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Overview of Machine Learning

Chapter Objectives

- To define machine learning (ML) and discuss its applications.
- To learn the differences between traditional programming and ML.
- To understand the importance of labeled and unlabeled data and its various usage for ML.
- To understand the working principle of supervised, unsupervised, and reinforcement learnings.
- To understand the key terms like data science, data mining, artificial intelligence, and deep learning.

1.1 Introduction

In today's data-driven world, information flows through the digital landscape like an untapped river of potential. Within this vast data stream lies the key to unlocking a new era of discovery and innovation. Machine learning (ML), a revolutionary field, acts as the gateway to this wealth of opportunities. With its ability to uncover patterns, make predictive insights, and adapt to evolving information, ML has transformed industries, redefined technology, and opened the door to limitless possibilities. This book is your gateway to the fascinating realm of ML—a journey that empowers you to harness the power of data, enabling you to build intelligent systems, make informed decisions, and explore the boundless possibilities of the digital age.

ML has emerged as the dominant approach for solving problems in the modern world, and its wide-ranging applications have made it an integral part of our lives. Right from search engines to social networking sites, everything is powered by ML algorithms. Your favorite search engine uses ML algorithms to get you the appropriate search results. Smart home assistants like Alexa and Siri use ML to serve us better. The influence of ML in our day-to-day activities is so much

that we cannot even realize it. Online shopping sites like Amazon, Flipkart, and Myntra use ML to recommend products. Facebook is using ML to display our feed. Netflix and YouTube are using ML to recommend videos based on our interests.

Data is growing exponentially with the Internet and smartphones, and ML has just made this data more usable and meaningful. Social media, entertainment, travel, mining, medicine, bioinformatics, or any field you could name uses ML in some form.

To understand the role of ML in the modern world, let us first discuss the applications of ML.

1.2 Applications of Machine Learning

In modern life, ML is relevant in many fields, and it has the potential to grow exponentially over time. Some of the fields where ML is used prominently are shown in Figure 1.1. However, ML is not limited to only these areas; you can find numerous other fields where ML is making an impact.

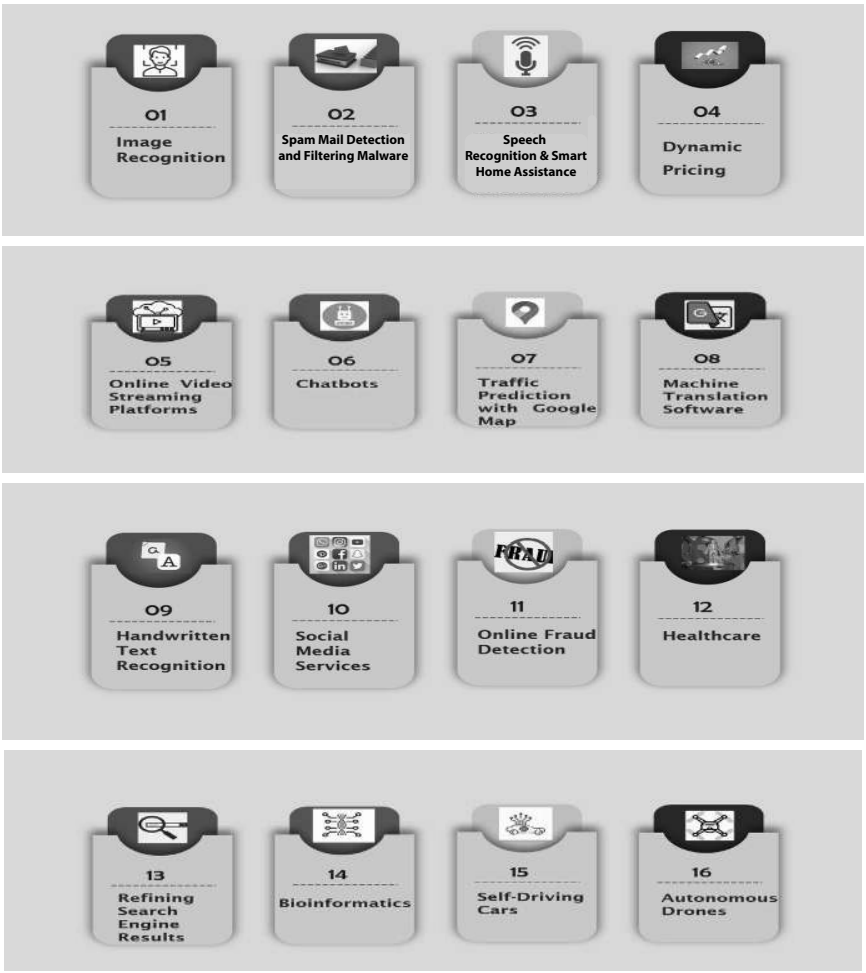

Figure 1.1 Applications of machine learning

Let us discuss the applications of ML in each of these areas.

Image Recognition

In the context of ML, image recognition refers to the ability of software to identify people, places, and objects in digital images. It is one of the complex problems of computer science that is solved with the help of ML. Most social networking platforms like Facebook and Pinterest use image recognition algorithms to identify people and objects in pictures posted by users. Google Photos uses this technique to group images based on people, objects, scenery, etc., in our phone galleries. Even self-driving cars use this to recognize objects and signals on the road.

Spam Email Detection and Filtering Malware

Spam emails have always been a menace, and you might have observed that your favorite mail service filters emails for you into different categories, namely primary, promotions, social, spam, etc. Behind the scenes, email services use ML algorithms to categorize emails. It is important to filter spam from the incoming mails, as they often contain links to malicious websites/applications. Users can tag an email as spam or not spam manually. This tagging is used to train ML models that identify such mails in the future. Mail service providers like Gmail and Yahoo use ML models to classify incoming mail as spam or non-spam.

Another application of ML is malware detection. Malware is an acronym for "malicious software". Malware can cause damage to our computer, server, or network by executing a harmful piece of code. The malware code is almost 95–98% similar to its descendants. Hence, security systems have started using ML to identify similar coding patterns. Using ML-powered security programs, these malware definitions can be regularly updated, and any malware can be detected spontaneously to provide the required protection against them.

Speech Recognition and Smart Home Assistants

ML is used for translating speech into text. This process is known as "speech recognition". Speech recognition is used for appliance control, voice dialing, voice search, and even virtual personal assistants to comprehend voice commands. Apple's Siri, Amazon's Alexa, and Google Assistant are popular smart home assistants, also known as intelligent personal assistants or virtual personal assistants. So next time you say, "Hey, Google! Find me the closest restaurant", remember an ML model is converting your speech input to equivalent text, which is then queried on search engines.

Dynamic Pricing

ML is widely used nowadays to set dynamic prices of plane tickets, sports or events tickets, cab prices, or the cost of Google Ads. These platforms set the prices of the items dynamically based on current demand, location, day, time, and other factors, as depicted in Figure 1.2. To relate this better, let us take an example of a cab service like Uber. It uses an ML model to decide the best price for rides at a given time. This is so accurate that the cab prices automatically increase in peak hours or during festival seasons. This can be seen even in the case of flights.

Figure 1.2 Machine learning powered dynamic pricing

Online Video Streaming Platforms

In the last few years the number of digital streaming platforms has increased, yet Netflix, Amazon Prime, and Disney Hotstar are unbeatable. One of the reasons behind the craze and popularity of these platforms is the use of ML to serve users based on their interests.

For instance, Netflix collects data about the user, such as the type of content they mostly watch, the time and days they prefer watching, the average ratings, search history, and browsing patterns. They also track activities such as play, pause, rewind, the playback speed of streaming, preferred language, etc. The data captured from user activities are used for training ML models that recommend movies and shows to users. This helps in keeping users engaged with the platform for a longer time.

Chatbots

Many applications or service providers offer support to their clients through an online chat with experts. Most of these applications use chatbots trained with our past chats with their agents. These chatbots become capable enough to answer user queries in real-time through ML. They fetch the required information from the website and serve it to the users. Recently, ChatGPT got the attention of the whole world due to its remarkable features.

Traffic Prediction with Google Map

Traveling without a Google map is unimaginable these days. It provides the shortest route and minimum distance and even predicts traffic and congestion. Google map uses ML models to serve

users behind the scenes. These ML models are trained by analyzing past and current data relevant to a particular route for which the user is seeking help.

Machine Translation Software

Almost all machine translation software leverages ML algorithms to convert words from one language to another. Google Translate is one of the applications that use machine translation. It can translate numerous voice/text inputs from a source language to the desired language. It can also be embedded in smartphones and smart watches. Google uses GNMT (Google Neural Machine Translation), which depends on natural language processing (a subset of ML) to output the most appropriate sentence translation.

Handwritten Text Recognition

Handwritten text recognition is a machine's ability to recognize the human handwritten text from different sources like papers, images, etc. Manual recognition of handwritten words is a tedious task, requires a lot of expertise, and is even error-prone. A handwritten text recognition system applies ML models to identify objects in handwritten text. These are very useful in correctly identifying handwritten addresses on postal mail and are even used by forensic teams to match the handwriting of two samples. Thus, it saves time and is preferred over manual handwriting recognition methods.

Social Media Services

Have you ever wondered how Facebook personalizes our news feed? Or how does Instagram suggests to us people we may know? From personalizing ads to our news feed, Instagram, Facebook, and other social networking giants use ML. These platforms notice the people we usually connect with, and then, based on our interests, location, and other attributes, they suggest people we may know. This is a continuous learning process and is done using ML models.

A similar approach gets used while Facebook pushes posts in your news feed. Based on what kind of content we like, share, and comment on, the underlying ML model understands our interests, and then relevant posts and advertisements are shown to us. Facebook even uses face recognition (another application of ML) to identify your friends in photos you post. It then tags them automatically. Facebook completes these tasks quickly, but it uses complicated ML algorithms that work and learn seamlessly in the backend. Similarly, YouTube analyses our watch history, and then by using ML, it suggests videos in our feed. Pinterest checks the objects/pins of the images we mostly search for using ML and then groups similar-looking images based on identified patterns.

Video Surveillance

Gone are the days when a single person used to monitor the footage of multiple CCTV cameras. Today, the video surveillance system is powered by ML that detects the possibility of crime even before it happens. Manual observation of each person's activity in multiple cameras is an exhaustive and tedious task. Hence, an ML-based system for video surveillance can detect unusual

activities of people (such as standing in one place for a long time or loitering around some areas) and can report them to prevent crimes.

Product Recommendations

Online shopping sites like Amazon, Flipkart, and Myntra use ML models to recommend products to users. These platforms suggest products through advertisements based on click stream analysis (user browsing activities). The ML algorithms used by these platforms learn about our shopping habits from past purchases, items we added to the cart, search history, etc. It has been observed that product recommendations generate approximately 35% of Amazon's revenue.

Online Fraud Detection

Nowadays, most monetary transactions are done online through payment gateways such as Google Pay, Paytm, PayPal, etc. To protect users from online money frauds, ML is used. Companies like PayPal use ML models to distinguish between legitimate and non-legitimate transactions. Modern financial systems have now deployed ML models to check millions of transactions for any fraudulent transaction through their platform.

Healthcare

ML is used most widely in healthcare and pharmaceuticals. The existing healthcare technology is now being amalgamated with ML to increase the quality of treatment, as depicted in Figure 1.3. ML algorithms analyze a patient's condition based on her medical history, and then they provide support to doctors by suggesting the best diagnosis or treatment. ML is not restricted to only medicine, but is even used in robotic surgeries.

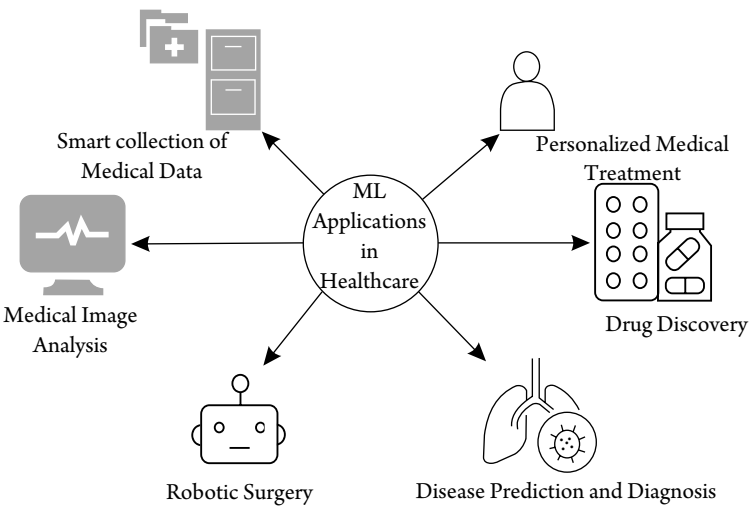

Figure 1.3 Applications of machine learning in healthcare

Refining Search Engine Results

When we search anything on Google, Bing, and other search engines, they go through trillions of web pages and provide us the search results. These search engines use ML algorithms that learn by observing user responses to their search results to improve the search results. For example, if the user opens the first two search results and stays on the web page longer, the ML model assumes that the displayed results follow the user's search query. Thus, the search results keep improving as the search engine model learns more and more with time.

Bioinformatics

Bioinformatics is interdisciplinary in biology, statistics, computer science, and mathematics. One of the primary things in bioinformatics is gathering biological information such as the DNA of organisms. This information is further analyzed using bioinformatics algorithms to identify solutions to real-world problems such as developing a vaccine for a disease. Normally, this involves manual identification of important features. With the help of ML, features are identified automatically to improve accuracy and efficiency.

Self-Driving Cars and Autonomous Drones

While driving a car, we need to control the speed, manage the steering to find a way through traffic, analyze the traffic and behavior of fellow riders, etc. All these tasks require motor skills and human consciousness. Similarly, to control the movements of drones or their speed, we need a lot of skill and expertise. A person can acquire these skills with minimal training. But when we want a machine to learn the process, we need different onboard ML techniques such as object detection, object localization, movement prediction, etc. Soon the market will be flooded with self-driven cars and drones, which are just leveraging ML to their best.

After going through the applications mentioned above of ML, one can understand that there are endless possibilities for ML in the modern world. Thus, there is a huge demand for ML experts worldwide. The main objective of this book is to train you as an expert on this remarkable technology that has already impacted our lives and has huge scope in the future.

1.3 History of Machine Learning

Let us dive deep into the history of ML to learn about the endless efforts put by various researchers to make this happen.

Development in ML can be broadly divided into the foundational phase, the transitional phase from theory to reality, and the contemporary phase. These phases and their timeline have been depicted in Figure 1.4. The major milestones of these phases are covered in the subsequent sections.

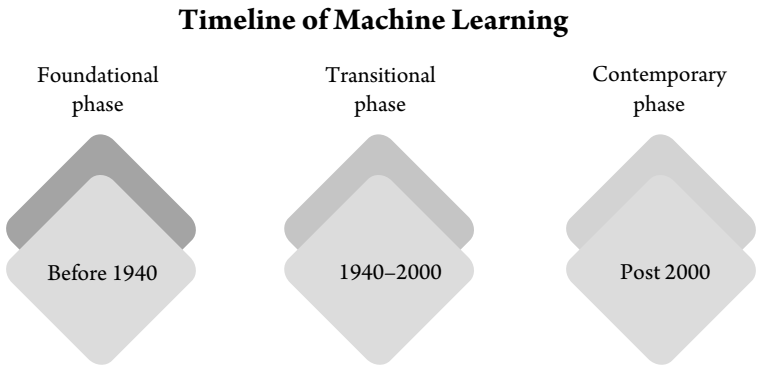

Figure 1.4 Phases of development in machine learning

1.3.1 Foundational Phase of Machine Learning (Before 1940)

The foundational phase of ML traces back to the evolution of computers. Table 1.1 enlists the milestones that serve as the foundations of ML development.

Table 1.1 Key milestones of the foundational phase of machine learning

Year	Milestone	Key Details
1642	The First Mechanical Calculator	Blaise Pascal created a mechanical calculator called Pascaline to help his father with tax accounting. It was designed to perform introductory algebra calculations like addition, subtraction, multiplication, and division.
1679	Birth of Modern Binary System	German mathematician Gottfried Wilhelm Leibniz invented a binary system that laid the foundation for modern computing.
1770	The Turk	Turk was a mechanical device designed to play chess like human beings. It indicated the possibilities of fully automated machines in the future.
1834	Punch-card Programming	Charles Babbage, the father of modern computing, conceptualized an all-purpose device programmed using punch cards.
1842	First Algorithm	Ada Lovelace, a young mathematician, proposed a sequence of instructions to solve a mathematical problem using Charles Babbage's theoretical programming. This was the very first algorithm that was formulated.
1847	Boolean Logic	George Boole created an algebraic form to reduce expressions and the values to either "true" or "false". It was later called Boolean logic. Based on Boolean logic, the CPU decides how to process inputs.
1927	Release of the Sci-fi Movie *Metropolis*	Fritz Lang directed a scientific fiction *Metropolis* to introduce "False Maria", a thinking machine. This was the first robot ever depicted on the silver screen.
1937	Turing Machine	Turing machines were introduced that were originally intended to formalize the computability notion. Most computer scientists would affirm that Turing machines are a formal notion that captures all computable problems.

1.3.2 Transitional Phase of Machine Learning (1940–2000)

The concepts laid in the foundation phase turned into reality during the transitional phase. Several new algorithms were proposed during this phase. Table 1.2 presents the key milestones of the transitional phase of ML.

Table 1.2 Key milestones of the transitional phase of machine learning

Year	Milestone	Key Details
1943–1951	Birth of Neural Network	Walter Pitts and Warren McCulloch modeled human neurons through electric circuits. Later, in his book, Donald Hebb explained the internal functions of neural networks. Finally, in 1951, Marvin Minsky made the first neural network.
1952	Samuel's Checkers Playing Program	Arthur Samuel created the first self-learning program that learns by experience and gets better at playing checkers games.
1957	Perceptron Conceptualization	Rosenblatt proposed the Perceptron for perceiving and recognizing. He explained the feasibility of implementing a perceptron and its working.
1959	Stanford's First Neural network	Stanford developed their first neural network – Madeline – to remove echoes over phone lines using an adaptive filter.
1960	Stanford's Cart	A Stanford graduate developed a cart to solve the problem of controlling a moon rover from the earth by rigging a buggy with a TV camera and remote control.
1985	An Artificial Neural Network Pronouncing Words Correctly	NETtalk application was developed as the first artificial neural network, which taught itself to correctly pronounce 20,000 words in one week.
1990	Boosting Algorithm Was Proposed	The boosting algorithm enhances the predicting power of ML by generating many weak models instead of a single model. Then, weak models are made strong by combining their predictions.
1995	Random Forest Algorithm	A Random Forest algorithm was introduced that creates multiple decision trees and merges them into a forest.
1997	A Computer Defeating Chess Grandmaster	IBM's Deep Blue defeated the chess grandmaster Garry Kasparov. This was the first time a computer machine had defeated a human chess expert.
1999	Computer-Aided Cancer Diagnostics	Computer-Aided Diagnostics (CAD) Prototype Intelligent Workstation, developed at the University of Chicago, tested 22000 mammograms. Its cancer detection was much more accurate than radiologists.

1.3.3 Contemporary Phase of Machine Learning (Post 2000)

The third phase witnessed the growth of computing power and data, and hence this phase contributed to the maximum developments in ML. This is also the phase where ML became part and parcel of our lives. A few milestones in this phase are summarized in Table 1.3.

Table 1.3 Key milestones of the contemporary phase of machine learning

Year	Milestone	Key Details
2006	Coining the Term "Deep Learning"	Geoffrey Hinton rebranded neural network research as deep learning in 2006. His techniques are used today to improve voice recognition and image-tagging tools.
2006	Beating the Netflix Prediction Algorithm	In 2006, Netflix launched a competition to beat its algorithm to predict consumer film ratings. After three years, AT&T scientists beat their algorithm.
2011	Watson Computer Wins over Jeopardy Champions	Watson computer is named after IBM's founder and was developed to answer questions in the Jeopardy quiz. In 2011, it competed against Jeopardy champions Brad Rutter and Ken Jennings, and won a $1 million prize. Later, this system was used as a doctor's assistant.
2012	Google Brain	Google Brain is a deep learning artificial intelligence (AI) research team that created a neural network to recognize humans and cats in YouTube videos.
2014	Chatbot Passes Turing's Test	Alan Turing designed a test that could be cleared by a machine only if it imitates a human in its conversation with real humans. A chatbot in 2014 successfully convinced 33% of human testers that it was a Ukrainian teen.
2015	AlphaGo Beats a Professional Go Player	Go is the most challenging board game in the world. In 2015, Google's AlphaGo competed with a professional Go player and won.
2015	PayPal's Hybrid Fraudster Detection System	PayPal used a hybrid approach to fight fraud. First, it detects the criminal's behavior. Later, an ML algorithm takes these characteristics as input parameters to identify criminals on the PayPal site.
2016	LipNet for Lip Reading	One of the research teams at Oxford designed an AI system that can lip read words with an accuracy of 93.4%.
2016	A Personal Digital Shopper with NLP	North Face, a retail giant, became the first retailer to use IBM Watson to assist shoppers. It suggested items to customers and helped them as human sales associates did.