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

Dr. Lucas Hui
lucasckhui@gmail.com

2024-01-30
Content

1. The evolution of Artificial Intelligence
2. Significance of Machine Learning
3. Impact of Artificial Intelligence in the near future
4. The Quantum Jump to Quantum Computing
5. Application of quantum computing in the near future
6. The synergy of quantum computing and artificial intelligence
7. Future opportunities and Conclusion
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://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
   • 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

AI turns brain signal to speech for a person

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

AI to design a walking robot

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

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

Jan 2020


Dec 2021

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”

ChatGPT as chosen scientist of the year

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

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

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

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

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

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

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
Thank you!

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

Dr. Lucas Hui
lucasckhui@gmail.com