Section 1, Week 1: Introduction to Artificial Intelligence (LEC)

I. Overview of AI: Definitions and History

- Data explosion

  We live in a world with an ever increasing amount of data that both humans and machines generate. It far outpaces humans' ability to extract meaningful information and make informed and complex decisions based on the extensive data to process.
  Every day, we create roughly 2.5 quintillion bytes of data (that's 2.5, followed by a staggering 18 zeros!)

  We may not be aware, but we have been using Artificial Intelligence based technologies in our daily routine. Scientists found that an average person today can process as much as 74 gigabytes (GB) of data a day.

  Artificial Intelligence is a technology that is transforming every walk of life with its five basic components including learning, reasoning, problem-solving, perception, and language understanding.

  What is a machine?

  A machine is a piece of equipment with moving parts that humans design to do a particular job. A machine usually needs electricity, gas, steam, and so on to work.

  What is a computer?

  A computer is an electronic machine that can store, find and arrange information, calculate amounts, and control other machines.

- What is Artificial Intelligence (AI)?
    - The human brain has the ability to think, read, learn, remember, reason, and pay attention. Such capabilities are termed cognitive skills. The term "**Intelligence**" is used for cognitive (connected with the processes of understanding) skills and thinking ability of humans and animals. We may also call it "natural intelligence."

    - Then what is Artificial Intelligence (referred to as AI in the remaining book)?

    - The terminology comprises two words "*Artificial*" and "*Intelligence*." **Artificial** refers to something that is not natural or is made by humans. AI is, then, intelligence demonstrated by a computer (an electronic machine), hence, it can also be referred to as "machine intelligence."

    - In other words, AI is best described as machines having human-like cognitive skills of learning and problem solving by making decisions in such a way that they can be associated with human minds.

    - To summarize, AI is a field of computer science (not science fiction) combining robust datasets with the aim of having computers simulate intelligent processes. Here the computer needs AI implemented in its system to demonstrate AI capabilities.

    - Today AI contributes much to our human lives. Industries, including retail, healthcare, manufacturing, agriculture, insurance, and finance, are already harnessing the many benefits of AI. There are companies that provide AI solutions, while others use AI within their organization to manage internal business operations or business growth. A few real world companies in the preceding categories will be described by the end of this book.

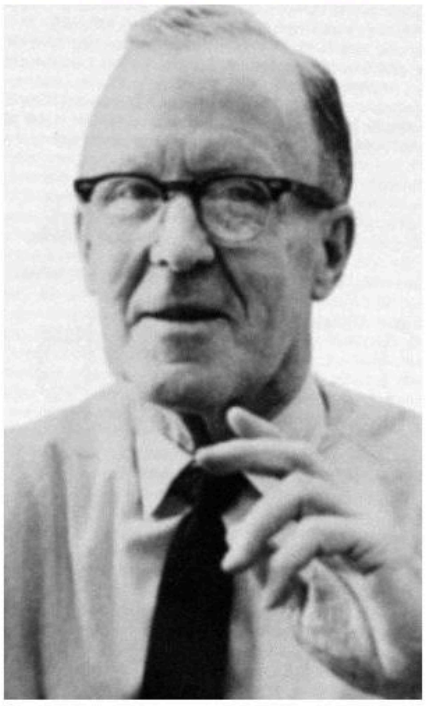
- Artificial Intelligence: History and evolution:
    - **Artificial Intelligence (AI)** has been studied for decades and is still one of the most elusive subjects in Computer Science.

- The year 1943: Warren McCulloch and Walter pits 1943 proposed a model of artificial neurons.

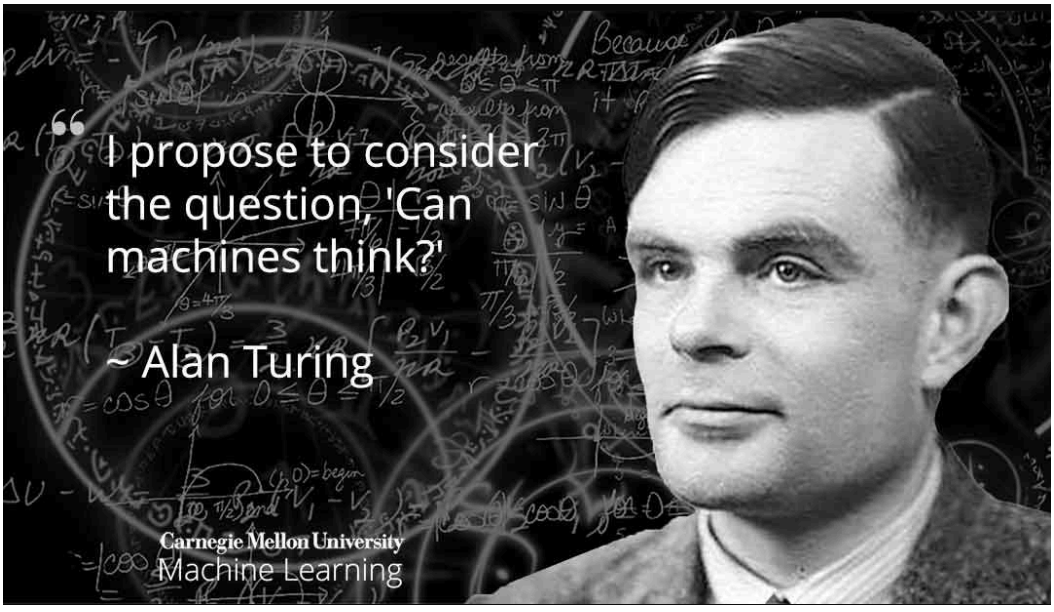
- The year 1949: Donald Hebb demonstrated modifying the connection strength between neurons. His rule is now called Hebbian learning.

Donald O Hebb

- Wrote The Organization of Behavior in 1949
- “When an axon of cell A is near enough to excite cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased” (Hebb 1949)



- The year 1950: Alan Turing, an English mathematician, pioneered Machine learning in 1950. Alan Turing proposed a test in his "Computing Machinery and Intelligence" publication. The test, called a Turing test, can check the machine's ability to exhibit intelligent behavior equivalent to human intelligence.



- The period between the 1950s and the 1970s revolved around the research on neural networks; the following three decades (1980s to 2010s) were the development of the applications of Machine Learning.

- In Figure 1.1, a brief timeline of the past six decades of how AI evolved from its inception has been depicted:

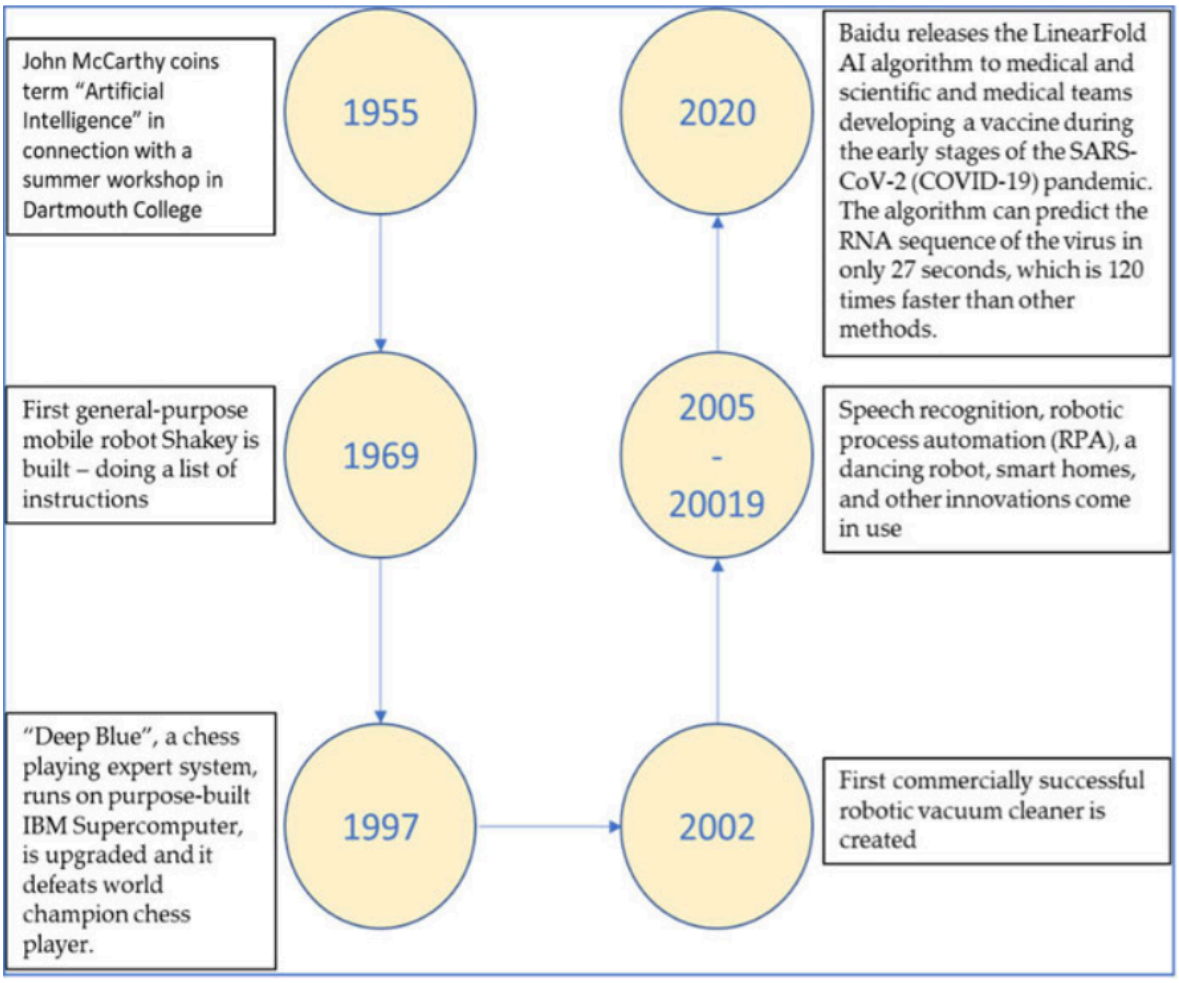
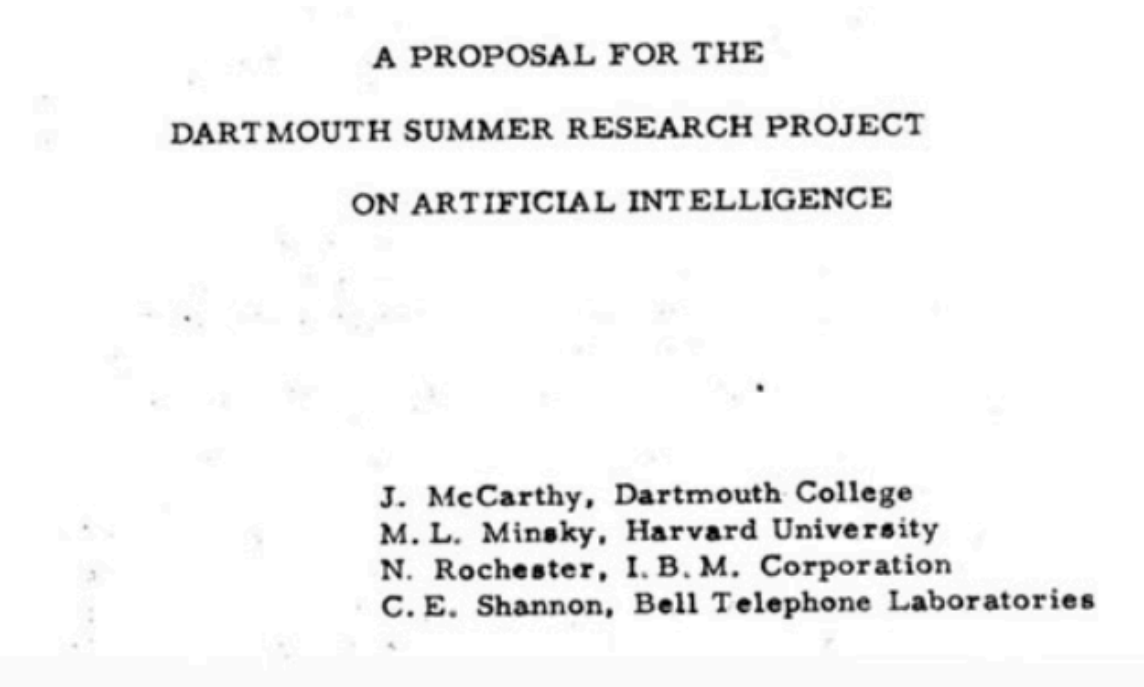


Figure 1.1: *The evolution of AI during the last six decades*

- The father of AI

John McCarthy is widely recognized as the "*Father of Artificial Intelligence*" due to his astounding contribution and innovations in the field of Computer Science and AI. John McCarthy coined the term "Artificial Intelligence" in his 1955 proposal for the *1956 Dartmouth Summer Research Project*, the first artificial intelligence conference, which was a seminal event for artificial intelligence as a field. Refer to Figure 1.2 which depicts the proposal where the term Artificial Intelligence was coined:



A PROPOSAL FOR THE

DARTMOUTH SUMMER RESEARCH PROJECT

ON ARTIFICIAL INTELLIGENCE

J. McCarthy, Dartmouth College
M. L. Minsky, Harvard University
N. Rochester, I. B. M. Corporation
C. E. Shannon, Bell Telephone Laboratories

Figure 1.2: *Proposal where the term Artificial Intelligence was coined*

In his proposal, he stated that the conference was "to proceed on the basis of the conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it."

In 1956, for the first time, Artificial Intelligence was coined as an academic field. The researchers thought about ways to make machines more cognizant, and they wanted to lay out a framework to better understand human intelligence.

John also paved the way for a few of the world's technological innovations like programming languages, the Internet, the web, and robots, to name just a few

He invented the first programming language for symbolic computation, LISP, and invented and established time-sharing. Human-level Artificial Intelligence and common-sense reasoning were two of his major contributions.

II. Types of Artificial Intelligence

Artificial Intelligence can be classified into two types:

- Based on the capabilities of AI
    - **Artificial narrow intelligence**

      Artificial narrow intelligence, ANI or Narrow AI, also called "Weak" AI, is goal oriented and is designed to perform singular tasks intelligently and extremely well without any human intervention.

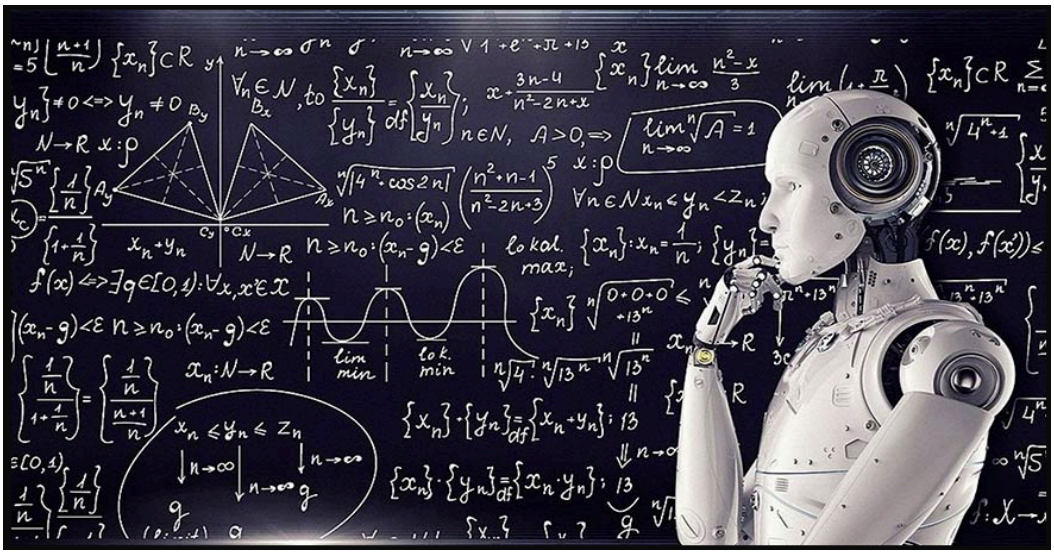
      Language translation and image recognition are examples of common uses for narrow AI. Siri is capable of processing human language and submitting
      a request to a search engine for retrieval. It explains why Siri is unable to answer abstract and complex queries that require emotional intelligence. It's mere digital assistance to perform basic inquiries and tasks.

Even if Narrow AI appears to be considerably more sophisticated, it operates within a predetermined, predefined scope. It can attend to a task in real-time, but they pull information from a specific dataset. In fact, what may appear as a complicated AI as a self-driving automobile is labeled Weak AI.

Narrow AI is unable to think. They lack the capability for autonomous reasoning, self-awareness, consciousness, and genuine intelligence.

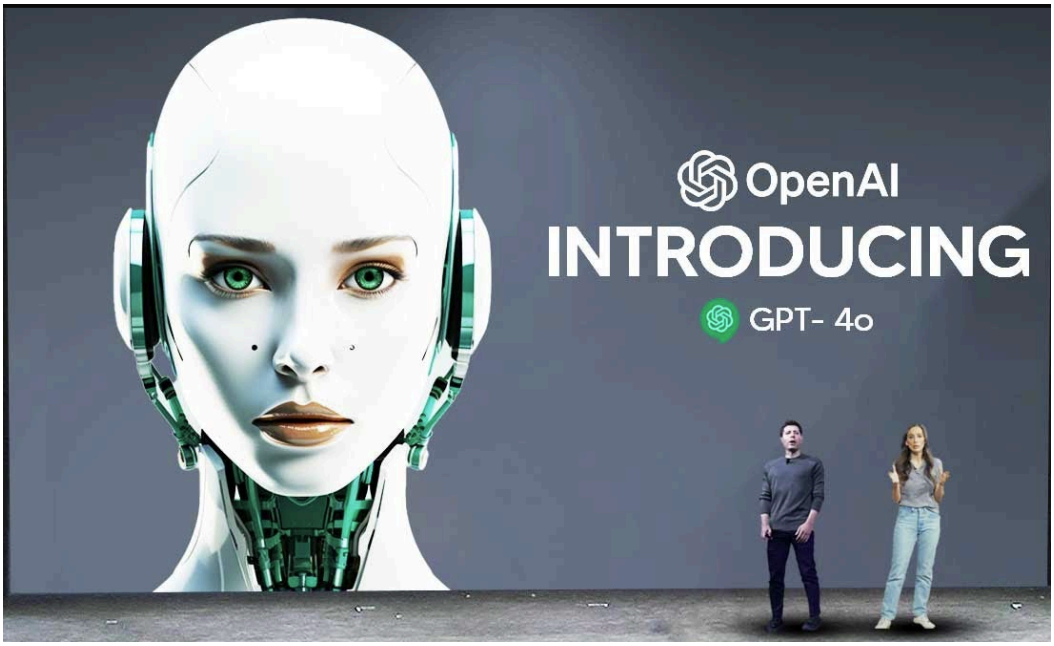
- **Artificial general intelligence**

  Artificial general intelligence (AGI), also called “Strong” AI, is an intelligent system with comprehensive or complete knowledge and cognitive computing capabilities.



In today's world, no true AGI systems exist and remain the stuff of science fiction. Sci-fi movies like "Her," where a human interacts with a machine displaying broad intellectual capabilities to learn, reason, and make their own decisions and judgments, while understanding belief systems. True AGI intellectual capacities would exceed human capacities because of its systems' ability to process huge data sets at incredible speeds.

Hence, no real-world systems as examples here.



https://youtu.be/DQacCB9tDaw
https://youtu.be/fXY1waoj2ns

- **Artificial super intelligence**

  Artificial superintelligence, or ASI, will be human intelligence in all aspects. ASI is a futuristic notion and idea about AI capabilities to supersede human intelligence. It will be self-aware and intelligent enough to surpass the cognitive abilities of humans.

  OpenAI's Unveils Shocking Plan: Artificial Super Intelligence (ASI) is Coming!
  https://youtu.be/-m84CvUuL9c

  Many are concerned about ASI and its impact on humankind. Individuals like Tesla CEO Elon Musk warned about the dangers of ASI-powered robots, even predicting “scary outcomes” like in <the movie> “The Terminator.”

- Based on the functionality of AI

AI can primarily be divided into four different categories based on functionality. Let us have a look at each:

- **Reactive AI**

These machines are the most basic type of AI system and perform best when all parameters are known. These machines do not have any memory or understanding of historical data and will not perform desirably in case of imperfect information input. Refer to Figure 1.3:

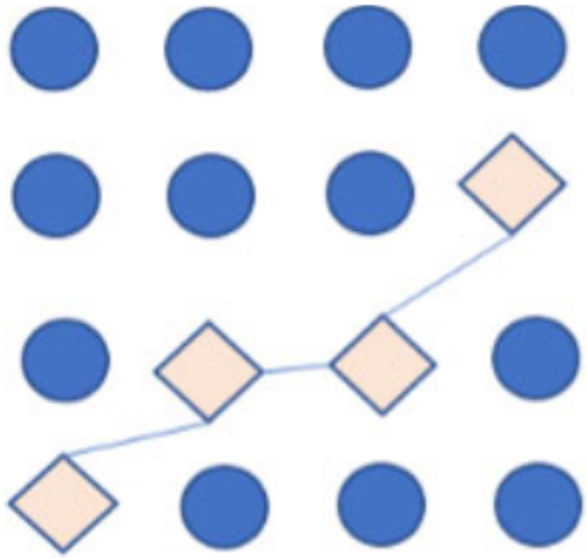


Figure 1.3: *Reactive AI*

These are good for simple classification and pattern recognition tasks where they specialize in just one field of work and can beat humans by their capacities to make faster calculations.

For example, in a chess game, the machine observes the opponents' moves and makes the best possible decision toward its win. This means reactive machines always respond to identical situations in the exact same way every time.

Face recognition is another example.

- **Limited memory**

  Limited memory AI can complete complex classification tasks and uses historical data to make predictions. They keep building on their memory, that is, storing the previous data and predictions, but memory is minimal. Refer to Figure 1.4:

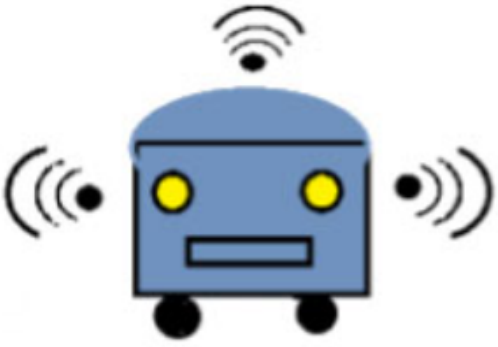


Figure 1.4: *Smart Car*

For example, this machine can suggest a restaurant based on the location data, food preference, and other such parameters that have been gathered.

Self-driving cars are limited memory AI. These use sensors to identify humans and animals crossing the road, obstacles on the path, steep roads, traffic signals, and so on to make better driving decisions.

- **Theory of Mind**

  A robot or a system powered by the Theory of Mind AI will be able to communicate deeper with human beings with its ability to understand thoughts, emotions, and feelings and adjust its behavior (social interaction) in accordance. Refer to Figure 1.5:

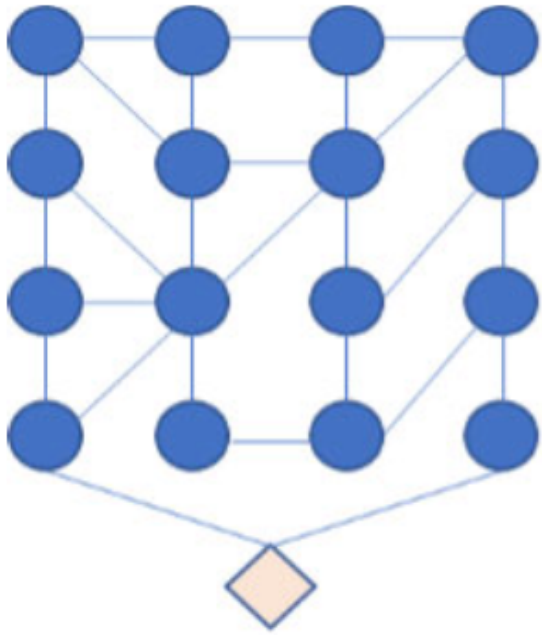


Figure 1.5: *Theory of Mind*

Such robots/systems will be able to explain their actions, and this is different from the current generation of AI. Theory of Mind AI-powered systems will be able to simulate the consequences of their actions. A new study describes a robot that can predict how another robot will behave, a first step in developing the so-called Theory of Mind

However, a machine based on this type is yet to be built in its entirety.

- **Self-aware**

Self-aware machines are the future generation of these new AI technologies. No such system is yet known to have been developed that possesses intelligence, is sentient, and is conscious. Such self-aware systems will be able to interact with and understand both humans and other AIs. Refer to Figure 1.6:

Figure 1.6: *Self-aware*

III. Key Concepts: Machine Learning, Deep Learning, and Neural Networks

- Machine Learning (ML)
  - **What is machine learning?**

    Machine learning is a method of data analysis that brings automation to analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn on their own from data without being explicitly programmed.

    The iterative aspect of machine learning is important because as the system is exposed to new data, it is able to adapt independently. They learn from previous behavior to produce reliable, repeatable

decisions and results. It's not a new science– but it has gained fresh momentum.

It is an application of AI that provides the system the ability to automatically learn and improve from experience, that is integrating the output back into the system. Refer to Figure 1.7. This figure describes the difference between traditional programming and machine learning. While traditional programming involves a computer running a program with input data and giving an output. Machine learning includes the input and its output fed again into the program which may continuously train itself based on the available data.

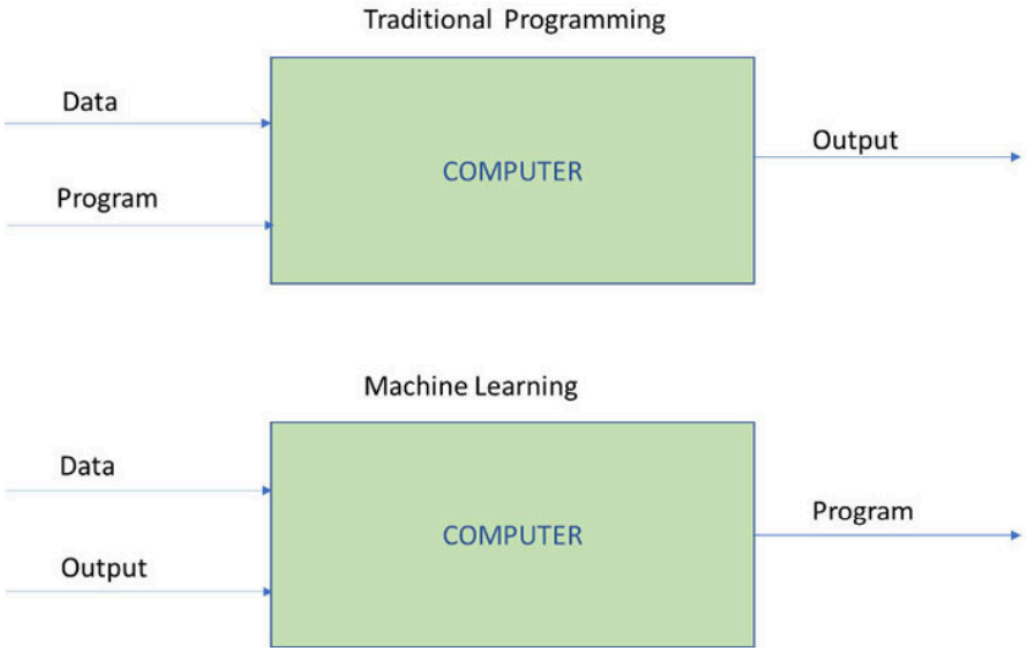


Figure 1.7: *Difference between Traditional Programming and Machine Learning*

Examples

- **Recognition**
  - **Image recognition**: Law enforcement uses machine learning-based image recognition tools to identify faces by matching them against a database of people.

    - **Speech recognition**: We may have used voice dialing or giving voice inputs to smartphones for google searches. This is also based on machine learning algorithms.
    - **Medical diagnosis**: Now, many physicians have started to use chatbots with speech recognition capabilities to discern patterns in patients' symptoms and help diagnose diseases.
- **Distances**
    - **Google Maps**: Google Maps does real-time data tracking by informing passengers of traffic and obstacles on the path. It was in form of the crowdiest and/or the shortest routes. These features are machine learning- enabled.
    - **Ride apps**: Ride apps like Uber use machine learning to forecast the expected arrival time by taking real-time traffic, GPS data, and Map APIs as input.
- **Email intelligence**
    - **Spam**: Ever wonder what few emails go into the spam folder? These are filtered on the basis of machine learning algorithms used by email providers.
    - **Email classification**: The classification of emails, say by Gmail, into Primary, Promotions, Social, and so on is also done using machine learning by Gmail.
    - **Suggested Smart replies**: Google email - Gmail recently also started suggesting smart replies based on the content of the email for better user experience and delight. These responses are customized per email too.
- **Social networking apps**
    - **Facebook**: Facebook automatically reflects faces and suggests friends tag while uploading a pic. Facebook uses AI and ML to identify faces.

What is data?

The most vital ingredient in machine learning and AI is the information fed to the systems to build intelligent models. Data refers to information that has been converted into a form that is more efficient for storing, processing, and transferring.

Data may be structured or unstructured, and is collected and stored in a format that makes it faster to be measured, reported, visualized, and analyzed. In contrast, raw data is a term used to describe data in its most basic digital format.

Following are some examples of data:

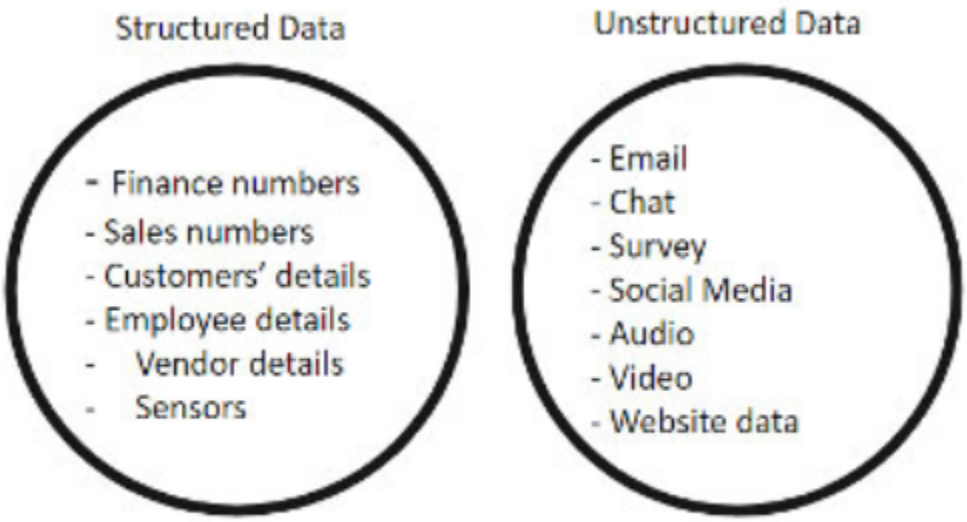


Figure 1.8: *Structured and Unstructured Data*

- Deep Learning:

What is Deep learning?

Deep learning is a subset of machine learning. It is a machine learning algorithm that uses deep (more than one layer) neural networks to analyze data and provide output attaining the highest rank in terms of accuracy when it is trained with a large amount of data.

The main difference between deep and machine learning is, machine learning models become better progressively but the model still needs some guidance. As in, the programmer needs to fix that problem explicitly in case of inaccurate outcomes. But in the case of deep learning, the model does feature extraction independently.

Examples

- **Chatbots**: Siri, which is Apple's voice-controlled virtual assistant. Is based on Deep Learning and gets smarter day by day by adapting itself according to the user and providing better-personalized assistance.

- **Self-driving / automatic cars**: These are also examples of deep learning.

- **Google AI Eye Doctor**: One of the initiatives from Google is Automated Retinal Disease Assessment or ARDA which uses artificial intelligence and deep learning to help healthcare workers detect diabetic retinopathy.

- **AI-based based music composers** and platforms such as Aiva, Amper and Ecrett Music, and so on are built using detailed algorithms that process the inputs of its users. The smart platform efficiently concocts a piece of music that totally fits users' criteria, based on a library of musicological knowledge, and builds stirring music instantly.

- **AI Dream Reader**: A group of researchers from the University of Kyoto in Japan used machine learning to study brain scans or analysis of human functional magnetic resonance imaging, where it could also generate visualizations of what a person is thinking when referring to simple, binary images. They then used deep learning / deep neural networks to decode thoughts.

  Once this technology develops further, it can allow drawing pictures, can visualize human dreams, hallucinations of psychiatric patients, and much more.

Machine learning techniques and training

Machine learning uses three techniques that teach computers to do what comes naturally to humans and animals-learn from the experience:

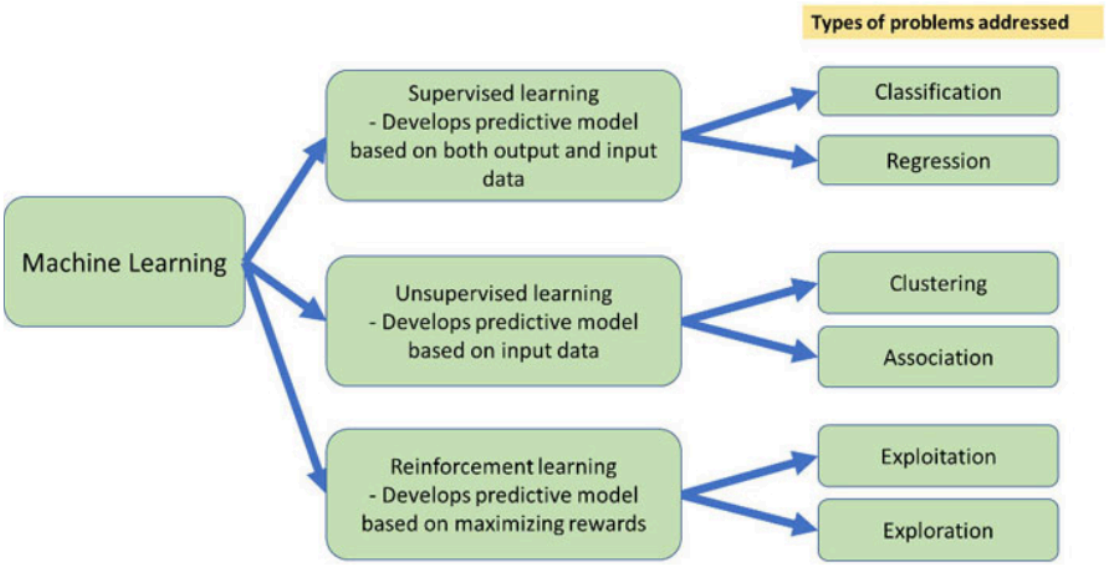


Figure 1.9: *Machine Learning*

Let's understand these three models:

- **Supervised learning**

Figure 1.10: *Supervised Learning: Learning under the supervision*

Supervised learning trains a model on known input and output data to
predict future outputs. Refer to Figure 1.11:

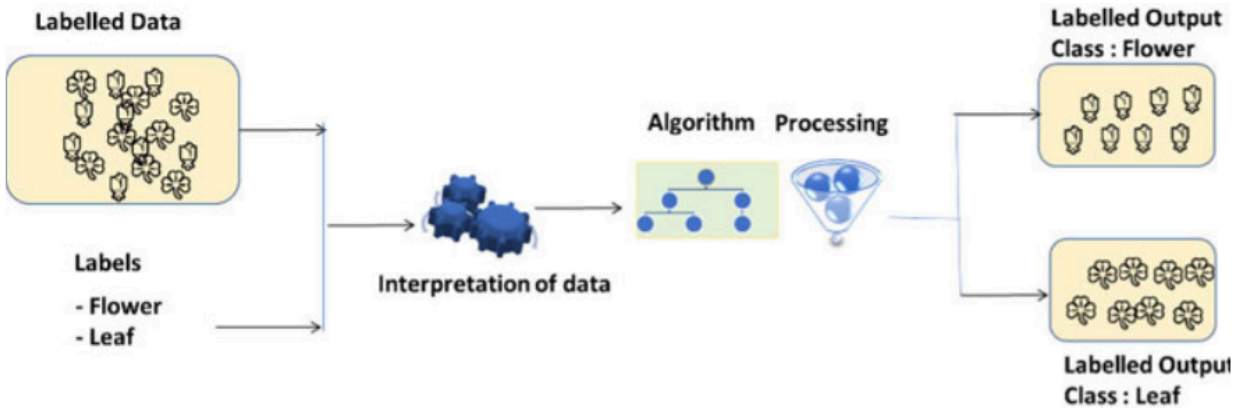


Figure 1.11: *Supervised Learning Model*

- **Unsupervised learning**

  Unsupervised learning uses hidden patterns or internal structures in the input data. Refer to Figure 1.12:

Figure 1.12: *Unsupervised Learning*

Example: Sorting flowers from leaves and forming two clusters. Refer to

Figure 1.13:

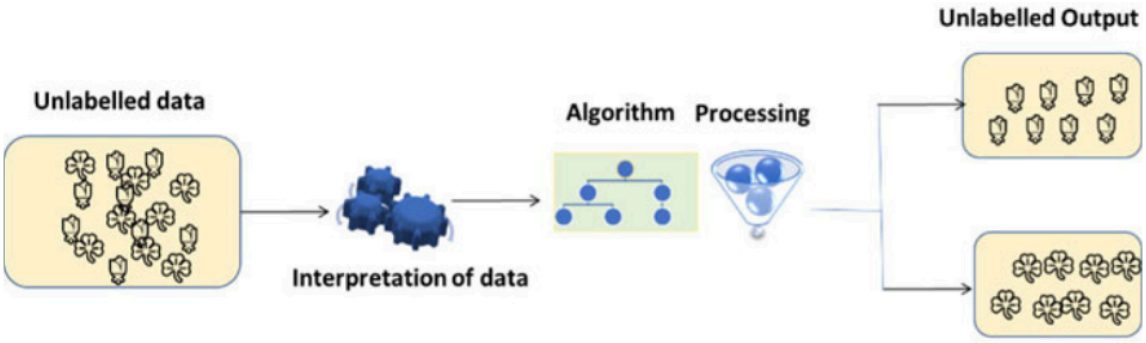


Figure 1.13: *Unsupervised Learning model*

- Reinforcement learning

  Reinforcement learning is based on rewarding desired behaviors and/or punishing undesired ones. In other words, use a reward system to train the model. Refer to Figure 1.14.

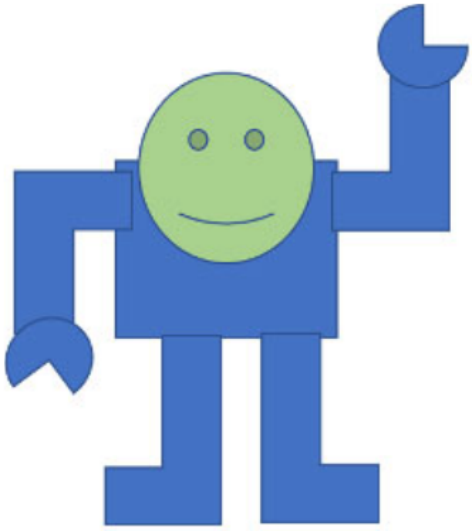


Figure 1.14: *Robot*

Example: A dog learning and unlearning actions and skills based on a reward mechanism. Refer to Figure 1.15:

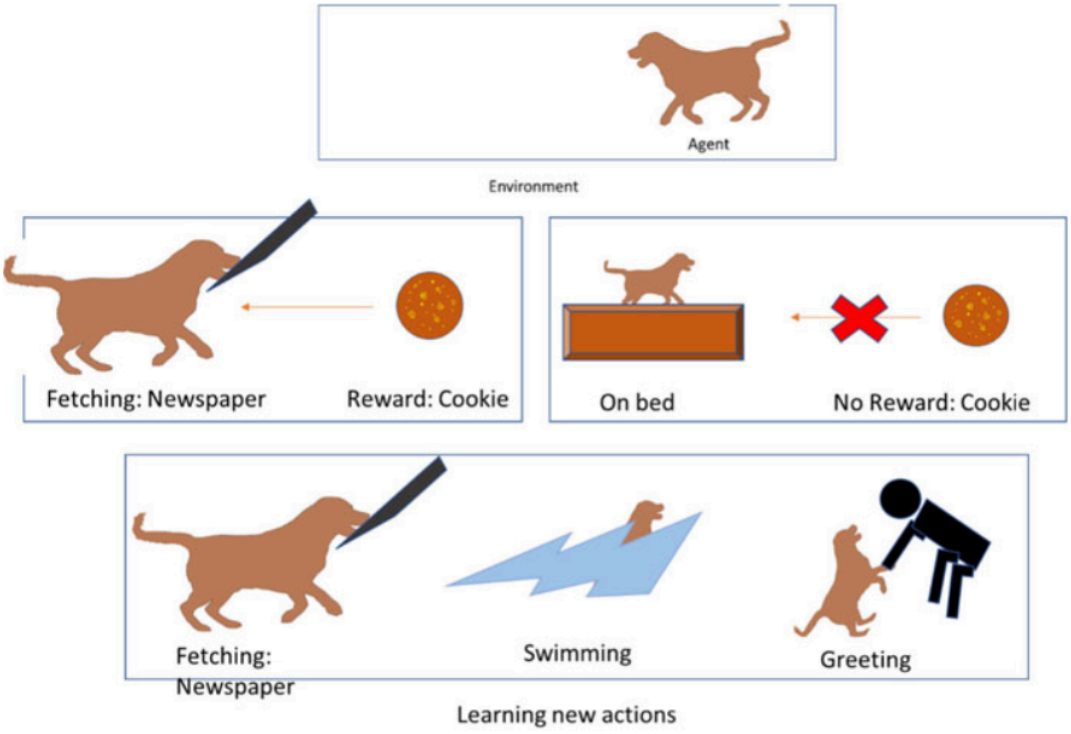


Figure 1.15: *Reinforcement Learning Model*

The following table highlights the major differences between the learning methodologies:

	Supervised learning	**Unsupervised Learning**	**Reinforcement Learning**
Input Data and methodology	Labeled data; Learn a pattern of inputs and their labels	Unlabeled data; Divide data into classes	No predefined data (all types of data); Works on interacting with the environment and maximizing the reward
Type of problems addressed	Regression and classification	Association and Clustering	Exploitation and Exploration
Supervision required	Extra supervision	No supervision	No supervision
Aim	Calculate outcomes	Discover underlying patterns	Learn a series of action
Solutions	Finds mapping equation on input data and its labels.	Classifies input data into classes by finding similar features	Maximizes reward by assessing the results
Model Building	The model is built and trained prior to testing.	The model is built and trained prior to testing.	The model is trained and tested simultaneously.

Table 1.1: *Difference between various models*

- Neural Networks:

  Neural networks refer to systems of neurons, either organic or artificial in nature. In regards to AI, it refers to a series of algorithms that aims at recognizing underlying relationships and patterns in a set of data through a process that imitates the way the human brain operates. At its heart, it is just multiplication and differentiation.

  As such, neural networks can help systems make intelligent decisions with limited human supervision simply because they can learn and model the relationships between input and output data that are nonlinear and complex.

  An Artificial Neural Network is made up of 3 components:
  - Input layer
  - Hidden (computation) layers
  - Output layer

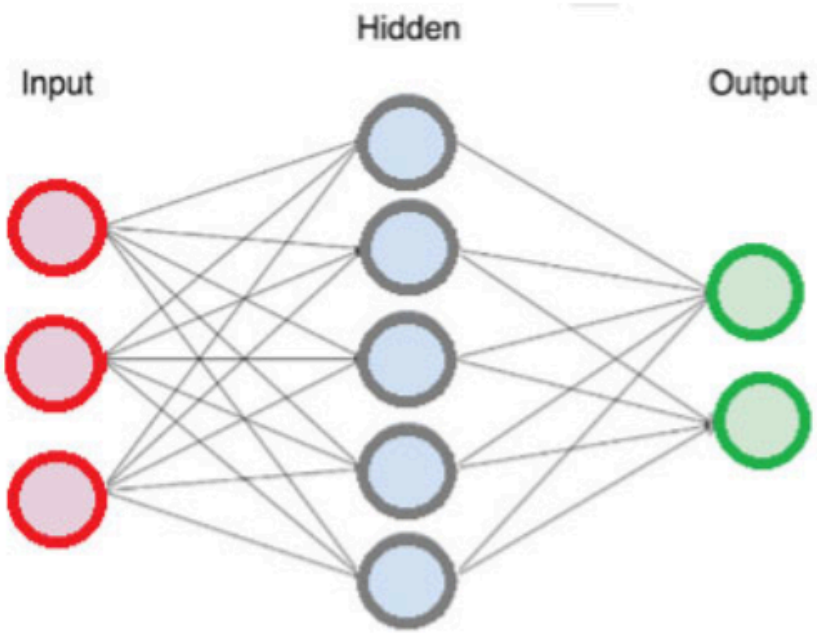


Figure 1.16: *ANN Artificial Neural Network*

In neural networks, learning happens in two steps:
- **Forward-Propagation** Helps in making a guess about the answer. As the name suggests, the input data is fed in the forward direction,

each hidden layer accepts the input data, processes it as per the activation function, and passes it to the successive layer.

- **Back-Propagation** It is the short form for “backward propagation of errors.” Backpropagation is the process of tuning a neural network's weights (input is modeled using randomly selected weights) to better the prediction accuracy, minimizing the error between the actual answer and guessed answer.

What machine learning can and cannot do

As per Wikipedia, *Machine Learning is a branch of computer science that gives “computers the ability to learn without being explicitly programmed.”*

Machine learning has algorithms that are fed data and these algorithms analyze the data to make predictions or recommendations. Such algorithms are coded by humans, in ways that these algorithms cannot learn. Machines only learn from the data that they receive and can analyze.

In a sense, rather than replacing the abilities of humans in the future, machines can make it easier to make complex computations fast enough to give conclusions that are stochastic, not deterministic.

Machine learning can do:

- Recognition
    - Image recognition
    - Text recognition
    - Voice recognition
- Recommendations
- Classification
- Text to Speech
- Predictive maintenance

Machine learning cannot do:

- Learning a language from hearing verbal utterances
- Human intention recognition
- Emotion recognition

- Gestures recognition
- Interact with and understand humans

Usually, machine learning algorithms require large amounts of data to be trained enough before they begin to give useful results.

Machine learning is not and will not be able to replace humans explicitly.

Key differences between artificial intelligence (AI) and machine learning (ML)

The following table highlights the major differences between AI and ML:

S.no.	Artificial Intelligence (AI)	Machine Learning (ML)
1.	Artificial intelligence is the ability of systems to acquire and apply knowledge mimicking human cognitive skills.	Machine Learning is a subset of Artificial intelligence and is about the ability of a machine to acquire knowledge or skill
2.	AI is a broader family consisting of ML and DL as its components.	ML is a subset of AI.
3.	AI aims to increase the chance of success and not accuracy.	ML aims to increase accuracy but is not programmed for success.
4.	AI targets simulate human intelligence to solve complex problems.	ML targets learning from input data to maximize the performance on related tasks.
5.	AI has a very wide variety of applications.	The scope of machine learning is constrained.
6.	AI is decision-making.	ML enables systems to learn new things from data and newer related data.
7.	It is developing a system that tries to simulate human intelligence to solve problems.	It involves creating self-learning algorithms.
8.	AI will go for finding the optimal solution that is focussed on success than accuracy	ML will go for a solution whether it is optimal or not, it is focused on accuracy than success
9.	AI leads to intelligence or wisdom.	ML leads to knowledge.
10.	AI can be categorized broadly into: Artificial Narrow Intelligence (ANI) Artificial General Intelligence (AGI) Artificial Super Intelligence (ASI)	ML can be categorized broadly into: Supervised Learning Unsupervised Learning Reinforcement Learning
11.	AI can work with structured, semi-structured, and unstructured data.	ML can work with only structured and semi-structured data.

Table 1.2: *Difference between Artificial Intelligence and Machine Learning*

Artificial Intelligence project life cycle

A project lifecycle describes the phases through which a project progresses. This sequence of the phases and their dependency is also clearly mentioned.

AI project life cycle mainly has 5 stages. These stages define the start to end of the development of AI-powered solutions in specific and clear steps:

The 5 stages of the AI Project Life Cycle are:

- Problem scoping
- Data acquisition
- Data exploration
- Modeling
- Evaluation

Figure 1.17 describes in sequence the various stages of an AI project life cycle:

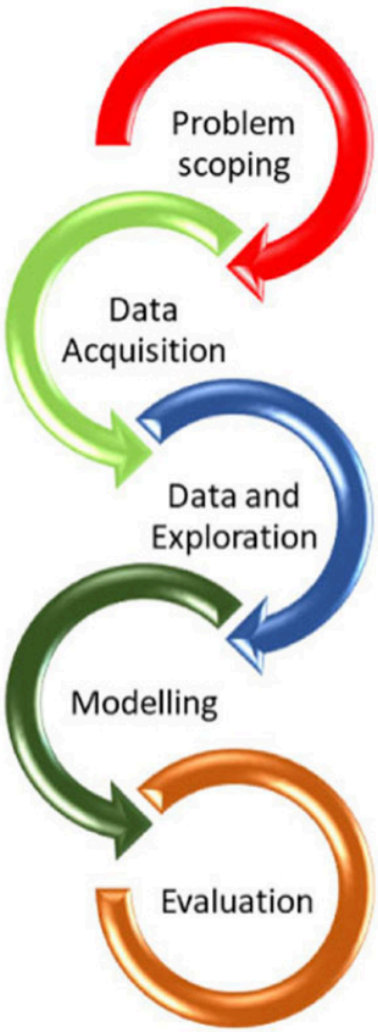


Figure 1.17: *AI Project Lifecycle*

Phase 1: Problem scoping

As the name suggests, this initial phase of the AI project lifecycle is all about understanding the problem, its scope, the boundaries, identifying the problem statement, various factors which affect the problem as well as all parameters and aspects that define the goal and the aim of the project. This scoping can be done by answering the 4Ws, which are:

Who: "Who" helps in identifying the stakeholders, categorizing all those who are directly or indirectly impacted by the problem.

What: "What" helps in understanding and identifying the nature of the problem while also collecting evidence to prove that the problem exists.

Where: "Where" helps in identifying the roots of the problem, where it arises, the situation, and the location it arises.

Why: "Why" helps with why the problem is worth solving.

Phase 2: Data acquisition

Data acquisition is the process of collecting accurate and reliable data that cumulatively cover variables and attributes of the problem statement in its entirety. Data can be in the format of text, video, images, audio, and so on and it can be collected from various sources like interest, journals, newspapers, and so on. That is data can be structured or unstructured or in any non-specific form.

Data can be collected from various sources:

- Databases
- Web pages
- Devices like cameras and sensors (e.g. in Autopilots, weather predictions)
- Public surveys /records of purchases, transactions, registrations, and more

Phase 3: Data exploration

Data exploration is the process of performing operations like data cleaning, finding missing values, removing useless data, and basic statistical analysis for arranging the data, gathered as in phase 2, uniformly and meaningfully.

Data can be arranged in the form of a table, plotting a chart, or making a database. Multiple visualization tools are available in the market for offering data in visibly grasping formats.

A few of the tools to use for data exploration are:

- Google charts
- Fusion charts
- Tableau
- High charts

Phase 4: Modeling

Modeling is the phase of the AI project lifecycle in which different models based on the visualized data can be created and developed. Models help in formulating mathematical relations between data and the outcome. These models can also be checked for their advantages and disadvantages Refer to Figure 1.18:

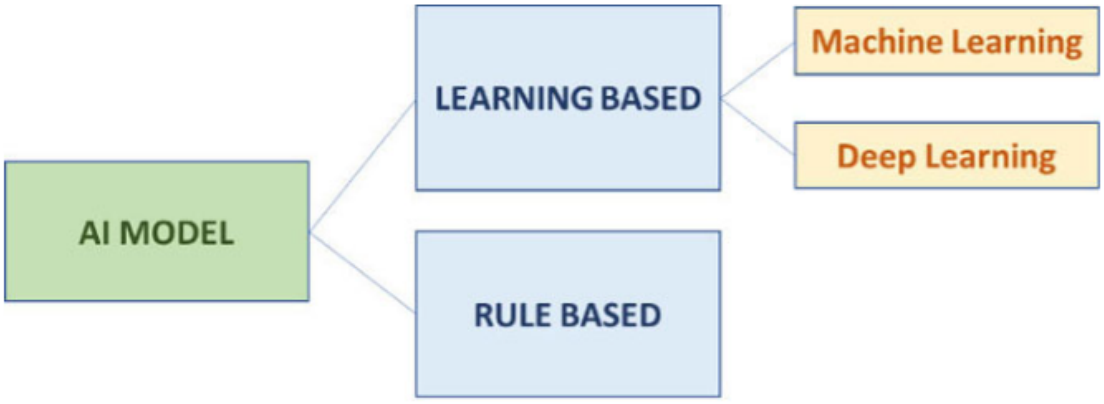


Figure 1.18: *AI Modelling*

While we have covered learning-based models in previous sections, a rule-based model is where the relationship or patterns in data are defined

by the developer. The machine performs tasks according to the information and these rules as given by the developer.

As an example, for rule-based learning, a bank grants a loan to a customer based on certain rules that measure the personal and financial information against a set of levels that help decide if a loan is to be granted.

Phase 5: Evaluation

Evaluation is the last phase in the AI Project lifecycle. Here the model developed is fed with input data and the outcome is compared against expected outcomes. This stage determines the reliability of the model and the completeness of the data fed into the model.

Career opportunities in artificial intelligence

The Artificial Intelligence field is vast to bring multiple career opportunities. These are primarily based on data, algorithms and machine learning, and application development.

The following table lists the most common career opportunities in the field of artificial intelligence:

S.No	Role Name	Qualification and strengths	Role Description
1	Big Data Engineer	• Knowledge of Big Data and various database systems. • Programming Languages like Python, R, Java, and so on.	• Build and administer the organization's big data. • Prepares, manages, and establishes big data environment. • Apply data concepts like migration, visualization, and mining.
2	Business Intelligence Developer	• Bachelor's degree in Computers and Mathematics. • Know Programming languages. • Know Data sets. • Problem-solving abilities. • Analytical capabilities. • Databases and Data warehouse.	• Create business models. • Analyze data sets to identify business trends. • Helps with brand recognition and awareness. • Prepare, develop, and operate business intelligence solutions.
3	Data Scientist	• Master's degree in Computers and Mathematics. • Know Programming languages. • Know Data sets. • Problem-solving abilities. • Analytical capabilities • Databases and Data warehouse.	• Manages and operates large datasets from different sources. • Tracks data collection methods and adds new data sources. • Utilizes data for business outcomes by making predictions.
4	Machine Learning Engineer	• Software engineer. • Know Programming languages. • Know Data sets.	• Combine software engineering and data science. • Applies algorithms to real-world applications. • Operates algorithms to create open-source libraries. • Harness big data techniques and computing systems/predictive models. • Make raw data meaningful. • Put machine learning solutions into production (means operational). • Experiments with programming languages including ML libraries. • Ensure data flow across between databases and deployed systems.
5	Research Scientist	• Specialized Ph.D. or advanced	• Highlight the theoretical side of

		master in Computers or Mathematics. • Gained expertise in ◦ Statistics. ◦ Applied mathematics. ◦ Applications related to machine learning and intelligence. • Significant knowledge of NLP and Reinforcement learning.	solutions. • Creates new networks. • Discover new ML approaches. • Devise Novel algorithms.

Table 1.3

Conclusion

AI is already a part of our lives. With the ease and automation it brings, AI is being a focus area in all fields of life, be it healthcare, manufacturing, or performing routine daily tasks. It is going to get evolved more and it is not too late to be on board the artificial intelligence wagon.

In the next chapter, we will be discussing key fields of applications in AI and methodologies and their impact on our society. At the end of the next chapter, we will be analyzing how we get ready for the future which will be the AI age.