



max planck institut
informatik

SIC Saarland Informatics
Campus

15 Years of Knowledge Graphs: Achievements, Challenges, Opportunities

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Max Planck Institute for Informatics

Saarland Informatics Campus

Germany

Outline

★ **Achievements**

★ **Challenges**

★ **Opportunities**

Machine Knowledge in Action



Morricone Oscar

Morricone Oscar



**traditional
search**

[Ennio Morricone - Wikipedia](#)

en.wikipedia.org/wiki/Ennio_Morricone

Ennio Morricone, OMRI (Italian: [ˈɛnnjo morriˈkoːne]; born 10 November 1928) is an Italian composer, orchestrator, conductor, and former trumpet player, writing in a wide range of musical styles. Since 1961, Morricone has composed over 400 scores for cinema and television, as well as over 100 classical works. His score to The Good, the Bad and the Ugly (1966) is considered one of

[Ennio Morricone - Awards - IMDb](#)

imdb.com/name/nm0001553/awards

Ennio Morricone on IMDb: Awards, nominations, and wins. For his magnificent and multifaceted contributions to the art of film music (statuette).

[ENNIO MORRICONE The Oscar Goes to Ennio Morricone - YouTube](#)

youtube.com/watch?v=AoW050XkqJA

Em 2007 o cinema americano reparou uma grande injustiça. Deu o Oscar, pelo conjunto da Obra, para Ennio Morricone. Nascido em Roma, em 1928, ele dedicou boa parte da vida a música e ao cinema. O ...

[Ennio Morricone: back in the saddle | Music | The Guardian](#)

theguardian.com/music/2016/jan/17/ennio-morricone-hateful-eight-oscar...

Ennio Morricone was rehearsing his latest concert when news came in that his score for Quentin Tarantino's The Hateful Eight had been nominated for an Oscar. "I was stood in front of a big ...

[Oscar winner Ennio Morricone on BBC Newsnight - YouTube](#)

youtube.com/watch?v=OvtZ6VSvk5o

Italian Ennio Morricone's Oscar victory for composing the original score for Quentin Tarantino's "The Hateful Eight," was the first competitive Oscar won by the 87-year old maestro with ...

[Forget Leo, Ennio Morricone finally won an Oscar after 500 ...](#)

independent.co.uk/arts-entertainment/films/news/forget-leo-ennio-morricone...

After clocking over 500 movie credits, legendary Italian composer Ennio Morricone finally landed Oscar gold at this year's Academy Awards. Winning for Quentin Tarantino's The Hateful Eight, he ...

Machine Knowledge in Action

Morricone Oscar

Morricone Oscar



Ennio Morricone > Academy Awards > Awards

Best Original Music Score
2016 · The Hateful Eight

Winner

Best Original Music Score
1987 · The Mission

Nominee

Best Original Music Score
2001 · Malèna

Nominee

Best Original Music Score
1979 · Days of Heaven

Nominee

Best Original Music Score
1992 · Bugsy

Nominee

Best Original Music Score
1988 · The Untouchables

Nominee

with
Knowledge
Graph

[en.wikipedia.org > wiki > Ennio_Morricone](https://en.wikipedia.org/wiki/Ennio_Morricone) ▼

Ennio Morricone - Wikipedia

In 2016, **Morricone** received his first competitive **Academy Award** for his score to Quentin Tarantino's film The Hateful Eight, at the time becoming the oldest person ...

[Andrea Morricone](#) · [Book:Ennio Morricone](#) · [Category:Ennio Morricone](#)

[www.imdb.com > name > awards](http://www.imdb.com/name/awards) ▼

Ennio Morricone - Awards - IMDb

Oscar, Best Achievement in Music Written for Motion Pictures, Original Score The Hateful Eight (2015). 2007, Winner Honorary Award. For his magnificent and ...

[www.theverge.com > ennio-morricone-best-original-score-academy-a...](http://www.theverge.com/ennio-morricone-best-original-score-academy-a...) ▼

Oscars 2016: Ennio Morricone wins Best Original Score for ...

Machine Knowledge in Action

Italian film music composers

Italian film music composers

with
Knowledge
Graph

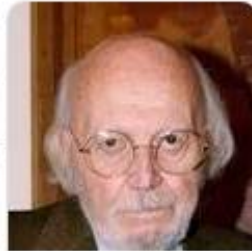
Music Composers / [Italy](#) / Film score



Ennio
Morricone



Nino Rota
1911–1979



Armando
Trovaoli
1917–2013



Piero Piccioni
1921–2004



Alessandro
Alessandroni
1925–2017



Stelvio
Cipriani
1937–2018



Luis Bacalov
1933–2017

[en.wikipedia.org](#) › [wiki](#) › [Category:Italian film score composers](#) ▼

[Category:Italian film score composers - Wikipedia](#)

Pages in category "**Italian film score composers**". The following 127 pages are in this category, out of 127 total. This list may not reflect recent changes ([learn ...](#))

[en.wikipedia.org](#) › [wiki](#) › [Ennio Morricone](#) ▼

[Ennio Morricone - Wikipedia](#)

Ennio Morricone, OMRI is an **Italian composer**, orchestrator, conductor, and former trumpet ...

The top 10 list was compiled by 40 **film composers** such as Michael Giacchino and Carter

Burwell. The **score** is ranked 23rd on the AFI's list of 25 ...

[Film music genres](#) · [Composer for Giuseppe ...](#) · [Forum Music Village](#)

[rateyourmusic.com](#) › [list](#) › [christmass61](#) › [there_is_so_much_more_th...](#) ▼

[There is so much more than Ennio Morricone ! \(Italian Film ...](#)

Machine Knowledge in Action

which pieces did Morricone compose

which pieces did
Morricone compose

with
Knowledge
Graph

Ennio Morricone > Compositions

Chi Mai

Here's to You

The Story of a Soldier

The Ecstasy of Gold

Nella fantasia

The Trio

Gabriel's Oboe

Metti, una sera a cena (uncut version)

Missa Papae Francisci

The Good, the Bad and the Ugly

Moment for Morricone

The Mexican

en.wikipedia.org > wiki > List_of_compositions_by_Ennio_Morricone ▾

List of compositions by Ennio Morricone - Wikipedia

This is a list of **compositions** by **composer**, orchestrator and conductor Ennio **Morricone**. ...

His score for The Mission (1986) **was** also at one point the world's best selling score.

Morricone's music for **The Good, the Bad and the Ugly** (1966) and Le ... with Steve Zissou
soundtrack features "**Here's To You**", featuring Joan Baez.

[Filmography](#) · [Advertising campaigns](#) · [Selected films with songs](#) ...

People also ask

How much is Ennio Morricone worth?



Ennio Morricone

Italian composer

History of Knowledge Bases



Cyc

WordNet



from humans
for humans

guitarist

⊂ {player, musician}

⊂ artist

{player, footballer}

⊂ athlete

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

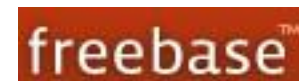
$\forall x, u, w: (\text{mother}(x, u) \wedge$
 $\text{mother}(x, w)$
 $\Rightarrow u = w)$

Wikipedia

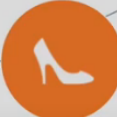
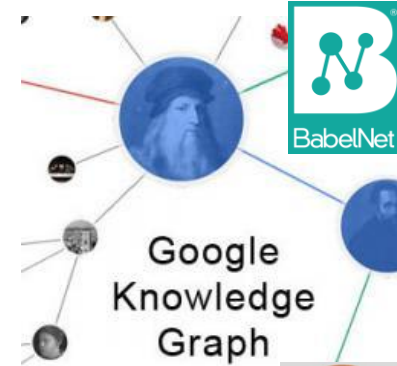


6 Mio. English articles
40 Mio. contributors

from algorithms
for machines



WIKIDATA



Zalando



1985

1990

2000

2005

2010

2020

Knowledge Bases (KB aka. KG)

subject-predicate-object triples about entities,
attributes of and relations between entities

+ composite
objects

predicate (subject, object)

type (Ennio Morricone, composer)

subtypeOf (composer, musician)

hasCreated (Ennio Morricone, Ecstasy of Gold)

wroteScoreFor (Ennio Morricone, The Mission)

workedWith (Ennio Morricone, Sergio Leone)

diedOf (Sergio Leone, heart attack)

hasSymptom (heart attack, left arm pain)

treats (Nitroglycerin, heart attack)

taxonomic knowledge

factual knowledge

expert knowledge

wonAward (Ennio Morricone, 12345)

awardName (12345, Grammy Hall of Fame)

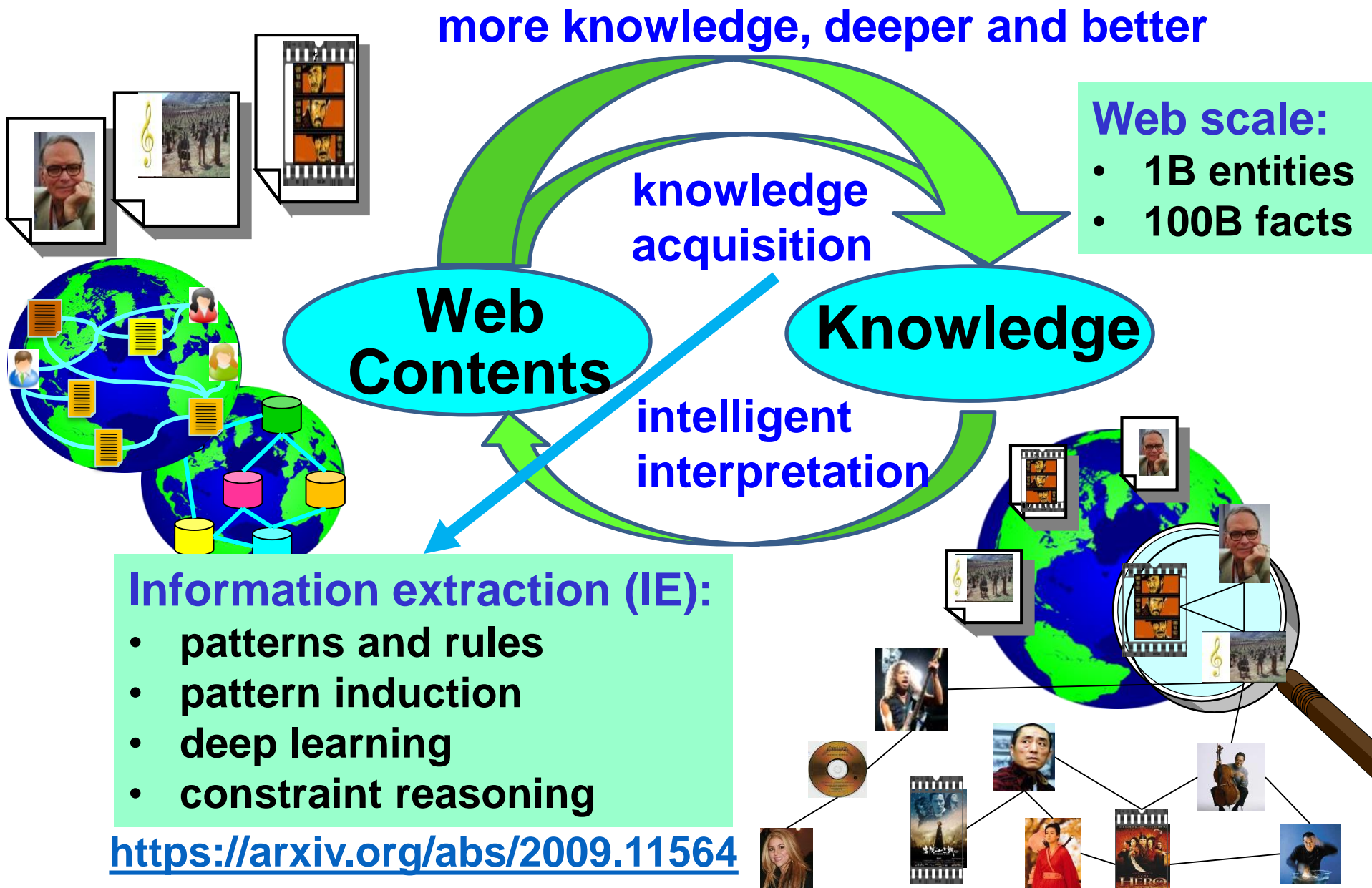
awardFor (12345, The Good, the Bad and the Ugly)

awardDate (12345, 8-February-2009)

awardPlace (12345, Los Angeles)

spatio-temporal
& contextual
knowledge

Automatic Knowledge Base Construction



KB Applications

Major use cases:

- semantic search & QA
- language understanding
- distant supervision for ML
- entity-centric text analytics
- data cleaning

Vertical domains:

- health
- food & nutrition
- finance
- consumer products

... ..

Outline

✓ **Achievements**

★ **Challenges**

★ **Opportunities**

Challenge #1: Know What People Want To Know

Ennio Morricone

From Wikipedia, the free encyclopedia



WIKIPEDIA
The Free Encyclopedia

Background information

typically in KB

Also known as	Maestro, Dan Savio, Leo Nichols
Born	10 November 1928 (age 91) Rome, Kingdom of Italy
Origin	Italy
Genres	Film music • classical • absolute music • jazz • pop • rock
Occupation(s)	Composer • orchestrator • conductor • musician • producer
Instruments	Trumpet • piano
Years active	1946–present
Associated acts	Gruppo di Improvvisazione Nuova Consonanza • Orchestra Roma Sinfonietta • Bruno Nicolai • Alessandro Alessandroni • Edda Dell'Orso • Curro Savoy • Susanna Rigacci • Mina • Yo-Yo Ma • Mireille Mathieu • Joan Baez • Andrea Bocelli • Morrissey • Roger Waters • Sarah Brightman • Amii Stewart • Paul Anka • Milva • Gianni Morandi • Dalida • Catherine Spaak • Pet Shop Boys • Hayley Westenra
Website	http://www.enniomorricone.org/

conductor, and former trumpet player, writing in a wide range of a and television, as well as over 100 classical works. His score to *The Good, the Bad and the Ugly* (1966) ed into the Grammy Hall of Fame.^[3] His filmography includes over 70 award-winning films, including all e *Cinema Paradiso*, *The Battle of Algiers*, Dario Argento's *Animal Trilogy*, 1900, *Exorcist II*, *Days of a Cage aux Folles I, II, III* and *Le Professionnel*, as well as *The Thing*, *The Mission*, *The Untouchables*.

uses Instruments
(Morricone,
{e-guitar, harmonica, whistling,
whips, jaw harp, car horns ...})

covered By Artists
(Morricone,
{Yo-Yo Ma, Metallica, Jay-Z,
Milva, Celine Dion ...})

songs About
(The Mission Theme,
South American indios)

... ..

not in any KB !

Ennio Morricone

OMRI






Morricone at the 2012 Cannes Film Festival

Background information

Also known as	Maestro, Dan Savio, Leo Nichols
Born	10 November 1928 (age 91) Rome, Kingdom of Italy
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Website	http://www.enniomorricone.org/

Challenge #1: Where Does Knowledge Come From ?

 Ennio Morricone OMRI	 Peter Gabriel Gabriel in November	 Sophie Hunger Sophie Hunger at Haldern Pop Festival 2019
Background information	Background information	Background information
Also known as Maestro, Dan Sa	Also known as Emilie Welti	Also known as Emilie Welti
Born 10 November 19 Rome, Kingdom	Born 31 March 1983 (age 37) Bern, Switzerland	Born 31 March 1983 (age 37) Bern, Switzerland
Origin Italy	Origin Zurich, Switzerland	Origin Zurich, Switzerland
Genres Film music · clas music · jazz · po	Genres electro folk	Genres electro folk
Occupation(s) Composer · orch conductor · musi	Occupation(s) Singer-songwriter, film composer	Occupation(s) Singer-songwriter, film composer
Instruments Trumpet · piano	Instruments Voice, guitar, blues harp, piano	Instruments Voice, guitar, blues harp, piano
Years active 1948–present	Years active 2002–present	Years active 2002–present
Associated acts Gruppo di Impro Nuova Consonan Roma Sinfonietta · Alessandro Ale Dell'Orso · Cuno Susanna Rigacci Ma · Mireille Mat Baez · Andrea B · Roger Waters · aran Brightman · Ami Stewart · Paul Anka · Milva · Gianni Morandi · Dalida · Catherine Spaak · Piet Shop Boys · Hayley Westenra	Labels Two Gentlemen, Manimal	Labels Two Gentlemen, Manimal
Website http://www.enniomorricone.org/	Website SophieHunger.com	Website SophieHunger.com



basic facts



KB



more
salient facts
from text + ...

Research Challenge:

- Enhance KB **coverage**
- Integrate models for **tuples and text**
- Ensure KB **reusability** and **explainability**

State of the Art:

This soundtrack earned Morricone a [?]

➡ Grammy, nomination, ...

Morricone used unusual instruments like [?]

➡ this, these, piano, ...

The Italian composer [?] wrote music for films

➡ also, himself, often, ...

contextual
embeddings
(BERT, GPT-3 ...)

Challenge #2: Know What Analysts Need

Knowledge workers (analysts, journalists, researchers) often need to **aggregate & compare** entities and classes

Examples:

- Marathon runners with most races under 2:10 h
- Electric cars with best range/energy ratio
- Anti-virus drugs with more than 10,000 patients in clinical trials


Research Challenge:

- Augment KB with rich set of **quantities**
- Enhance search to support **analytic queries**

+ easy over structured DB and KB, but **very limited coverage**

-- **more insight in (fresh) Web contents**

-- **search engines useless**

 WIKIDATA	1-Feb-2020	#subjects	#triples
Marathon runner → best time	1629	18	
Car model → range	3195	4	
Car model → engine power	3195	0	

Outline

✓ **Achievements**

✓ **Challenges**

★ **Opportunities**

- **Entities with Quantities**
- **Qfacts from Text**
- **Qfacts from Web Tables**

Entities with Quantities

Quantity:
(value, unit, context)

Motivation: Quantity (Filter) Queries

- runners with marathon under 2:10:00
- musicians worth more than 100 Mio Euros
- hybrid cars with battery range above 50 km

not answerable from KGs because of low coverage
→ extract **answers from Web sources** ! (text, tables ...)

≠ quantity lookups !

best time of Eliud Kipchoge

how much is Jay-Z worth

electric range of Toyota Yaris

Quantity Queries: State of the Art

what is jay-z worth



All



Images

What is Jay-Z worth? More

Settings

Tools

About 49.500.000 results (0,53 seconds)



View all

\$1 billion

With a net **worth** of \$1 billion, he is one of the wealthiest musicians in the world. The rapper has earned millions from sellout tours and chart-topping albums over the course of his nearly 30-year career. But music is far from his only money-making venture.

Dec 4, 2019

Quantity Queries: State of the Art

rappers worth more than 200 million dollars



All



News

rappers worth more than 200 million dollars

About 10.400.000 results (0,71 seconds)

[www.forbes.com](#) › [sites](#) › [zackomalleygreenburg](#) › 2019/06/13 › hip-... ▼

Hip-Hop's Next Billionaires: Richest Rappers 2019 - Forbes

Jun 13, 2019 - Sure enough, Forbes declared him **hip-hop's** first billionaire earlier this month. ... gross has since surged from \$500,000 to **more than \$2 million** per stop). ... is almost entirely predicated on a conservative estimate of that brand's **value**. ... perhaps the most likely candidate

[www.liveabout.com](#) › [Rap & Hip Hop](#) › [Top Picks](#) ▼

The Top 20 Richest Rappers in the World - LiveAbout

May 24, 2019 - While no **rapper** has yet to reach the **billion dollar** mark, a few are ... 50 Cent declared a net **worth** of \$16 **million** and asked the judge to ... The man born James Todd Smith has amassed **more than** a cool hundred **million**, ...

[wealthygorilla.com](#) › [Top Lists](#) ▼

The 25 Richest Rappers in the World 2020 | Wealthy Gorilla

I.Am's net **worth** is \$75 **million**, making him the 23rd richest **rapper** in the world. ... even when most of the people featured here have been in the industry **for far longer than** him. ... Master P's net **worth** is estimated at **\$200 million** this year.

Prototype System QSearch

<https://qsearch.mpi-inf.mpg.de/>

rappers worth more than 120 million euros

[V.T. Ho et al.:
ISWC 2019,
WSDM 2020]



rappers worth more than 120 million euros

Search

Parsed: rappers → worth → more than 120 million euros

Result

Source

Equals: 137.2 million (euros)

50 Cent

Earlier this year , Forbes estimated 50 Cent 's net worth to be \$ 155 million

Sean Combs

Jay Z

YC (rapper)

That makes YC 's total investment in all the companies combined worth roughly \$ 1.05 billion .

Kanye West

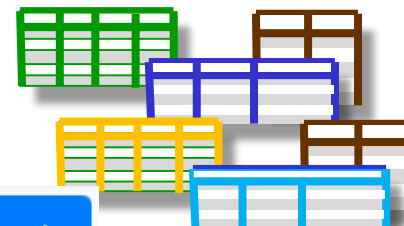
West 's company Yeezy , which has collaborated with Adidas in the past , received a valuation putting its total worth close to \$ 1.5 billion , The Blast

- **Qfact extraction** from Web text by deep learning (LSTM, Transformer ...) with distant supervision
- **Qfact matching** via language models with embeddings

Prototype System QuTE

<https://qsearch.mpi-inf.mpg.de/table/>

[V.T. Ho et al.:
WWW 2021]



Search

Web contains 100 Mio's of tables,
spreadsheets, JSON files, data lakes ...

footballers who transferred
for more than 50 Mio. Euros

footballers

Neymar



Pg-Title List of most expensive association football transfers

- ↳ World football transfer record
- ↳ Historical progression

Surrounding Text Comparison of fees in different nations is complicated by varying exchange rate . This table uses British Pound Sterling prior to 1999 and Euro from 1999 to present .

Year	Player	Selling club	Buying club	Fee (£)	Fee (€)	Fee (UK£ , after adjusted inflation)	Percentage change from last record (+ %)
2017	Neymar	Barcelona	Paris Saint -	198,000,000	222,000,000	198,000,000	125

Cristiano Ronaldo



Pg-Title List of Portuguese football records in other countries

- ↳ Highest transfer fees

Surrounding Text Notes

#	Name	From	To	Fee (€ million)	Date	Source (s)
3	Cristiano Ronaldo i Explain	Manchester United	Real Madrid	94	26 June 2009	

Virgil van Dijk



Pg-Title 2017-18 Southampton F.C. season

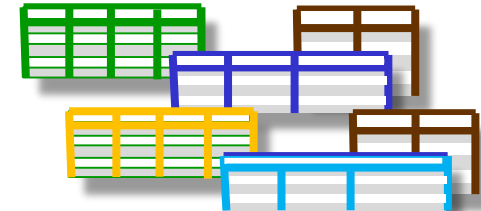
- ↳ Transfers

Surrounding Text Players transferred out Players loaned out Players released

Date	Playing position	Name	Club	Fee	Ref .
1 January 2018	DF	Virgil van Dijk i Explain	Liverpool	£75 million	

Qfacts from Web Tables

Web contains 100 Mio's of ad-hoc tables,
plus spreadsheets, JSON files ...
with a wealth of additional facts



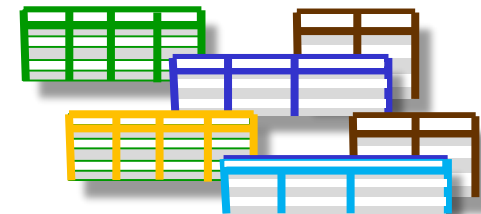
Name	Head	Site	Size	Value
Bayern	Hansi Flick	Allianz Arena	75000	2.549
Real	Zidane	Bernabeu	81044	3.649
Man City	P. Guardiola	Etihad Stadium	55017	2.258
Liverpool	J. Klopp	Anfield	53394	1.845

Problems:

- Generic & uninformative **headers**
- Unclear association of **columns**
- Incomplete & ambiguous **values**
- Inconsistent **encodings** of values

Qfacts from Web Tables

Web contains 100 Mio's of ad-hoc tables,
plus spreadsheets, JSON files ...
with a wealth of additional facts



Name	Head	Site	Size	Value (in Bio. Euro)
Bayern	Hansi Flick	Allianz Arena	ca. 75000	est. 2.5 Bio
Real	Zidane	Bernabeu	81044	3.649
Man City	P. Guardiola	Etihad Stadium	n/a	2.049 GBP
Liverpool	J. Klopp	Anfield	499 *	1700 Mio GBP

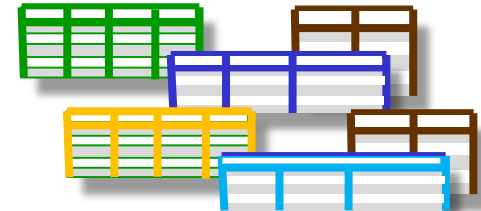
* CoVid limit, usually 53394, record 61905 (1952)

Problems:

- Generic & uninformative **headers**
- Unclear association of **columns**
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- Inconsistent **encodings** of values

Problem: Column Alignment

Web contains 100 Mio's of ad-hoc tables,
plus spreadsheets, JSON files ...
with a wealth of additional facts



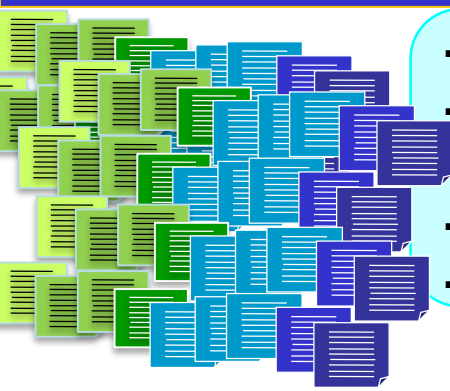
Name	Head	Site	Size	Value
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Real	Zidane	Bernabeu	81044	3.649
Man City	P. Guardiola	Etihad Stadium	55017	2.258
Liverpool	J. Klopp	Anfield	53394	1.845

Problem: Which Q-column refers to which E-column?

Prior works:

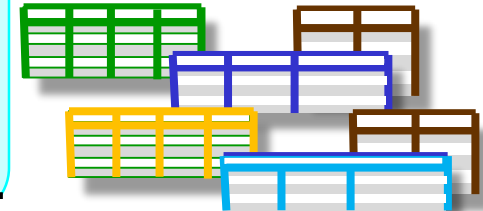
- **Heuristics:** leftmost E, closest-left E, most-unique E
- **Classifier:** based on layout and value features
- **Inf.Theory:** cross-column entropy, approx. functional dependencies

Column Alignment with Text Evidence



... Estadio Bernabeu ... 81000 seats ...
... Anfield ... 51950 fans ...
... Anfield ... 48235 ...
... Anfield ... Reds ... 0 attendance ...
... Santiago Bernabeu ... president until ...

[V.T. Ho et al.: WWW'21]



Name	Head	Site	Size	Value (in Bio Euro)
Bayern	Hansi Flick	Allianz Arena	75000	2.549
Real	Zidane	Bernabeu	81044	3.649
Man City	P. Guardiola	Etihad Stadium	55017	2.258
Liverpool	J. Klopp	Anfield	53394	1.845

Solution: Search large text corpus for supporting evidence

- for each (e,q) cells in candidate column pair E-Q
retrieve snippets with e mention and approx. q
- for each candidate E-Q pair compute confidence score

Take-Home Message

Next-Generation Knowledge Bases:
key asset for **robust, interpretable, versatile** AI applications
(cognitive assistants, language & visual understanding ...)

Challenges:

Coverage, Analytics ...



General & Verticals



Health, Food, Finance ...

Opportunity:

Entities with Quantities

**Thank You !
Questions ?**