



max planck institut
informatik

What Computers Know, Should Know, and Shouldn't Know

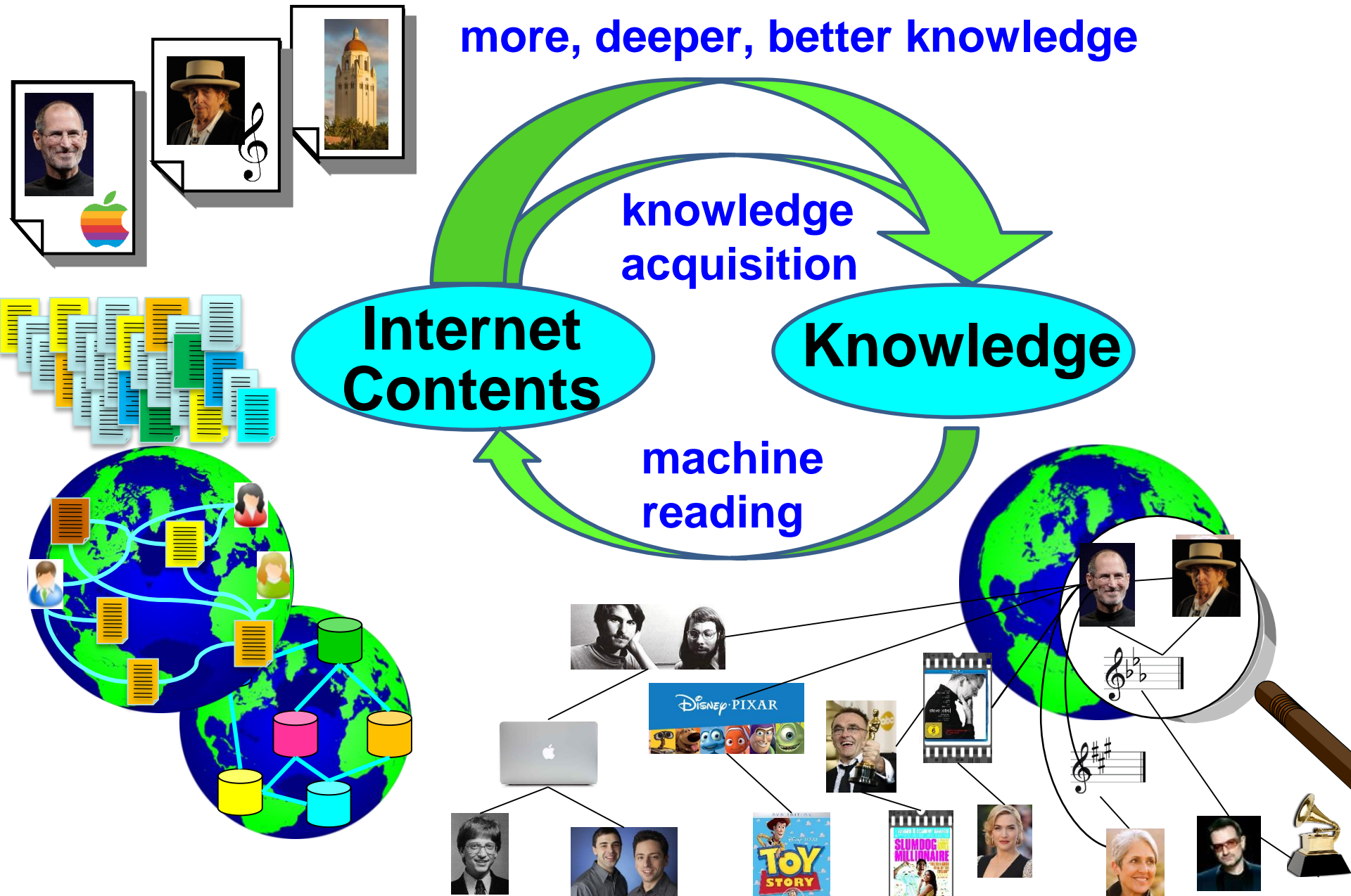
Gerhard Weikum

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<http://mpi-inf.mpg.de/~weikum>

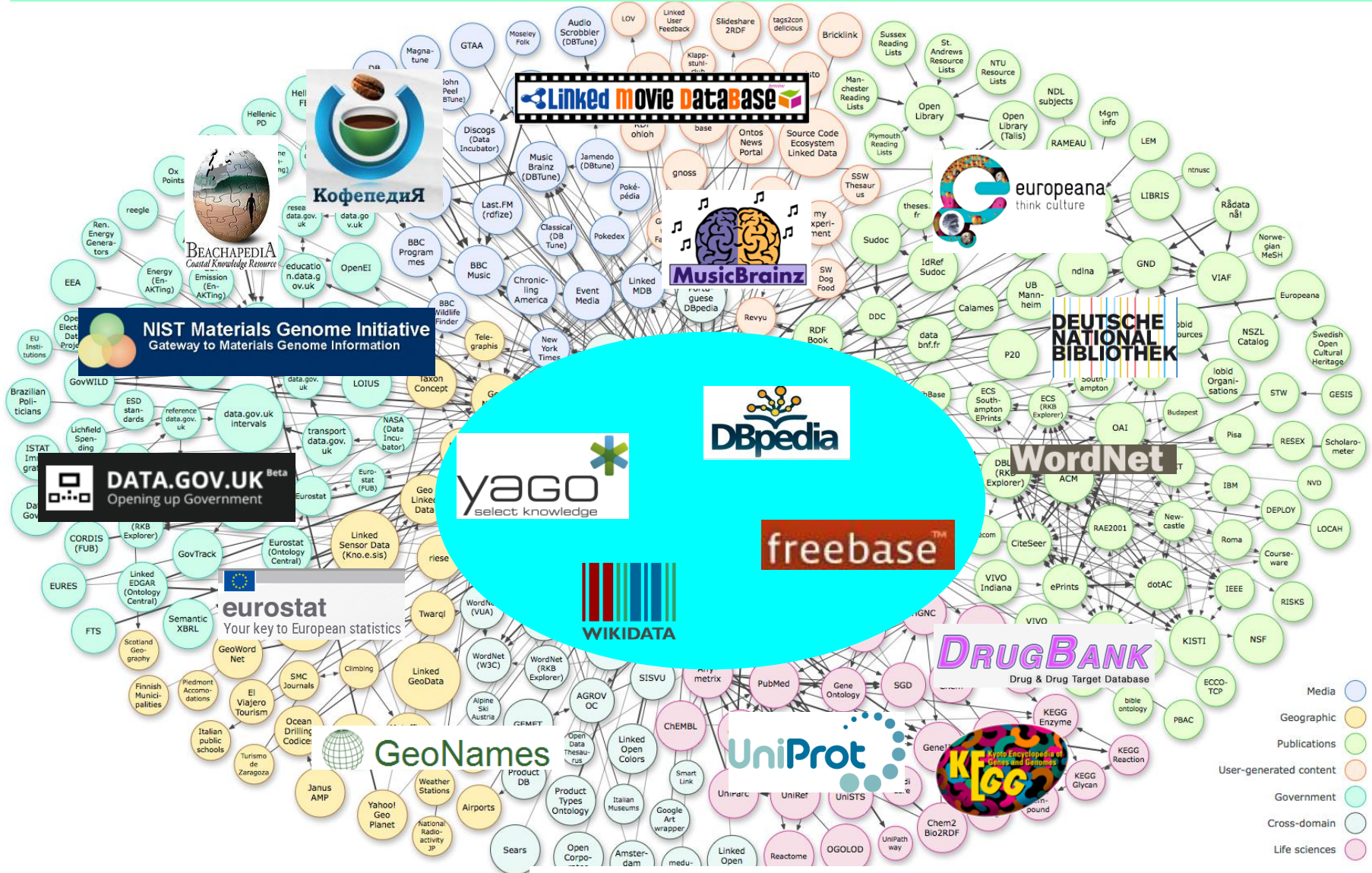
Turn Text & Data into Knowledge

more, deeper, better knowledge



Web of Knowledge and Open Data

> 100 Billion subject-predicate-object facts from > 1000 sources



Web of Knowledge and Open Data

- 10M entities in 350K types
- 200M facts
- 100 languages
- >95% accuracy

yAGO
select knowledge

- 5M entities in 250 types
- 500M facts for 6000 relations

DBpedia

- 600M entities
- 20B facts

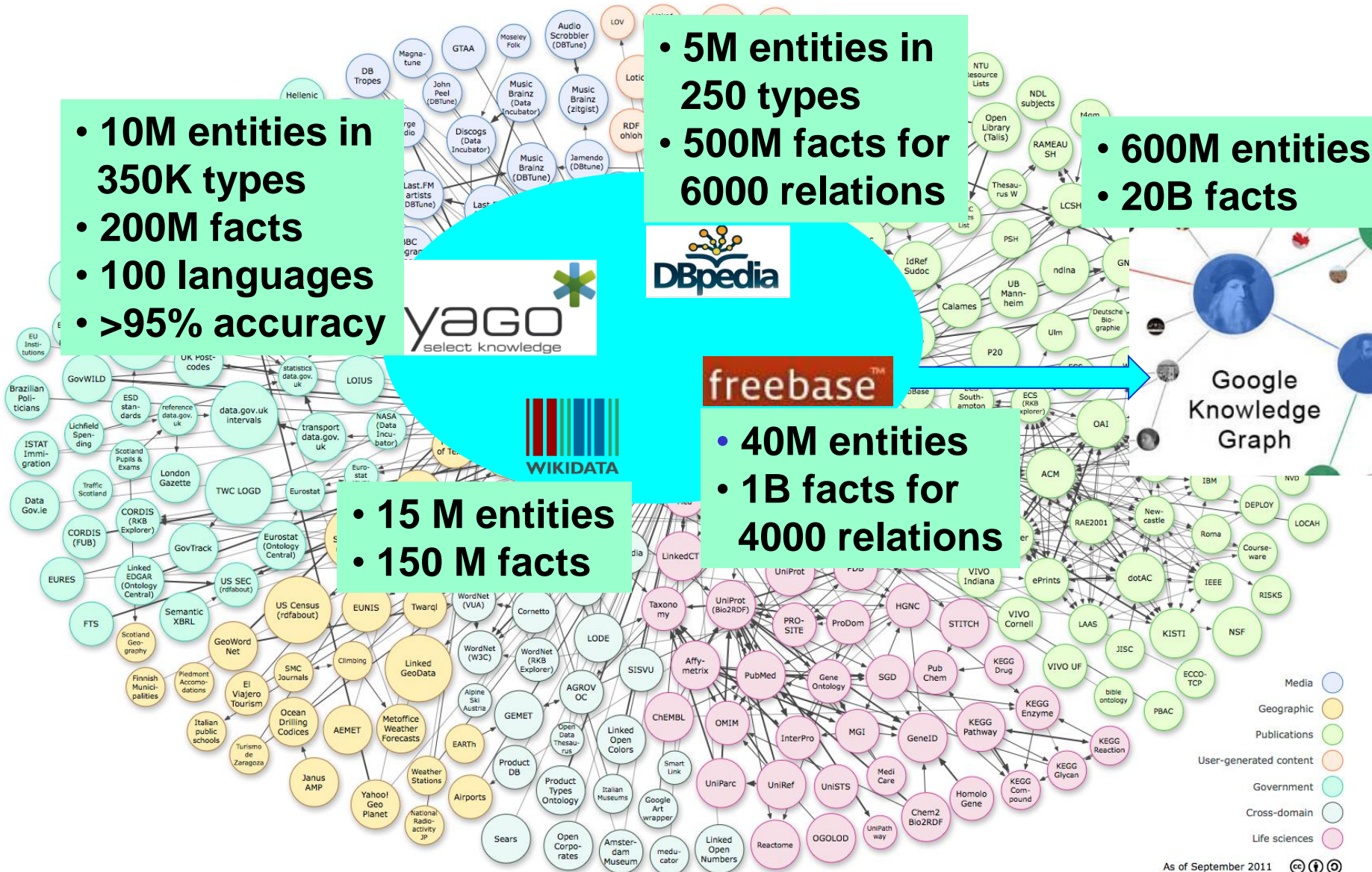
freebase™

- 15 M entities
- 150 M facts

WIKIDATA

- 40M entities
- 1B facts for 4000 relations

Google
Knowledge
Graph



Web of Knowledge

> 100 Billion **subject-predicate-object** facts from > 1000 sources

predicate (**subject**, **object**)



type (SteveJobs, entrepreneur)
type (SteveJobs, computer architect)
subtypeOf (entrepreneur, businessperson)

hasFounded (SteveJobs, Apple)
hasDaughter (SteveJobs, LisaBrennan)
namedAfter (AppleLisa, LisaBrennan)
diedOf (SteveJobs, pancreatic cancer)

hasSymptom (pancreatic cancer, jaundice)
treats (ErlotinibHydrochloride, pancreatic cancer)

taxonomic knowledge

factual knowledge

domain expert knowledge

Knowledge for Intelligent Applications

Enabling technology for:

- **disambiguation**
in written & spoken natural language
- **deep reasoning**
(e.g. QA to win quiz game)
- **machine reading**
(e.g. to summarize book or corpus)
- **semantic search**
in terms of entities&relations (not keywords&pages)
- **smart recommendations**
for business and leisure (via smartphone)
- **entity-level linkage**
for Big Data & Deep Text: cleaning, integration, analytics

Machine Knowledge for Answer Engines

**Precise and concise answers
for advanced information needs:**



properties of entity

★ **Nobel laureate who outlived two world wars and all his children?**

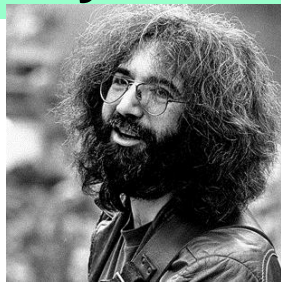
sets of entities

★ **Politicians who are also scientists?**



relationships between entities

★ **Commonalities & relationships among:
Steve Jobs, Jerry Garcia, John Muir, Wyatt Earp?**



Machine Knowledge for Answer Engines

**Precise and concise answers
for advanced information needs:**

real applications

- ★ **Proteins that bind to the Zika virus?**
- Antidepressants that interfere with thyroid drugs?**
- Polymer materials for super-capacitators?**
- German philosophers influenced by William of Ockham?**
- Green politicians mentioned in Panama Papers?**

Outline

✓ **Introduction**

★ **What Computers Know**

★ **What Computers Should Know**

★ **What Computers Shouldn't Know**

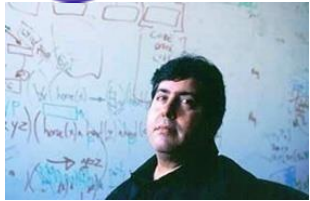
★ **Conclusion**

History of Digital Knowledge Bases



Cyc

WordNet



from humans
for humans

guitarist \subset
 {player, musician}
 \subset artist
 {player, footballer}
 \subset athlete

Wikipedia



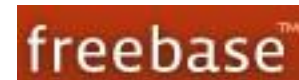
5 Mio. English articles
 20 Mio. contributors

$\forall x: \text{human}(x) \Rightarrow$
 $(\exists y: \text{mother}(x, y) \wedge$
 $\exists z: \text{father}(x, z))$

$\forall x, u, w: (\text{mother}(x, u) \wedge$
 $\text{mother}(x, w)$
 $\Rightarrow u=w)$

from algorithms
for machines

WolframAlpha



SIEMENS
Ingenuity for Life

Walmart



1985

1990

2000

2005

2010

Pattern-based Harvesting: Fact-Pattern Duality

Task populate relation *composed*
starting with *seed facts*

[Brin 1998, Etzioni 2004,
Agichtein/Gravano 2000]

Facts & Fact Candidates

(Dylan, Knockin)

(Gerrard, Now)

(Dylan, Hurricane)

(Morricone, Ecstasy)

(Zappa, Godfather)

(Austen, Pride&Prejudice)

(Gabriel, Biko)

(Puebla, CheGuevara)

(Jobs, Apple)

(Newton, Gravity)

Patterns

X wrote the song Y

X wrote ... including Y

X covered the story of Y

X has favorite movie Y

X is famous for Y

...

- good for **recall**
- noisy, drifting
- **not robust** enough
for high precision

KB from Open Information Extraction

Output examples:

„Morricone“	„wrote“	„Ecstasy of Gold“
„Morricone“	„wrote score for“	„Revenant“
„Morricone’s music“	„appeared in“	„For a Few Dollars More“
„the maestro’s music“	„used in“	„many westerns“
„Lisa’s voice“	„adds to the mood of“	„Ridley Scott’s Gladiator“
„Dylan“	„first success was“	„Blowin’ in the Wind“
„Dylan’s hit“	„played in“	„Forest Gump“
„everybody“	„knows“	„Blowin’ in the Wind“
„everybody“	„makes“	„mistakes“

Lessons learned:

- **High recall**, **low precision**
- **Good enough** for certain (search) applications
- **Easy** to deploy, run and scale
- **Lack of canonicalization** induces **big noise** (ignorance on homonymy & synonymy)

Constrained Reasoning for Logical Consistency

[Suchanek 2009, Nakashole 2011]

Use **knowledge** (consistency constraints)
for joint reasoning on hypotheses
and pruning of false candidates

Hypotheses:

composed (Dylan, Hurricane)
composed (Morricone, Ecstasy)
~~composed (Zappa, Godfather)~~
composed (Rota, Godfather)
composed (Gabriel, Biko)
~~composed (Austen, Pride&Prejudice)~~
~~composed (Jobs, Apple)~~
~~composed (Newton, Gravity)~~

Constraints:

$\forall x, y: \text{composed}(x, y) \Rightarrow \text{type}(x) = \text{musician}$
 $\forall x, y: \text{composed}(x, y) \Rightarrow \text{type}(y) = \text{song}$
 $\forall x, y, w: \text{composed}(x, y) \wedge \text{composed}(w, y) \Rightarrow x = w$
 $\forall x, y, t, b, e: \text{composed}(x, y) \wedge \text{composedInYear}(y, t) \wedge$
 $\text{bornInYear}(x, b) \wedge \text{diedInYear}(x, e) \Rightarrow b < t \leq e$
 $\forall x, y: \text{sings}(x, y) \wedge \text{type}(x, \text{singer-songwriter}) \Rightarrow \text{composed}(x, y)$

consistent subset(s) of hypotheses (“possible world(s)“, “truth“)
→ **Weighted MaxSat** solver for set of logical clauses
→ max posterior (MAP) for **prob. factor graph** (MLN, PSL ...)

KB from Model-based Information Extraction

Output examples:

Ennio_Morricone

Ennio_Morricone

„Morricone’s music“

„the maestro’s music“

Lisa_Gerrard

Bob_Dylan

„Dylan’s hit“

„everybody“

„everybody“

composed

composed_score

„appeared in“

„used in“

composed_score

composed

„played in“

„knows“

„makes“

Ecstasy_of_Gold

The_Revenant

„For a Few Dollars More“

„many westerns“

Gladiator

Blowin’_in_the_Wind

„Forest Gump“

„Blowin’ in the Wind“

„mistakes“

Lessons learned:

- High precision, lower recall
- Model specification (constraints) requires modest effort
- Canonicalization of entities (S,O) has great value
- Canonicalization of predicates (P) limits coverage

Challenges: Open-Ended KB & KB Curation

- Integrate Open IE and Model-based IE for **Open-Ended KB construction**
- Fill gaps by techniques for **KB completion**:
 - mine rules and apply them
 - compute latent factors from KB tensor and infer missing facts
- Understand and manage **KB Life-Cycle**
 - **corroborate** dubious facts, **curate** spurious facts
 - **ingest** emerging facts, **invalidate** outdated facts
 - **self-reflect** on **KB gaps** and inaccuracies (missing predicates ...)

Missing on Predicates & Salient Facts

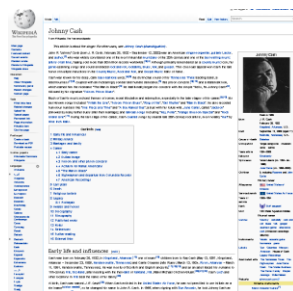
Which **salient facts** about an entity are in Wikipedia infobox?

Johnny Cash



Cash in 1955

Born	J. R. Cash February 26, 1932 Kingsland, Arkansas, U.S.
Died	September 12, 2003 (aged 71) Nashville, Tennessee, U.S.
Cause of death	Diabetes mellitus
Occupation	Singer-songwriter, actor
Years active	1954–2003
Spouse(s)	Vivian Liberto (m. 1954; div. 1966) June Carter (m. 1968–2003; her death)
Children	Rosanne (1955–) Carlene (1955–) Kathy (1956–) Rosie (1958–2003) Cindy (1959–) Tara (1961–) John (1970–)



Military career	
Allegiance	 United States of America
Service/branch	 United States Air Force
Years of service	1950–1954
Rank	 Staff sergeant
Musical career	
Genres	Country, rockabilly, ^[1] rock and roll, gospel
Instruments	Vocals, guitar
Labels	Sun, Columbia, Mercury, American, House of Cash, Legacy Recordings
Associated acts	The Tennessee Three, The Highwaymen, June Carter Cash, The Statler Brothers, The Carter Family , Waylon Jennings
Website	johnnycash.com

Notable instruments

Martin Acoustic Guitars^[2]

romanticRelationship
(Johnny Cash,
JuneCarter, 1961-2003)
featuredInMovie
(romanticRelationship(...),
WalkTheLine))

playedConcertAtLocation
(JohnnyCash,
SanQuentinStatePrison)

covered (JohnnyCash,
One by U2)

covered (JohnnyCash,
MercySeat by NickCave)

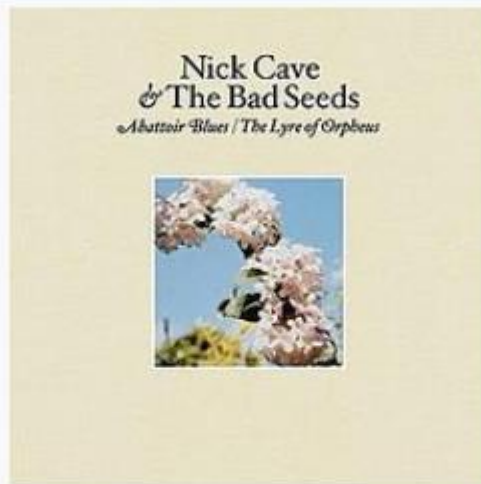
.....

not in any KB !

Missing on Predicates & Salient Facts

Which **salient facts** about an entity are in Wikipedia infobox?

Abattoir Blues / The Lyre of Orpheus



Studio album by Nick Cave and the Bad Seeds

Released 20 September 2004
Recorded March–April 2004 at Studio Ferber in Paris, France
Genre Alternative rock
Length 82:30
Label Mute
Producer Nick Launay

Nick Cave and the Bad Seeds chronology

<i>Nocturama</i> (2003)	<i>Abattoir Blues / The Lyre of Orpheus</i> (2004)	<i>B-Sides & Rarities</i> (2005)
----------------------------	---	---

Singles from *Abattoir Blues / The Lyre of Orpheus*

- "Nature Boy"
Released: 6 September 2004
- "Breathless / There She Goes, My Beautiful World"
Released: 15 November 2004
- "Get Ready for Love"
Released: 14 March 2005

isOnAlbum

(Let the Bells Ring, AbbatoirBlues)

lyricsAbout

(Let the Bells Ring, JohnnyCash)

isOnAlbum

(O'Children, AbbatoirBlues)

playedInMovie

(O'Children, HarryPotter 6)

not in any KB !

Outline

- ✓ **Introduction**
- ✓ **What Computers Know**
- ★ **What Computers Should Know**
- ★ **What Computers Shouldn't Know**
- ★ **Conclusion**

Spectrum of Digital Knowledge (1): School Education for Computers

taxonomic knowledge:

type (SteveJobs, entrepreneur), **subtypeOf** (entrepreneur, businessperson)

type (SteveJobs, inventor), **subtypeOf** (inventor, human)

type (SteveJobs, YogaPractitioner), **type** (SteveJobs, GratefulDeadFan)

long-tail
classes

factual knowledge:

hasFounded (SteveJobs, Apple), **CEO** (SteveJobs, Apple)

long-tail entities

hasDaughter (SteveJobs, LisaBrennan), **namedAfter** (AppleLisa, LisaBrennan)

hasFavoriteSong (SteveJobs, Imagine), **hasFavoriteSong** (SteveJobs, Truckin')

dated (SteveJobs, JoanBaez), **admired** (SteveJobs, BobDylan)

composed (JoanBaez, Diamonds&Rust), **lyricsAbout** (Diamonds&Rust, BobDylan)

sangAt (JoanBaez, memorialForSteveJobs)

long-tail relations

spatial & temporal knowledge:

diedOn (SteveJobs, 5-Oct-2011), **diedIn** (SteveJobs, Palo Alto)

happened (**hasFounded** (SteveJobs, Apple), Cupertino, 1976)

validDuring (**CEO** (SteveJobs, Apple), 1997-2011)

Spectrum of Digital Knowledge (2): Kindergarten and University

commonsense properties:

property (lemon, yellow), **property** (lemon, juicy), **property** (lemon, sour),
ability (fish, swim), **ability** (human, speak), **usedFor** (classroom, teaching),
maxHeight (human, 2.5 m), **maxLength** (snake, 10 m)

commonsense rules:

$\forall x: \text{human}(x) \Rightarrow (\exists y \text{ mother}(x,y)) \wedge (\exists z \text{ father}(x,z))$

$\forall x, y, z \text{ mother}(x,y) \wedge \text{mother}(x,z) \Rightarrow y = z$

domain-specific expert knowledge:

type (Ubiquinone-8, coenzyme), **expresses** (COQ8, Ubiquinone-8)
causes (lack of Ubiquinone-8, mitochondrial disorder)

Spectrum of Digital Knowledge (3): Grounded in Data

terminological knowledge:

means (“Apple“, AppleComputerCorp), **means** (“Big Apple“, NewYorkCity)
means (“Woz“, SteveWozniak), **means** (“Woz“, WizardOfOz)
means („MPG“, milesPerGallon), **means** („MPG“, Max-Planck-Gesellschaft)
means („rock“, big stone), **means** („rock“, rock music)

emerging knowledge:

happenedOn (ElectionOfMayorOfRome, 19-June-2016)

type (VirginiaRaggi, politician), **ho**
type (Brexit, event), **type** (Bregret,

visual knowledge:

<http://www.image-net.org>

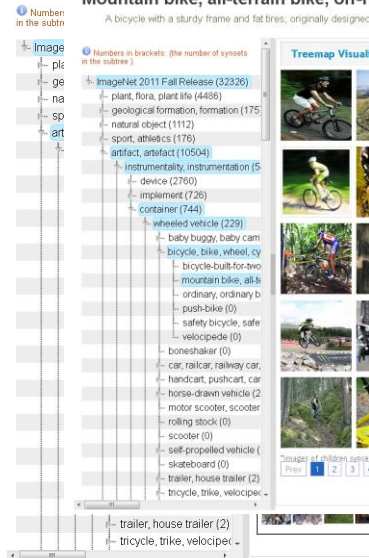
bikes → mountain bikes
entrepreneurs

Bicycle, bike, wheel, cycle

A wheeled vehicle that has two wheels and is moved by foot ped

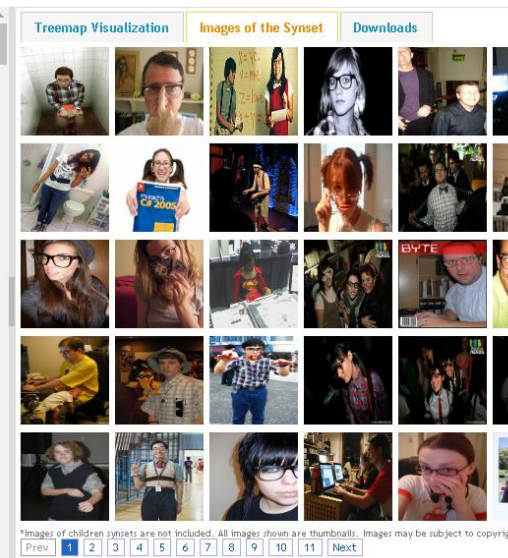
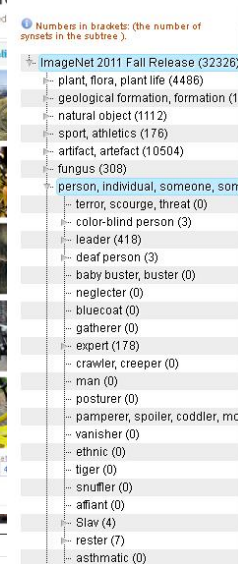
Mountain bike, all-terrain bike, off-r

A bicycle with a sturdy frame and fat tires, originally designed



Swot, grind, nerd, wonk, dweeb

An insignificant student who is ridiculed as being affected or boringly studious



*Images of children synsets are not included. All images shown are thumbnails. Images may be subject to copyright.

Spectrum of Digital Knowledge (4): Learned in Life

socio-cultural and social knowledge:

invented (computer, Eckert and Mauchley, USA),

invented (computer, KonradZuse, Germany),

invented (computer, AlanTuring, UK), **invented** (computer, SteveJobs, young nerds)

drink (beer, Germany), **drink** (wine, California), **drink** (lassi, India)

alleviates (ice, bruises), **alleviates** (eucalyptusOil, sinusitis)

belief knowledge:

believe (Ptolemy, **center** (world,earth), **believe** (Galileo, **center** (world, sun))

believe (ChinesePeople, **badLuckNumber** (4))

believe (AustralianAborigines, **taboo** (photosOfDeadPeople))

process knowledge:

type (changeTire, mechanicalTask)

subtask (changeTire, loosenBolts), **subtask** (changeTire, liftCar),

requires (loosenBolts, spiderWrench), **requires** (liftCar, jack)

precedes (loosenBolts, liftCar)

Knowledge Gaps

Temporal and Spatial Knowledge

Long-Tail Knowledge (on types and entities)

Dynamic Knowledge (events, emerging entities)

Open-Ended Knowledge (relation types)

On-the-Fly Knowledge

Visual Knowledge (on types and long-tail entities)

Cultural Knowledge

Commonsense Knowledge

Social Knowledge

Intensional Knowledge

Negative Knowledge

Open-Ended Relation Types

**Comprehensive repository of binary (and n-ary) predicates
(with type signatures and paraphrases)**

Early work:

- **WordNet** (Miller/Fellbaum), **VerbNet** (Palmer et al.)
- **DIRT** (Lin/Pantel: KDD'01)

Recent work:

- **PATTY** (Nakashole et al.: EMNLP'12)
- **Biperpedia** (Gupta et al.: VLDB'14)
- **RELLY** (Grycner et al.: EMNLP'15)
- **PPDB** (Ganitkevich et al.: HLT-NAACL'13)
- **DEFIE** (Bovi et al.: TACL'15)
- **FrameBase** (Rouces et al.: ESWC'15)
- **schema.org**
- **more at Google, Microsoft, ... ?**

Commonsense Knowledge: Not So Common

Every child knows that

apples are green, red, round, juicy, ...
but not fast, funny, verbose, ...

pots and pans are in the kitchen or cupboard, on the stove, ...
but not in the bedroom, in your pocket, in the sky, ...

children usually live with their parents

But: commonsense is rarely stated explicitly

Plus: web and social media have reporting bias

color of elephants ?

pink elephant: 0.9 Mio on Google

grey elephant: 0.4 Mio on Google



rich family: 27.8 Mio on Bing

poor family: 3.5 Mio on Bing

singers: 22.8 Mio on Bing

workers: 14.5 Mio on Bing

Acquiring Commonsense Knowledge

Approach 1: Knowledge engineers

→ WordNet (Miller/Fellbaum)

**Problem: only for partOf
with limited coverage**

Approach 2: Crowdsourcing

→ ConceptNet (Speer/Havasi)

Problem: coverage and scale

Approach 3: Pattern-based harvesting

→ WebChild (Tandon et al.)

Problem: noise and robustness

Many specific approaches for subclassOf (hypernymy)

Pattern-based Harvesting of Commonsense Properties

[N. Tandon et al.: AAAI 2011, WSDM 2014]

Approach: Start with **seed facts**

hasProperty (apple, round)

hasAbility (dog, bark)

hasLocation (plate, table)

Learn **patterns** that express these relations, such as
X is very Y, X can Y, X put in/on Y, ...

Apply patterns to Web, books, N-grams corpora, image tags, etc.
→ **statistics**, semisupervised **learning**, constraint **reasoning**

hasColor (elephant, grey), **hasShape** (circle, round) ...

hasAbility (fish, swim), **hasAbility** (human, talk) ...

usedFor (book, learn), **usedFor** (computer, learn)

partOf (wheel, bike), **partOf** (wheel, car) ...

hasTemperature (oven, hot), **hasTaste** (chili, hot)

WebChild KB:

5 Mio. assertions

semantically typed

sense-disambiguated

Commonsense & Visual Contents

[N. Tandon et al.: CIKM 15, AAAI 16]



Refined part-whole relations from web&books text and image tags

→ 6.7 Mio sense-disambiguated triples for physicalPartOf, visiblePartOf, hasCardinality, memberOf, substanceOf

trafficJam:



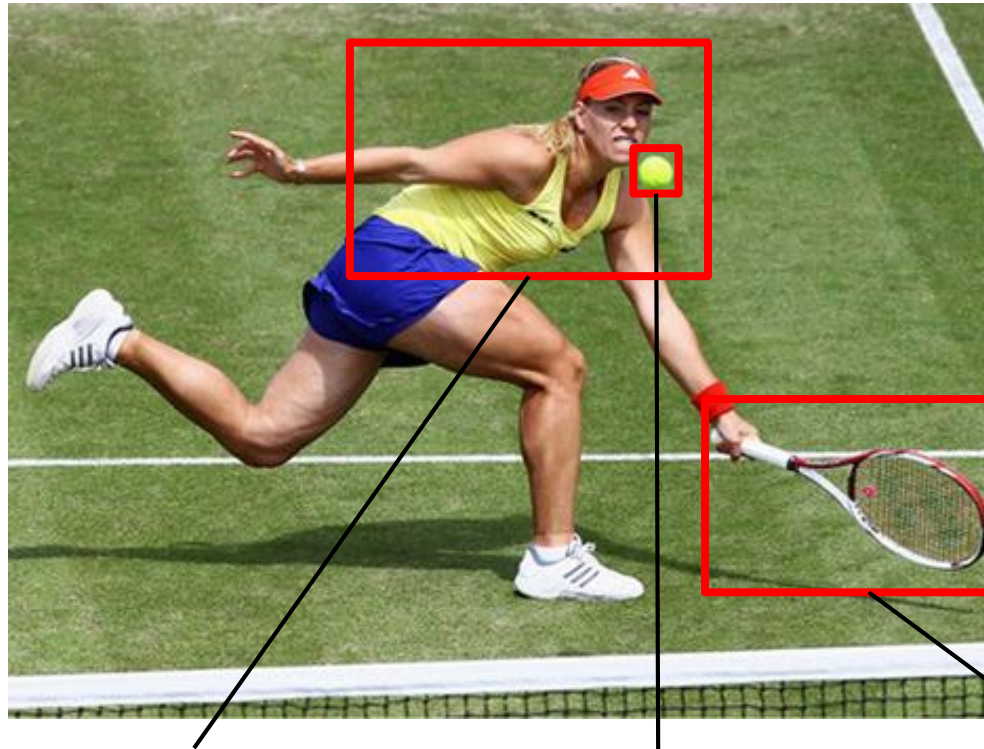
Activity knowledge from movie&TV scripts, aligned with visual scenes

→ 0.5 Mio activity types with attributes: location, time, participants, prev/next

Commonsense for Language Understanding

- **How-to queries:**
repair a bike tire, pitch a tent, cross a river, ...
- **Scene search (over videos, books, diaries):**
romantic dinner, dramatic climb, ...
- **Question disambiguation:**
hottest battles with Jay-Z ?
hottest place on earth ?
Germany's keeper at the Euro ?
- **Sentiment analysis:**
the bar was cold and the beer was warm: freezing and thirsty
the bar was cool and the beer, too
the hot springs are very cool

Commonsense for Computer Vision



woman (o1)

?

lemon (o2)

racket (o3)

+ commonsense
knowledge:

hasColor (tennisball, yellow)

hasShape (tennisball, round)

occursAt (tennisball, tennis court)

occursAt (racket, tennis court)

⇒ tennisball(o2)

Commonsense for Image Description



cake, 8 candles, 2 boys, 4 girls

→ boys and girls behind a cake with candles

**+ commonsense
knowledge:**

→ happy children at birthday party

Challenge: Commonsense Rules

Horn clauses:

can be learned by Inductive Logic Programming

$\forall x,m,c: \text{type}(x,\text{child}) \wedge \text{mother}(x,m) \wedge \text{livesIn}(m,t) \Rightarrow \text{livesIn}(x,t)$

$\forall x,m,f: \text{type}(x,\text{child}) \wedge \text{mother}(x,m) \wedge \text{spouse}(m,f) \Rightarrow \text{father}(x,f)$

**Advanced rules beyond Horn clauses:
specified by human experts**

$\forall x: \text{type}(x,\text{spider}) \Rightarrow \text{numLegs}(x)=8$

$\forall x: \text{type}(x,\text{animal}) \wedge \text{hasLegs}(x) \Rightarrow \text{even}(\text{numLegs}(x))$

$\forall x: \text{human}(x) \Rightarrow (\exists y: \text{mother}(x,y) \wedge \exists z: \text{father}(x,z))$

$\forall x: \text{human}(x) \Rightarrow (\text{male}(x) \vee \text{female}(x))$

$\forall x: \text{human}(x) \wedge \neg \text{adopted}(x) \Rightarrow \text{numParents}(x)=2$

$\forall x: \text{pope}(x) \Rightarrow \neg (\exists y: \text{father}(x,y))$

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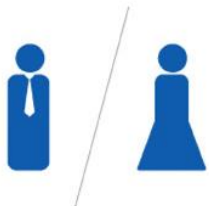
What Computers Know About You ... (But Shouldn't ?)



**Nobody interested
in your research?
We read your papers!**



The Dark Side of Knowledge



Applicant Data



Social Web Analysis



Social Intelligence Risk Score

Goal: Privacy Risk Advisor

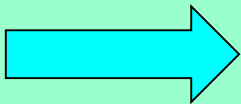
Users are tracked, linked, targeted, rated ...

Algorithmic decisions made with this data

The first screenshot shows a grid of social media platform icons (Amazon, Facebook, Messenger, Google+, YouTube, Instagram, Pinterest, etc.) under the heading 'Searching 61+ Social Media Platforms'. The second screenshot shows a progress bar for a background check on 'kimelfeld' at 91%, with a message: 'Your search history is 100% private. kimelfeld will NOT be notified about your search.' The third screenshot is a 'Background Check Report on kimelfeld' listing various data points checked, such as Full Name, Current Address, Phone Numbers, Prior Residences, Relatives, Aliases & AKAs, Age & DOB, Neighbors, Property Records, Bankruptcies, Judgments & Liens, Marriage & Divorce, Birth & Death Records, Misdemeanors, Criminal Check, and Sex Offender Records. It also includes a 'Limited Time Offer!' for a report from \$19.95 to \$9.95 and a 'continue' button.

Established privacy models

- Data: single database
- Adversary: computationally powerful, but agnostic
- Goal: anonymity guarantee
- Measures: data coarsening, perturbation, limit queries



Today's user behavior & risks

- Data & User: multimodal, **social, agile, longitudinal**
- Adversary: **world knowledge & probabilistic inference**
- Goal: **alert & advise, bound risk**
- Measures: **guide user** on policies, selective anonymization

Transparency of Data & Awareness of Users

Zoe



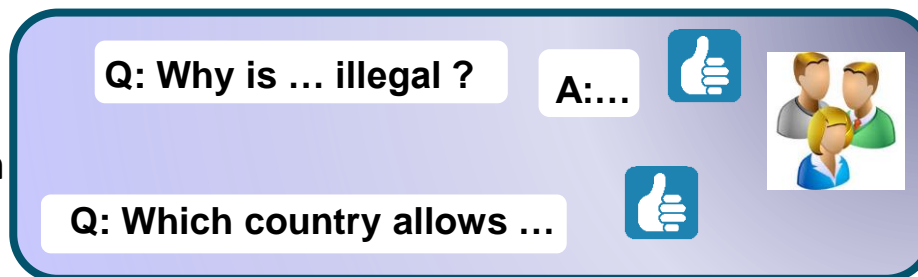
facebook

social
network



Quora

QA &
discussion
forum



movie
review
community



CANNABITS
online
shop



2011 2012 2013 2014 2015 2016

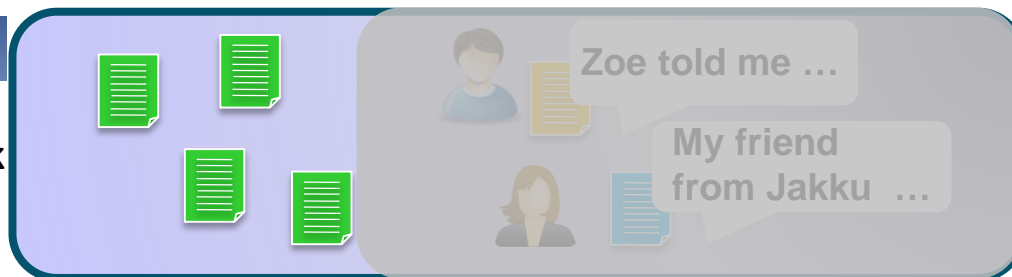
Transparency of Data & Awareness of Users

Zoe



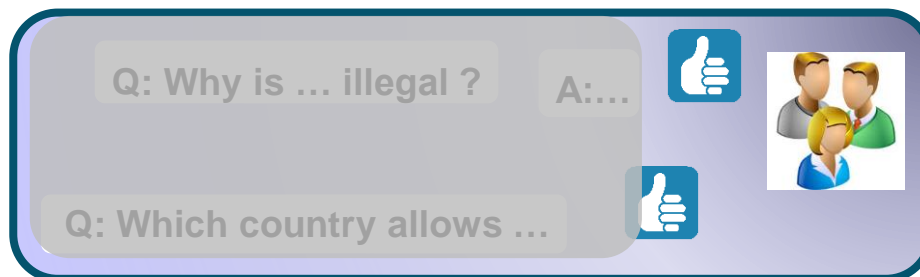
facebook

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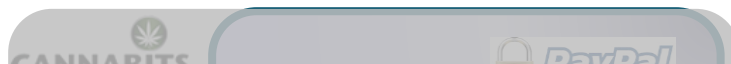


Quora

QA &
discussion
forum



movie
review
community

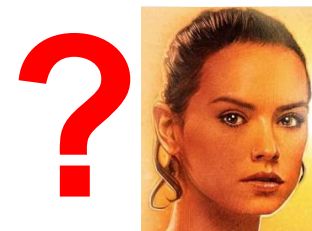


Peter
Druschel

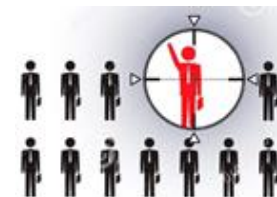
Rupak
Majumdar

Michael
Backes

Gerhard
Weikum



job application



rejected



2016

ERC Synergy Grant
imPACT (2015-2020):
Privacy, Accountability,
Compliance and Trust
In Tomorrow's Internet

Ranking-based Risk Assessment

[J. Biega et al.: SIGIR 16]

Quora

Search for questions, people, and topics

FMLA

Pregnancy

Sex

Medicine and Healthcare

Jobs and Careers

Career Advice

Should I tell prospective employers that I am pregnant?

I am being laid off from a large co in July for the birth of my child. I v to know since I just got a good re and telling them I will be available debating whether or not to tell the do not have to tell them, and they honest and simply making sure I

amy63628



★1

Fluoxetine symptoms??

Hi everyone, So on friday i was dignosed with clincial depression and PTSD and was put on fluoxetine starting at 2.5ml (to be increased gradually because i'm quite young) So yesterday i was really hyper but i was excited because i was going to see a concert later in the night so i'm going to put

2 replies 0 votes

Last reply 15 days ago



*social media,
online
communities,
review forums,
query logs,
...*

4 Answers

R-Susceptibility:

1. Capture **sensitive topics** (depression, gambling, debts, ...) with **knowledge** on vocabulary & correlations
→ **latent topic models** (LDA, word2vec skip-gram)
2. Estimate user susceptibility per topic:
→ **quantitative risk measures**
3. **Rank users:** compute **top-k targets**
→ alert user, recommend selective anonymization

Outline

- ✓ **Introduction**
- ✓ **What Computers Know**
- ✓ **What Computers Should Know**
- ✓ **What Computers Shouldn't Know**
- ★ **Conclusion**

What Computers Know

The Bright Side of Knowledge:

available at high coverage & quality
core asset for smart applications
focus on encyclopedic knowledge



The Blank Side of Knowledge:

commonsense: properties and rules
social and cultural knowledge:
salience, experience, credibility
textual and visual knowledge



The Dark Side of Knowledge:

tracking, rating, targeting individuals
→ data transparency & privacy risk advice

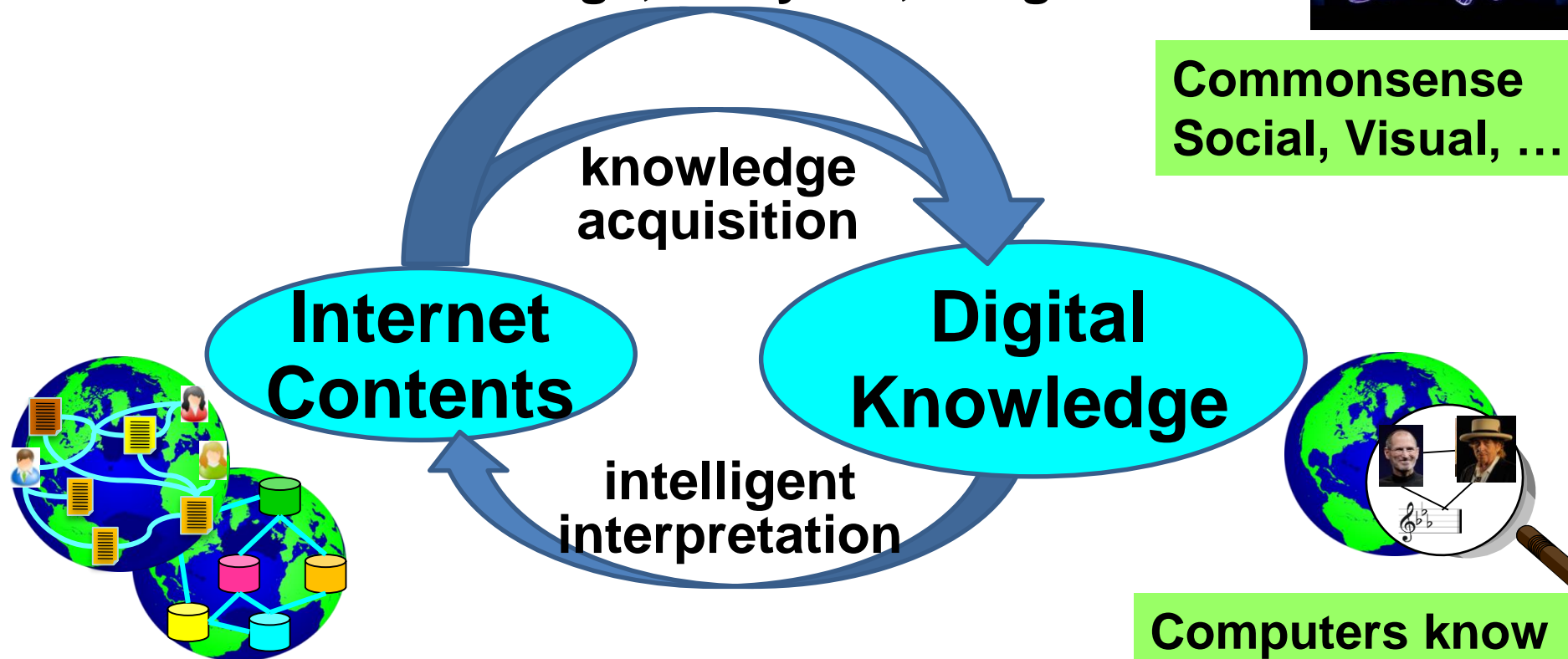


Take-Home Message

more knowledge, analytics, insight



Commonsense
Social, Visual, ...



**Computers know
about YOU !**

