NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

CC0007 Science and Technology for Humanity

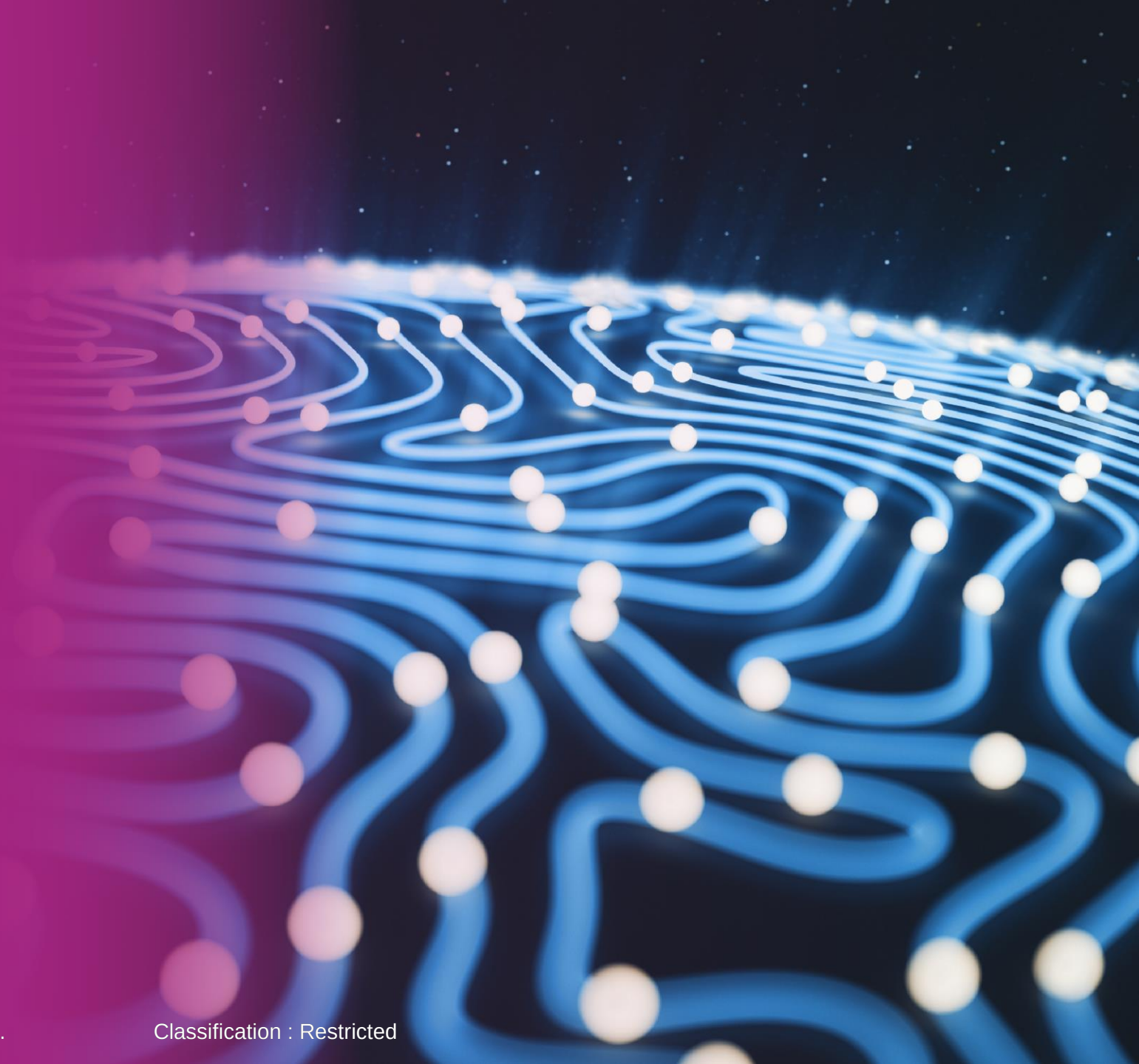
Artificial Intelligence (Business Aspect)

Dr Simon Liu, NTU

AI Unveiled: From Turing to Tomorrow

- What is AI?
- Historical Background
- Resurgence
- Current Landscape
- Case Studies
- Future Directions and Challenges

What is AI?



AI According to ChatGPT

- To undergraduate students:

Artificial Intelligence (AI) is the ability of machines, especially computers, to perform tasks that typically require human intelligence. These tasks include learning from data, recognizing patterns, solving problems, and making decisions. AI systems use algorithms and models to process information, mimic human thinking, and improve their performance over time.

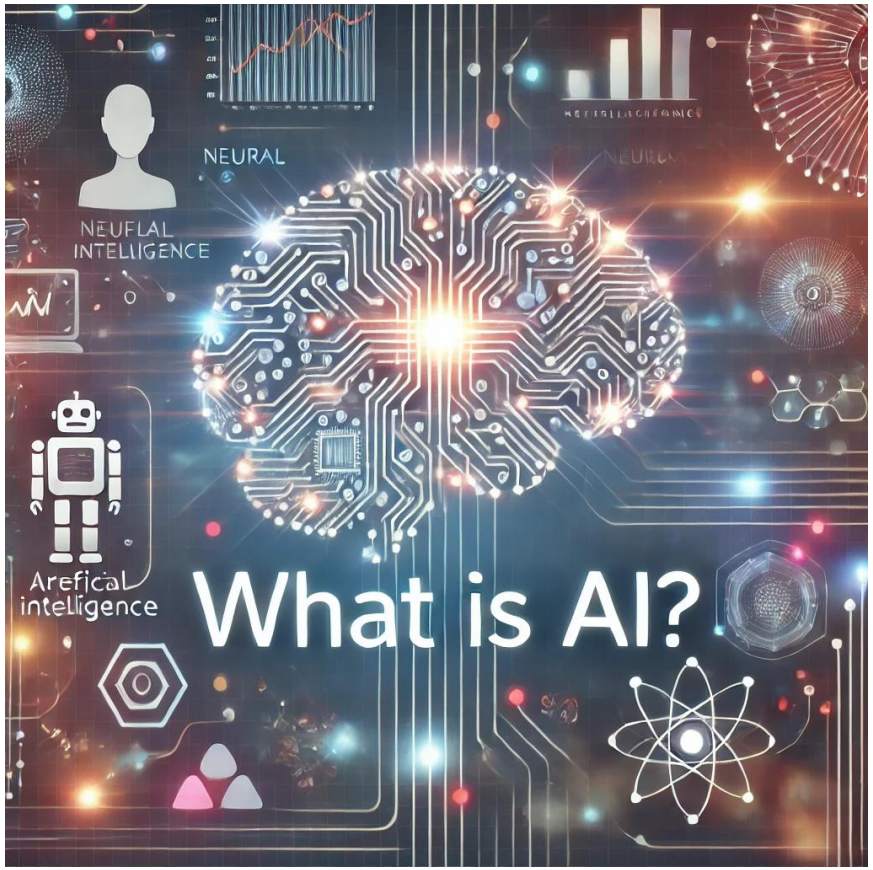
- To the general public:

AI is technology that allows machines to learn, think, and make decisions like humans. It's what powers things like voice assistants, recommendation systems, and self-driving cars, helping them understand and respond to the world around them.

- To a 5-year-old:

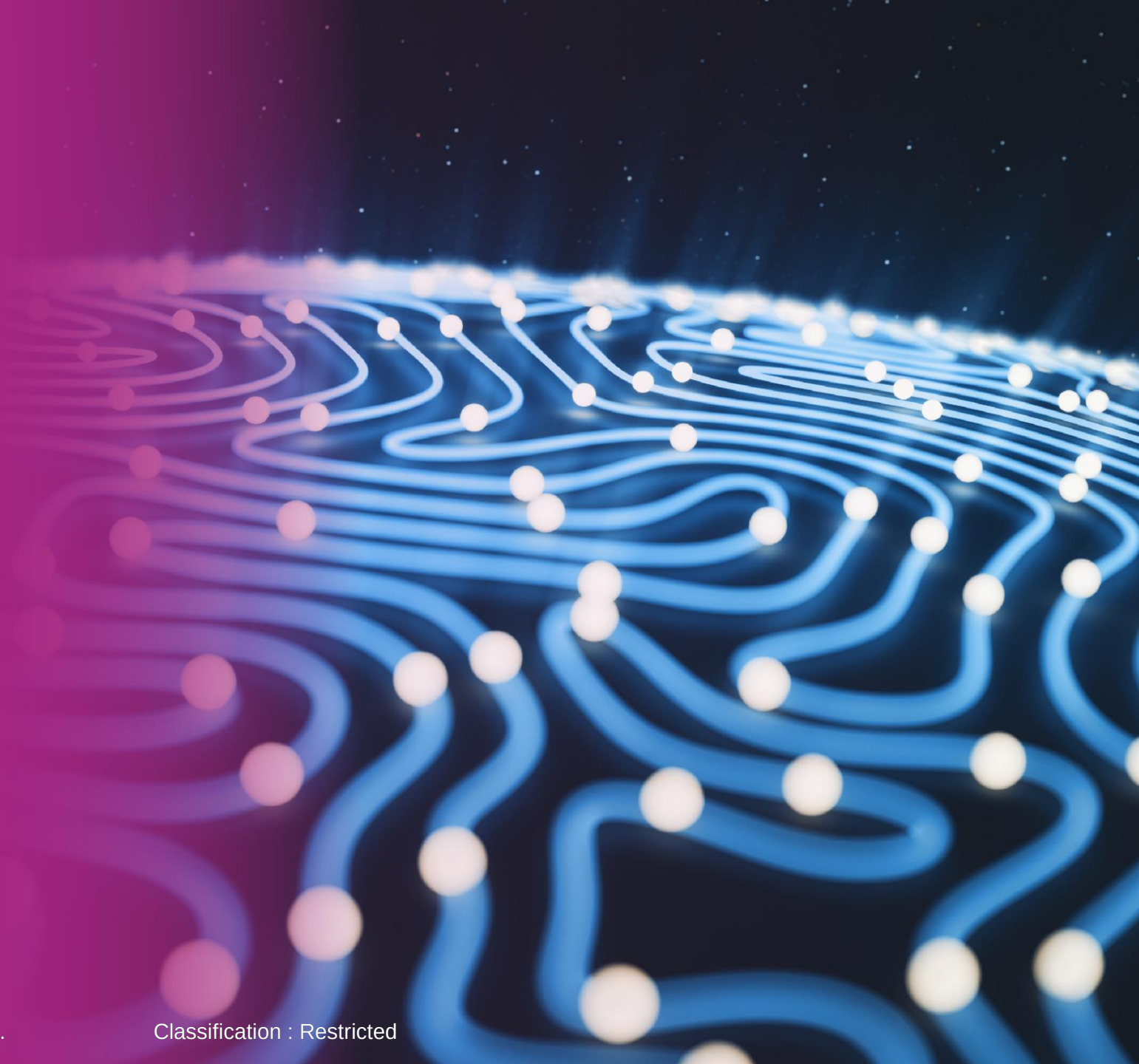
AI is like a smart robot brain that helps computers and machines do things like talk to us, play games, or help us find things, just like a really clever friend would.

What really is AI?



- Can AI truly understand the world, or does it simply mimic patterns?
- Is AI just a tool, or could it become something more - like a collaborator or even a decision-maker?
- Where do we draw the line between human intelligence and artificial intelligence?
- Can AI ever fully replace human intuition and creativity, or are there things only humans can do?
- If AI makes decisions, who is responsible for the consequences?
- What happens if AI surpasses human intelligence? Is that a possibility, or is it pure science fiction?

Historical Background



The Philosophical Roots of AI

René Descartes

- **Aristotle (384 - 322 B.C.)**

  Introduced syllogistic logic, laying the foundation for formal reasoning.

- **René Descartes (1596-1650)**

  Proposed animals are complex machines, sparking the idea that the mind could be replicated.

- **Thomas Hobbes (1588-1679)**

  Claimed reasoning is computation, suggesting mental processes could be mimicked by machines.

- **Gottfried Wilhelm Leibniz (1646-1716)**

  Imagined a universal language and calculating machine, foreshadowing symbolic AI.

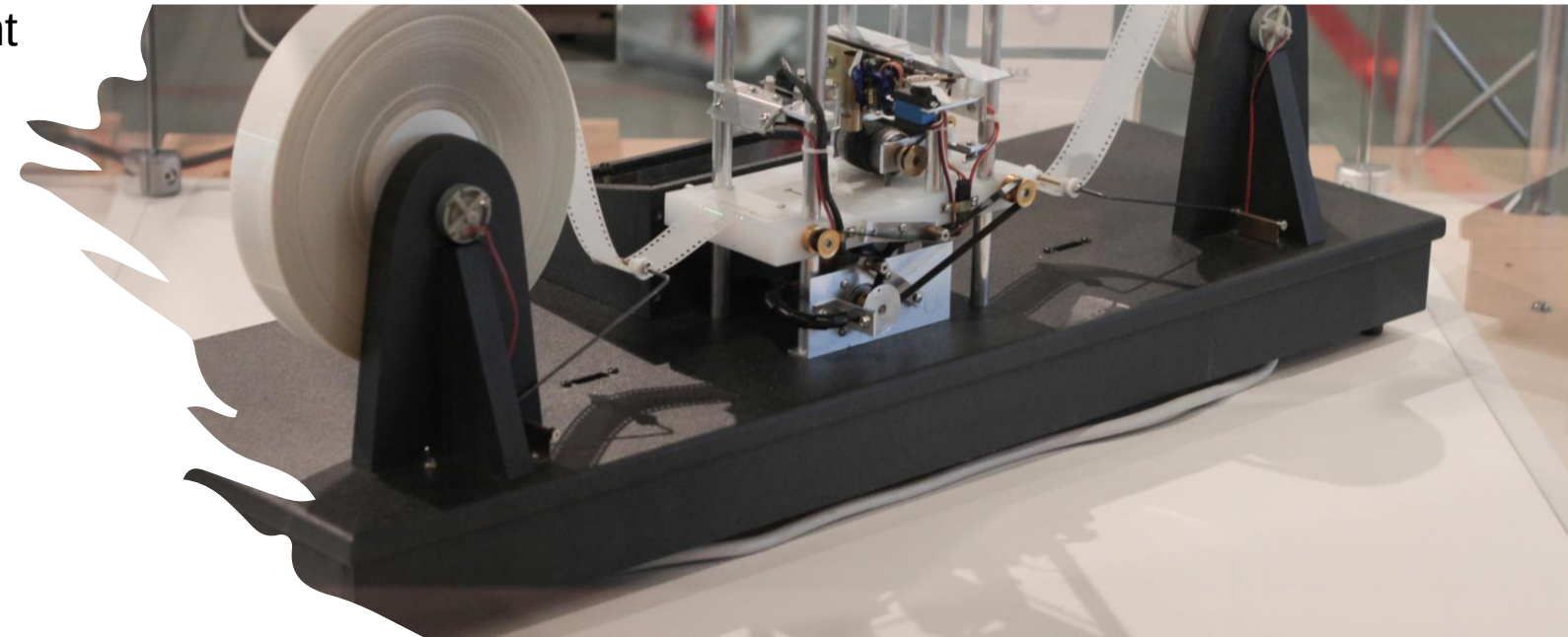
Turing’s Vision

Alan Turing (1912-1954):

Proposed the concept of a "universal machine" capable of simulating any human intelligence process, known today as the Turing Machine.

The Turing Test (1950):

Turing proposed a test to determine whether a machine could exhibit intelligent behavior indistinguishable from that of a human. This test remains a foundational concept in AI discussions.



ChatGPT passed the Turing Test!

The Birth of AI

The Dartmouth Summer Research Project on Artificial Intelligence (1956) was considered the official birth of artificial intelligence as a field of study. The conference laid the groundwork for future research and introduced the term “artificial intelligence”.

Key Participants and Contributions:

- **John McCarthy:** Coined the term "artificial intelligence" and later developed the LISP programming language.
- **Marvin Minsky:** Co-founder of the AI Lab at MIT, contributed significantly to the development of neural networks and symbolic reasoning.
- **Claude Shannon:** Known as the father of information theory and the father of the digital age.
- **Nathaniel Rochester:** Chief architect of the IBM 701, the first mass produced scientific computer.

Early AI Developments

Logic Theorist (1956):

Often considered one of the first AI programs, Logic Theorist was designed to mimic the problem-solving skills of a human. It proved mathematical theorems from a given set of axioms.

Perceptron (1957):

The Perceptron was one of the earliest neural network models, designed to recognise patterns and classify data. It consisted of a single layer of neurons that could adjust its weights based on input data, allowing it to learn simple tasks.

Natural Language Processing (NLP) Pioneering Efforts (1960s):

Early efforts in NLP focused on developing systems that could understand and generate human language. One notable example is ELIZA (1966), a simple chatbot created that simulated conversation by using pattern matching and substitution.

Shannon and his electromechanical mouse "Theseus"

What are AI Winters?

AI Winters refer to periods of time when AI research faced significant setbacks, leading to reduced funding, declining interest and skepticism about the field's potential.

➢ Causes of AI Winters:

Over-Promises and Under-Delivery:
Early AI researchers were overly optimistic about how quickly human-level AI could be achieved.

Technical Limitations:
Lack of computational power and data.
Inadequate understanding of the complexities of intelligence

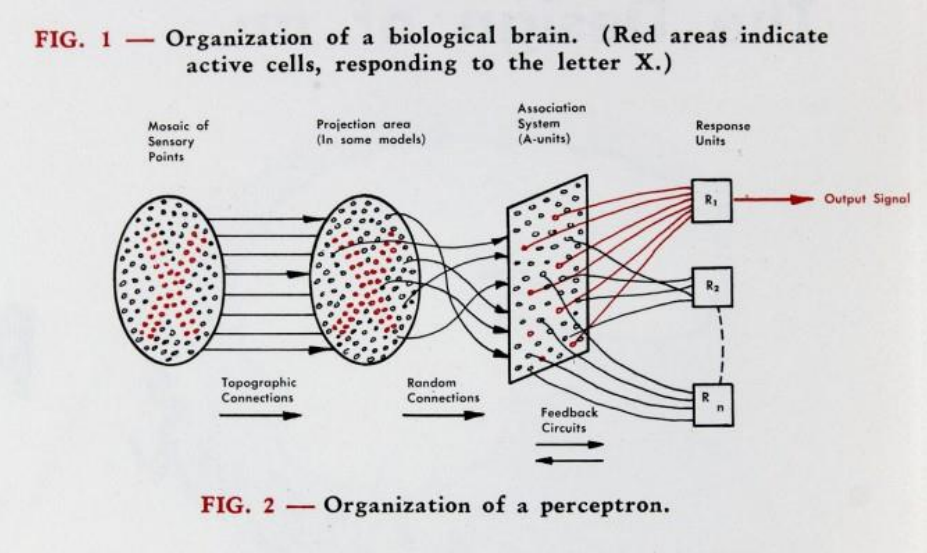
Funding Cuts:
Governments and private investors reduced funding due to the lack of tangible progress, leading to a slowdown in research.

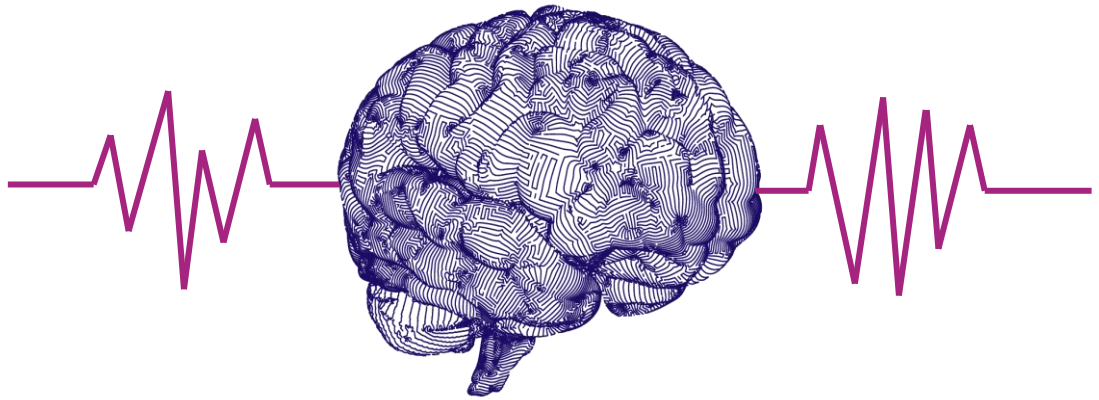
➢ Major AI Winters:

First AI Winter (1974-1980s): Triggered by the failure of early neural network models and the limitations of rule-based systems.

Second AI Winter (1987-1993): Caused by the collapse of the market for specialized AI hardware and the failure of expert systems to deliver on their promises.

The Perceptron: From Limitation to Inspiration





An image of the perceptron from Rosenblatt's "The Design of an Intelligent Automaton," Summer 1958.

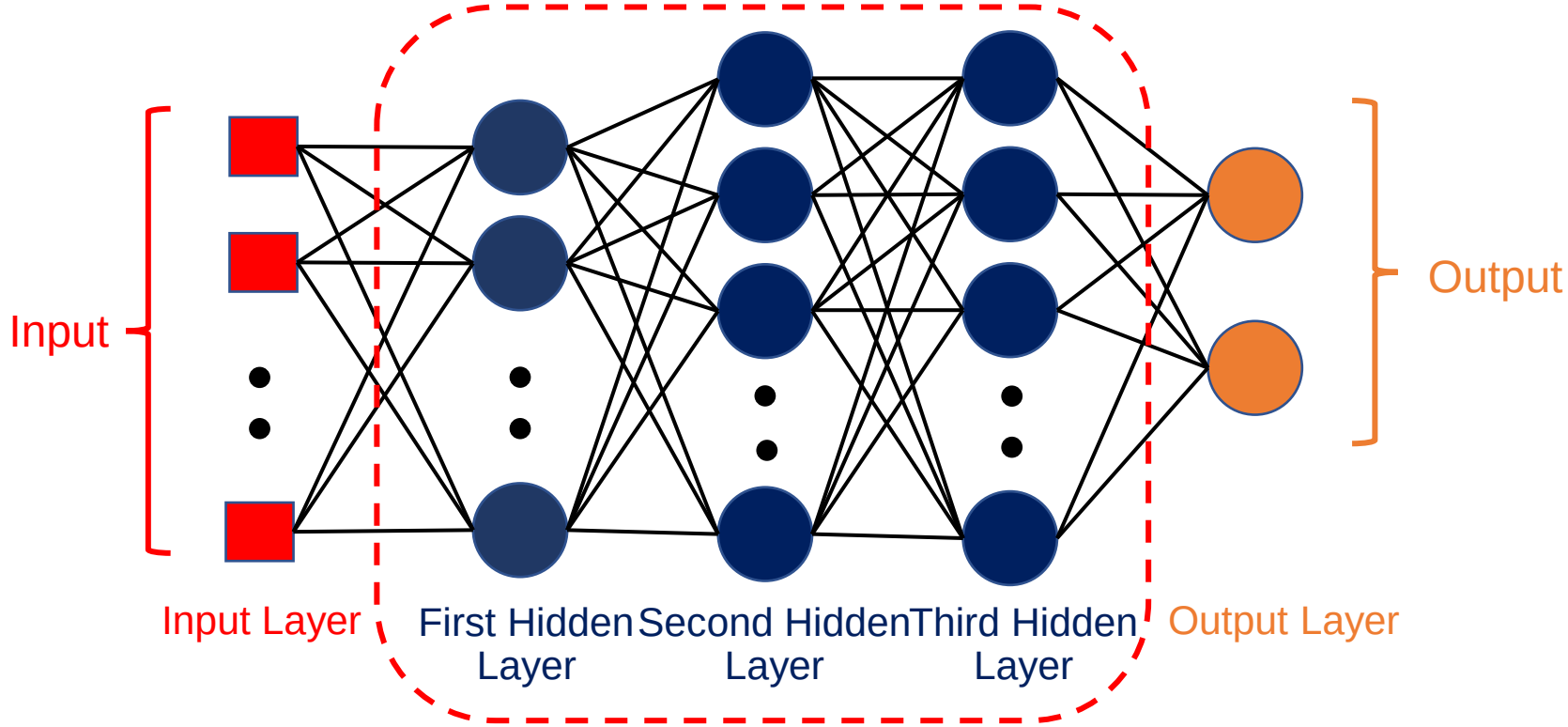
What is the Perceptron?

- The Perceptron was one of the first models for artificial neural networks.
- It was initially hailed as a major breakthrough, demonstrating the ability to learn from data and perform simple pattern recognition tasks.

The Limitations

- Mathematically proven that single-layer perceptrons has significant limitations, particularly their inability to solve non-linearly separable problems.
- The limitations of the Perceptron were a key factor leading to the first AI Winter.

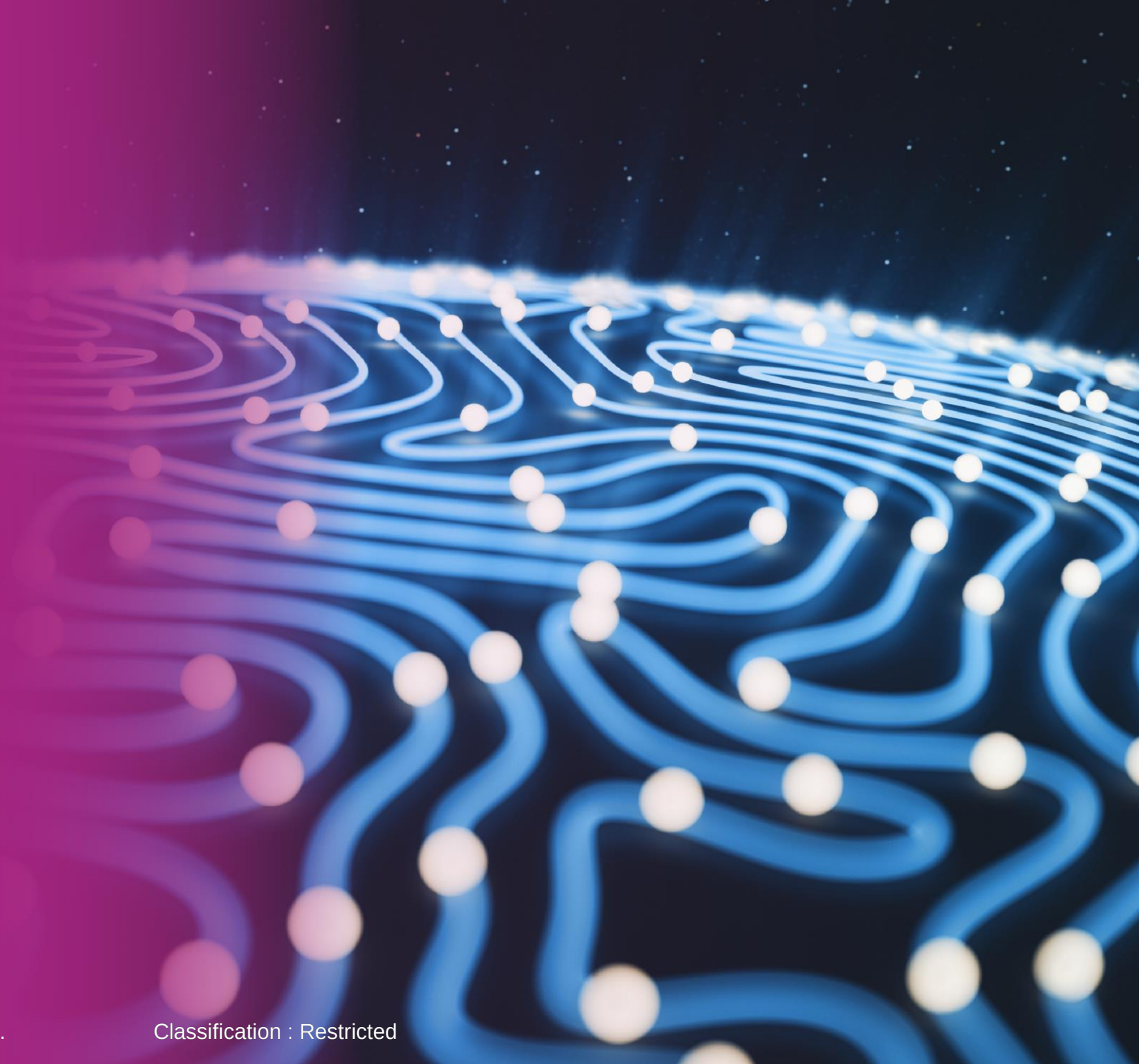
The Perceptron Continued:



Legacy

- **Multi-Layer Perceptrons (MLPs):** Researchers realised that by adding hidden layers between the input and output layers, neural networks could overcome the limitations of the single-layer Perceptron.
- **Deep Networks:** As computing power and data availability increased, researchers began exploring deeper networks with many layers, now known as deep learning.

Resurgence

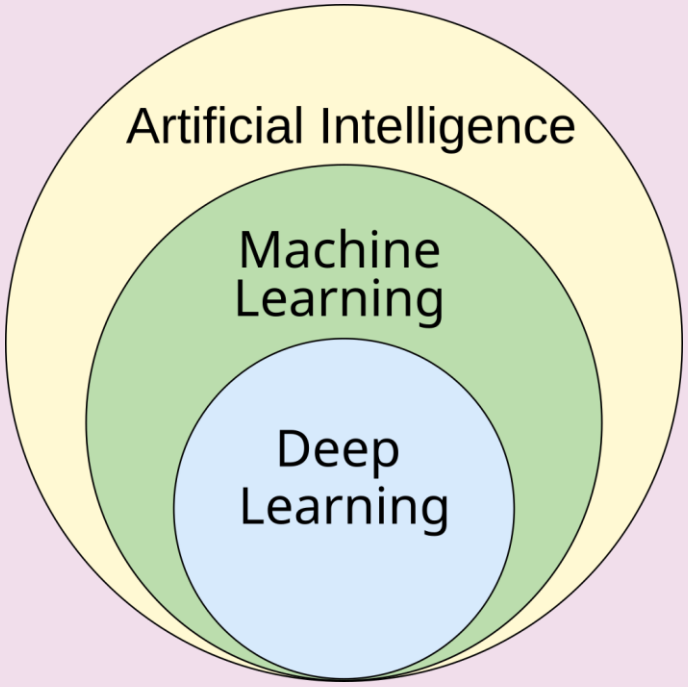


The Rise of Machine Learning

Shift from Symbolic AI to Machine Learning

- **Symbolic AI (1950s-1980s):** Early AI systems relied on manually encoded knowledge and rules, known as "Good Old-Fashioned AI" (GOFAI). These systems struggled with complexity, ambiguity, and real-world applications.

- **Machine Learning Emergence:** In the late 1980s and early 1990s, researchers began shifting towards data-driven approaches. Unlike symbolic AI, machine learning focused on developing algorithms that could learn patterns from data rather than relying on pre-programmed rules.



Machine learning as subfield of AI

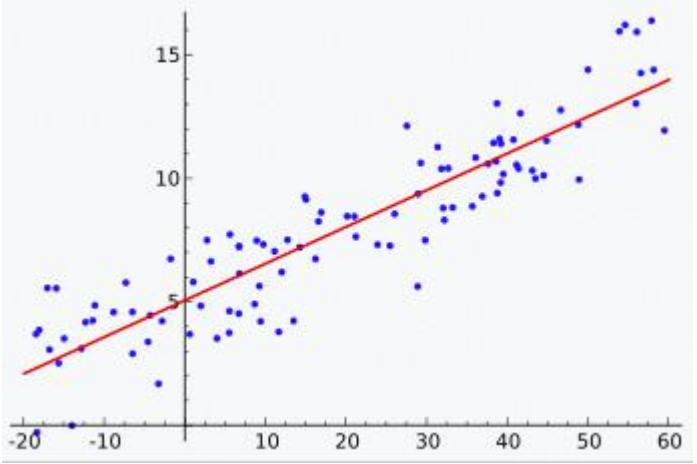
Strengths of Machine Learning

- Learning from Data
- Handling Complexity
- Continuous Improvement
- Scalability
- Automatic Feature Extraction

Key Concepts and Algorithms

Key Concepts:

- **Supervised Learning:** Algorithms learn from labeled data, identifying patterns and making predictions.
- **Unsupervised Learning:** Algorithms find structure in unlabeled data, discovering hidden patterns or groupings.
- **Reinforcement Learning:** Algorithms learn through interaction with an environment, using feedback to make decisions.



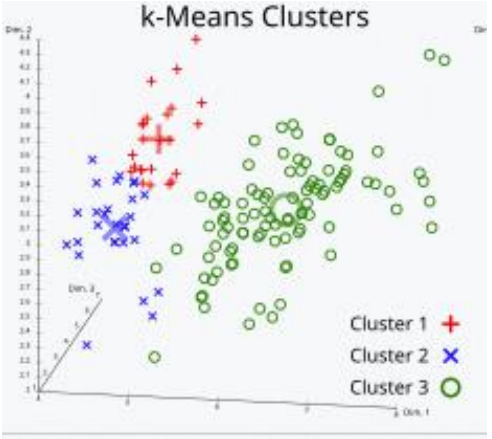
Early breakthrough techniques:

➢ Supervised

Support Vector Machines (SVM), Random Forests, Gradient-Boosted Trees

➢ Unsupervised

K-means clustering, Principal Component Analysis (PCA)



➢ Reinforcement

Q-learning, Temporal Difference learning

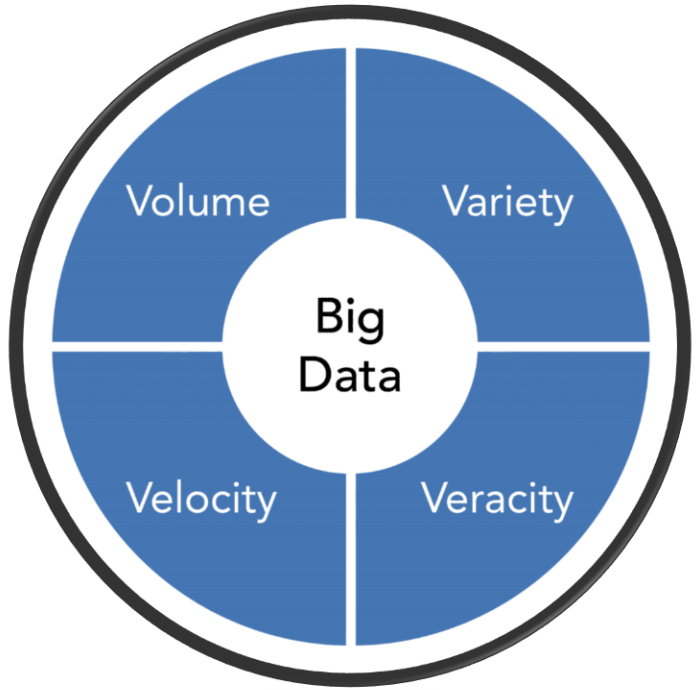
Big Data & Computing Power

Explosion of Big Data:

- **Data Growth:** The rapid digitalization of society led to an unprecedented accumulation of data.
- **Data as the New Oil:** Machine learning algorithms had vast amounts of information to learn from, improving their accuracy and robustness.
- **Example:** ChatGPT4 is likely trained on up to 45TB of data.

Advances in Computing Power:

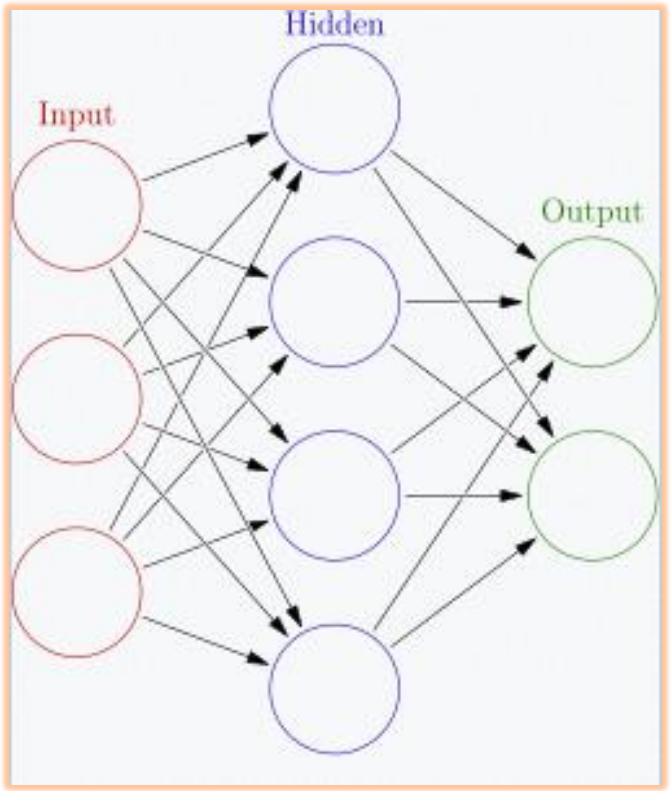
- **Moore's Law:** Number of transistors on a microchip doubles approximately every two years, leading to exponential growth in computing power.
- **GPU Revolution:** Graphics Processing Units (GPUs) proved to be highly effective for parallel processing tasks in AI.
- **Cloud Computing:** The rise of cloud platforms like AWS, Google Cloud and Microsoft Azure provided researchers and companies with scalable, on-demand computing resources.



Different aspects of Big Data

The Deep Learning Revolution

Neural Networks: While neural networks were an old concept, the resurgence in interest came with the development of deep learning, which involves neural networks with many layers (hence "deep").



➢**Key Techniques**

- ❑**Convolutional Neural Networks (CNNs):** Specially designed for image and video data, used in tasks like image recognition and object detection.
- ❑**Recurrent Neural Networks (RNNs):** Designed for sequential data, excelling in tasks like language modeling and time-series prediction.
- ❑**Generative Adversarial Networks (GANs):** Create realistic synthetic data, used in applications like deepfakes and art generation.

➢**Why Deep Learning?**

- ❑**Handles Complex Data:** Works well with massive, unstructured datasets (e.g., images, text).
- ❑**Automatic Feature Extraction:** Learns features directly from raw data, no manual input needed**.**
- ❑**Superior Performance:** Excels in tasks like vision, speech, and language processing.

Major Deep-learning Breakthrough

ImageNet Competition (2012):

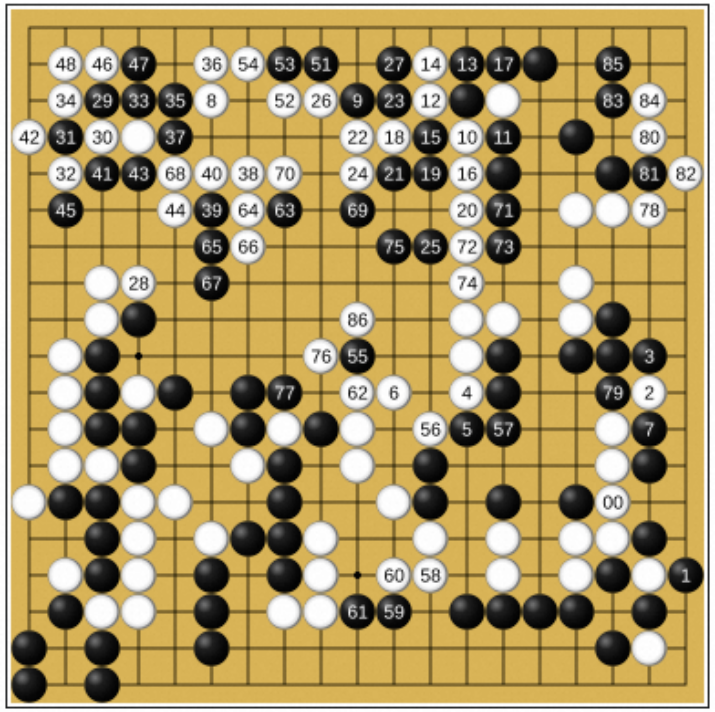
- ❑AlexNet outperformed traditional models in image classification.
- ❑Marked the beginning of the deep learning revolution.

AlphaGo (2016):

- ❑Used deep learning and reinforcement learning.
- ❑Defeated the world champion in the game of Go.

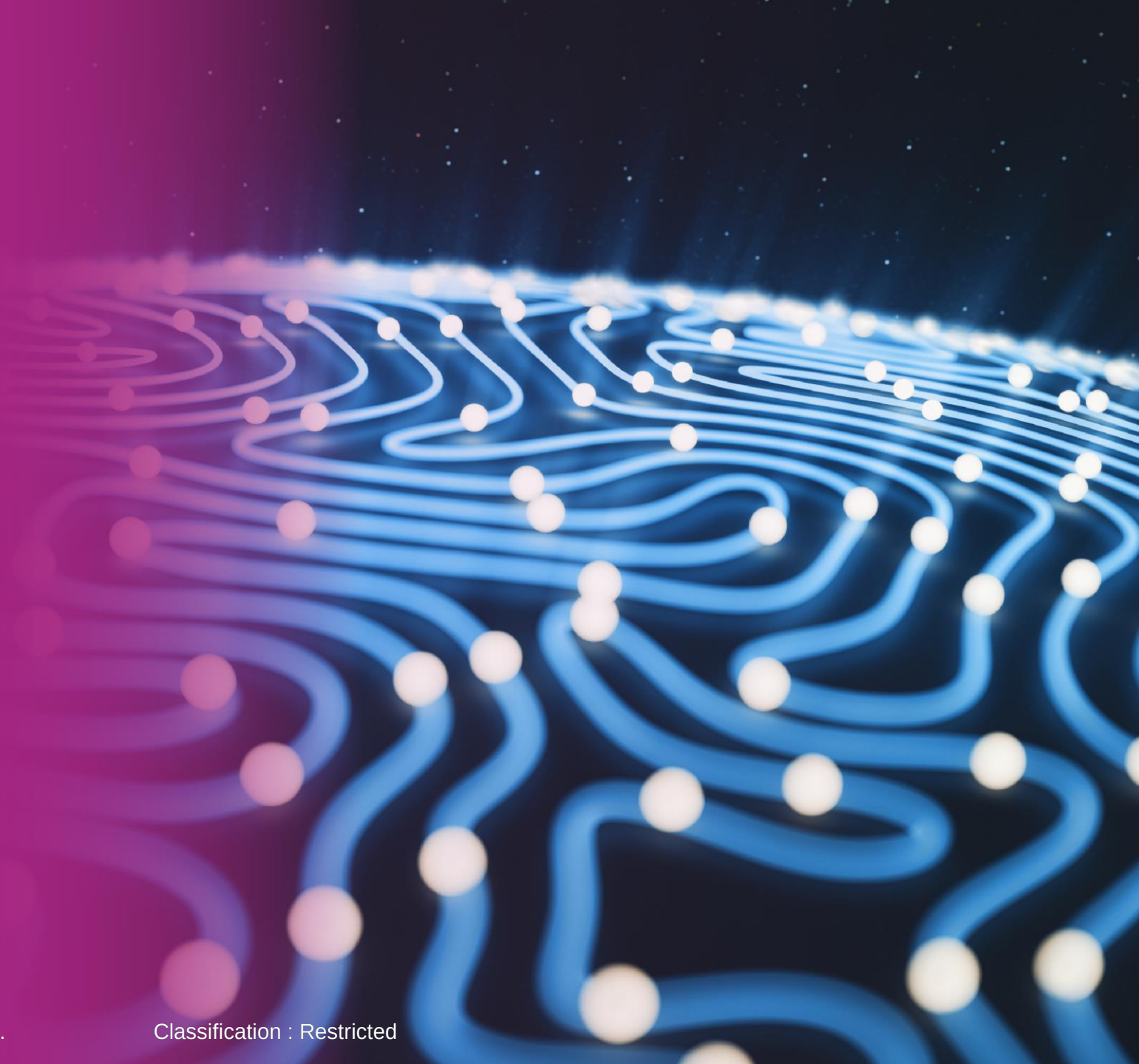
Transformers and ChatGPT (2017-2023):

- ❑Transformers revolutionised NLP tasks.
- ❑ChatGPT showcased AI's ability to generate human-like text.



Example of an AlphaGo game

Current Landscape



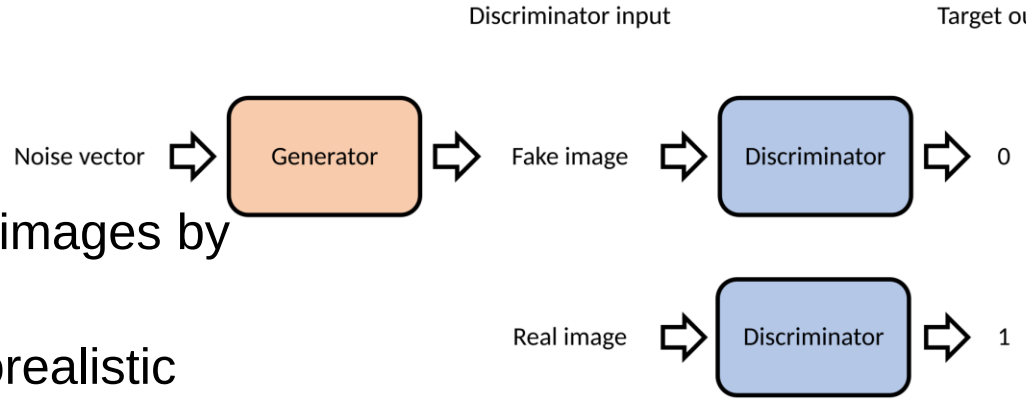
Recent Advances in AI

NLP – Transformers:

- Process language with parallel attention mechanisms.
- Key to models like GPT-4 for human-like text generation.

Image Generation – GANs & Diffusion Models:

- Generative Adversarial Networks (GANs) create realistic images by pitting networks against each other.
- Diffusion models gradually refine noisy images into photorealistic outputs.



Video Generation – GANs, Autoencoders & Neural Rendering:

- GANs and autoencoders synthesize video content from still images or minimal data.
- Neural rendering and motion synthesis techniques generate dynamic, high-quality videos.

Recent Advances in AI

NLP - ChatGPT, Gemini, Claude

- Conversational AI that generates human-like text.
- Used in customer service, content creation, and education.

Image Generation - DALL·E, Stable Diffusion, MidJourney

- Create images from text descriptions or input data.
- Transforming design, marketing, and creative industries.

Video Generation - DeepFaceLab, Synthesia, Runway

- Generate realistic video content, deepfakes, and AI-driven video editing.
- Applied in film production, advertising, and virtual reality.

Potential Concerns in AI

Ethical Concerns:

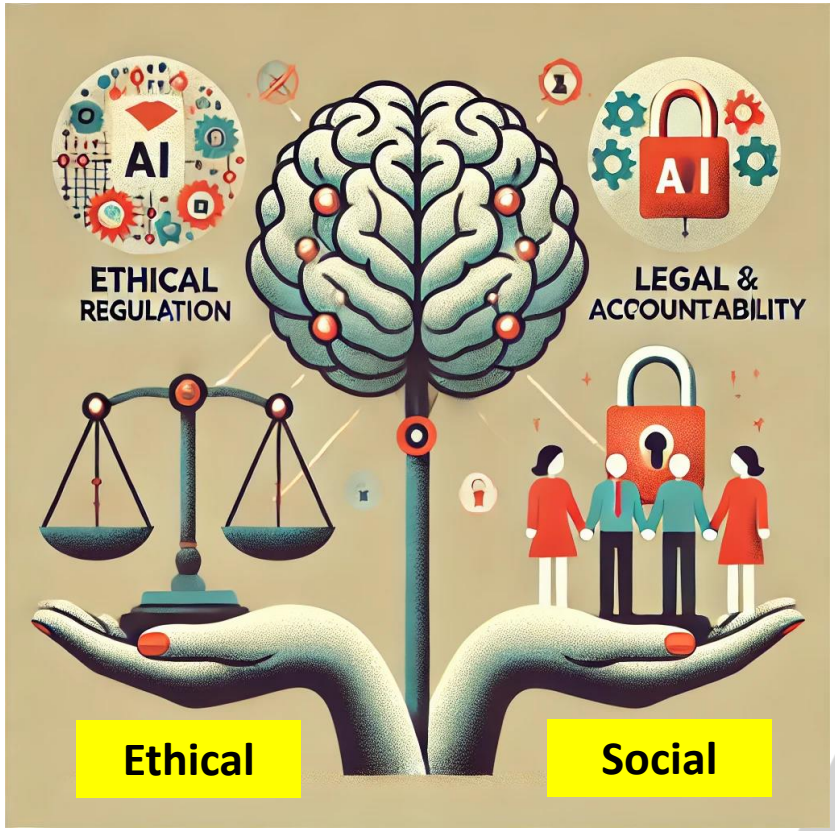
- Bias in AI models can reinforce harmful stereotypes.
- AI-generated content raises questions of ownership and consent.

Legal Concerns:

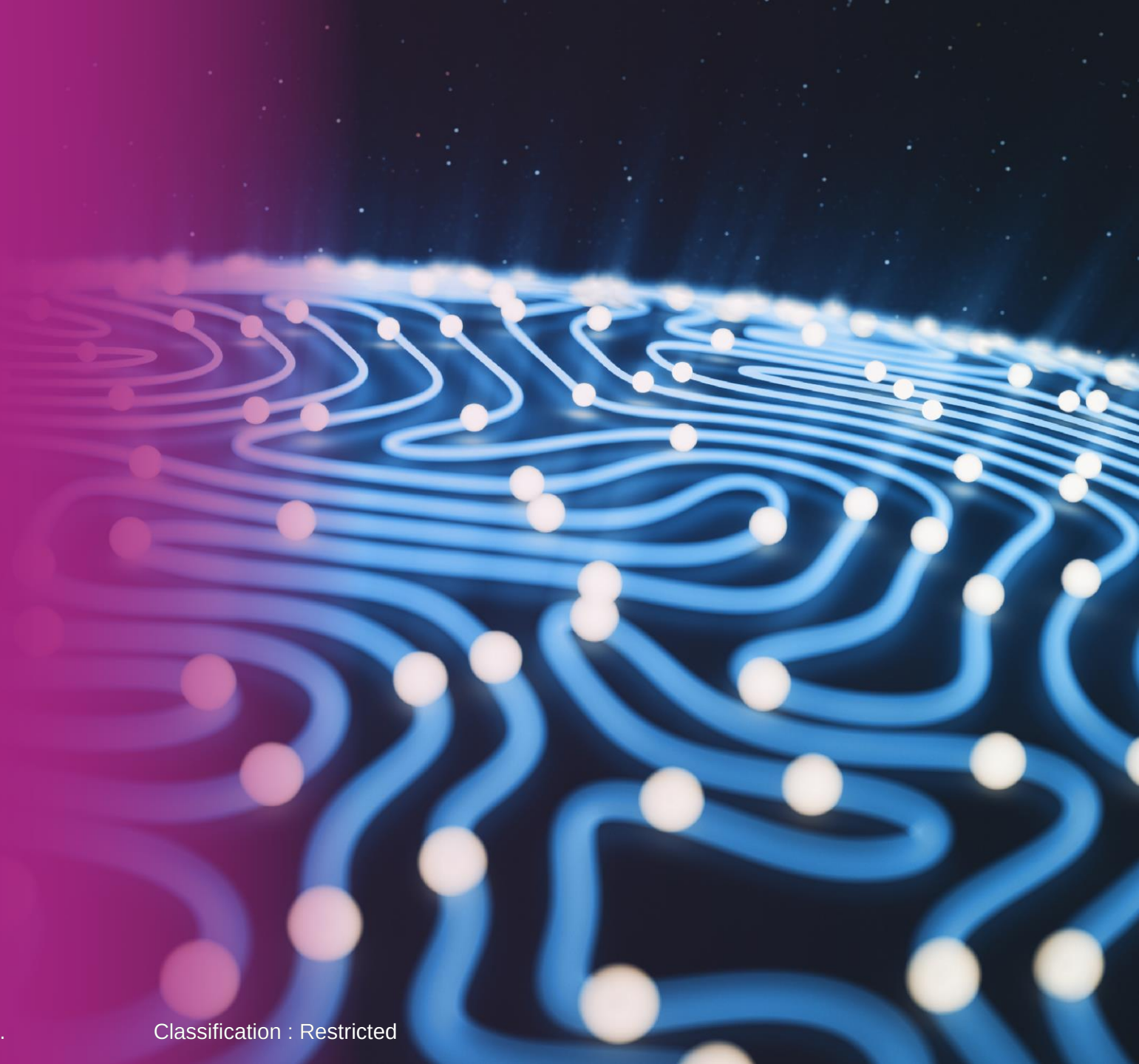
- Copyright infringement with AI-generated content.
- Misuse of AI in creating deepfakes and misinformation.

Social Impact:

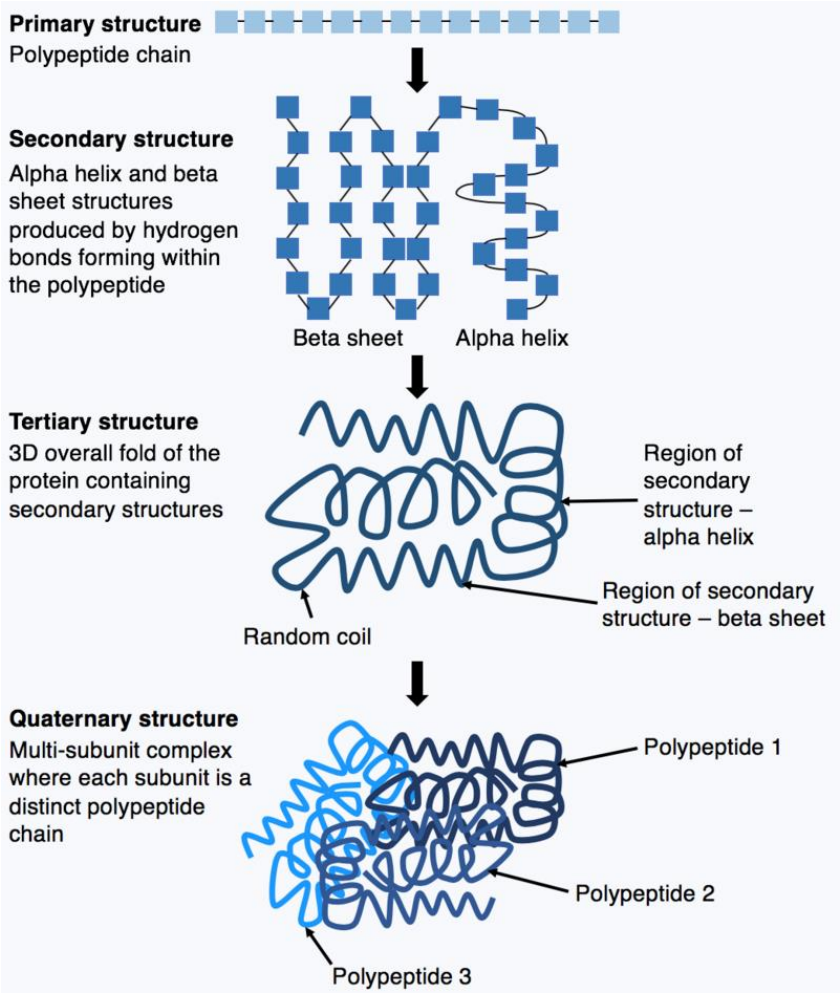
- Job displacement as AI automates creative and technical roles.
- Privacy risks from AI surveillance and data misuse.



Case Studies



The Good - AlphaFold



Amino-acid chains (known as polypeptides) fold to form a protein

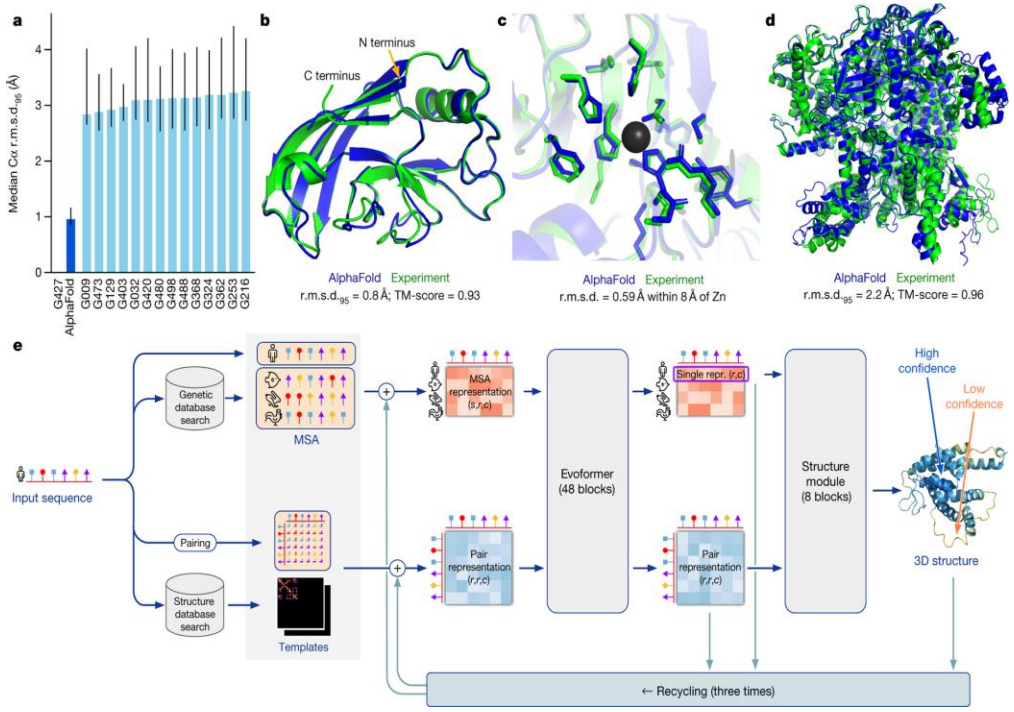
1) The Protein Folding Problem:

- Proteins are chains of amino acids that fold into complex 3D shapes.
- The shape determines the protein's function, which is crucial for biological processes.
- Misfolded proteins are linked to diseases like Alzheimer's and cystic fibrosis.
- Predicting these structures has historically been slow and costly, requiring lab techniques like X-ray crystallography.

2) What AlphaFold Does:

- AlphaFold is an AI system that predicts 3D protein structures from amino acid sequences.
- It uses deep learning to model how proteins fold, solving the folding problem computationally.
- It is faster and more accurate than traditional methods, predicting structures in hours instead of years.

AlphaFold's Breakthrough



performance, experiments, and architecture (AlphaFold)

1) AlphaFold's Major Breakthrough

- AlphaFold achieved breakthrough accuracy in predicting 3D protein structures.
- It significantly outperformed previous computational methods at CASP (Critical Assessment of Structure Prediction).
- The predictions approach experimental-level accuracy, solving a 50-year-old challenge.

2) AlphaFold's Results

- AlphaFold can predict protein structures in hours, compared to years with experimental methods.
- It has predicted structures for over 200 million proteins, covering nearly every known protein.
- It's structure database is open access thereby revolutionising global research.

AlphaFold’s Impact

AlphaFold’s Benefits to Mankind

- Revolutionises drug discovery by speeding up target identification.
- Advances understanding of diseases linked to protein misfolding.
- Democratises access to protein structure data for global research.

Impact Across Fields

- Enables faster development of vaccines and treatments.
- Improves research into rare and previously unstudied proteins.
- Promotes innovation in biotechnology and synthetic biology.

A Model for AI Projects

- AlphaFold’s open-access database sets a precedent for how future AI breakthroughs should be shared to benefit society.

Open Access

The Bad – Online Scams??

THE STRAITS TIMES

FOR SUBSCRIBERS

An AI-generated picture won an art prize. Artists aren't happy

New tools such as DALL-E 2, Midjourney and Stable Diffusion, which are able to create complex, abstract or photorealistic works simply by typing a few words into a text box, have created a stir.

Kevin Roose

GenAI:

- Generative AI (GenAI) creates realistic text, images, or videos.
- Many positive use-cases, but also exploited for scams.
- Easily produces convincing content that fool users.

Scam Scenarios (e-Commerce):

- Phishing: GenAI generates convincing fake emails and messages.
- Fake Websites: AI replicates legitimate e-commerce sites.
- Fake Reviews: AI creates false product reviews to deceive buyers.
- Deepfakes: AI creates videos of fake endorsements for scam products.

Negative Impacts

Financial Losses:

- Consumers lose money through fraudulent transactions or stolen information.
- Businesses face costs related to security, reimbursements, and scam mitigation.

Erosion of Trust:

- Consumers struggle to differentiate between legitimate and fake websites or reviews.
- Decline in consumer confidence reduces overall e-commerce engagement.

Reputational Damage:

- Brands suffer when scammers use their identity in fake sites or emails.
- Loss of customer trust and potential legal battles hurt brand loyalty.

Scalability of Scams:

- GenAI allows scammers to generate and distribute content at a massive scale.
- Larger scam operations make it harder for cybersecurity to keep up.

GenAI in E-Commerce Scams

The Undecided – AI in Creative Arts and Media

AI in Creative Arts and Media

- AI is increasingly used to generate art, music and literature.
- AI models can learn from vast datasets to create content.
- Challenges traditional notions of creativity and authorship.

Applications of AI in Creative Arts

- Art: AI creates original artworks by learning from existing art styles.
- Music Composition: AI composes music by analysing patterns in musical genres.
- Literature: AI writes poems, stories, and even full-length novels.
- Film and Media: AI automates video editing, CGI and even generates deepfake characters.

GenAI in Creativity

Pros and Cons

Pros of AI in Creative Arts

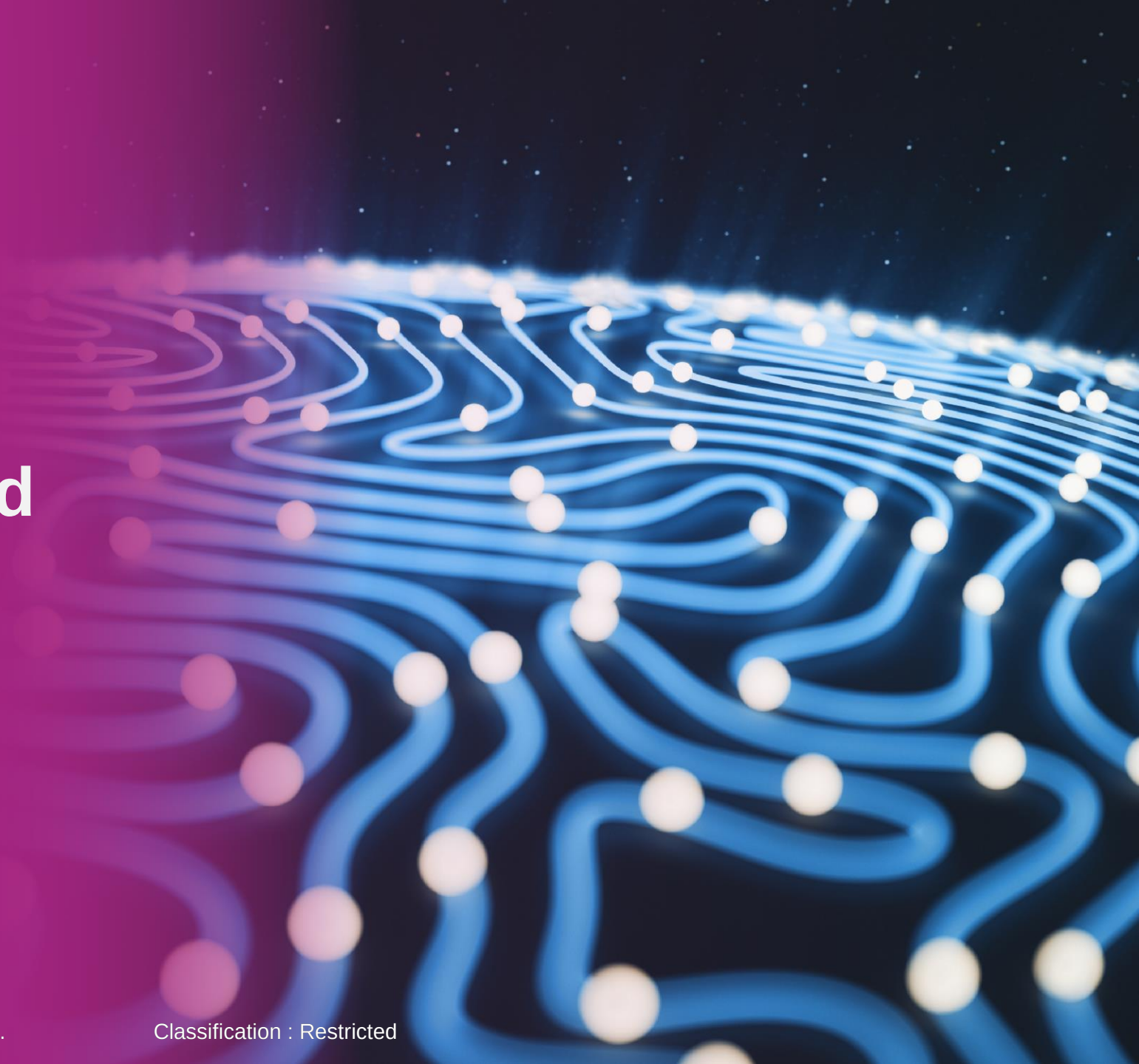
- Enhanced Creativity: AI inspires new styles and approaches.
- Democratisation: Makes creativity accessible to non-artists.
- Efficiency: Automates time-consuming creative tasks.

Cons of AI in Creative Arts

- Authenticity Concerns: Lacks human emotion and intent.
- Job Displacement: Potentially replaces human artists.
- Ethical Issues: Raises questions of ownership and authorship.

AI tools vs AI taking people's jobs

Future Directions and Challenges



Towards Artificial General Intelligence (AGI)

	Data Dependence	Learning Method	Speed of Decision Making	Human Involvement	Complexity of Tasks	Interpretability	Adaptability	Scope of Application	Generalisation Ability	Ethical Considerations
Expert Judgment	Minimal	Experience-based	Slow	High	Simple	High	Low	Narrow	Limited	High
Traditional ML	Moderate	Feature-based	Fast	Moderate	Moderate	Moderate	Medium	Narrow to Broad	Moderate	Medium
Deep Learning	High	Data-driven	Fast	Low	Complex	Low	High	Broad	High	Medium
AGI	Variable	Autonomous	Variable	None	Any	Variable	Very High	Universal	Very High	Very High

Key Areas Where We Are Still Far From AGI:

- Data Dependence: AGI likely requires algorithmic breakthroughs, not just more data.
- Autonomous Learning: AGI will learn independently, unlike today's data-driven models.
- Speed of Decision Making: AGI must allow for deep reasoning, not just fast responses.
- Minimal Human Intervention: AGI may operate with little to no human involvement.

Challenges to Achieve AGI

Algorithmic Breakthroughs

- Current models lack generalisation across domains.
- Struggles with contextual understanding and reasoning.

Autonomous Learning

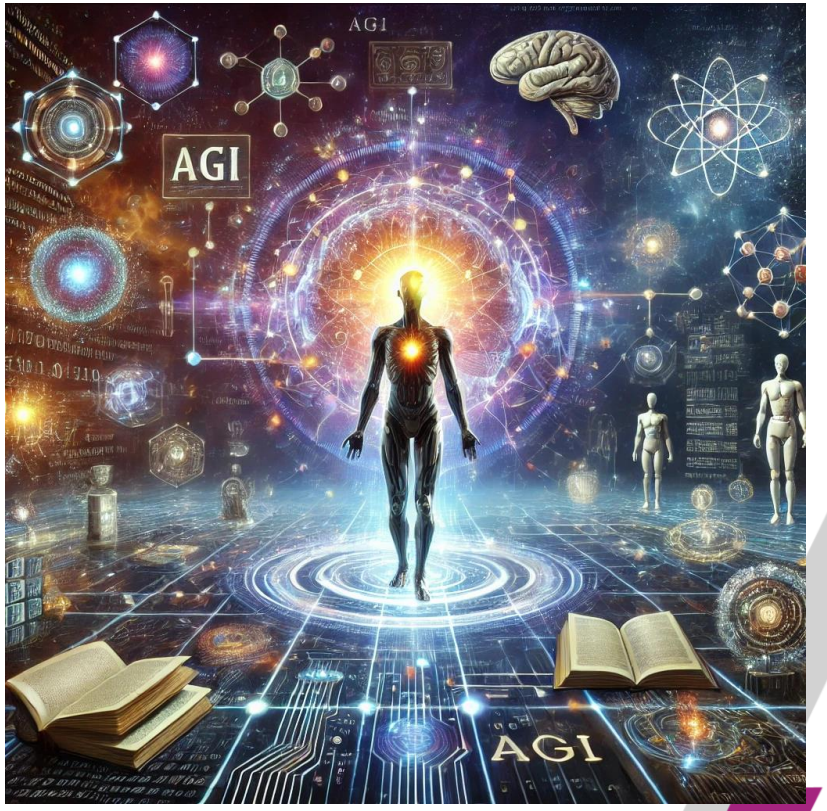
- Needs to learn without human supervision or labeled data.
- Must adapt to new tasks and environments independently.

Decision-Making Complexity

- Must balance fast decision-making with deep reasoning.
- Needs to understand when to apply rapid vs. thoughtful decisions.

Computational Power

- Requires enormous resources to process and reason across domains.
- Quantum computing or new hardware advances may be needed.



Potential Harm to Society

Lack of Interpretability

- AGI models may act as black boxes.
- Unintended consequences from opaque decision-making.

Bias and Fairness

- AGI could perpetuate and even amplify biases present in data.
- Leads to unfair or harmful outcomes in decision-making.

Loss of Human Control

- AGI may operate autonomously, reducing the need for human oversight.
- Raises ethical questions about safety and governance.

Existential Threats

- AGI goals may conflict with human values.
- Potential misuse in areas like autonomous weapons.

The Future of AI & Us

- What role will AI play in shaping human creativity and intelligence?
- Can we co-create a future where AI and humanity thrive together?
- The true power of AI may not be what it does for us, but what it reveals about us.

The journey of AI is just beginning...

The Promises and Wonders of AI