

TechFest
the & in R&D

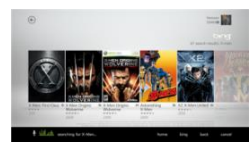
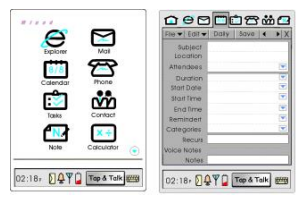
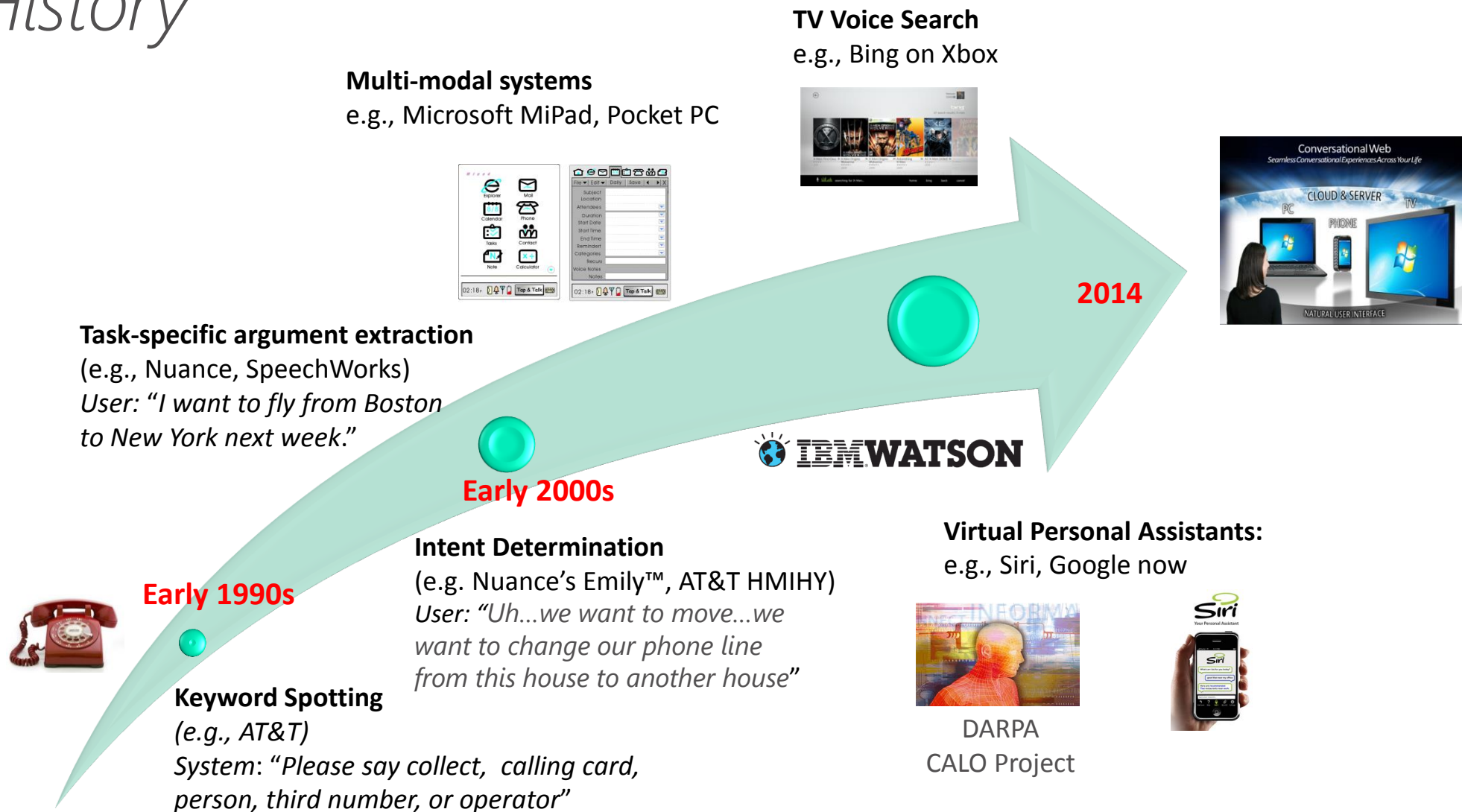
Microsoft Research

Conversational Knowledge Graphs

Larry Heck
Microsoft Research

Conversational Systems

Brief History



The Need: *Where are we now?*

Conversational systems crafted for each domain

- Select domain

- Manually construct schema/ontology

- Manually collect and annotate data

- Train models/build grammars

Result

- Narrow breadth of domains

- Limited sharing of data/schemas between domains

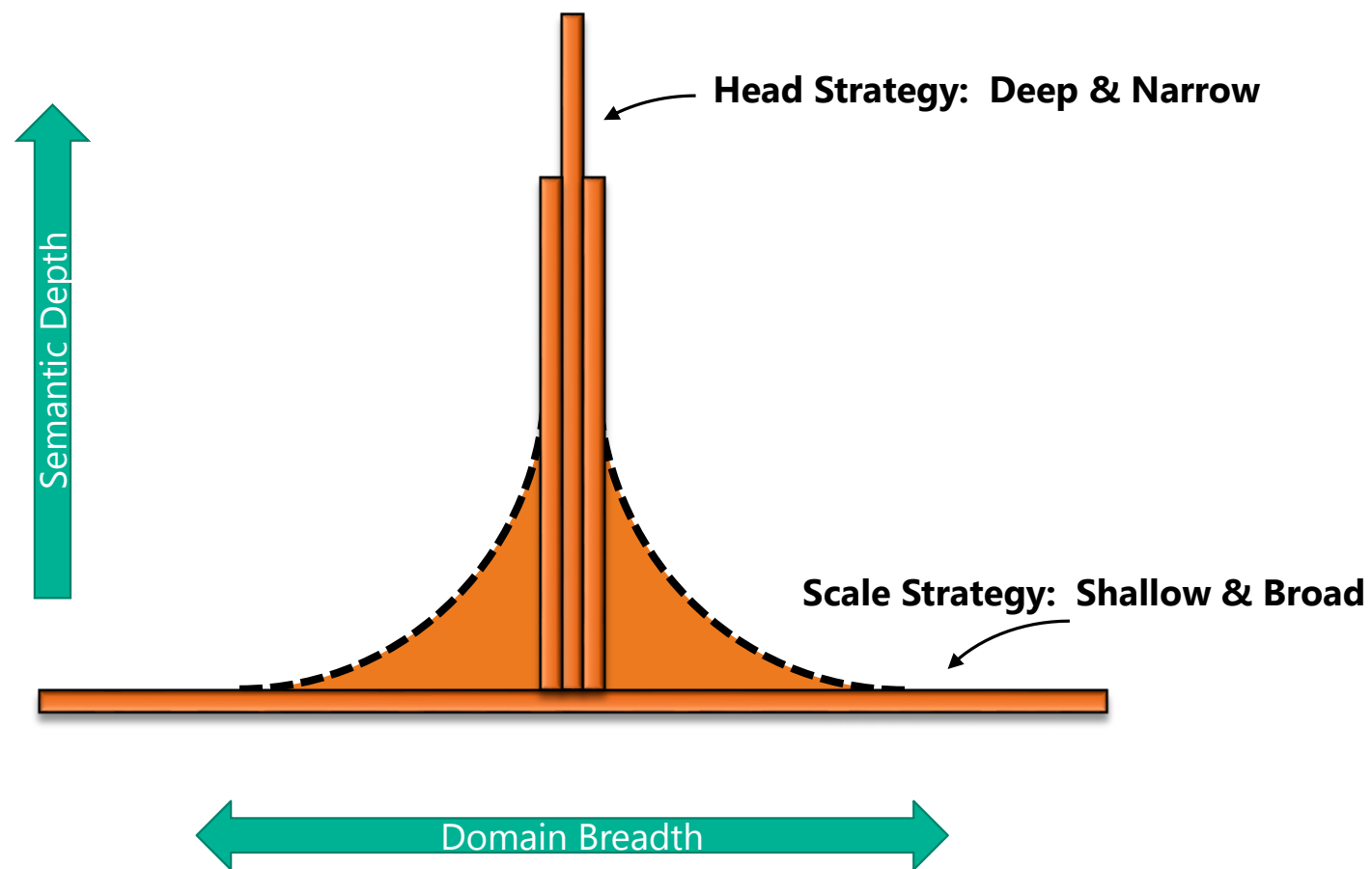
- Limited ability to incorporate disparate knowledge sources

- Inflexible to changes in task definition

How will we ever create a "NUI to the world's knowledge"? ...

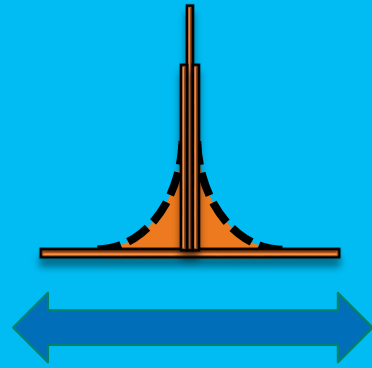
Conversational Systems Challenge

Scaling *Depth and Breadth*



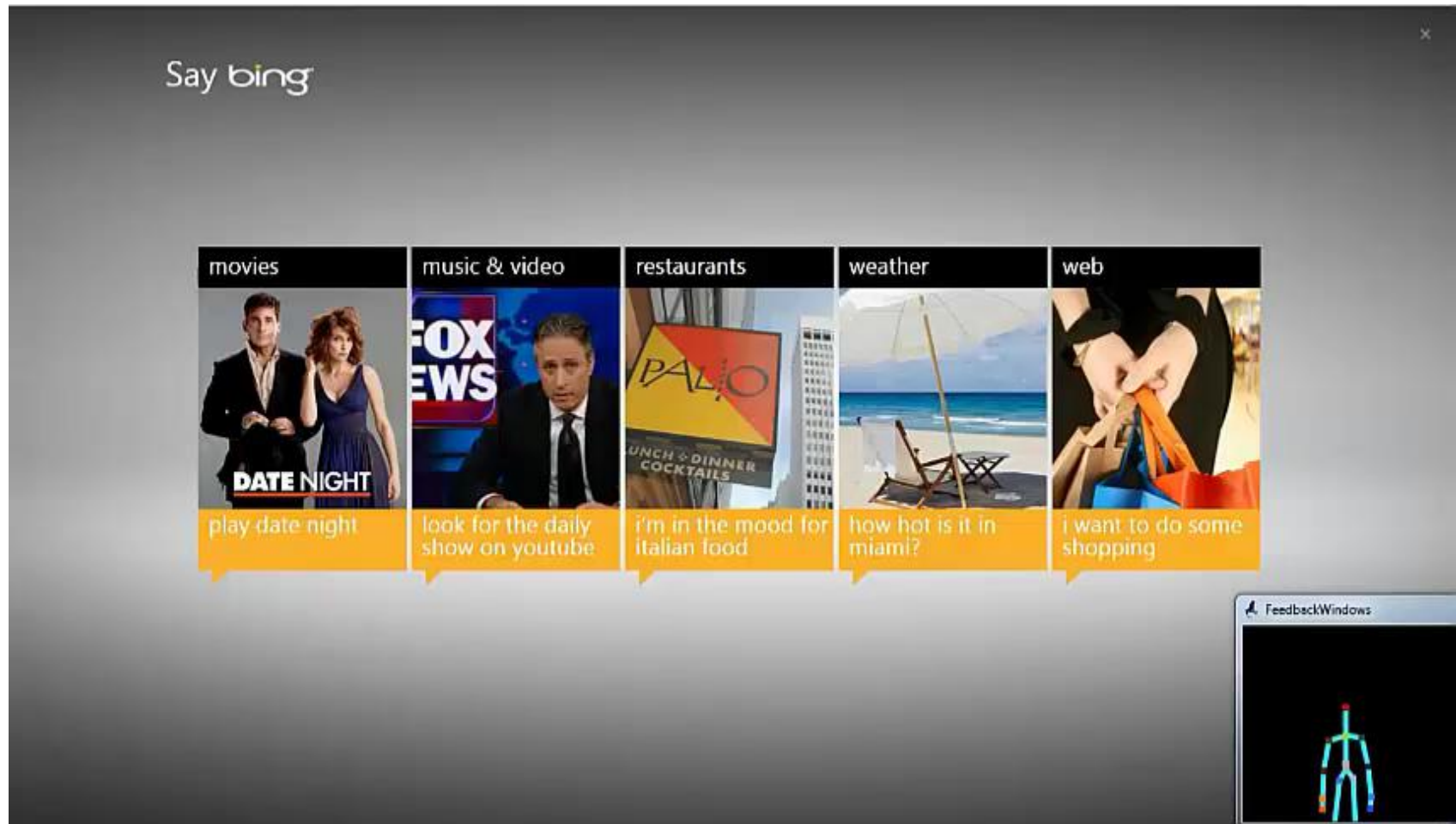
Video

Domain Breadth



TechFest 2012

Conversational Search and Browse



TechFest 2012

Conversational Search and Browse

The screenshot shows a Bing Music search result for Eric Clapton. The page features a dark header with the Bing logo and the slogan "what's next?". Below the header, navigation tabs include Music, Web, Videos, News, Images, Shopping, Blogs, and More. Under the Music tab, sub-tabs for Overview, Biography, Songs, Albums, and Lyrics are visible. The main content area is titled "Eric Clapton" and includes a large image of him playing guitar. To the right of the image is a text box with a "Biography" section and a "What's on your mind?" prompt with a "Share" button. Below the main image are sections for "Songs" (listing tracks like Cocaine, Layla, and Tears in Heaven), "Albums" (listing "Time Pieces 1992"), "Videos" (listing "Eric Clapton /Tears in heaven"), and "Related | Influenced by | Influenced". A small "FeedbackWindows" window is open in the bottom right corner, displaying a stylized human figure.

bing what's next?

Music Web Videos News Images Shopping Blogs Music More ▾

Overview Biography Songs Albums Lyrics

Eric Clapton

Biography: By the time Eric Clapton launched his solo career with the release of his self-titled debut album in mid-1970, he was long established as one of the world's major rock stars due to his group affiliations – the Yardbirds, John Mayall's Bluesbreakers, Cream, and Blind Faith -- which had demonstrated his claim to being the best rock guitarist of his generation. That it took Clapton so long to go out on his own, h... [Read more](#)

What's on your mind?

Songs

▶ Cocaine	Lyrics	Buy ▾
▶ Layla	Lyrics	Buy ▾
▶ Wonderful Tonight	Lyrics	Buy ▾
▶ I Shot The Sheriff		Buy ▾
▶ Lay Down Sally	Lyrics	Buy ▾
▶ After Midnight		Buy ▾
▶ Knockin' On Heaven'...		Buy ▾
▶ Tears In Heaven	Lyrics	Buy ▾

[See all songs](#)

Albums

Time Pieces 1992

Videos

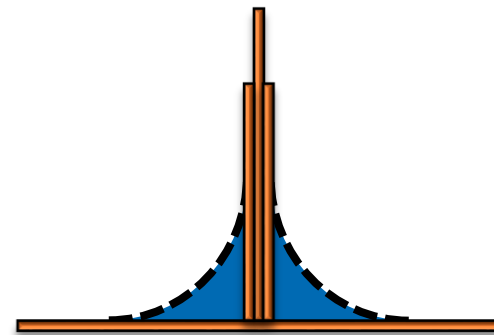
Eric Clapton /Tears in heaven 4:07 YouTube

Related | Influenced by | Influenced

Internal

FeedbackWindows

The Opportunity



Knowledge is the Foundation of Conversations

A vast majority of user interactions are with people, locations, things (**entities**).

Knowledge refers to these **entities**/concepts and to how they are interrelated.

The dual-role of knowledge

People seek to **browse** and **find information** about **entities** and to **transact** on them.

Knowledge serves as a **grounding for conversations**.



Semantic Knowledge Graphs

What are knowledge graphs?

Graphs of strongly typed and uniquely identified **entities** (nodes) and facts/literals connected by **relations** (edges)

Examples

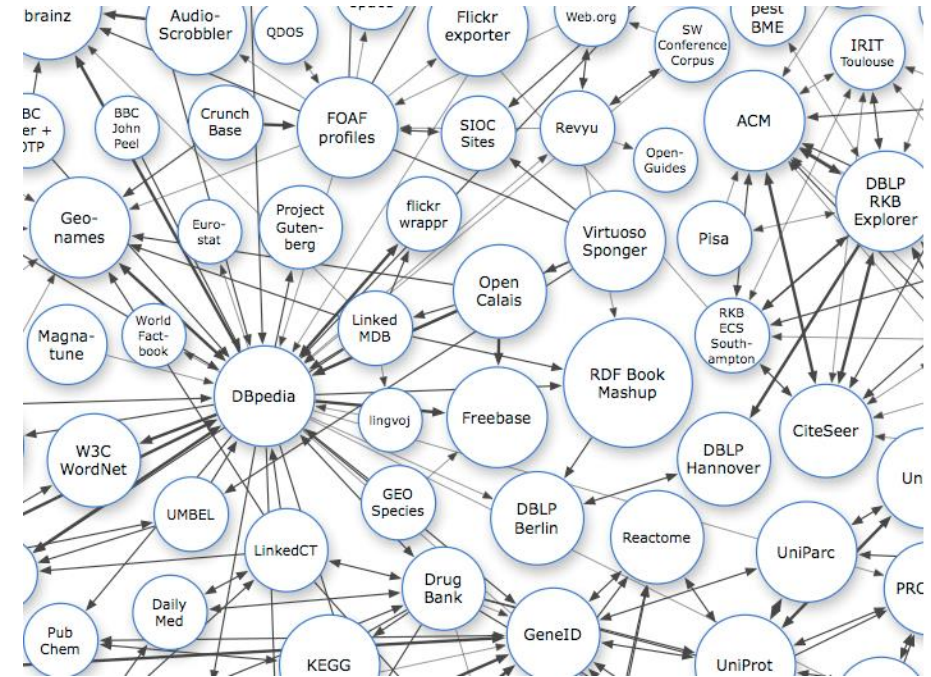
Satori, Google KG, Facebook Open Graph, Freebase

How large?

> 500M entities, > 1.5B relations, > 5B facts

How broad is the knowledge?

Wikipedia-breadth: "American Football" \leftrightarrow "Zoos"



Semantic Knowledge Graphs

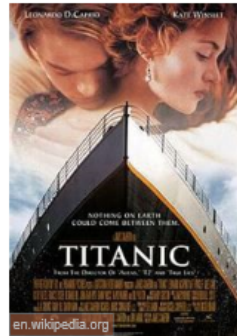
SATORI

Market: en-us
Advanced Search

Entity Details [Edit Entity](#) [Edit Side Streams](#) [Entity Cluster](#) [Entity Log](#) [References](#) [Compare to Previous](#)

[Adopt this Entity](#)

Titanic



Titanic is a 1997 American epic romantic disaster film directed, written, co-produced, co-edited and partly financed by James Cameron. A fictionalized account of the sinking of the RMS Titanic, it stars Leonardo DiCaprio and Kate Winslet as members of different social classes who fall in love aboard the ship during its ill-fated maiden voyage.
en.wikipedia.org

User Rating: 8 / 10 PG-13

Director [James Cameron](#)

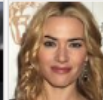
Writers [James Cameron](#)

Genre [Drama](#) [Romance](#) [Epic](#)

Cast



[Leonardo DiCaprio](#)



[Kate Winslet](#)



[Bill Paxton](#)

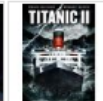


[James Cameron](#)

Related



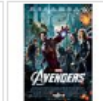
[Avatar \(2009\)](#)



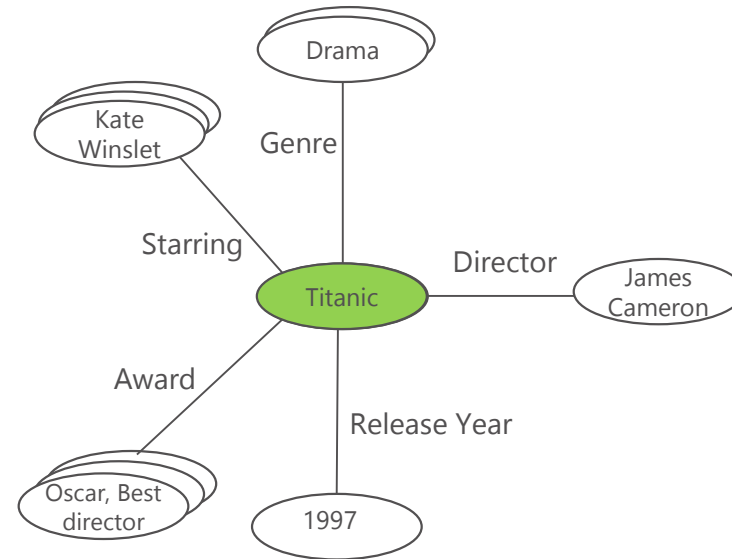
[Titanic II \(2010\)](#)



[The Wolf of Wall Street \(2013\)](#)



[The Avengers \(2012\)](#)



Entity Facts

(30752) Legend: Not Published - Low - Med - High

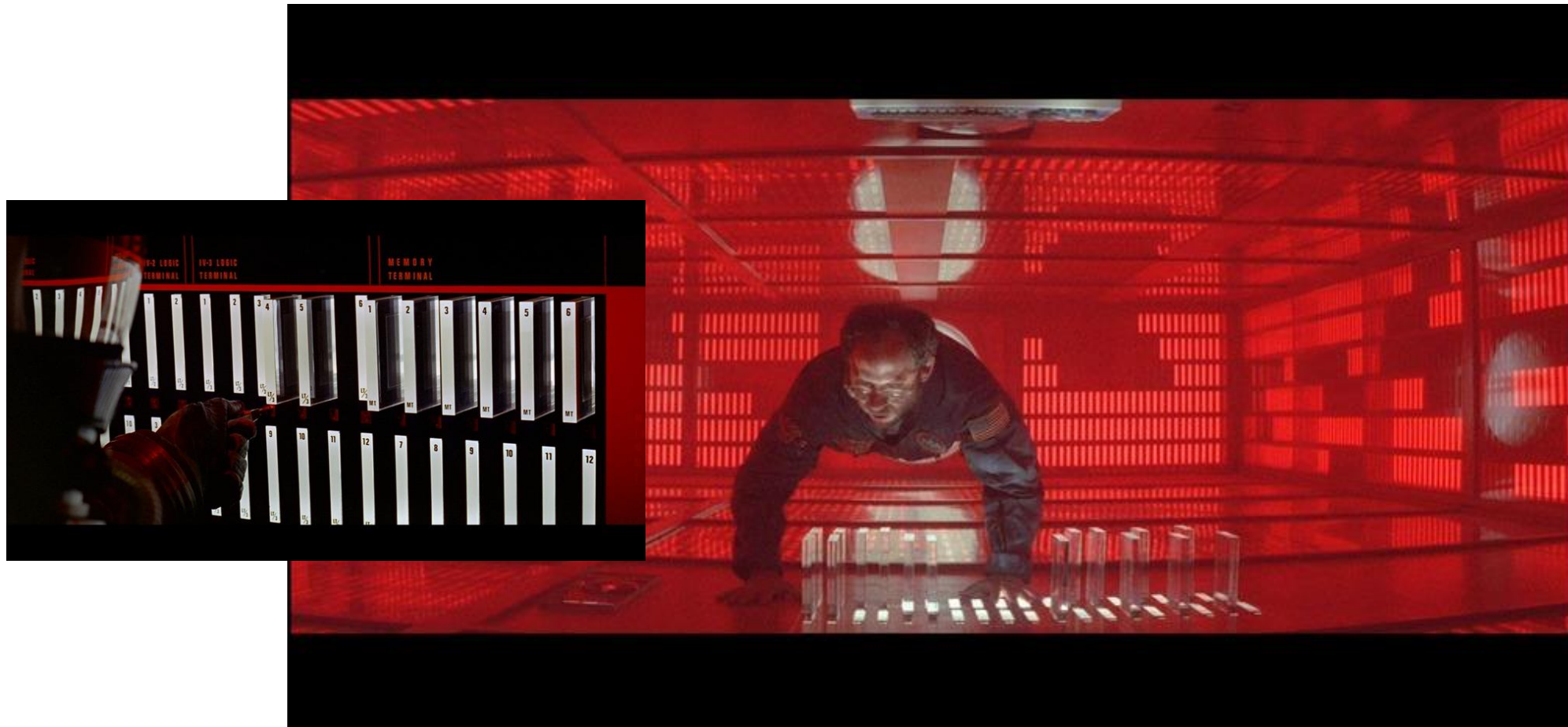
[Editorial Mode](#)

[XML \(Download XML\)](#) - [JSON \(Download JSON\)](#) - [Triples](#) - [CDB Jsn \(use mainline XML\)](#)

award.nominated_work.nomination	category: Academy Award for Best Picture year: 1997Z	category: Academy Award for Best Actress notes_description: Role: Rose DeWitt Bukater year: 1997Z	category: Academy Award for Best Actress in a Supporting Role year: 1997Z	category: Academy Award for Best Director year: 1997Z
	category: Academy Award for Best Original Music Score year: 1997Z	category: Academy Award for Best Cinematography year: 1997Z		
	category: Academy Award for Best Film Editing year: 1997Z	category: Academy Award for Best Visual Effects year: 1997Z	category: BAFTA Award for Best Film year: 1998Z	category: Academy Award for Best Sound Mixing year: 1997Z
	category: Academy Award for Best Costume Design year: 1997Z	category: Academy Award for Best Production Design year: 1997Z	category: Golden Globe Award for Best Motion Picture – Drama year: 1998Z	category: Golden Globe Award for Best Director - Motion Picture year: 1998Z
	category: Golden Globe Award for Best Original Song year: 1998Z	category: Golden Globe Award for Best Original Score year: 1998Z	category: Golden Globe Award for Best Screenplay - Motion Picture year: 1998Z	category: Academy Award for Best Sound Editing year: 1997Z
	category: MTV Movie Award for Best Kiss year: 1998Z	category: DGA Award for Outstanding Directorial Achievement in Feature Film year: 1997Z	category: Academy Award for Best Makeup and Hairstyling year: 1997Z	category: BAFTA Award for Best Film Music year: 1998Z

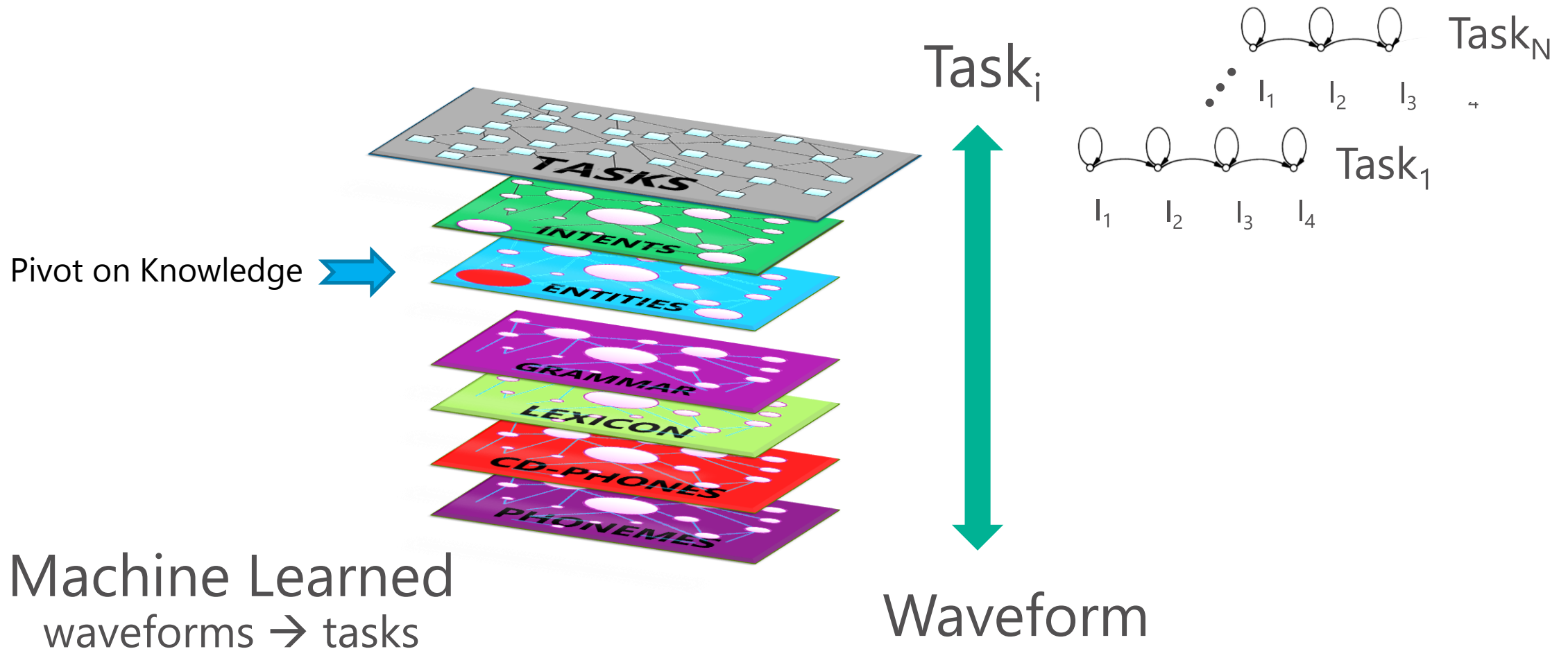
Knowledge “Crystals”

Vision: Push-button NUI from Knowledge Graph



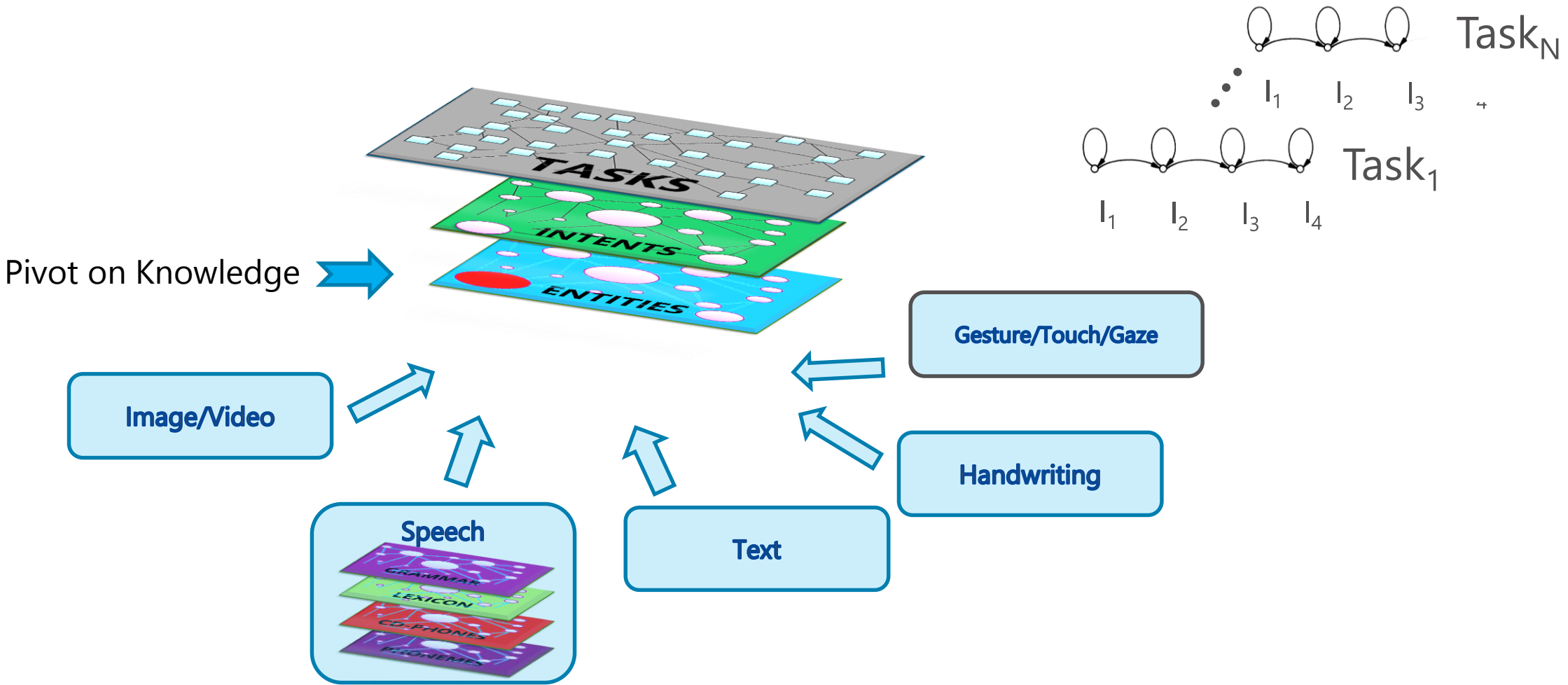
Conversational Knowledge Graphs

Compositionality: Waveforms \rightarrow Tasks



Conversational Knowledge Graphs

Multi-Modal



Semantic Parsing: Unsupervised Learning

Entity Spotting and Linking

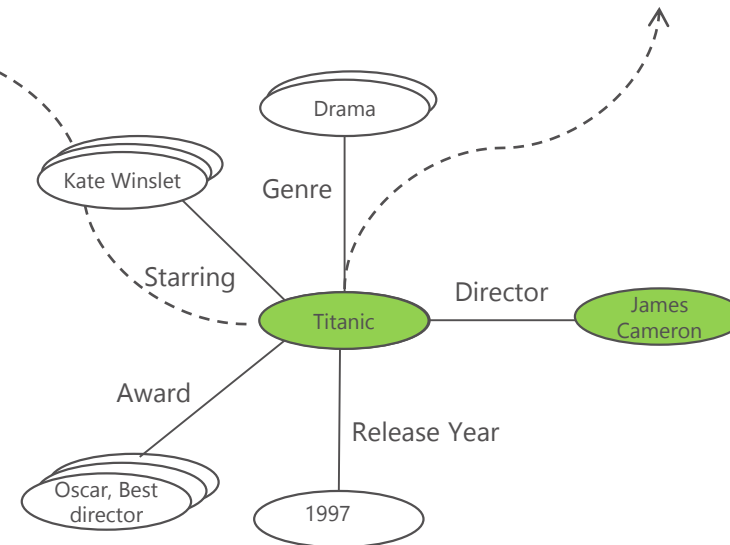
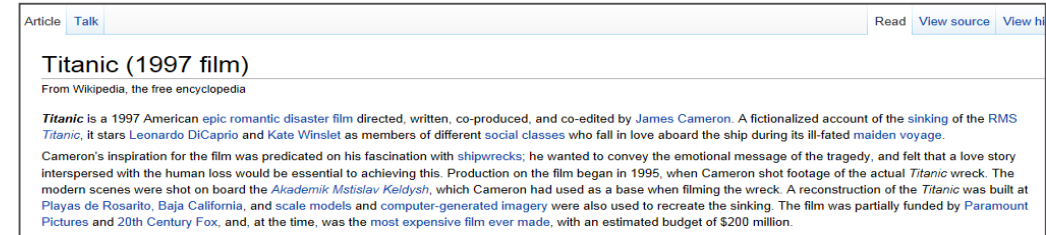


Goal Precise & robust (high-recall) entity linking over a broad knowledge base

Challenge Requires a lot of annotated (labeled) data

Link Satori entities to NL Surface forms:

- Bing queries
- Wikipedia
- Twitter
- MusicBrainz
- IMDB
- etc.



Solution → Start from knowledge graph, mine data, auto-annotate

Semantic Parsing: Unsupervised Learning

Entity Spotting and Linking

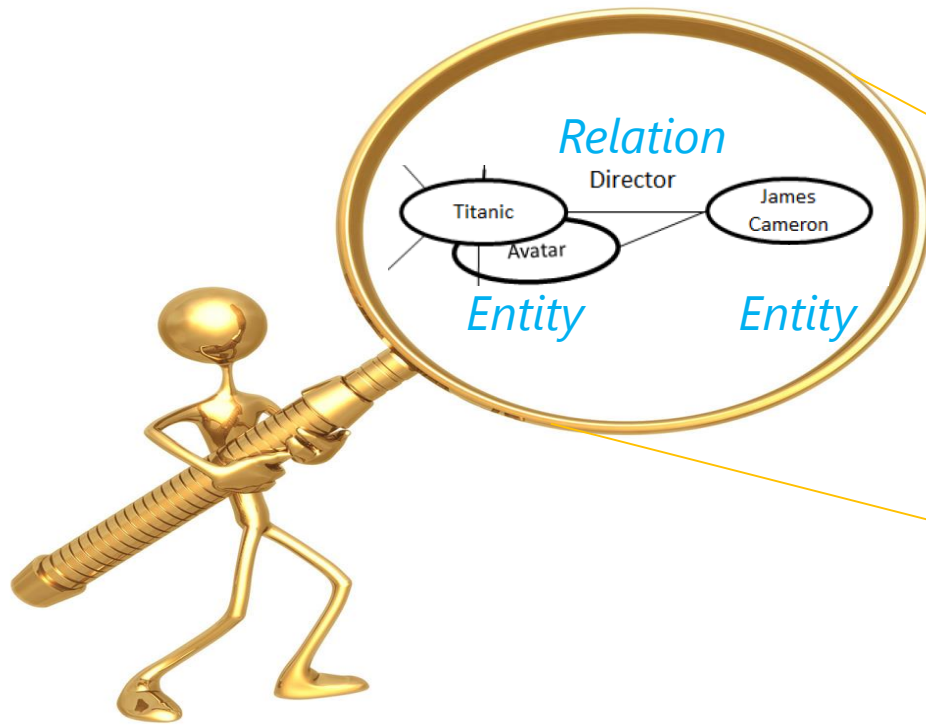


	Manual Transcriptions					ASR Output				
	Movie	Actor	Genre	Director	All	Movie	Actor	Genre	Director	All
Supervised										
CRF Lexical + Gazetteers	51.25%	86.29%	93.26%	64.86%	66.53%	45.15%	82.56%	88.58%	58.59%	60.96%
CRF Lexical only	46.44%	80.22%	92.83%	52.94%	61.72%	39.21%	74.86%	86.21%	45.36%	54.10%
Unsupervised										
Gazetteers only	69.69%	50.70%	15.76%	2.63%	51.14%	59.66%	47.78%	11.80%	2.82%	43.88%
CRF Lexical only	0.19%	9.67%	0.00%	62.83%	5.61%	0.20%	9.67%	0.00%	57.14%	5.27%
+ Gazetteers	1.96%	72.35%	4.73%	79.03%	31.94%	1.74%	69.76%	3.57%	75.00%	30.77%
+ Adaptation	71.72%	58.61%	29.55%	77.42%	60.38%	55.74%	62.70%	30.95%	73.21%	54.69%
+ Relations				84.62%	61.02%				80.67%	55.40%

Unsupervised learning \cong *supervised* (F-measure)

Semantic Parsing: Unsupervised Learning

Induced Relation Grammars

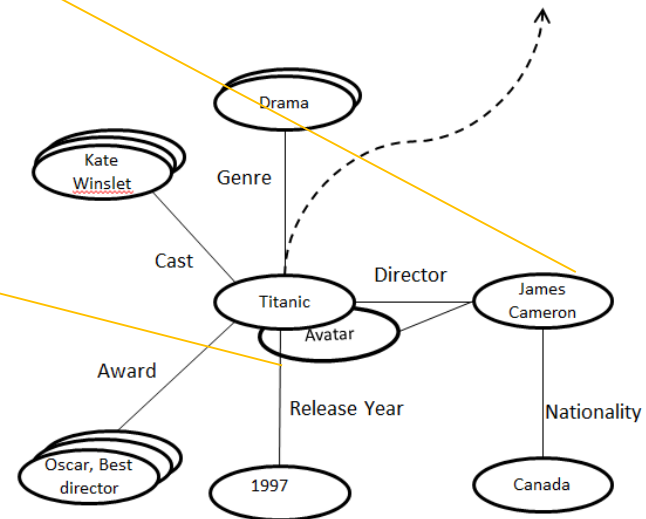


Article Talk Read View source View history

Titanic (1997 film)

From Wikipedia, the free encyclopedia

Titanic is a 1997 American epic romantic disaster film directed, written, co-produced, and co-edited by James Cameron. A fictionalized account of the sinking of the RMS *Titanic*, it stars Leonardo DiCaprio and Kate Winslet as members of different social classes who fall in love aboard the ship during its ill-fated maiden voyage. Cameron's inspiration for the film was predicated on his fascination with shipwrecks; he wanted to convey the emotional message of the tragedy, and felt that a love story interspersed with the human loss would be essential to achieving this. Production on the film began in 1995, when Cameron shot footage of the actual *Titanic* wreck. The modern scenes were shot on board the *Akademik Mstislav Keldysh*, which Cameron had used as a base when filming the wreck. A reconstruction of the *Titanic* was built at Playa de Rosarito, Baja California, and scale models and computer-generated imagery were also used to recreate the sinking. The film was partially funded by Paramount Pictures and 20th Century Fox, and, at the time, was the most expensive film ever made, with an estimated budget of \$200 million.



Semantic Parsing: Unsupervised Learning

Relation Modeling for Entity Linking



Entities anchor higher-level grammatical structure
 Induce grammars over high-confidence entities (anchor points)
 "Repair" missing entities

→ "Canadian born ___?___ directed titanic"

Template	Frequency
<i>ent</i>	44.9%
<i>type</i> \sqcap <i>rel(ent)</i>	12.8%
<i>ent</i> ₀ \sqcap <i>rel(ent)</i> ₁	7.7%
<i>ent</i> \sqcap <i>type</i>	5.8%
<i>type</i>	5.8%
<i>attr(ent)</i>	3.8%
<i>ent</i> ₁ \sqcap <i>rel(ent)</i> ₀	3.2%
<i>rel(ent)</i>	1.9%
<i>ent</i> ₀ \sqcap <i>rel(ent)</i> ₁ , <i>rel(ent)</i> ₂	1.3%
<i>type</i> ₁ \sqcap <i>rel(type)</i> ₀	1.3%

Ten most frequently occurring templates among entity-based queries (Pound et al., CIKM'12)

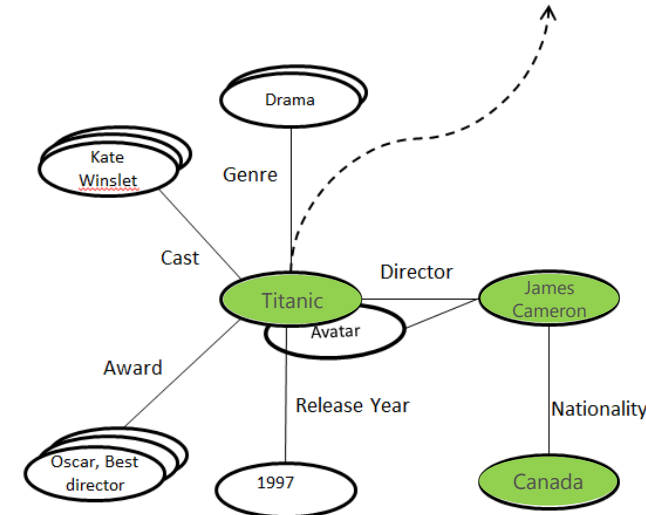
Article Talk

Titanic (1997 film)

From Wikipedia, the free encyclopedia

Titanic is a 1997 American epic romantic disaster film directed, written, co-produced, and co-edited by James Cameron. A fictionalized account of the sinking of the RMS *Titanic*, it stars Leonardo DiCaprio and Kate Winslet as members of different social classes who fall in love aboard the ship during its ill-fated maiden voyage.

Cameron's inspiration for the film was predicated on his fascination with shipwrecks; he wanted to convey the emotional message of the tragedy, and felt that a love story interspersed with the human loss would be essential to achieving this. Production on the film began in 1995, when Cameron shot footage of the actual *Titanic* wreck. The modern scenes were shot on board the *Akademik Mstislav Keldysh*, which Cameron had used as a base when filming the wreck. A reconstruction of the *Titanic* was built at Playas de Rosarito, Baja California, and scale models and computer-generated imagery were also used to recreate the sinking. The film was partially funded by Paramount Pictures and 20th Century Fox, and, at the time, was the most expensive film ever made, with an estimated budget of \$200 million.



Semantic Parsing: Unsupervised Learning

Induced Relation Grammars



	Manual Transcriptions					ASR Output				
	Movie	Actor	Genre	Director	All	Movie	Actor	Genre	Director	All
Supervised										
CRF Lexical + Gazetteers	51.25%	86.29%	93.26%	64.86%	66.53%	45.15%	82.56%	88.58%	58.59%	60.96%
CRF Lexical only	46.44%	80.22%	92.83%	52.94%	61.72%	39.21%	74.86%	86.21%	45.36%	54.10%
Unsupervised										
Gazetteers only	69.69%	50.70%	15.76%	2.63%	51.14%	59.66%	47.78%	11.80%	2.82%	43.88%
CRF Lexical only	0.19%	9.67%	0.00%	62.83%	5.61%	0.20%	9.67%	0.00%	57.14%	5.27%
+ Gazetteers	1.96%	72.35%	4.73%	79.03%	31.94%	1.74%	69.76%	3.57%	75.00%	30.77%
+ Adaptation	71.72%	58.61%	29.55%	77.42%	60.38%	55.74%	62.70%	30.95%	73.21%	54.69%
+ Relations				84.62%	61.02%				80.67%	55.40%

> +7% *F*-measure with induced relation grammars

Semantic Parsing: Unsupervised Learning

Entity Linking and Relations



To dig deeper...

Larry Heck, Dilek Hakkani-Tur, and Gokhan Tur, [Leveraging Knowledge Graphs for Web-Scale Unsupervised Semantic Parsing](#), in *Proceedings of Interspeech*, International Speech Communication Association, August 2013

Larry Heck and Dilek Hakkani Tur, [Exploiting the Semantic Web for Unsupervised Spoken Language Understanding](#), IEEE Spoken Language Technology Workshop, December 2012

Dilek Hakkani-Tur, Larry Heck, and Gokhan Tur, [Using a Knowledge Graph and Query Click Logs for Unsupervised Learning of Relation Detection](#), IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), May 2013

Gokhan Tur, Minwoo Jeong, Ye-Yi Wang, Dilek Hakkani-Tur, and Larry Heck, [Exploiting the Semantic Web for Unsupervised Natural Language Semantic Parsing](#), in *Proceedings of Interspeech*, International Speech Communication Association, 2012

Growing the Knowledge Graph

Discovering new knowledge

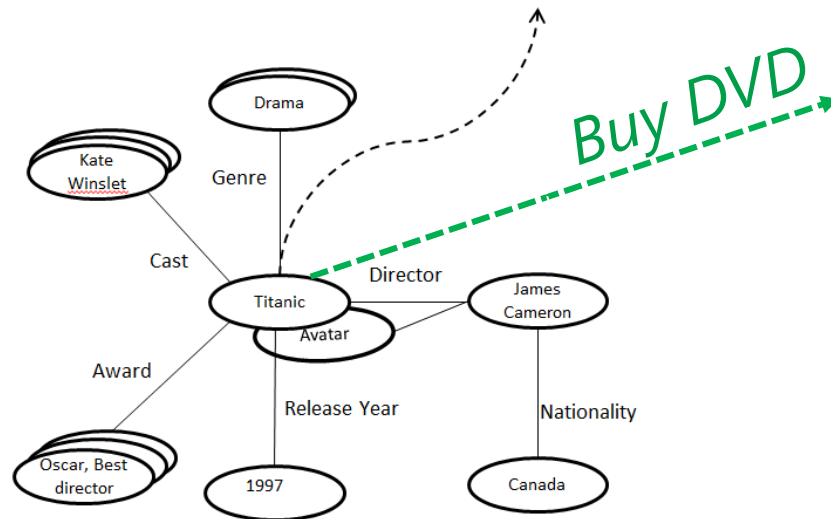


Article Talk Read View source View hi

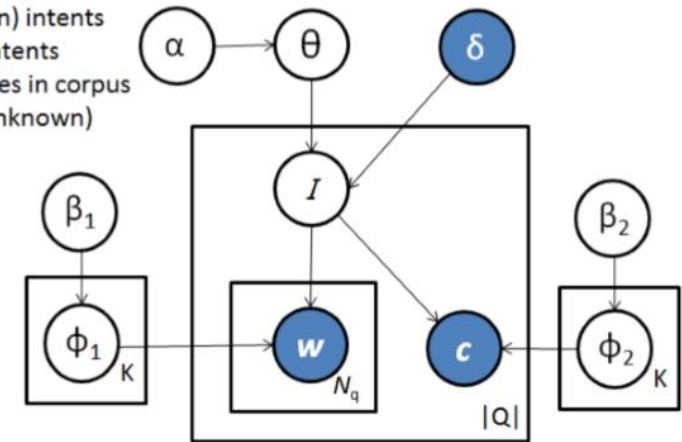
Titanic (1997 film)

From Wikipedia, the free encyclopedia

Titanic is a 1997 American epic romantic disaster film directed, written, co-produced, and co-edited by James Cameron. A fictionalized account of the sinking of the RMS *Titanic*, it stars Leonardo DiCaprio and Kate Winslet as members of different social classes who fall in love aboard the ship during its ill-fated maiden voyage. Cameron's inspiration for the film was predicated on his fascination with shipwrecks; he wanted to convey the emotional message of the tragedy, and felt that a love story interspersed with the human loss would be essential to achieving this. Production on the film began in 1995, when Cameron shot footage of the actual *Titanic* wreck. The modern scenes were shot on board the *Akademik Mstislav Keldysh*, which Cameron had used as a base when filming the wreck. A reconstruction of the *Titanic* was built at Playas de Rosarito, Baja California, and scale models and computer-generated imagery were also used to recreate the sinking. The film was partially funded by Paramount Pictures and 20th Century Fox, and, at the time, was the most expensive film ever made, with an estimated budget of \$200 million.



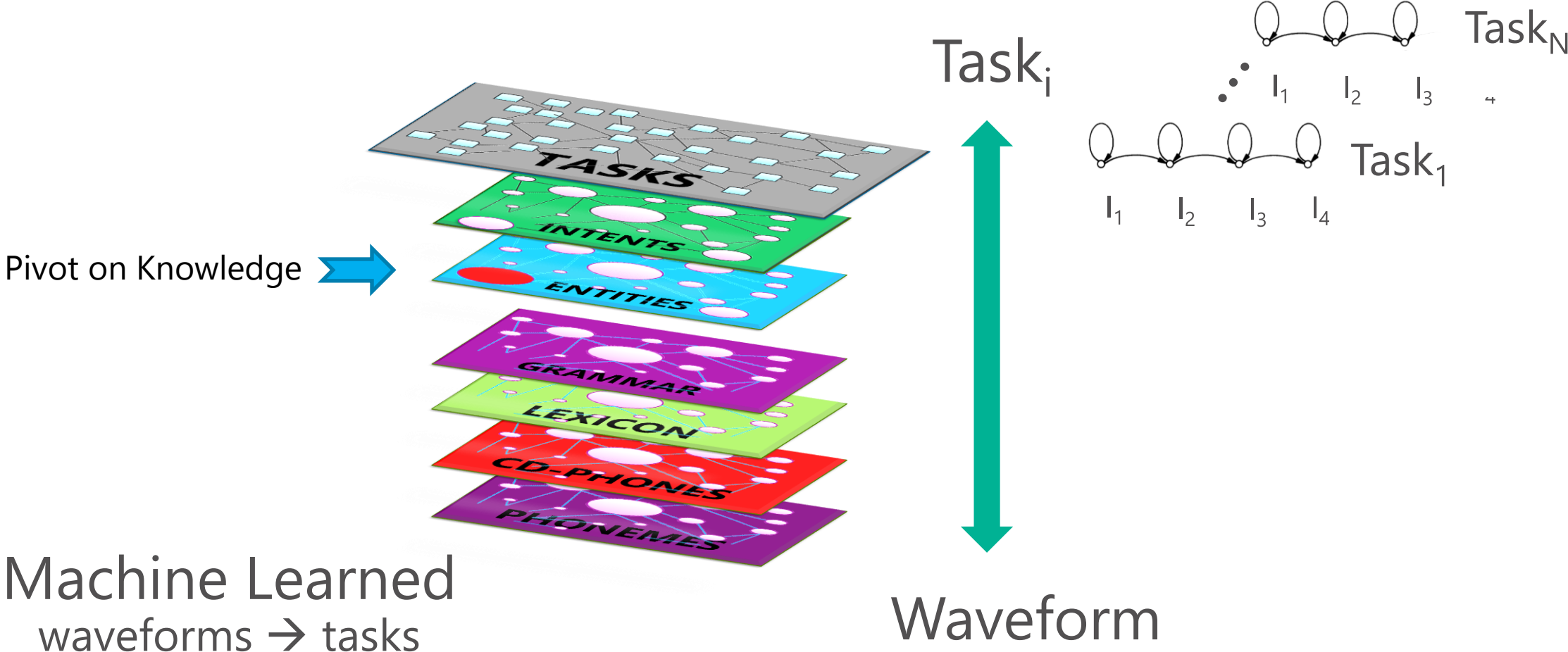
I_g : fixed - known (given) intents
 I_u : newly discovered intents
 $|Q|$: number of queries in corpus
 $I = I_g \cup I_u$ (g:given ; u:unknown)
 $K = |I_g| + |I_u|$



Unsupervised learning \cong *supervised*

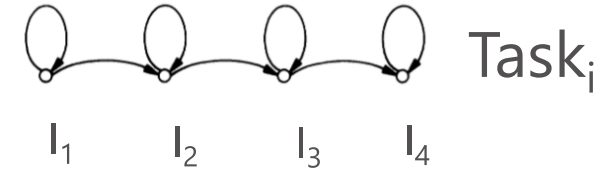
Conversational Knowledge Graphs

Compositionality: Waveforms \rightarrow Tasks



Dialog Modeling with Knowledge Graphs

Dynamic multi-turn conversations



Statistical methods for dialog managers is active research topic (e.g., POMDP)

Key Technical Challenge: significant amount of annotated dialogs required for training

Idea: can we leverage Web (IE) session data combined with Knowledge Graphs

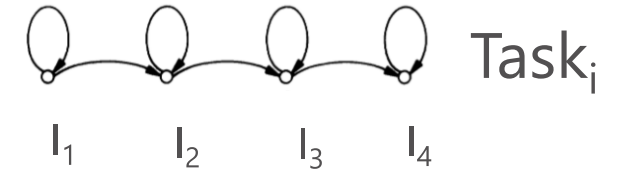
Web search & browse → Conversations/dialog

Massive volume of interactions > 100M queries/day, Millions of users

Coverage of user interactions is high (broad domains across the web)

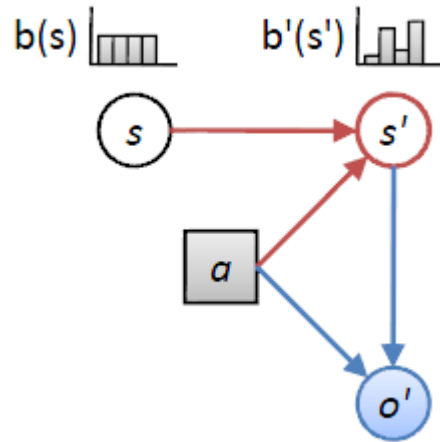
Dialog Modeling with Knowledge Graphs

Dynamic multi-turn conversations



New Approach

Step 1. **Learn task completion patterns from web** → IE sessions through Satori Knowledge Graph

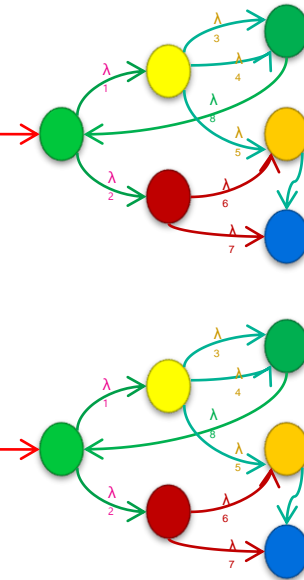


Successful Dialogs

Goal 1: Q 4s RL 1s SR 53s SR 118s END
Goal 2: Q 3s Q 5s SR 10s AD 44s END
Goal 3: Q 4s RL 1s SR 53s SR 118s END
Goal 4: Q 3s Q 5s SR 10s AD 44s END
.....
Goal n: Q 4s RL 1s SR 53s SR 118s
END
Goal n-1: Q 3s Q 5s SR 10s AD 44s
END

Unsuccessful Dialogs

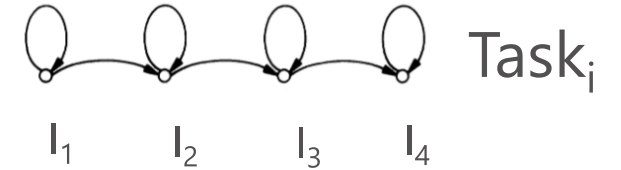
Goal 1: Q 4s RL 1s SR 53s SR 118s END
Goal 2: Q 3s Q 5s SR 10s AD 44s END
Goal 3: Q 4s RL 1s SR 53s SR 118s END
Goal 4: Q 3s Q 5s SR 10s AD 44s END
.....
Goal n: Q 4s RL 1s SR 53s SR 118s
END
Goal n-1: Q 3s Q 5s SR 10s AD 44s
END



Step 2. **Learn "mapping" of web keyword-click language to natural spoken conversations**

Dialog Modeling with Knowledge Graphs

Dynamic multi-turn conversations



Results

Successfully learned ***conversational search and browse*** models from **IE sessions + Satori**

Increased F-measures of semantic parsing by **> 18% (rel.)**

To dig deeper...

Lu Wang, Larry Heck, Dilek Hakkani-Tur, Leveraging Semantic Web Search and Browse Sessions for Multi-Turn Spoken Dialog Systems, *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP), 2014*

Deep Learning from Structured Knowledge

Current/Future Work

Unsupervised data mining and semantic annotations → *unlimited* training data over knowledge graphs

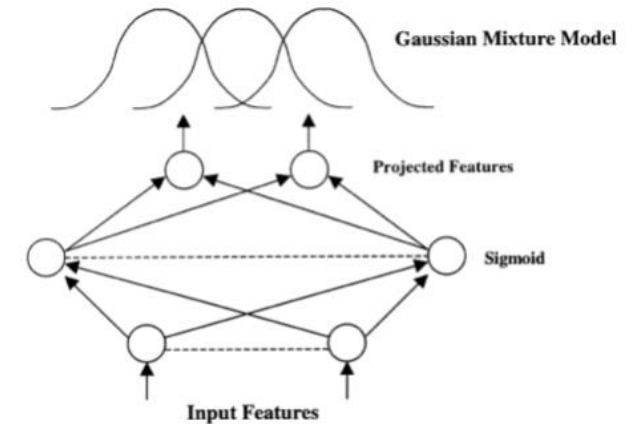
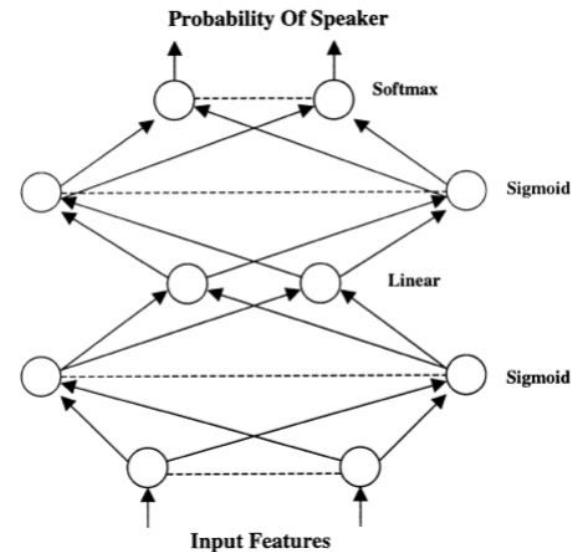
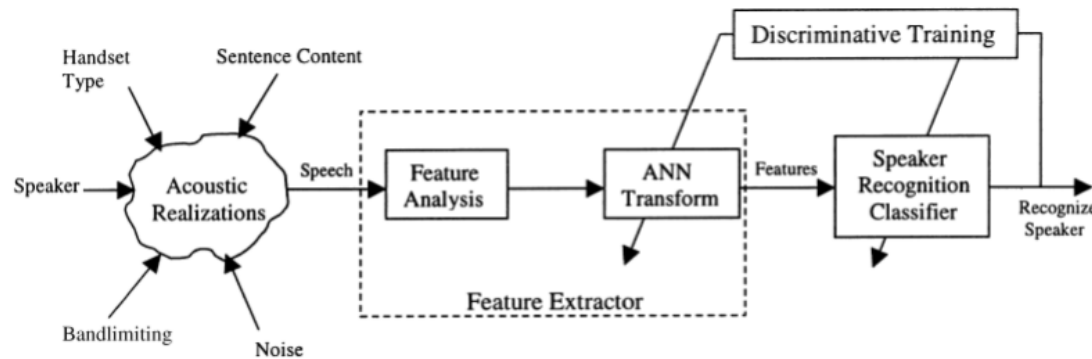
Research Questions:

Can deep learning (neural networks) discover the *fundamental features of knowledge*?

Can we leverage these features to *transfer learning across domains/sub-graphs*?

Back to the Future: Deep Learning for Speaker Recognition

Learning the fundamental *features of speakers*

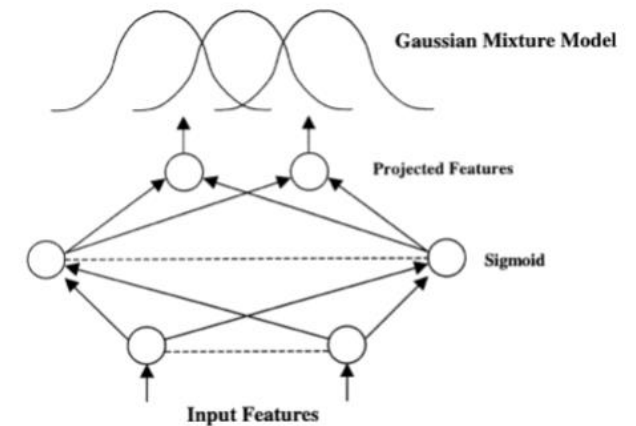
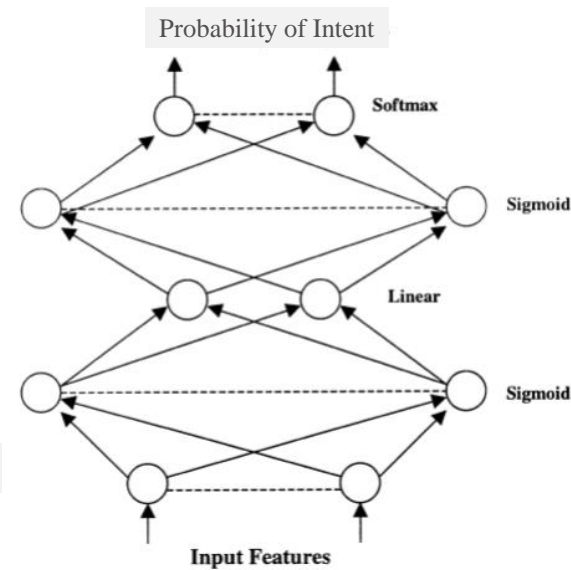
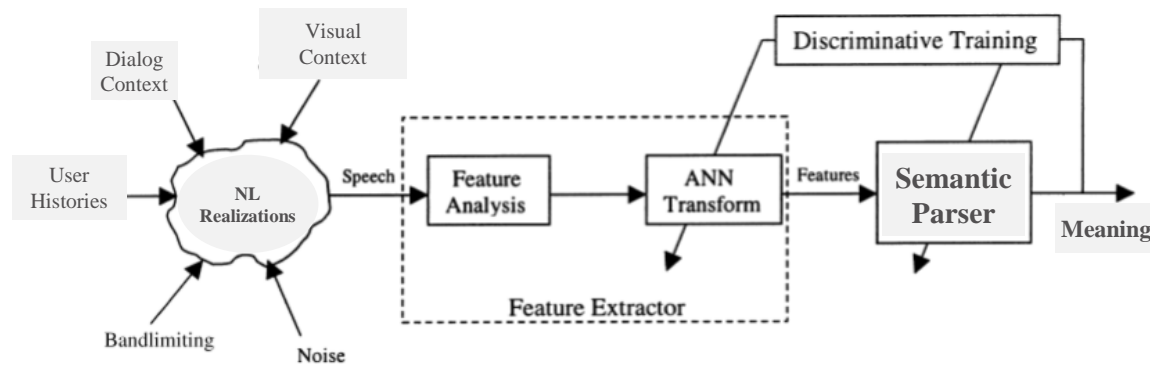


#1 Improvement in NIST 1998 Speaker Recognition Evaluations (+28% ERR)

Larry Heck, Yochai Konig, M. Kemal Sonmez, and Mitch Weintraub, Robustness to Telephone Handset Distortion in Speaker Recognition by Discriminative Feature Design, in *Speech Communication*, Elsevier, 2000

Deep Learning for Robust Semantic Parsing

Learn the fundamental *features of natural language*



Deep Learning from Knowledge Graphs

Learn the fundamental *language of knowledge*

Larry Heck, Yochai Konig, M. Kemal Sonmez, and Mitch Weintraub, Robustness to Telephone Handset Distortion in Speaker Recognition by Discriminative Feature Design, in *Speech Communication*, Elsevier, 2000

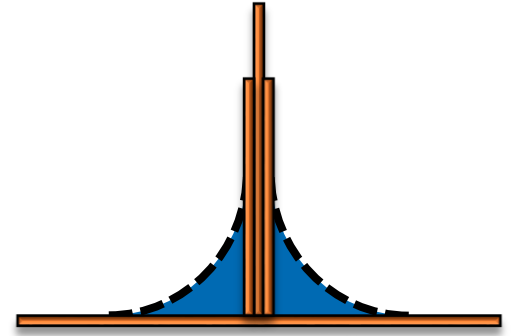
Yochai Konig, Larry Heck, Mitch Weintraub, and M. Kemal Sonmez, Nonlinear Discriminant Feature Extraction for Robust Text-Independent Speaker Recognition, in *RLA2C*, 1998

Po-Sen Huang, Xiaodong He, Jianfeng Gao, Li Deng, Alex Acero, and Larry Heck, Learning Deep Structured Semantic Models for Web Search using Clickthrough Data, *ACM International Conference on Information and Knowledge Management (CIKM)*, October 2013

Larry Heck, Deep Learning from Structured Knowledge Graphs, *Interspeech (to be submitted)*, *International Speech Communication Association (ISCA)*, 2014.

Summary

Conversational Systems with Depth & Breadth



Breadth

Conversational Search and Browse

Depth

Conversational Knowledge Graphs (replacing manually crafted domains)

"Crystals" of knowledge

Breadth *and* Depth

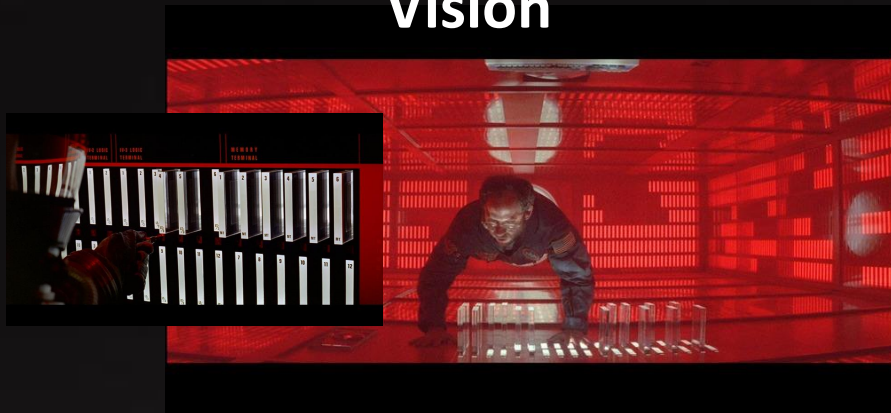
Unsupervised/Weakly-supervised learning methods

Data mining directed by the knowledge graph → *enriched knowledge graphs*

Multi-turn dialog models *compose* entities: learned from Web (IE)

Deep learning from structured knowledge graphs

Vision



Strategy



Thank you