Innovation to shape future: A.I. and Quantum leap

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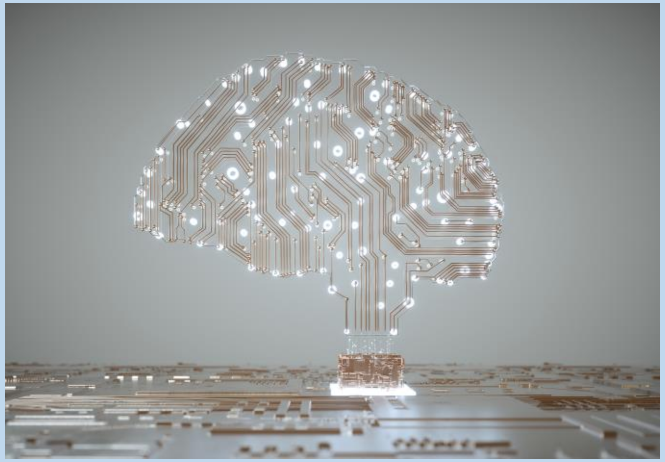
2024-01-30

Content

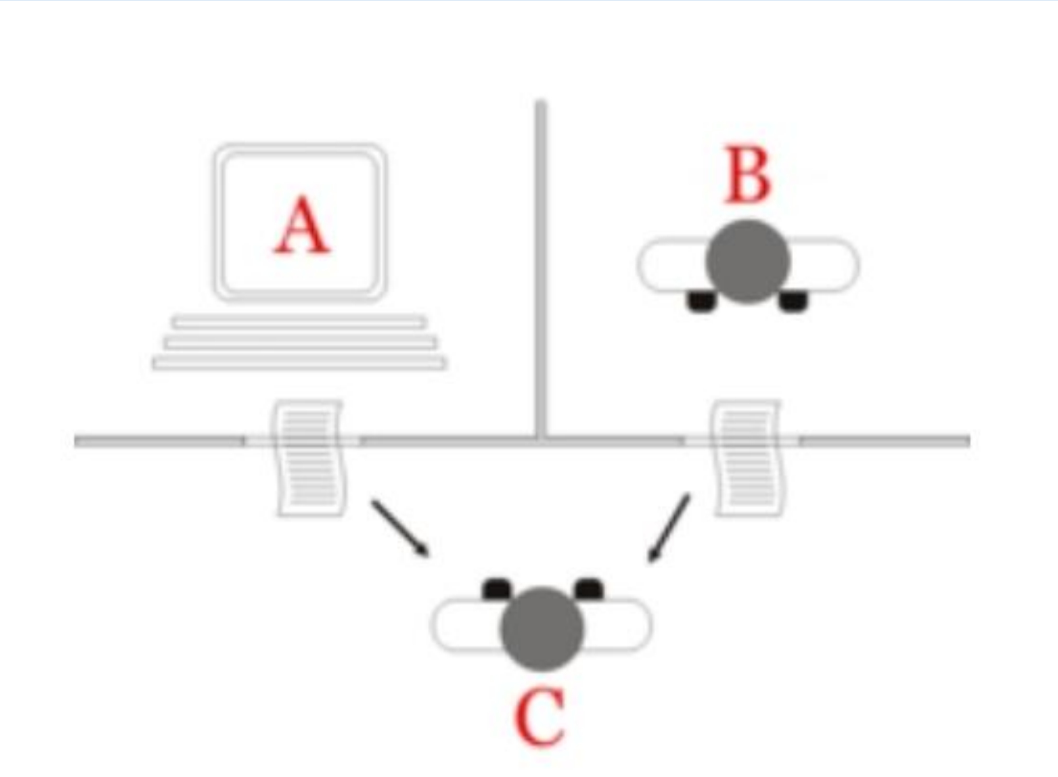
1. Evolution of Artificial Intelligence

- Birth of Artificial Intelligence
  - The term "Artificial Intelligence" : 1956 Dartmouth Conference
  - Turing Test (1950)
- Early interpretation of "Intelligence" – rules and instructions
  - Intellectual activities: Expert systems, path planning, Game playing
  - Symbolism (Newell & Simon 1956)
  - Natural Language Processing (Chomsky 1957)
  - Knowledge representation of reasoning (McCarthy 1958)
  - Robotics (Engelberger 1961)
- Beyond rules and instructions
  - Simulation of Human Intelligence: Artificial Neural Networks
  - Bayesianism (Pearl 1988): intelligence needs to handle probability and statistics
  - Fuzzy logics (Zadeh 1965)
  - Genetics algorithms (Holland 1975)
  - Neural Symbolism (Smolensky 1988): intelligence means symbols are handled in a neural network
  - Eventually leads to : Machine learning



Turing Test

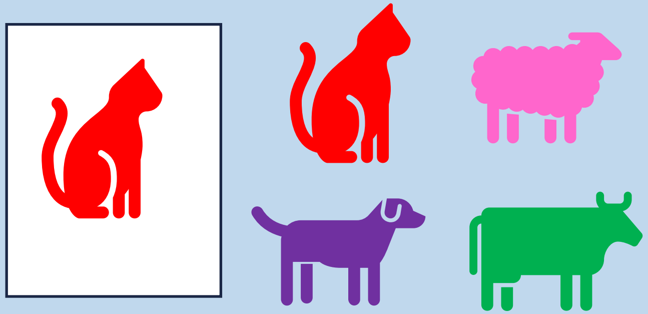
- Alan Turing (1912-1954)
- 1950: “Can you distinguish a machine from a human?”
- Original design: text communication
- Applicable to visual, sound and others
- The ‘machine’ is a black box



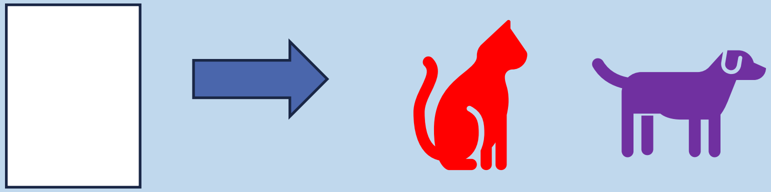
Source (Jan 2022)
https://en.wikipedia.org/wiki/Turing_test

Machine Learning

- ML is subset of AI : “the machine Learns from previous experiences”
- Supervised learning
  - E.g. 1000 cat / dog / cow / sheep photos for training
  - A new animal photo for testing
  - Success if it can recognize a cat’s photo being a cat

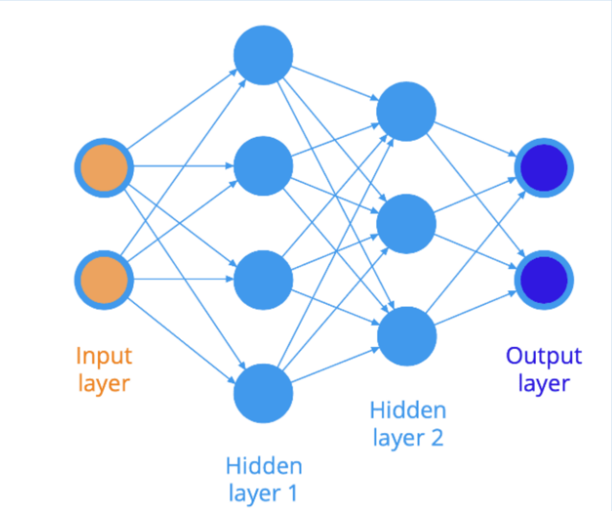


- Unsupervised learning
  - The training input is not labelled, need to discover the rules
  - E.g. 1000 photos or either cats or dogs, the machine need to classified into two groups

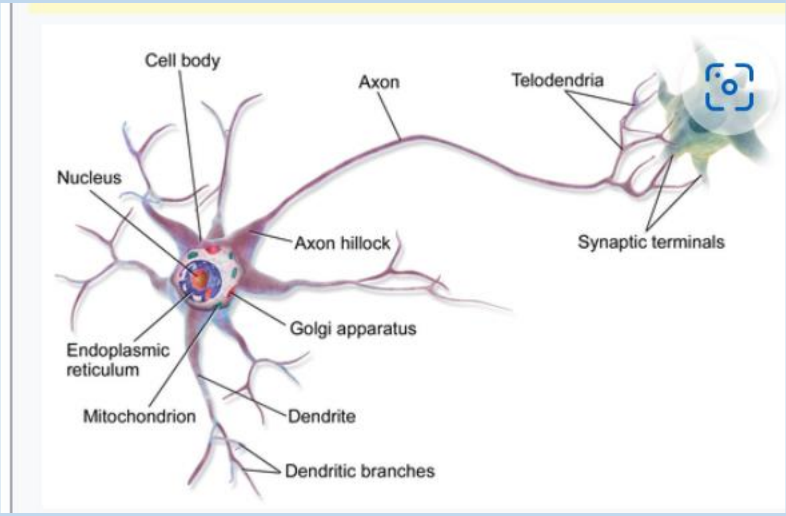


2. Significance of Machine Learning

- Neural Network
  - Get ideas from neurons
  - Artificial Neural Network (ANN)



https://www.coodingdessign.com/machine-learning/calculus-in-action-neural-networks/

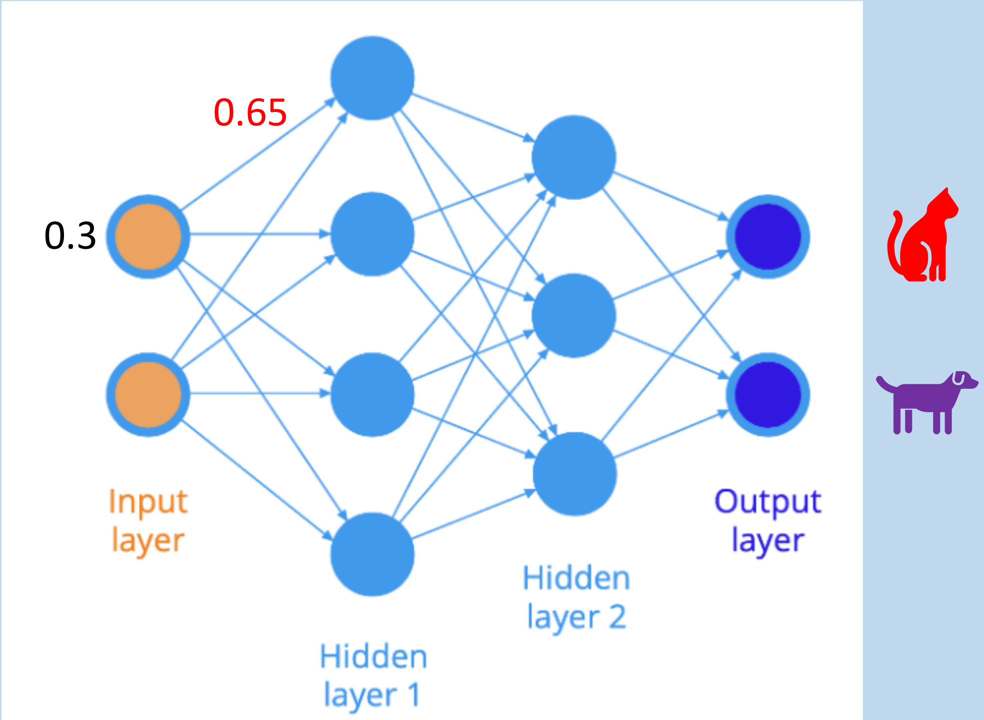


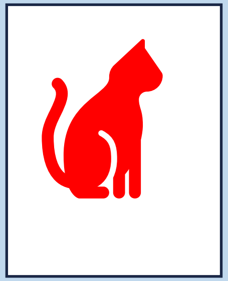
https://en.wikipedia.org/wiki/Neuron

Neural Network (Artificial Neural Network)

1. Each node (neuron) has a value (0 to 1)
2. Each edge (connection) has a parameter
3. Layers of nodes: input, hidden, output
   - Input: (e.g. photo pixels)
   - Hidden layers: features (hopefully)
   - Output: one node for cat, one for dog
4. Value of a node is math function of
   - Previous layer node values, & edge parameters (weight, bias)

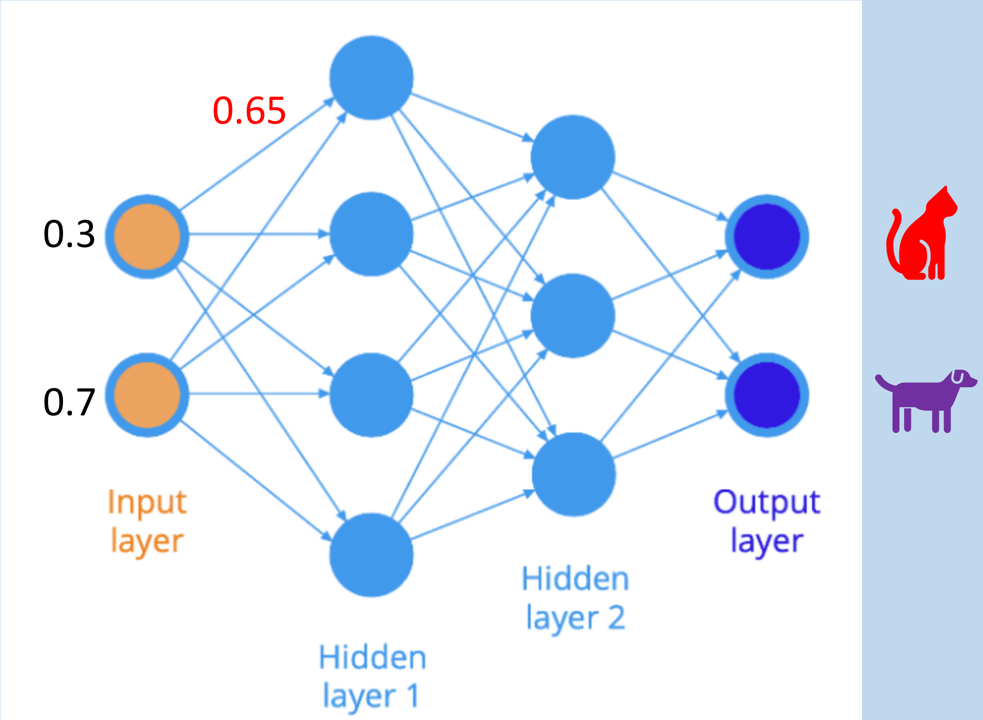
- "Recognize a cat photo": given a cat photo, will have cat output node value = 1, dog output node value = 0 (or at least the cat output node value is largest)
- Training : an engineering problem of tuning the parameters, in many rounds, such that our goal is achieved

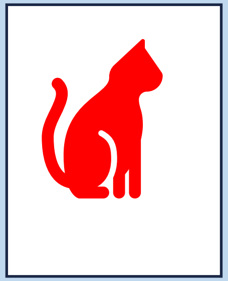




Training Details (for a Cat photo) Steps 1 & 2

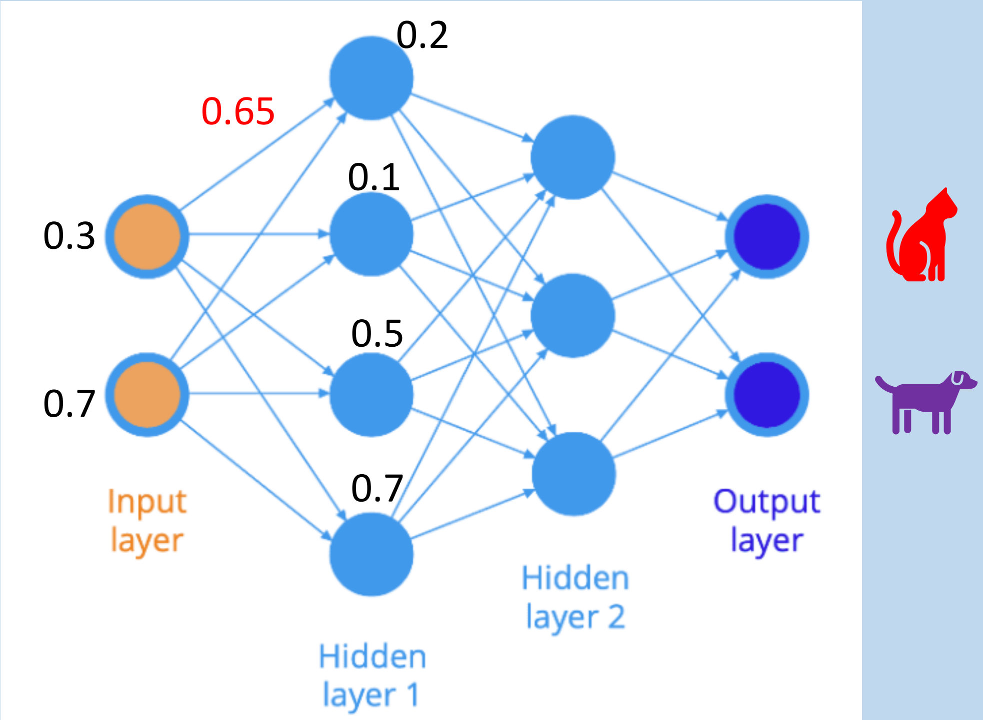
1. Randomly assign parameters (weight, bias) at the edges
2. Set input layer nodes value of the pixels
3. Calculate node values at hidden layer 1
4. Calculate node values at hidden layer 2
5. Calculate node values at output layer
6. If at output layer (cat node value = 1) and (dog node value = 0) then training done!
7. Use a feedback formula (back propagation) to adjust parameters at edges
8. Go to step 3.

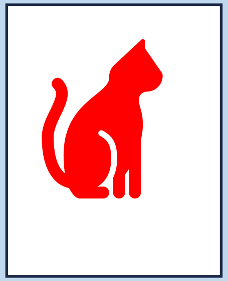




Training Details (for a Cat photo) Step 3

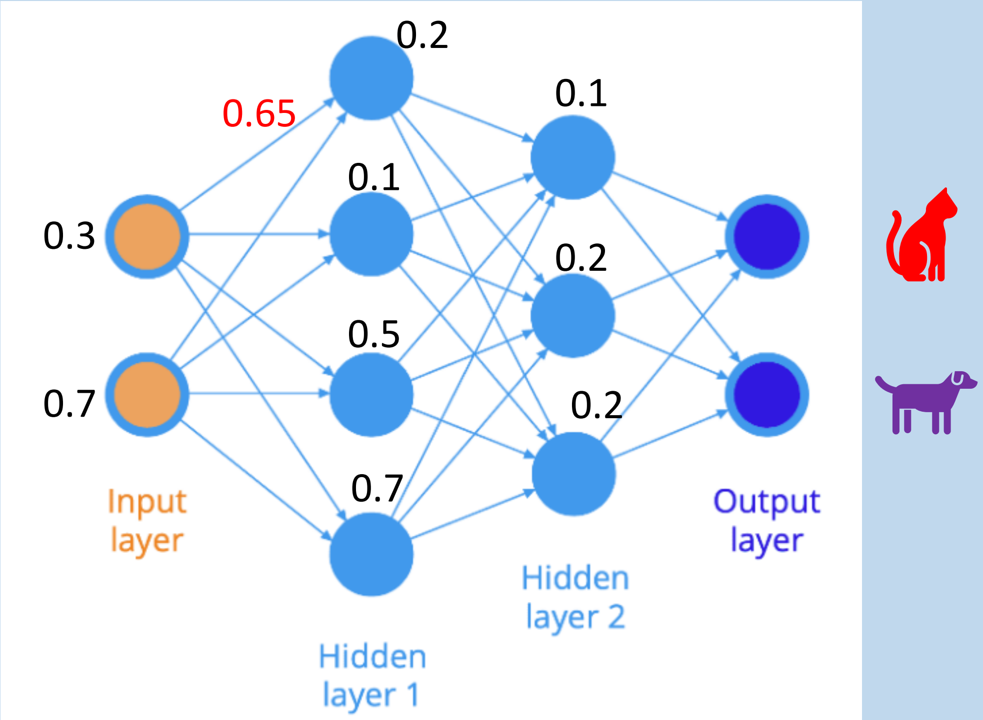
1. Randomly assign parameters (weight, bias) at the edges
2. Set input layer nodes value of the pixels
3. Calculate node values at hidden layer 1
4. Calculate node values at hidden layer 2
5. Calculate node values at output layer
6. If at output layer (cat node value = 1) and (dog node value = 0) then training done!
7. Use a feedback formula (back propagation) to adjust parameters at edges
8. Go to step 3.

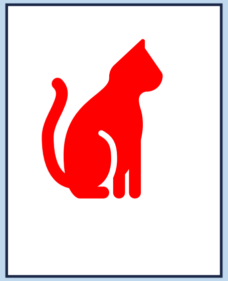




Training Details (for a Cat photo) Step 4

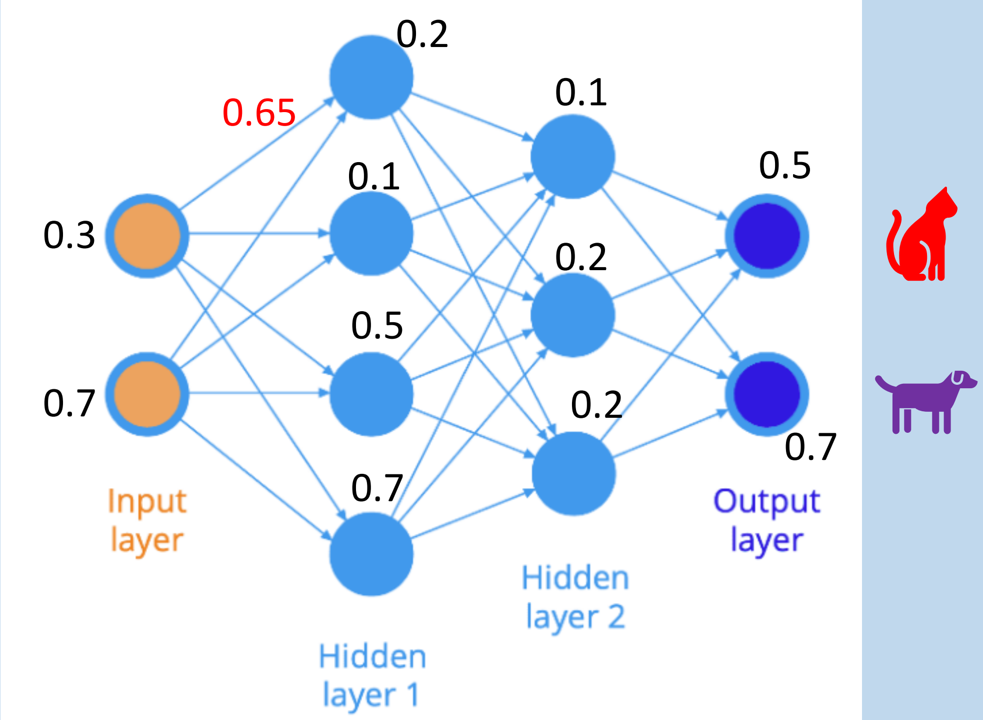
1. Randomly assign parameters (weight, bias) at the edges
2. Set input layer nodes value of the pixels
3. Calculate node values at hidden layer 1
4. Calculate node values at hidden layer 2
5. Calculate node values at output layer
6. If at output layer (cat node value = 1) and (dog node value = 0) then training done!
7. Use a feedback formula (back propagation) to adjust parameters at edges
8. Go to step 3.

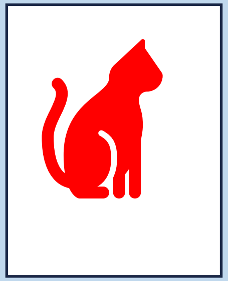




Training Details (for a Cat photo) Step 5

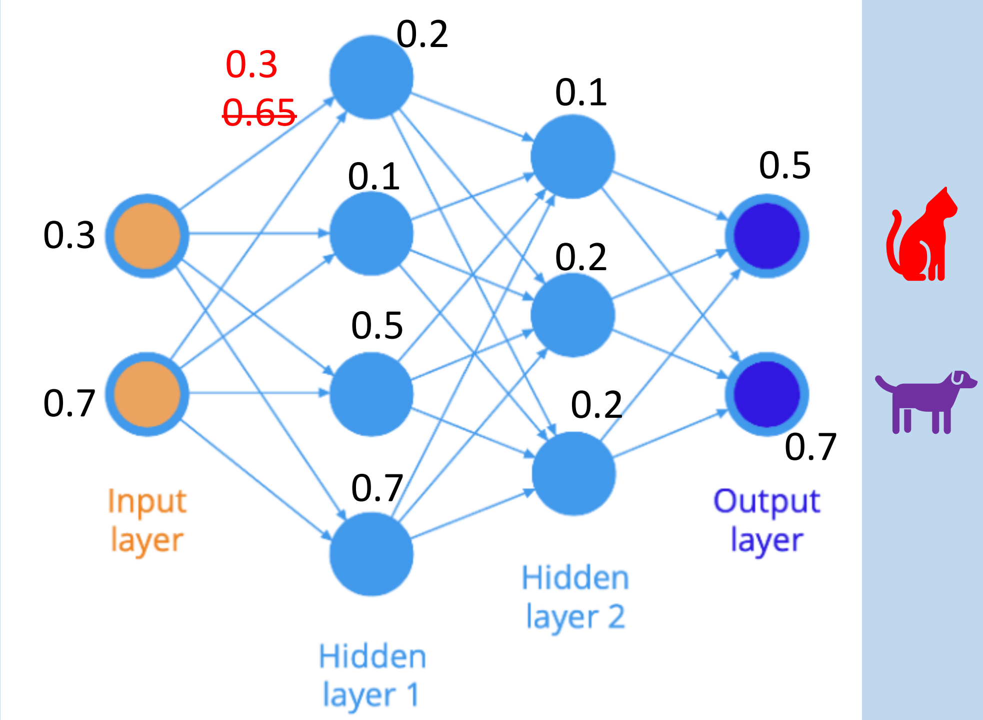
1. Randomly assign parameters (weight, bias) at the edges
2. Set input layer nodes value of the pixels
3. Calculate node values at hidden layer 1
4. Calculate node values at hidden layer 2
5. Calculate node values at output layer
6. If at output layer (cat node value = 1) and (dog node value = 0) then training done!
7. Use a feedback formula (back propagation) to adjust parameters at edges
8. Go to step 3.

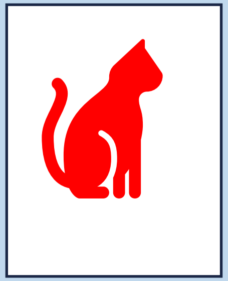




Training Details (for a Cat photo) Steps 6 & 7

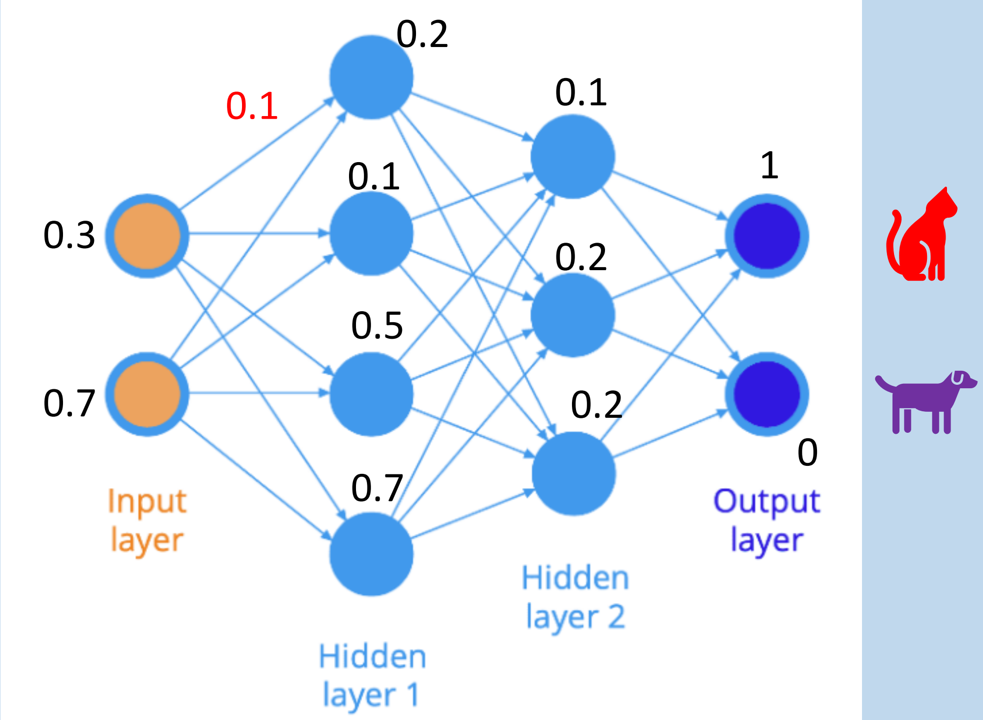
1. Randomly assign parameters (weight, bias) at the edges
2. Set input layer nodes value of the pixels
3. Calculate node values at hidden layer 1
4. Calculate node values at hidden layer 2
5. Calculate node values at output layer
6. If at output layer (cat node value = 1) and (dog node value = 0) then training done!
7. Use a feedback formula (back propagation) to adjust parameters at edges
8. Go to step 3.

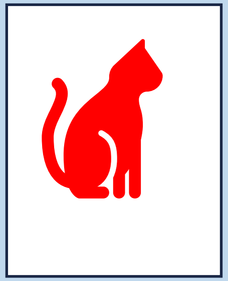




Training Complete (for a Cat photo)

1. Randomly assign parameters (weight, bias) at the edges
2. Set input layer nodes value of the pixels
3. Calculate node values at hidden layer 1
4. Calculate node values at hidden layer 2
5. Calculate node values at output layer
6. If at output layer (cat node value = 1) and (dog node value = 0) then training done!
7. Use a feedback formula (back propagation) to adjust parameters at edges
8. Go to step 3.



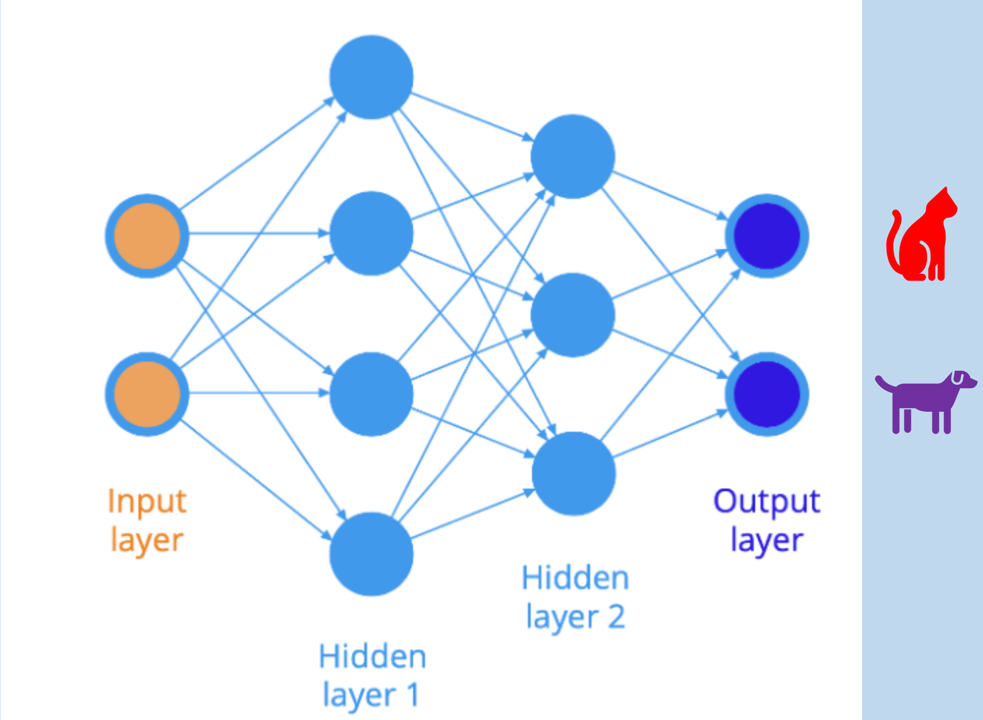


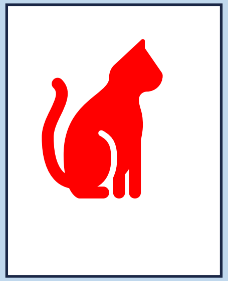
Training Summary (for a Cat photo)

1. Aim: When training is completed, a new photo can also be correctly recognized

2. Mechanical process of learning from past experience

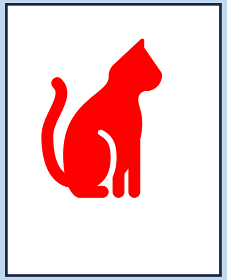
3. Extremely resource intense iterative process
4. Need a lot of data as training input

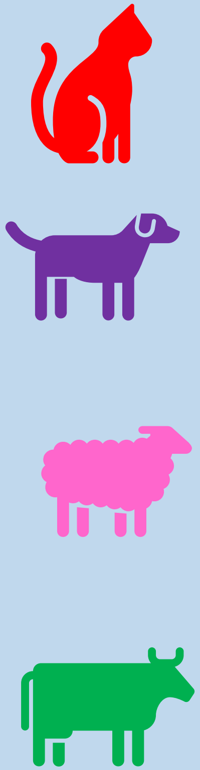




Machine Learning basic

1. Features (many levels) : ear, round eyes, long tail, horn, hair, fat, tall …
2. The larger the size (number of parameters/edges) of neural network, the better
3. Different strategies of training:
    a) Cat + dog first, then add cow, then sheep
    b) Cat + dog , then cow + sheep, combine the two models
    c) 1000 cat and 1 dog photos, create another 999 dog photos
    d) Combine many 10 cat + 10 dog + 10 cow + 10 sheep models
    e) …
4. Related concepts & variations
    - Reinforcement learning (1998 Sutton & Barto 1998)
    - Convolutional Neural Networks (Fukushima 1980) : focus on vision
    - Deep learning (Hinton 2006)
    - Deep Reinforcement learning (Mnih and others 2013)
    - Generative Adversarial Networks GAN (Goodfellow and others 2014)
    - …





Significance of Machine Learning

1. Needs a lot of computational resource
   - Addressed by: advance in Internet, chips, cloud services
2. Needs a lot of training data
   - Addressed by: advance in Internet, e-commerce, IoT devices (automatic sensing)
3. Society huge need for prediction / recognition
   - Product recommendation (online shopping, vacation, financial products, entertainment, …)
   - Machine predictive maintenance
   - Medical image diagnosis
   - Product quality control
   - Autonomous Guided Vehicle (AGV)
   - Better let the machine to learn by themselves
   - Important pillar of Artificial Intelligence

3. Impact of AI in the near future

A. AI to improve productivity
   1. optimize existing practices
   2. empower human employees
   3. Effectively affect all sectors
      1. Healthcare: early disease detection, personalized treatment plan
      2. Transportation: traffic management, autonomous vehicles
      3. Business: customer services, marketing, risk management
      4. And others: manufacturing, entertainment …
   4. Concerns: computer crime, privacy, security, ethical considerations, job replacement …

B. AI accelerates research in many areas
   - Expect more innovation

10 Illegal things AI is doing at 2023

1. Identity theft
2. Facial recognition
3. Cyber attacks
4. Data manipulation
5. Misinformation
6. Data exploitation
7. Cryptocurrency manipulation
8. Automated bot networks
9. Swamp attacks
10. Counterfeit products

https://www.youtube.com/watch?v=29K4eBupXW0

AI & research cases

- Model condition of chemical process (borylation reaction) in synthesizing drug molecules

Dec 2023

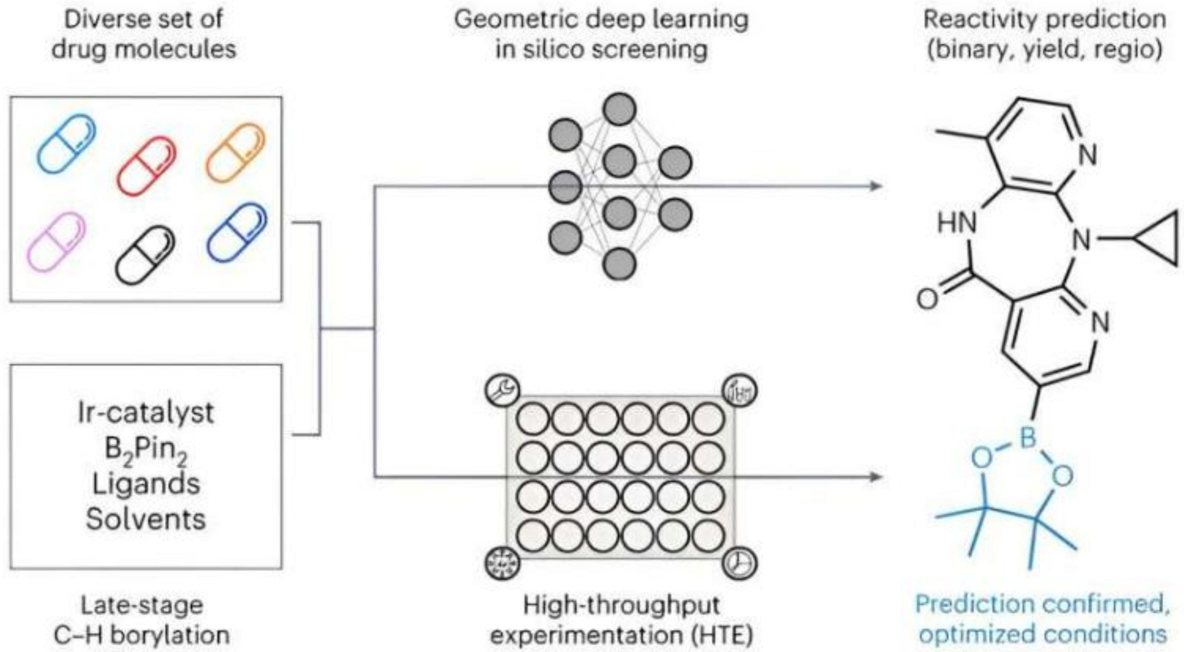
https://techxplore.com/news/2023-11-artificial-intelligence-paves-medicines.html

Home / Machine learning & AI

NOVEMBER 30, 2023 Editors' notes

Artificial intelligence paves way for new medicines

by Ludwig Maximilian University of Munich



Credit: *Nature Chemistry* (2023). DOI: 10.1038/s41557-023-01360-5

TechXplore

AI turns brain signal to speech for a person

- Research with a person
- UCSF
- 75% of words right
- Published in Nature (Feb 2023)

CBC

AI brings researchers one step closer to restoring speech in people with paralysis

New technology is 'big advance' in interpreting brain signals to let someone speak, say researchers

Jennifer La Grassa, Tashauna Reid · CBC ·
Posted: Aug 24, 2023 1:00 AM PDT | Last Updated: August 24, 2023

participant in the UCSF study of speech neuroprostheses, uses a digital link wired to her cortex to interface with an avatar on May 22 in El Cerrito, Calif. At left is UCSF clinical research coordinator Max Dougherty. (Noah Berger)

Article

A high-performance neuroprosthesis for speech decoding and avatar control

https://doi.org/10.1038/s41586-023-06443-4
Received: 3 February 2023
Accepted: 17 July 2023
Published online: 23 August 2023
Check for updates

Sean L. Metzger[1,2,3,7], Kaylo T. Littlejohn[1,2,4,7], Alexander B. Silva[1,2,3,7], David A. Moses[1,2,7], Margaret P. Seaton[1,7], Ran Wang[1,2], Maximilian E. Dougherty[1], Jessie R. Liu[1,2,3], Peter Wu[4], Michael A. Berger[5], Inga Zhuravleva[4], Adelyn Tu-Chan[6], Karunesh Ganguly[2,6], Gopala K. Anumanchipalli[1,2,4] & Edward F. Chang[1,2,3]

Speech neuroprostheses have the potential to restore communication to people living with paralysis, but naturalistic speed and expressivity are elusive[1]. Here we use high-density surface recordings of the speech cortex in a clinical-trial participant with severe limb and vocal paralysis to achieve high-performance real-time decoding

Aug 2023

https://www.cbc.ca/news/health/paralysis-brain-speech-1.6943743

AI to design a walking robot

- AI in design and research
- Prompt: Design a robot that can walk
- Complete in 26 seconds


AI Was Asked to Design a Walking Robot. It Came Up With This.

TECH 11 October 2023 By KAI XIANG TEO, BUSINESS INSIDER

The AI-designed robot. (Northwestern University)

Oct 2023

https://www.sciencealert.com/ai-was-asked-to-design-a-walking-robot-it-came-up-with-this

Xenobot (AI to design configuration of cells)

Xenobot: 'robot' from Xenopus (frog) cells

PNAS
Vol. 117 | No. 4

RESEARCH ARTICLE | BIOLOGICAL SCIENCES

A scalable pipeline for designing reconfigurable organisms

Sam Kriegman, Douglas Blackiston, Michael Levin, and Josh Bongard Authors Info & Affiliations

Edited by Terrence J. Sejnowski, Salk Institute for Biological Studies, La Jolla, CA, and approved November 26, 2019 (received for review June 24, 2019)

January 13, 2020 | 117 (4) 1853-1859 | https://doi.org/10.1073/pnas.1910837117

Significance

Most technologies are made from steel, concrete, chemicals, and plastics, which degrade over time and can produce harmful ecological and health side effects. It would thus be useful to build technologies using self-renewing and biocompatible materials, of which the ideal candidates are living systems themselves. Thus, we here present a method that designs completely biological machines from the ground up: computers automatically design new machines in simulation, and the best designs are then built by combining together different biological tissues. This suggests others may use this approach to

Jan 2020

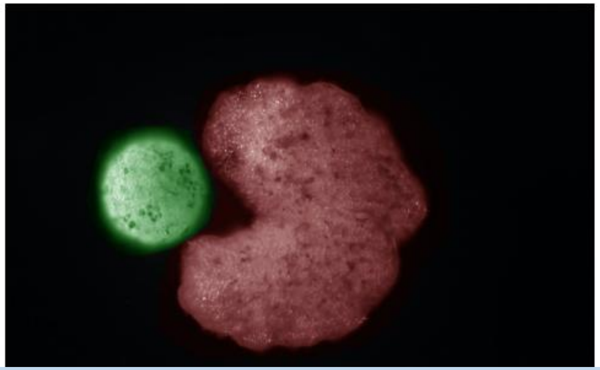
https://www.pnas.org/doi/full/10.1073/pnas.1910837117

BBC Science Focus

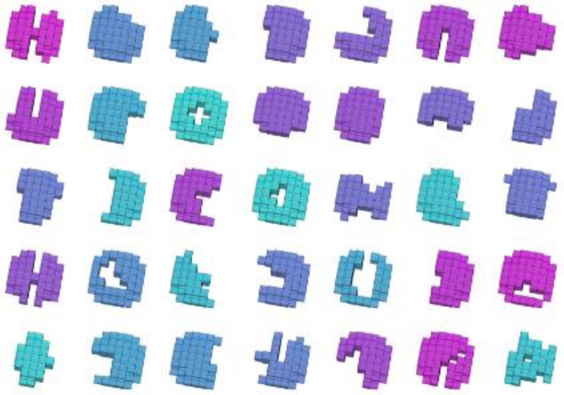
News | Future tech | Nature | Space | Human body | Everyday science

Living robots that are capable of self-replicating created in US lab

The Pac-Man-shaped 'xenobots' made from frog cells could one day help to clean up the environment or help design personalised medical treatments.



Often the computer comes up with simple, efficient solutions that humans fail to see. It's entirely possible that human cognitive limits and biases will prevent us from ever manually designing truly useful xenobots. But, with computer software designing xenobots for us, the sky's the limit.



The team used computer simulations to develop xenobot shapes that replicate more often than simple spheres © Douglas Blackiston/Sam Kriegman

Dec 2021

https://www.sciencefocus.com/news/living-robots-that-are-capable-of-self-replicating-created-in-us-lab

AI for scientific discovery

- AI tools for scientific discovery
- Polymathic AI
- U of Cambridge and others
- From models of some areas, help to build models for another area
- Analogy: “when you know 5 different languages, it is easier for you to learn a new one”

TechXplore

OCTOBER 13, 2023 Editors' notes

Scientists begin building AI for scientific discovery using tech behind ChatGPT

by University of Cambridge

Credit: Pixabay/CC0 Public Domain

An international team of scientists, including from the University of Cambridge, have launched a new research collaboration that will leverage the same technology behind ChatGPT to build an AI-powered tool for scientific discovery.

Oct 2023

https://techxplore.com/news/2023-10-scientists-ai-scientific-discovery-tech.html

ChatGPT as chosen scientist of the year

- ChatGPT as one of 10 chosen scientists of the year by Nature (Dec 2023)

EL PAÍS

Science

SILICON VALLEY · YOUTUBE · GOOGLE · LATEST NEWS

SCIENTISTS >

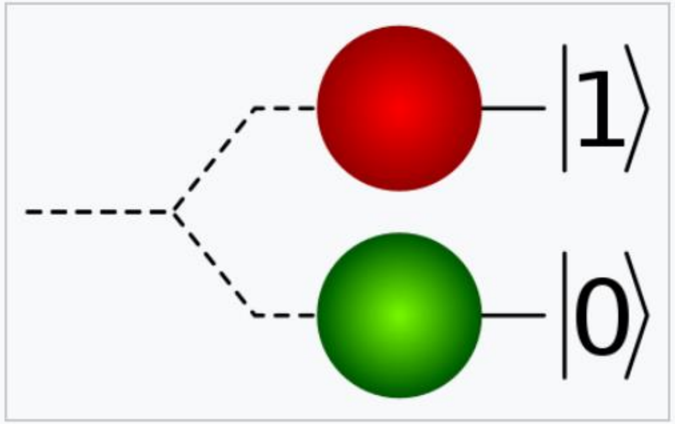
For the first time, the journal 'Nature' has chosen a non-human being — ChatGPT — as one of its scientists of the year

The prestigious scientific publication highlights the chatbot alongside one of its creators, a forgotten pioneer of weight loss drugs and the scientist behind a historic breakthrough against cancer

https://english.elpais.com/science-tech/2023-12-13/for-the-first-time-the-journal-nature-has-chosen-a-non-human-being-chatgpt-as-one-of-its-scientists-of-the-year.html

4. The Quantum Jump to Quantum Computing

- Quantum physics properties:
  - Wave-particle duality, superposition, quantum entanglement, quantum uncertainty, quantum state collapse
  - Qubit
- Qubit
  - A quantum system
  - Superposition of two states (Cf bit: 0/1)
  - Allows parallel computing possibilities
- Quantum computer
  - Use Qubits

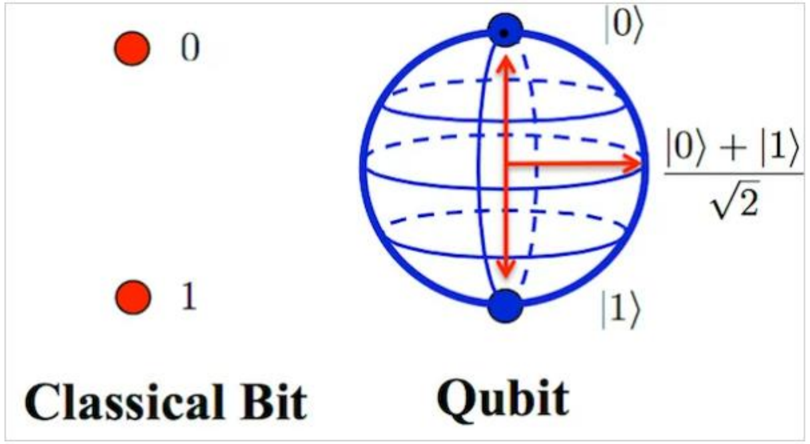


The general definition of a qubit as the quantum state of a two-level quantum system.

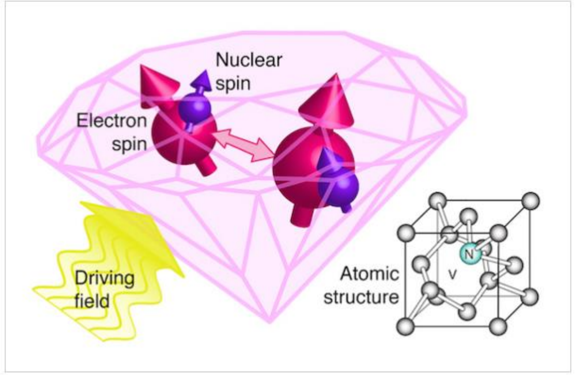
https://en.wikipedia.org/wiki/Qubit

Qubit Implementation

- Advanced material science
- In diamond: Nitrogen vacancy center
- Many other possibilities, hot research topic



A representation of a qubit. Image courtesy of the University of Strathclyde.

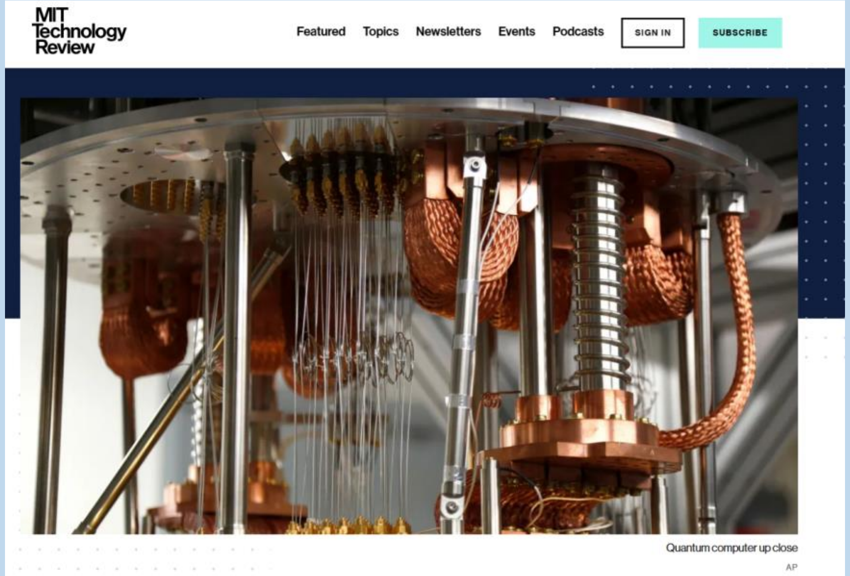


Graphical representation of the qubit creation process using diamonds. Image courtesy of the American Physical Society.

https://www.allaboutcircuits.com/news/aluminum-nitride-could-replace-diamond-in-qubit-creation//

5. Application of quantum computing in the near future

- Parallel processing of difficult mathematic problems
  - Cryptography
    - RSA algorithm based on factorization
  - Optimization and modelling
    - Financial modelling – portfolio optimization
    - Supply chain optimization
    - Path optimization
    - Machine learning
- Simulation – use one quantum system to simulate another quantum system with high fidelity
  - Molecular interaction modelling
  - Drug discovery
  - Material science
  - Genomic research

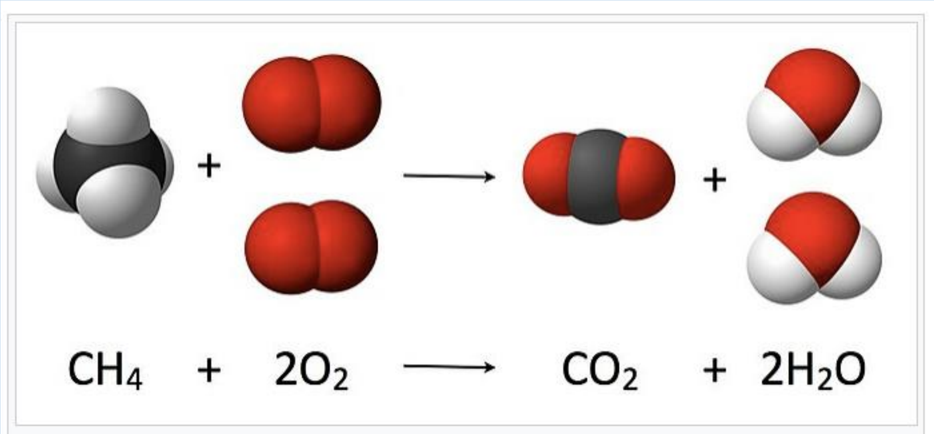


https://www.technologyreview.com/2019/09/18/132956/ibms-new-53-qubit-quantum-computer-is-the-most-powerful-machine-you-can-use/

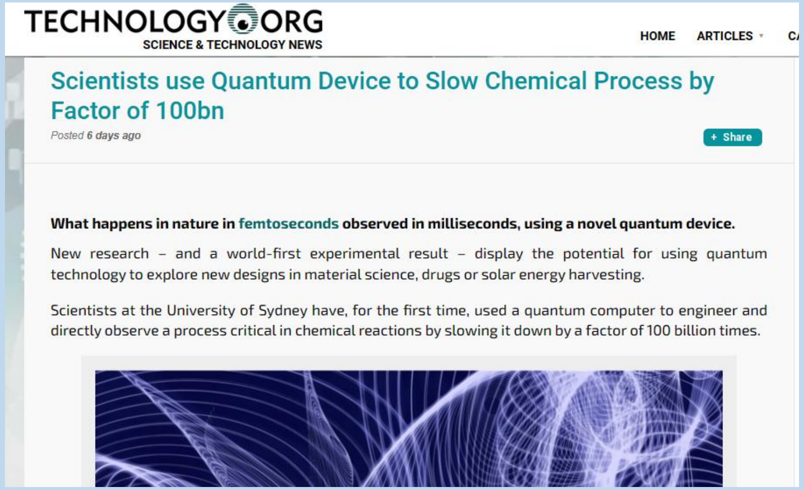
Quantum computing: Chemical Simulation

- Method 1: Treat Chemical relation as an optimization problem (use the parallel processing property)

- Method 2: direct simulation as a quantum system
  - Effectively slow the process by factor of 100bn
  - Great contribution to research!



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



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HOME ARTICLES

Scientists use Quantum Device to Slow Chemical Process by Factor of 100bn

Posted 6 days ago

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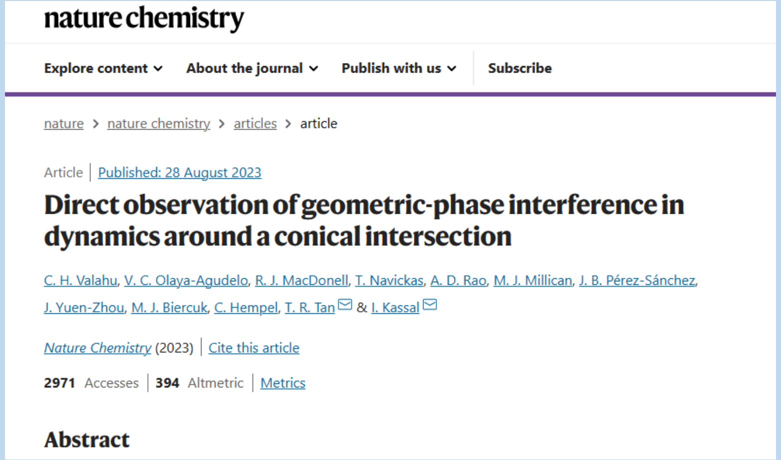
What happens in nature in femtoseconds observed in milliseconds, using a novel quantum device.

New research – and a world-first experimental result – display the potential for using quantum technology to explore new designs in material science, drugs or solar energy harvesting.

Scientists at the University of Sydney have, for the first time, used a quantum computer to engineer and directly observe a process critical in chemical reactions by slowing it down by a factor of 100 billion times.

https://www.technology.org/2023/09/15/quantum-device-slows-chemical-process-by-factor-of-100bn/



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Article | Published: 28 August 2023

Direct observation of geometric-phase interference in dynamics around a conical intersection

C. H. Valahu, V. C. Olaya-Agudelo, R. J. MacDonell, T. Navickas, A. D. Rao, M. J. Millican, J. B. Pérez-Sánchez, J. Yuen-Zhou, M. J. Biercuk, C. Hempel, T. R. Tan & I. Kassal

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2971 Accesses | 394 Altmetric | Metrics

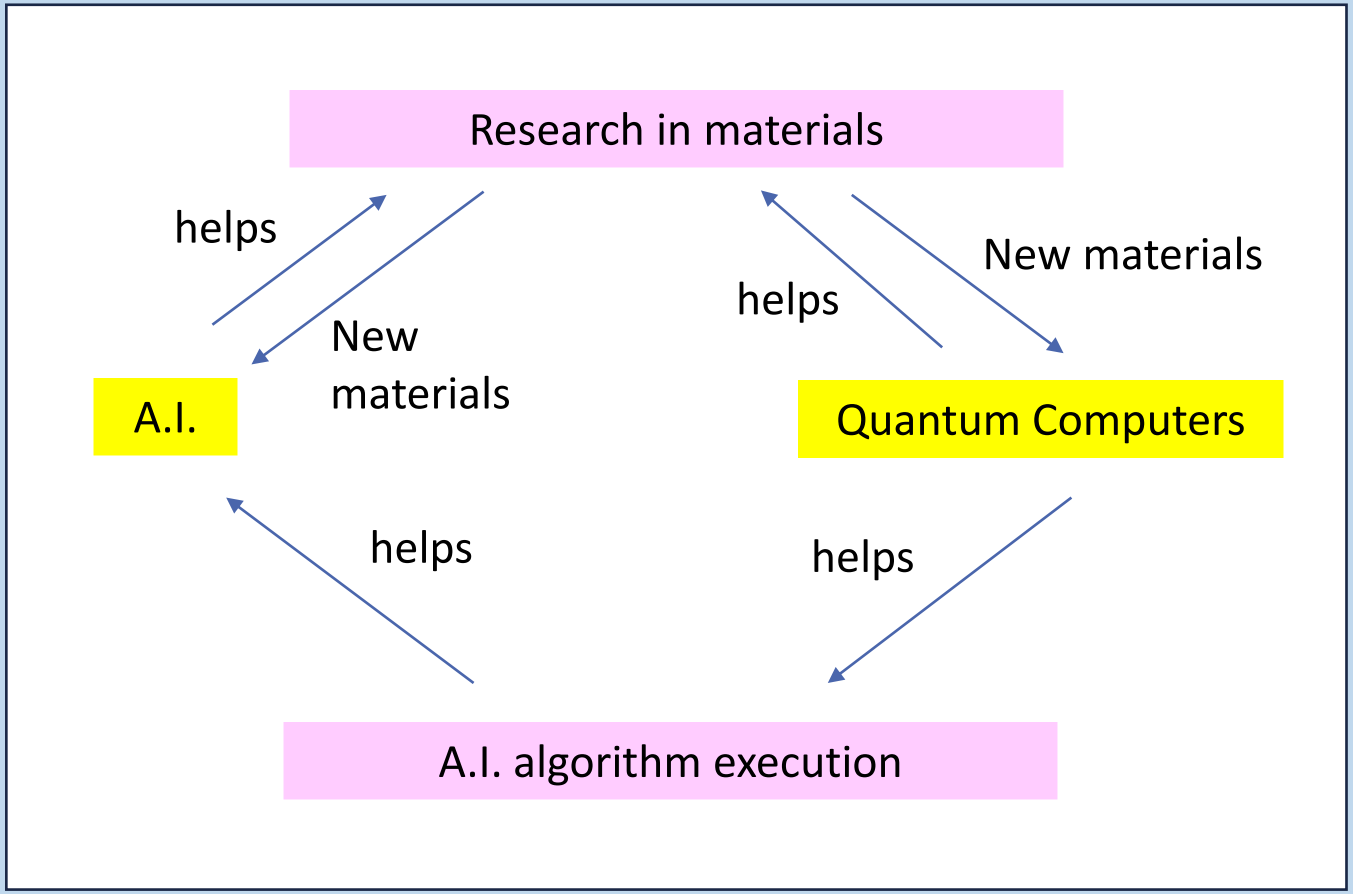
Abstract

https://www.nature.com/articles/s41557-023-01300-3

Sep 2023

6. Synergy of quantum computing and AI

- A.I. to help research
- Quantum computers to help algorithm execution
- Quantum computers to help material science research
- Positive feedback loop

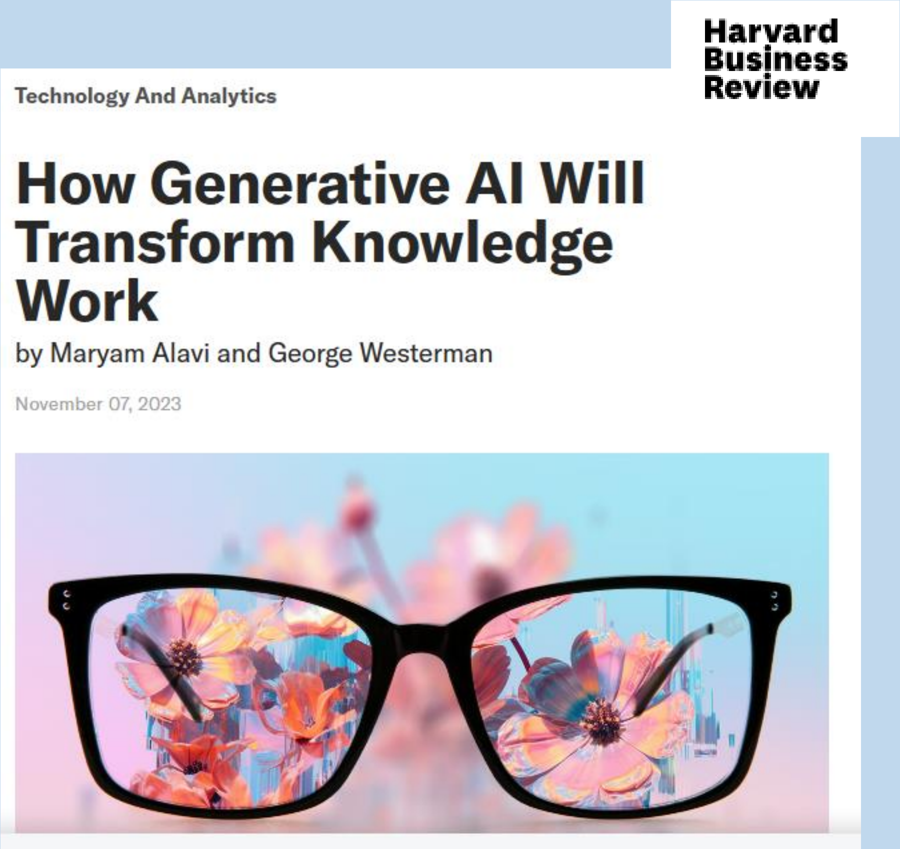


7. Future opportunities and Conclusion

1. AI and quantum computing demonstrate applicability across numerous domains
2. Research & Innovation being a particularly noteworthy domain
3. AI and quantum computing will benefit a lot!
4. Foreseeing progress in diverse domains
5. Embracing these cutting-edge technologies, particularly AI, becomes imperative for empowering ourselves and staying abreast of technological advancements

One approach to use AI

- Use tools wisely to improve ourselves
  1. Reducing cognitive load for more regular structural tasks
  2. Boosting cognitive capacity for non-structural tasks
  3. Improving learning



Nov 2023

https://hbr.org/2023/11/how-generative-ai-will-transform-knowledge-work

Thank you!

Innovation to shape future: A.I. and Quantum leap

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