14.4: Future of Information Systems

14.4.1: Quantum computer

Some of these concepts require me to go into a little more technical details to explain the concept.

Let's go over essential key terms you should know related to quantum computer.

Definition: Terms

Qubit - The basic unit of information in a quantum computer. Unlike binary bits, qubits can represent a 0, 1, or a superposition of both states at the same time due to the quantum mechanical phenomenon of superposition.

Superposition - The ability of a quantum system like a qubit to exist in multiple states simultaneously. This allows qubits to represent both 0 and 1 at the same time.

Entanglement - When two qubits become correlated such that the state of one qubit affects the state of the other, even when separated by large distances. This enables quantum parallelism.

Quantum Parallelism - The ability of a quantum computer to evaluate multiple computational paths in parallel, calculating on all possibilities simultaneously.

Interference - The cancellation of probabilities that occurs when qubits are measured, collapsing superposition states to a single state. Both constructive and destructive interference occur.

Quantum Algorithm - An algorithm designed to run on a quantum computer harnessing properties like superposition and entanglement to solve problems faster than classical algorithms.

Quantum Supremacy - The point at which a quantum computer can solve a problem that is practically impossible for a classical computer in a reasonable amount of time.

Today's computers use bits as data units. A bit value can only be either 0 or 1, as we discussed in Chapter 2. Quantum computers use qubit, which can represent a combination of both 0 and 1 simultaneously, leveraging the principles of quantum physics. Superposition is a fundamental property of quantum mechanics where a quantum system can exist in multiple states simultaneously. This means a quantum bit or qubit can represent a 0 and 1 at the same time, unlike a classical binary bit which can only be in a single 0 or 1 state. Superposition is what gives quantum computers their ability to perform calculations on multiple possibilities in parallel, enabling powerful computational capabilities not possible with regular bits alone. The concept of superposition contrasts with our everyday experience where objects exist in only one state at a time. But at the quantum scale, particles behave according to the strange rules of quantum mechanics, allowing counterintuitive phenomena like superposition.

This is a game-changer for computing and will disrupt all aspects of information technology. The benefits include a significant speed increase in calculations that will enable solutions for unsolvable problems today. However, there are many technical problems to be solved yet since all the IS elements will need to be re-imagined. Google announced the first real proof of a working quantum computer in 2019 (Menard, et al., 2020). Menard et al. also indicated that the industries that would benefit from this new computer type would be industries with complex problems to solve, such as pharmaceutical, autonomous vehicles, cybersecurity, or intense mathematical modeling such as Finance, Energy. For a full report, please visit McKinsey.com.

Example: A problem that cannot be solved with today's problem but can by Quantum computer

Factoring very large numbers

> Factoring is the process of breaking down a composite number into its smaller constituent prime numbers.
>
> The number 60 is a composite number that can be factored into its prime constituents:
>
> 60 = 2 x 2 x 3 x 5
>
> So the prime factors of 60 are: 2, 2, 3, and 5.
>
> Factoring breaks down a larger composite number into the smaller prime numbers that multiply together to make that composite number. This process reveals the smallest constituent parts of a number.

Classical computers can factor smaller numbers efficiently but have trouble factoring large prime numbers. For example, factoring a number with over 200 digits would take longer than the universe's age on even the most powerful supercomputers today.

However, a quantum computer with enough stable qubits could theoretically factor such a large number efficiently in minutes or hours. This is because quantum computing harnesses the ability of qubits to represent 0 and 1 simultaneously to perform calculations on all possible factors in parallel.

Whereas normal bits can only represent 0 or 1, qubits can represent a superposition of both states at once. This allows quantum computers to solve problems with a vast number of variables much faster than checking each possibility sequentially like classical computers.

Large number factoring is relevant for cryptography, where the security of widely used schemes depends on the difficulty of factoring large prime numbers. Quantum computers could upend modern cryptography.

Quantum computing's exponential parallelism enabled by qubits in superposition provides capabilities far beyond binary bits, allowing problems to be solved that are impossible or impractical with classical computing. Factoring large primes is one example highlighting the quantum advantage.

While Quantum has begun to apply to practical solutions, it still has a long way to go before it can deploy to the mass, according to Intel, one of the leading chip manufacturer.

14.4.2: Blockchain

Definition: Essential Blockchain-related Terms

Blockchain - A distributed ledger technology that records transactions in immutable, linked blocks that are secured using cryptography.

Distributed Ledger - A database that is shared, replicated, and synchronized among multiple participants across a decentralized peer-to-peer network.

Block - containers that carry transactions, timestamps, and reference the previous block via a cryptographic hash. Chained together to create the blockchain.

Node - Any computer connected to the blockchain network that stores and verifies blocks and transactions.

Mining - The process where nodes compete to validate transactions and create new blocks, for which they earn cryptocurrency rewards.

Cryptography - Encryption techniques used in blockchain to secure data through cryptographic hash functions and digital signatures.

Consensus - Method for nodes in a blockchain network to agree on the legitimate state of the ledger. Common algorithms include proof-of-work and proof-of-stake.

Smart Contracts - Self-executing lines of code that run on a blockchain when predetermined conditions are met.

A blockchain is a set of blocks or a list of records linked using cryptography to record a transaction and track assets in a network. Anything of value can be considered an asset and be tracked. Examples include a house, cash, patents, a brand. Once a transaction is recorded, it cannot be changed retroactively. Hence, it is considered highly secured.

Blockchain has many applications, but bitcoin is mostly associated with it because it was the first application using blockchain technology. Sometimes bitcoin and blockchain are mistakenly meant to be the same thing, but they are not.

Bitcoin is digital money or a cryptocurrency. The crypto market grew to over $3 trillion in late 2021, led by Bitcoin and Ethereum. Emerging uses of blockchain include NFTs (non-fungible tokens) for digital art and collectibles, as well as Metaverse and Web3 applications. It is an open-source application built using blockchain technology. It is meant to eliminate the need for a central bank since people can directly send bitcoins. Simply put, bitcoin keeps track of a list of who sends how many bitcoins to another person. One difference with today's money is that a bitcoin's value fluctuates since it works like a stock. Anyone can buy different bitcoin cryptocurrencies or other cryptocurrencies on bitcoin exchanges such as Coinbase. Bitcoin and other cryptocurrencies are accepted by a few organizations such as Wikimedia, Microsoft, Wholefoods. However, bitcoin's adoption is still uncertain. If the adoption by major companies is accelerated, then banking locally and globally will change significantly.

Some early businesses have begun to use blockchain as part of their operations. Kroger uses IBM blockchain to trace food from the farms to its shelves to respond to food recalls quickly (IBM.com.) Amazon Managed Blockchainis a fully managed service that makes it easy to create and manage scalable blockchain networks.

Example: Kroger uses IBM Blockain

Kroger uses the IBM Food Trust blockchain solution to trace food products across its complex supply chain. This provides enhanced traceability from farm to store shelf.

For example, Kroger can track fresh produce like lettuce from the grower, through processing facilities, distribution centers, and finally to the grocery shelf. At each stage, data like timestamps, locations, temperatures etc. are recorded on the immutable blockchain ledger.

If there is ever a foodborne illness outbreak, Kroger can use the Food Trust data to quickly identify the source. They can trace back the contaminated lettuce to the exact farm, batch, and date. This enables targeted recalls to remove only affected product vs. clearing entire shelves.

In the past, tracing items back through the supply chain was slow, difficult, and imprecise. The transparency and speed enabled by the blockchain allows Kroger to pinpoint issues and reduce waste. This improves food safety while also reducing costs and maintaining customer trust.

So why can't today's computer achieve the same thing for Kroger?

Here are a few reasons why it is challenging for today's system to provide the end-to-end traceability that a blockchain solution can.

- Centralized systems - Typical supply chain databases are fragmented across different companies and centralized within each entity. There is no complete visibility across the full chain.
- Lack of transparency - Participants like suppliers and distributors don't have access to the same data, which inhibits transparency.
- Manual processes - Tracking often involves manual paperwork, spreadsheets, scanned documents etc. that can be error-prone.
- Lack of trust - Suppliers may be hesitant to share sensitive data with competitors under traditional systems.
- Difficult to trace - With no unified ledger, tracing back a contaminated item across multiple nodes is extremely challenging and time consuming.
- Data silos - Information lives in organizational silos, making it hard to connect data across the entire supply network.
- Vulnerable to fraud - Centralized databases can be more easily manipulated without the immutable, cryptographically-secured records of a blockchain.

The decentralized, transparent, and cryptographically-verified nature of blockchains overcomes many of the shortcomings of traditional supply chain tracking systems. This enables the end-to-end traceability needed for food safety and recall situations.

14.4.3: Artificial Intelligence (AI)

Artificial intelligence (AI) comprises many technologies to duplicate the functions of the human brain. It has been in research since the 1950s and has seen an ebb and flow of interest. AI has advanced rapidly in recent years, though the goal of duplicating all facets of human cognition remains elusive.

To understand and duplicate a human brain, AI is a complex interdisciplinary effort that involves multiple fields such as computer science, linguistics, mathematics, neuroscience, biology, philosophy, and psychology. One approach is to organize the technologies as below, and commercial solutions have been introduced:

- **Robotics**: Advances in sensorimotor skills allow robots to perform manual tasks with greater precision, safety, and adaptability. However, costs remain prohibitive for many applications.this trend is more recent even though it has been in research for decades. Robots can come in different shapes, such as a familiar object, an animal, or a human. It can be tiny or as big as it can be designed:

  A nanobot is a robot whose components are on the scale of about a nanometer.

  A robot with artificial skins to look like a human is called a humanoid. They are being deployed in limited situations such as assistants to police, senior citizens who need help, etc. Two popular robots are Atlas from Boston Dynamic and humanoid Sophia from Hanson Robotics.

  Consumer products such as the smart vacuum iRobot Roomba are now widely available. The adoption of certain types of robots has accelerated in some industries due to the pandemic: Spot, the dog-like robot from Boston dynamics, is used to patrol for social distancing.

Figure 14.4.1: Sophia, First Robot Citizen at the AI for Good Global Summit 2018. Image by ITU Pictures is licensed under CC BY 2.0

- **Natural language processing**: Systems like ChatGPT demonstrate impressive conversational abilities and knowledge, though remain limited in reasoning and common sense compared to humans.
- **Computer vision**: AI can identify and categorize images, detect anomalies, read documents, and more at high accuracy. Applications include manufacturing, medicine, and self-driving cars.
- **AI generated content**: Models like DALL-E 2 and Stable Diffusion create synthetic imagery and art from text prompts with increasing sophistication. Legal and ethical questions persist around originality and ownership.

- **Algorithmic trading**: AI performs high-speed analytics of news and market data to automate stock trading, often faster than human traders. Concerns include overreliance and flash crashes.
- **Neural networks:** Neural networks are a class of machine learning algorithms modeled loosely after the human brain's network of neurons. They have seen significant advances in recent years. Neural networks enable AI systems to infer knowledge from data, learn from experience, and perform human-like cognitive functions. They remain an active research field as we pursue more advanced AI capabilities. Key innovations include:
  - Deep learning neural nets with many layers that can extract complex patterns from large datasets. Applications include image and speech recognition.
  - Spiking neural networks that mimic biological neuron spikes more closely. They are computational efficient for tasks like pattern recognition.
  - Generative adversarial networks (GANs) comprising two neural nets competing against each other to generate new content. Used for image and video generation.
  - Recursive neural networks that apply the same set of weights recursively over a structured input like a graph. Used in natural language processing.
  - Neuromorphic hardware like GPUs tailored to massively parallel neural net computations. This specialized hardware trains networks faster.
  - An example: This is a collection of hardware and software technologies. The hardware includes wearable devices that allow humans to control machines using thoughts such as Honda Motor's Brain-Machine Interface. This is still in the research phase, but its results can impact many industries such as healthcare.

The goal of 100% duplicating a human brain has not been achieved yet since no AI systems have passed the Alan Turing test known as Turing Test to answer the question 'Can a machine think?" Alan is widely considered a founder of the AI field and devises a test to a machine's ability to show the equivalent intelligent behavior to that humans. The test does not look for correct answers but rather answers closely resemble those a human would give.

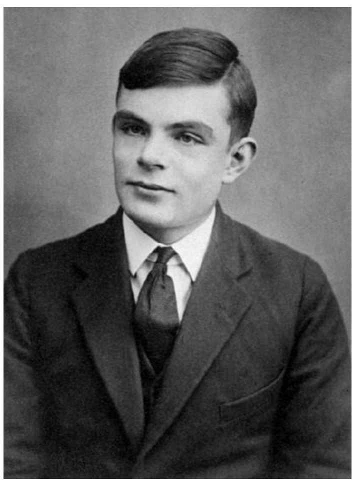
Figure 14.4.2 Alan Turing Aged 16. Image is licensed Public Domain

Even though AI has not been able to duplicate a human brain yet, its advances have introduced many AI-based technologies such as AI bot, robotics in many industries. AI progress has contributed to producing many practical business information systems that we discussed throughout this book such as, voice recognition, cameras, robots, autonomous cars, etc. It has also raised concerns over how ethical is the development of some AI technologies as we discussed in previous chapters.

Advances in artificial intelligence depend on the continuous effort to collect vast amounts of data, information, and knowledge, advances in hardware, sophisticated methods to analyze both unconnected and connected large datasets to make inferences to create new knowledge, supported by secured, fast networks.

AI has advanced rapidly, with innovations like DeepMind's AlphaFold for protein folding, AI generated art and content, and natural language models like ChatGPT demonstrating new capabilities.

Now, in 2023, we have the first AI robot as the world's words 1st Experiental CEO. Meet Mika the CEO in this video.

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