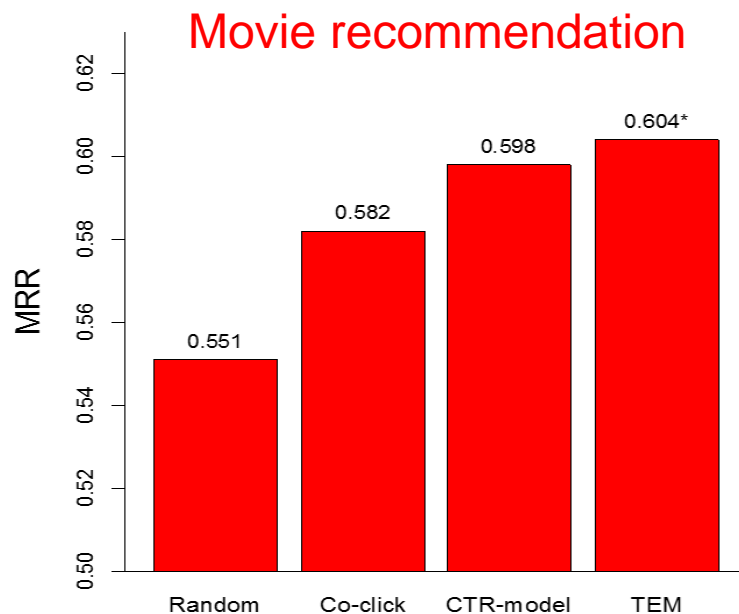
Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Recommendation accuracy

- Metric: **MRR**

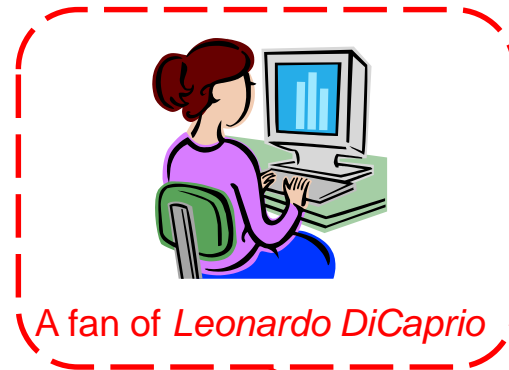
- calculates the reciprocal of the rank of the first hit in the list

- $$MRR = \frac{1}{|Q|} \sum_{n=1}^{|Q|} \frac{1}{rank^{(n)}}$$



Efficacy of personalization

- Case study

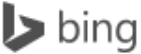




Related movie entities		
Co-click	CTR-model	TEM
Iron Man 3 Man of Steel Star Trek (2013) Django Unchained	Iron Man 3 Star Trek (2013) Django Unchained Man of Steel	Django Unchained Iron Man 3 Star Trek (2013) Man of Steel

Learning to Recommend Related Entities to Search Users [Bin Bi, et al., WSDM 2015]

Other Entity Personalization Experience



 [See all images](#)

Florence
City






Florence is the capital city of the Italian region of Tuscany and of the province of Florence. It is the most populous city in Tuscany, with approximately 380,000 inhabitants, expanding to over 1,520,000 in the metropolitan area.
en.wikipedia.org

Local time: 9:12 PM 4/16/2015
Population: 370,092 (2010)
Area: 39.54 sq miles (102.41 km²)
Explore area: [Florence](#) · [Tuscany](#) · [Italy](#)






Travel tip: Everyone's heard the Doors of Paradise, the Duomo, +

Colleges and universities: [University of Florence](#) · [Accademia di Belle Arti di Firenze](#) · [European University Institute](#) · [Accademia italiana](#) +

Points of interest [See all \(10+\)](#)


 Florence Cathedral	 Uffizi Gallery	 Ponte Vecchio	 David	 Palazzo Vecchio
--	---	--	--	--

People also search for [See all \(10+\)](#)


 Venice	 Rome	 Pisa	 Milan	 Naples
--	---	---	--	---

See results for


Florence
Oregon
Florence is a city in Lane County, Oregon, United States. As of the 2010 census, the city had a total pop...




Florence
South Carolina
Florence is a city located in Florence County, South Carolina, United States. The city is the county seat of ...




Florence
Kentucky
Florence is a home rule-class city in Boone County, Kentucky, in the United States. Florence is part of the ...



Florence
New Jersey
Florence Township is a township in Burlington County, New Jersey, United States. As of the 2010 United Stat...



Florence
Arizona
Florence is a town in and the county seat of Pinal County, Arizona, United States. The population was 25...



Other Entity Personalization Experience



SIGIR 2015

SIGIR is the major international forum for the presentation of new research results and for the demonstration of new systems and techniques in information retrieval.

wikicfp.com

Dates: Aug 09 - 13, 2015

Location: [Santiago](#)

Website: [SIGIR 2015](#)

Submissions due: Jan 28, 2015

People also search for

[CIKM 2015](#) (Oct 19, 2015)

[WWW 2015](#) (May 20, 2015)

[AAAI 2016](#) (Feb 12, 2016)

[ECIR 2015](#) (Mar 29, 2015)

[KDD 2015](#) (Aug 10, 2015)

[See more](#) ▾



Special Inspector General for Iraq Reconstruction

The Office of the Special Inspector General for Iraq Reconstruction was created as the successor to the Coalition Provisional Authority Office of Inspector General. SIGIR was an independent government agency created by the Congress to provide oversight of the use of the \$52 billion U.S. reconstruction program in Iraq. Stuart W. Bowen, Jr. was app... +

en.wikipedia.org

Founded: 2004

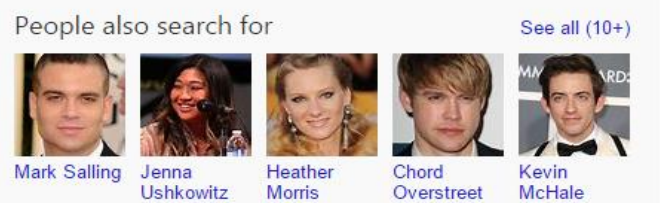
Other Entity Personalization Experience

$$P(\text{entity}|\text{user}, \text{query})$$



Harry Shum Jr.
Dancer

Harry Shum, Jr. is an American singer, songwriter, dancer, actor and choreographer. He is best known for his role as Mike Chang on the Fox television show Glee. He has appeared in dance films such as Stomp the Yard, You Got Served, Step Up 2: The Streets and Step Up 3D. He also played the character of Elliot Hoo in The Legion of Extraordin...



Harry Shum
Researcher of Computer Vision

Heung-Yeung "Harry" Shum is Executive Vice President, Technology & Research at Microsoft. He is known for his research on computer vision and computer graphics, and for the development of web search engine Bing.

Experience [v](#)

Education [v](#)



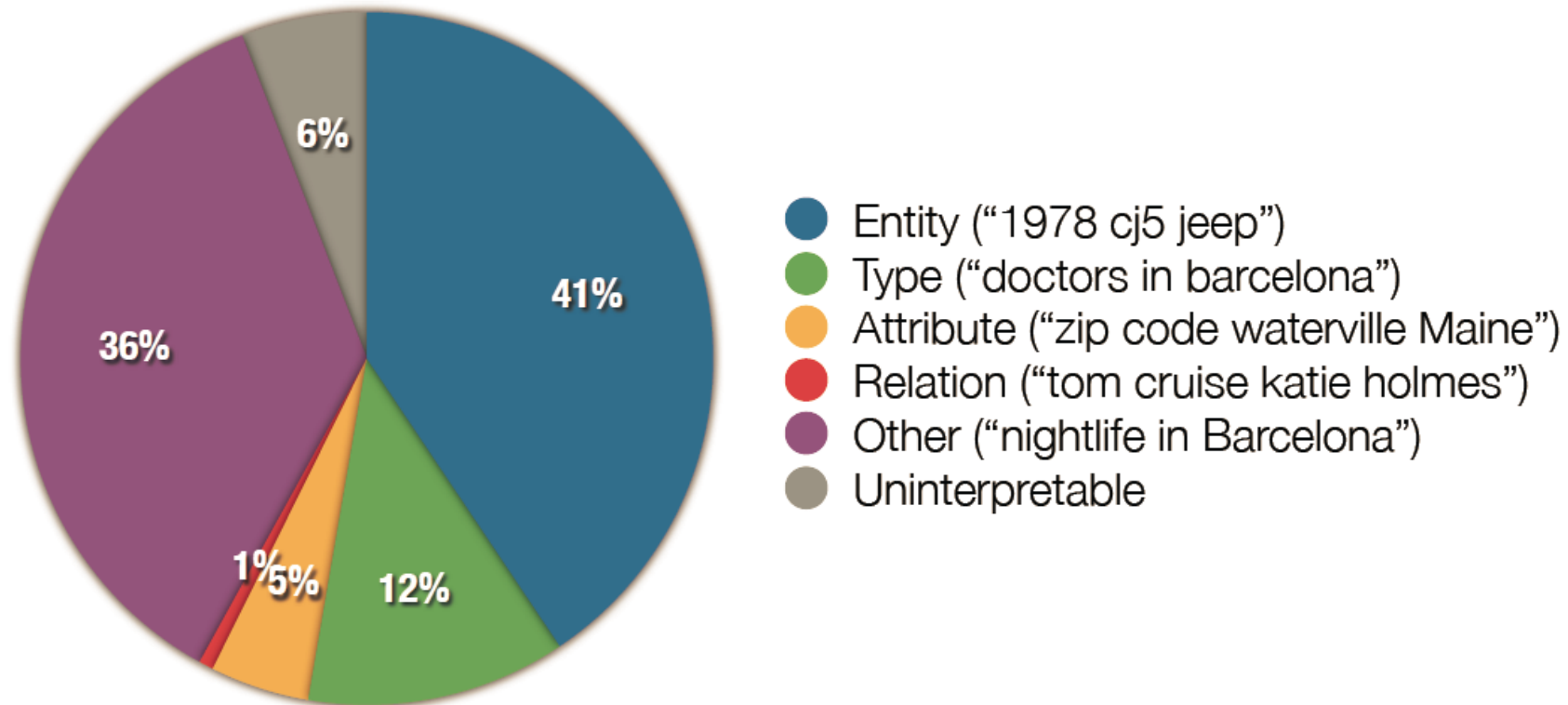
Entity Recommendation & Understanding Taxonomy

- $P(\text{entity}|\text{entity})$
 - Recommendations given an entity
 - Co-occurrence
 - Similarity
 - Entity Linking
 - Interpretation
- $P(\text{entity}|\text{user})$
 - Recommendations given a user
 - Universal recommender system
 - $P(\text{entity}|\text{user}, \text{item})$
 - $P(\text{entity}|\text{user}, \text{query})$
- $P(\text{entity}|\text{query})$
 - Recommendations given a query

Entity Recommendation & Understanding Taxonomy

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 - Recommendations given a query

$P(\text{entity}|\text{query})$



Ad-hoc Object Retrieval in the Web of Data [Jeffrey Pound, et al., WWW 2010]
Entity Linking and Retrieval for Semantic Search [Edgar Meij, et al., WSDM 2014]

$P(\textit{entity}|\textit{query})$


- Entity Retrieval/Finding
- Knowledge Base Question and Answering (KB QnA)
- Web-based Question and Answering (Web QnA)

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

bing famous basketball player

Web Images Videos Maps News More 40 Sign in

Famous Basketball players




Michael Jordan LeBron James Kobe Bryant Magic Johnson Larry Bird Wilt Chamberlain 1936 - 1999 Kareem Abdul-Jabbar Shaquille O'Neal

bing italian composers

Web Images Videos Maps News More 46 Sign in

Italy - Composers



Giacomo Puccini 1858 - 1924 Gioachino Rossini 1792 - 1868 Ennio Morricone Claudio Monteverdi 1567 - 1643 Vincenzo Bellini 1801 - 1835 Giovanni Pierluigi da Palestrina 1525 - 1594 Jean-Baptiste Lully 1632 - 1687 Nino Rota 1911 - 1979

$P(\textit{entity}|\textit{query})$ – Entity Retrieval/Finding

- TREC Entity Track (2009 – 2011)
 - Related Entity Finding Task
 - Given
 - Input entity
 - Type of the target entity (PER/ORG/LOC)
 - Narrative (describing the nature of the relation in free text)
 - Return related entities

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

Input Entity: **Boeing 747**

Target Entity Type: **Organization**

Narrative: **Airlines that currently use Boeing 747 planes**

Input Entity: **The food network**

Target Entity Type: **Person**

Narrative: **Chefs with a show on the food network**

Input Entity: **Eurail**

Target Entity Type: **Location**

Narrative: **What countries does Eurail operate in**

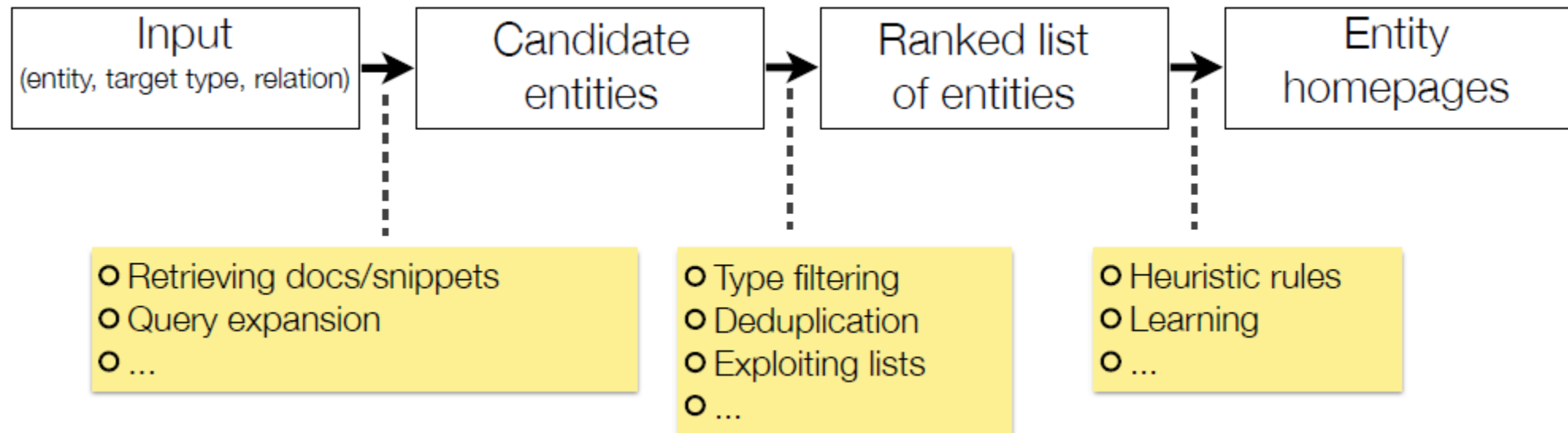
Input Entity: **Dow Jones**

Target Entity Type: **Organization**

Narrative: **Find companies that are included in the Dow Jones industrial average**

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

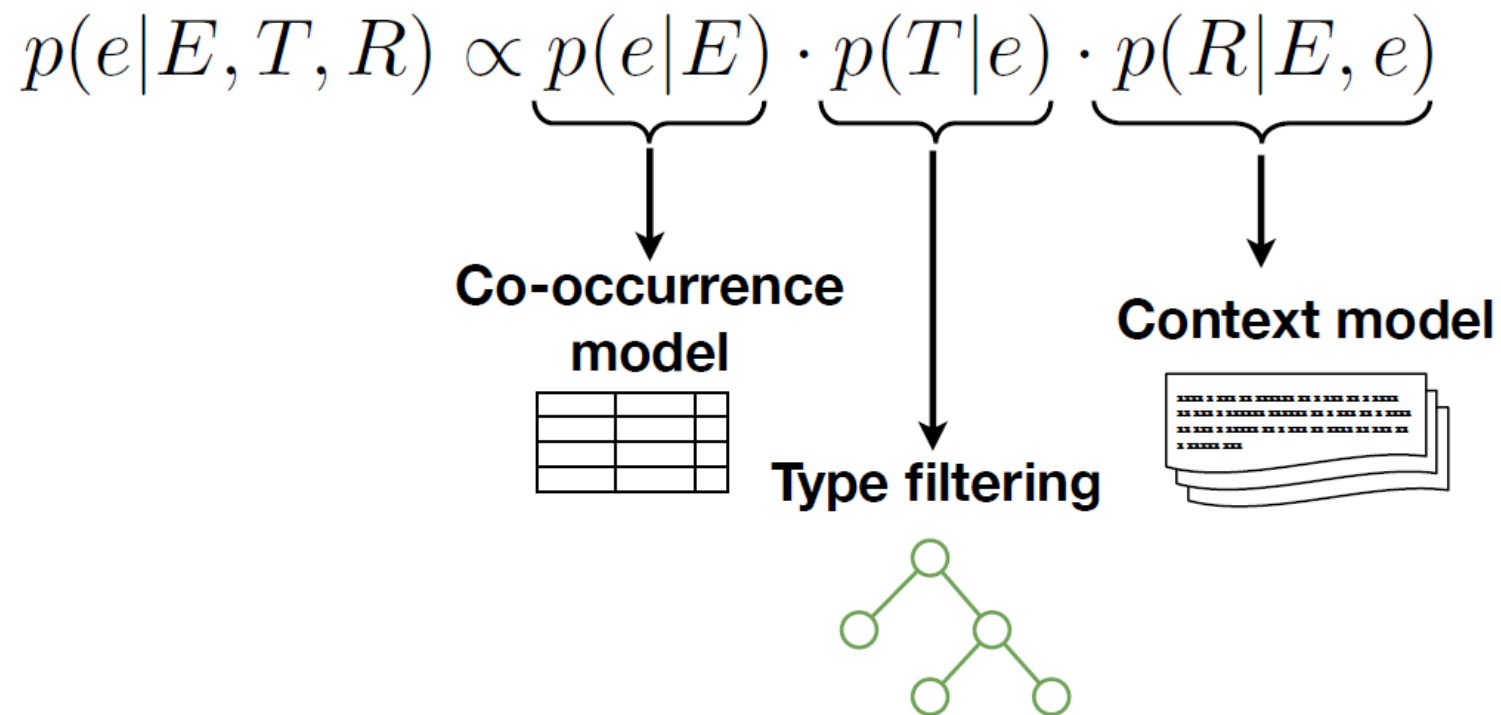
- A typical pipeline



Entity Linking and Retrieval for Semantic Search [Edgar Meij, et al., WSDM 2014]

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

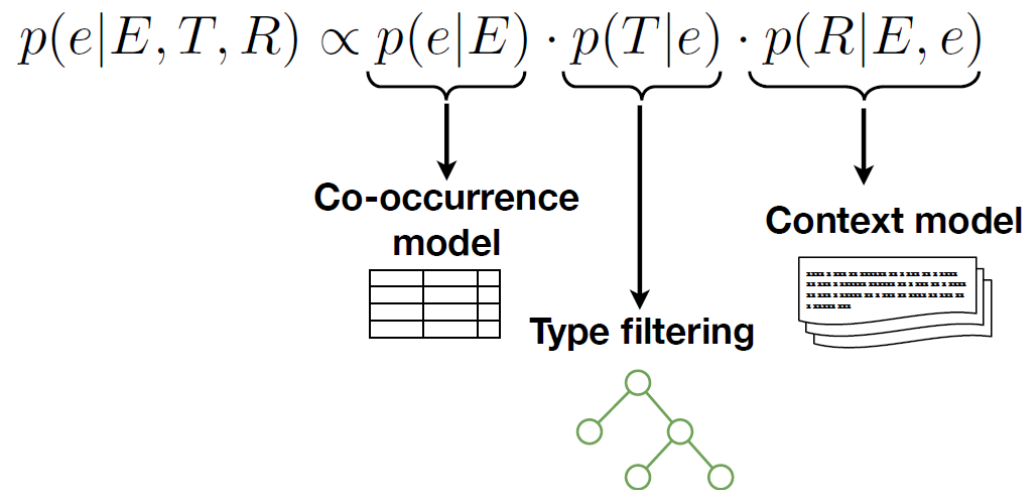
- Three component model



Related Entity Finding Based on Co-Occurrence [Marc Bron, et al., TREC 2009]

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

$$P(R|E, e) = P(R|\theta_{Ee}) = \prod_{t \in R} P(t|\theta_{Ee})^{n(t,R)}$$



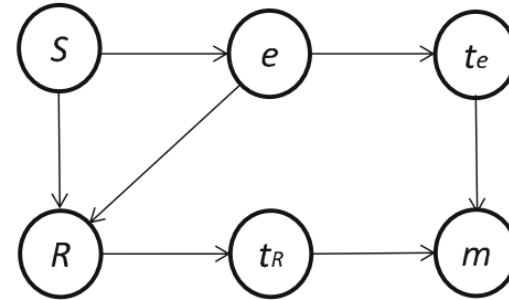
$$P(t|\theta_{Ee}) = \frac{1}{|D_{Ee}|} \sum_{d \in D_{Ee}} P(t|\theta_d)$$

$$P(t|\theta_d) = \frac{n(t, d) + \mu \cdot P(t)}{\sum_{t'} n(t', d) + \mu}$$

Related Entity Finding Based on Co-Occurrence [Marc Bron, et al., TREC 2009]

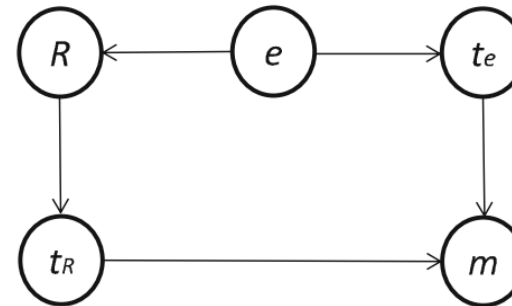
$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

Model A



$$p(e, m = 1 | R, S) \propto p(R | e, S) p(e | S) \sum_{t_R} \sum_{t_e} p(m = 1 | t_e, t_R) p(t_e | e) p(t_R | R)$$

Model B



$$p(e, m = 1 | R) \propto p(R | e) p(e) \sum_{t_R} \sum_{t_e} p(m = 1 | t_e, t_R) p(t_e | e) p(t_R | R)$$

Related Entity Finding by Unified Probabilistic Models [Yi Fang, et al., World Wide Web 2013]

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

Input Entity: Dow Jones

Target Entity Type: Organization

Narrative: Find companies that are included in the Dow Jones industrial average

$p(m = 1 e, R)$	$p(R e)p(e)$	MA	$p(R e, S)p(e S)$	MB
nasdaq	microsoft	boeing	coca cola	boeing
bloomberg	boeing	ibm	boeing	coca cola
ibm	<i>federal reserve</i>	pfizer	<i>cnnmoney</i>	microsoft
news corporation	<i>european</i>	coca cola	<i>futures</i>	nasdaq
Yahoo	coca cola	intel	microsoft	ibm
atari	<i>uw</i>	alcoa	pfizer	intel
washington post	ibm	<i>cnnmoney</i>	alcoa	merck
boeing	intel	mcdonald's	ibm	dupont
<i>stanford</i>	<i>futures</i>	merck	<i>federal reserve</i>	caterpillar
enterprise media group	merck	microsoft	mcdonald's	<i>stanford</i>

Related Entity Finding by Unified Probabilistic Models [Yi Fang, et al., World Wide Web 2013]

$P(entity|query)$ – Entity Retrieval/Finding

- Knowledge base are largely incomplete

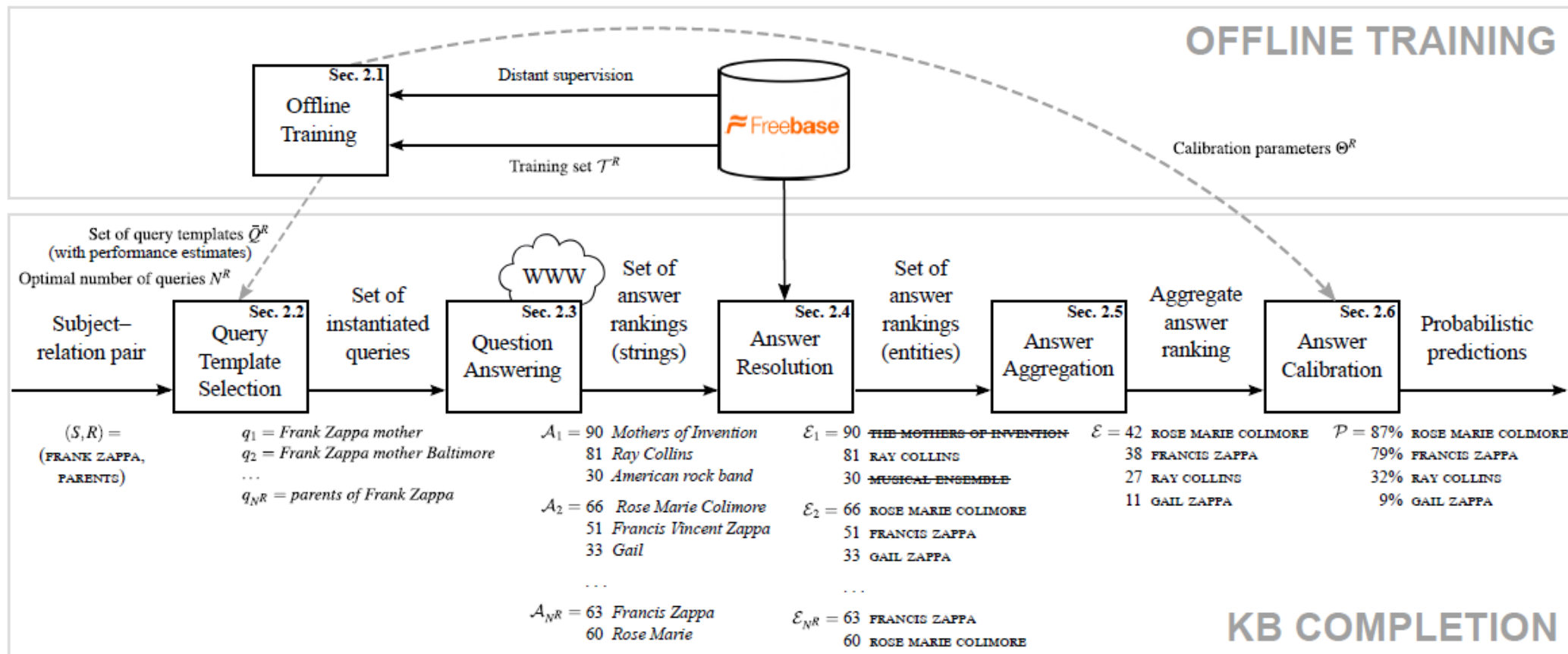


Relation	Percentage unknown	
	All 3M	Top 100K
PROFESSION	68%	24%
PLACE OF BIRTH	71%	13%
NATIONALITY	75%	21%
EDUCATION	91%	63%
SPOUSES	92%	68%
PARENTS	94%	77%
CHILDREN	94%	80%
SIBLINGS	96%	83%
ETHNICITY	99%	86%

Entity Retrieval/Finding techniques can be used in Knowledge Base Completion

Knowledge Base Completion via Search-Based Question Answering [Robert West, et al., WWW 2014]

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

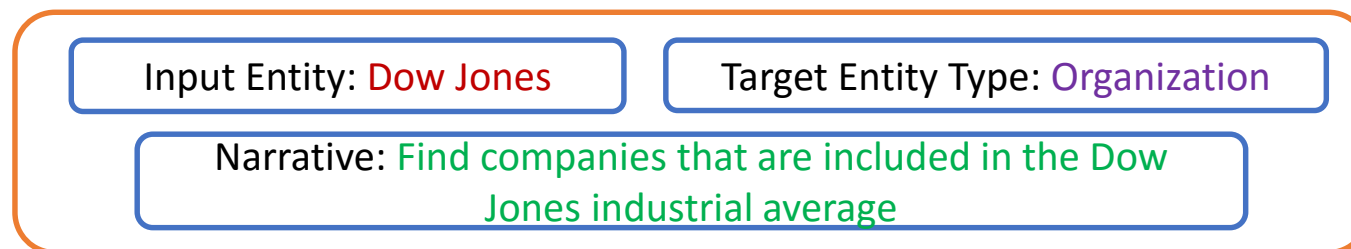


Knowledge Base Completion via Search-Based Question Answering [Robert West, et al., WWW 2014]

$P(\text{entity}|\text{query})$ – Entity Retrieval/Finding

- Challenges

- The TREC’s related entity finding track is relatively easy since the “query intent” is known



- In real world search engines, we need to understand the intent of queries




$P(\text{entity}|\text{query})$ – KB QnA

bing MS Beta

who is tom cruise's first wife

Web Images Videos Maps News More

5,030,000 RESULTS Any time ▾

 **Mimi Rogers**
Tom Cruise · First wife


Data from: [Wikipedia](#)

bing MS Beta

the tallest building in china

Web Images Videos Maps News More

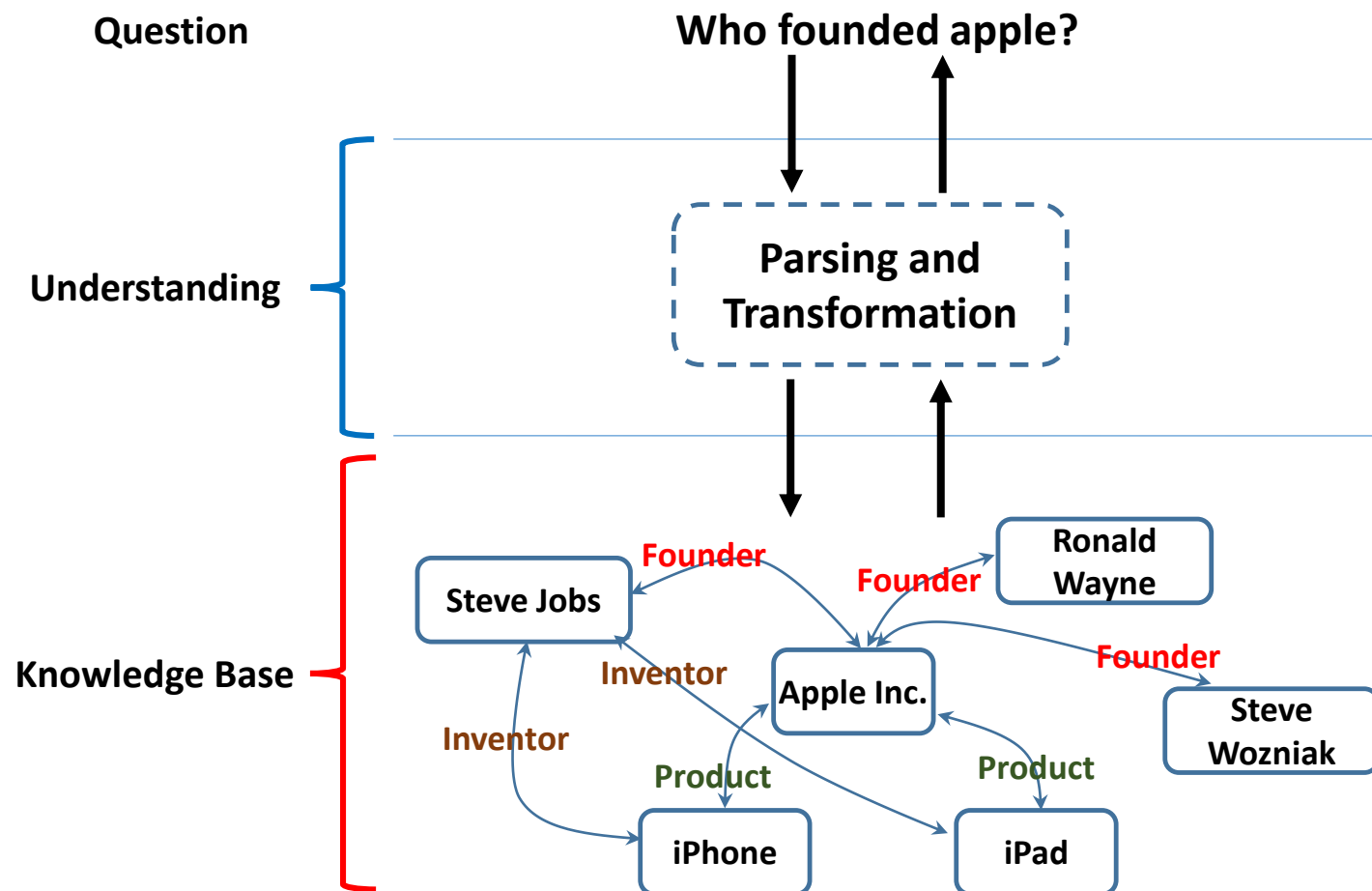
2,410,000 RESULTS Any time ▾

 **Shanghai Tower**
China · Highest building

Data from: [Wikipedia](#)

$P(entity|query)$ – KB QnA

- Typical Architect of KB QnA



Open Domain Question and Answering via Semantic Enrichment [Huan Sun, et al., WWW 2015]

An Incomplete List of Academic Papers on KB QnA

- Unger et al. “Template-based question answering over RDF data.” WWW-2012.
- Yahya et al. “Natural language questions for the web of data.” EMNLP-2012.
- Cai & Yates. “Large-scale semantic parsing via schema matching and lexicon extension.” ACL-2013.
- Kwiatkowski et al. “Scaling semantic parsers with on-the-fly ontology matching.” EMNLP-2013.
- Berant et al. “Semantic parsing on Freebase from question-answer pairs.” EMNLP-2013.
- Zou et al. “Natural language question answering over RDF: a graph data driven approach.” SIGMOD-2014.
- Yih et al. “Semantic parsing for single-relation question answering.” ACL-2014.
- Bao et al. “Knowledge-Based Question Answering as Machine Translation.” ACL-2014.
- Berant & Liang. “Semantic Parsing via Paraphrasing.” ACL-2014.
- Yao & Van Durme. “Information extraction over structured data: Question answering with freebase.” ACL-2014.
- Fader et al. “Open question answering over curated and extracted knowledge bases.” KDD-2014.
- Bordes et al. “Open question answering with weakly supervised embedding models.” ECML-PKDD-2014.
- Bordes et al. “Question answering with subgraph embeddings.” EMNLP-2014.
- Yang et al. “Joint relational embeddings for knowledge-based question answering.” EMNLP-2014.
- Reddy et al. “Large-scale Semantic Parsing without Question-Answer Pairs.” TACL, 2014.
- Yih et al. “Semantic Parsing via Staged Query Graph Generation: Question Answering with Knowledge Base.” ACL-2015

$P(\text{entity}|\text{query})$ – KB QnA

- Semantic Parsing

Who did Tom Cruise marry in 1987?



semantic parsing

Type.Person \sqcap Marriage.(Spouse.TomCruise \sqcap StartDate.1987)



execute logical form

Mimi Rogers

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Traditional statistical semantic parsing
 - Manually annotated logical forms

What's California's capital?

Capital.California

How long is the Mississippi river?

RiverLength.Mississippi

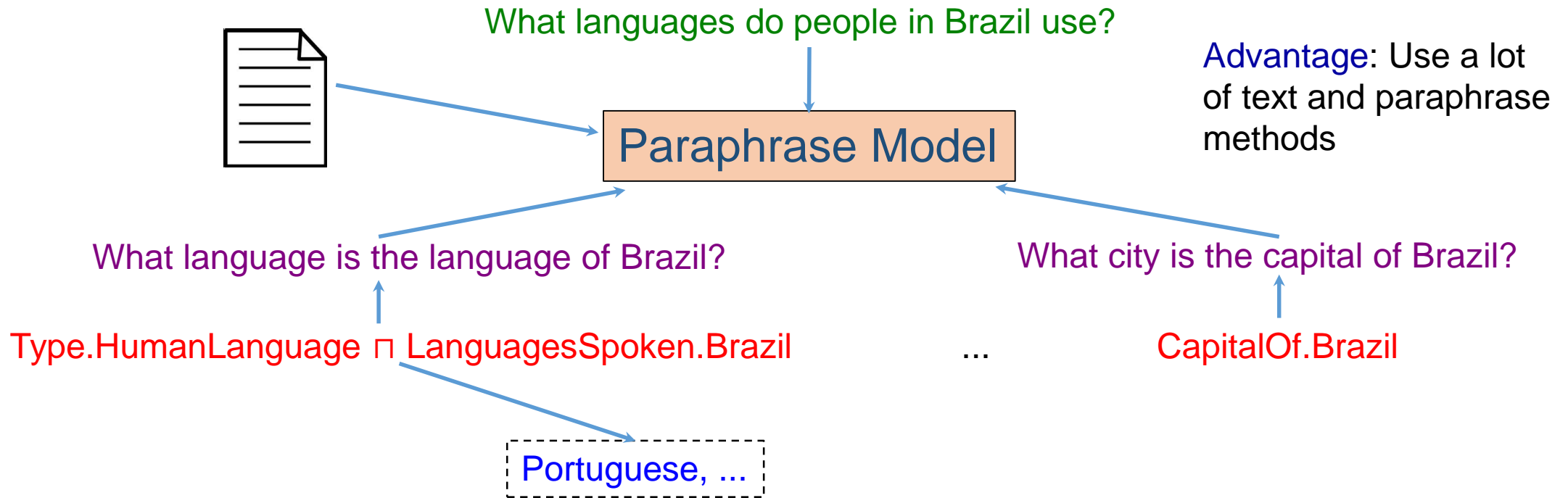
...

...

- Limitations
 - Requires experts | slow, expensive, does not scale!
 - Restricted to limited domains

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA



- Simple model suggests candidate logical forms
- Simple model generates canonical utterances
- Ranking of canonical utterances

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Input

- Knowledge-base K
- Training set of question-answer pairs $\{(x_i, y_i)\}_1^n$

What are the main cities in California? SF, LA, ...

- Output

- Semantic parser that maps questions x to answers y through logical forms z

Countries in Asia \longrightarrow Type.Country \sqcap ContainedBy.Asia

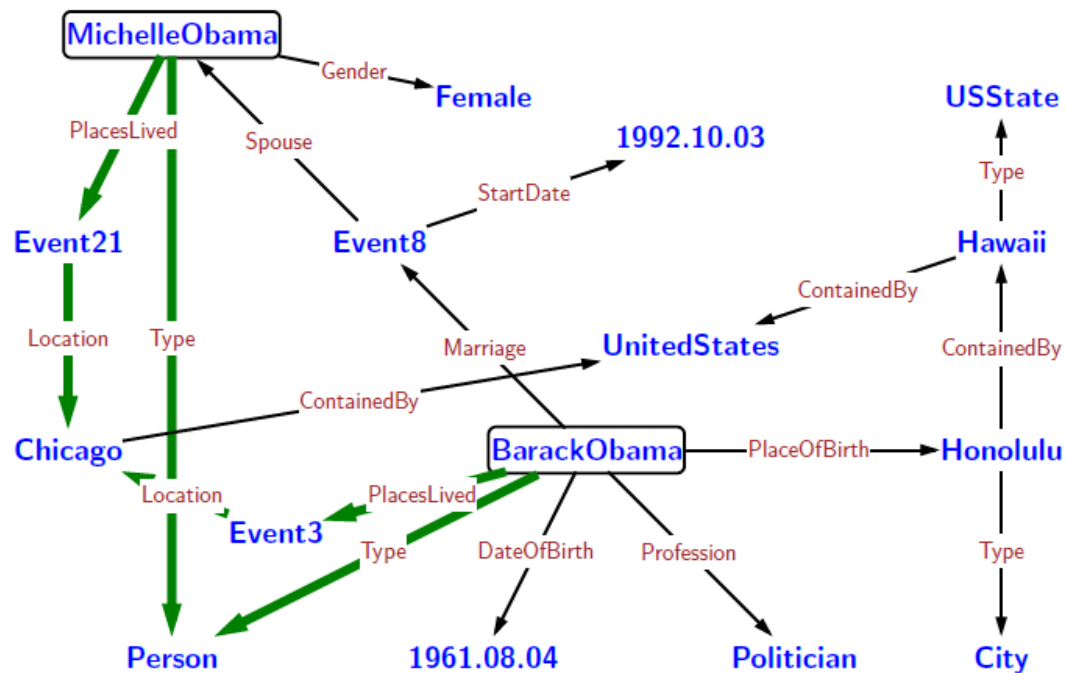
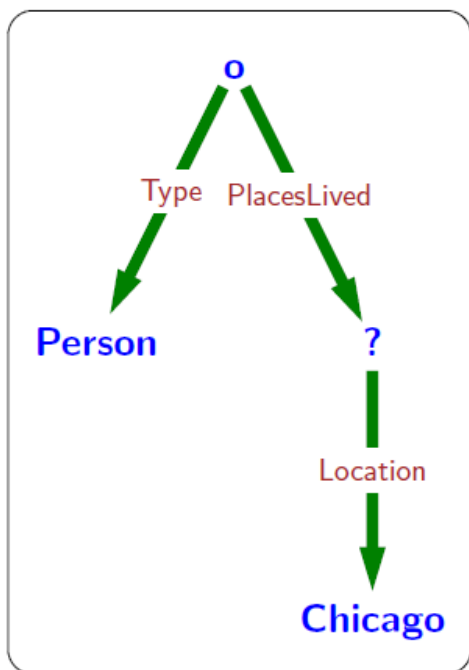
\longrightarrow China, Japan, India, ...

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(entity|query)$ – KB QnA

- Logical forms are graph templates

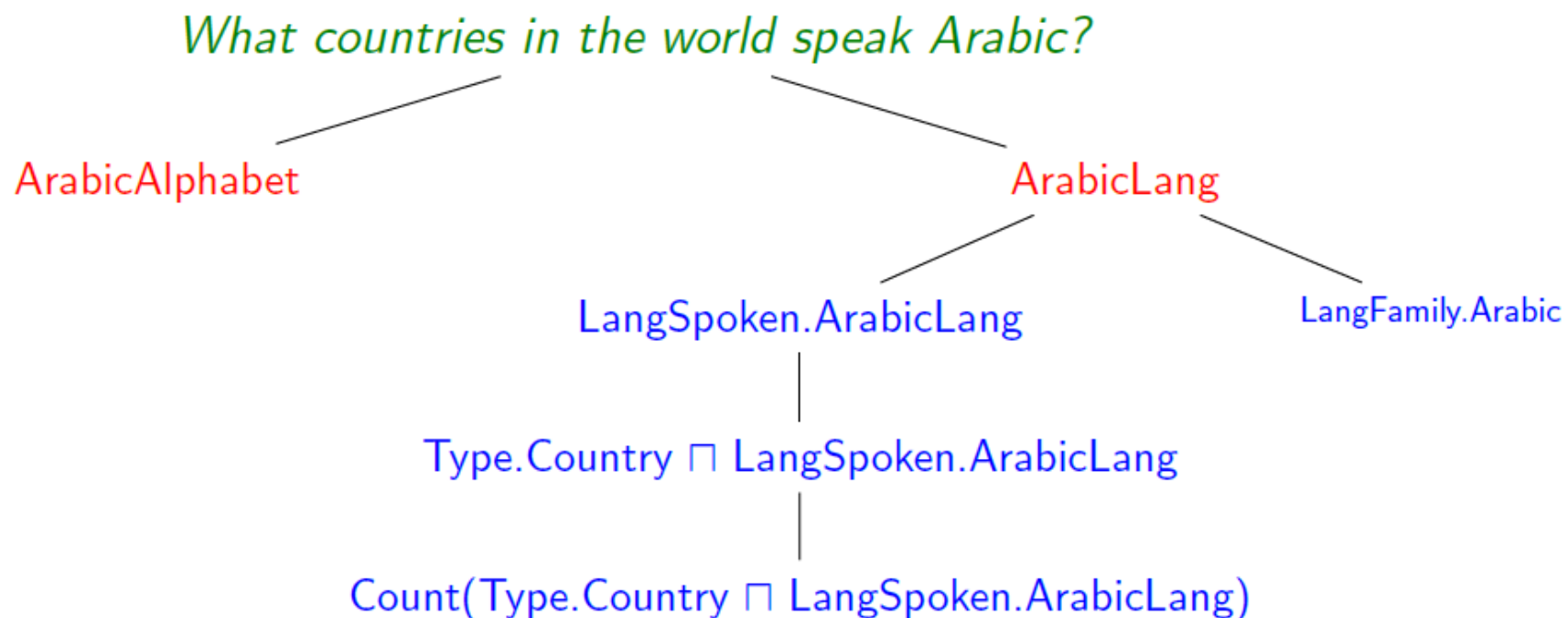
Type.Person \sqcap PlacesLived.Location.Chicago



Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Candidate logical forms



Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Candidate logical forms

Template	Example	Question
$p.e$	Directed.TopGun	<i>who directed Top Gun</i>
$p_1.p_2.e$	Employment.EmployerOf.SteveBalmer	<i>Where does Steve Balmer work?</i>
$p.(p_1.e_1 \sqcap p_2.e_2)$	Character.(Actor.BradPitt \sqcap Film.Troy)	<i>Who did Brad Pitt play in Troy?</i>
Type. $t \sqcap z$	Type.Composer \sqcap SpeakerOf.French	<i>What composers spoke French?</i>
count(z)	count(BoatDesigner.NatHerreshoff)	<i>How many ships were designed by Nat Herreshoff?</i>

$p, p_1 p_2$ – Freebase properties
 e, e_1, e_2 – Freebase entities

t – Freebase type
 z – logical form

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Canonical utterance generation



↓ syntactic analysis

What country is Arabic language spoken in?

What country spoken the languages Arabic language?

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Canonical utterance generation

	$d(p)$ Categ.	Rule	Example
$p.e$	NP	WH $d(t)$ has $d(e)$ as NP ?	<i>What election contest has George Bush as winner?</i>
	VP	WH $d(t)$ (AUX) VP $d(e)$?	<i>What radio station serves area New-York?</i>
	PP	WH $d(t)$ PP $d(e)$?	<i>What beer from region Argentina?</i>
	NP VP	WH $d(t)$ VP the NP $d(e)$?	<i>What mass transportation system served the area Berlin?</i>
$R(p).e$	NP	WH $d(t)$ is the NP of $d(e)$?	<i>What location is the place of birth of Elvis Presley?</i>
	VP	WH $d(t)$ AUX $d(e)$ VP ?	<i>What film is Brazil featured in?</i>
	PP	WH $d(t)$ $d(e)$ PP ?	<i>What destination Spanish steps near travel destination?</i>
	NP VP	WH NP is VP by $d(e)$?	<i>What structure is designed by Herod?</i>

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Paraphrase model

What countries in the world speak Arabic?

What country is Arabic language spoken in?

- Simple paraphrase model utilizing a lot of text
 - Association model - Paralex
 - Vector space model - Wikipedia

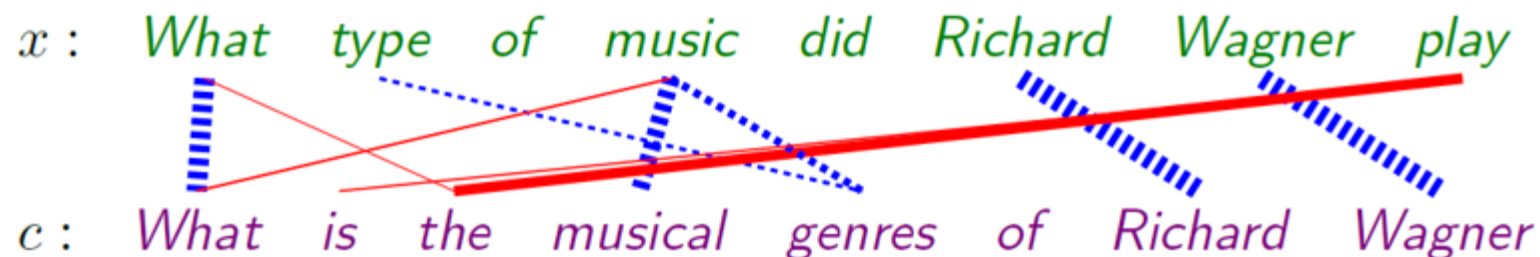
$$\phi_{\text{pr}}(x, c) = \phi_{\text{as}}(x, c) + \phi_{\text{vs}}(x, c)$$

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

Association: pair of spans $(x_{ij}, c_{i'j'})$

type of music \Leftrightarrow musical genre



PARALEX corpus with 18 millions pairs of question paraphrases

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- Vector Space Model

Train word vectors $v(w)$:

C : content words in utterance x

$$v(x) = \frac{1}{|C|} \sum_{x_i \in C} v(x_i)$$

Learn a matrix W to estimate “similarity” score

$$s(x, c) = v(x)^\top W v(c)$$

Options for W

- Identity: dot product
- Diagonal: dot product with scaling
- Full matrix: interactions between dimensions

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

x : What type of music did Richard Wagner play?

as : What is the musical genres of Richard Wagner?

vs : What composition has Richard Wagner as lyricist?

x : Where is made Kia car?

as : What place is founded by Kia motors?

vs : What city is Kia motors a headquarters of?

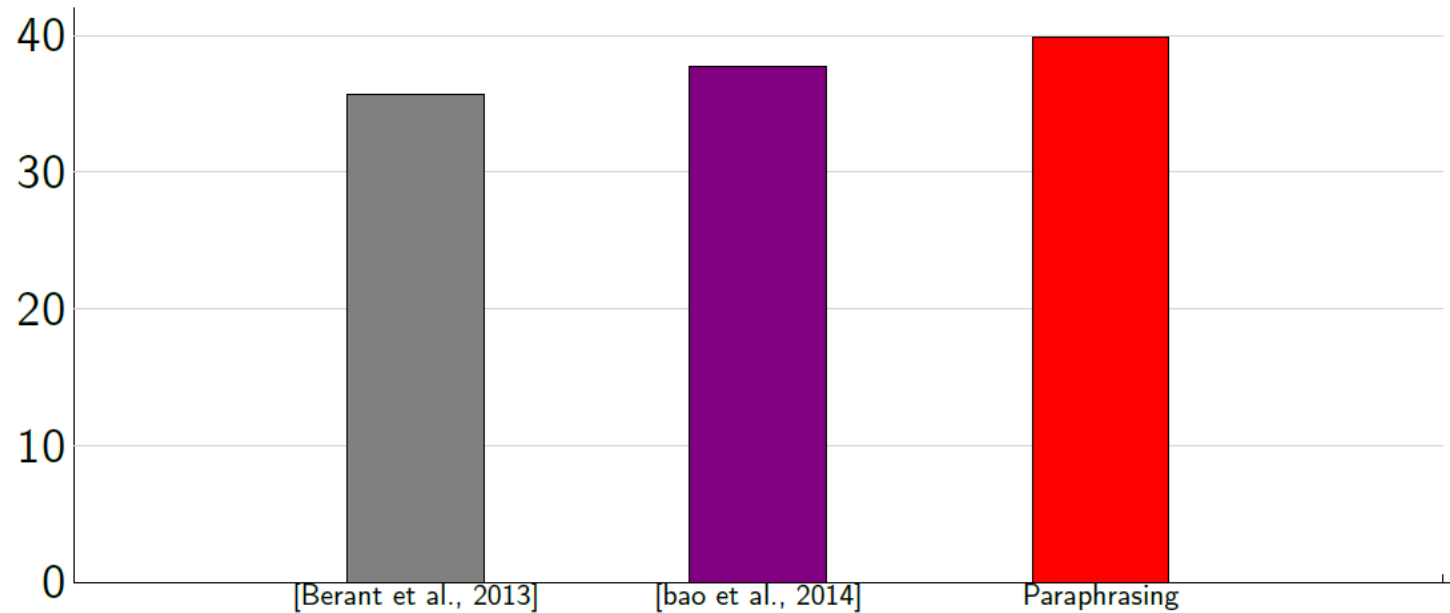
Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\textit{entity}|\textit{query})$ – KB QnA

- WebQuestions dataset
 - What character did Natalie Portman play in Star Wars? → Padme Amidala
 - What kind of money to take to Bahamas? → Bahamian dollar
 - What currency do you use in Costa Rica? → Costa Rican colon
 - What did Obama study in school? → political science
 - What do Michelle Obama do for a living? → writer, lawyer
 - What killed Sammy Davis Jr? → throat cancer
- 5,810 questions crawled from Google Suggest and answered using AMT

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

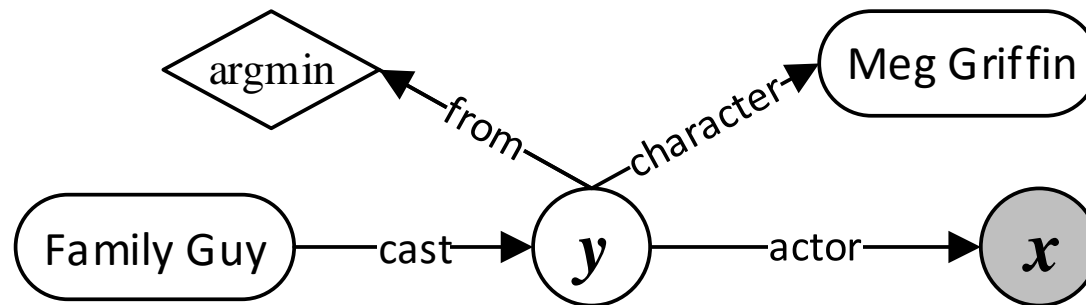


Outperforms previous state-of-the-art

Semantic Parsing via Paraphrasing [Jonathan Berant, et al., ACL 2014]

$P(\text{entity}|\text{query})$ – KB QnA

- “Who first voiced Meg on Family Guy?”
- $\lambda x. \exists y. \text{cast}(\text{FamilyGuy}, y) \wedge \text{actor}(y, x) \wedge \text{character}(y, \text{MegGriffin})$

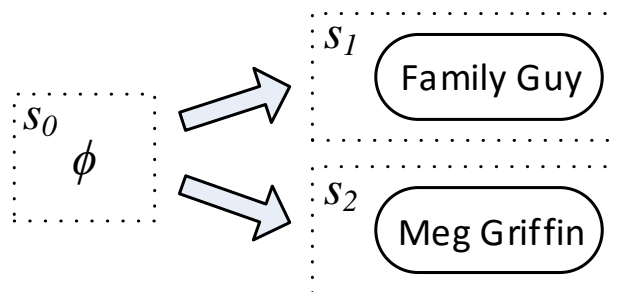


Semantic Parsing via Staged Query Graph Generation: Question Answering with Knowledge Base [Scott Yih, et al., ACL 2015]

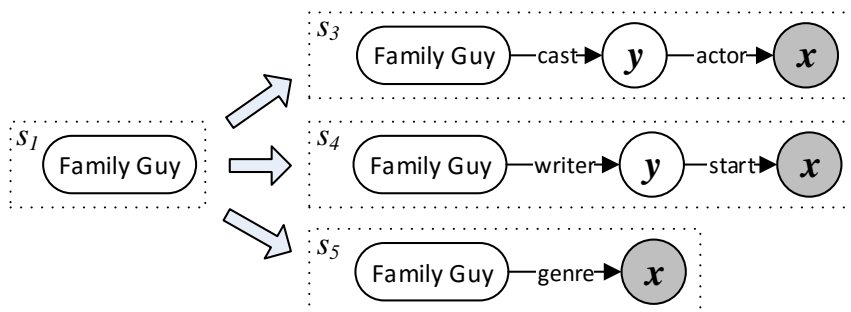
$P(\text{entity}|\text{query})$ – KB QnA

“Who first voiced Meg on Family Guy?”

1. Topic Entity Linking (E2E tool)

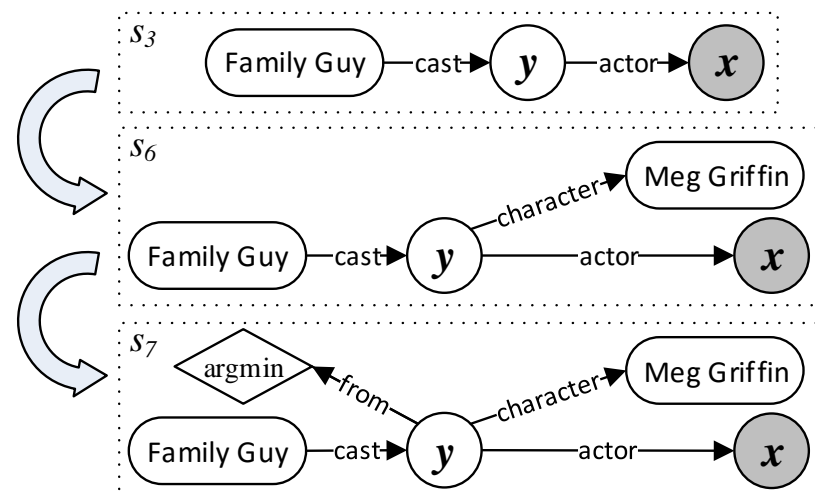


2. Core Inferential Chain (DSSM)



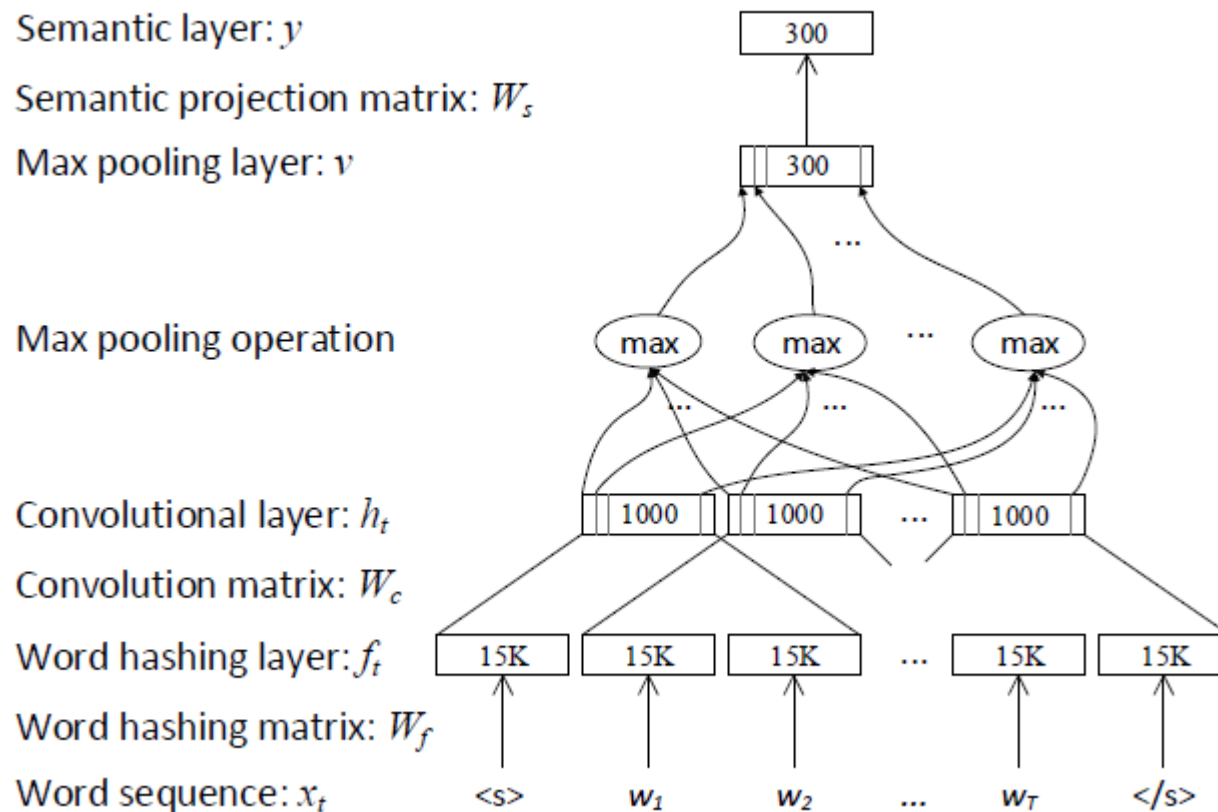
- Leveraging KB more tightly when forming the parse (search pruning)
- The expressiveness of the query graphs controlled by search actions

3. Augmenting Constraints



Semantic Parsing via Staged Query Graph Generation: Question Answering with Knowledge Base [Scott Yih, et al., ACL 2015]

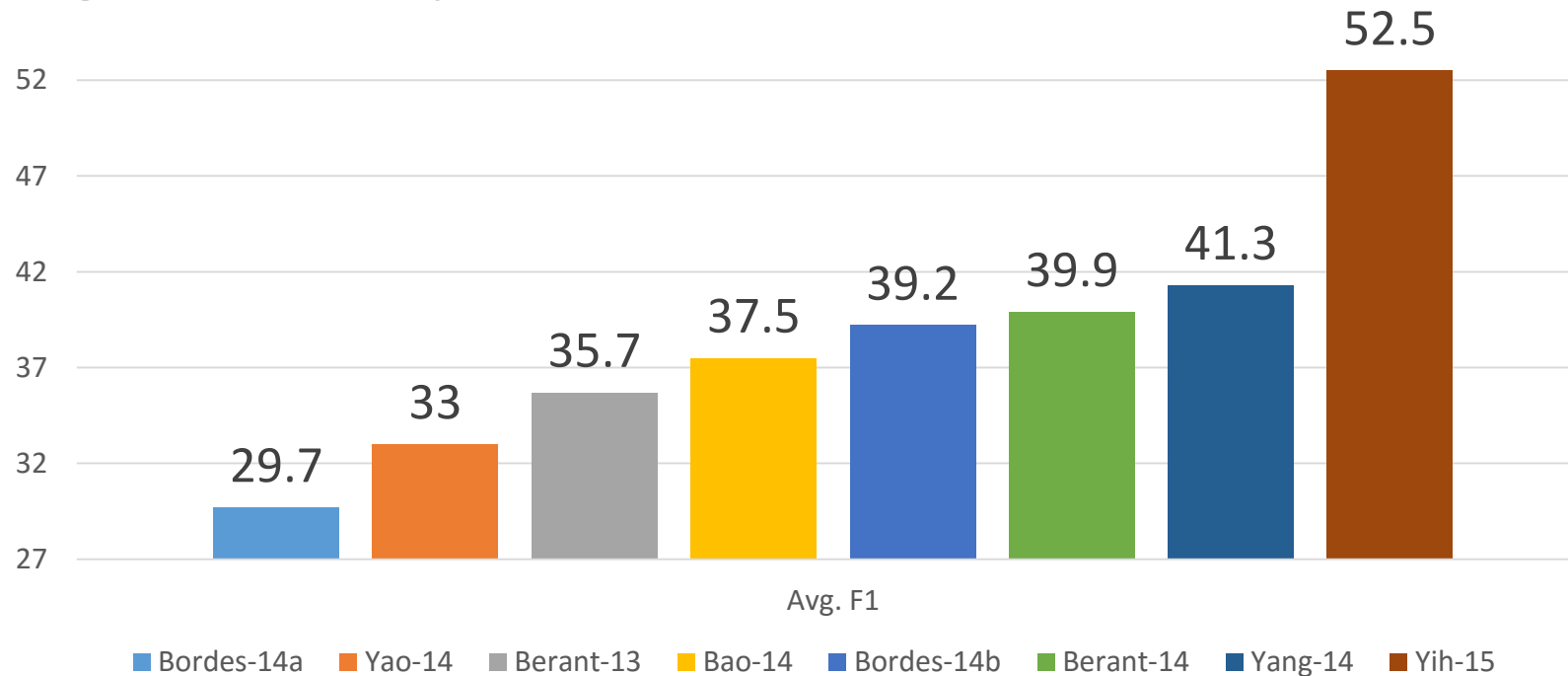
$P(\text{entity}|\text{query})$ – KB QnA



Semantic Parsing via Staged Query Graph Generation: Question Answering with Knowledge Base [Scott Yih, et al., ACL 2015]

$P(entity|query)$ – KB QnA

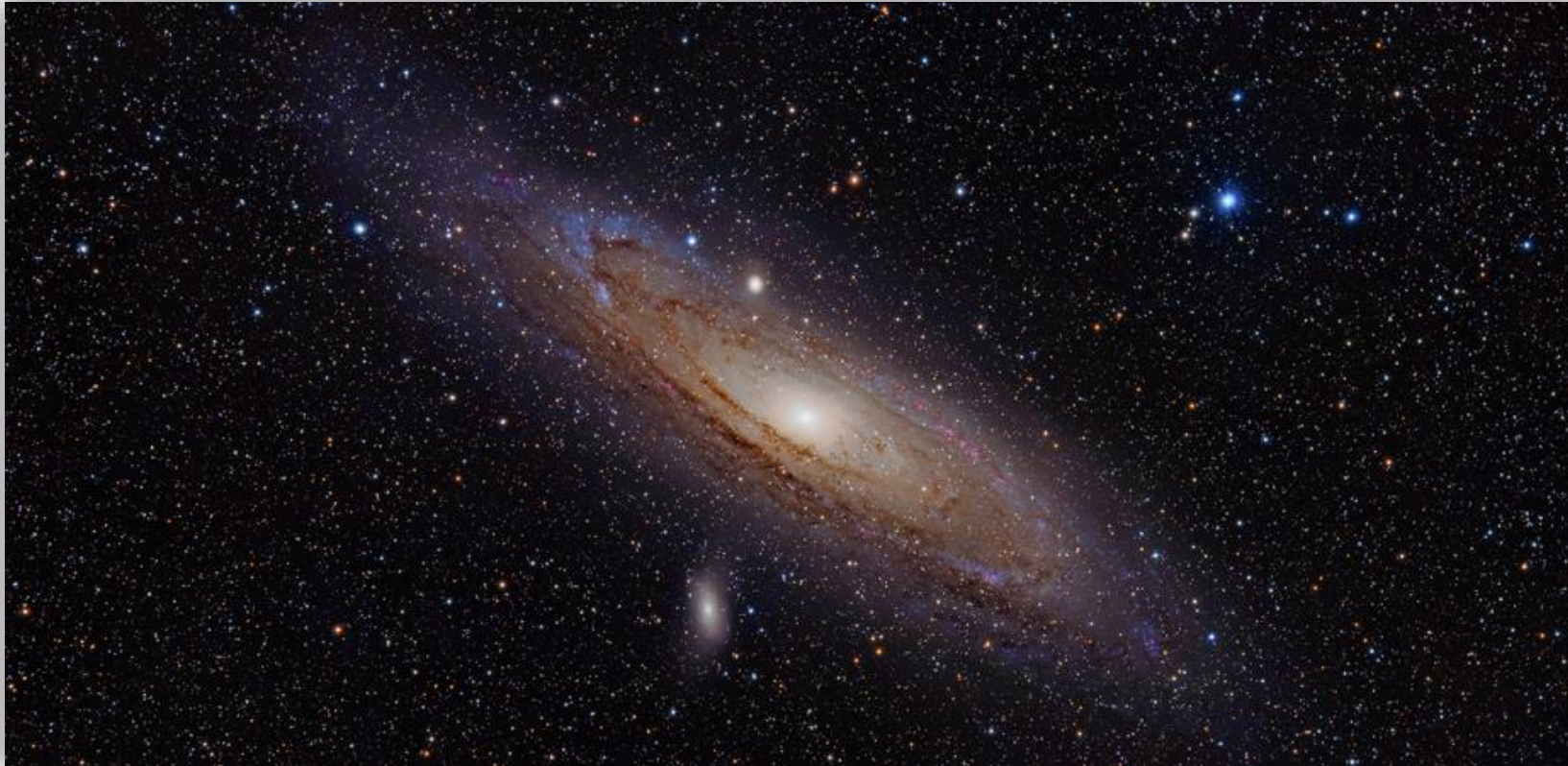
Avg. F1 (Accuracy) on WebQuestions Test Set



Semantic Parsing via Staged Query Graph Generation: Question Answering with Knowledge Base [Scott Yih, et al., ACL 2015]

$P(\text{entity}|\text{query})$ – Web QnA

- Knowledge Base is largely incomplete



$P(\text{entity}|\text{query})$ – Web QnA

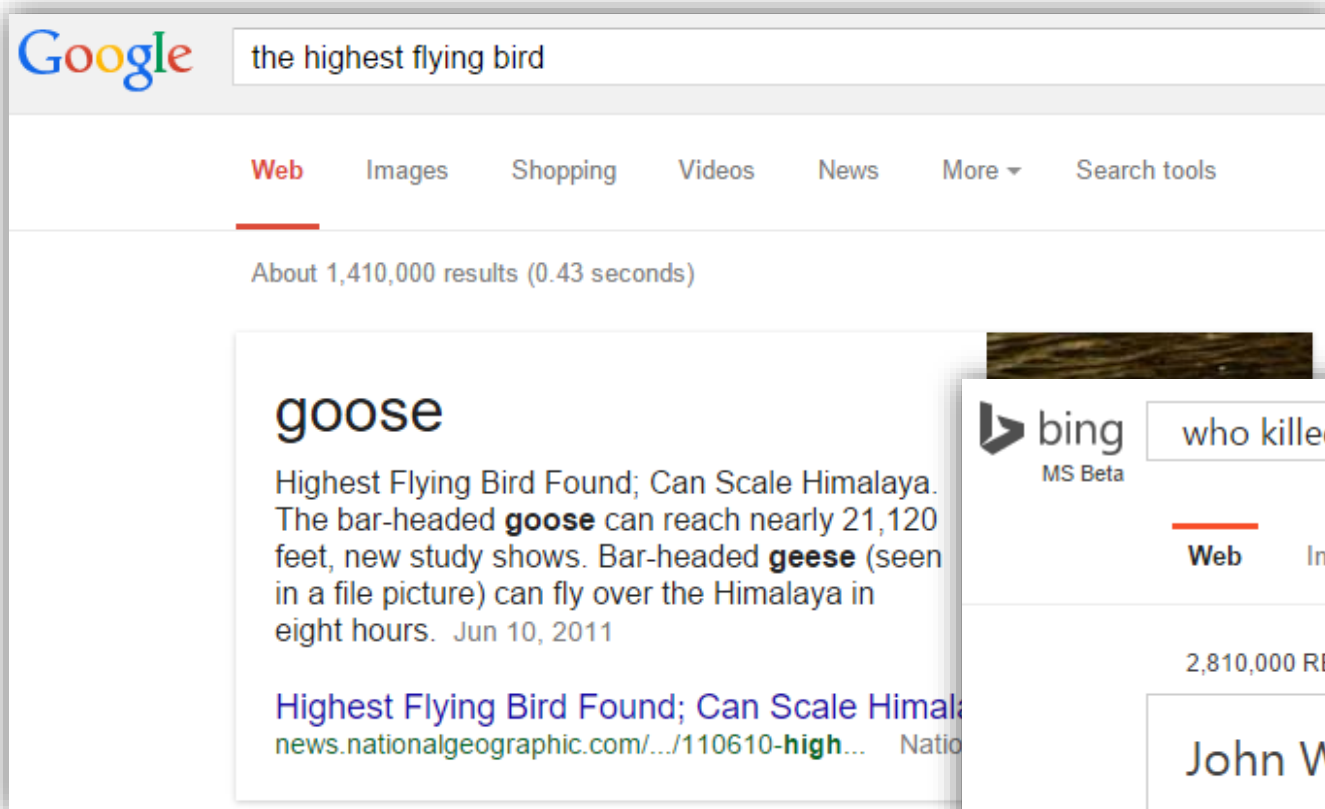
- Knowledge Base is largely incomplete



Relation	Percentage unknown	
	All 3M	Top 100K
PROFESSION	68%	24%
PLACE OF BIRTH	71%	13%
NATIONALITY	75%	21%
EDUCATION	91%	63%
SPOUSES	92%	68%
PARENTS	94%	77%
CHILDREN	94%	80%
SIBLINGS	96%	83%
ETHNICITY	99%	86%

Knowledge Base Completion via Search-Based Question Answering [Robert West, et al., WWW 2014]

$P(\text{entity}|\text{query})$ – Web QnA



Google

the highest flying bird

Web Images Shopping Videos News More Search tools

About 1,410,000 results (0.43 seconds)

goose

Highest Flying Bird Found; Can Scale Himalaya. The bar-headed **goose** can reach nearly 21,120 feet, new study shows. Bar-headed **geese** (seen in a file picture) can fly over the Himalaya in eight hours. Jun 10, 2011

[Highest Flying Bird Found; Can Scale Himalaya](https://news.nationalgeographic.com/.../110610-high...)
news.nationalgeographic.com/.../110610-high... Natio



bing MS Beta

who killed abraham lincoln

Web Images Videos Maps News More

2,810,000 RESULTS Any time

John Wilkes Booth

The assassination of Lincoln was planned and carried out by the well-known stage actor John Wilkes Booth, as part of a larger conspiracy in a bid to revive the Confederate cause.

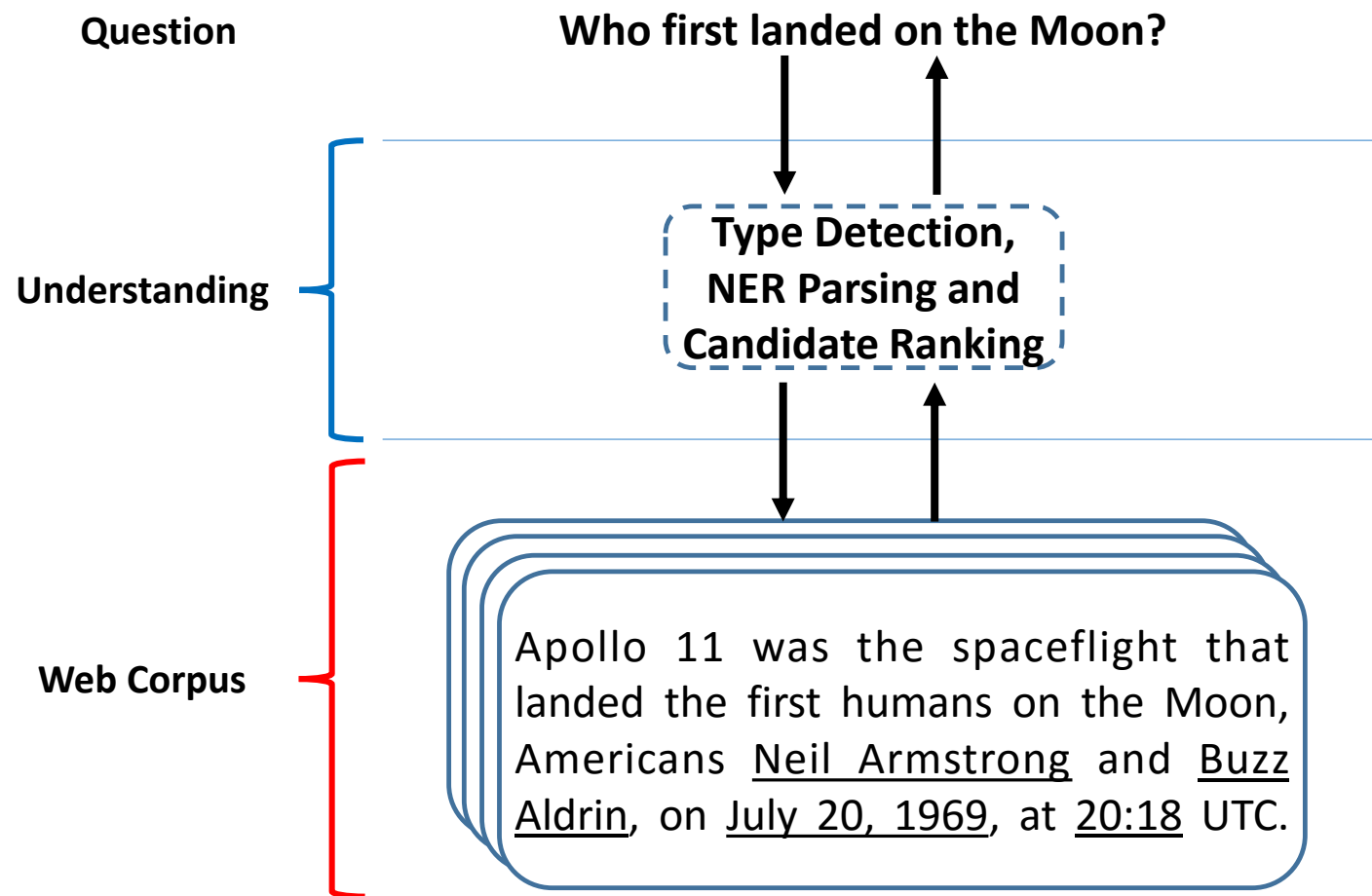
Reference: en.wikipedia.org/...sassination_of_Abraham_Lincoln Feedback

An Incomplete List of Academic Papers on Web QnA

- Dumais et al. “Web Question Answering: Is More Always Better?” SIGIR-2002.
- Brill et al. “An analysis of the AskMSR question-answering system.” EMNLP-2002.
- Chu-Carroll et al. “A multi-strategy and multi-source approach to question answering.” Technical report-2006.
- Ko et al. “A probabilistic graphical model for joint answer ranking in question answering.” SIGIR-2007.
- Schlaefer et al. “A pattern learning approach to question answering within the ephyra framework.” TSD-2006.
- Azari et al. “Web-Based Question Answering: A Decision-Making Perspective.” UAI-2003.
- Ravichandran et al. “Learning surface text patterns for a Question Answering system.” ACL-2002.
- Kwok et al. “Scaling question answering to the web.” TOIS-2001.
- Brill et al. “Data-intensive question answering.” TREC-2001.
- Bian et al. “Finding the Right Facts in the Crowd: Factoid Question Answering over Social Media.” WWW-2008.
- Cheng et al. “EntityRank: Searching Entities Directly and Holistically.” VLDB-2007.
- Lin et al. “Question answering from the web using knowledge annotation and knowledge mining techniques.” CIKM-2003.
- Chaturvedi et al. “Joint question clustering and relevance prediction for open domain non-factoid question answering.” WWW-2014

$P(\text{entity}|\text{query})$ – Web QnA

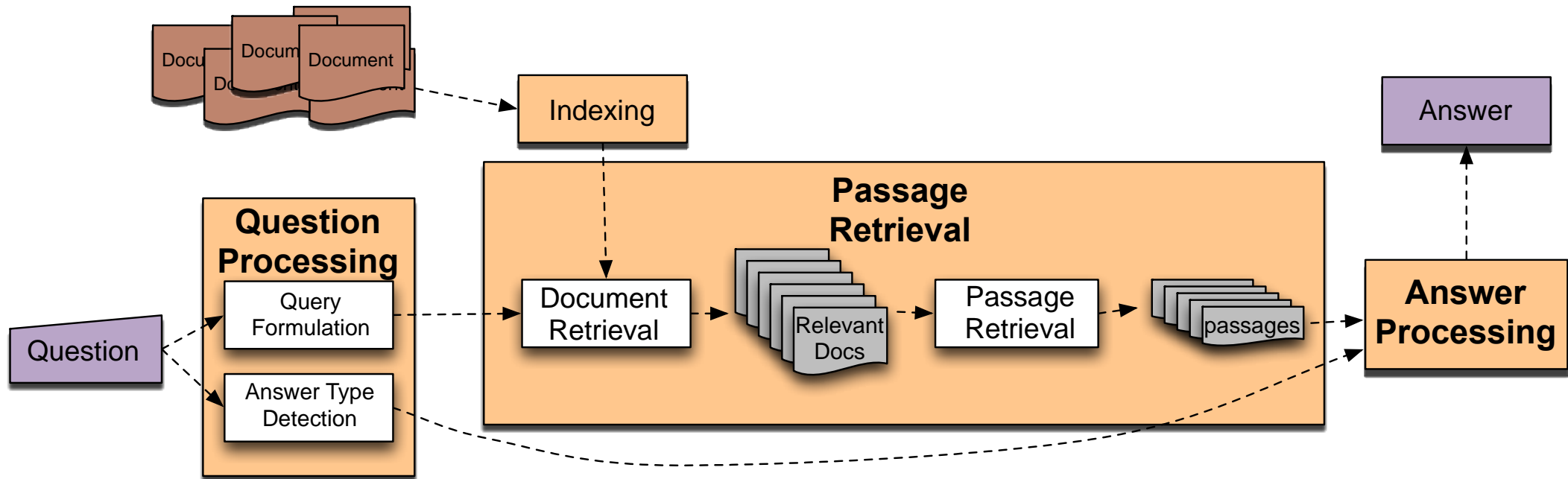
- Typical Architect of Web QnA



Open Domain Question and Answering via Semantic Enrichment [Huan Sun, et al., WWW 2015]

$P(\text{entity}|\text{query})$ – Web QnA

- Detailed Architect



Question Answering [Dan Jurafsky, Stanford]

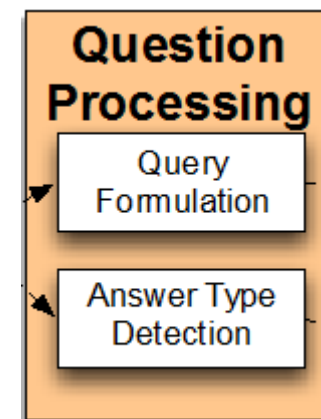
$P(\textit{entity}|\textit{query})$ – Web QnA

- QUESTION PROCESSING
 - Detect question type, answer type
 - Formulate queries to send to a search engine
- PASSAGE RETRIEVAL
 - Retrieve ranked documents
 - Break into suitable passages and rerank
- ANSWER PROCESSING
 - Extract candidate answers
 - Rank candidates

Question Answering [Dan Jurafsky, Stanford]

$P(\text{entity}|\text{query})$ – Web QnA

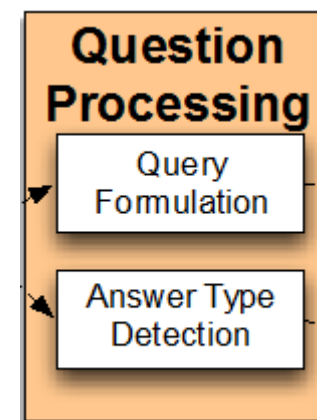
- Answer Type Detection: Name Entities
 - Who first landed on the moon?
 - Person
 - Where is the headquarters of Microsoft?
 - Location
 - What is the largest country in terms of population?
 - Country
 - **Highest flying bird**
 - **Animal/Bird**



Question Answering [Dan Jurafsky, Stanford]

$P(\text{entity}|\text{query})$ – Web QnA

- 6 coarse classes
 - ABBEVIATION, ENTITY, DESCRIPTION, HUMAN, LOCATION, NUMERIC
- 50 finer classes
 - LOCATION: city, country, mountain...
 - HUMAN: group, individual, title, description
 - ENTITY: animal, body, color, currency...

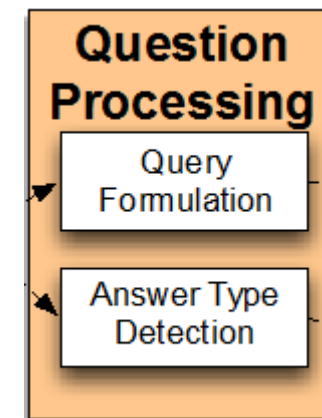
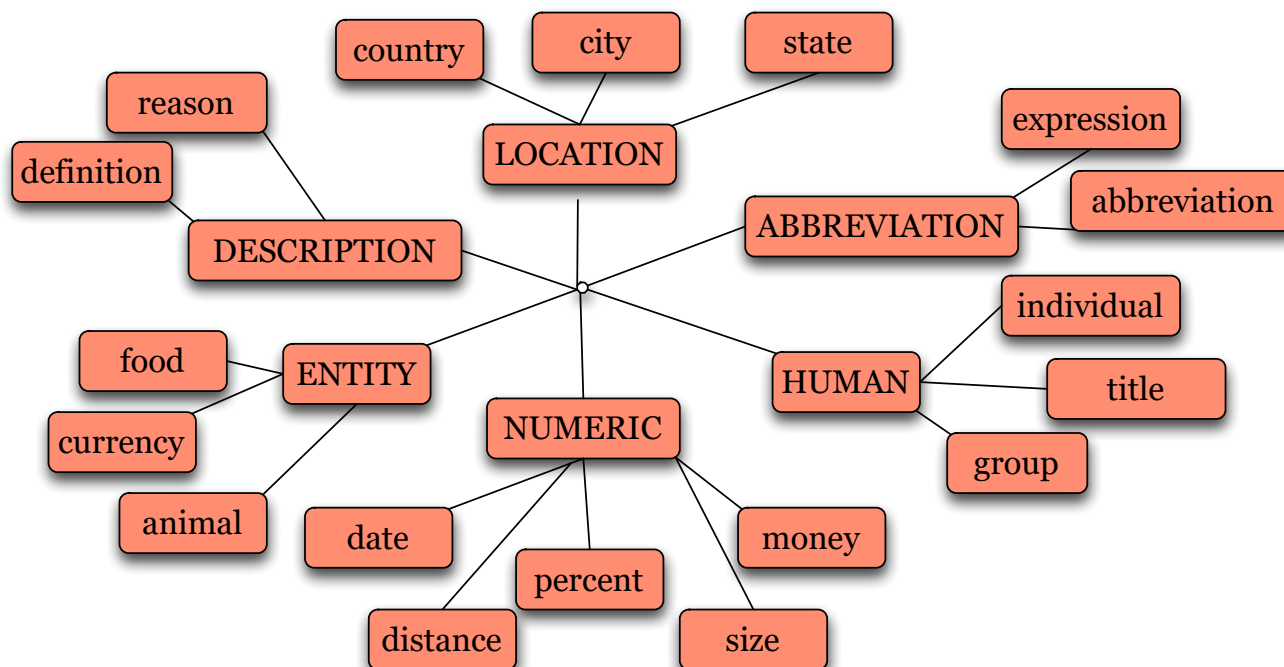


Learning Question Classifiers [Xin Li, et al., COLING 2002]

Question Answering [Dan Jurafsky, Stanford]

$P(\text{entity}|\text{query})$ – Web QnA

- Part of the Answer Type Taxonomy



Learning Question Classifiers [Xin Li, et al., COLING 2012]

Question Answering [Dan Jurafsky, Stanford]

$P(\text{entity}|\text{query})$ – Web QnA

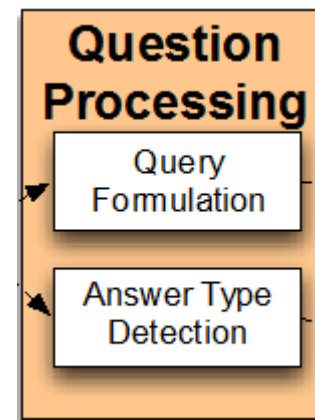
- Answer Type Detection

- Rules

- Regular expression based rules
 - Who {is|was|are|were} PERSON
 - Question headword
 - Which **city** in China has the largest number of foreign financial companies?
 - What is the state **flower** of California?

- Machine Learning

- **Define** a taxonomy of question types
 - **Annotate** training data for each question type
 - **Train** classifiers for each question class using a rich set of features: Question words and phrases; Part-of-speech tags; Parse features (headwords); Named Entities; Related words

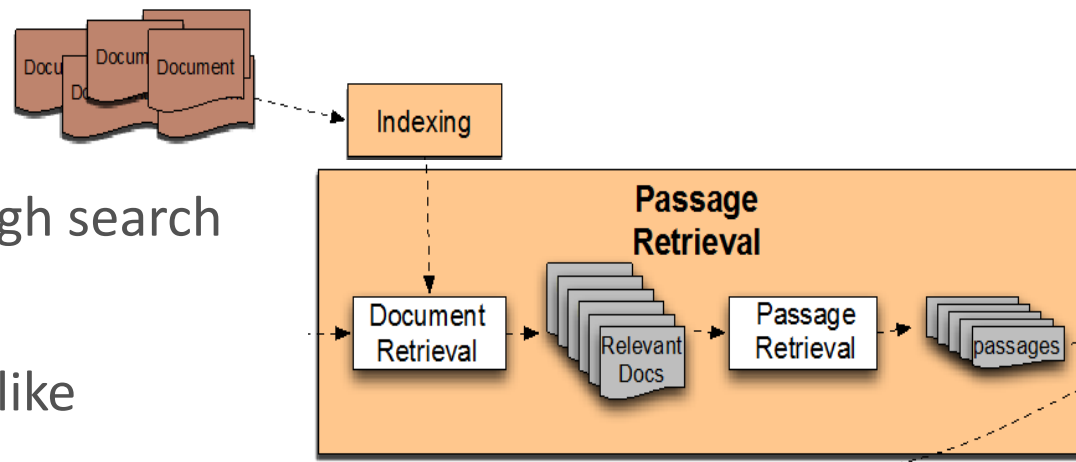


Question Answering [Dan Jurafsky, Stanford]

$P(\text{entity}|\text{query})$ – Web QnA

- Passage Retrieval

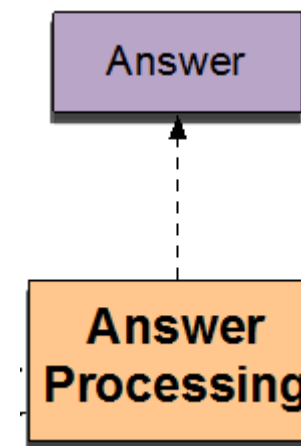
- Retrieve documents using query terms through search engines
- Segment the documents into shorter units, like paragraphs.
- Passage ranking, features
 - Number of Named Entities of the right type in passage
 - Number of query words in passage
 - Number of question N-grams also in passage
 - Proximity of query keywords to passage
 - Longest sequence of question words
 - Rank of the document containing passage
 - ...



Question Answering [Dan Jurafsky, Stanford]

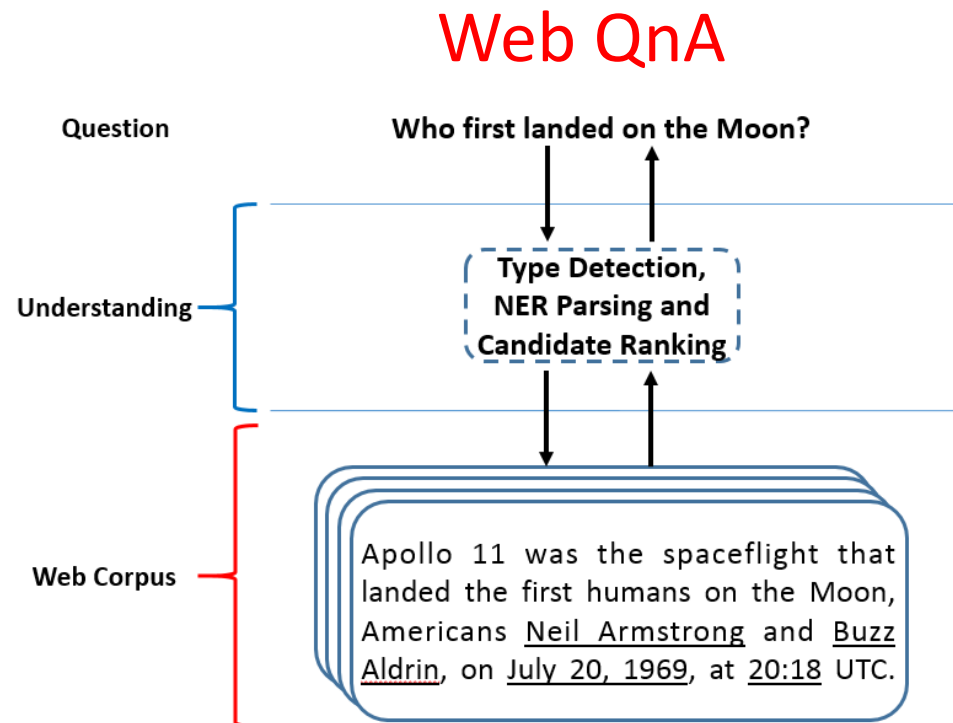
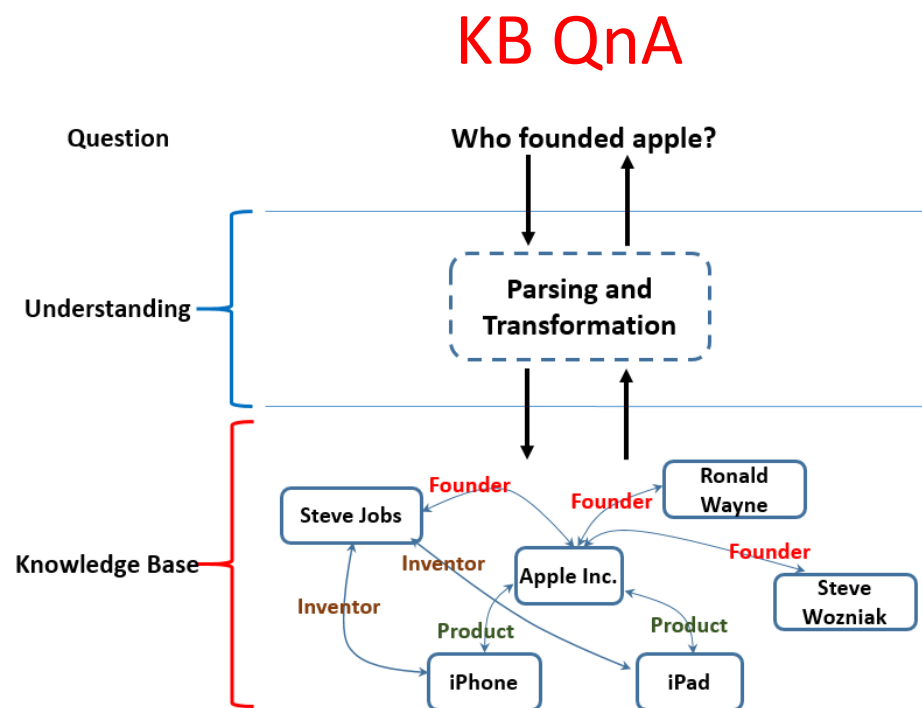
$P(\text{entity}|\text{query})$ – Web QnA

- Run an answer-type named-entity tagger on the passages
 - Each answer type requires a named-entity tagger that detects it
 - If answer type is CITY, tagger has to tag CITY
- Return the string with the right type:
 - How many bones in a human body? (**Number**)
 - The human skeleton is the internal framework of the body. It is composed of **270 bones** at birth – this total decreases to **206 bones** by adulthood after some bones have fused together.

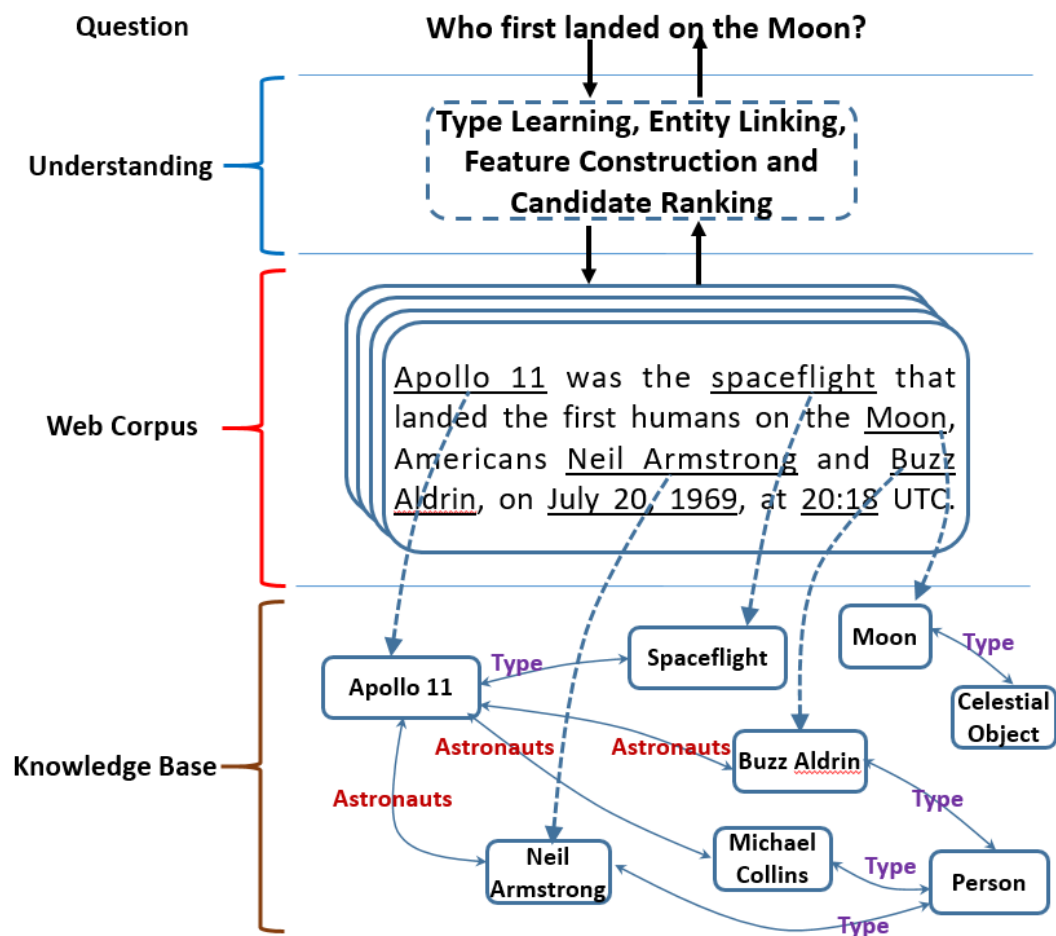


Question Answering [Dan Jurafsky, Stanford]

$P(\text{entity}|\text{query})$



$P(\text{entity}|\text{query})$ – Web-KB QnA

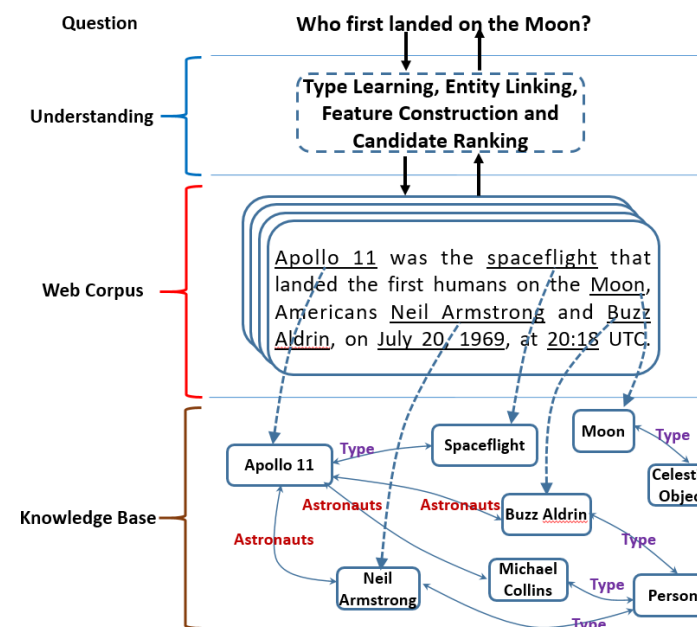


Open Domain Question and Answering via Semantic Enrichment [Huan Sun, et al., WWW 2015]

$P(\text{entity}|\text{query})$ – Web-KB QnA

- Advantages

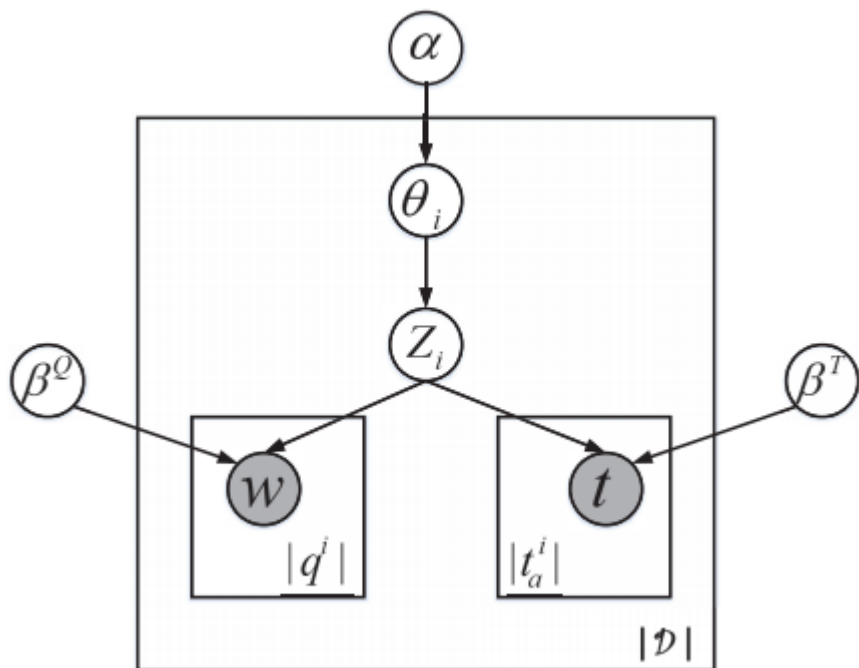
- Entity Linking: Reduce redundancy among answer candidates
- Answer candidates \longrightarrow Freebase types
- Freebase information \longrightarrow semantic features for ranking



Open Domain Question and Answering via Semantic Enrichment [Huan Sun, et al., WWW 2015]

$P(\text{entity}|\text{query})$ – Web-KB QnA

- Type detection is modeled latently



The likelihood of observing a question q and its answer types t_a as:

$$\begin{aligned}\mathcal{L} &= \prod_{i \in \mathcal{D}} P(q^i, t_a^i | \alpha, \beta^Q, \beta^T) \\ &= \prod_{i \in \mathcal{D}} \int_{\theta_i} P(\theta_i | \alpha) P(q^i, t_a^i | \theta_i, \beta^Q, \beta^T) d\theta_i\end{aligned}$$

Variational EM to optimize

$$\begin{aligned}[\log \mathcal{L}] &= \sum_{i \in \mathcal{D}} E_Q \log P(\theta_i | \alpha) + \sum_{i \in \mathcal{D}} E_Q \log P(Z_i | \theta_i) \\ &\quad + \sum_{i \in \mathcal{D}} E_Q \log P(w \in q^i, t \in t_a^i | Z_i, \beta^Q, \beta^T) \\ &\quad + H(Q(\theta, Z))\end{aligned}$$

Open Domain Question and Answering via Semantic Enrichment [Huan Sun, et al., WWW 2015]

$P(entity|query)$ – Web-KB QnA

- Experiments
 - Search Queries

	Systems	MRR	Precision	Recall	F1
	QuASE	0.6402	0.5962	0.5691	0.5823
Web QnA	AskMSR+	0.5337	0.3782	0.3760	0.3771
KB QnA	SEMPRE	0.2372	0.2646	0.1940	0.2239

Open Domain Question and Answering via Semantic Enrichment [Huan Sun, et al., WWW 2015]

Outline

- Introduction to Entity and Knowledge
- Demonstration of Microsoft's Entity Experience
- Entity Recommendation and Understanding
 - $P(\textit{entity}|\textit{entity})$
 - $P(\textit{entity}|\textit{user})$
 - $P(\textit{entity}|\textit{query})$
- **Summary**

Summary

Entity Recommendation & Understanding Taxonomy

- $P(\text{entity}|\text{entity})$ - Recommendations given an entity
 - Co-occurrence
 - Similarity
 - Entity Linking
 - Interpretation
- $P(\text{entity}|\text{user})$ - Recommendations given a user
 - Universal Recommender System
 - $P(\text{entity}|\text{user}, \text{item})$
 - $P(\text{entity}|\text{user}, \text{query})$
- $P(\text{entity}|\text{query})$ - Recommendations given a query
 - Entity Retrieval/Finding
 - Knowledge Base Question and Answering
 - Web Question and Answering

Challenges

- Entity Understanding
 - Ranking, KB completion, Entity Triggering ($P(query|entity)$), ...
- User Understanding
 - Users' Entity Preference, Interest Drift, Multiple Sources (query, url click, entity pane click), ...
- Query Understanding
 - Query Intent (definition, list, factoid, question, etc.), Question Type, ...
- Document Understanding
 - Entity Linking, NER, Event Detection, ...

Challenges

- Query Entity Linking
 - Short and noisy
 - When a user types “Florence”, which one to link?
 - Utilize user location
 - Utilize previous queries in the same session

Personalized Entity
Linking System



See results for

Florence
Oregon
Florence is a city in Lane County, Oregon, United States. As of the 2010 census, the city had a total pop...

Florence
South Carolina
Florence is a city located in Florence County, South Carolina, United States. The city is the county seat of ...

Florence
Kentucky
Florence is a home rule-class city in Boone County, Kentucky, in the United States. Florence is part of the ...

Florence
New Jersey
Florence Township is a township in Burlington County, New Jersey, United States. As of the 2010 United Stat...

Florence
Arizona
Florence is a town in and the county seat of Pinal County, Arizona, United States. The population was 25...

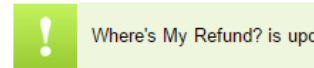
Florence
City
Florence is the capital c province of Florence. It approximately 380,000 i metropolitan area.
en.wikipedia.org
Local time: 9:12 PM 4/
Population: 370,092 (2
Area: 39.54 sq miles (1
Explore area: Florence
Travel tip: Everyone's I
Colleges and universit
Belle Arti di Firenze · E
italiana +

Challenges

- Question Understanding
 - Rules are not always correct
 - “where is my refund”
 - location?
 - When and how to get refund
 - “when a cat loves a dog”
 - Date Time?
 - TV series



Where's My Refund?



Get up-to-date refund information using the tool more than once every 24 hours, usually only once. You should only call if it has been longer.



When to check status...

- Within 24 hours after we've received your e-filed tax return
- 4 weeks after you mail your paper return
- "Where's My Refund?" is updated more than once every 24 hours

When a Dog Loves a Cat



When a Dog Loves a Cat is a TVB modern drama series broadcast in July 2008. Miu Chun was once diagnosed with cancer, and became really depressed. Cheung Ka-Ka, a nurse, comforted him and later became his girlfriend. Soon after he ... +

en.wikipedia.org

First episode: Jul 21, 2008

Last episode: Aug 15, 2008

Number of episodes: 20

Episode duration: 45 minutes

Network: TVB

Origin: Hong Kong

Cast



Myolie Wu
Chow Chi-yu



Raymond Wong



Gallen Lo

People also search for

[See all \(10+\)](#)



Wars of In-Laws II



A Journey Called Life



Forensic Heroes II



The Four



Moonlight Resonance

Challenges

- Question and Answering
 - TREC data - Web QnA
 - WebQuestions data – KB QnA
 - All the question in these research datasets are real and valid questions
 - Who first landed on the moon
 - Who killed Abraham Lincoln
 - Real world scenario
 - When is the end of the world
 - Who won the world cup 2017
 - A data set contains both valid and invalid questions
 - Make sure the algorithms won't return answers for invalid questions

The ancient Mayans predicted the world would end on **December 21, 2012**. Or rather, those interpreting the Mayan calendar – which ran out on **December 21** – guessed it ran out then as there was no world beyond this last day. Aug 18, 2014

[Our days are numbered: 7 end of world predictions you've ...
www.mirror.co.uk/news/weird.../days-numbered-7-end-world-4069965](http://www.mirror.co.uk/news/weird.../days-numbered-7-end-world-4069965)

Related Tutorials

- Entity Linking and Retrieval (Meij, Balog and Odijk)
 - <http://ejmeij.github.io/entity-linking-and-retrieval-tutorial/>
- Entity Resolution (Getoor and Machanavajjhala)
 - http://www.umiacs.umd.edu/~getoor/Tutorials/ER_VLDB2012.pdf
- Constructing and Mining Web-scale Knowledge Graphs tutorial (Bordes, Gabrilovich)
 - <http://www.cs.technion.ac.il/~gabr/publications/papers/KDD14-T2-Bordes-Gabrilovich.pdf>
- The Recommender Problem Revisited (Amatriain, Mobasher)
 - <http://www.slideshare.net/xamat/kdd-2014-tutorial-the-recommender-problem-revisited>
- Question Answering Lecture (Jurafsky)
 - <https://web.stanford.edu/class/cs124/lec/qa.pdf>

Thanks!

Hao Ma: haoma at Microsoft.com

Yan Ke: yanke at Microsoft.com