

# Journey from Turing Machine to Machine Learning

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## Abstract

*This study reviews the journey from Turing machine to machine learning. When Turing said, "What we want is a machine that can learn from experience", and that "the prospect of letting the machine rewrite its own instructions provides the means for this", the idea of artificial intelligence was first proposed, it was in the 1940s. "This article reviews common-sense definitions of machine intelligence; motivates the research in artificial intelligence and machine learning. This study throws light on how machines are developing intelligence like human being in today's era. One of the most frequently asked question in current era is that "Can a machine think and behave like human?" In several domains, intelligent machines will eventually replace or modify human capabilities. The above question led to an idea for Artificial intelligence, AI. Artificial intelligence, which is intelligence displayed by machines, has significantly enhanced the efficiency of production and service systems over the previous two decades. AI research is having an impact on various fields of life as an expert system. Expert systems are increasingly being used to solve complex problems in a variety of fields. The idea of intelligent machines emerged past long back with the development of Turing Machines. So, this review work will be discussing about the origin of intelligence in machines and the current behaviour of intelligent machines.*

**Keywords:** Artificial intelligence, machine learning, Turing machine, stored programme, reinforcement learning, Alan Turing

## INTRODUCTION OF TURING MACHINE AND ITS ORIGIN

Today's world is totally dependent on computers, or we can say semiconductors with binary operations in the form of 0 and 1. *Computer* name was given to those people whose calculation speed was fast to solve numerical calculation with maximum accuracy; and in the 19th century, this term was applied on machines which began to replace humans to perform calculation related tasks. A big revolution arose when the calculation speed increased, and mechanical components were replaced by electronic components. One disadvantage of this era of computer was that they were rebuilt to solve a particular problem and could not solve more problems at the same time [1]. To solve another type of

problem, their circuit had to be changed. In 1936, an English mathematician Alan Turing thought that a computer can solve any problem if it is capable to change the given problem into mathematical expressions and then reduce it into a string in the form of binary bits and could take only two decisions true or false. Along with this the digital computer had born, but still it was just an imaginary machine [1]. Training a network of artificial neurons to carry out a certain task was one of Turing's original concepts [2].

After Second World War, Alan Turing created first modern style computer which was easily programmable, and it could be used to solve many

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complex problems. He believed that computers could think; and with the right program, they can also do same behaviour as human being. A philosopher Ramon Llull presented his thought about machine intelligence, that was "reasoning could be artificially implemented in the machines" in 1315 and in 1936; Alan Turing introduced theoretical idea which was based on the principle of "A machine can emulate any machine" that is called TURING MACHINE [3]. A concept like state machines, automata, or combinational logic, the Turing machine was merely a mathematical model. The actions of the scanner were controlled by a programme of instructions that was also stored in the memory in the form of symbols. Alan Turing described his device as "A computing machine, that consisted of a limitless memory and a scanner that moves back and forth through the memory, symbol by symbol" [4]. This was Turing's stored-program concept, and it implied that the machine could operate on, and thus modify or improve, its own programme [5]. The architecture of machine included four main parts:

1. An endless roll of tape that could be written on and on which symbols could be added, removed, and rewritten.
2. The head, which could travel up and down the tape and write, delete, or rewrite symbols on it, was the second component [6]. The head resembled the head that a hard disc has.
3. The third component was a state register, which served as the machine's memory. That was holding the current state of the machine.
4. Under the tape head and next to the machine's current state, the transition table has a symbol. This specifies the next action of the tape head and new state of the machine [7].

To check how the machine can think, apply Turing test on Turing machine. The Turing test was a method to investigate the artificial intelligence for determining whether a machine is capable to think like a human being. Three terminals were needed for the Turing test, one of which was physically isolated from the other two. On one terminal, the command was given by a computer, while the remaining two terminals were handled by humans [8]. Amid the test, one human was asking questions to both participants i.e., human and computer, the second human and the computer was giving responses of these which was asked by the 1st human. The questioner questioned the respondents about a particular topic while adhering to a predetermined structure and context. The questioner could determine which respondent was a human after asking a set number of questions and for a set amount of time [9]. The test was conducted again and again; if the questioner makes the correct determination in half of the test runs or less [9], on behalf of this computer was considered to have some intelligence. In essence, all contemporary computers are universal Turing machines [10]. What we want is a computer that can learn from experience; and the mechanism for this, according to Turing in 1947, is the "possibility of letting the machine alter its own instructions". In a report titled "Intelligent Machinery", he first presented many of the key ideas of AI. But Turing did not publish this paper, and many of his ideas were reinvented by others.

## LIMITATIONS OF TURING MACHINE

Because of its excellent computing capabilities, the Turing machine can serve as a general-purpose mathematical model for contemporary computers. But some limitations of this machine were:

### Computational Complexity Theory

A limitation of Turing machine was that, it did not model the strength of particular arrangement well. Modern computers with stored programmes, for instance, are examples of a more specialised type of abstract machine known as the Random Access Stored Programme. The RASP keeps its software in memory separate from its finite-state goal [11].

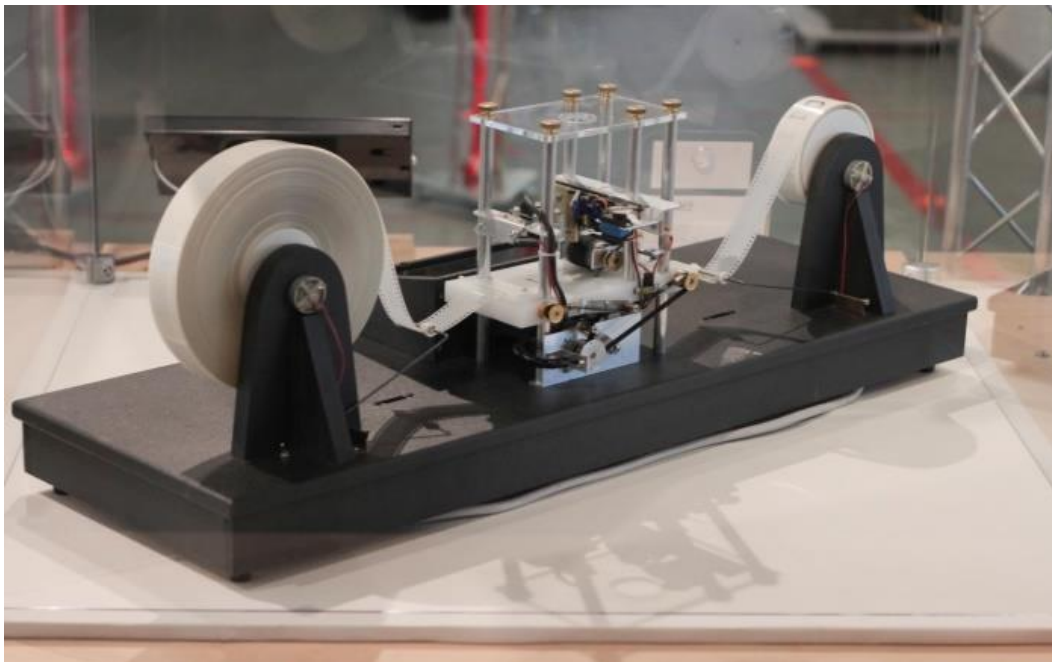
### Concurrency

A one type of limitation was consisting by Turing machine that was 'Concurrency', Turing machine was not too concurrent. During contrast, there was always shelling concurrent system with no input that could compute an integer of unbounded size [11].

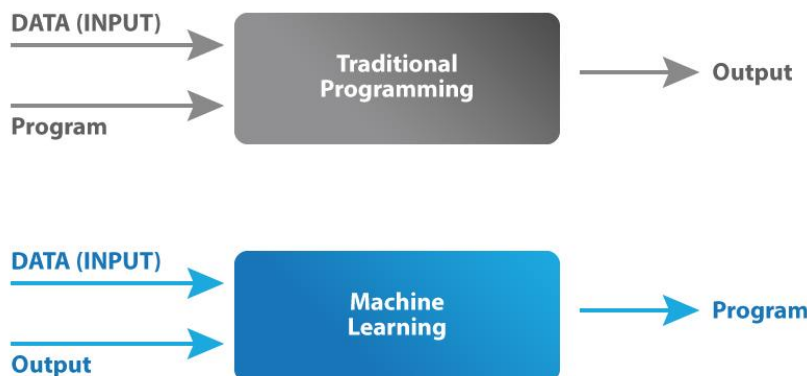
## MACHINE LEARNING

Arthur Samuel gave the term Machine Learning in the year 1959. He described the field of study known as "machine learning" as one that "gives computers the power to learn without being explicitly programmed" [12]. But in simple language, we can define the term of Machine learning as, "Machine learning is the field of study or art that gives the ability to computer to learn from data or we can say it is an approach in which the computer takes some data, learn from their past experience and penalties and improve their self without doing changes in the program and give the best suitable path, result or idea to solve the problem" as shown in Figure 1.

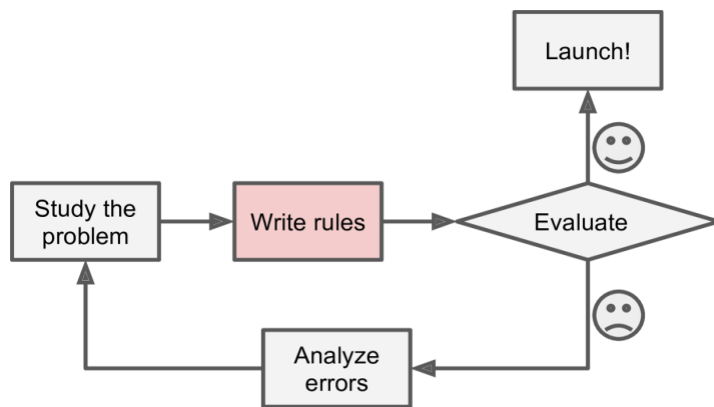
In the traditional programming approach, the main problem was that if we want to identify the particular problem and solve it, then we need to write the code again and again (Figures 2 and 3). Many times, if the problem was more difficult and bigger, than our code length would also increase but in the machine learning approach, we can write some set of rules with the help of different machine learning algorithm and provide some data, it may be labelled or unlabelled also, or it may be in any form also like images, audio file, video file etc. The code will learn from the data, validate it, test it and then give the result. If result is not good, again evaluate it until the best result occurs. It is somewhat like to give the training to a new child for detect and predict the result according to the condition (Figure 4) [13].



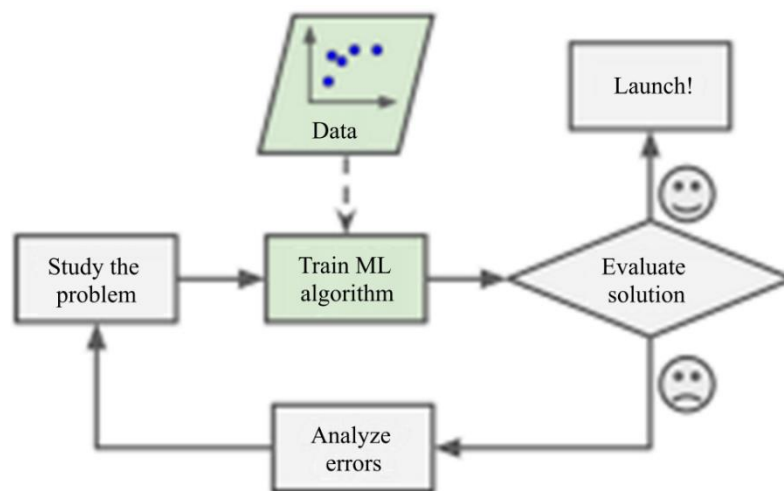
**Figure 1.** Turing Machine [14].



**Figure 2.** Traditional programming and Machine learning [15].



**Figure 3.** Traditional Approach [15, 16].



**Figure 4.** Machine learning approach.

### Types of Machine Learning

There are many types of machine learning techniques available according to their uses and it is also dependent on the size or type of problem.

#### *Based on Trainer/Supervision*

Machine learning system can be classified according to the trainer availability. In some conditions, we provide trainer or in some conditions, we do not provide trainer, or in some conditions, we need both. So according to supervision, we can divide it into four major categories:

#### *Supervised Learning*

In the supervised machine learning, we provide a supervisor, or in simple language we can say that a trainer in the form of training dataset to the algorithm. It includes the desired solution that are called labels.

#### *Unsupervised Learning*

In the unsupervised machine learning, we do not provide a supervisor, or in simple words we can say that the system learns without a trainer. The system gives the result on their judgments and guesses. The training data in this kind of learning is not labelled.

#### *Semi Supervised Learning*

The term semi-supervised is the combination of two sub terms; one is semi that means half and the other is supervised that means provide a trainer and it gives its identity automatically. If we combine

both definitions, then the clear meaning is obtained; that means in this type of Machine learning technique, we provide some training dataset with labels and algorithm, find a suitable pattern in the unlabelled dataset. We use this approach because labelled data is usually time consuming and costly.

#### *Reinforcement Learning*

In Reinforcement learning, the learning system called agent selects and performs actions and gets rewards or we can say penalties and again make best strategy called policy to achieve goal in an uncertain, potential and complex environment.

#### **Based on Size of the Training Dataset and Learning Capability**

Machine learning system can be also classified based on the size of training data and learning approach i.e., system is capable to learn incrementally or not from a stream of incoming data. On behalf of this, it may be categorized into two types:

#### *Batch Learning*

Because batch learning requires the system to learn via all the data that is currently available, it is not possible for the system to learn incrementally and must instead be done offline. In this method of learning, the system is educated before being put into use, where it operates without picking up new information. It only applies the knowledge it has gained.

#### *Online Learning*

In online learning, the system is capable to learn incrementally by feeding the data into some small groups/parts; these are called mini-batches. In this type of learning, each step is faster and cheaper because it uses less computing resources and take less time also. It is great for those systems where the new data is coming continuously.

### **ADVANTAGES OF MACHINE LEARNING**

Machine learning is the subset of Artificial Intelligence. Machine learning gives the capability to machine to behave and take decisions like human-beings. It also gives the ability to learn and develop their own programs with minimum human intervention. In today's scenario, all the fields and areas that need this type of approach are like defence, automobile sector, manufacturing sector, for internal security etc. Many tasks can be automated thanks to machine learning, especially those that individuals with their intrinsic intelligence can complete. To achieve human like intelligence into machines is possible only with the help of various types of machine learning techniques. Businesses can use machine learning to automate their daily routine tasks. It also provides the help to create better data analysis model so that data analytics can take better decision for improving the industry health, its production quality and product service with the uses of less resources and man power. A model that can process and evaluate a vast amount of complex data and produce reliable results is created with the aid of machine learning. Such machine learning algorithms can help firms take advantage of valuable opportunities and mitigate unknowable hazards.

### **MACHINE LEARNING APPLICATIONS**

Artificial intelligence is present in every machine but we need to identify and use it in a proper manner. One of the popular methods to identify and use it for solving the real-world problems is machine learning. In the machine learning, computer software with various i/o devices (sensing device like as camera, mice etc.) work as a human brain and do behave like human. We are seeing that ML is being used in every sector; so, we elaborate some few fields where the machine learning is widely applied to do some complex tasks; these are:

#### **Machine Learning Application in Transportation**

The issues in transportation are becoming challenge which we are facing day by day due to rapidly increasing population, globalization, industrial production, environment degradation, safety concern

and the less availability of time also. Our current or traditional transportation system cannot handle it much more because we have scarce resources. But with the help of availability of computational power, cheaper hardware instruments and massive progress in the technology, machine learning models are a suitable method to overcome these problems. In some cases, intelligent transportation system, object detection for traffic surveillance, analysis of traveller's behaviour, sentiment analysis for traveling, and for dynamic pricing machine learning-based solutions have already proved themselves to give much better result and give better performance in comparison to trading solutions.

### ***Self-driving Cars***

It is one of the most popular applications of machine learning in today's world, because today, the world definitely needed such type of cars. Machine learning plays a great role in manufacturing such type of cars. Most popular automobile companies like Tesla are working on self-driving cars. These companies are using unsupervised and semi supervised learning methods to train such type of cars to detect the objects, take decisions, understand the safety precautions, and determine traffic rules also, during driving.

### ***Traffic Prediction***

In the past few years, almost all big and metropolitan cities are facing traffic related problems; these problems are in existence due to fast increase in industrialization and civilization. And people are purchasing own vehicles in more amount as required, so the number of vehicles on roads are increasing. To reduce such types of problems, machine learning plays a vital role. One of the most popular methods is ITMS (Intelligent Traffic Management System). It is a logistic regression mechanism especially designed for LoRa (Long Range Wide Area Network). Smart sensors are used to collect the data, and then transfer to LoRa cloud Platform for data analysis process, this processed data is used as an input for ITMS. ITMS includes traffic prediction through LoRa, and provides protection of cities with public surveillance, and manages the parking also [17].

### ***Machine Learning Application in Media***

Machine learning is widely use in social media platform. Most of the social media companies are applying machine learning on their social media platform for their own and user benefits. Artificial intelligence is being used more and more on social media sites like Facebook and Instagram. Users no longer call or email firms; instead, they just leave a comment on their social media platform for a swift response. This is due to the advancement of social media and chat applications [18]. One of the most popular uses of machine learning is image identification. It is used to identify things like digital photos, people, places, and items. So, with this approach, most popular social media use this application.

### ***Face Recognition System***

If you have uploaded a picture of you with your friend, and Face book automatically recognizes your friend and tag it; in this technique, Face book checks the poses and notices the unique features and then matches these features with your friend list database. This entire process is complicated in the backend, but it seems simple application of ML on the frontend. The entire procedure is a component of a Facebook initiative called Deep Face, which identifies people in photos and recognizes faces.

### ***Similar Pins***

One of the most important components of computer vision is machine learning, which analyses the information gleaned from images and videos in a user's social network work profile to suggest other pins with related themes.

### ***People Recommendation***

Facebook continuously does patrolling on your profile and notices the friends that are connected with you, whose profile that you are visit recently, your interests, etc.; behalf on this and continuous learning method, Facebook suggest you list of persons who somehow know you. It is possible with the help of machine learning techniques.

### Machine Learning Application in Healthcare

Machine learning models are being used more and more in the healthcare industry, and in the not-too-distant future, doctors and other medical professionals may be able to accurately forecast how long patients with terminal conditions will live. By minimizing unneeded testing, medical systems will gain knowledge from data and assist patients in saving money.

Radiologists will be replaced by machine learning algorithms. However, computers and robots cannot replace doctors or nurses, but they can play a vital role in the field of life-saving technology. The machine learning has capability to transform the healthcare domain.

### Drug Discovery and its Manufacturing

Discovery and manufacturing of drug is lengthy, expensive and time consuming because thousands of compounds are needed to pass the series of tests. With the use of machine learning algorithms, we can speed up and also do split in very small parts this lengthy multi-step process. Pfizer is collaborating with IBM Watson on immuno-oncology research [19]. This is one of the most important applications of IBM Watson for drug discovery, as it also determines the best participant for a drug clinical trial [20].

### Personalized Medication

Machine learning has a high potential for growth in personalized treatment in the near future, and it will be critical in determining which genetic makers and genes respond to a specific treatment or medication, as well as providing better disease assessment. In future, increased usage of sensor with integrated devices and mobile apps it will be helping to monitoring the health-measurement remotely. Through this way, people will also reduce their overall healthcare costs (Figures 5 and 6) [21, 22].

### LIMITATIONS OF MACHINE LEARNING

The field of Artificial Intelligence (AI) and its sub-field Machine Learning (ML) is developing and improving themselves day by day. Machines are trained to behave like humans enabling them to do complex cognitive functions like informed decision-making, deductive reasoning, and inferences. Human society is gradually becoming more reliant on smart machines to solve day to day challenges and make decisions. We have achieved great victories like Microsoft Cortana, Amazon Alexa, google Assistant, Apple Siri and AlphaGo, but AI technologies have several limitations that will still need more effort to overcome these limitations:

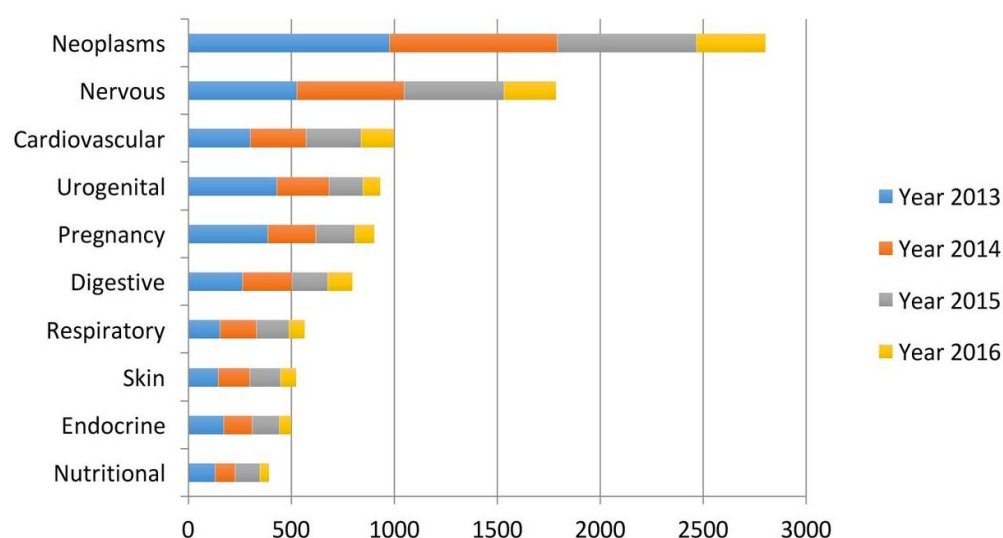
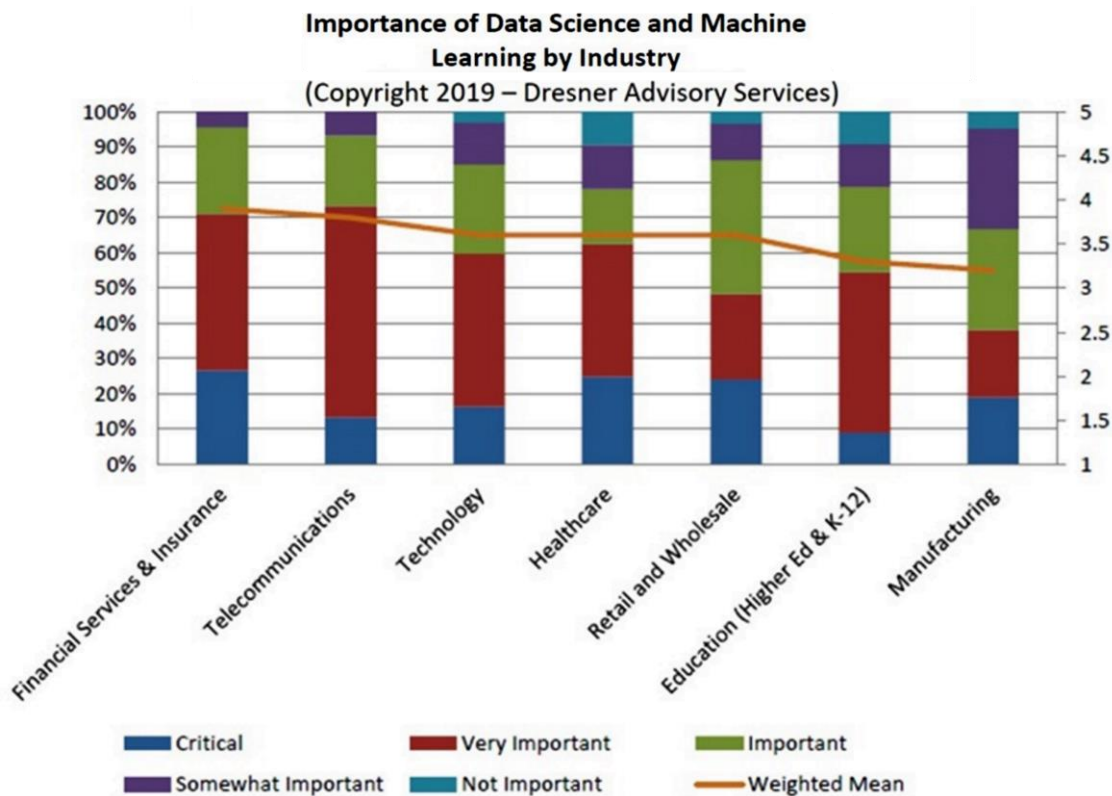


Figure 5. Uses of Artificial intelligence and machine learning.



**Figure 6.** Artificial intelligence with MI in Finance sector.

**Interpretability**

We have no formal or mathematically defined definition of term ‘interpretability’ but we have idea to define this as “interpretability is a state or cause where the human is capable to absorb or understand the result of decision”. In the machine learning approach, A problem could also arise if the machine learning we developed is not more easily interpretable,, then it will not give better understandable result to human; from this human cannot absorb the effects of the model once it is deployed it, and also will not take decision behalf on the result of such type of model. This type of model will be powerless, and useless for any firm, industry or sector. Because the human interpretation follows that rules lay beyond the technical skill. If the model is highly interpretable, then it will be easy to understand for human being to take more reliable decisions [23]. This problem, interpretability is one of the main qualities that should be achieved by machine learning if we want apply machine learning more in practice.

**Misapplication**

People are using machine learning to try and analyze systems and try to give the answer to this question, that is, what is the nature of this technique, is it deterministic or stochastic in nature? In current scenario, machine is capable to decide that they are violating the physical laws or not. For stochastic systems, the crises of machine learning are divided in two ways:

**P-hacking**

Before understanding p-hacking, first we have to understand p-values. P-Values are numbers between 0 and 1, if the p-value is closer to zero, on behalf of this we get good results of experiment. From this definition, we can say P-hacking is a process to do improvement in the p-values. P-hacking is a big problem in machine if the p-value of our machine learning model is too high, then this type of model will not give us good result and will also misuse of our valuable resources. Suppose a company has billions of GB data, and the company wants to benefit their business with the help of this data through processing it, but it is not sure whether the result will be beneficial for the business by using this data or not. And if it uses such type of data to fit their machine learning model, then the model will not be

able to find the right and accurate relationship among the data; and if we talk about the result, then it may give good result but it does not mean we are sure. If we deploy such type of model to find the solution to business related problems and it does not give good result then it will be clearly wastage of company's valuable resources and all this will also waste of lot of time; p-value can be high (For statistical significance value of p must be less than 0.05), such type model is not right for our machine learning model and may also cause loss to the company. So, we need to find better way to reduce the p-value; from this, we will utilize our resources in a better way, we will also ensure the reliability of performance results of the dataset.

### ***Scope of the Analysis***

If we talk about the scope in machine learning, it is not limited. It is a field into itself. Applications related to this technique are used in various fields such as banking and finance; various types of research areas are included into this like as auto mobile industry, robotics, quantum computing and many more. Various tech giant companies have already invested billions of dollars into the part of research and development on this. We cannot say surely that development will end in this area but somehow there are some skills related limitations because this field required deep knowledge of statistics and probability, physics, computer science, computer programming languages, Linear Algebra, better understanding of data structure, data visualization and data mining and great mathematical or computational thinking. So, those persons who want to work and get better opportunity of job in this field and its related field, should have these skills. Then they will be able work in this field in better way.

### **Data**

This is a massive problem. If you feed model in poor way, then the model give you result not up to the expectation. Such type of problem arises from two ways:

#### ***Lack of Data***

Mainly, machine learning model learns through data; thus, they need large amount of data to learn in better way and give more precise and useful result. The best example of these neural networks, Neural networks are eating much amount of data; so, they require massive amount of training data. If the architecture of neural network is large, they need more data to produce good and reliable result. Reusing of data is a bad idea, so we cannot go for this way. If we have more data, then we will produce good result and predict good prediction also for upcoming problems which we will face in near future.

#### ***Lack of Good Data***

Suppose you have generated thousands of amount of fake data and put it in your neural network, then what will it do? The neural network will train itself and then when you test on unseen data, the performance of this will not be good and hence does not give good prediction. We have observed that, if there is sufficient amount of data but due to lack of clarity of data you get inappropriate results. Similar to how a lack of strong features can make an algorithm perform poorly, a lack of solid and accurate data might restrict a machine learning model's potential.

### **Ethics**

Prof. Yuval Noah Harari is a historian, philosopher and best-selling author of 'Sapiens' and 'Homo Deus' who has given the term '*dataism*' which refers to new stage of civilization where people will trust on algorithms and data in more amount in comparison to their judgments and logics. The idea of dependency of our trust on data and algorithms is more in comparison to our judgments, it can be risky or wealthy because these include pros and cons both. These algorithms are helping the human beings where human does not work accurately to find the solution of problem on providing dataset. Somehow, we are getting some benefits from these algorithms. But on the other hands we are replacing someone's job with the uses of an algorithm, through this way, machine learning algorithms are violating the ethical ramifications. It is also a limitation of ML, so we should go further to find more better way so that the ML algorithms will not violate our ethical ramifications (Tables 1 and 2).

**Table 1.** Small roadmap for evolution of machine learning.

1950	Alan Turing found a way to determine that computers have some piece of intelligence? That was Turing test. In the 1950, In the IBM's computer lab, Arthur Samuel developed a computer program which was capable to play checkers' game. He designed alpha-beta pruning and a scoring function. This function tried to measure the chances of win at the given side and position also. This programme for deciding the next move is based on minima planning or strategy, which means it made the decision based on assumption that their opponent was attempting to maximize the value of the scoring function [24]. In this era, Isaac Asimov gave the Three Laws for robotics [25].
1957	Frank Rosenblatt developed 1st neural network for computers. He made it for IBM 704 to recognize the visual patterns. In 1951, K-nearest neighbor algorithm was developed by Evelyn Fix and Joseph Hodges [26]. In 1959, MIT established their 1st AI Lab in Cambridge [27].
1967	In 1961, First Robot was introduced into GM's assembly production line [28]. In 1963, First Machine Learning Program tic-tac-toe was written by Donald Michie with the uses of reinforcement learning [29]. In 1964, he demonstrated First AI program which could understand natural language by Dr. Danny Bobrow [30]. In 1965, First AI based Chatbot "ELEZA" was created by Joseph Weizenbaum, it used pattern matching and substitution methodology to do the task, simulate conversation/mimic human conversation [31].
1980	Bayesian methods were introduced for probabilistic inference [32]. The processing speed and learning capacity of neural networks are accelerated by multilayers, feedforward neural networks, and backpropagation [33].
1990	Robert Schapire invented boosting algorithms, such as Adaboost, to lessen bias and produce strong learners from collections of weak learners, such as decision trees [34]. Schapire introduced boosting concept in 1990.
2000	Long term-short Term memory term was introduced by Sepp Hochreit and Jurgen Schmidhuber in 1997 [35]. Face Recognition Grand Challenge was launched to test face recognition algorithms [36]. In this era, Support vector machines Algorithm has become popular.
2010	Deep learning becomes feasible with arrival of GPUs which lead the uses explosively for applications of machine learning in society, for example IoT, chat bots, self-driving vehicles, fraud detection, recommendations engine [37]. This was the transformative era of CNN innovation and transfer learning in computer vision [38].
Late 2020s	Advancements in pre trained language models using a range of techniques including attention, bidirectionality and the Transformer architecture [39]. GPT-3 175B parameter model adapts to unseen tasks with few-shot in context learning i.e., no need to update weights [40]. Performance does not plateau with model size increase [41–43].

**Table 2.** Journey of Turing machine to Artificial intelligence.

1950	Alan Turing wrote a paper called computing machinery and Intelligence discussing how to build intelligent machines, test their intelligence, and potentially make them indistinguishable from humans-proposing the famous Turing Test, which would become one of the measurements for Artificial intelligence programs.
1956	The Dartmouth Summer Research Project on Artificial Intelligence was widely thought to be the event that founded AI as a field at Dartmouth College in Hanover, New Hampshire, over 8 weeks with approximately 20 people in attendance including Arthur Samuel, Oliver Selfridge, Claude Shannon, Ray Solomonoff, Marvin Minsky, John McCarthy and Nathaniel Rochester.
1961	Ultimate was the first industrial robot to replace a human on an assembly line at a GM automobile manufacturing plant in New Jersey
1965	ELIZA was a natural language program created by Joseph Weizenbaum to handle dialogue, the precursor to chatbots specifically in the role of a Rogerian psychotherapist, pairing and imitating possible responses.
1969	Shakey the Robot, developed by Charles Rosen and his team, was the first general purpose mobile robot. Sharkey was able to navigate with consideration for its own limitations in its given terrain. It did not "speak" but communicated with its programming team with teletype and CRT display.
1980	Researchers and scientists still worked to improve programs and computing power and eventually this work precipitated the growing tech of the 90s, which brought on the boom of the 2000s.
1997	New AI program development slowed at the start of the decade but finished strong with the introduction of the IBM's Deep blue computer, which beat the world's reigning chess champion, Gary Kasparov.
1999	Sony releases the AIBO (Artificial Intelligence Robot), a robotic dog made to learn by interacting with people and its environment. It could understand and respond to over a thousand voice commands and recognize its owner.

2000	Honda releases ASIMO, which was a humanoid robot made to move and react autonomously and serve as a mobility assistant. ASIMO became a bit of an ambassador for household robots by making appearances on television shows, the New York Stock Exchange, going on a world tour and meeting heads of state and conducting the Detroit Symphony Orchestra.
2002	iRobot releases the first version of the Roomba, a robot vacuum that travels around areas to clean while avoiding obstacles and returning itself to its charging station when done, bringing autonomous robot into daily households.
2010	Researchers like Dr. FeiFei Li worked to expand data sets, train models, and create neural networks as part of the ImageNet project that have become the basis for the image recognition apps that exist today
2011	IBM's supercomputer, Watson, could understand natural language and was able to best the top two Jeopardy Contestants in the world, Ken Jennings and Brad Rutter, in a televised game.
Late 2011	Apple's Siri, bringing in the age of personal virtual assistants in our pockets.

## CONCLUSION

We have seen how machines have adopted the human like intelligence and hence they are able to work like human. We have also seen what was the role of Alan Turing in evolution of a simple hardware machine to a modern machine with intelligence, and what problems were faced when the machine could not change themselves according to problems. What are limitations and problems associated with this machine so that machine has failed to drive exact definition of intelligent machine. We have seen some theories about machine intelligence and then we came on machine learning approach and analysed the answers of questions like: what we can say about this technique? how does it work? We have also seen what the application in real world are to help to find the solution of problems. What are the problems and limitation associated with this approach and hence find the idea and way to overcome these problems.

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