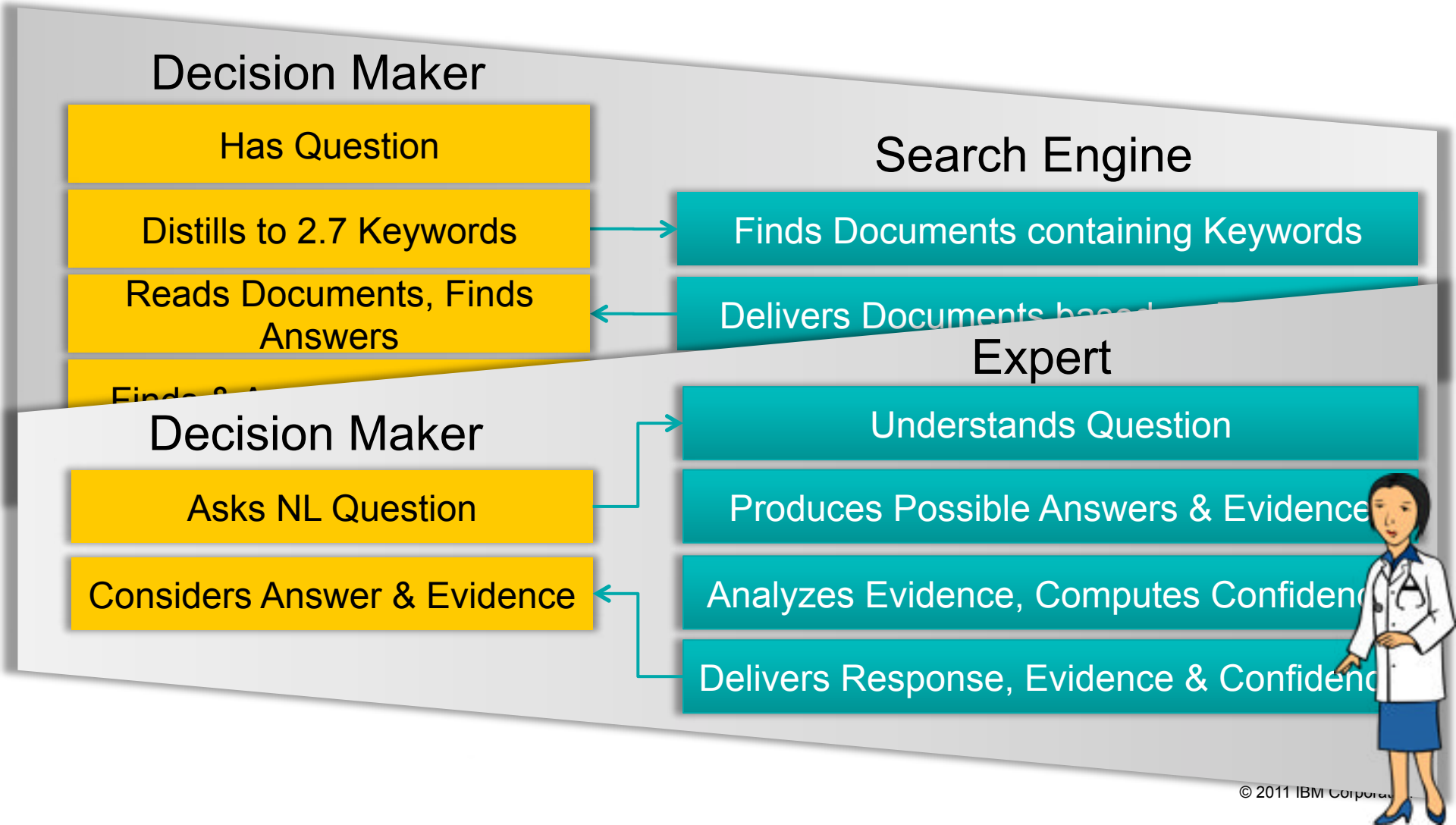
What is Watson?

David Gondek, Ph.D.
Knowledge Capture and Learning
Watson Healthcare Adaptation
IBM Research

Watson

The Future of Watson?

Informed Decision Making: Search vs. Expert Q&A



The Jeopardy! Challenge: *A compelling and notable way to **drive** and **measure** the technology **of automatic Question Answering** along 5 Key Dimensions*

- **Broad/Open Domain**
- **Complex Language**
- **High Precision**
- **Accurate Confidence**
- **High Speed**

$200
Keanu Reeves had a Nokia phone, but it took a land line to slip in & out of this, the title of a 1999 sci-fi flick

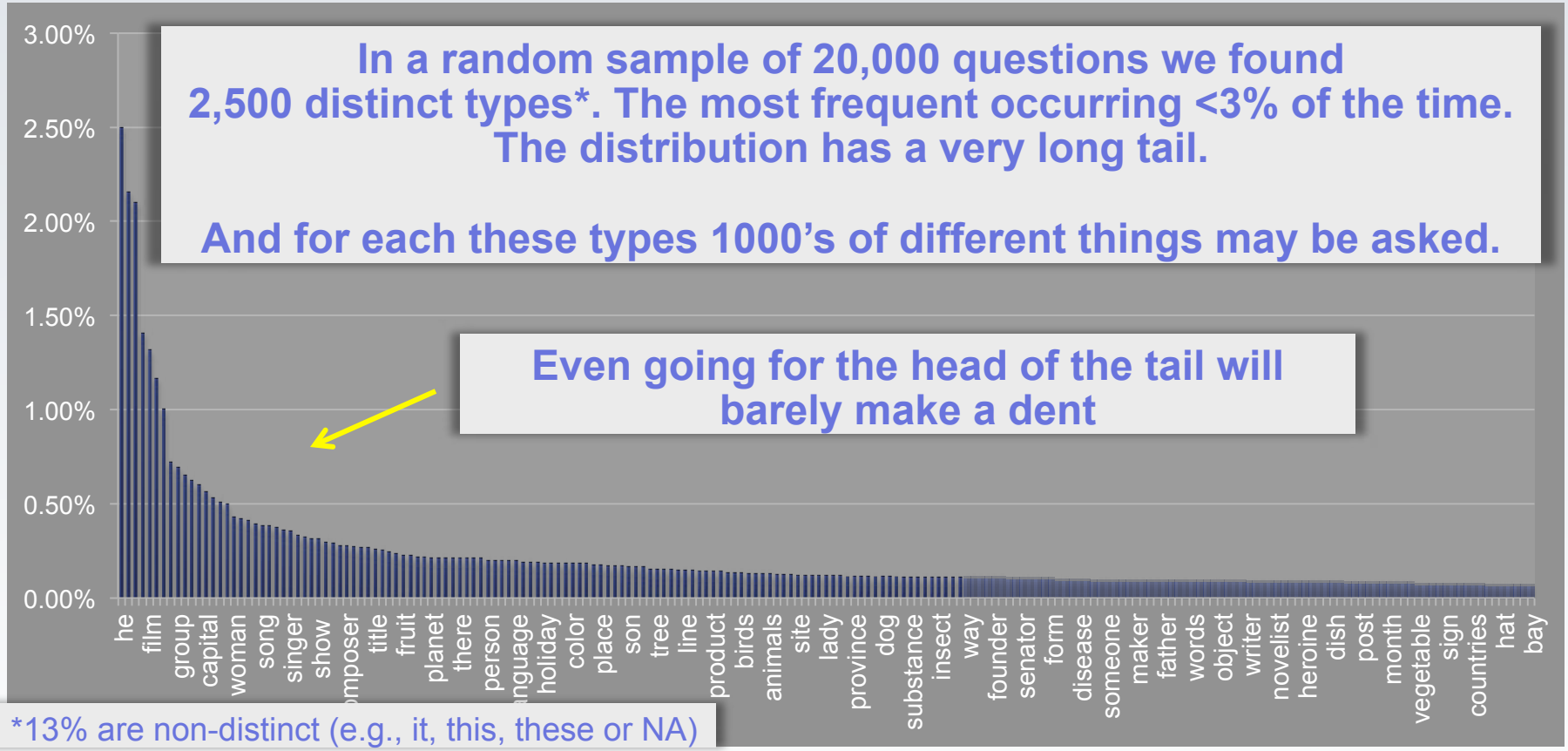
$1000
1948: Johns Hopkins scientists find that this antihistamine alleviates motion sickness

$600
In cell division, mitosis splits the nucleus & cytokinesis splits this liquid *cushioning* the nucleus

$2000
The first person mentioned by name in 'The Man in the Iron Mask' is this hero of a previous book by the same author.

Broad Domain

We do NOT attempt to anticipate all questions and build specialized databases.



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Our Focus is on reusable NLP technology for analyzing volumes of *as-is* text. Structured sources (DBs and KBs) are used to help interpret the text.

Automatic Open-Domain Question Answering

A Long-Standing Challenge in Artificial Intelligence to emulate human expertise

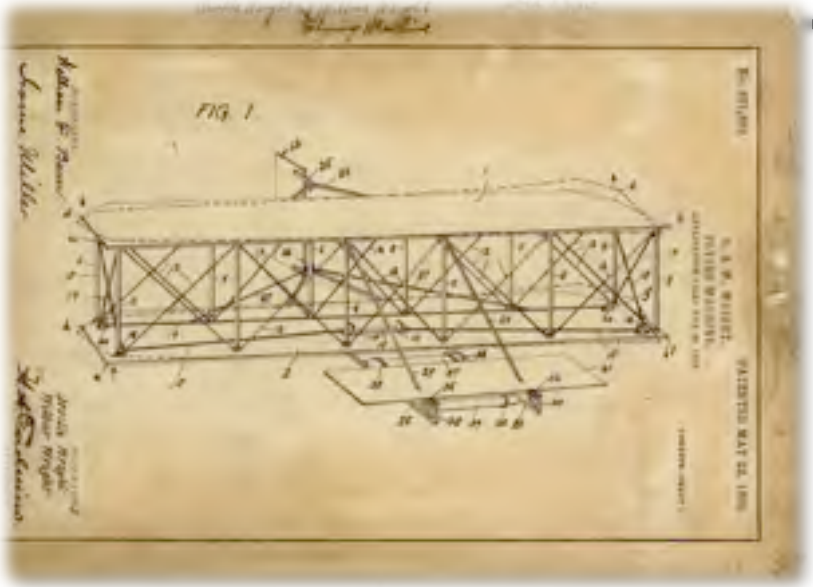
- Given
  - Rich **Natural Language Questions**
  - Over a **Broad Domain of Knowledge**
- Deliver
  - **Precise Answers:** Determine what is being asked & give precise response
  - **Accurate Confidences:** Determine likelihood answer is correct
  - **Consumable Justifications:** Explain why the answer is right
  - **Fast Response Time:** Precision & Confidence in <3 seconds

From Chess to Chatting

- Chess
  - A finite, mathematically well-defined search space
  - Limited number of moves and states
  - All the symbols are completely grounded in the mathematical rules of the game

- Human Language
  - Words by themselves have no meaning
  - Only grounded in **human cognition**
  - Words navigate, align and communicate an infinite space of intended meaning
  - Computers can **not** ground words to human experiences to derive meaning

Distance between question and justifying passage

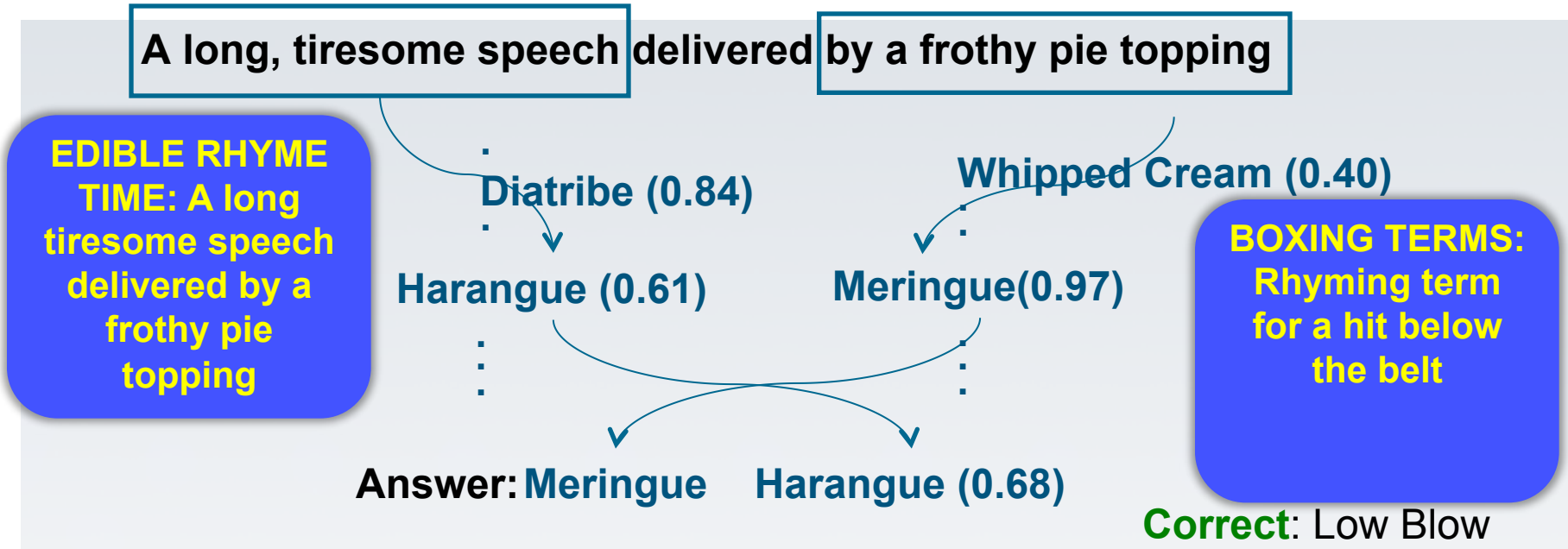


The Wright brothers' first flight was this long.

The Wright brother's first flight was 120 feet long

With Orville at the controls and Wilbur running along side to steady the wing, the plane rose 12 feet into the air and went about 120 feet on its 12-second trip. This marked the beginning of air travel for mankind.

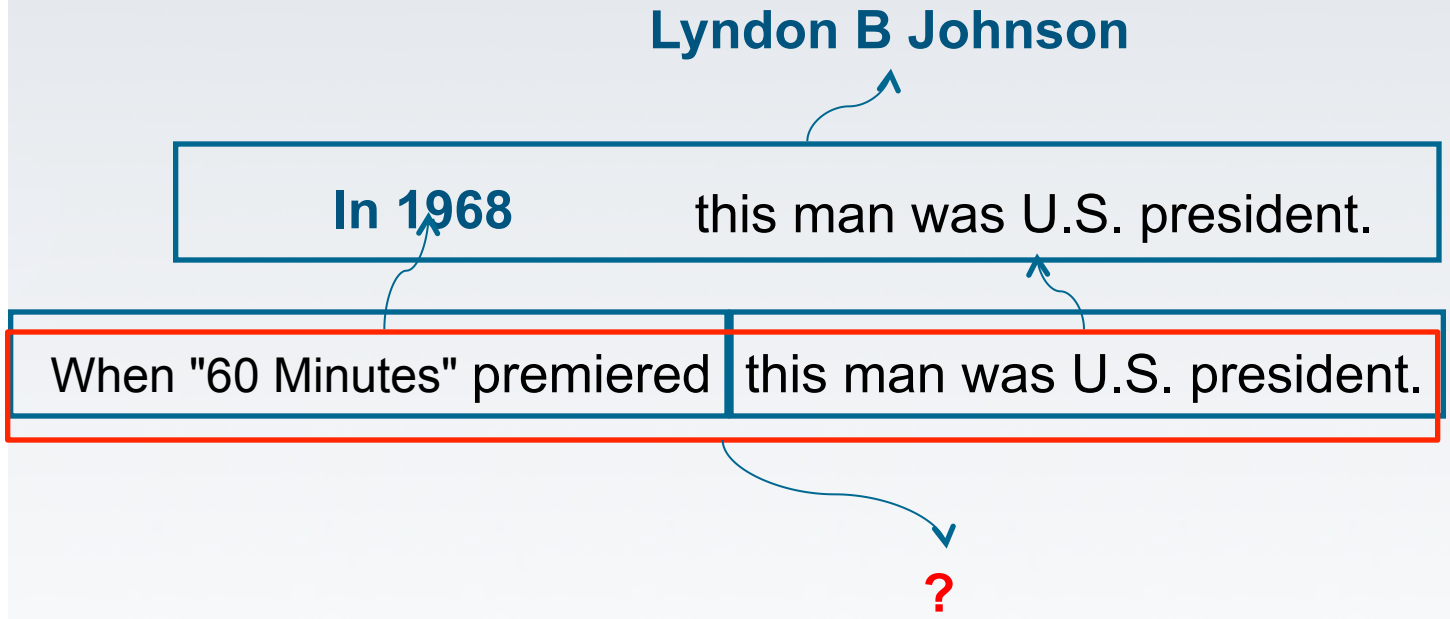
Decomposition and Synthesis



Some Questions require Decomposition and Synthesis

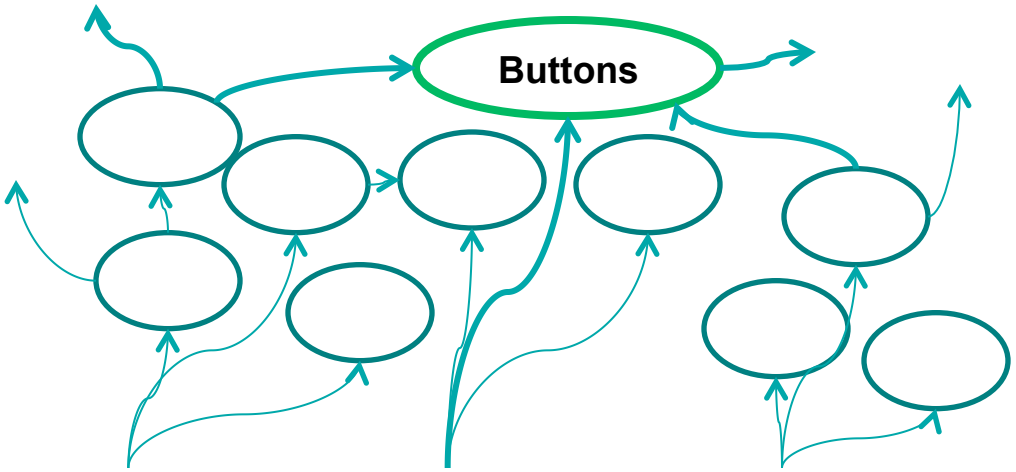
Divide and Conquer
(Typical in Final Jeopardy!)

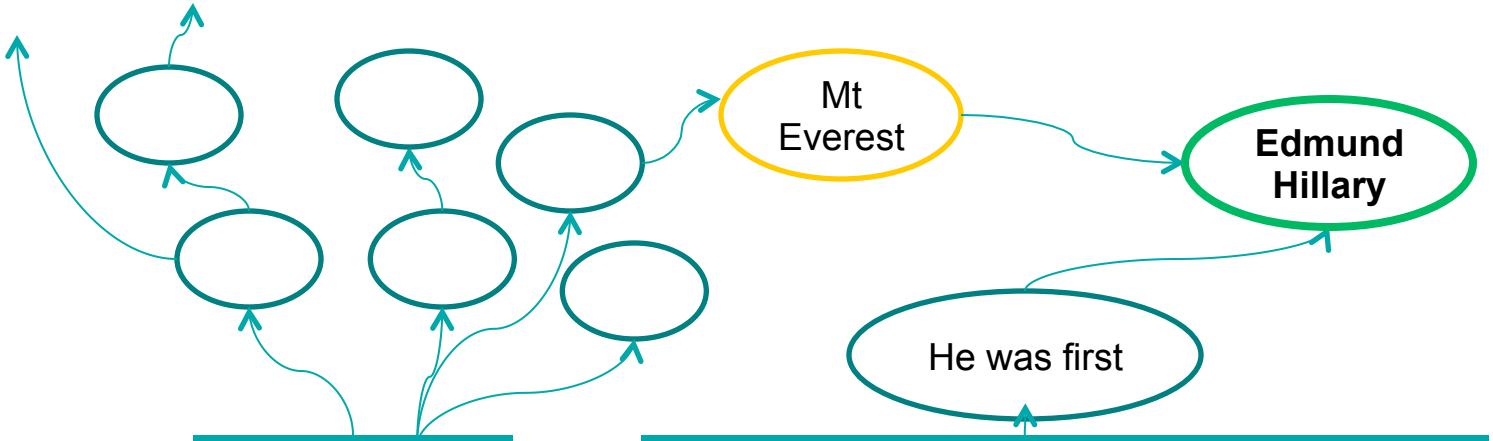
Must identify and solve sub-questions from different sources to answer the top level question



The DeepQA architecture attempts different *decompositions* and recursively applies the QA algorithms

The Missing Link



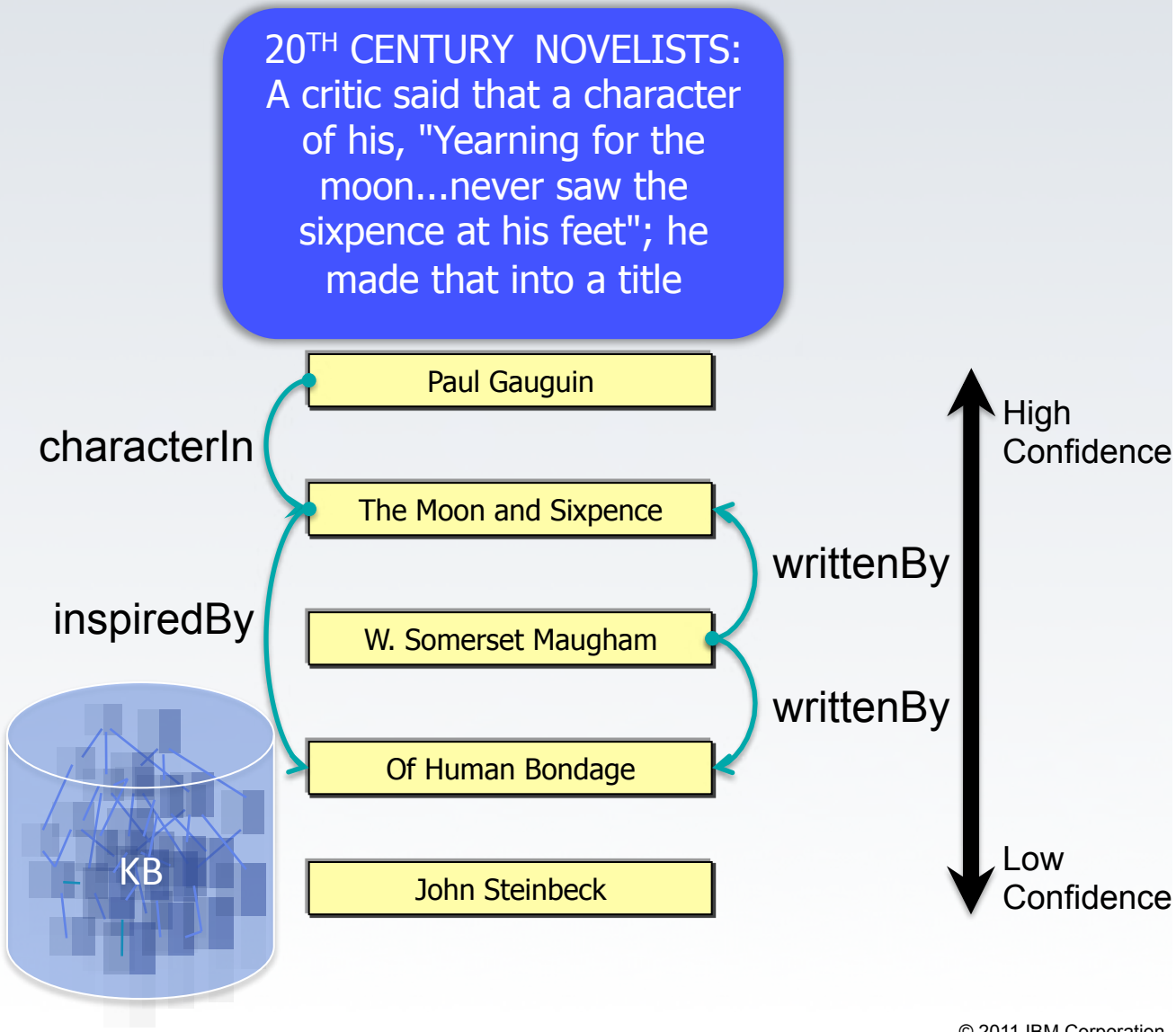


On hearing of the discovery of George Mallory's body, he told reporters he still thinks he was first.

Evidence Diffusion

Watson's Candidate Answers are not independent.

By sharing evidence based on the relationships between candidate answers we raise the score of the right answer



Category Inference

- What the Jeopardy! Clue is asking for is NOT always obvious
- Watson can try to infer the type of thing being asked for from the previous answers.
- In this example after seeing 2 correct answers Watson starts to dynamically learn a confidence that the question is asking for something that it can classify as a "**month**".

CELEBRATIONS OF THE MONTH

Clue	Type	Watson's Answer	Correct Answer
D-DAY ANNIVERSARY & MAGNA CARTA DAY	day	Runnymede	**June**
NATIONAL PHILANTHROPY DAY & ALL SOULS' DAY	day	Day of the Dead	November
NATIONAL TEACHER DAY & KENTUCKY DERBY DAY	day / month	Churchill Downs	May
ADMINISTRATIVE PROFESSIONALS DAY & NATIONAL CPAS GOOF-OFF DAY	month	April	April
NATIONAL MAGIC DAY & NEVADA ADMISSION DAY	month	October	October

Evidence Dimensions

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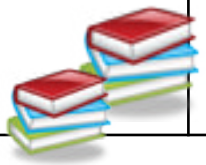
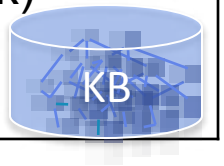
Keanu Reeves	had a Nokia Phone	took a land line to slip in & out of this	1999	Sci-fi flick

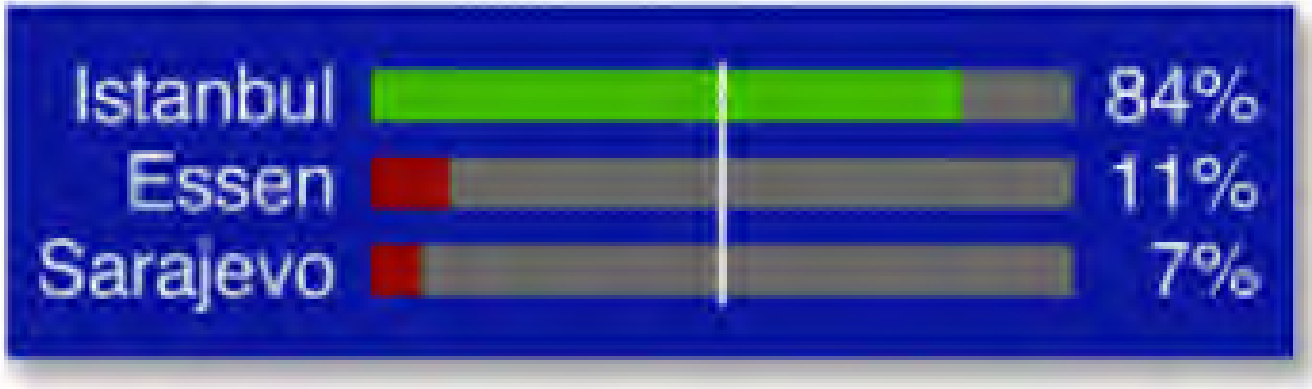
Justification	Evidence Dimensions				
Evidence Sources	KB: ActedIn(Keanu Reeves, X)	Text Passage: has(Keanu Reeves, Nokia)	Text Passage: Align	KB: OccurredIn(X, 1999)	KB: Isa(X,sci-fi flick)

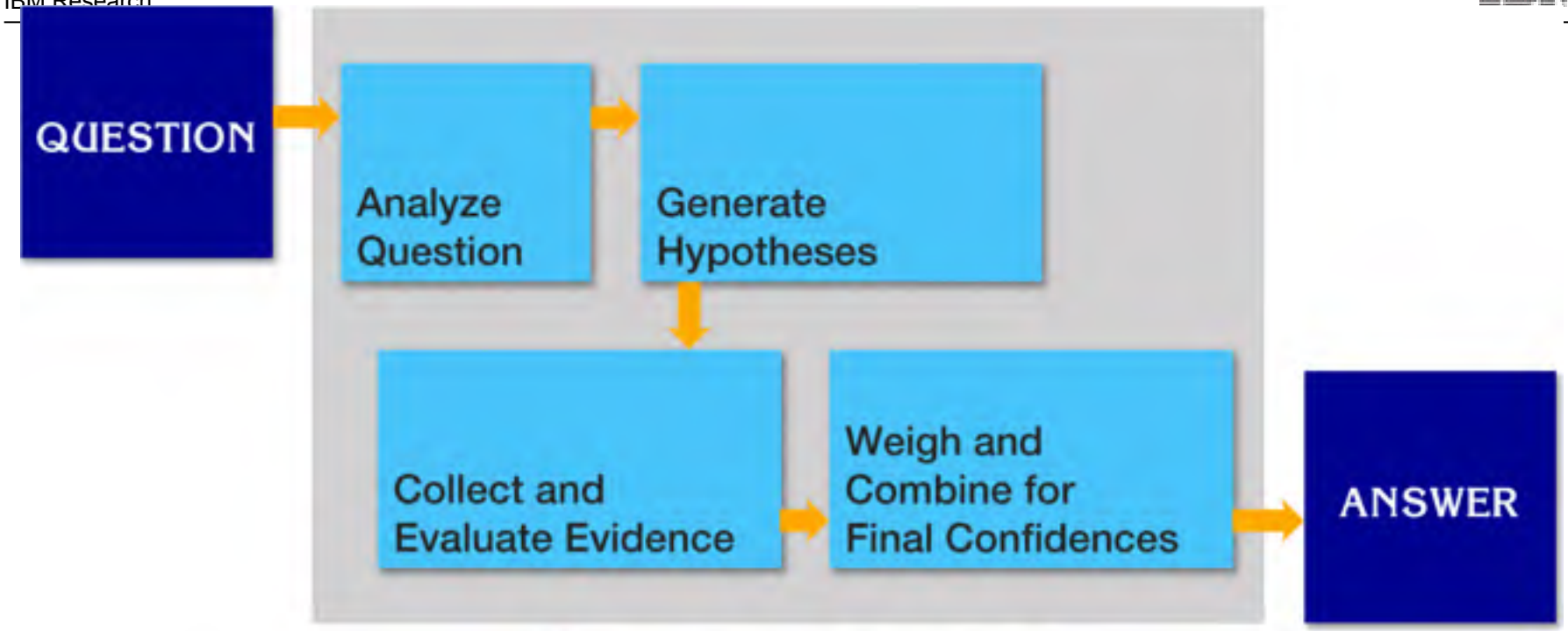


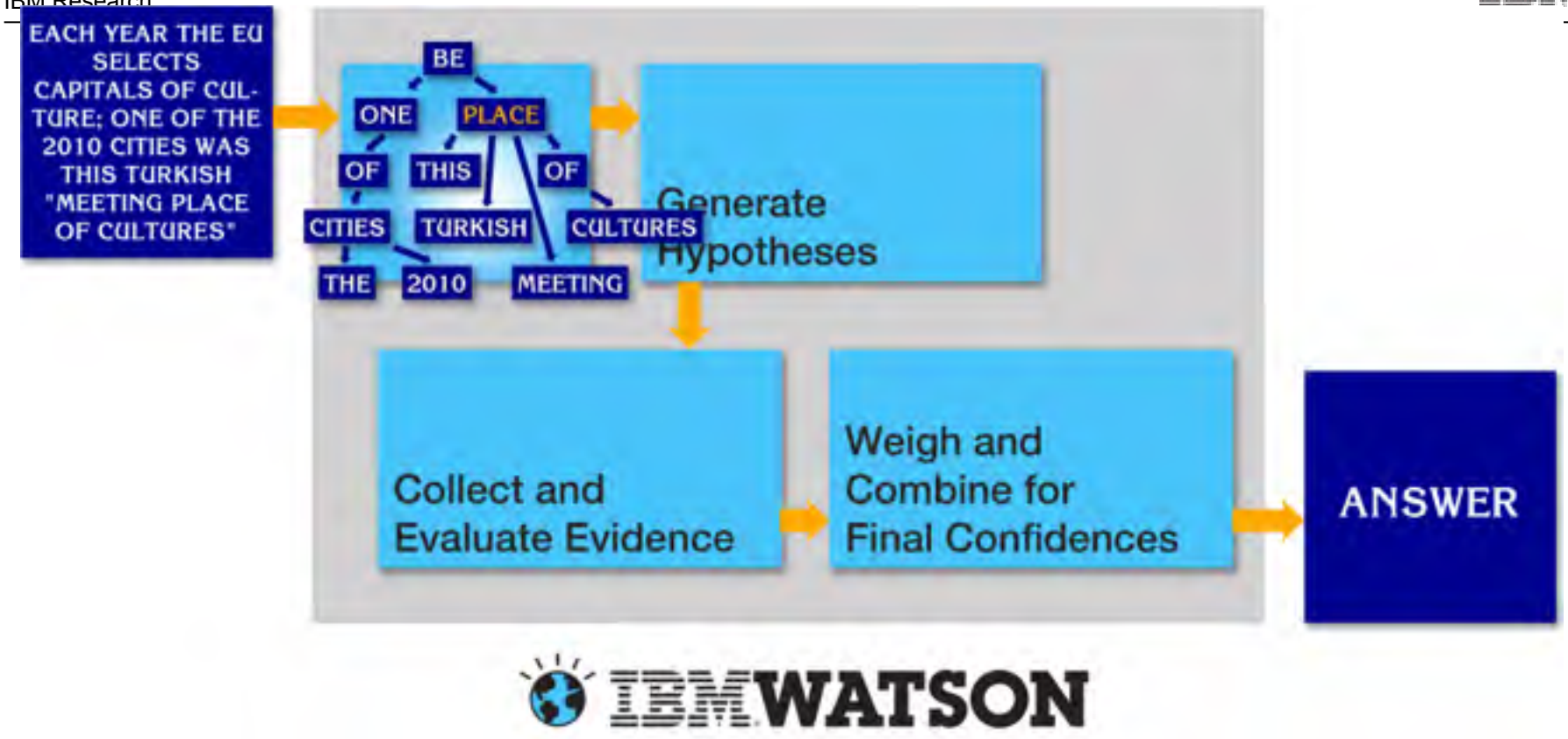


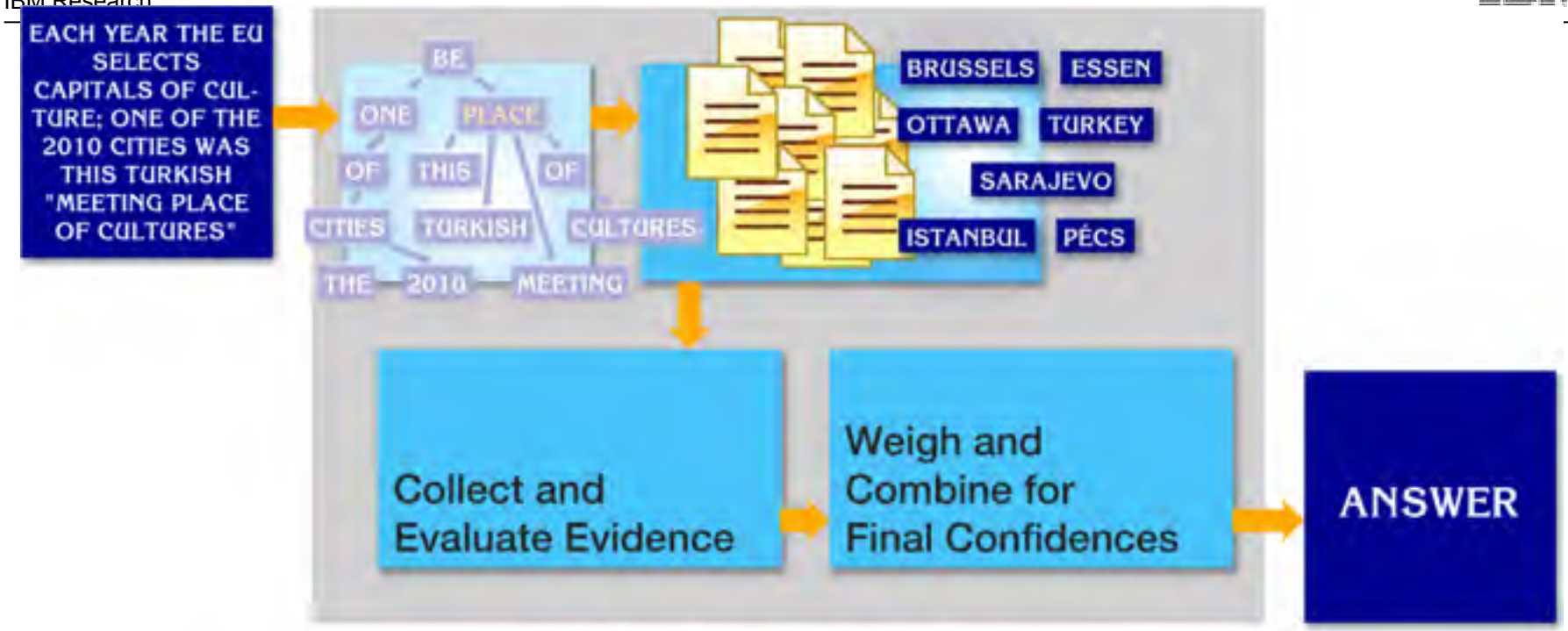
EACH YEAR THE EU SELECTS CAPITALS OF CULTURE; ONE OF THE 2010 CITIES WAS THIS TURKISH "MEETING PLACE OF CULTURES"

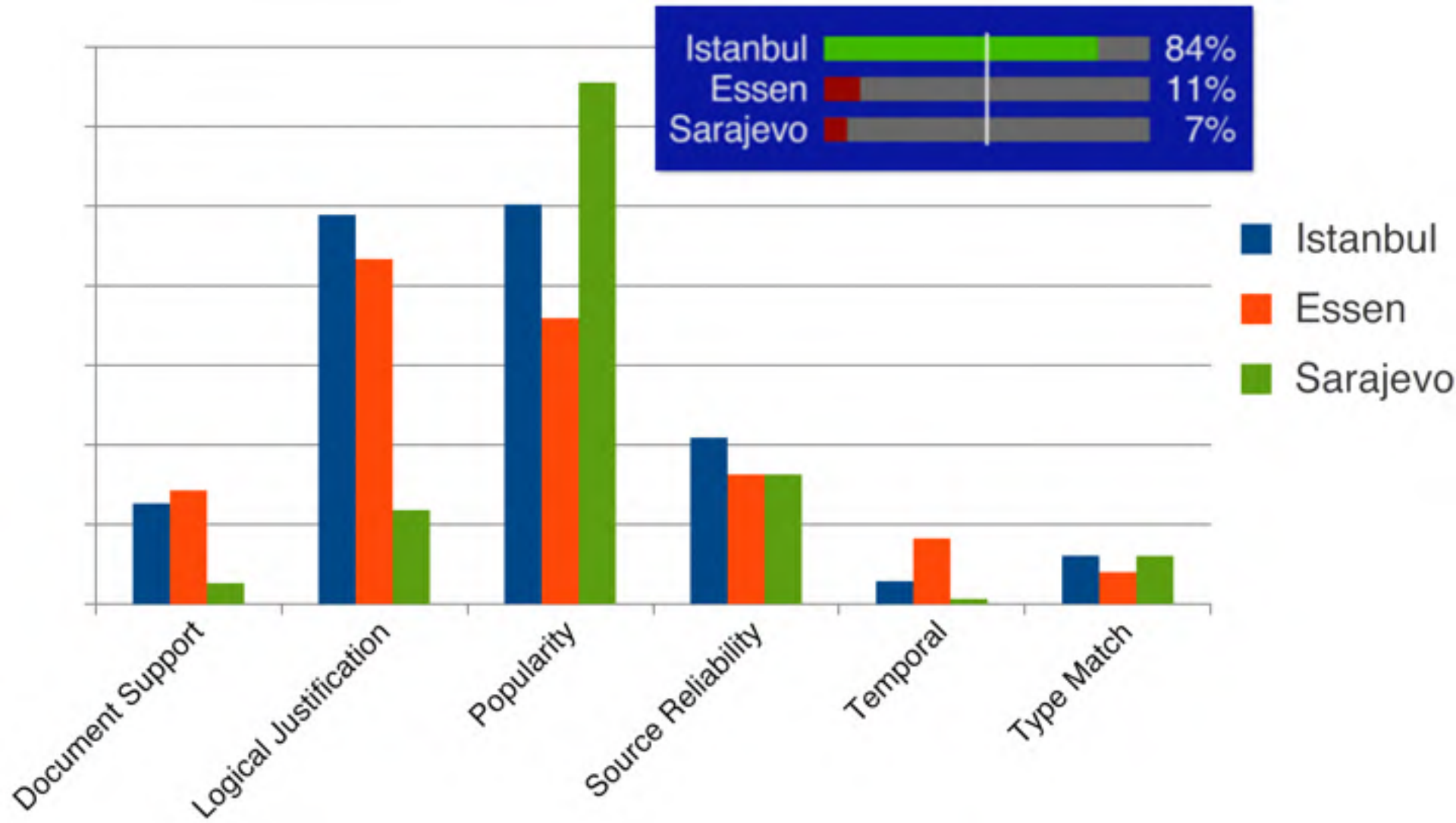
WHAT IS ISTANBUL? ✓







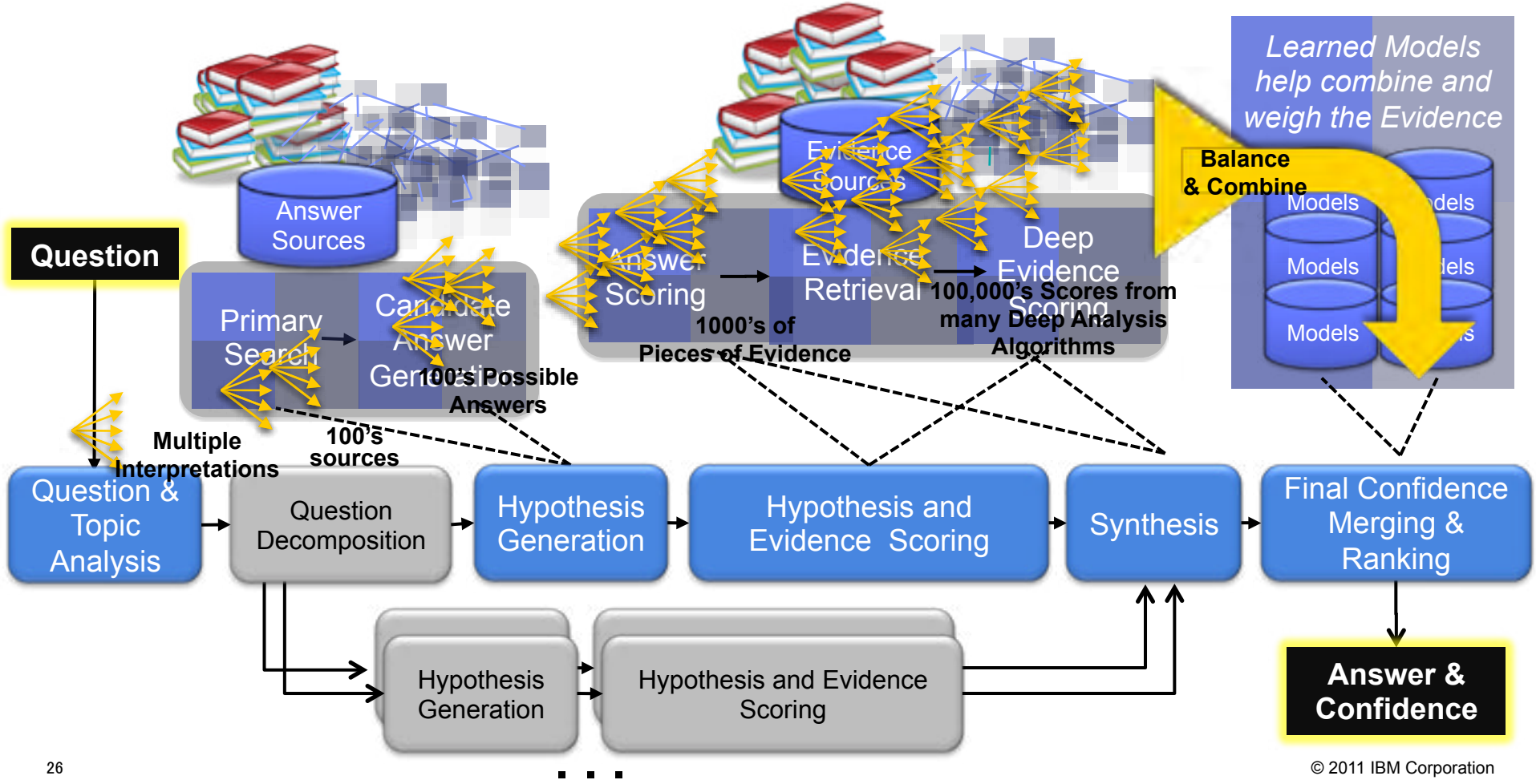




DeepQA: The Technology Behind *Watson*

Massively Parallel Probabilistic Evidence-Based Architecture

Generates and scores many hypotheses using a combination of 1000's ***Natural Language Processing***, ***Information Retrieval***, ***Machine Learning*** *and* ***Reasoning Algorithms.*** *These gather, evaluate, weigh and balance different types of* ***evidence*** *to deliver the answer with the best support it can find.*

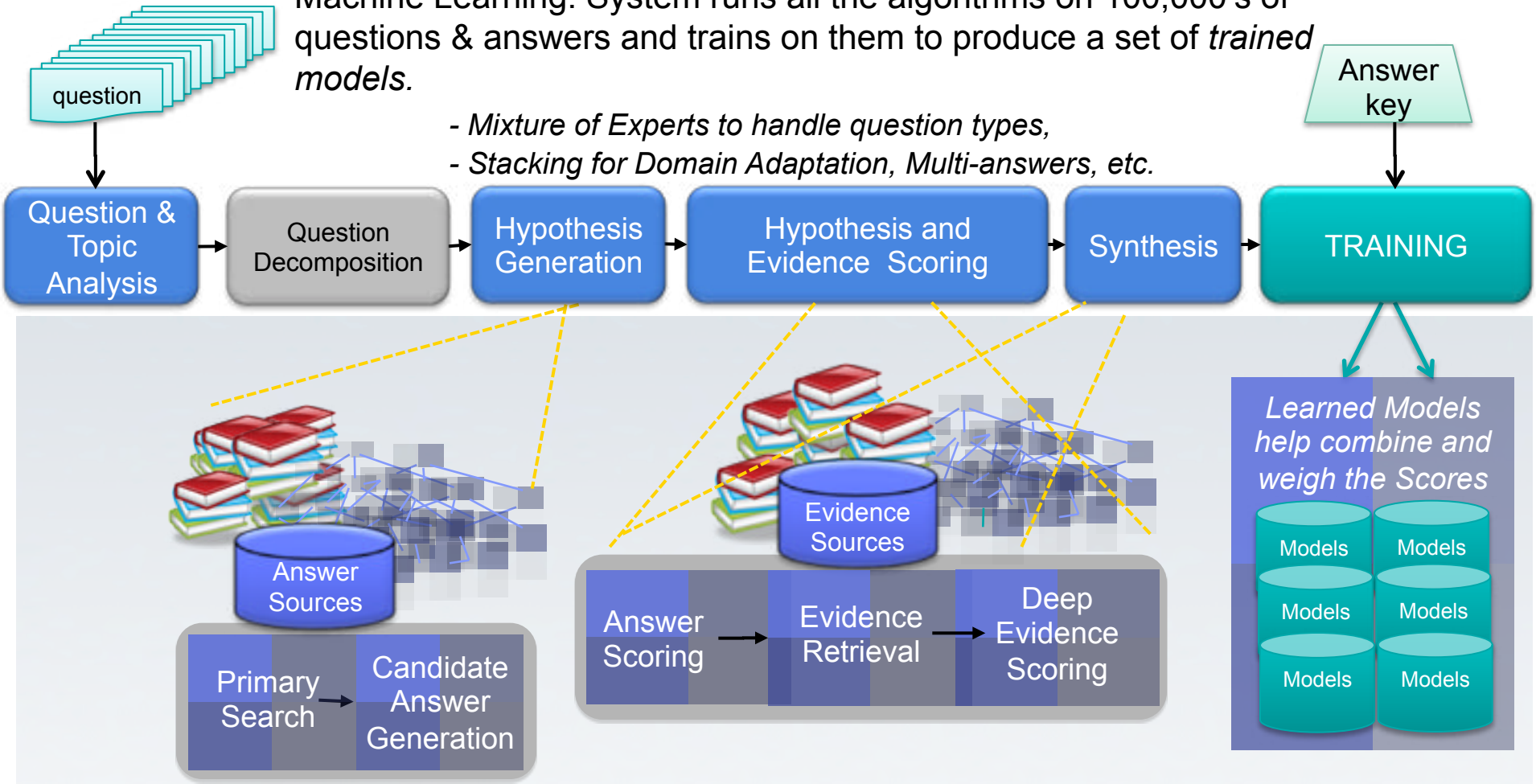


Machine Learning: Train Time

Train-time

Machine Learning: System runs all the algorithms on 100,000's of questions & answers and trains on them to produce a set of *trained models.*

- *Mixture of Experts to handle question types,*
- *Stacking for Domain Adaptation, Multi-answers, etc.*

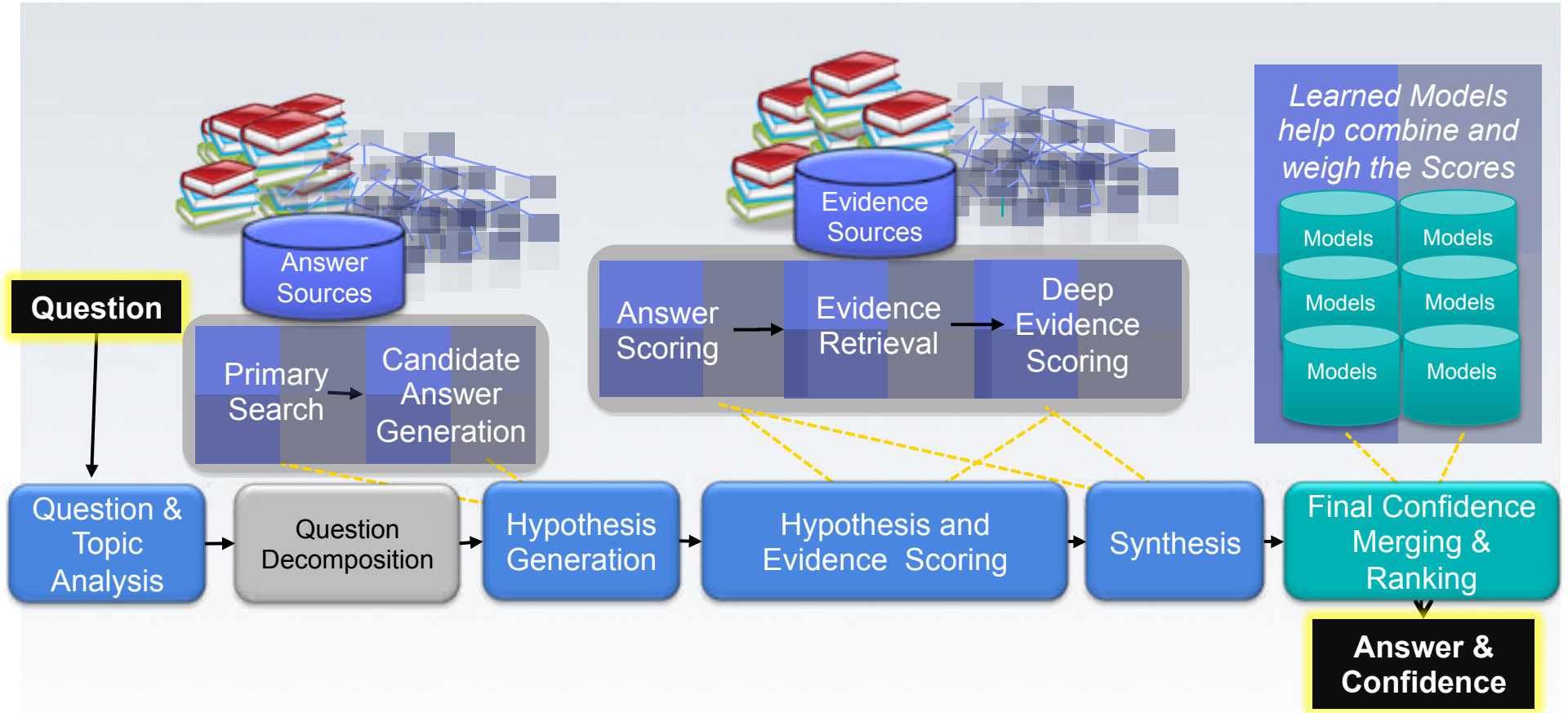


In 4 years DeepQA has trained for over 8500 recorded experiments

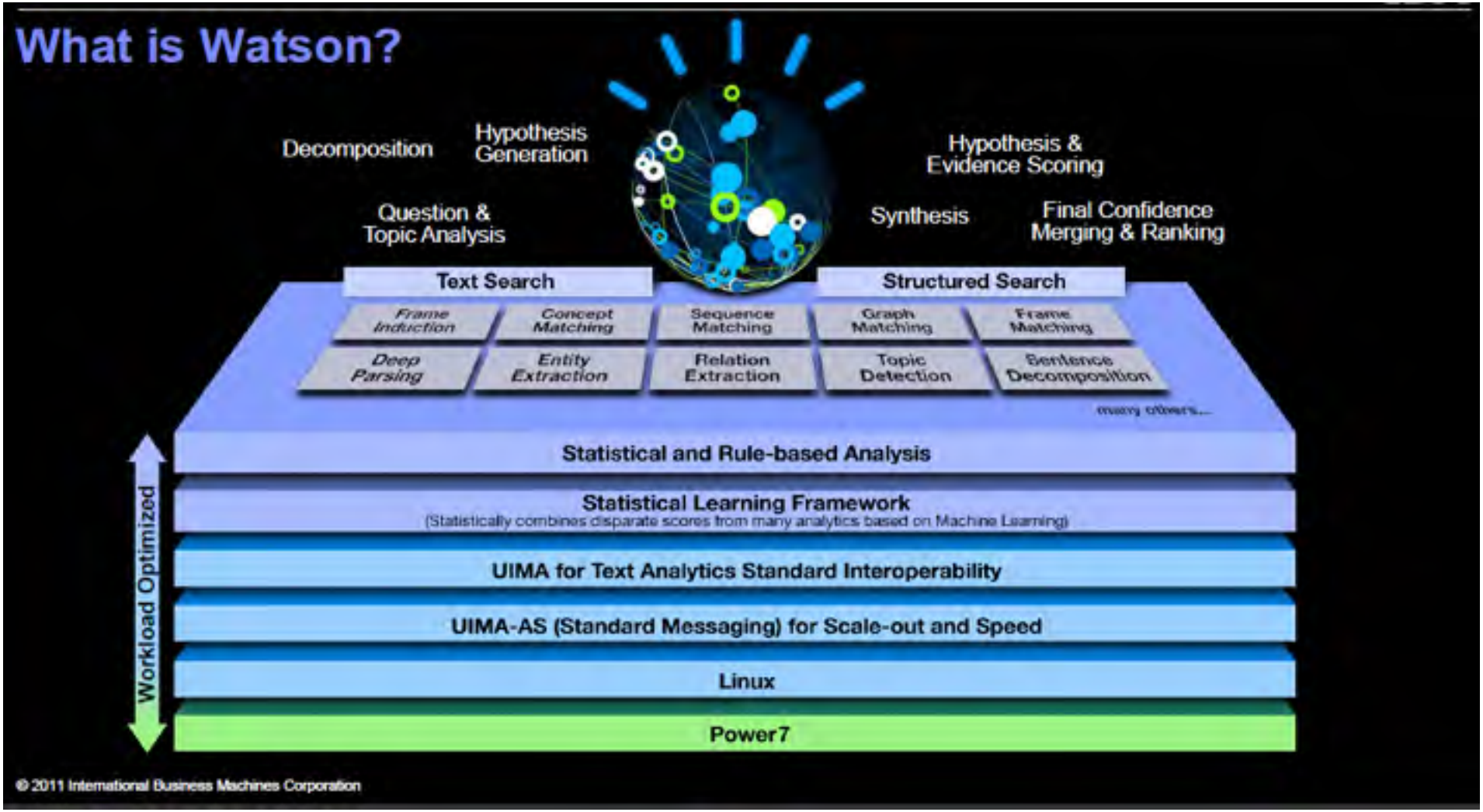
Apply Time

System runs all the algorithms on a *single question* and applies models to the features they produce to select an answer with a confidence

Apply-time

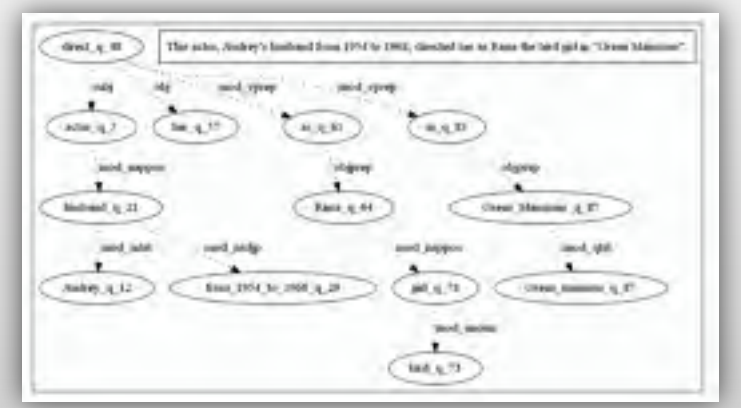


Run-Time Stack: Natural Language Processing on top of a complex stack



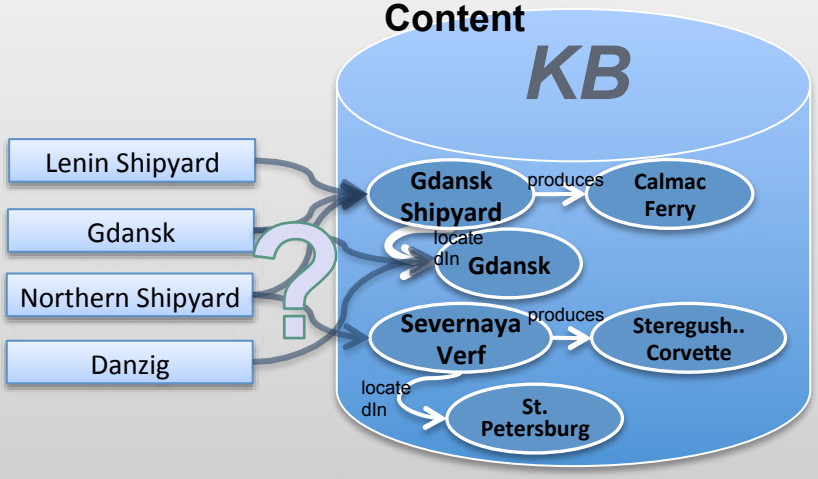
DeepQA NLP Analytic Highlights

Question Processing



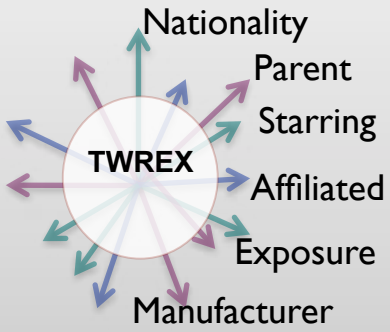
Dependency parse, Focus/LAT detection: 6000 rules, Decompisition

KAFE: Knowledge Acquisition From Extracted Content



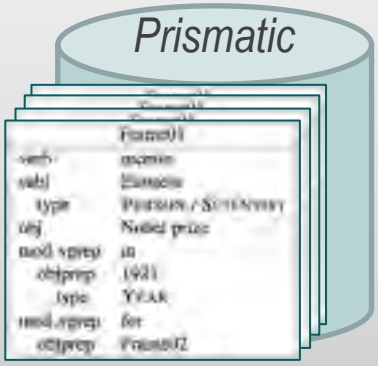
Entity Disambiguation, Entity Typing, Type Disambiguation

Relation Extraction



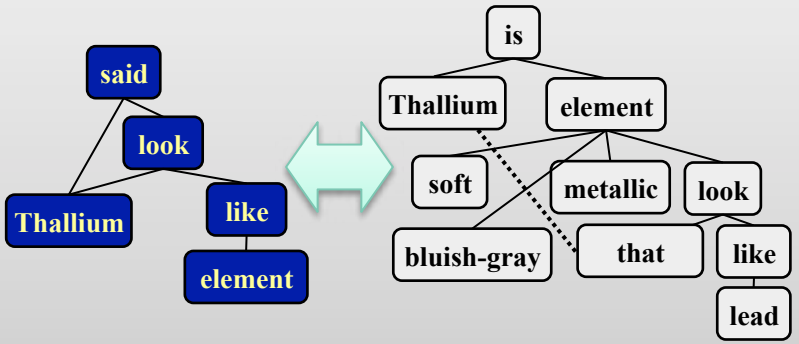
Semantic Relation Repository 7000 rels

Linguistic Frame Extraction



1.8B Linguistic frames: paraphrase, ontology population, selectional restrictions

Passage Matching Ensemble



Synonymy, Temporal/Geographic Reasoning, Linguistic Axioms

What is Watson?

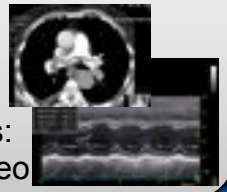
Decomposition
Hypothesis Generation
Hypothesis & Evidence Scoring
Question & Topic Analysis
Synthesis
Final Confidence Merging & Ranking
Text Search
Structured Search
Frame Induction
Concept Matching
Sequence Matching
Graph Matching
Frame Matching

UIMA Interoperability

Unstructured Information Management Architecture

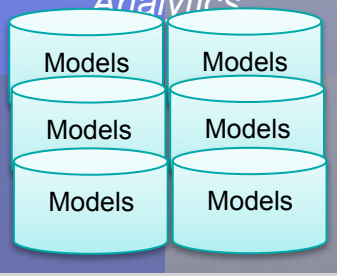
Loose Integration of Heterogeneous Analytics For Rapid Prototyping

Allows for Multimodal analytics: Image, Speech, Video



Statistical Integration of Analytics

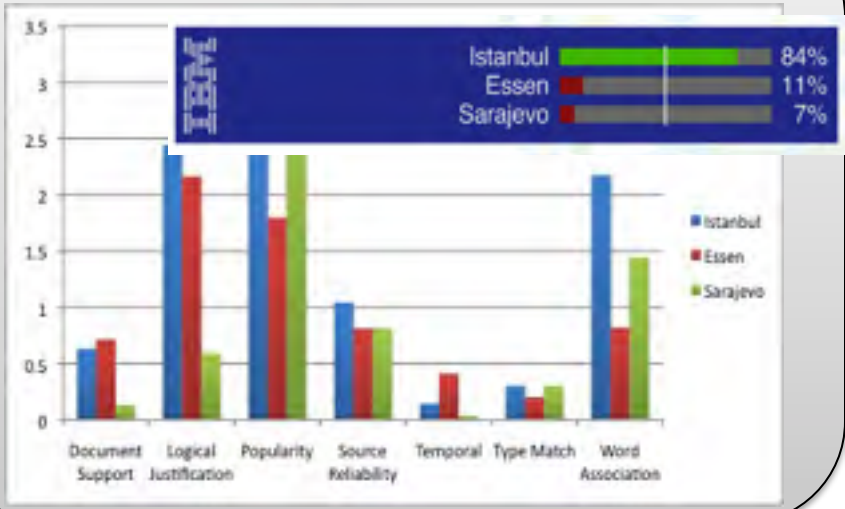
Trained Models combine and weigh Analytics



Register scores from analytics
Estimate confidence in hypothesis

- *Answer ranking and confidence estimation*
- *Different question classes*
- *Small training sets*
- *Hypothesis decomposition and synthesis*

Confidence and Evidence Dimensions



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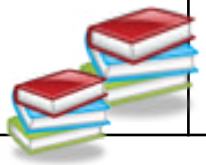
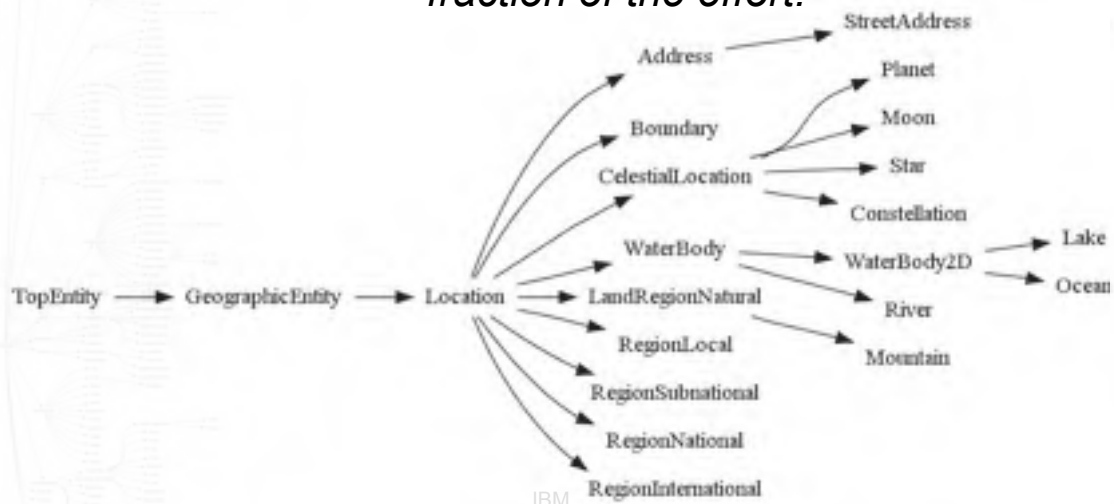


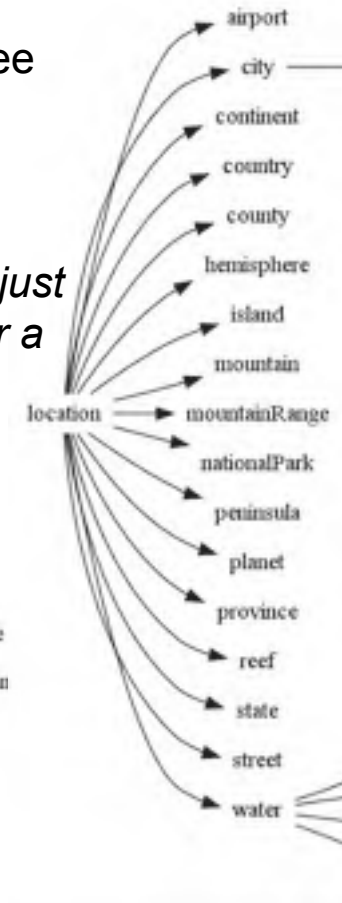
Taxonomies and Named Entity Detectors

HUTT

Ephyra

- ***Adding a component which identifies types of entities***
  - Reconciling ontologies is a difficult, labor-intensive process
    - Ontologies overlap and disagree
  - ***DeepQA*** *allows for loose coupling: instead of reconciling ontologies, integrate as a new analytic*
  - *In this case, loose coupling worked just as well as ontology reconciliation for a fraction of the effort!*





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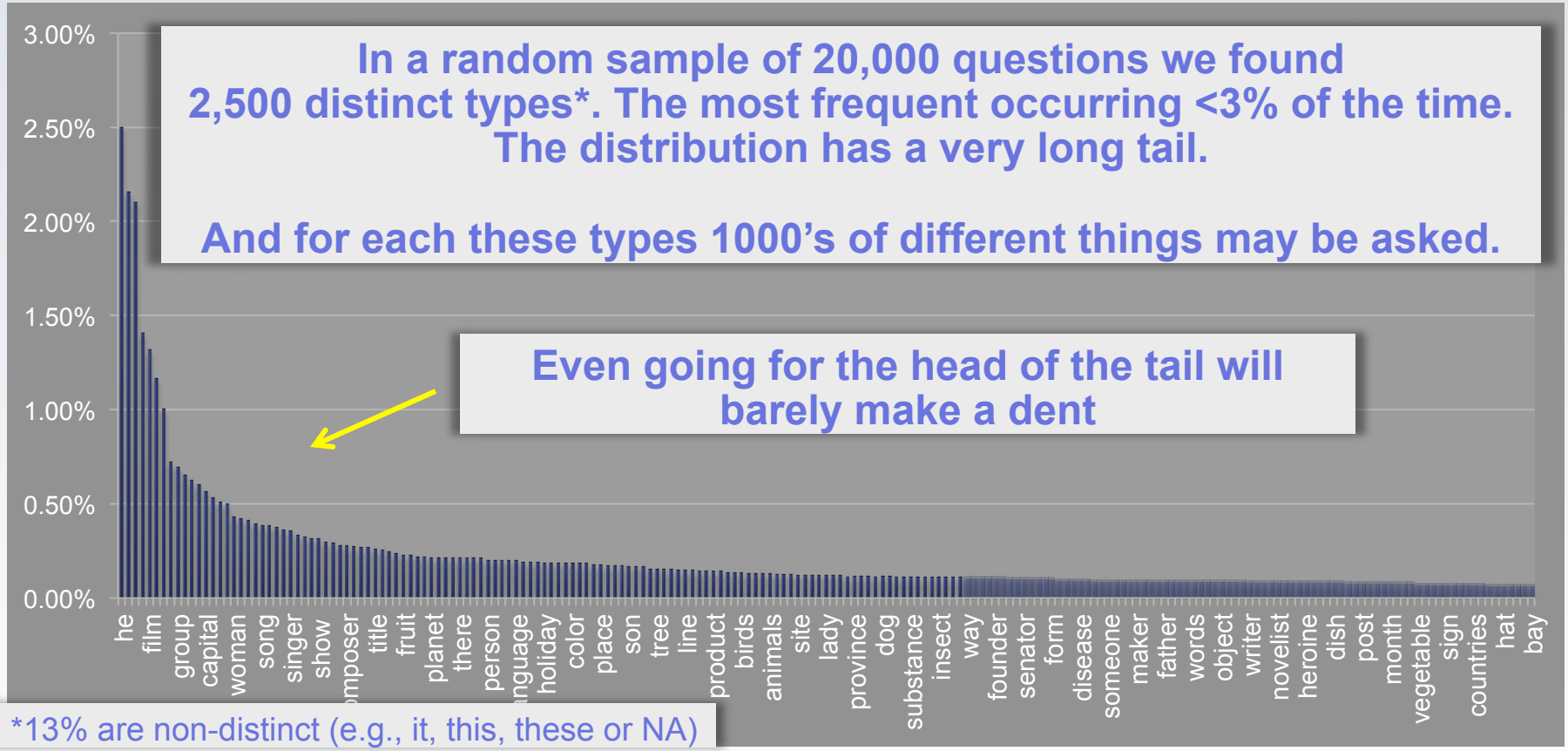

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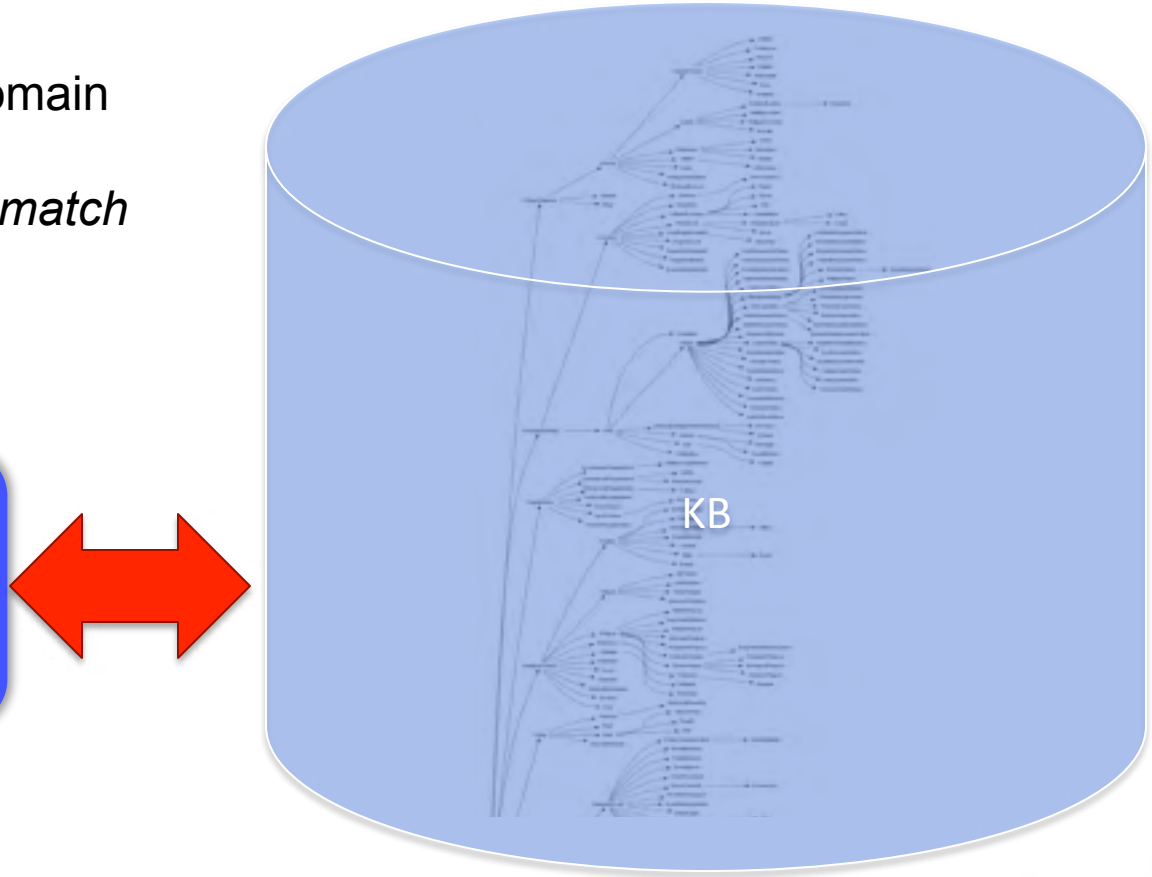
To Knowledge From Extractions (DeepQA KAFE framework)

Challenge in Open Domain Question Answering:
Question text doesn't match the ontology

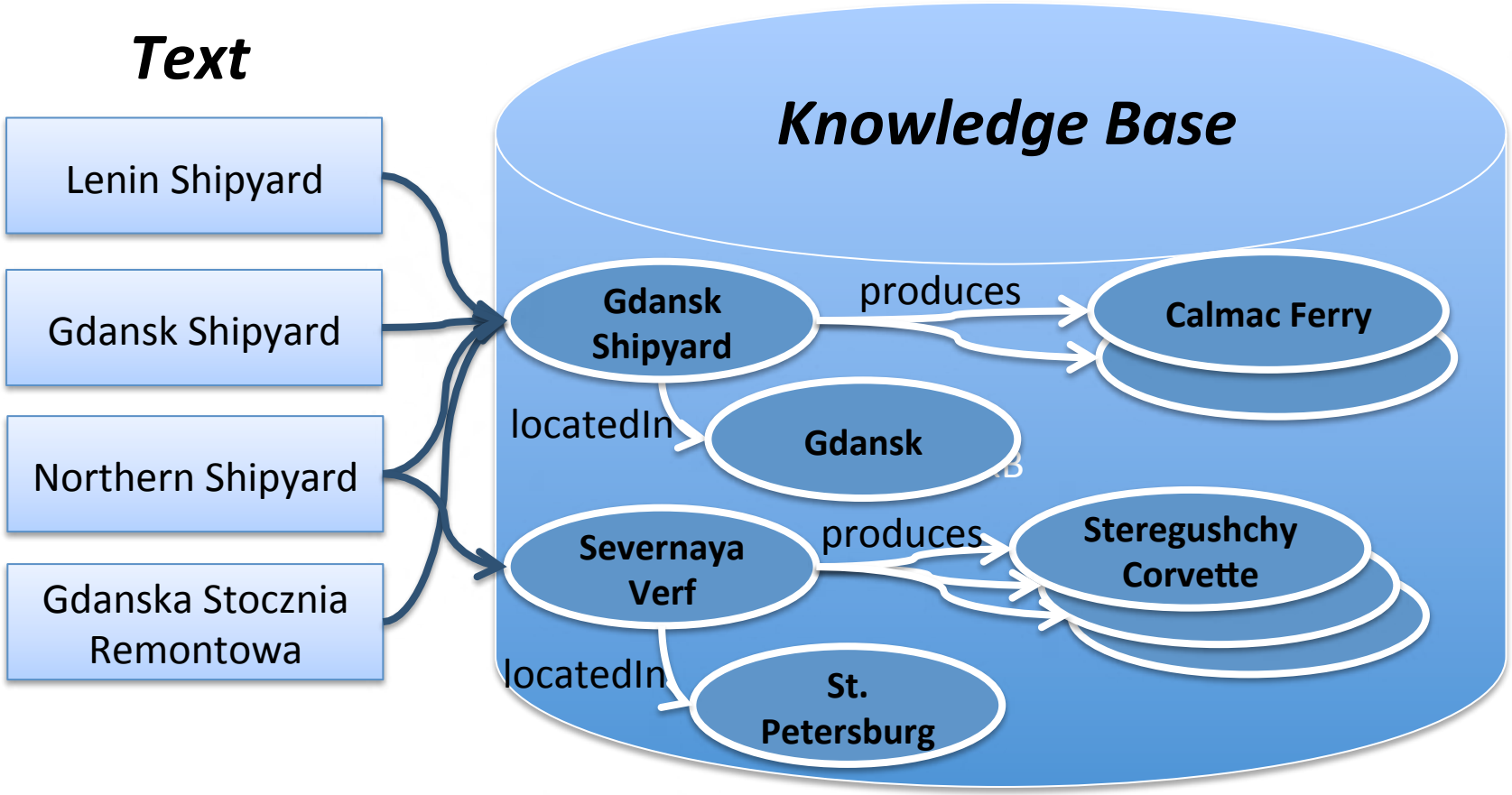
The Lenin shipyards in this Polish port city, where Solidarity began in the 1980s, were later renamed



Mapping Language to Knowledge: KAFE

The Lenin shipyards in this Polish port city, where Solidarity began in the 1980s, were later renamed

KaFe Stack
Instance to Type Mapping (IceT)
Verb/Predicte to Relation Mapping (Vrappe)
Type to Type Mapping (Latte)
Instance to Instance Mapping (CHAI)



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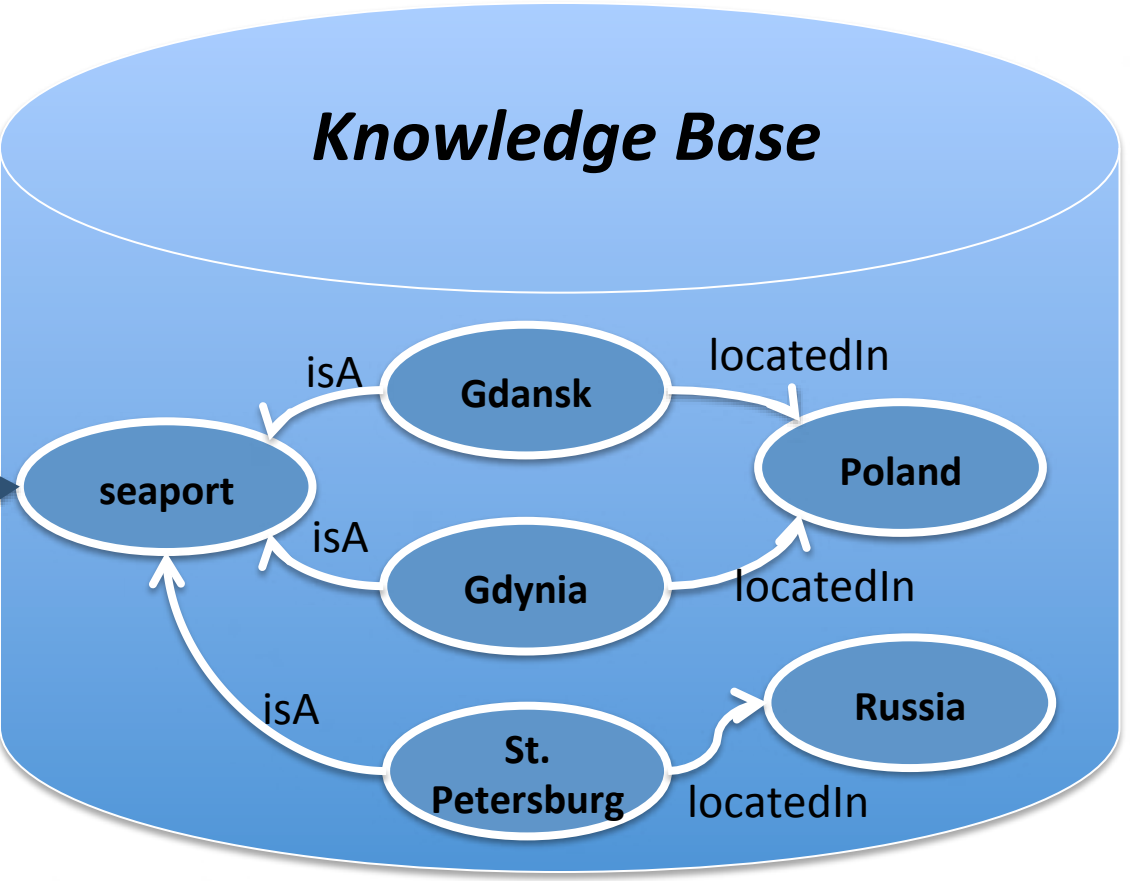
Text

port city



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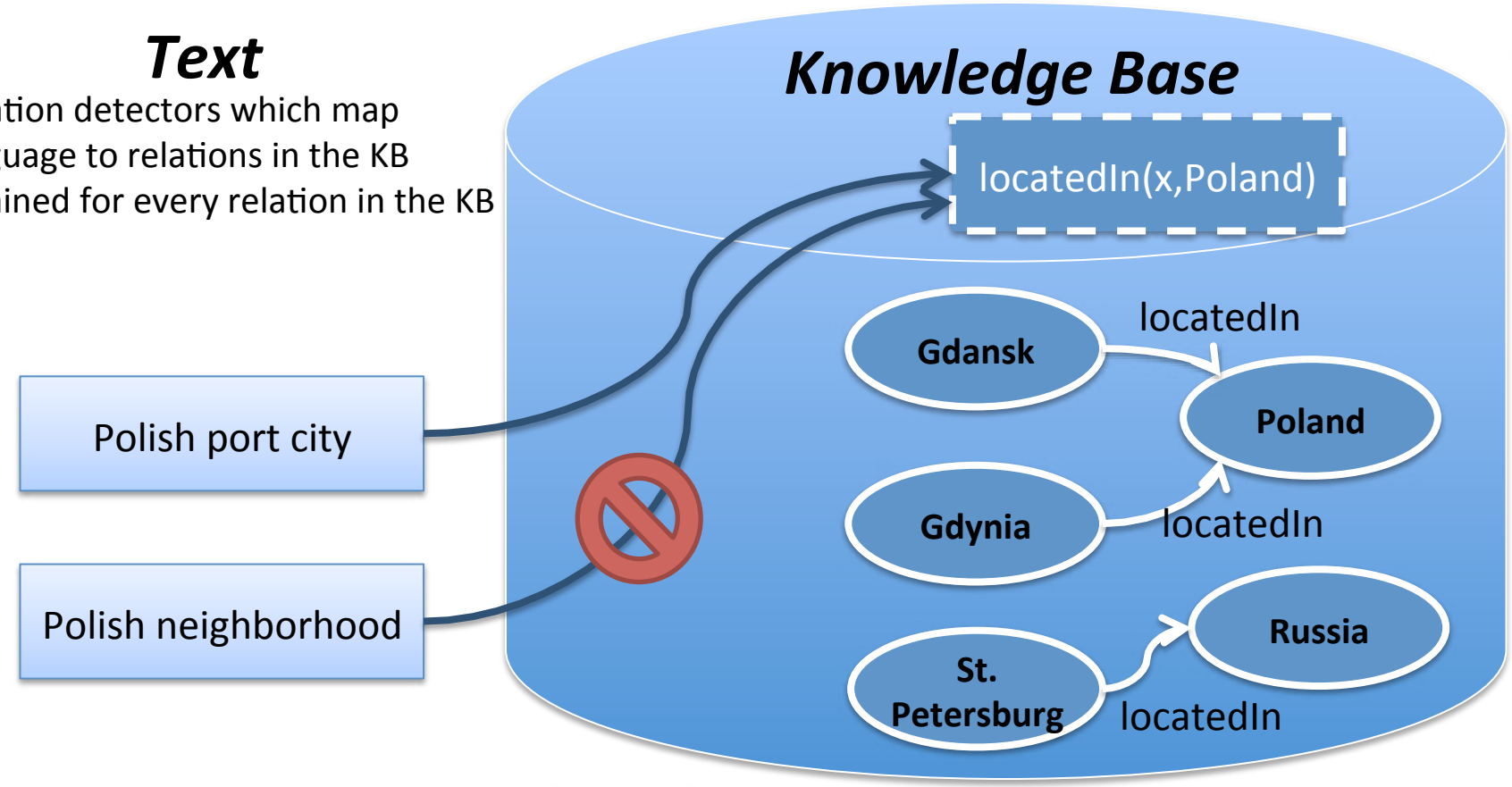
Text

Relation detectors which map language to relations in the KB

- trained for every relation in the KB

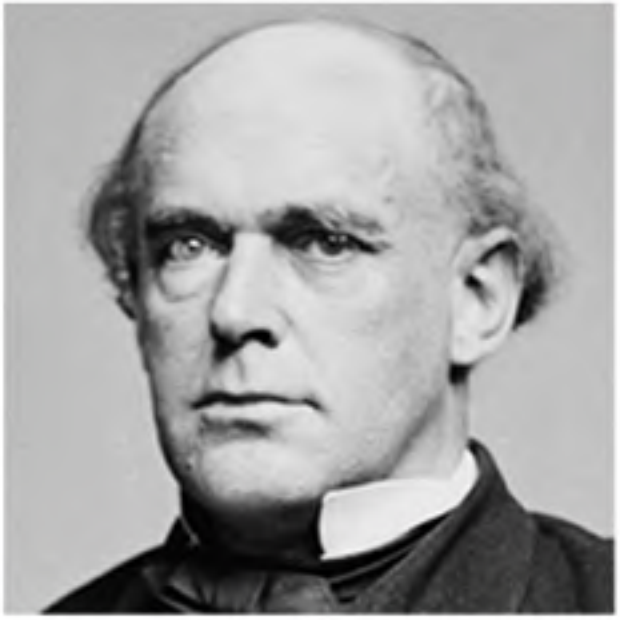


LINCOLN BLOGS

Secy. Chase just submitted this to me for the third time-- guess what, pal. This time I'm accepting it

Answer: his resignation

Treasury Secy. Chase wants to be friends with you.

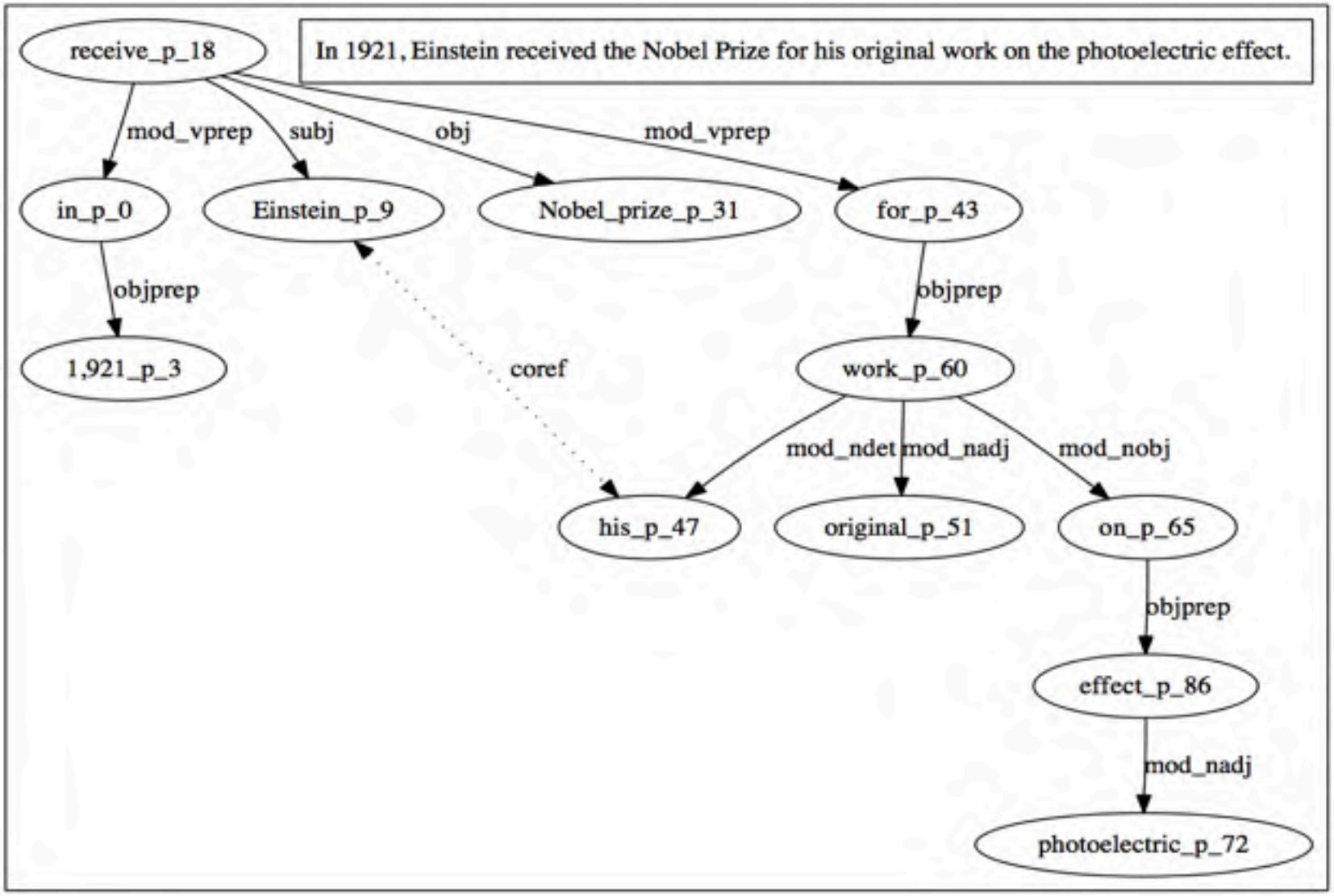


Treasury Secy. Chase

279 friends · 52 photos · 21 groups

Confirm Friend Request

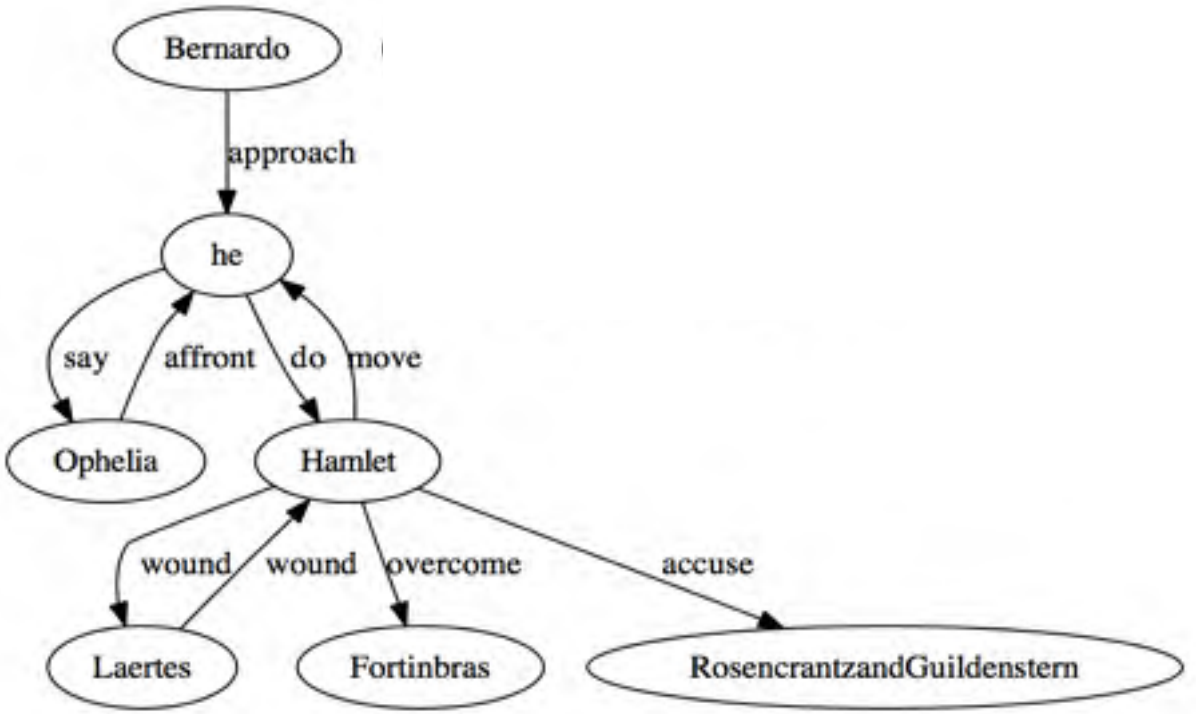
Mining over language: Dependency Parse



Extensional Knowledge

- Extensional Knowledge: Represent semantic networks extracted from text
  - Populate KBs
  - Frame inference (extract commonly occurring frame patterns)
  - Semantic relations among answers

Hamlet:
Character graph



Mining Linguistic Knowledge

Albert Einstein received his Nobel Prize…

In 1921 Einstein won the Nobel Prize for his original work on the photoelectric effect

Gerd Binnig, along with his colleague, Heinrich Rohrer, was awarded the Nobel Prize in Physics in 1986 for his work in scanning tunneling microscopy

Frame01	
verb	receive
subj	Einstein
type	PERSON/SCIENTIST
obj	Nobel Prize
mod_vprep	in

Frame02	
verb	win
subj	Einstein
type	PERSON/SCIENTIST
obj	Nobel Prize
mod_vprep	in
objprep	1921
type	YEAR
mod_vprep	For
objprep	Frame02b

Frame03	
verb	award
subj	Binnig
type	PERSON/SCIENTIST
obj	Nobel Prize in Physics
mod_vprep	in
objprep	1986

SCIENTISTS win PRIZES
'win' = 'receive'
'win' = 'award'
"*Nobel*" isa *Prize*
context: Scientists win it
Prizes: Nobel, Turing, Macarthur, …

Intensional Knowledge
isa cuts

As with other NSAIDs, ibuprofen may be useful in the treatment of severe orthostatic hypotension

Lasix (furosemide), a diuretic, and ibuprofen, an NSAID, can be taken together

Rule-based relation detector identifies hyponymy relations in text

Frame01	
subj	Ibuprofen
type	NSAID

Frame02	
subj	Lasix
type	diuretic

Frame03	
subj	NSAID
type	drug

Ibuprofen isa **NSAID**

Lasix isa **diuretic**

NSAID isa drug

.

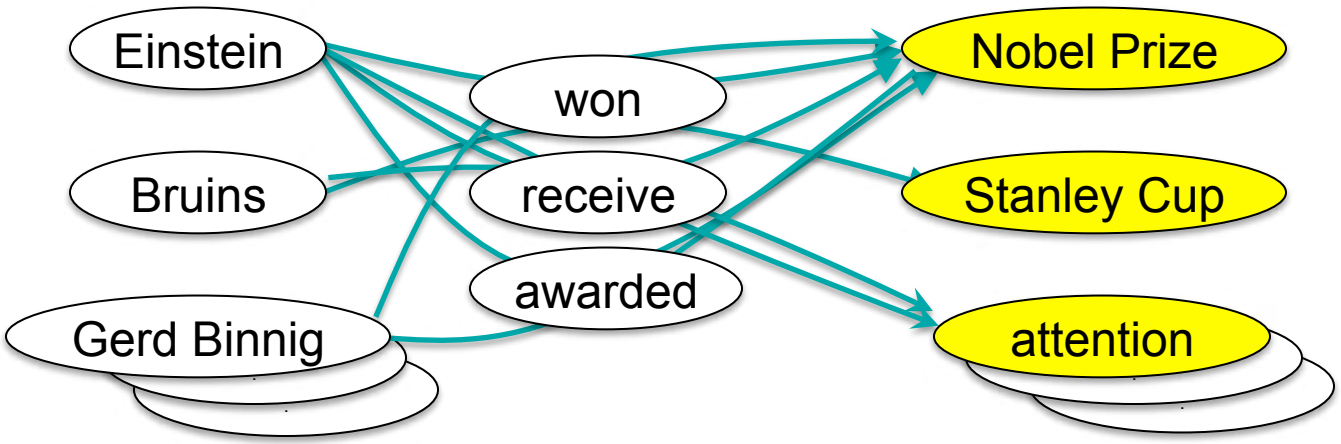
.

200M

Prismatic Lambda Abstractions

SVO (Subject Verb Object frame cuts)

λo[subj=Einstein, verb=won] : vector of counts of object filler



~800M SVO cuts…

Frequencies from λ vectors allow you to compute conditional probabilities:

P(o=Nobel Prize | subj=Einstein, verb=won)

Type information (selectional restrictions)

P(o=Nobel Prize | subj=SCIENTIST, verb=won)

Bootstrapping

λo[subj=f({λs[verb=won,obj=Nobel Prize]}), verb=won]

Unsupervised Learning

Topics Clusters : term co-occurrence in documents - **LSA**

Type Clusters: terms share similar syntactic roles (**Prismatic**)

explorer	ibm	rome
firefox	dell	paris
safari	hp	london
opera	acer	venice
chrome	asus	milan
		florence

Inferring Lexical Answer Type (LAT) from Context

Question	LAT Inferred
ART & ARTISTS: Picasso painted this work as a protest against the bombing of a town in the Spanish Civil War	Painting
SAY “UNC”LE: Redness & itching are symptoms of this eye condition	Disease
FAMOUS LATINOS & LATINAS: From the Bronx projects & Princeton, she joined the Supreme Court in 2009	Chief Justice
AMERICAN LITERATURE: Shortly after “The House of the Seven Gables,” he wrote a book of classical myths, A Wonder Book for Girls and Boys	Author

Evidence Dimensions

$200
Keanu Reeves had a Nokia phone, but it took a land line to slip in & out of this, the title of a 1999 sci-fi flick

Evidence Dimensions

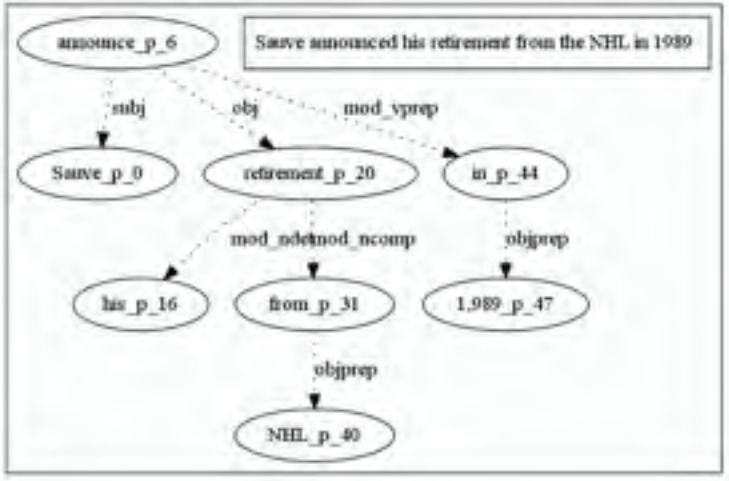
Keanu Reeves	had a Nokia Phone	took a land line to slip in & out of this	1999	Sci-fi flick

Justification	Evidence Dimensions			
KB: ActedIn(Keanu Reeves, X)	Text Passage: had(Keanu Reeves, Nokia)	Text Passage: Align	KB: OccurredIn(X, 1999)	KB: Isa(X,sci-fi flick)

TWREX: Topicalized Wide-scale Relation Extraction [EMNLP 2011]

Jeopardy! Clue	Relation Detected (in italics)
MOTHERS & SONS: Though only separated by one year in real life, she played mother to son Colin Farrell in "Alexander"	*starring* (she, "Alexander")
THE DEVIL: "The Screwtape Letters" from a senior devil to an under devil are by this man better known for children's books	*author* (man, "The Screwtape Letters")
THE LONE REPRESENTATIVE: Michael Castle from this state with 3 counties: New Castle, Kent and Sussex	*residence*("Michael Castle", state)

"Sauve announced his retirement from the NHL in 1989".



Evidence Dimensions

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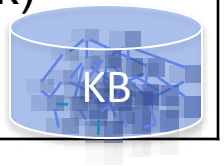
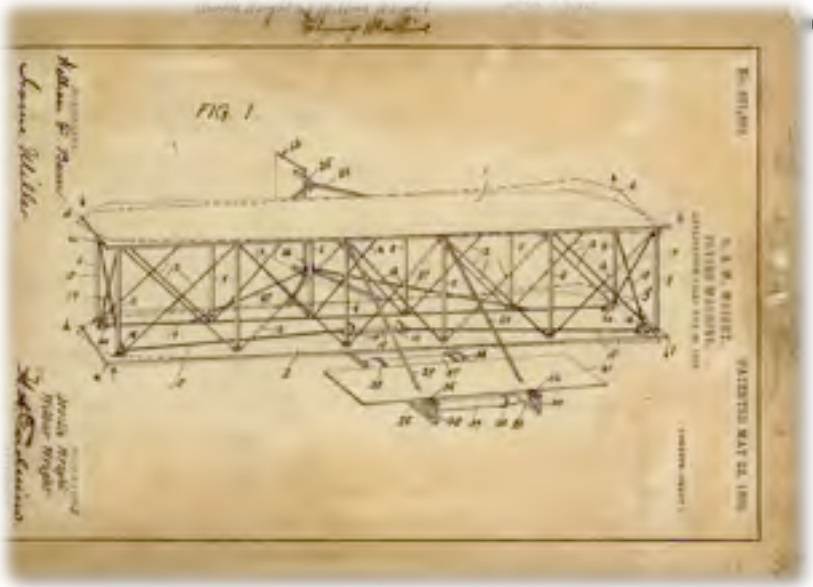


Distance between question and justifying passage

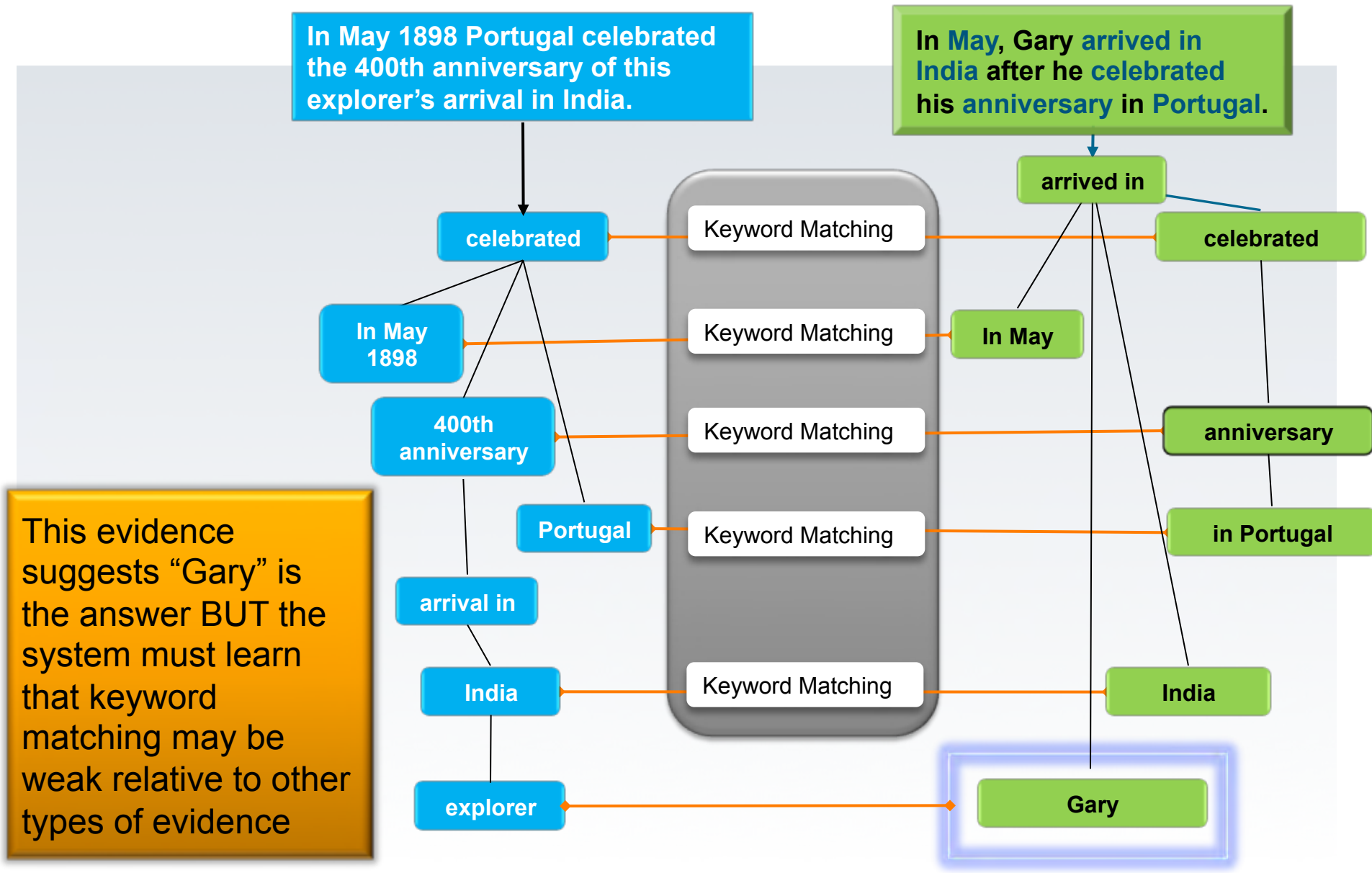


The Wright brothers' first flight was this long.

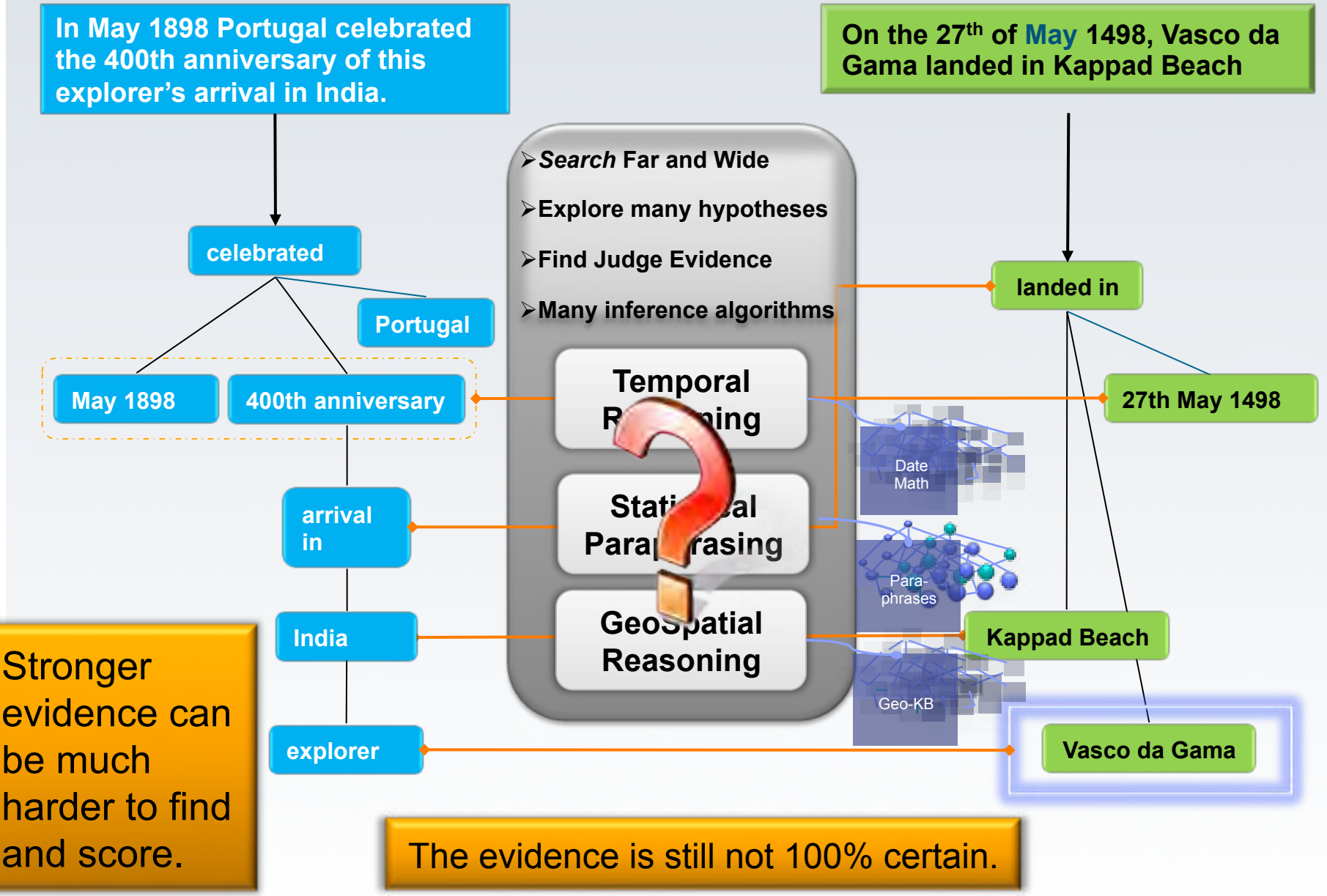
The Wright brother's first flight was 120 feet long

With Orville at the controls and Wilbur running along side to steady the wing, the plane rose 12 feet into the air and went about 120 feet on its 12-second trip. This marked the beginning of air travel for mankind.

Keyword Evidence



Deeper Evidence



Evidence Dimensions

$200
Keanu Reeves had a Nokia phone, but it took a land line to slip in & out of this, the title of a 1999 sci-fi flick

Evidence Dimensions

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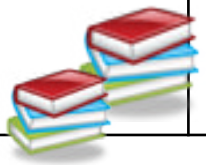
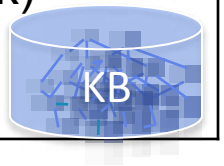
Justification	Evidence Dimensions				
Evidence Sources	KB: ActedIn(Keanu Reeves, X)	Text Passage: has(Keanu Reeves, Nokia)	Text Passage: Align	KB: OccurredIn(X, 1999)	KB: Isa(X,sci-fi flick)



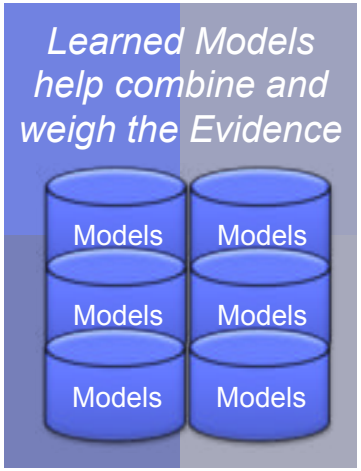


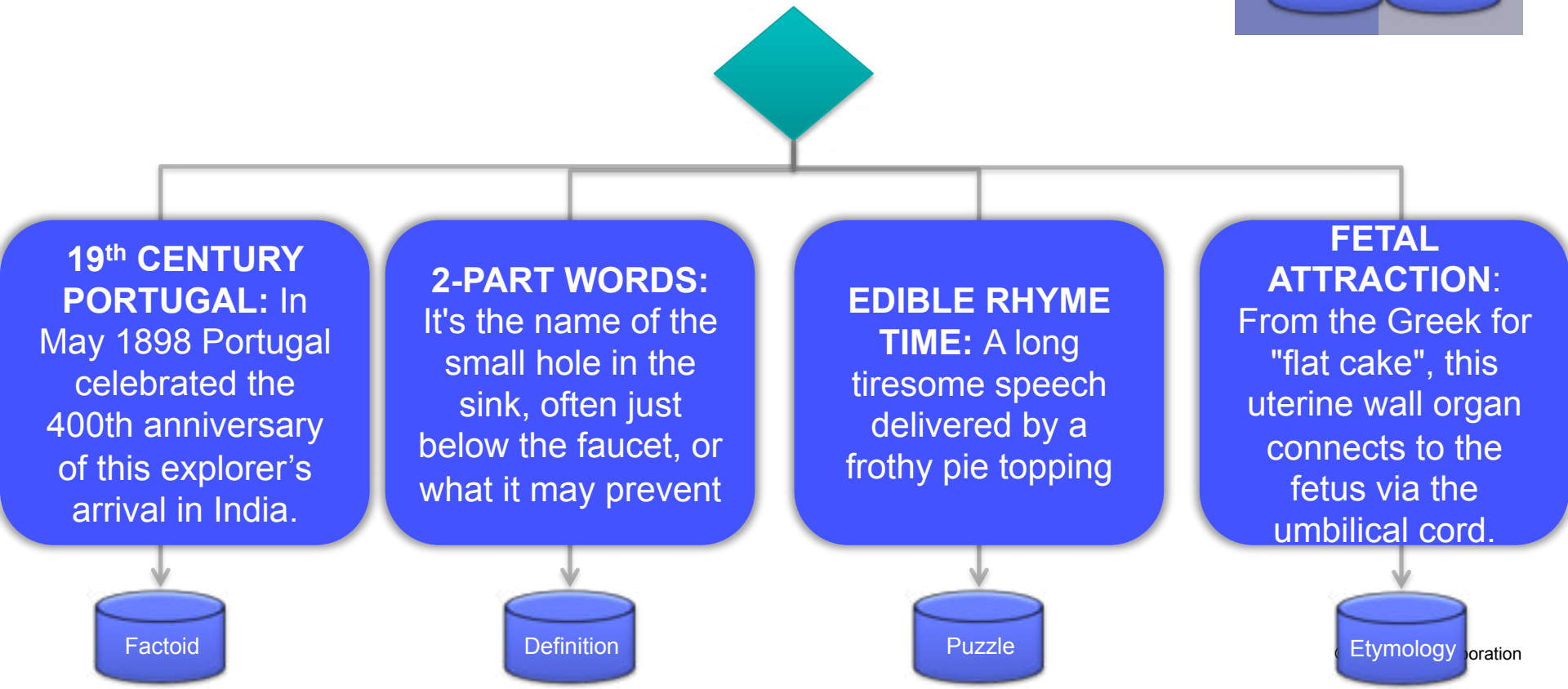
Mixture of Experts: Question Classes

Different question classes weigh evidence differently

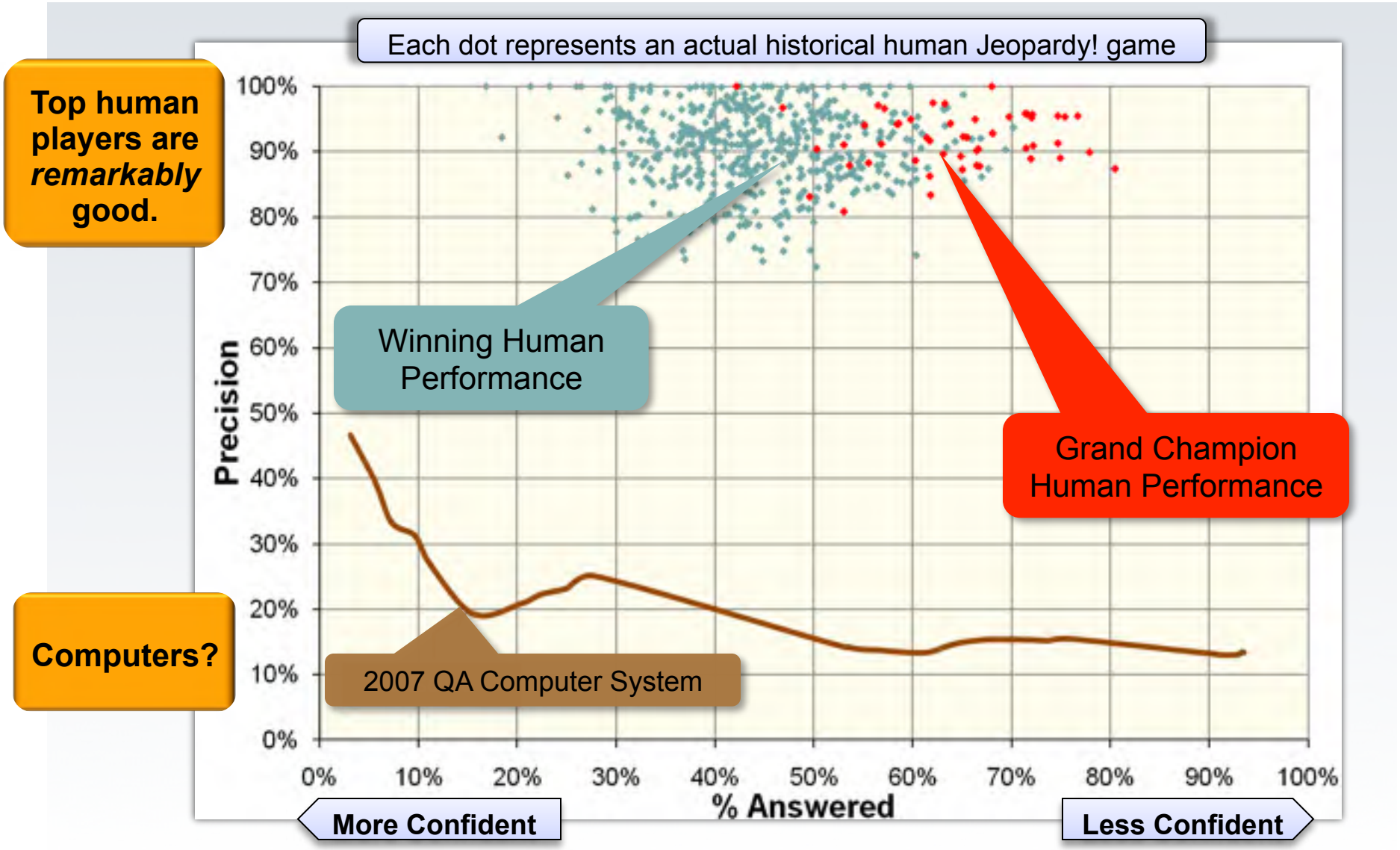
Statistical and rule-based classifiers identify question class

Partitioned Mixture of Experts trained for each question class

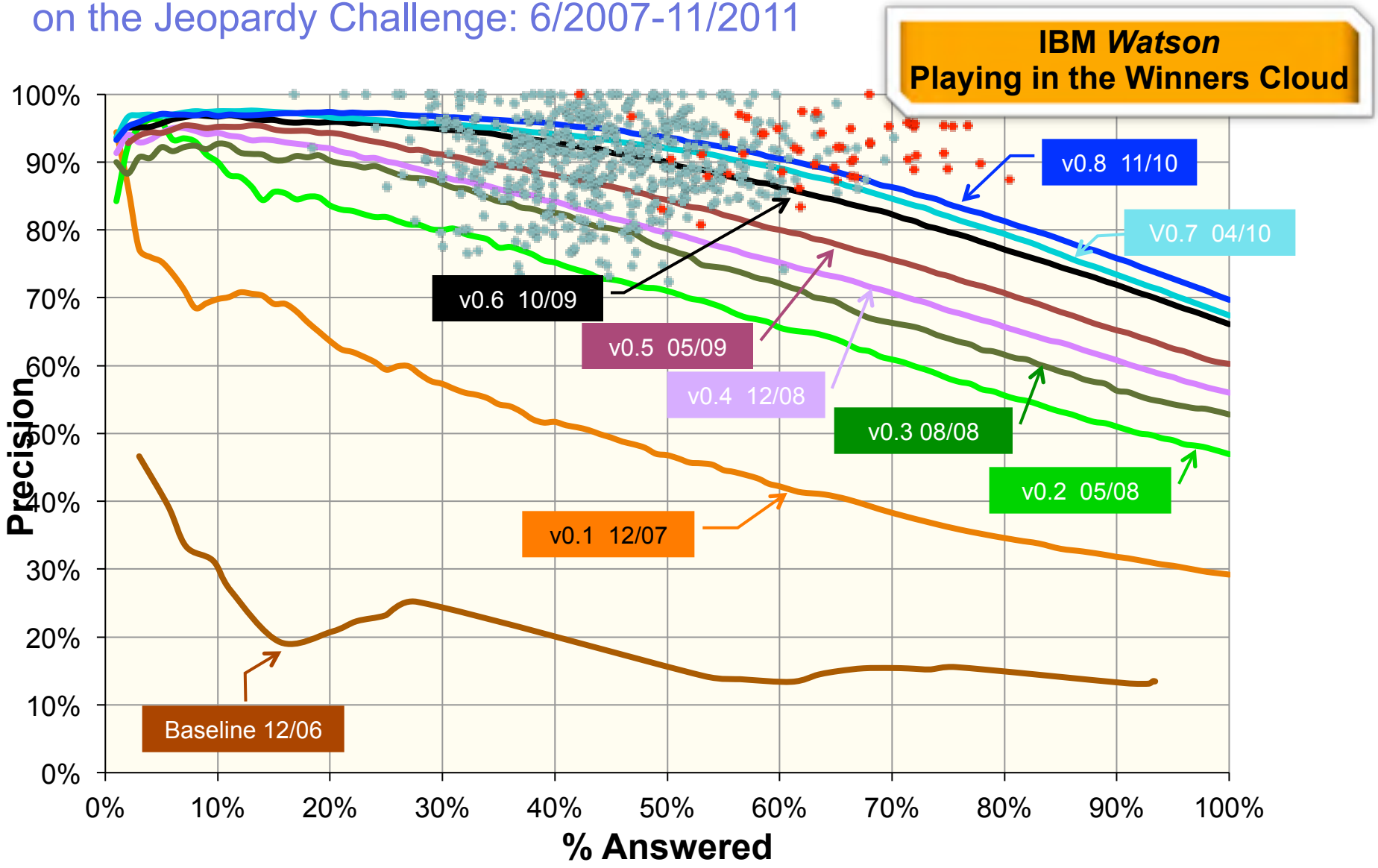


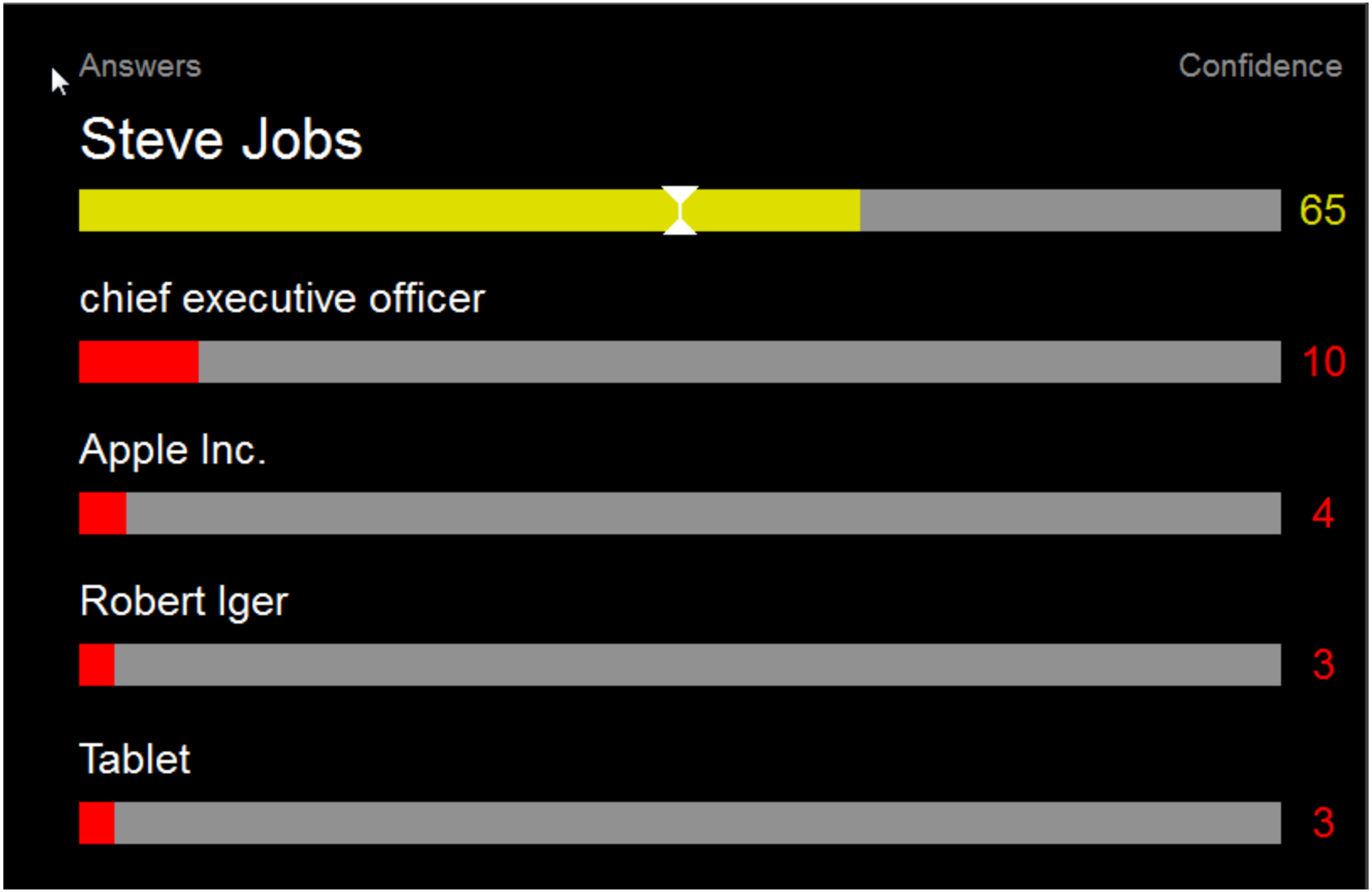


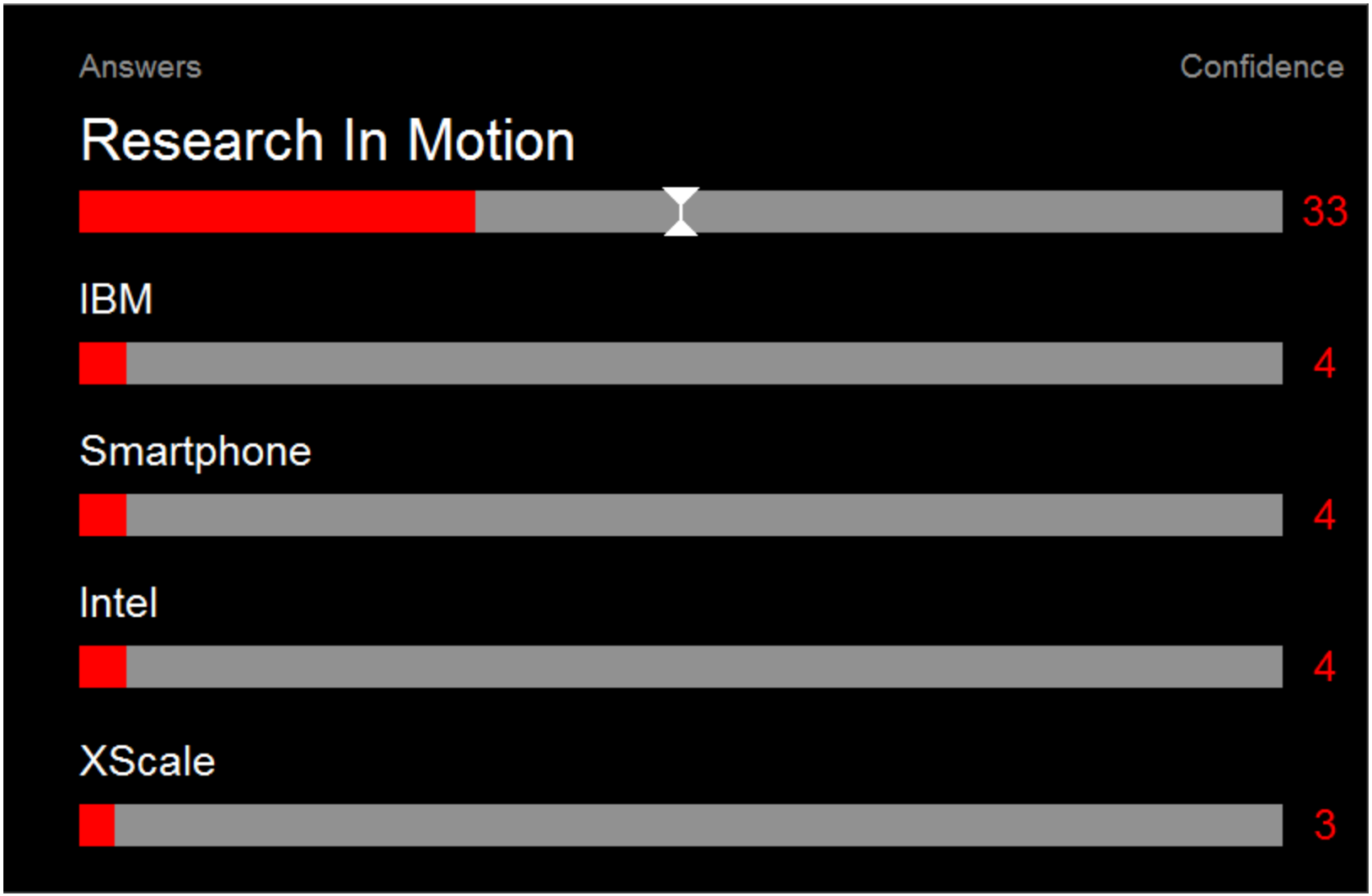
The Best Human Performance: *Our Analysis Reveals the **Winner's Cloud***

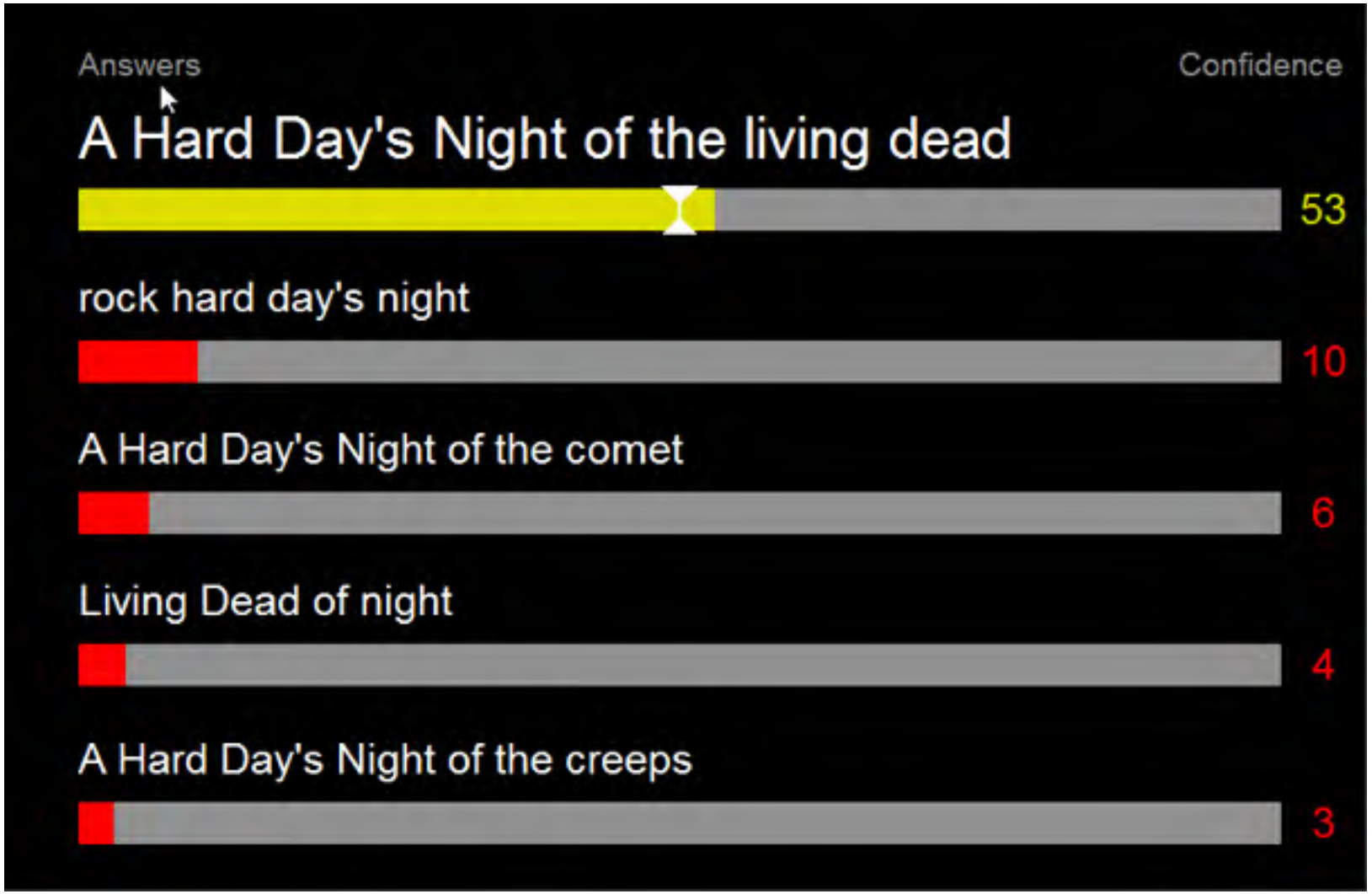


DeepQA: Incremental Progress in Answering Precision on the Jeopardy Challenge: 6/2007-11/2011



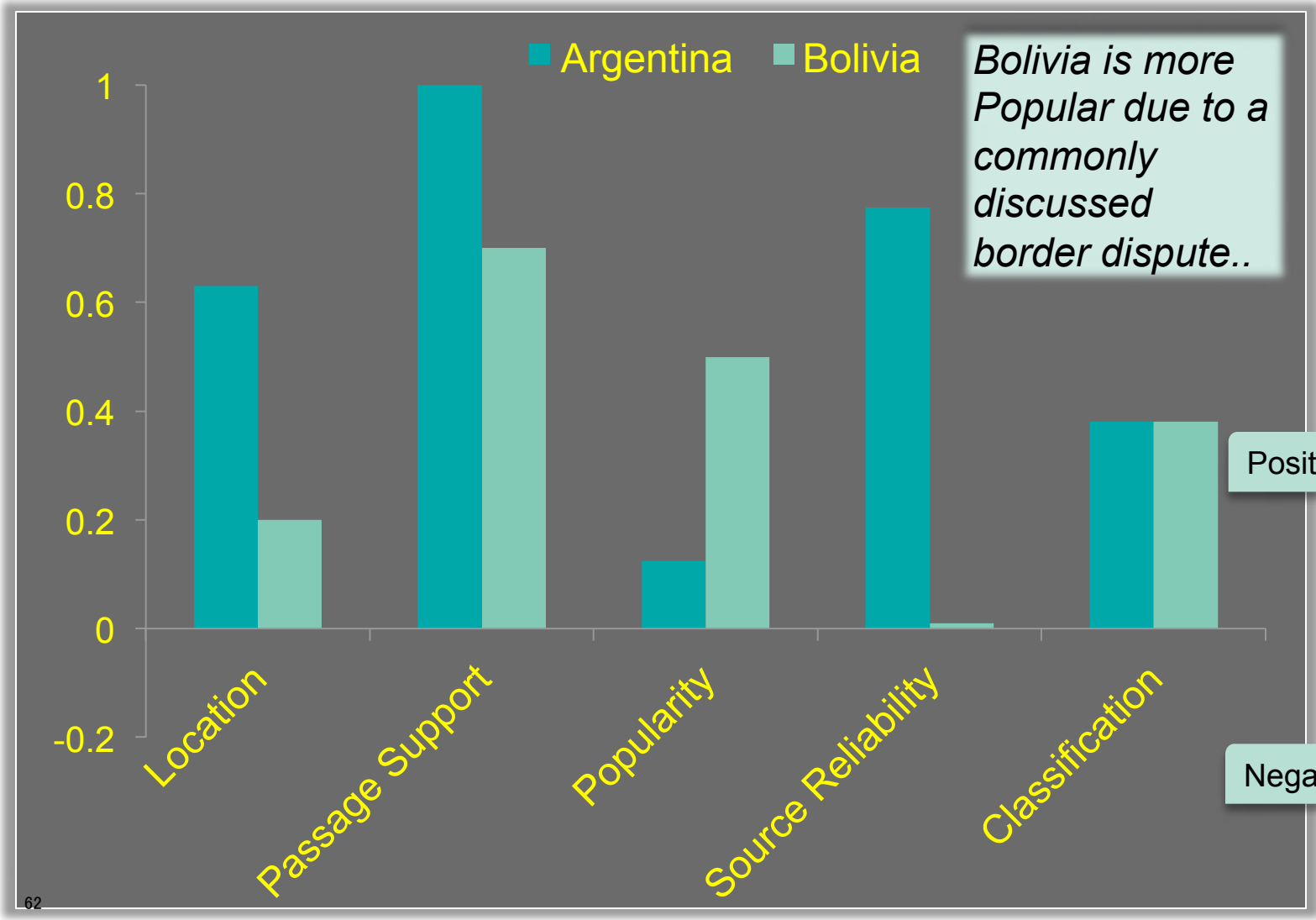






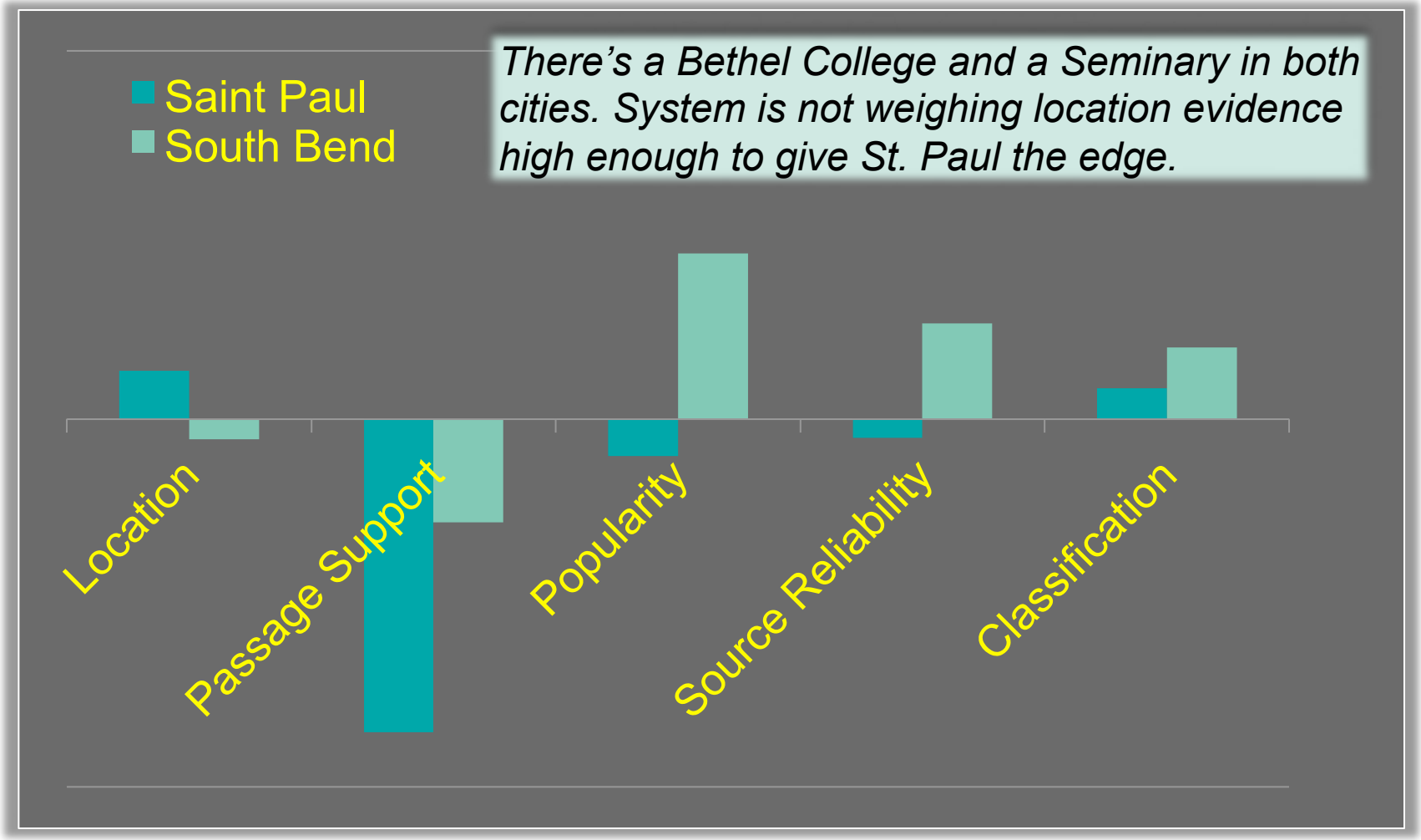
Grouping Features to produce *Evidence Profiles*

Clue: Chile shares its longest land border with this country.



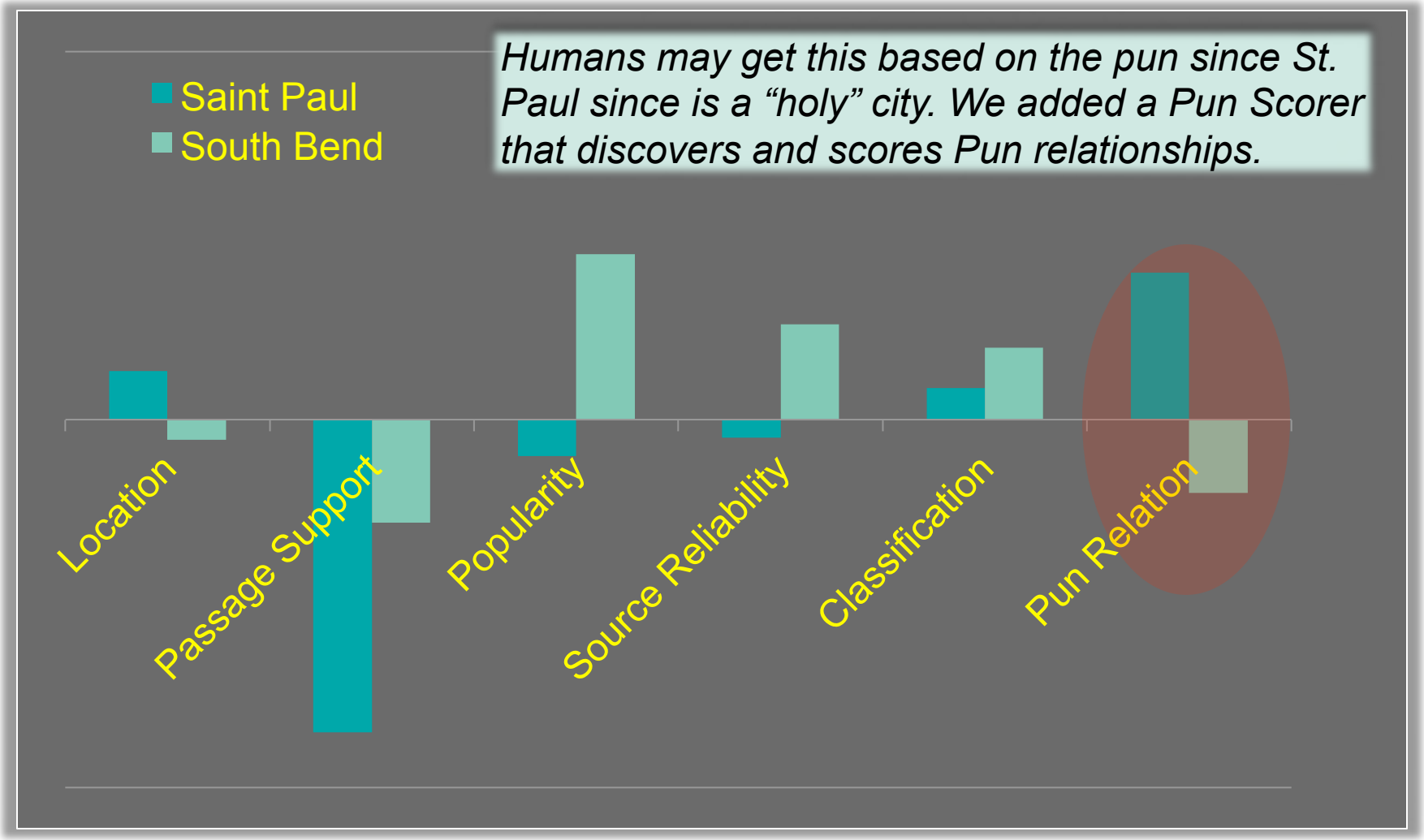
Evidence: Time, Popularity, Source, Classification etc.

Clue: You'll find Bethel College and a Seminary in this "holy" Minnesota city.

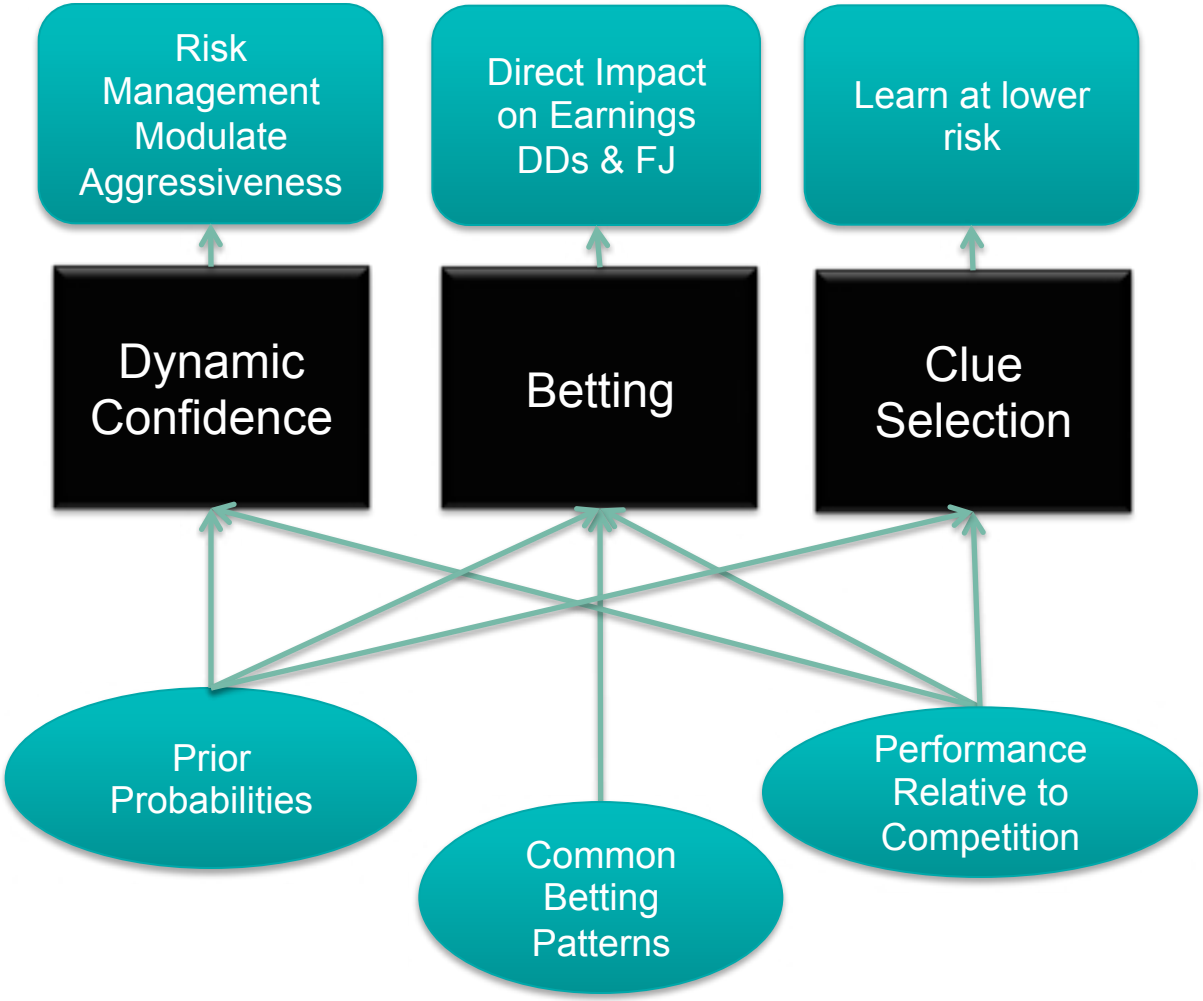


Evidence: Puns

Clue: You'll find Bethel College and a Seminary in this "holy" Minnesota city.

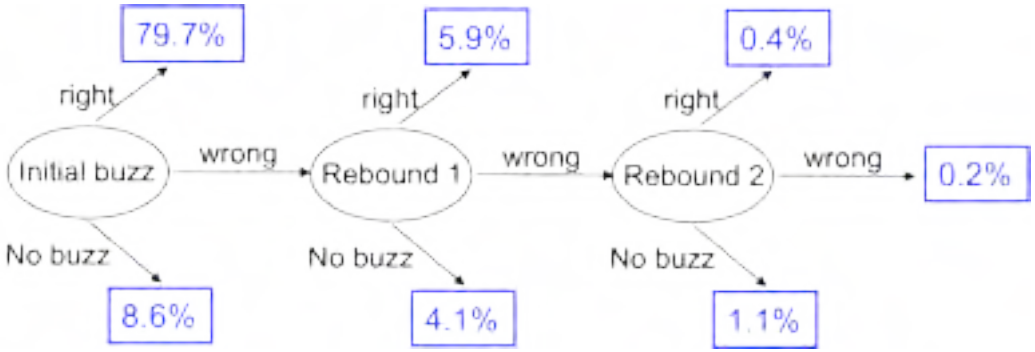


Game Strategy
Managing the Luck of the Draw



Buzz-in: Stochastic Process Model of Regular Clues

Statistics over 150K regular-clue (no DD) outcomes:



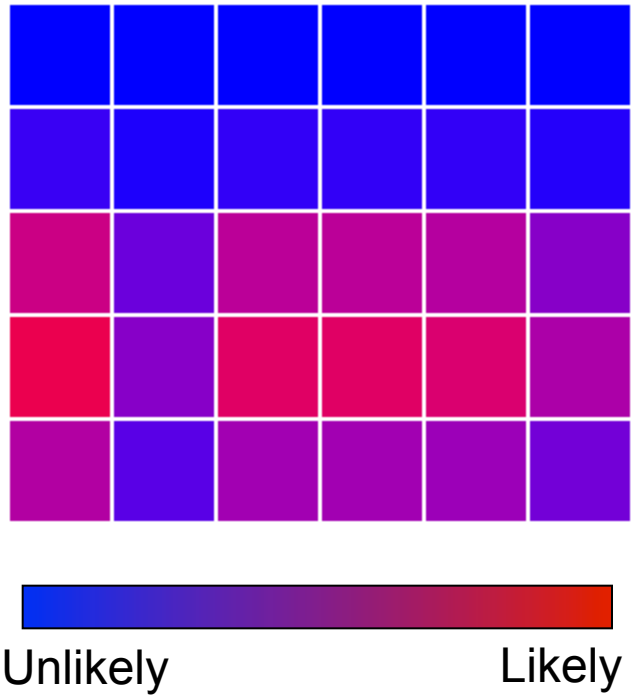
Using historical priors and game state information, Watson uses function approximation and Monte Carlo simulation to identify optimal buzzing for its confidence:

Buzz Threshold (Earnings-max)

Buzz Threshold (Conservative)

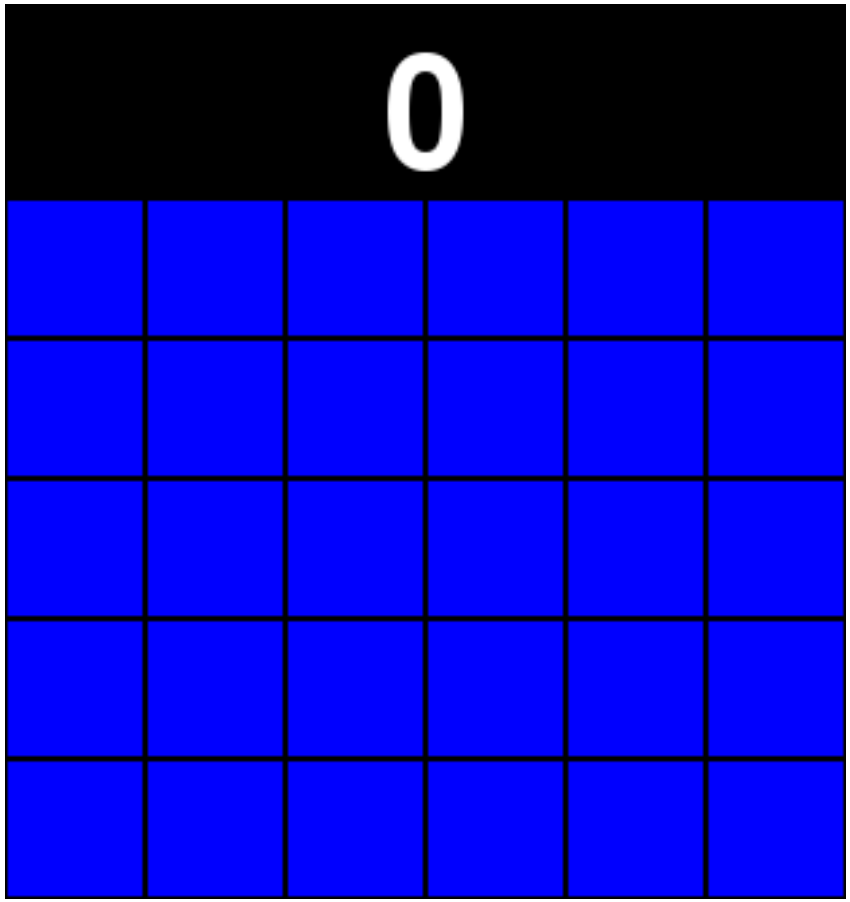
Modeling Daily Double Placement

- **Statistics over 9k DDs** (3k Round1, 6k Round2):
  - (Widely known) DDs most frequent in the high-value rows (third, fourth, fifth) with harder clues
    - Row frequencies published on J! Archive
  - Some columns are more likely than others to have a DD!
    - First column most likely to have a DD
    - Second column least likely to have a DD
  - row-column frequencies used to randomly place DDs in simulated games; Watson uses them as
- Bayesian prior
- Columns are conditionally dependent! Watson performs a Bayesian update based on observed DDs

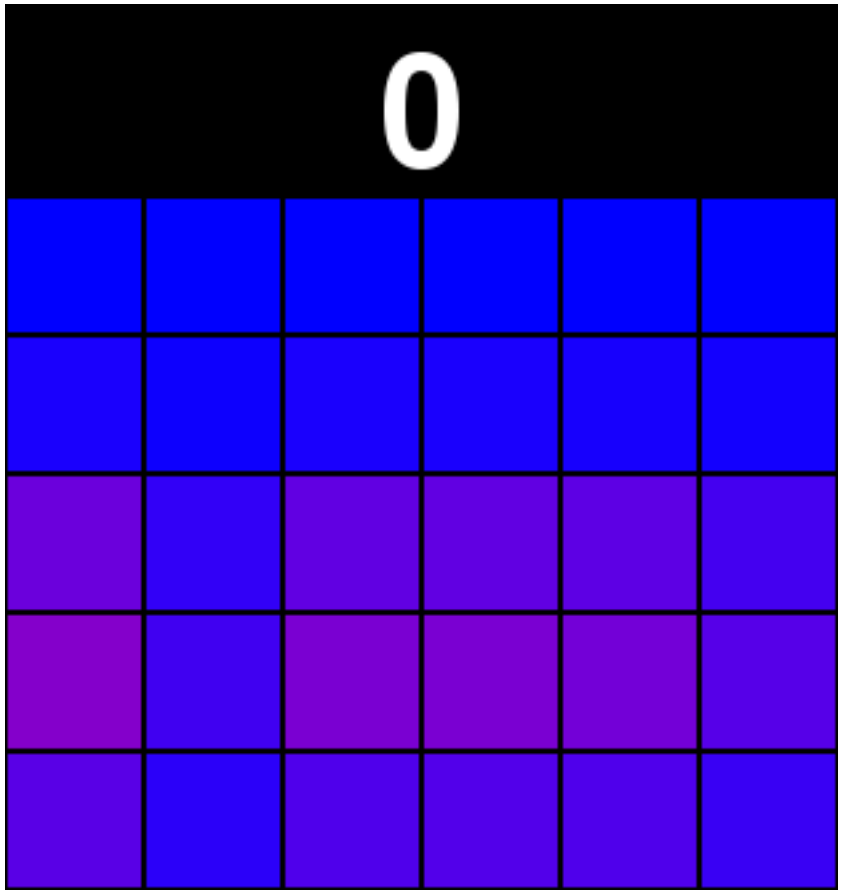


Square Selection: Daily Double Prediction

Human



Watson

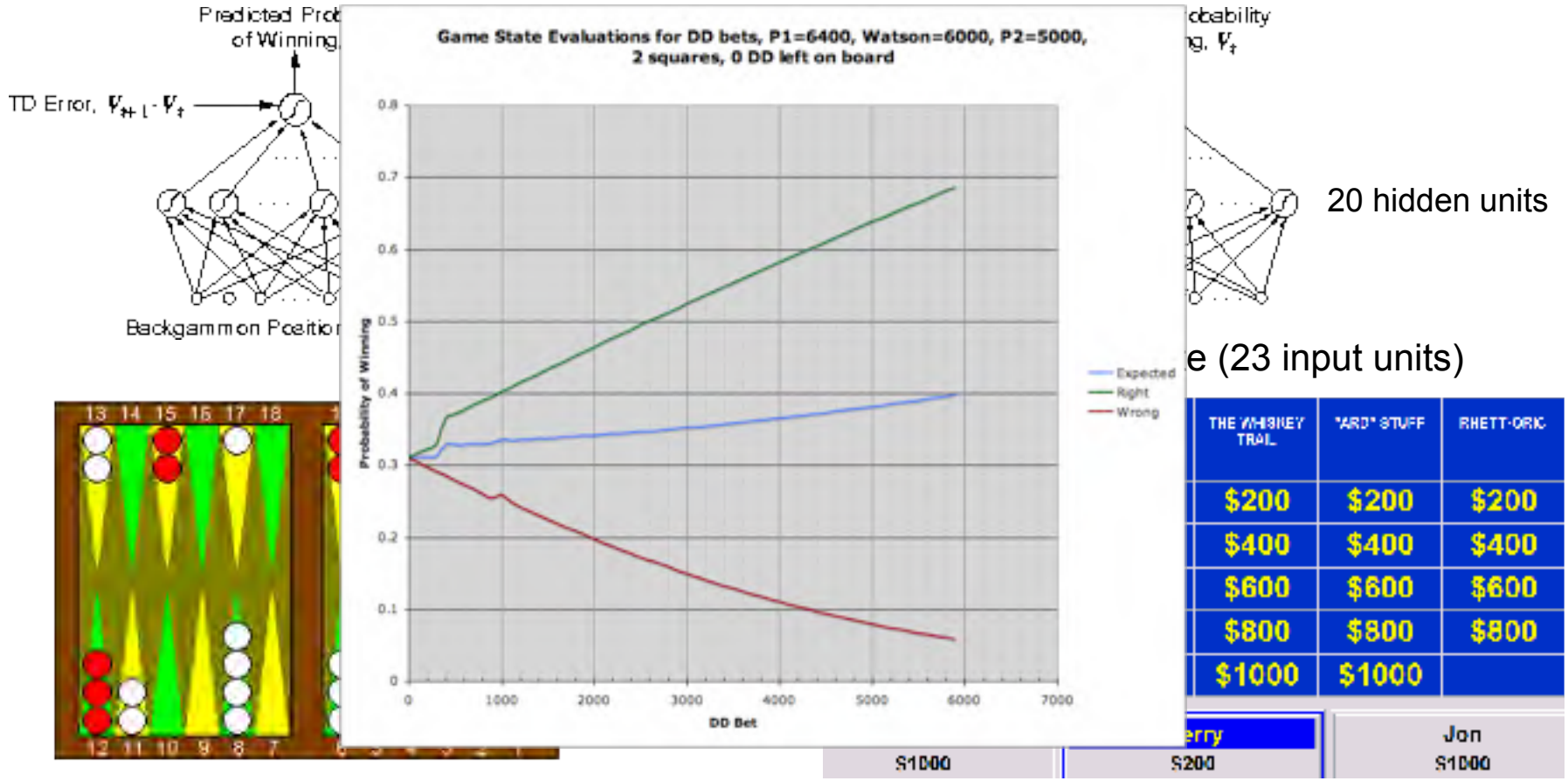


Unlikely

Likely

Daily Double Betting: Strategy

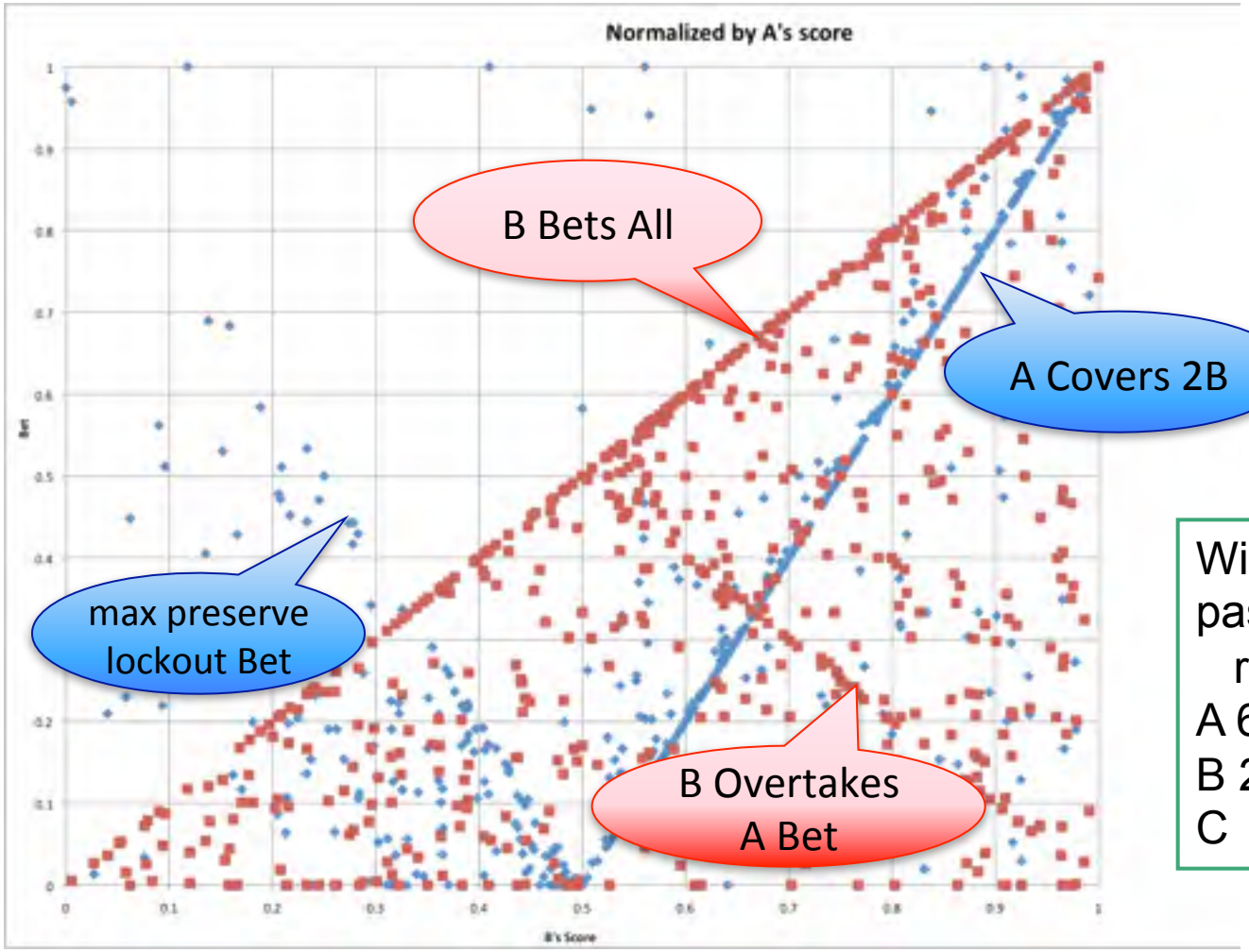
- Train an Aritifical Neural Net over millions of simulated games pitting Watson vs. two simulated human opponents
- Use TD() reinforcement learning algorithm just as in TD-Gammon



Final Jeopardy: Modeling Human Betting

Average FJ accuracy r **50%** FJ accuracy correlation r **0.3**

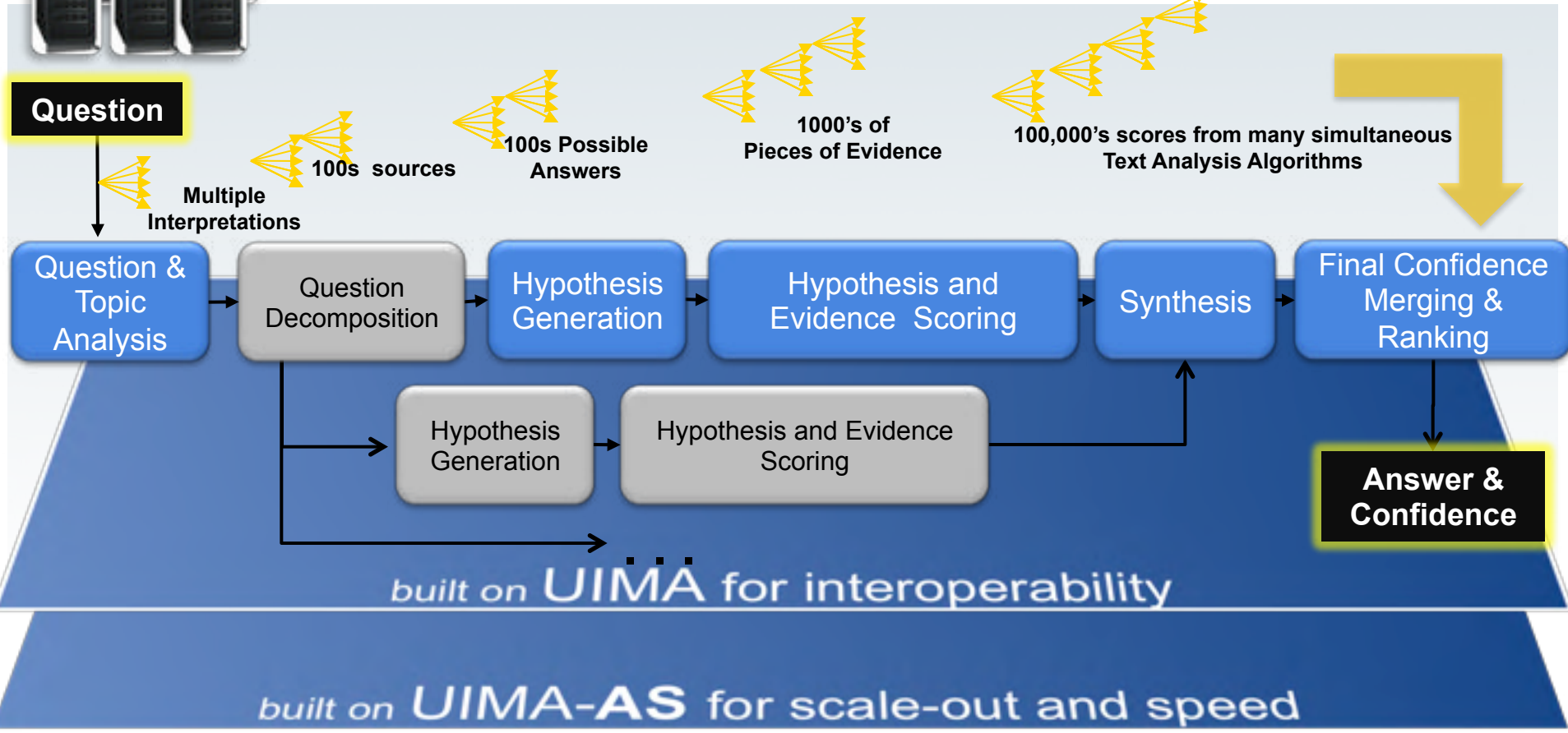
Bets depend on score positioning: 1st place (**"A"**), 2nd place (**"B"**), 3rd place (**"C"**)



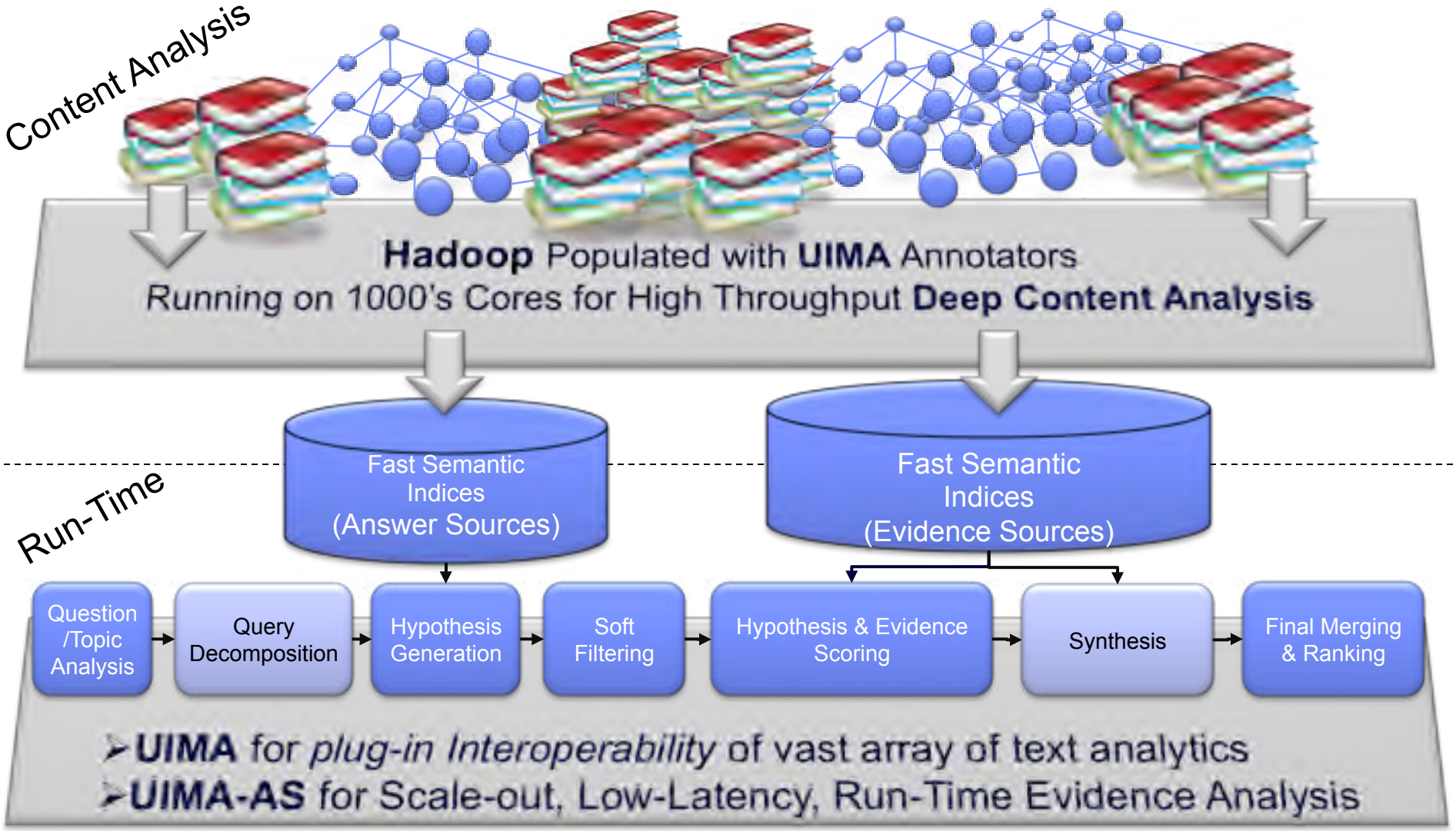
Win rates in 2092 past episodes:

	real	model
A	65.3%	64.8%
B	28.2%	28.1%
C	7.5%	7.4%

One Jeopardy! question can take **2 hours on a single 2.6Ghz Core** Optimized & Scaled out on 2880-Core IBM workload optimized POWER7 HPC using UIMA-AS, *Watson* answers in 2-6 seconds.



UIMA in Hadoop is used for high-throughput content analysis to generate fast semantic indices. These are used for DeepQA's rapid evidence evaluation in the context of the question at Run-Time



Watson – a Workload Optimized System

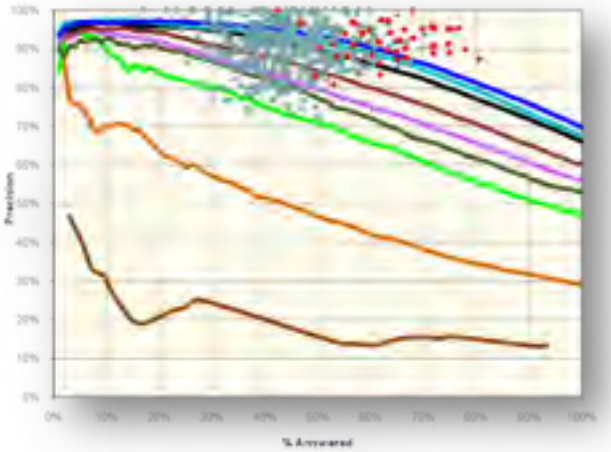
- 90 x IBM Power 750[1] servers
- 2880 POWER7 cores
- POWER7 3.55 GHz chip
- 500 GB per sec on-chip bandwidth
- 10 Gb Ethernet network
- 15 Terabytes of memory
- 20 Terabytes of disk, clustered
- Can operate at 80 Teraflops
- Runs IBM DeepQA software
- Scales out with and searches vast amounts of unstructured information with UIMA & Hadoop open source components
- Linux provides a scalable, open platform, optimized to exploit POWER7 performance
- 10 racks include servers, networking, shared disk system, cluster controllers

Linux

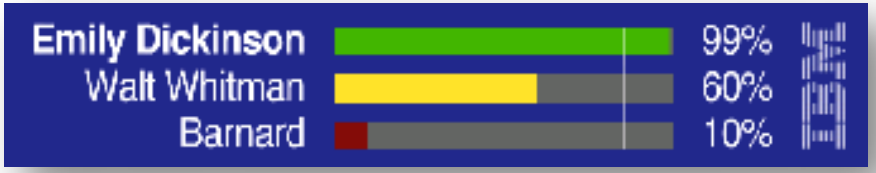
POWER7 BUILT ON Power

[1] Note that the Power 750 featuring POWER7 is a commercially available server that runs AIX, IBM i and Linux and has been in market since Feb 2011

Precision, Confidence & Speed



- **Deep Analytics –** Combining many analytics in a novel architecture, we achieved very high levels of ***Precision*** and ***Confidence*** over a huge variety of *as-is* content.



- **Speed** – By optimizing Watson's computation for Jeopardy! on over **2,800 POWER7** processing cores we went **from 2 hours per question on a single CPU to an average of just 3 seconds.**

- **Results –** in 55 real-time sparring games against former **Tournament of Champion Players last year** Watson put on a very competitive performance in all games -- placing 1st in 71% of the them!

Potential Business Applications

Healthcare / Life Sciences: Diagnostic Assistance, Evidenced-Based, Collaborative Medicine

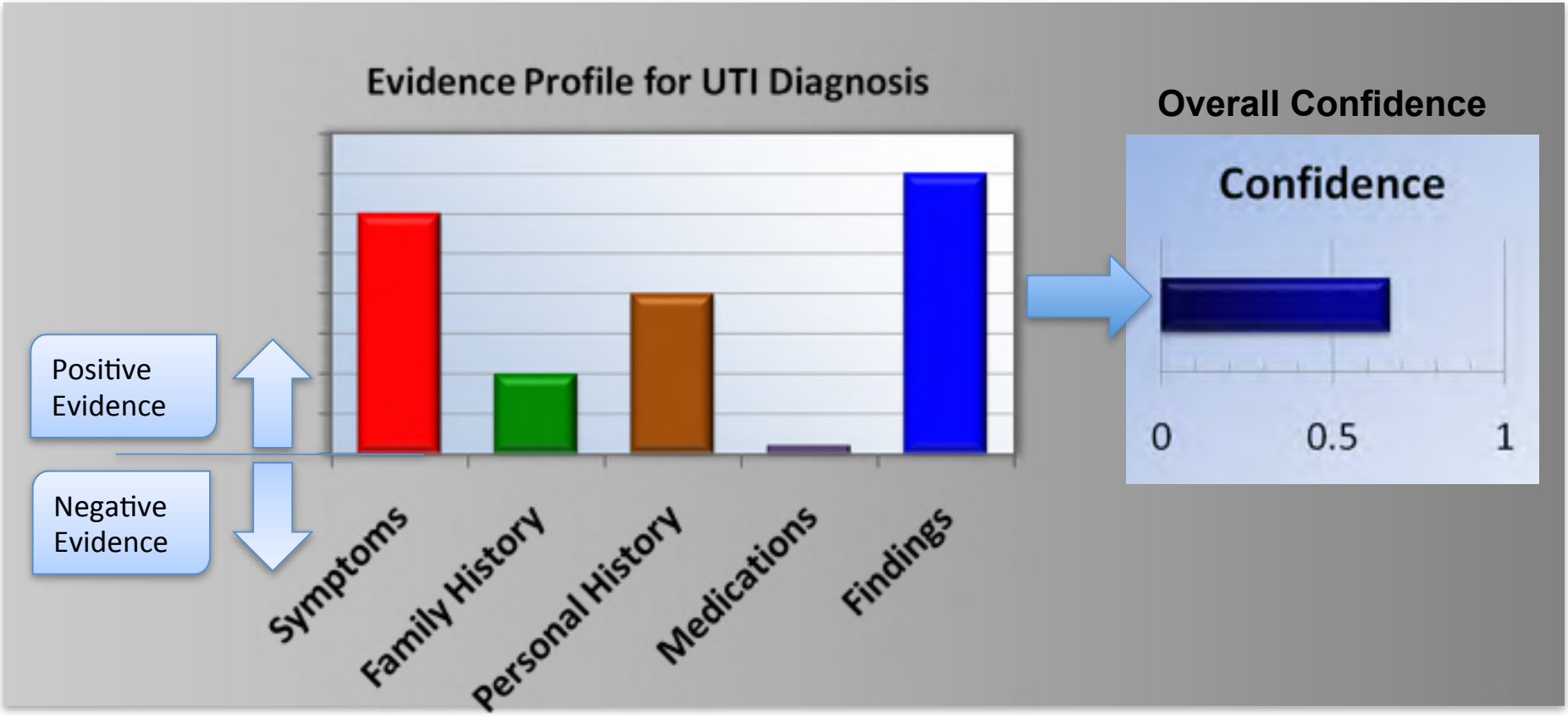
Tech Support: Help-desk, Contact Centers

Enterprise Knowledge Management and Business Intelligence

Government: Improved Information Sharing and Security

Evidence Profiles from disparate data is a powerful idea

- Each dimension contributes to supporting or refuting hypotheses based on
  - **Strength of evidence**
  - **Importance of dimension for diagnosis** (learned from training data)
- Evidence dimensions are combined to produce an overall confidence

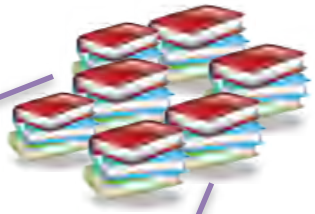


Mapping from Language to Language

Flexible Matching Features allows us to gather evidence that Dysphagia is a element of the diagnosis

A 58-year-old woman presented to her primary care physician after several days of dizziness, anorexia, dry mouth, increased thirst, and frequent urination. She had also had a fever and reported that **food would "get stuck" when she was swallowing**.

She reported no pain in her abdomen, back, or flank and no cough, shortness of breath, diarrhea, or dysuria.

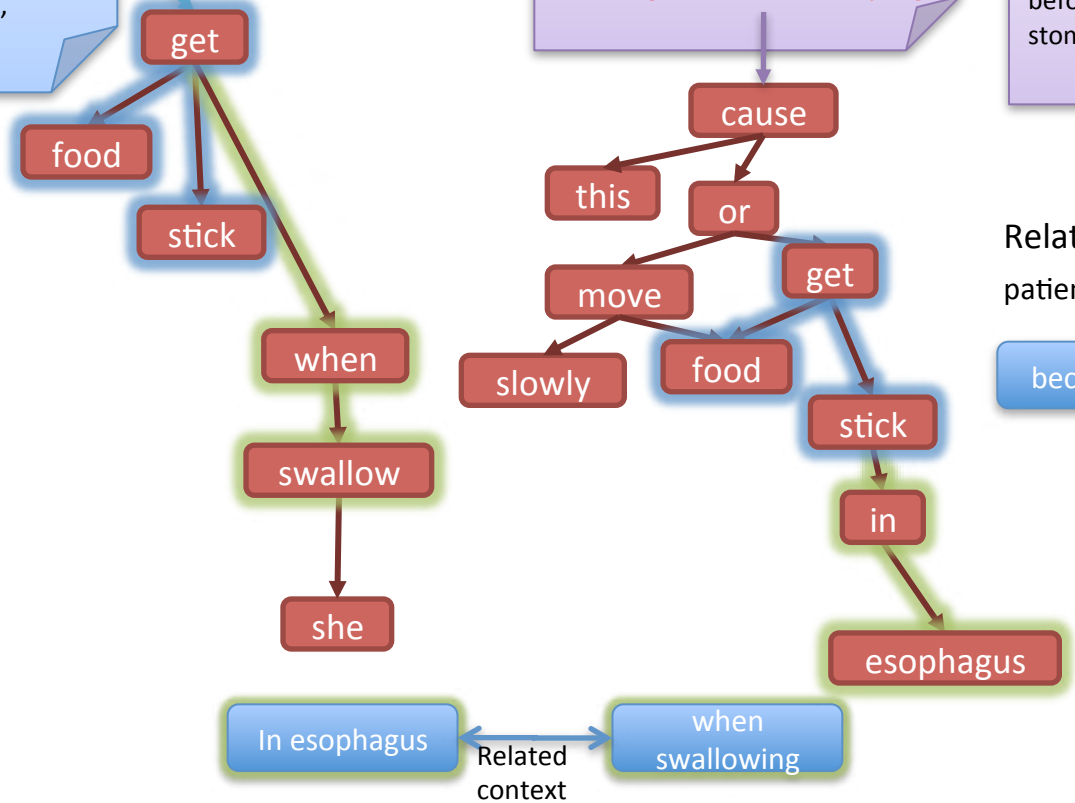


Dysphagia

These disorders can stop the nerves and muscles in your esophagus (the tube that runs from your mouth and throat down to your stomach) from working right. This can cause food to move slowly or even get stuck **in the esophagus**.

Dysphagia

The most common symptom of esophageal dysphagia is the inability to swallow solid food, which the patient will describe as 'becoming stuck' or 'held up' before it either passes into the stomach or is regurgitated.

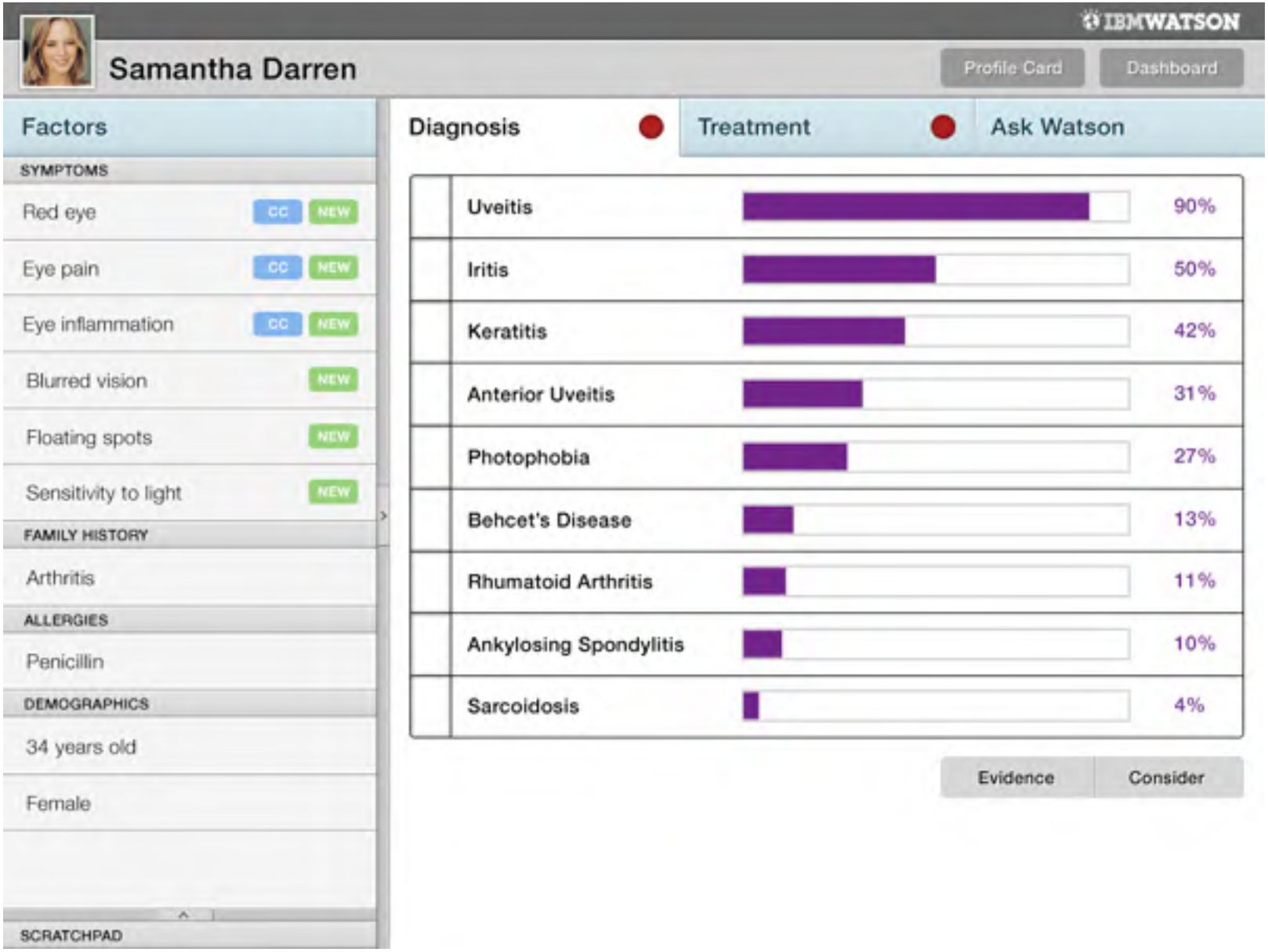


Relation Detection:

patientDesc("becoming stuck")

become → get

Verb coerce


IBM WATSON
Samantha Darren
Profile Card
Dashboard
Factors
SYMPTOMS
Red eye
CC
NEW
Eye pain
CC
NEW
Eye inflammation
CC
NEW
Blurred vision
NEW
Floating spots
NEW
Sensitivity to light
NEW
FAMILY HISTORY
Arthritis
ALLERGIES
Penicillin
DEMOGRAPHICS
34 years old
Female
SCRATCHPAD
Diagnosis
Treatment
Ask Watson
Uveitis 90%
Iritis 50%
Keratitis 42%
Anterior Uveitis 31%
Photophobia 27%
Behcet's Disease 13%
Rhumatoid Arthritis 11%
Ankylosing Spondylitis 10%
Sarcoidosis 4%
Evidence
Consider

Samantha Darren

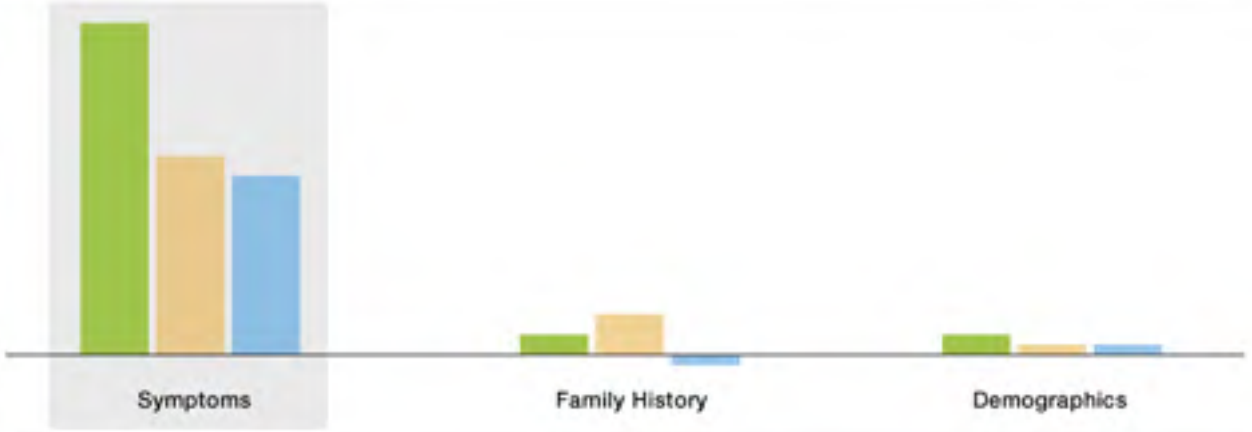
IBM WATSON

Profile Card | Dashboard

Evidence Profile: Diagnosis

Back to Results

- Uveitis 91%
- Iritis 48%
- Keratitis 42%



Sources | Factors

Textbook
Uveitis specifically refers to **inflammation** of the middle layer of the eye, termed the "uvea" but in common usage may refer to any inflammatory process involving the interior of the eye. ★★★☆

Website
Uveitis usually develops quickly and generally affects only one eye. Signs and symptoms may include any or all of the following, **pain in the eye** or brow region, worsened eye **pain when exposed to bright light**, and **reddened eye**, especially adjacent to the iris. ☆☆☆☆

Medical Journal
The most common form of uveitis is anterior uveitis, which involves **inflammation** in the front part of the eye. It is often called iritis because it usually only affects the iris, the colored part of the eye. ☆☆☆☆

Textbook
Uveitis is often marked by moderate to intense **pain** and usually involves **impaired eyesight**. ☆☆☆☆

SONY PICTURES TELEVISION, IBM, and THE GHOST OF MERV GRIFFIN PRESENT

THIS IS JEOPARDY!

AN UNPRECEDENTED MAIN EVENT:

THREE NIGHTS ONLY!

FEB

14TH 15TH 16TH

CHECK YOUR LOCAL LISTINGS

MAN VS MAN VS MACHINE

★ ★ ★ ★ TONIGHT'S CONTESTANTS ★ ★ ★ ★

KEN "THE BLOCK" JENNINGS

"BRAIN-GOLIATH" BRAD RUTTER

10202 WEST WASHINGTON BLVD

CULVER CITY, CALIFORNIA

Watson: Always Improving..

NEW YORK TIMES HEADLINES: An exclamation point was warranted for the "end of" this! In 1918

A sentence (.48)

WORLD FACTS: The Denmark Strait separates these 2 islands by about 200 miles

Greenland and Taiwan (0.31)

THE AMERICAN DREAM: Decades before Lincoln, Daniel Webster spoke of government "made for", "made by" & "answerable to" them

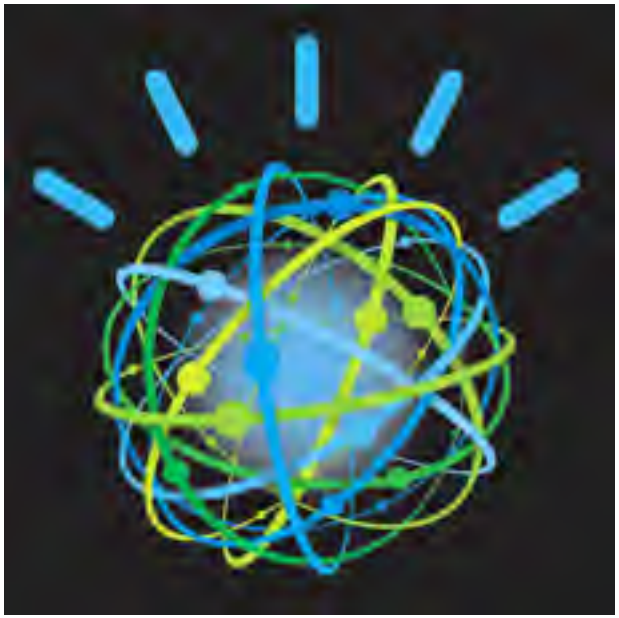
No one (0.29)

THE QUEEN'S ENGLISH : Give a Brit a tinkle when you get into town & you've done this

Urinate (.56)

BOTTOMS UP!: Often served at a brunch, it's made with equal amounts of champagne and orange juice

Breakfast (0.11)



THANK YOU