Applications of Artificial Intelligence

– Winter Term 21/22 –

Chapter 01

Introduction

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Outline

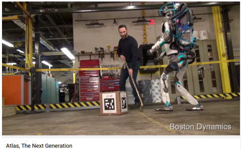
Artificial Intelligence (AI)

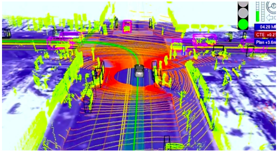
- Goal: Implement **intelligent behavior in artificial systems**

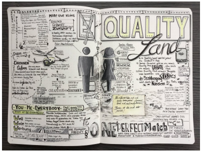
> *" For thousands of years, we have tried to understand how we think. [...] The field of A.I. goes further still: It attempts not just to understand but also to* **build intelligent entities***."*
>
> (Russel/Norvig)

- **What are examples of "intelligent behavior"?**
  - Playing checkers / chess / Go / Super Mario?
  - Planning routes? Recognizing letters in scans?
  - Automatically "understanding" text?
- **AI's boundaries are fuzzy and ever changing**!
  ("AI is whatever hasn't been done yet.")

Artificial Intelligence (AI) images: [4, 2]





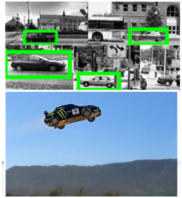


Typical Aspects of Intelligent Behavior

- reasoning, problem solving, planning
- perception, communication, (complex) acting
- learning

Scientific Goals of AI

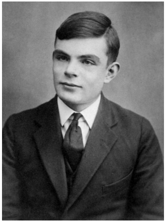
1. ... **engineering**: build tools/solutions that are *useful*.
2. ... **epistemology**: What principles underly intelligence? Where are its boundaries?



AI has Different Facets / Lines of Research image: [1]

Thinking Humanly (cognitive science)	**Thinking Rationally (logic, deduction)**
Automating [...] activities we associate with human thinking, such as decision-making, [...], learning *(Bellmann 1978)*	The study of mental faculties through the use of computational models *(Charniak & McDermott, 1985)*
Acting Humanly (Turing test)	**Acting Rationally (agents, robots)**
The art of creating machines that perform functions that require intelligence when performed by people *(Kurzweil, 1990)*	emulate intelligent behavior in terms of computational processes *(Schalkoff, 1990)*

Acting Humanly: The Turing Test (1950)



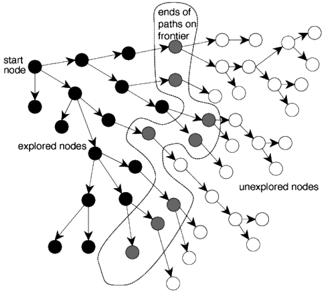
- KI = reproducing human behavior such that a human tester cannot distinguish the machine from another human.
- The tester performs text communication *(chat)* with a machine and with a human. If the tester cannot identify which partner is the machine, the machine has passed the Turing test.[1]

[1] Solutions are claimed to exist: http://isturingtestpassed.github.io/

AI operates on two Levels image: [8]

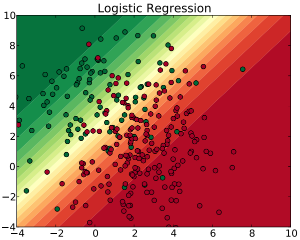
Symbolic Level

- the concept "cat"
- manipulation of **discrete** symbols
- **search** and inference
- knowledge is represented **explicitly**
- logic, knowledge graphs,
  rule-based systems, ...

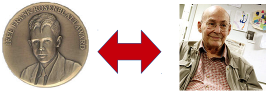


Subsymbolic Level

- audiosignal of the word "cat"
- manipulation of **real-valued variables** / signals
- knowledge is represented **implicitly** *(e.g., in numerical vectors/matrices)*.
- machine learning, optimization in $\mathbb{R}^d$



AI: History



Frank Rosenblatt Marvin Minsky

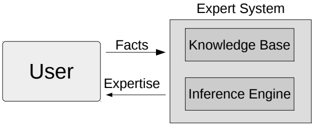
1950s (“Look Ma, no Hands” – Era)

- Dartmouth Conference (1956):
  the term “artificial intelligence” is coined.
- first systems
  - Logic Theorist *(proves theorems in propositional logic)*
  - Checker *(wins “checkers” against humans)*
  - General Problem Solver *(solves symbolic integration problems)*

1960s: First Disappointments

- systems work in toy worlds, but do not scale to realistic scenarios *(combinatorial explosion)*.
- limitations in storage and compute power.
- problems more complex than assumed *(example: NLP)*.
- basic limitations of algorithms
  (example: perceptron (Minsky & Papert, 1969)).

AI: History



1980s (Knowledge-intensive Phase)

- **Subsymbolic level**: **neural networks**
  - connection of neurons known to solve general learning tasks.
- **Symbolic level**: **expert systems**
  - declarative, dynamic knowledge bases
  - problem solving as an inference process
  - development of expert systems
    (medical diagnosis, technical troubleshooting)

1990s (AI Winter)

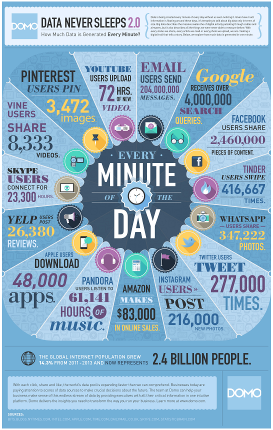
- AI promises do not hold up in practice.
- expert system: **maintenance** difficult.
- expert systems: **knowledge engineering** expensive *(common-sense knowledge?)*.
- **neural networks**: training hard.

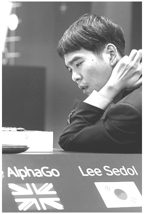
→ massive **cuts** in AI funding.

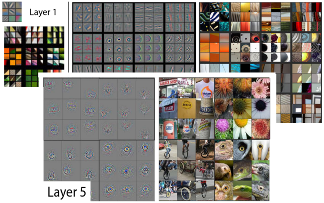
AI: History images: [3, 9, 12]

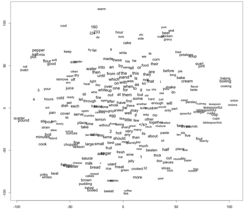
2000s - today

- **increasing relevance** of AI topics *(especially machine learning)* due to *big (unstructured) data*.
- more data
  → more powerful models
  → harder problems solvable.
- “**deep learning hype**” *(since 2012)*.





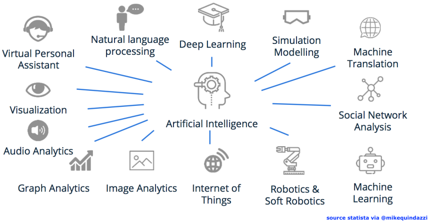




Outline

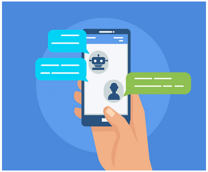
AI → NLP

AI has many applications dealing with different data (sensors, images, graphs, ...).



Natural Language Processing (NLP)

- NLP = automated processing of (*written*) natural language.
- NLP addresses many interesting problems: *search+recommendation, chatbots, question answering, information extraction, translation ...*



How Hard is NLP? [5]

In the 1967 Stanley Kubrick **movie** "2001: A Space Odyssey", the spaceship's **computer HAL** can

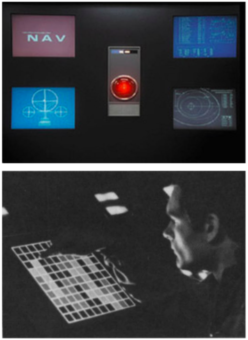
1. display graphics
2. play chess
3. conduct natural, open-domain conversations with humans.

How well did the filmmakers predict what computers would be capable of in 2001?

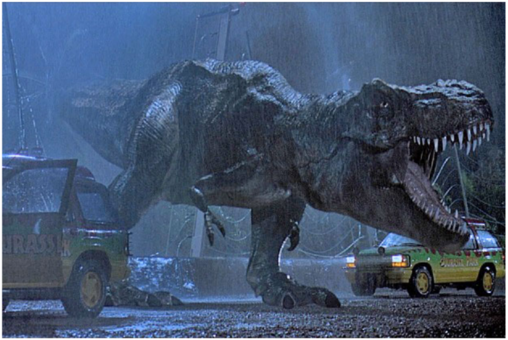
How Hard is NLP? [5]

1. Graphics

HAL



Jurassic Park (1993)



How Hard is NLP? [5]

2. Chess

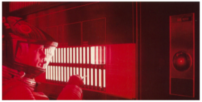
HAL

Deep Blue (1997)

How Hard is NLP? [5]

3. Dialog

HAL



David Bowman: Open the pod bay doors, HAL.

HAL: I'm sorry, Dave, I'm afraid I can't do that.

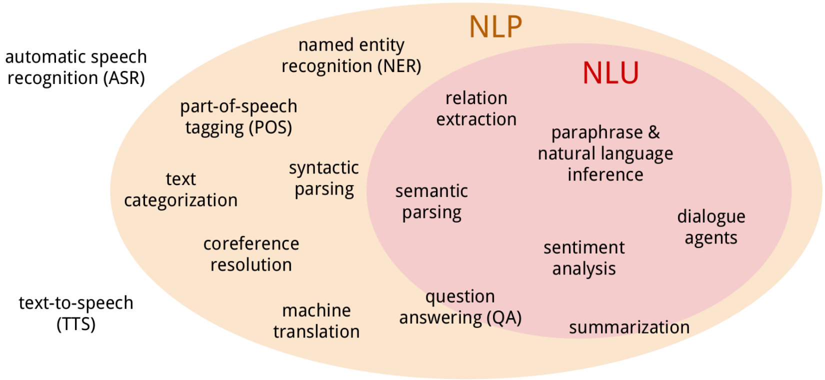
David: What are you talking about, HAL?

HAL: I know that you and Frank were planning to disconnect me, and I'm afraid that's something I cannot allow to happen.

Siri (2011)

Colbert: … I don't want to search for anything! I want to write the show!
Siri: Searching the Web for "search for anything. I want to write the shuffle."
Colbert: … For the love of God, the cameras are on, give me something?
Siri: What kind of place are you looking for? Camera stores or churches?

NLP Tasks


automatic speech recognition (ASR)
named entity recognition (NER)
NLP
NLU
part-of-speech tagging (POS)
relation extraction
paraphrase & natural language inference
text categorization
syntactic parsing
semantic parsing
dialogue agents
coreference resolution
sentiment analysis
text-to-speech (TTS)
machine translation
question answering (QA)
summarization

NLP: History

-1980s

- pattern matching with rule sets *(example: Hearst Patterns)*
- linguistically rich, grounded systems
- restricted applications

NP such as {**NP**,}* {(and/or)} **NP**	→ **Football teams**, such as **the Eagles** or the **Patriots**, ...
NP, **especially** {NP,}* {and/or} **NP**	→ I really like **animals**, especially **birds of prey**.

1990s - 2000s

- the "statistical revolution" in NLP → machine learning.
- focus on sparse, hand-derived representations

2010s

- significant boost in accuracy
- focus on dense, learned features *(representation learning)*
- deep learning, huge neural networks.

NLP: History

Today, NLP experiences an **explosion of interest**!

- voice-driven assistants (Siri, Google Now, Microsoft Cortana)
- natural-language search (Google, Facebook Graph Search)
- question answering (Google, IBM's Watson, Wolfram Alpha)
- web-scale relation extraction (Google, many startups)
- sentiment analysis for automated trading (many hedge funds)
- legal discovery (Cataphora, H5)
- business intelligence (Palantir, Quid)
- social media analytics (a zillion startups)
- content summarization (Summly, other startups)

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Content Analytics
Knowledge Management
Homepage

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Computer Vision
Mixed Reality
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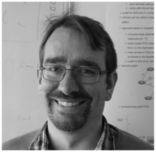

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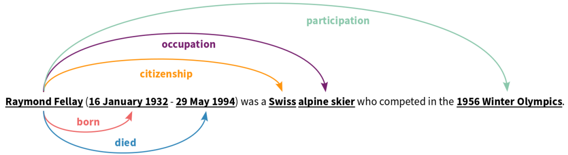
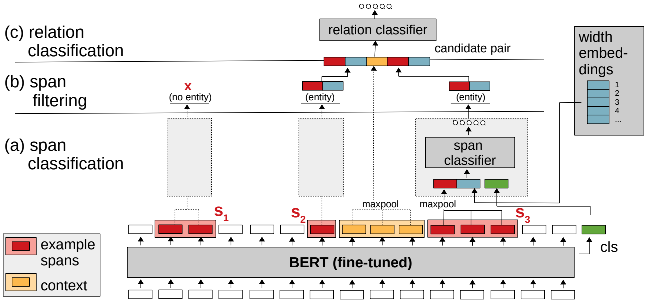
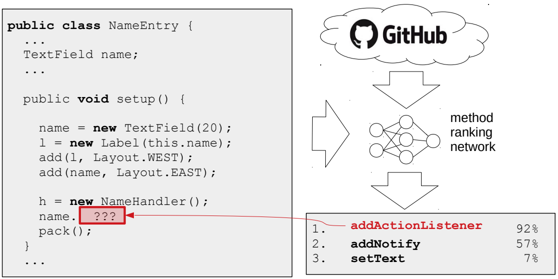
NLP@LAVIS: Joint Entity/Relation Extraction[2]

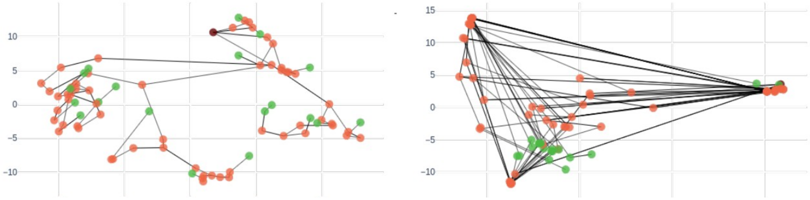




[2] Eberts, Ulges: Span-based Joint Entity+Relation Extraction with Transformer Pre-training (ECAI'20).

NLP@LAVIS: NLP on Source Code[3]

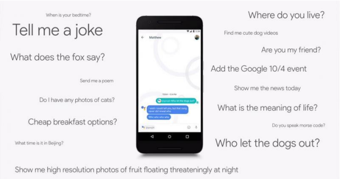


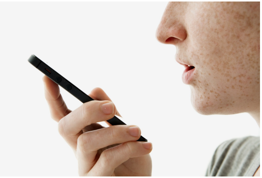


[3] Binder, Villmow, Ulges: Bidirectional Transformer Language Models for Smart Autocompletion of Source Code (SENSYBLE-Workshop'20).

Outline

Question Answering (QA)





Question Answering: a difficult Challenge

- Where do hyenas live? → *on a Canadian airline.*
- What is the population of Maryland? → *three.*

Challenge: Interpreting the Question

> *"We knew that the right query was 'Who are my friends who like running?' But the poor users didn't know this. They would say 'Who are people who like to run?' or 'Who are runners?' or 'Which of my friends run?' They would express it in every conceivable way that was not 'friends who like running'—which was the only way Graph Search understood it."*
>
> (Lars Rasmussen, Facebook, 2013)

Interpreting the Target Data

"What university was Woodrow Wilson president of?"

> *"Woodrow Wilson (1856-1924), served as the 28th president of the USA" vs. "Woodrow Wilson was a professor at Princeton, where he acted as rector..."*

Question Types image: [7]

“Factoid” Questions

- answers consist of short facts

Question	Answer
Where is the Louvre Museum located?	in Paris, France
What’s the abbreviation for limited partnership?	L.P.
What are the names of Odin’s ravens?	Huginn and Muninn
What currency is used in China?	the yuan
What kind of nuts are used in marzipan?	almonds
What instrument does Max Roach play?	drums
What’s the official language of Algeria?	Arabic
How many pounds are there in a stone?	14

Figure 28.1 Some sample factoid questions and their answers.

- widely applied in commercial systems
- our project’s focus

Complex Questions

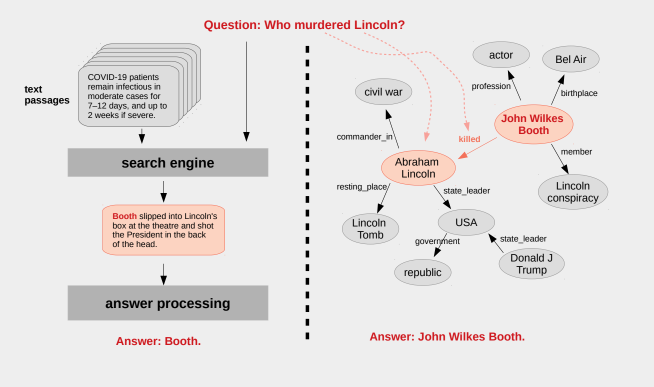
- questions with more **complex answers** *(definitions, explanations, biographies, chains of arguments)*, ...
- ex.: *Why did Hitler come to power? Who is Gillian Jacobs?*
- subject to research until today.

QA Approaches

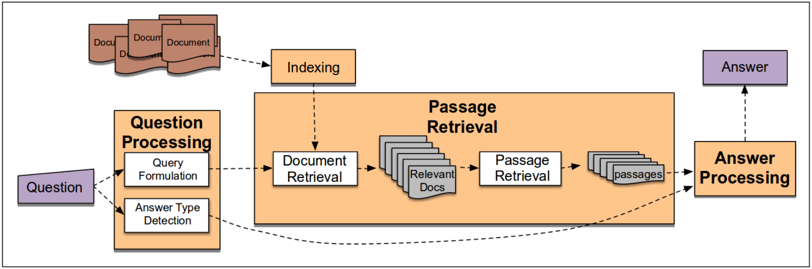
Two Paradigms

1. IR based *(Google Assistant)*
2. knowledge based *(Siri, Wolframalpha)*

Modern systems are usually **hybrids** *(e.g., Watson)*



IR based QA image: [7]



- Knowledge base comes as **natural language text**.
- Three processing steps
  1. Question Processing
  2. Passage Retrieval *(find the right passages)*
  3. Answer Processing
- Use of **information retrieval** (Step 2) and **machine learning** (Steps 1+3)

1) Question Processing

Task

Gain information on the question *(and, hence, its answer)*

a) **answer type**
b) **query formulation**
c) **relations**
d) the **focus** *(the term that would be replaced in the answer)*

Example

"What Shakespearean play featured Shylock ?"

answer type	ENTY/cremat[4]
query	shakespeare shylock
relations	appearsIn(shylock, ?) $\wedge$ author(Shapespeare, ?)
focus	"what Shapespearean play"

[4] This class contains "inventions, books and other creative pieces"

1a) Question Processing: Answer Type image: [7]

"Who founded Virgin Airlines" → *PERSON/INDIVIDUAL*

"What Canadian centre has the largest population?" → *GEO/CITY*

- estimates the type of **answer** expected for the question
- is used to **filter** answer candidates
- is also called "**question classification**"
- see typical classes below

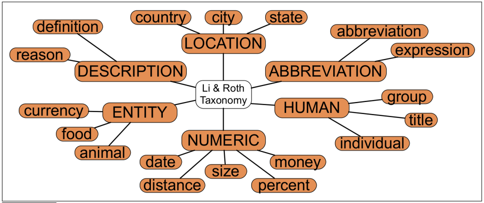


Figure 28.3 A subset of the Li and Roth (2005) answer types.

1b) Question-Processing: Query Extraction

What war added 'jeep' and 'quisling' to the English language ?

- We formulate a **query**.
- Why not simply use the **question**? Because it is better to prioritize key terms!

Example Prioritization [10]

1. *words in quotation marks*
2. *NNPs (singular nouns) in named entities*
3. *nominal groups with adjectives*
4. *other nominal groups*
5. *nouns with adjectives*
6. *all other nouns*
7. *verbs*
8. *adverbs*
9. *the focus term*
10. *all other words*

- We can formulate **multiple queries** *(recall matters!)*

Passage Retrieval: Example

Question

"Who was Queen Victoria's second son?"

Candidate Passages

The Marie biscuit is named after Marie Alexandrovna, the daughter of Czar Alexander II of Russia and wife of Alfred, the second son of Queen Victoria and Prince Albert.

Victoria (Alexandrina Victoria; 24 May 1819 – 22 January 1901) was Queen of the United Kingdom of Great Britain and Ireland from 20 June 1837 until her death. From 1 May 1876, she adopted the additional title of Empress of India.

Queen Victoria Hotel offers Aristocratic heritage with discreet service and tasteful décor. Located in Cape Town Central, the hotel offers airport transportation, babysitting, ...

Passage Retrieval: Approaches

Frequent approach: supervised learning from sample data
(= questions + labeled passages)

Features used

1. **match with answer type**: How many entities in the passage have the right answer type *(z.B. PERSON/individual)*?
2. **match with question**: How many keywords from the question are in the passage? How many **n-grams**? How **close** are keywords to each other?
3. **match with document**: What was the document's rank in document search?
4. **passage importance**: Is the passage at the document's beginning? Does it contain Wikipedia anchor terms?

3) Answer Processing

Abraham Lincoln was assassinated by John Wilkes Booth on Good Friday, April 14, 1865, while attending a play at Ford's Theatre as the American Civil War was drawing to a close.

Possible Approaches

- limit to named entities
- take the type of named entities into account
- proximity to other terms from the query
- use sentence structure / parse tree
- use term similarities *(word2vec, PPMI, Resnik)*?
- use generalization/specialization *(beagle* `is_a` *dog)*
- formulate patterns *(does "born in" appear?)*
- novelty *(answer+question should not overlap)*

Outline

IBM Watson[6]

The “Jeopardy Challenge”

- Jeopardy = popular US quiz show
- hints (“questions”) with factoid answers
- Questions come in categories

Category	**Literary Monsters**
Clue	*Assembled from dead bodies, the monster in this Mary Shelley book turns against his creator.*
Answer	*Frankenstein.*

- Some question categories are quite specific

Category	**Rhyme Time**
Clue	*It’s where Pele stores his ball.*
Answer	*Soccer locker.*

IBM Watson[6]

- team of 20 engineers, 3 Jahre (+ previous prototypes)
- system achieves **human performance**
  - ... answers 70 % of all questions (accuracy = 80 %)
  - ... 3 seconds response time *(on dedicated hardware)*

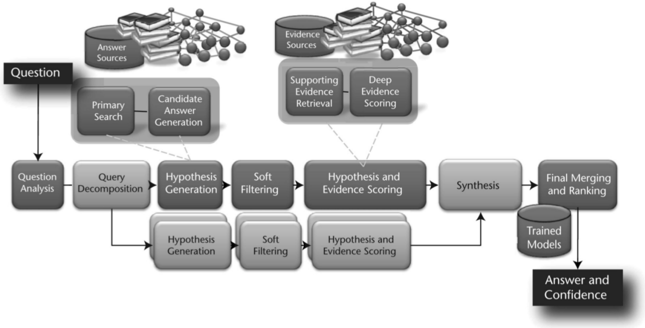
Knowledge Base I: 20,000 question-answer pairs, labeled with ...

- ... **question type** (z.B. “rhyme”, “definition”, “math”, ...)
- ... 2,500 different **Lexical Answer Types (LATs)**
  (z.B. song, president, he ...)
- ... semantic **relations**
  (z.B. person_birthplace, product_producer, ...)

Knowledge Base II: Corpora

- **text corpora**: Wikipedia, news articles, literature
  (all expanded with web documents)
- **databases** (e.g., IMDB) and **knowledge graphs**.

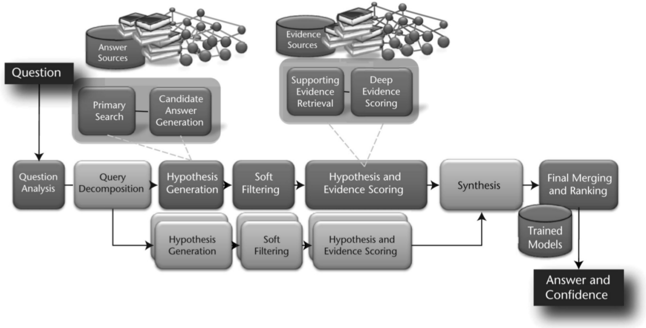
IBM Watson: Architecture image: [6]



Approach

- similar to **classical IR QA**
- many additional analysis steps, > **100 modules**
- Idea: generate as many candidates as possible (>> 100), rank these.

IBM Watson: Architektur image: [6]



Approach (cont'd)

- **information extraction** *(entities + relations)*
- **NLP techniques**: coreferences, parse trees, extraction of *logical forms*, ...
- **Wikipedia link analysis** (anchor terms are better candidates)

→ heavy use of **machine learning**.

Watson: *Evidence Scoring*

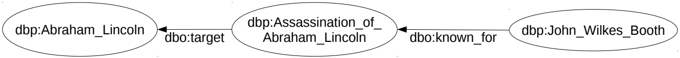
> 50 **components score candidate answers**:

1. Passage retrieval with query = question + candidate answer
   (how much evidence do we find?)

```
q = question(Abraham Lincoln murdered) +
     answer(John Wilkes Booth) → 27 hits
```

1. President Lincoln is shot in the head at Ford's Theatre ...
2. Abraham Lincoln, now viewed as a martyr who ended slavery ...
3. ...

2. use knowledge graphs



`1 match of medium quality (path length 2, confidence 98%)`

3. term overlap between question + answer passage
   (tf-idf oder sequence length [11])

Question: Who murdered Lincoln at Ford Threatre?

Passage: President Abraham Lincoln is shot in the head at Ford Theatre
in Washington, D.C. The assassin, actor John Wilkes Booth, ...

`Maximum Overlap (Smith-Waterman Algorithm): 13 characters`

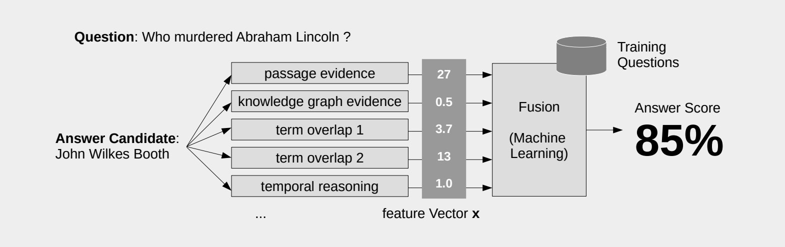
Watson: *Evidence Scoring*

4. **structure comparison** between answer and question *(logical forms)*
5. **popularity** of target documents *(e.g., PageRank)*
6. **(simple) reasoning**: spatially, temporally, taxonomically

Question: Who murdered Lincoln on April 14 1865?

Answer 1: Lee Harvey Oswald	temporal reasoning	`unlikely (born in 1939)`
Answer 2: Ford's Theatre	taxonomic reasoning	`unlikely (not is_a person)`

A machine learning combines the resulting scores to a **ranking**:



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