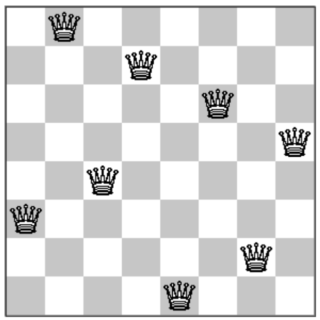
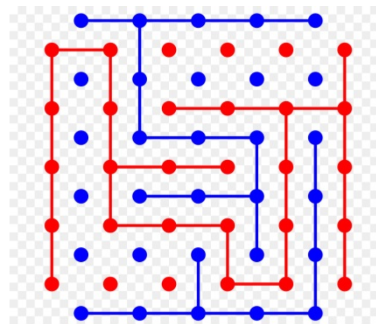
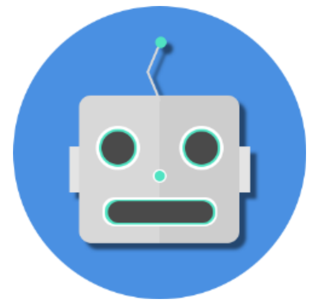
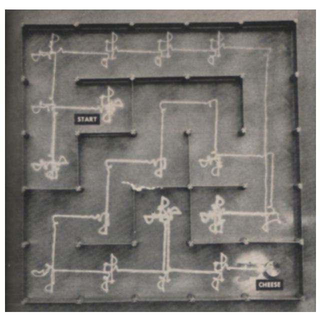
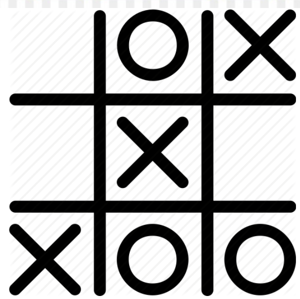
GE2340 Artificial Intelligence

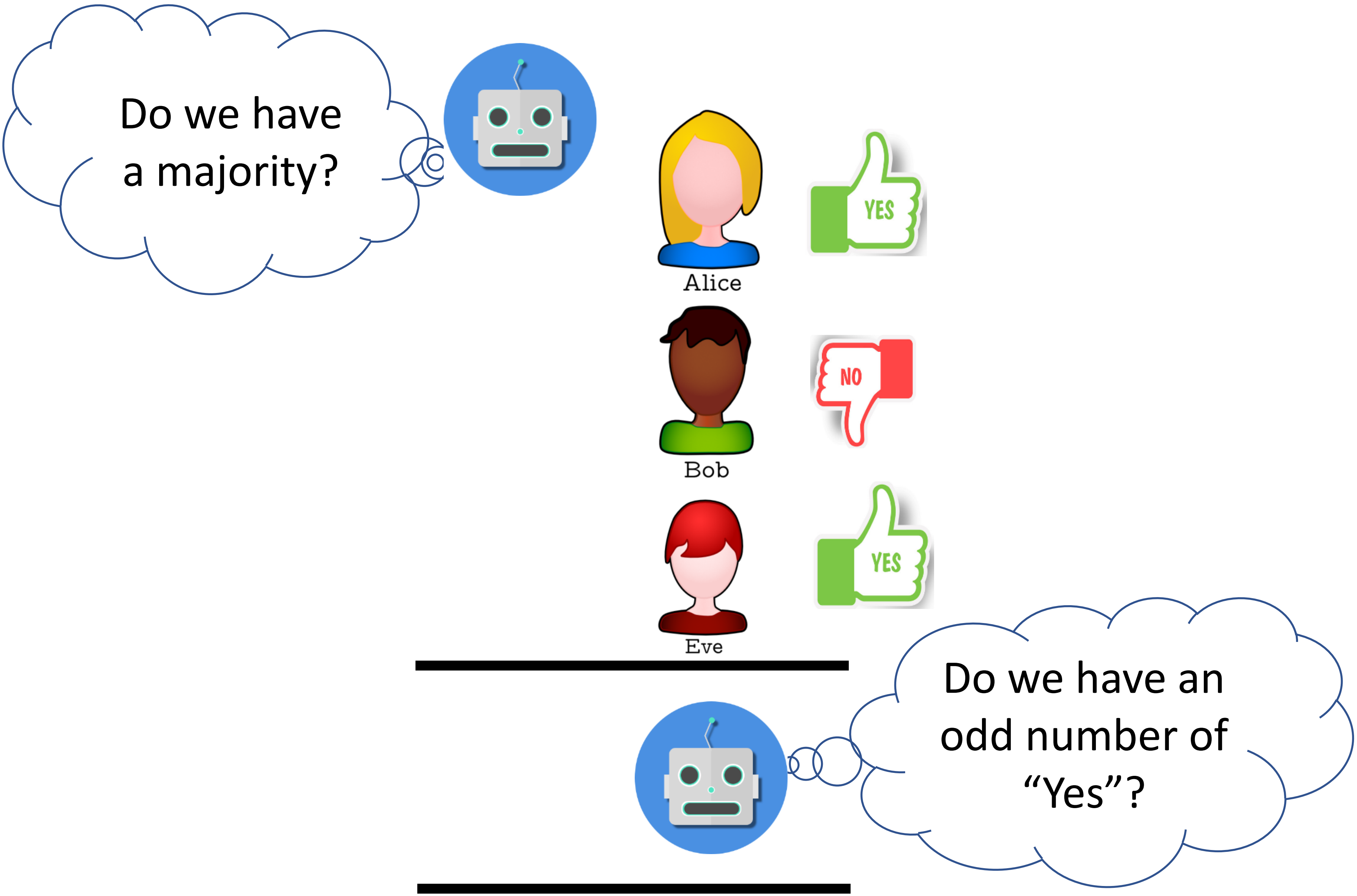
Searching under Uncertainty



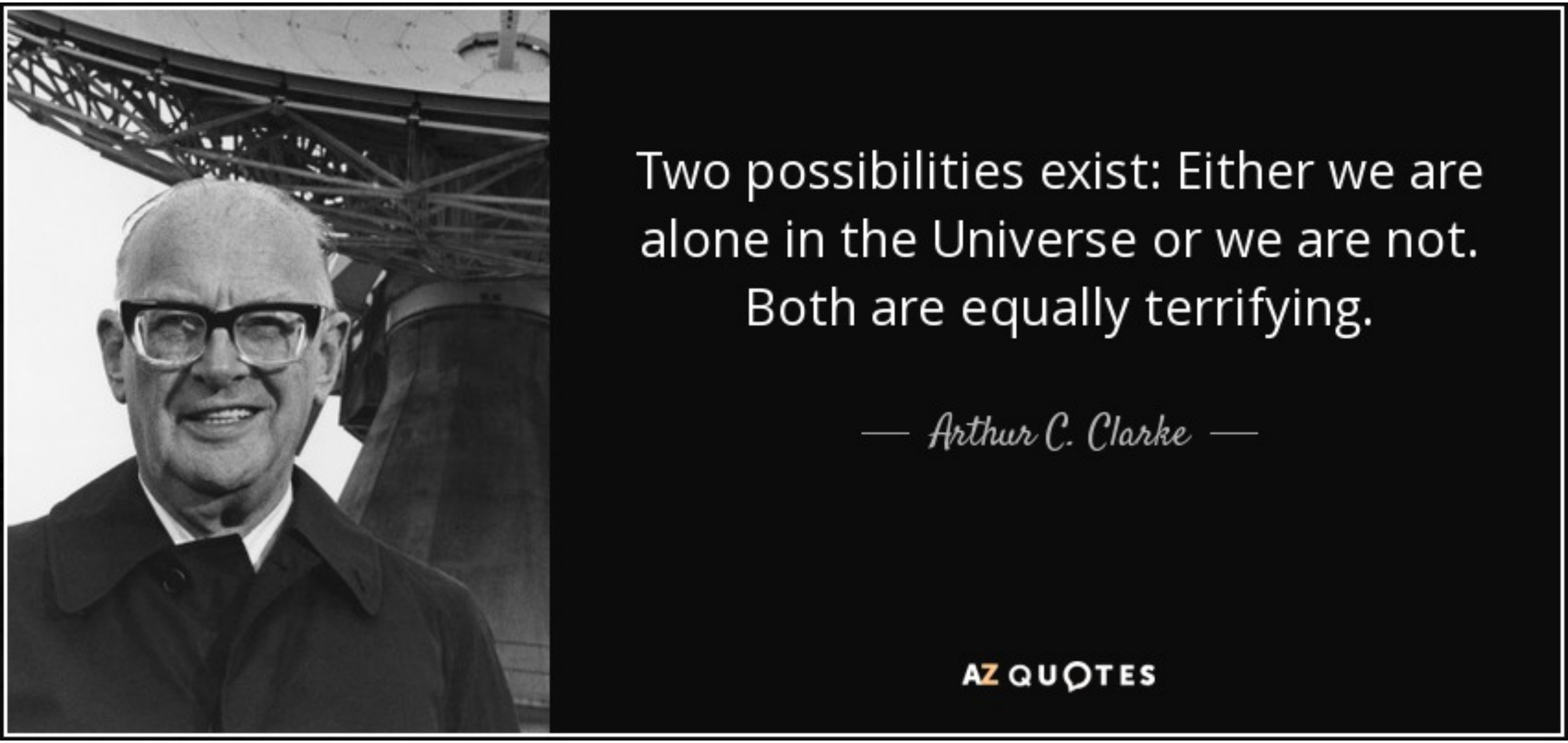
Chee Wei Tan

Story Thus Far: Asking the Right Questions



Searching for Answer under Uncertainty

Searching for Answer under Uncertainty



Searching for Answer under Uncertainty

How far is the moon from the earth?

What is the number of atoms in the observable universe?

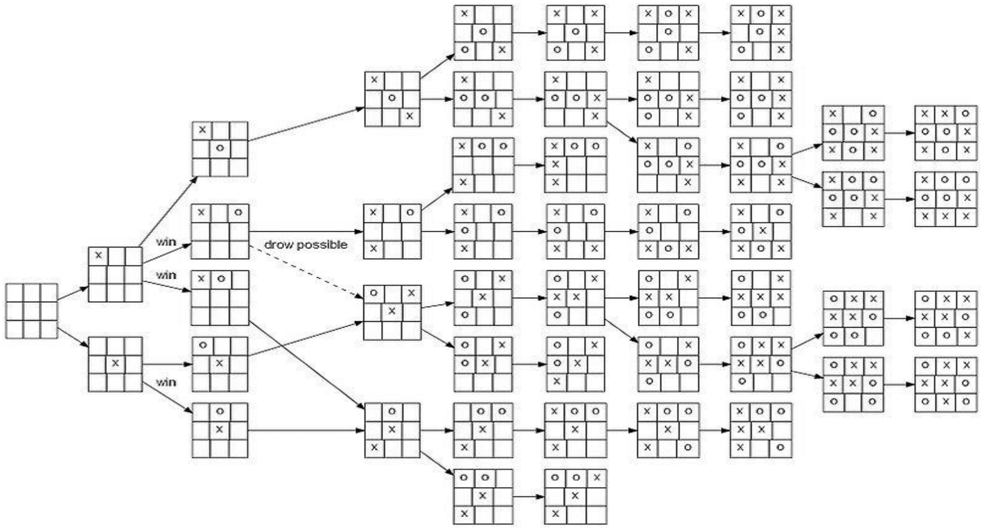
How many leaves are on this tree?

https://www.wired.com/2012/12/how-many-leaves-are-on-this-tree/

Searching for Answer under Uncertainty

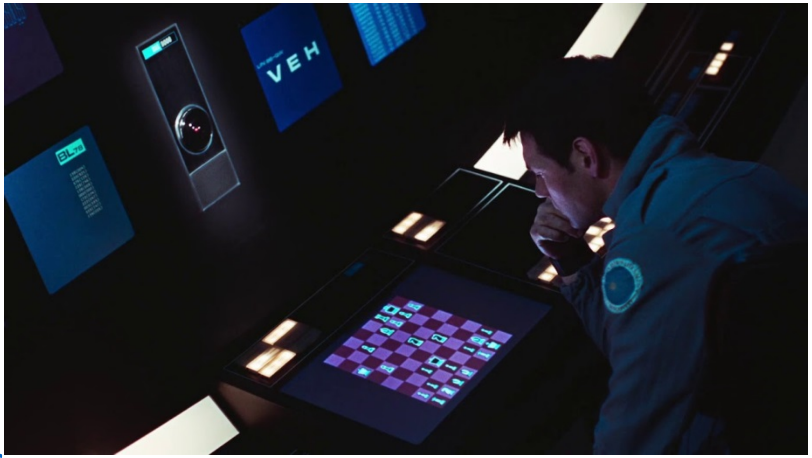
What is the size of the game tree in Tic Tae Toe?

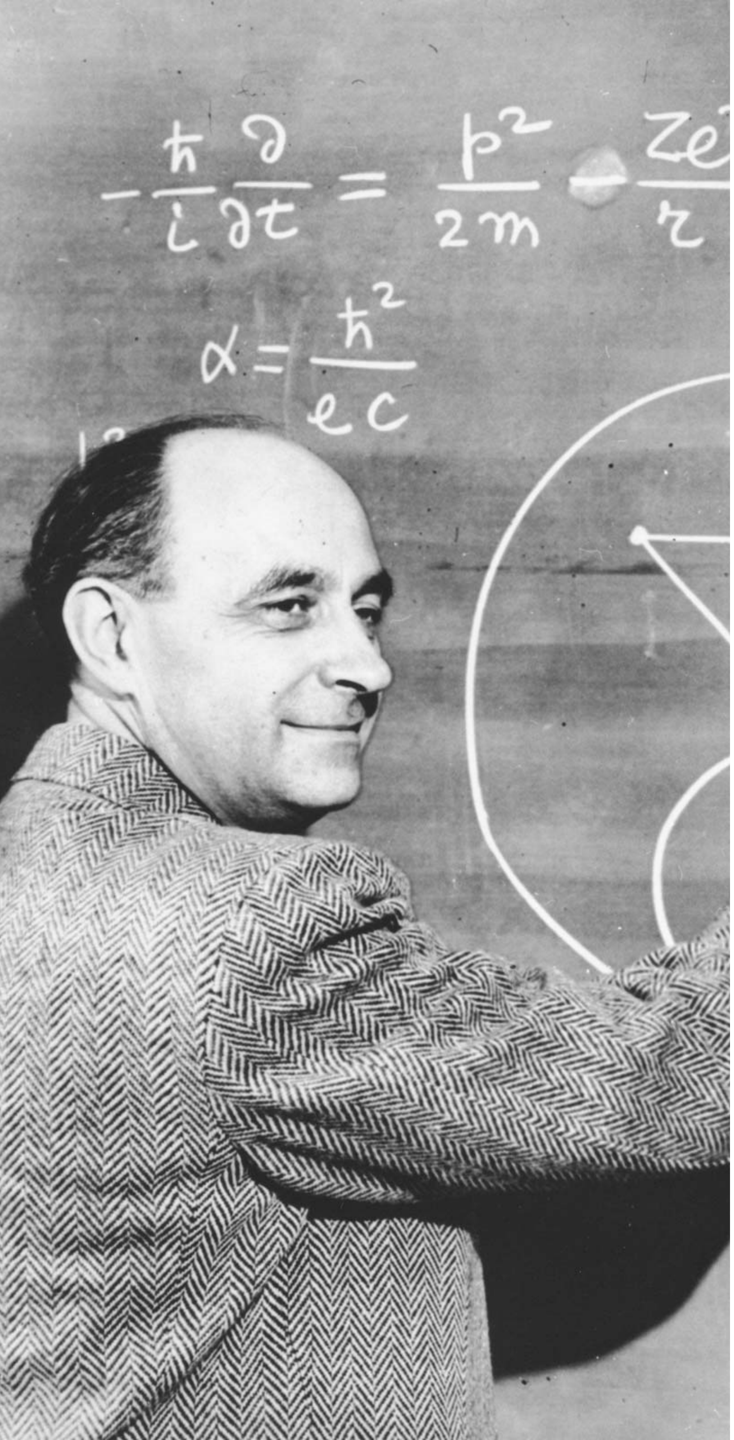
The game-tree complexity of a game is the number of leaf nodes in the smallest full-width decision tree that establishes the value of the initial position. A full-width tree includes all nodes at each depth.



What is the size of the game tree in chess?

Shannon’s Number
https://en.wikipedia.org/wiki/Shannon_number

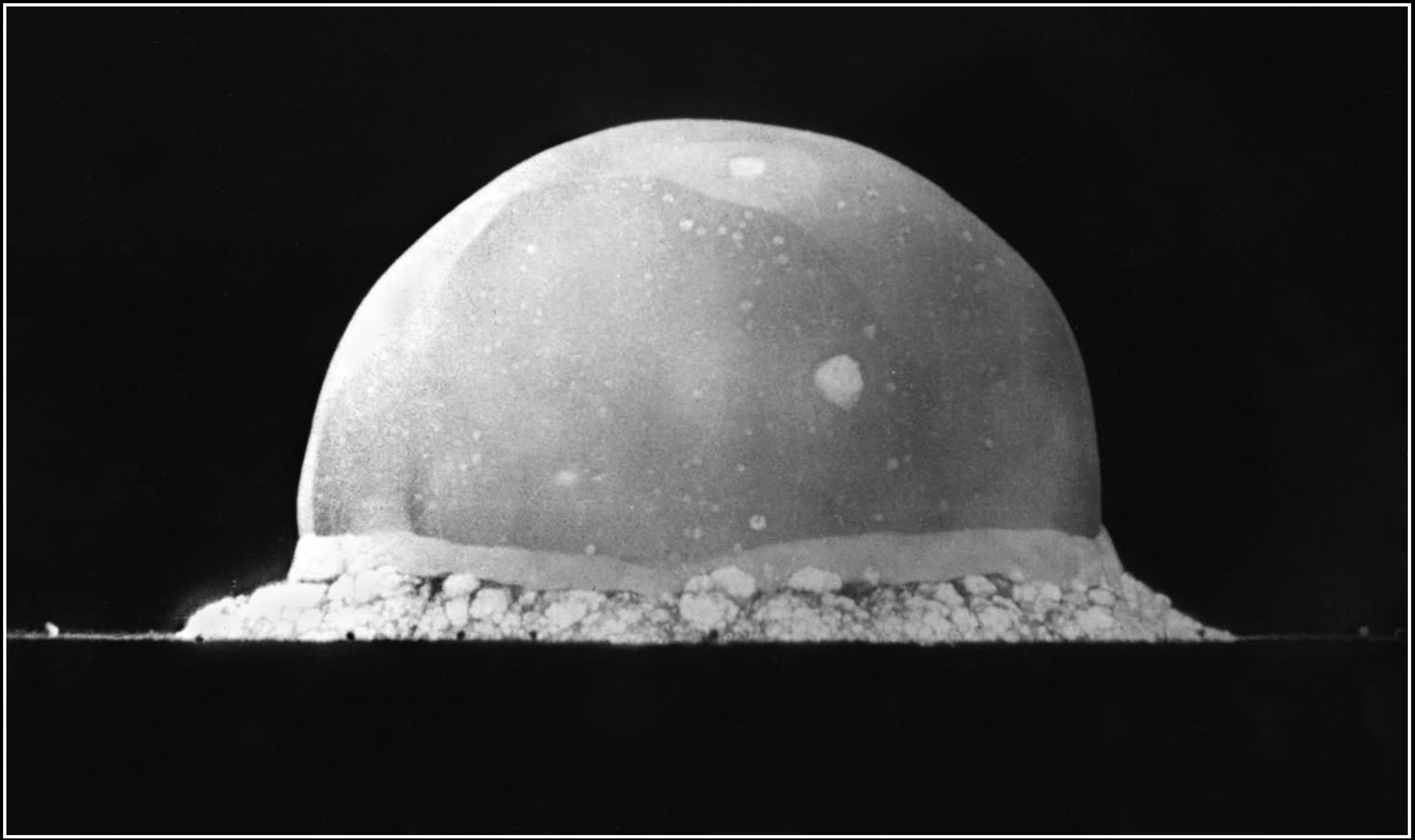




Enrico Fermi

- Enrico Fermi (1901-1954) won the Nobel Prize in 1938 for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons. He has been called the "architect of the nuclear age" and the "architect of the atomic bomb".
- He contributed to statistical mechanics, and made the first predictions of pion-nucleon resonance, relying on statistical methods, since he reasoned *that exact answers were not required when the theory was wrong anyway.*
- He once said “I can calculate anything in physics within a factor 2 on a few sheets; to get the numerical factor in front of the formula right may well take a physicist a year to calculate, but I am not interested in that”
- He amused his friends by inventing questions which have a whimsical quality about them; one of the most famous is *"How many piano tuners are there in Chicago?"*“

https://en.wikipedia.org/wiki/Enrico_Fermi



Trinity Explosion (1945)

Trinity Explosion (1945)

My Observations During the Explosion at Trinity on July 16, 1945

- E. Fermi

On the morning of the 16th of July, I was stationed at the Base Camp at Trinity in a position about ten miles from the site of the explosion.

The explosion took place at about 5:30 A.M. I had my face protected by a large board in which a piece of dark welding glass had been inserted. My first impression of the explosion was the very intense flash of light, and a sensation of heat on the parts of my body that were exposed. Although I did not look directly towards the object, I had the impression that suddenly the countryside became brighter than in full daylight. I subsequently looked in the direction of the explosion through the dark glass and could see something that looked like a conglomeration of flames that promptly started rising. After a few seconds the rising flames lost their brightness and appeared as a huge pillar of smoke with an expanded head like a gigantic mushroom that rose rapidly beyond the clouds probably to a height of the order of 30,000 feet. After reaching its full height, the smoke stayed stationary for a while before the wind started dispersing it.

About 40 seconds after the explosion the air blast reached me. I tried to estimate its strength by dropping from about six feet small pieces of paper before, during and after the passage of the blast wave. Since at the time, there was no wind I could observe very distinctly and actually measure the displacement of the pieces of paper that were in the process of falling while the blast was passing. The shift was about 2 1/2 meters, which, at the time, I estimated to correspond to the blast that would be produced by ten thousand tons of T.N.T.

http://www.atomicarchive.com/Docs/Trinity/Fermi.shtml

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My Observations During the Explosion at Trinity on July 16, 1945 — E. Fermi

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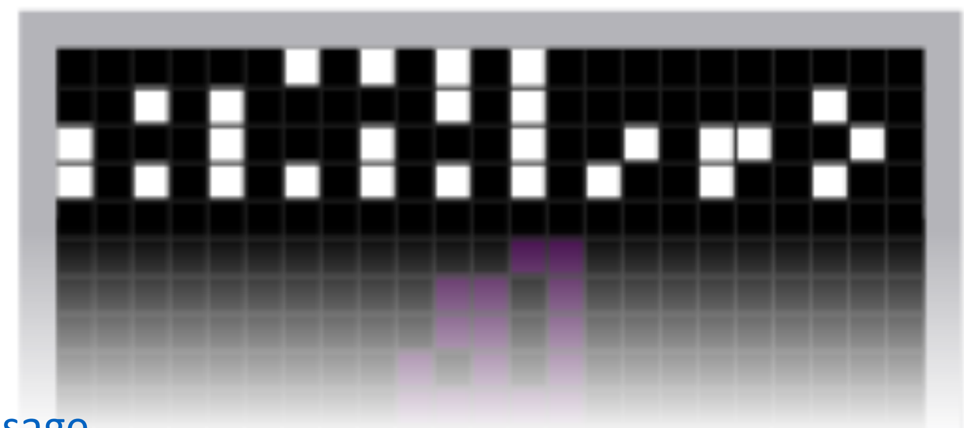
- Fermi's estimate of 10 kilotons of TNT was well within an order of magnitude of the now-accepted value of 21 kilotons.
- This one pager validates Fermi's claim that "*I can calculate anything in physics within a factor 2 on a few sheets; to get the numerical factor in front of the formula right may well take a physicist a year to calculate, but I am not interested in that*".

Searching for Answer under Uncertainty

Fermi Paradox (1950): there are an estimated 200–400 billion stars in the Milky Way ($2–4 \times 10^{11}$) and 70 sextillion (7×10^{22}) stars in the observable universe. Where are the aliens?
https://en.wikipedia.org/wiki/Fermi_paradox

Drake Equation (1961): a Fermi-type argument used to estimate the number of active, communicative extraterrestrial civilizations in the Milky Way galaxy
https://en.wikipedia.org/wiki/Drake_equation

Arecibo message (1974):
A message from Earth including the first ten integers in base 2 (binary representation)
https://en.wikipedia.org/wiki/Arecibo_message



Fermi Questions

- A "Fermi question“, originating in physics, is a question that seeks a fast, rough estimate of quantity which is either difficult or impossible to measure directly.
- How many piano tuners are there in Chicago?

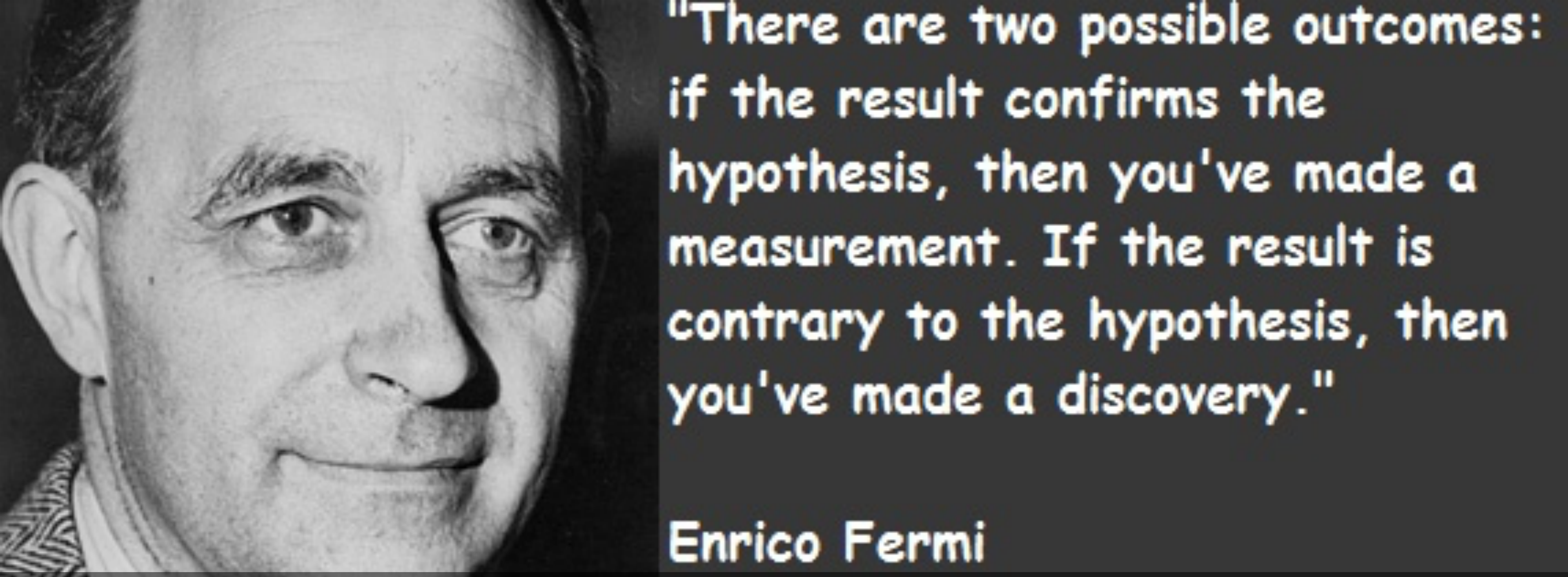
  (a) 120 (b) 225 (c) 560 (d) 750

- Let’s vote!

Fermi Questions in All Walks of Life

Here are a few examples of practical Fermi Questions:

- Business: "How many teens within a 30 mile radius of our proposed fast food restaurant?"
- Environmental policy: "By how much would the amount of trash in landfills be reduced if it became illegal to throw away plastic grocery bags?"
- Educational policy: "If the school district reduces the maximum class size to 20 students, how much would it cost to hire the extra teachers?"
- Public health: "A virulent strain of influenza is spreading and everyone in our county needs to be vaccinated by a qualified health care professional. How quickly can this be done?"
- Personal finance: "I am going to work in a fast food restaurant to cover my college tuition, books, and living expenses. Will I need to take out a loan? Will I have enough time to study?"
- Event planning: "Our city is organizing a parade with a mile-long route. About 150 organizations have expressed interest in being in the parade. For how much time will the streets need to be closed along the route?"



http://www.atlapa.gob.pa/es/evento/enrico-fermi

Fermi Questions

- Cultivate the ability to make good guesses and predict the solution of a problem. Thinking about Fermi questions enables you to imagine, question your hypothesis and assumptions and know what to measure to accomplish your goals.
- Divide and conquer strategy of solving hard problems

Examples on Making Educated Guesses

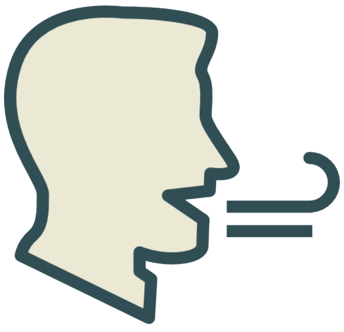
Let's look at a few more examples of Fermi Questions. Let's take a vote before looking at the reasoning process.
Note that some estimates used may not be accurate at all. Making Fermi estimates means to iteratively gather more data to refine guess.

- How many people in the world are talking on their cell phones in any given minute?

  (a) 10 million (b) 120 million (c) 210 million (d) 520 million

- What is the volume of air that I breathe in a day?

  (a) 70 Liters (b) 700 Liters (c) 3500 Liters (d) 7200 Liters

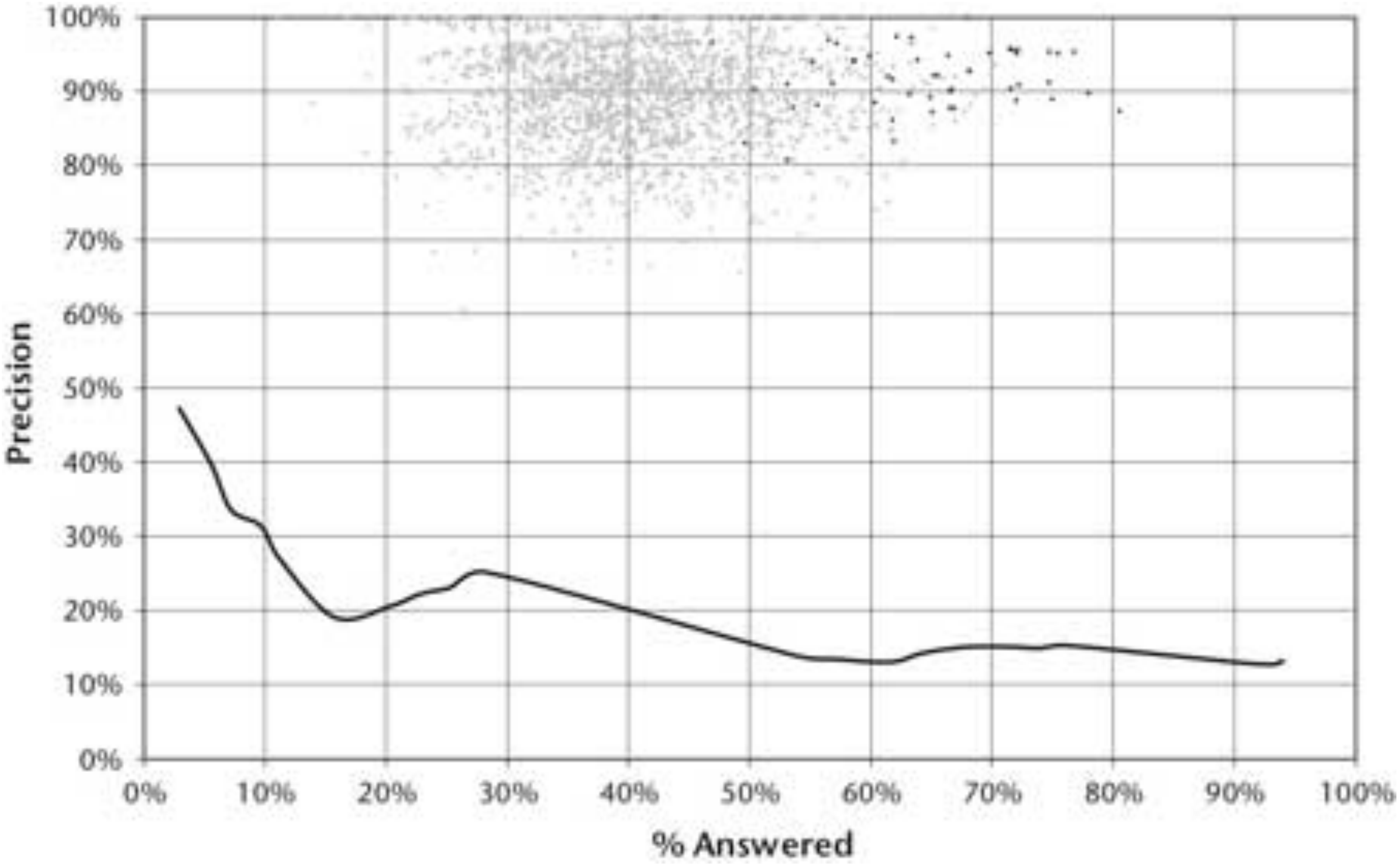


What is IBM DeepQA?

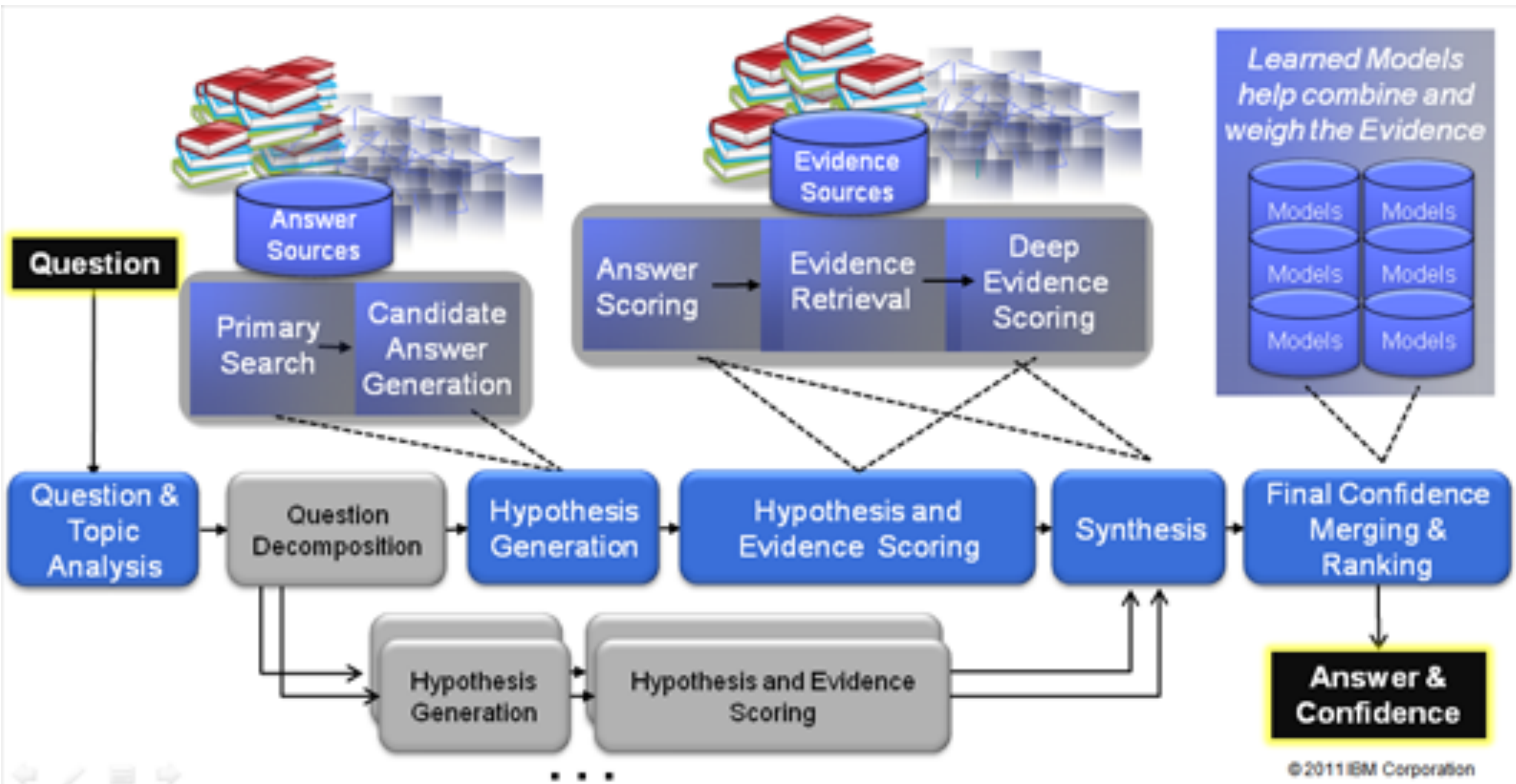
- IBM's follow up project to DeepBlue designed to answer questions posed in natural language
- Capable of playing Jeopardy! at human championship level
- Initial corpus of documents that are Unstructured data
  - For Jeopardy! – roughly ~400 TB of data plus Wikipedia
- Parsed as Subject-Verb-Object into "Syntactic Frames" that forms a "Semantic Net"

https://www.aaai.org/Magazine/Watson/watson.php

Initial Performance



DeepQA Architecture



Generate, Score and Rank Hypothesis

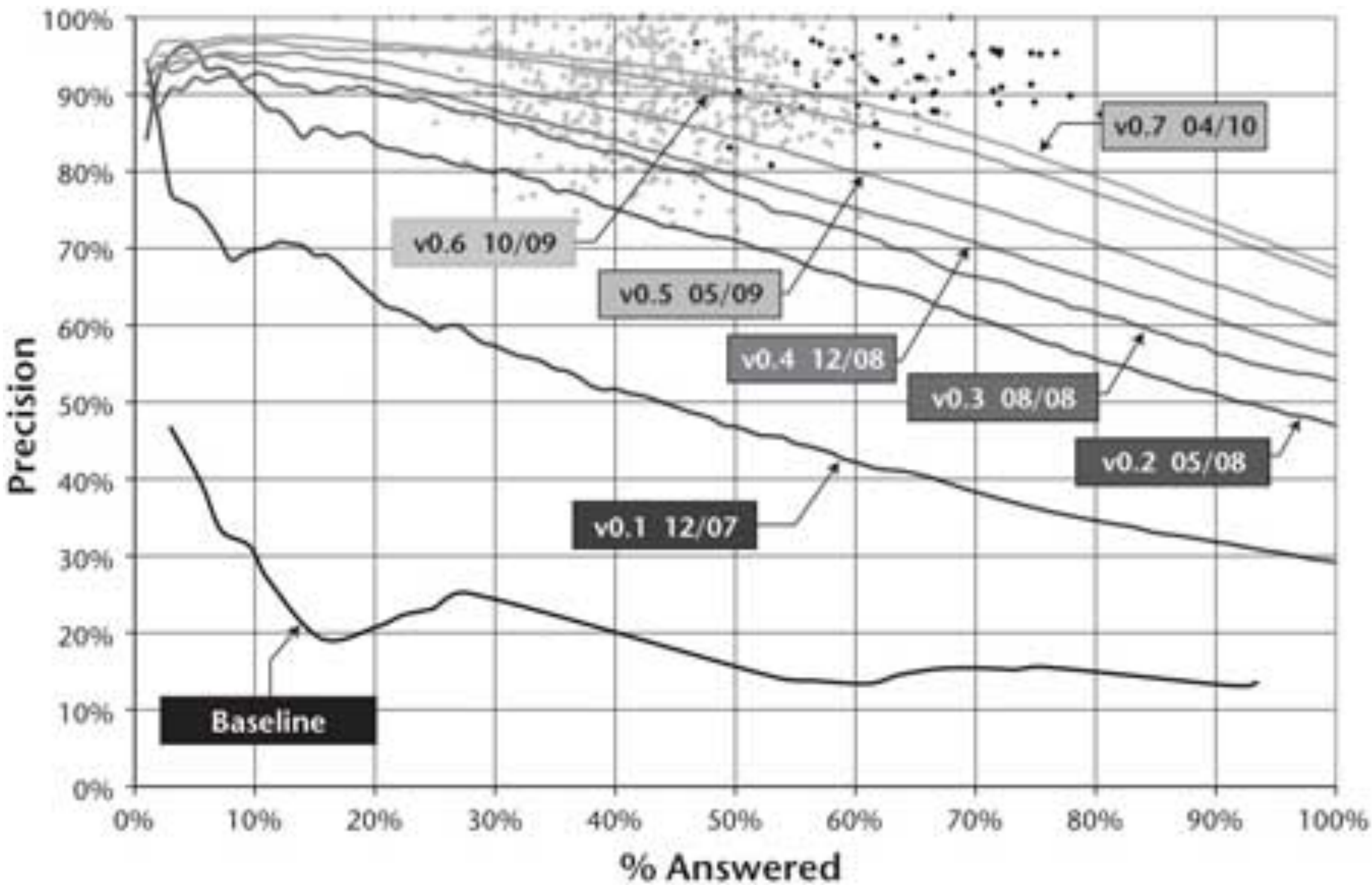
- Generate candidate answers from different sources
  - 85% of time correct answer within top 250 at this stage
  - Filtering to let through ~100 answer candidates

- Score the candidate answers based on supporting evidence
  - More than 50 different types of scoring methods, e.g., temporal, geospatial, popularity, reliability

- Generate confidence level estimation
  - Indicates how confident each answer may be
  - Some form of machine learning is needed
  - Different question types might weigh scores differently
  - Probabilistic and Bayesian estimation

- Rank candidates based on confidence
  - Answer is the candidate with highest confidence level

DeepQA Performance



DeepQA on Watson

- With a single CPU - ~ 2 hours to get an answer
  - Not fast enough for Jeopardy!
  - Questions take ~ 3 seconds on average to read

- Take advantage of the parallel capabilities of DeepQA
  - 90 Power 750 servers = 2880 CPUs
    - 80 TFLOPS
  - Able to answer in 3-5 seconds

Jeopardy! Challenge

- In January 2011 Watson competed against two of the best Jeopardy! Champions
  - Ken Jennings – $3,172,700 in winnings
  - Brad Rutter - $3,470,102 in winnings

- Two matches played
  - Questions chosen from unaired episodes

Outcome

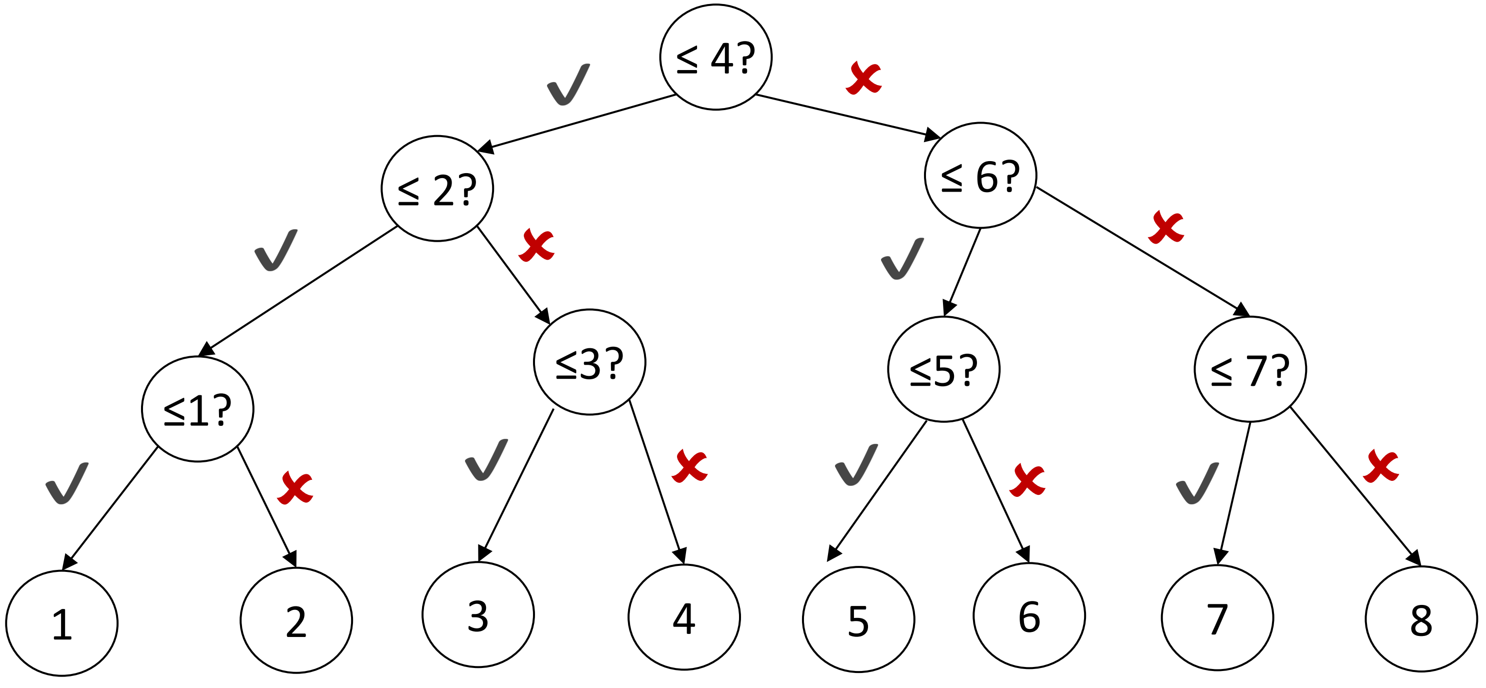
- First Game
  - Watson wins - $35,734
  - Rutter - $10,400, Jennings - $4,800
- Second Game
  - Watson - $77,147
  - Jennings - $24,000, Rutter - $21,600

20 Questions (Number Game)

- Two-player game between guesser and challenger
- Challenger selects a number between 1 and *N* without revealing it that the guesser must identify with *at most* 20 questions
- Any yes-no question the guesser can think of is admissible
- Example (Say *N* is 32):
- `Guesser: Is it 1? Is it 2? Is it 3? …`
- `Guesser: Is it 32? Is it 31? Is it 30? …`
- `Guesser: Is it even? Is it prime?`
- `Guesser: ?`

Number Game: Guess a number between 1 and 8

- A binary search tree (≤ denotes “less or equal than”):



20 Questions (Number Game)

- How to design yes-no questions?
- What do you observe between *N* and the binary tree?
- If the challenger tends to pick certain number, does that influence how you ask questions (thereby the shape of the binary search tree)?
- How to minimize the expected number of questions to ask?

Shannon Entropy

- A yes/no question (Boolean question) contains exactly one bit of information (bit = binary digit)

Claude Shannon: The Mathematical Theory of Communication

Bell System Technical Journal, 1948

Shannon's measure of information is the number of bits to represent the amount of uncertainty (randomness) in a data source, and is defined as the entropy

$$H = -\sum_{i=1}^{n} p_i \log(p_i)$$

where there are n symbols 1, 2, ... n, each with probability of occurrence of p_i

Intuition on Shannon's Entropy

Why $$H = -\sum_{i=1}^{n} p_i \log(p_i)$$

Suppose you have a long random string of two binary symbols 0 and 1, and the probability of symbols 1 and 0 are p_0 and p_1

Ex: 00100100101101001100001000100110001 ....

If any string is long enough say N, it is likely to contain Np_0 0's and Np_1 1's. The probability of this string pattern occurring (the likelihood) is equal to

$$p = p_0^{Np_0} \, p_1^{Np_1}$$

Thus, the number of possible patterns is $1/p = p_0^{-Np_0} \, p_1^{-Np_1}$

Number of bits to represent all possible patterns is $\log(p_0^{-Np_0} \, p_1^{-Np_1}) = -\sum_{i=0}^{1} Np_i \log p_i$

The average number of bits to represent the symbol is therefore

$$-\sum_{i=0}^{1} p_i \log p_i$$

More Intuition on Entropy

- Assume a binary memoryless source (e.g., a flip of a coin). How much information do we receive when we are told that the outcome is a *head*?

  - If it's a fair coin, i.e., P(*head*) = P (*tail*) = 0.5, thus we say that the *amount of information is 1 bit*.

  - If we already know that it will be (or was) head, i.e., P(*head*) = 1, the *amount of information is zero!*

  - If the coin is not fair, e.g., P(*heads*) = 0.9, the *amount of information is more than zero but less than one bit!*

  - Intuitively, the amount of information received is the same if P(*heads*) = 0.9 or P (*heads*) = 0.1.

Example

Three symbols a, b, c with corresponding probabilities:

P = {0.5, 0.25, 0.25}

What is H(P)?

Three weather conditions in London: Rain, sunny, cloudy with corresponding probabilities:

Q = {0.48, 0.32, 0.20}

What is H(Q)?

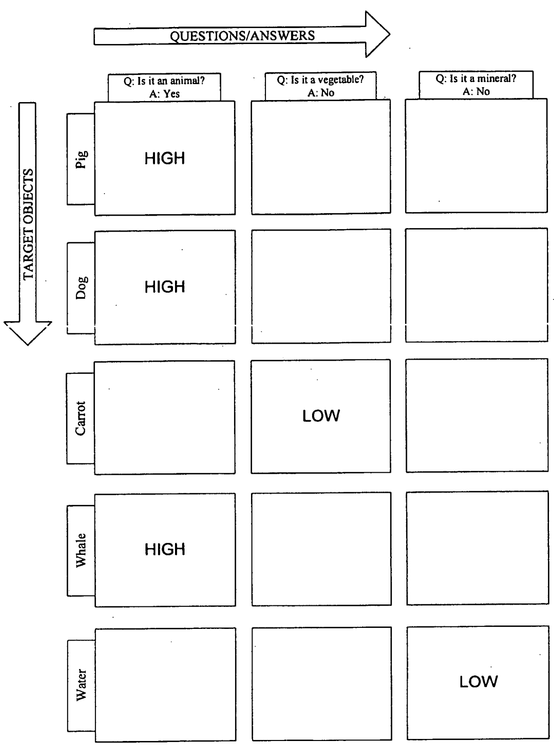
20 Questions (20q Game)

- Identify an object based on “20 Questions” game
- http://20q.net started out in 1995 knowing one object, a cat, and one question
- *Training by playing*: Neural network trained by online players at the 44 millionth game in Sept 2006 and 89 millionth game in Oct 2020
- 20Q guesses correctly 76% of the time (98% of the time with 25 questions)
- “Because 20Q does not simply follow a *binary decision tree*, answering a question incorrectly will not throw it completely off” - 20Q.net

20 Questions (20q US Patent)

Artificial neural network guessing method and game

US20060230008A1, United States Patent, 2005



405 404 401 402 403

Question	Top Target Objects: Dog	Cat	Chicken	Whale	Lion	Eagle	Agreeability (Total number of YES's)	Disagreeability (Total number of NO's)	Margin or Difference
1. Does it bite?	YES	NO	NO	NO	NO	NO	1	5	4
2. Would you find it on a farm?	YES	YES	YES	NO	NO	NO	3	3	0
3. Can you pet it?	YES	YES	NO	NO	NO	NO	2	4	2
4. Is it round?	NO	NO	NO	NO	NO	NO	0	6	6
5. Is it fury?	YES	YES	NO	NO	YES	NO	3	3	0
6. Does it have seeds?	NO	NO	NO	NO	NO	NO	0	6	6
7. Is it bigger than a duck?	YES	YES	NO	YES	YES	YES	5	1	4
8. Is it found in salad bars?	NO	NO	NO	NO	NO	NO	0	6	6
9. Can you eat it?	NO	NO	YES	NO	NO	NO	1	5	4
10. Is it loyal?	YES	NO	NO	NO	NO	NO	1	5	4

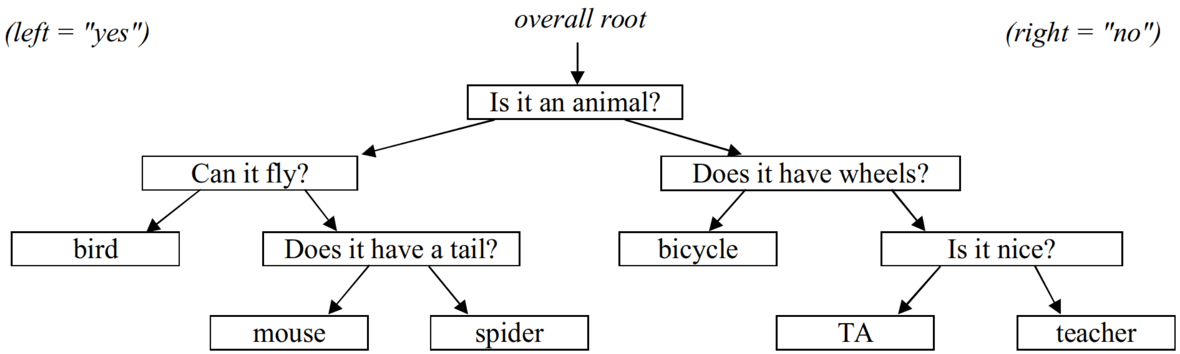
406

Figure 4

20 Questions (20q Game)

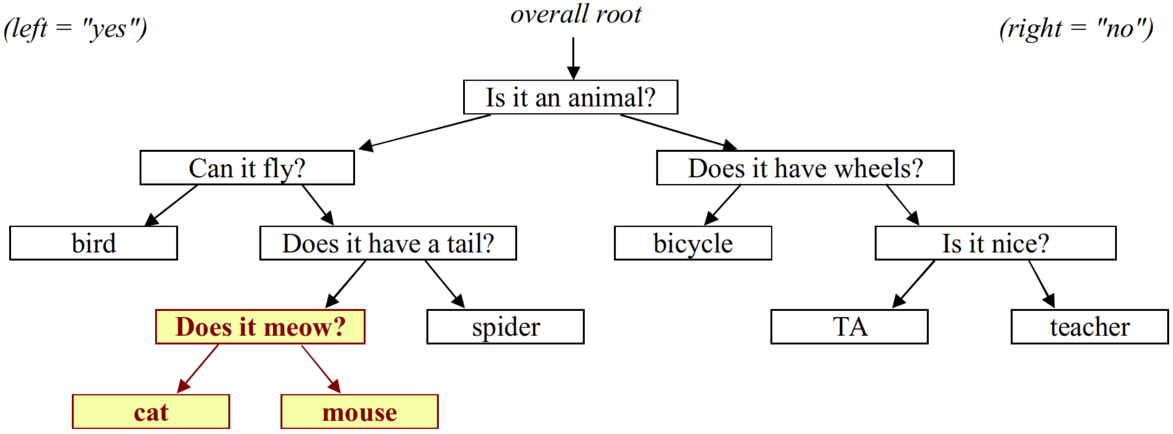
- Store the data of questions and answers in a binary tree
- “Learn” after losing a game by asking human player for new data

```
Q:Is it an animal?
Q:Can it fly?
A:bird
Q:Does it have a tail?
A:mouse
A:spider
Q:Does it have wheels?
A:bicycle
Q:Is it nice?
A:TA
A:teacher
```



20 Questions (20q Game)

- When the computer loses, ask human player for a new Q/A node to grow "*knowledge tree*"




```
Is it an animal? y
Can it fly? n
Does it have a tail? y
Is your object: mouse? no
Drat, I lost. What is your object?
cat
Type a yes/no question to
distinguish cat from mouse: Does
it meow?
And what is the answer for cat? y
```

Present-Time Discoveries by AI, NASA data

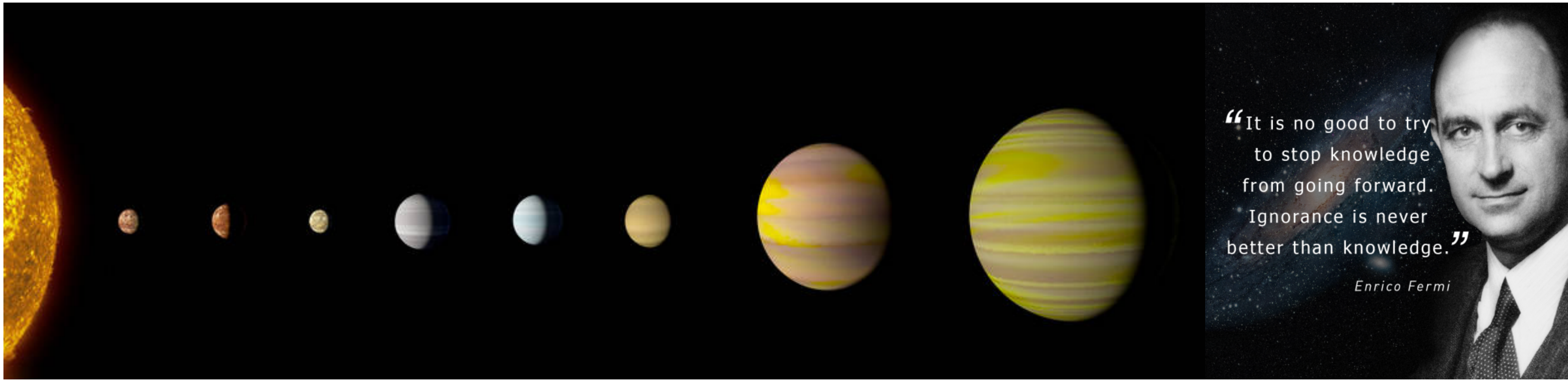
Two new "super Earths" planets K2-293b, K2-294b were spotted by a machine-learning algorithm called AstroNet-K2, a neural network modified to hunt through data from the Kepler space telescope's K2 campaign. The "deep learning" algorithm is able to separate real exoplanet signals from false positives.

TensorFlow

Artificial Intelligence, NASA Data Used to Discover Eighth Planet Circling Distant Star (December 2017)
https://www.nasa.gov/press-release/artificial-intelligence-nasa-data-used-to-discover-eighth-planet-circling-distant-star

Discovery Alert! Two new planets – found by AI (April 2019)
https://exoplanets.nasa.gov/news/1565/discovery-alert-two-new-planets-found-by-ai/

⭐-gazing: Centuries-Old Human Intelligence



Terence Tao, The Cosmic Distance Ladder (2010)

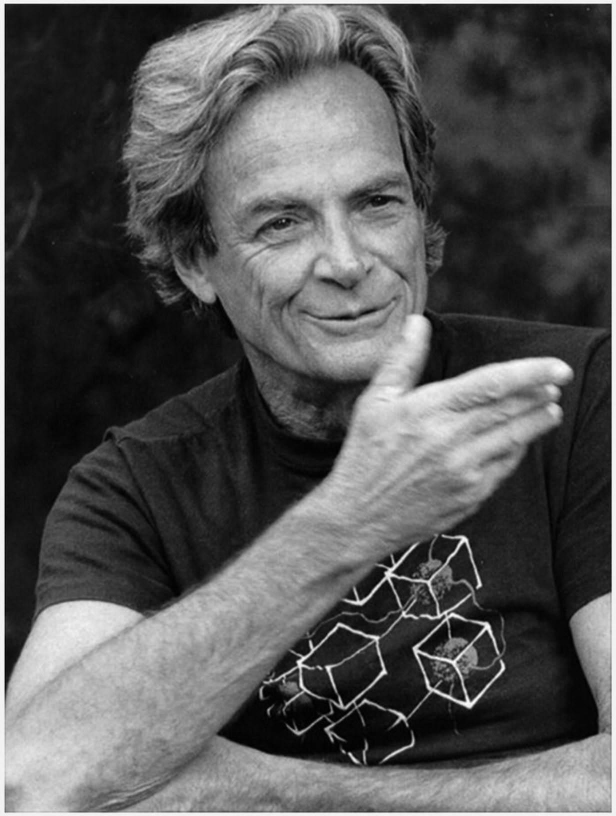
https://www.youtube.com/watch?v=7ne0GArfeMs

Talk poster (https://sumo.stanford.edu/old/speakers/2011/Tao-poster_FOM.pdf)
A highly-accessible talk on how brilliant human beings made Fermi-type computations based on the right kind of observations and data more than 2000 years ago.

A 2010 AMS Einstein Public Lecture in Mathematics sponsored by the American Mathematical Society (AMS). The lectures began in 2005, to celebrate the one hundredth anniversary of Einstein's annus mirabilis (Year of Miracles) when Albert Einstein’s three fundamental papers changed the course of 20th-century physics in 1905.

The Best Physics Teachers I Never Had: From Fermi to Feynman

Richard Feynman on **Artificial General Intelligence**



Audience Question:

Do you think there will ever be a machine that will think like human beings and be more intelligent than human beings?

Richard Feynman's Answer:

First of all, do they think like human beings? I would say no and I'll explain in a minute why I say no. Second, for "whether they be more intelligent than human beings" to be a question, intelligences must first be defined. If you were to ask me are they better chess players than any human being? Possibly can be, yes, "I'll get you, some day".

In a lecture held by Nobel Laureate Richard Feynman (1918–1988) on September 26th, 1985, the question of artificial general comes up.

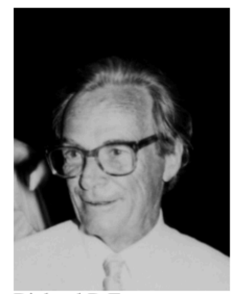
Murat Durmus (@CEO_AISOMA)

Richard Feynman: Can machines think? https://www.youtube.com/watch?v=ipRvjS7q1DI

The Computing Machines in the Future

Richard P. Feynman

Abstract This address was presented by Richard P. Feynman as the Nishina Memorial Lecture at Gakushuin University (Tokyo), on August 9, 1985.



Richard P. Feynman
©NMF

It's a great pleasure and an honor to be here as a speaker in memorial for a scientist that I have respected and admired as much as Prof. Nishina. To come to Japan and talk about computers is like giving a sermon to Buddha. But I have been thinking about computers and this is the only subject I could think of when invited to talk.

The first thing I would like to say is what I am not going to talk about. I want to talk about the future computing machines. But the most important possible developments in the future, are things that I will not speak about. For example, there is a great deal of work to try to develop smarter machines, machines which have a better relationship with the humans so that input and output can be made with less effort than the complex programming that's necessary today. This goes under the name often of artificial intelligence, but I don't like that name. Perhaps the unintelligent machines can do even better than the intelligent ones. Another problem is the standardization of programming languages. There are too many languages today, and it would be a good idea to choose just one. (I hesitate to mention that in Japan, for what will happen will be that there will simply be more standard languages; you already have four ways of writing now and attempts to standardize anything here result apparently in more standards and not fewer.) Another interesting future

Richard P. Feynman (1918 – 1988). Nobel Laureate in Physics (1965)
California Institute of Technology (USA) at the time of this address

Richard Feynman: The Computing Machines in the Future
http://cse.unl.edu/~seth/434/Web%20Links%20and%20Docs/Feynman-future%20computing%20machines.pdf


NASA
SPACE APPS
CHALLENGE
HONG KONG
Where
Online (all-virtual)
When
Friday - Sunday
October 2 - 4, 2020
https://spaceapps.algebragame.app
Partners and Sponsors
U.S. Consulate General
Hong Kong and Macau
AmCham
香港天文台
HONG KONG OBSERVATORY
PolyMath
Nautilus Software Technologies
CityU
Department of
Computer Science