Chapter:

Machine Learning with Internet of Things

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Abstract- *Internet of Things (IoT) is use to develop a smarter environment and a simplified life-style by saving time, energy, and money. IoT consists of a set of connected devices that can transfer data among one another in order to optimize their performance; these actions occur automatically and without human awareness or input. The Internet of Things generates massive volumes of data from millions of devices like Sensors, cameras, and instruments that can be combined to provide previously unachievable insights. Machine learning is powered by data and generates achievable insight from it. Machine learning uses past behavior of IoT devices to identify patterns and builds models that help to predict future behavior and events based on their own. The use of machine learning to leverage IoT based approaches have only proven to be more accurate, sensitive, cost-effective, and timesaving.*

Cities always demand services to enhance the quality of life and make existing services more efficient. So in this chapter Smart city is used as use case to explain Machine learning algorithms on IOT devices.

Keywords – Machine learning algorithms, Internet of things, Smart city, Classification, Regression.

Introduction-

As per the recent revolution in the industry, Internet of thing is the most trending technology. The Internet of Things (IoT) describes the network of physical objects “things” that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from ordinary household objects to sophisticated industrial tools. Internet of Things is the concept of connecting any device to the Internet and to other connected devices.

Devices and objects with built in sensors are connected to an Internet of Things platform, which integrates data from the different devices and applies analytics to share the most valuable information with applications built to address specific needs.

The Internet of Things generates massive volumes of data from millions of devices. Machine learning is powered by data and generates insight from it. Machine learning uses past behavior to identify patterns and builds models that help predict future behavior and events.

Machine Learning is a concept which allows the machine to learn from examples and experience, and that too without being explicitly programmed. So instead of you writing the code, what you do is you feed data to the generic algorithm, and the algorithm/ machine builds the logic based on the given data.

Machine Learning is a subset of artificial intelligence which focuses mainly on machine learning from their experience and making predictions based on its experience.

Internet of Things:

IoT devices are basically smart devices which have support for internet connectivity and are able to interact with the other devices over the internet and grant remote access to a user for managing the device as per their need.

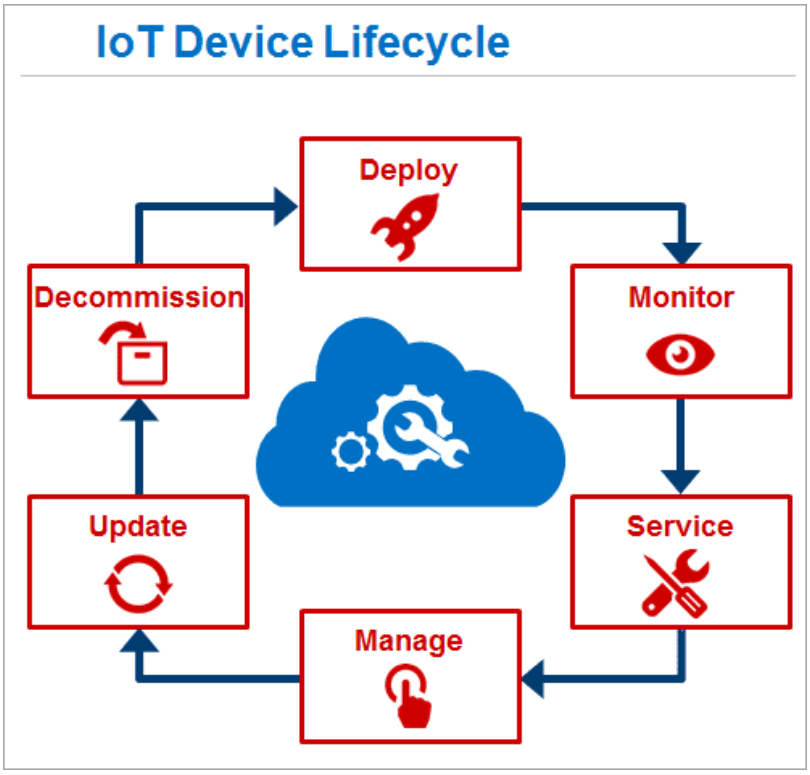
It basically depends on two things to transform a normal device into IoT smart device.

They are:

1. The device which has the capability to connect with the internet in any way.
2. The device which is integrated with technology like sensors, functional software, some inbuilt technology which support network connections and also actuators.

When both these functionalities are combined together an IoT device is formed. Earlier only simple watches were only used to see the time and date, but now the smart IoT watches allow a user to see heartbeat rate, calorie count, steps walked etc.

Life cycle of IoT:



IoT has a very simple lifecycle of development.

Deployment followed by monitoring, servicing, managing, which is followed by regular updates and decommissioning at the end.

Four steps to get the most value from your IoT data:

The IoT journey has evolved over the last several years. But it is definitely a journey. Let's look at the four steps every organization needs to master to truly realize value from their IoT efforts.

Step 1: Gather data:

IoT data is a data gathered from devices into a usable format.

Step 2: Visualize patterns:

As per the trend in technology, expectations of businesses rise. As the market developed, the focus shifted from instrumenting data to visualizing it. Once you begin to understand the patterns in your data, you can go to visualize and increase value to the business.

Step 3: Advance to analytics

IoT journey focuses on making data even smarter through analytics. Analytics allows you to couple real-time, IoT device data with existing, longer-term and historic information. It's a more complete picture of what's happening with your devices and in your environment. It also allows you to spot patterns and make predictions, and adopt new practices that proactively avert risk and avoid potential problems.

Step 4: Infuse with Artificial Intelligence

IoT focuses on using Artificial Intelligence to do even more with your data. Even with a refined use case on how IoT can help your business, you'll still have too much data, especially as you combine data sets. It's easy to become overwhelmed, so that's where AI comes in. Machine learning will help you clean up the data you have, distil it down to the most relevant pieces, and find the seemingly desperate data sets that actually matter.

With those efforts, you'll find even more synergy within your data. It also helps identify what data should be used and what should be thrown out, because all data is not equal. As you refine the process, you'll be able to do more sophisticated tasks like forecast models, apply predictive maintenance and anomaly detection. In other words, you gain the right, rich context that helps make sense of what you are seeing. You'll also be able to solve problems more easily and perhaps even identify new opportunities and business models.

Machine Learning:

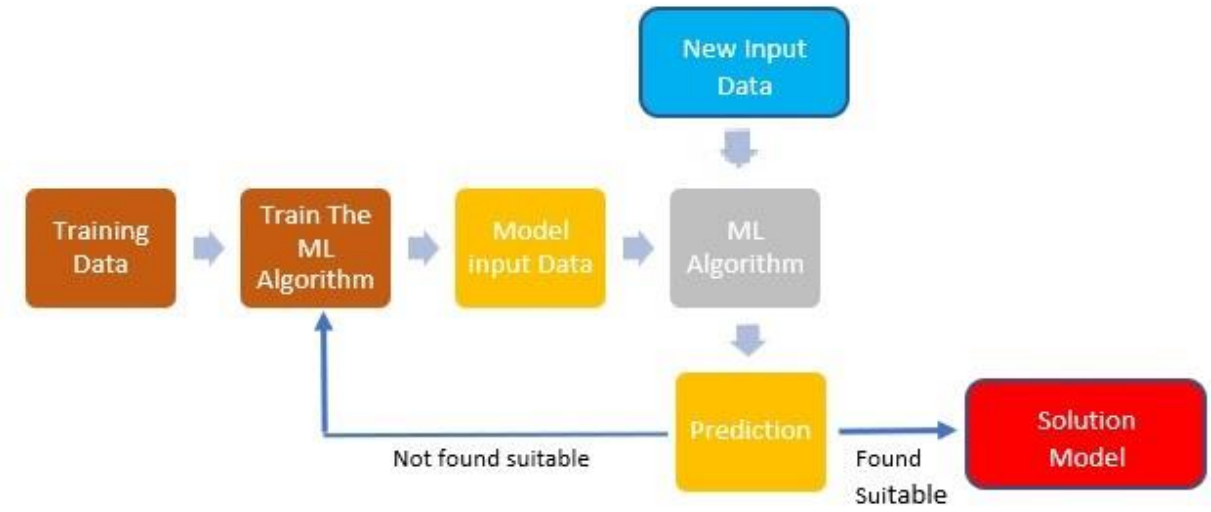
It enables the computers or the machines to make data-driven decisions rather than being explicitly programmed for carrying out a certain task. These programs or algorithms are designed in a way that they learn and improve over time when are exposed to new data.

As per Arthur Samuel, 1959, Machine Learning is the field of study that gives computers the ability to learn without being explicitly programmed.

As per Tom Mitchell, 1997, A computer program is said to learn from experience E with respect to some task T and some performance measure P, if its performance on T, as measured by P, improves with experience E.

Machine Learning is a buzzword in the technology world right now and for good reason, it represents a major step forward in how computers can learn.

How ML Works?



Training Data: Training data is an extremely large dataset that is used to teach a machine learning model. Training data is used to teach prediction models that use machine learning algorithms how to extract features that are relevant to specific business goals.

Train the ML Algorithm: Machine Learning algorithm is trained using a training data set to create a model.

ML Algorithm: When Model input Data and New input data is introduced to the ML algorithm, it makes a prediction on the basis of the model.

Prediction: The prediction is evaluated for accuracy and if the accuracy is found suitable, the Machine Learning algorithm is deployed. If the accuracy is not found suitable, the Machine Learning algorithm is trained again and again with an augmented training data set.

Need Of ML Algorithm:

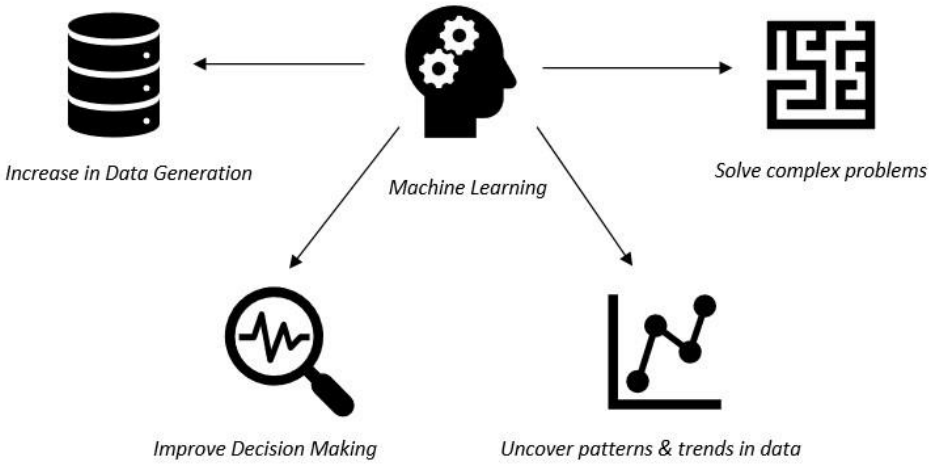
With the availability of big data, it is finally possible to build predictive models that can study and analyze complex data to find useful insights and deliver more accurate results. Machine learning is important because it gives enterprises a view of trends in customer behavior and operational business patterns, as well as supports the development of new products.

Why Machine Learning is so important?

1. **Increase in Data Generation:** Due to excessive production of data, we need a method that can be used to structure, analyze and draw useful insights from data. This is where Machine Learning

comes in. It uses data to solve problems and find solutions to the most complex tasks faced by organizations.

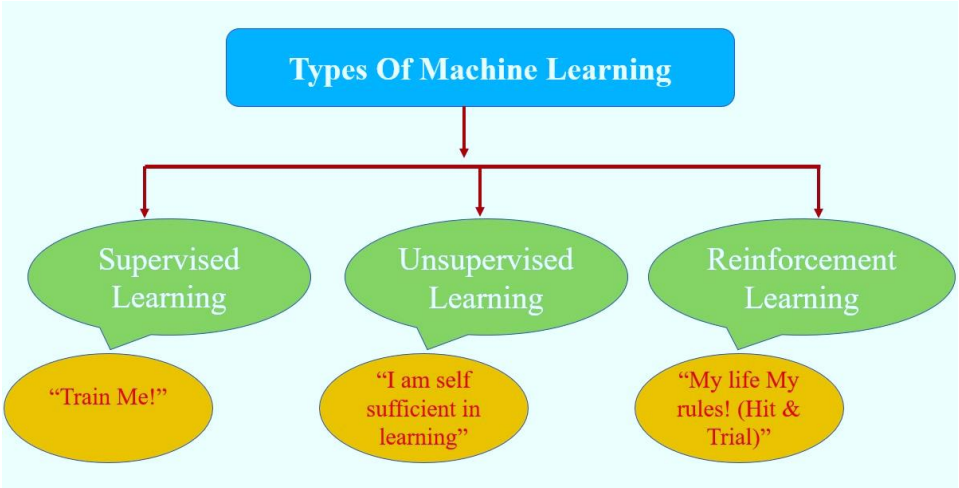
2. **Improve Decision Making:** By making use of various algorithms, Machine Learning can be used to make better business decisions.



3. **Uncover patterns & trends in data:** Finding hidden patterns and extracting key insights from data is the most essential part of Machine Learning. By building predictive models and using statistical techniques, Machine Learning allows you to dig beneath the surface and explore the data at a minute scale. Understanding data and extracting patterns manually will take days, whereas Machine Learning algorithms can perform such computations in less than a second.
4. **Solve complex problems:** From detecting the genes linked to the deadly ALS disease to building self-driving cars, Machine Learning can be used to solve the most complex problems.

Types of Machine Learning

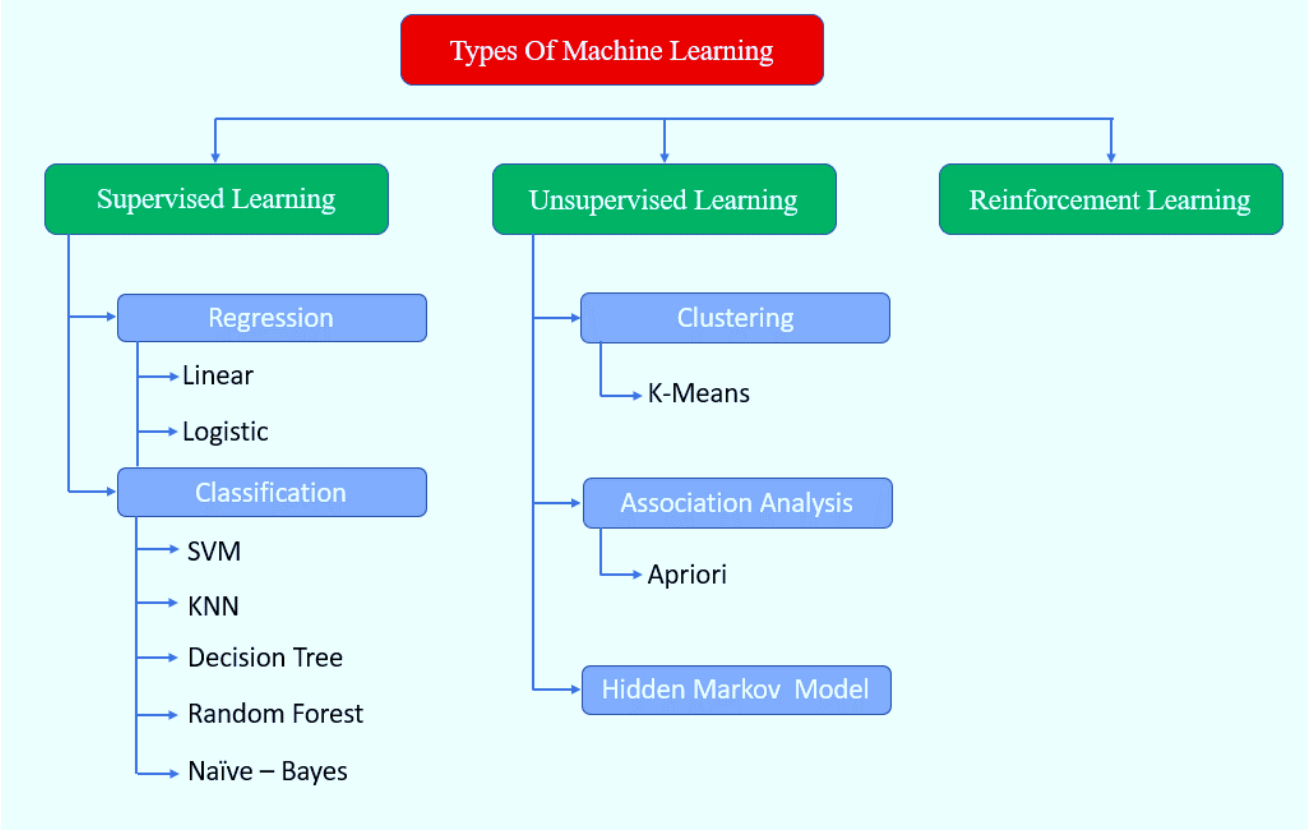
Machine learning is sub-categorized to three types:



Types of ML	Supervised Learning	Unsupervised Learning	Reinforcement Learning
Definition	The model gets trained by using labelled data	The model learns through observation using unlabelled data.	The model interacts with environment and find out what is the best outcome
Types of Problems	Regression, Classification	Association, Clustering	Reward based
Types of data	labelled data	unlabelled data	No pre-defined
Training	External supervision	No supervision	No supervision
Approach	start making a prediction or decision when new data is given to it	automatically finds patterns and relationships in the dataset	concept of hit and trial method
Popular Algorithms	Linear Regression, Logistic Regression, SVM, KNN	K-Means, C-Means	Q-Learning, SARSA

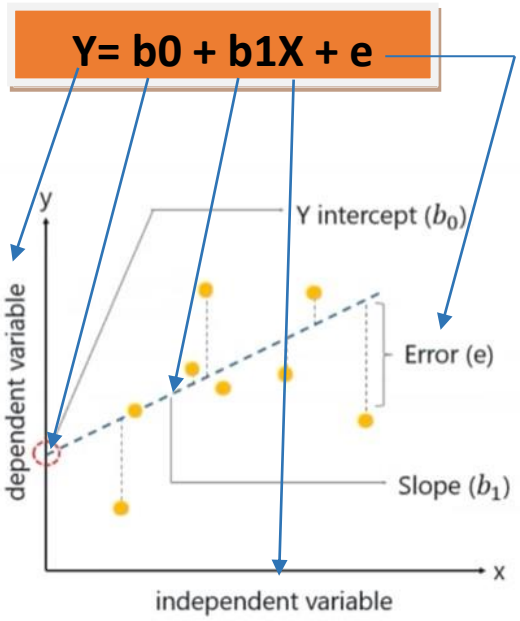
Algorithms of machine Learning:

Here is the list of commonly used machine learning algorithms. These algorithms can be applied to almost any data problem:



1. Linear Regression

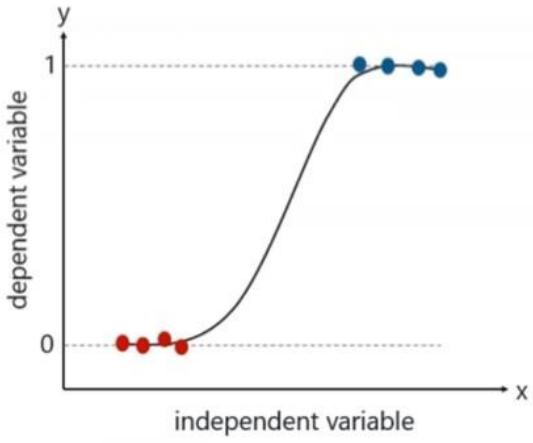
It is used to estimate real values based on continuous variable(s). Here, we establish the relationship between independent and dependent variables by fitting the best line. This best fit line is known as the regression line and is represented by a linear equation:



Linear Regression is mainly of two types: Simple Linear Regression and Multiple Linear Regression. Simple Linear Regression is characterized by one independent variable. And, Multiple Linear Regression (as the name suggests) is characterized by multiple (more than 1) independent variables. While finding the best fit line, you can fit a polynomial or curvilinear regression. And these are known as polynomial or curvilinear regression.

2. Logistic Regression

It is a classification, not a regression algorithm. It is used to estimate discrete values (Binary values like 0/1, yes/no, true/false) based on a given set of the independent variable(s). In simple words, it predicts the probability of occurrence of an event by fitting data to 0 and 1 (as expected).



$$P(X) = \frac{e^{(\beta_0+\beta_1 x)}}{e^{(\beta_0+\beta x)}+1}$$

$$\Rightarrow p(e^{(\beta_0+\beta x)}+1) = e^{(\beta_0+\beta_1 x)}$$

$$\Rightarrow p.e^{(\beta_0+\beta x)} + p = e^{(\beta_0+\beta_1 x)}$$

$$\Rightarrow p = e^{(\beta_0+\beta_1 x)} - p.e^{(\beta_0+\beta x)}$$

$$\Rightarrow p = e^{(\beta_0+\beta_1 x)}(1-p)$$

$$\Rightarrow \frac{p}{(1-p)} = e^{(\beta_0+\beta_1 x)}$$

$$\Rightarrow \ln[\frac{p}{(1-p)}] = (\beta_0 + \beta_1 x)$$

odds= p/ (1-p) = probability of event occurrence / probability of not event occurrence
ln(odds) = ln(p/(1-p))
logit(p) = ln(p/(1-p)) = b0+b1X1+b2X2+b3X3....+bkXk

-Above, p is the probability of the presence of the characteristic of interest. It chooses parameters that maximize the likelihood of observing the sample values rather than that minimize the sum of squared errors (like in ordinary regression).

3. Decision Tree

It is a type of supervised learning algorithm that is mostly used for classification problems. It works for both categorical and continuous dependent variables. In this algorithm, the population splits into two or more homogeneous sets. This is done based on the most significant attributes/ independent variables to make as distinct groups as possible.
In the below figure, population is classified into four different groups based on multiple attributes to identify 'if they will play or not'. To split the population into different heterogeneous groups, it uses various techniques like Gini, Information Gain, Chi-square, and entropy.

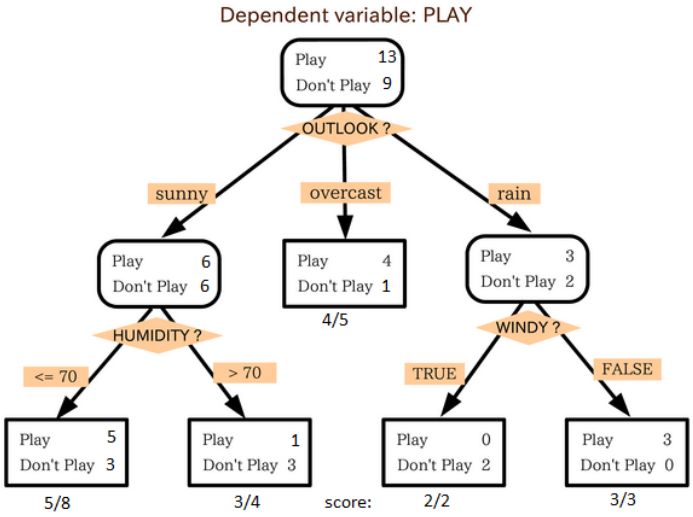


Fig: Decision Tree

4. SVM (Support Vector Machine)

It is a classification method. In this algorithm, we plot each data item as a point in n-dimensional space with the value of each feature being the value of a particular coordinate.

For example, if we only had two features like Height and Hair length of an individual, we'd first plot these two variables in two-dimensional space where each point has two coordinates. These co-ordinates are known as Support Vectors**.**

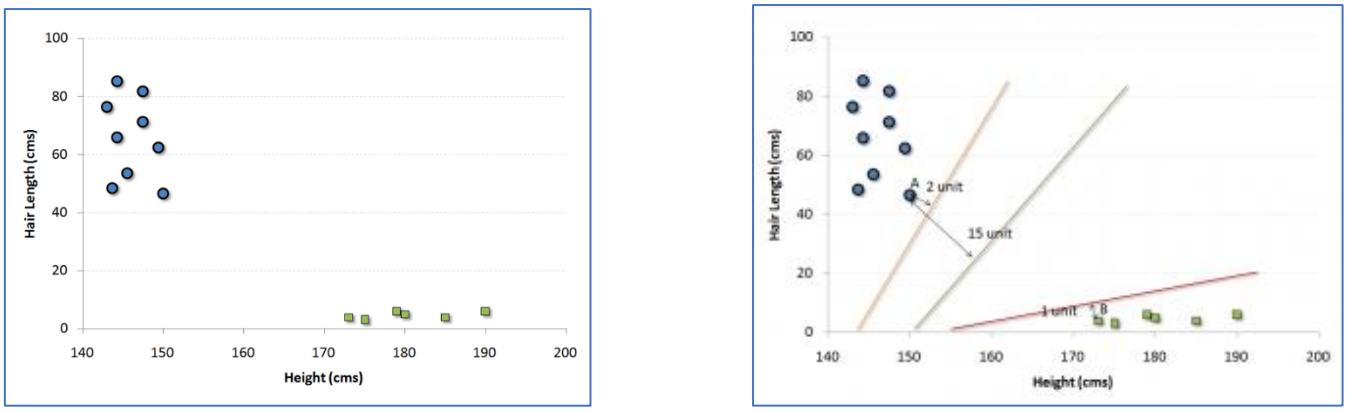


Fig: SVM

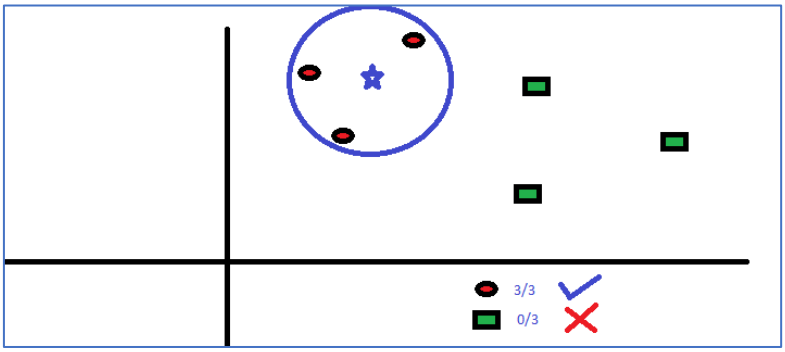
Now, find some *lines* that split the data between the two differently classified groups of data. This will be the line such that the distances from the closest point in each of the two groups will be the farthest away.

In the above example shown in fig, the line which splits the data into two differently classified groups is the *black* line, since the two closest points are the farthest apart from the line. This line is our classifier. Then, depending on where the testing data lands on either side of the line, that's what class we can classify the new data as.

5. KNN (k- Nearest Neighbors)

It can be used for both classification and regression problems. However, it is more widely used in classification problems in the industry. K nearest neighbors stores all available cases and classifies new cases by a majority vote of its k neighbors. The case assigned to the class is most common amongst its K nearest neighbors measured by a distance function.

These distance functions can be Euclidean, Manhattan, Minkowski and Hamming distances. The first three functions are used for continuous function and the fourth one (Hamming) for categorical variables. If K = 1, then the case is simply assigned to the class of its nearest neighbor. At times, choosing K turns out to be a challenge while performing kNN modeling.



KNN can easily be mapped to our real lives. If you want to learn about a person, with whom you have no information, you might like to find out about his close friends and the circles he moves in and gain access to his/her information!

Things to consider before selecting KNN:

- KNN is computationally expensive
- Variables should be normalized else higher range variables can bias it
- Works on pre-processing stage more before going for kNN like an outlier, noise removal

6. Random Forest

Random Forest is a trademarked term for an ensemble of decision trees. In Random Forest, we've got a collection of decision trees (so-known as "Forest"). To classify a new object based on attributes, each tree gives a classification and we say the tree "votes" for that class. The forest chooses the classification having the most votes (over all the trees in the forest).

Each tree is planted & grown as follows:

1. If the number of cases in the training set is N, then a sample of N cases is taken at random but *with replacement*. This sample will be the training set for growing the tree.
2. If there are M input variables, a number m<<M is specified such that at each node, m variables are selected at random out of the M and the best split on this m is used to split the node. The value of m is held constant during the forest growth.
3. Each tree is grown to the largest extent possible. There is no pruning.

7. K-means:

It is an iterative algorithm that divides the unlabelled dataset into k different clusters in such a way that each dataset belongs only one group that has similar properties.

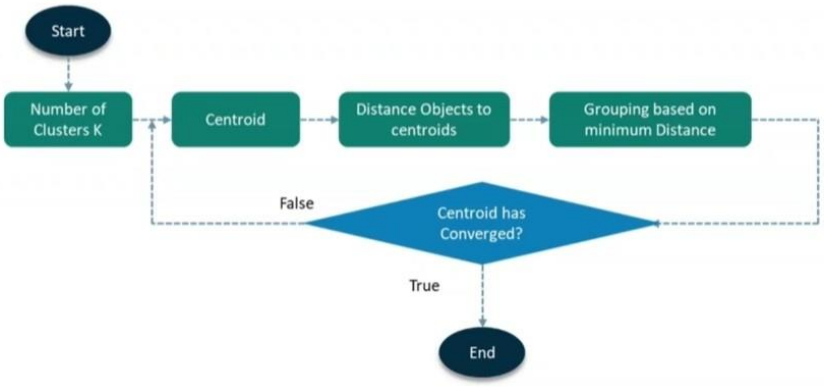


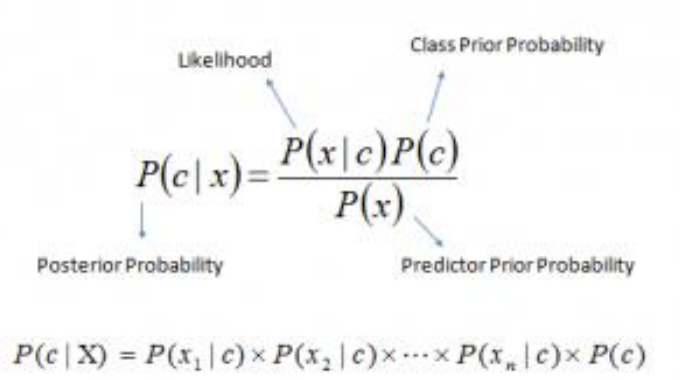
Fig: Steps Of the K- means Algorithm

8. Naive Bayes

It is a classification technique based on Bayes' theorem with an assumption of independence between predictors. In simple terms, a Naive Bayes classifier assumes that the presence of a particular feature in a class is unrelated to the presence of any other feature. For example, a fruit may be considered to be an apple if it is red, round, and about 3 inches in diameter. Even if these features depend on each other or upon the existence of the other features, a naive Bayes classifier would consider all of these properties to independently contribute to the probability that this fruit is an apple.

The Naive Bayesian model is easy to build and particularly useful for very large data sets. Along with simplicity, Naive Bayes is known to outperform even highly sophisticated classification methods.

Bayes theorem provides a way of calculating posterior probability P(c|x) from P(c), P(x) and P(x|c).
Look at the equation below:



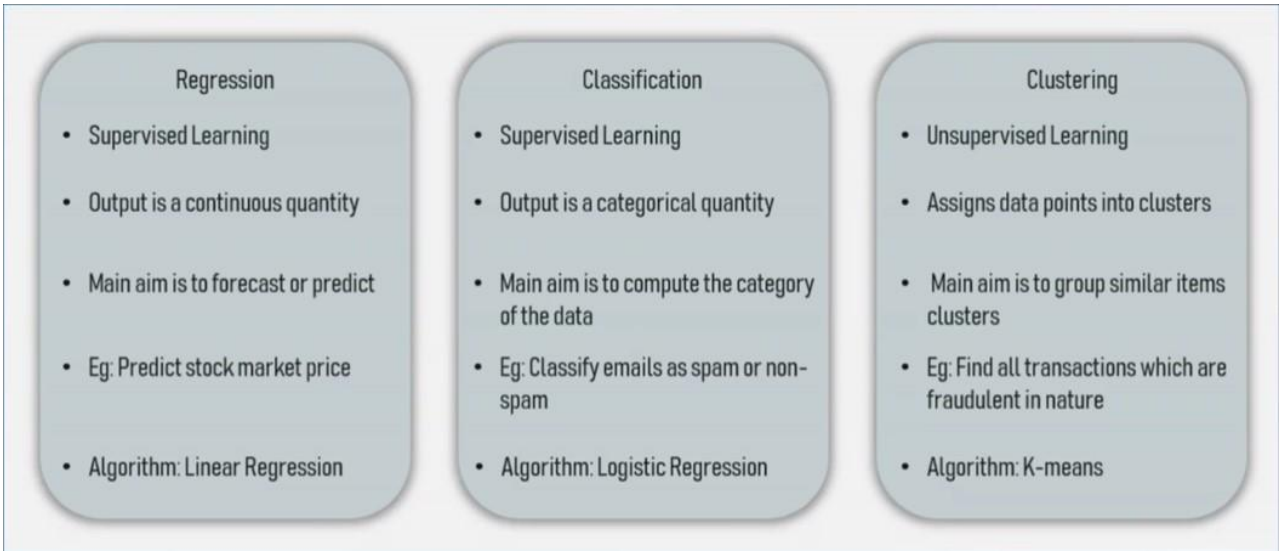
Here,

- $P(c|x)$ is the posterior probability of *class* (*target*) given *predictor* (*attribute*).
- $P(c)$ is the prior probability of *class*.
- $P(x|c)$ is the likelihood which is the probability of *predictor* given *class*.
- $P(x)$ is the prior probability of *predictor*.

Machine Learning Algorithm's Phases:

Machine Learning algorithm is an evolution of the regular algorithm. It makes your programs "smarter", by allowing them to automatically learn from the data you provide. The algorithm is mainly divided into:

- **Training Phase:** The process of training an Machine Learning model involves providing an Machine Learning algorithm with training data to learn from. The term Machine Learning model refers to the model artifact that is created by the training process.
- **Testing Phase:** In machine learning, testing phase of model is referred to as the process where the performance of a fully trained model is evaluated on a testing set



Applications of ML:

Traffic Alerts (Maps)

Google Maps is the app to use for assistance in directions and traffic. But, How does it know that?

It's a combination of People currently using the service, historic Data of that route collected over time and few tricks acquired from other companies. Everyone using maps is providing their location, average speed, the route in which they are traveling which in turn helps Google collect massive Data about the traffic, which makes them predict the upcoming traffic and adjust your route according to it.

Social Media (Facebook)

One of the most common applications of Machine Learning is Automatic Friend Tagging Suggestions in Facebook or any other social media platform. Facebook uses face detection and Image recognition to automatically find the face of the person which matches it's Database and hence suggests us to tag that person based on DeepFace.

Transportation and Commuting (**Uber**)

Uber is one of the application of machine learning which is use for Transportation and Commuting.

It uses Machine Learning algorithm layered on top of Historic Trip Data to make a more accurate ETA prediction. With the implementation of Machine Learning, they saw a 26% accuracy in Delivery and Pickup.

Products Recommendations (Amazon)

When we are searching for any product though we didn't buy it still recommendations are predicted on many sites related to your search. This is happen because Google tracks your search history, and recommends ads based on your search history. This is one of the coolest applications of Machine Learning. In fact, 35% of Amazon's revenue is generated by Product Recommendations.

Virtual Personal Assistants

As the name suggests, Virtual Personal Assistants assist in finding useful information, when asked via text or voice. Few of the major applications of Machine Learning here are:

- Speech Recognition
- Speech to Text Conversion
- Natural Language Processing
- Text to Speech Conversion
- virtual-assistants-applications-of-machine-learning

For answering the question asked to assistant, it searches for information or recalls your related queries to collect info. Recently personal assistants are being used in Chatbots which are being implemented in various food ordering apps, online training websites and also in Commuting apps.

Self Driving Cars

This is one of the coolest application of Machine Learning. Machine Learning plays a very important role in Self Driving Cars. The leader in this business and their current Artificial Intelligence is driven by hardware manufacturer NVIDIA, which is based on Unsupervised Learning Algorithm.

Dynamic Pricing

Setting the right price for a good or service is an old problem in economic theory. There are a vast amount of pricing strategies that depend on the objective sought. Be it a movie ticket, a plane ticket or cab fares, everything is dynamically priced.

Uber's biggest uses of Machine Learning comes in the form of surge pricing. If you are getting late for a meeting and you need to book an Uber in a crowded area, get ready to pay twice the normal fare. Even for flights, if you are traveling in the festive season the chances are prices will be twice the original price.

Google Translate

Google's GNMT(Google Neural Machine Translation) is a Neural Machine Learning that works on thousands of languages and dictionaries, uses Natural Language Processing to provide the most accurate translation of any sentence or words. Since the tone of the words also matters, it uses other techniques like POS Tagging, NER (Named Entity Recognition) and Chunking. It is one of the best and most used Applications of Machine Learning.

Online Video Streaming (Netflix)

Netflix is one of the best application of Machine Learning.

The Netflix algorithm constantly gathers massive amounts of data about users' activities like:

- When you pause, rewind, or fast forward

- What day you watch content (TV Shows on Weekdays and Movies on Weekends)
- The Date and Time you watch
- When you pause and leave content (and if you ever come back)
- The ratings Given (about 4 million per day), Searches (about 3 million per day)
- Browsing and Scrolling Behavior

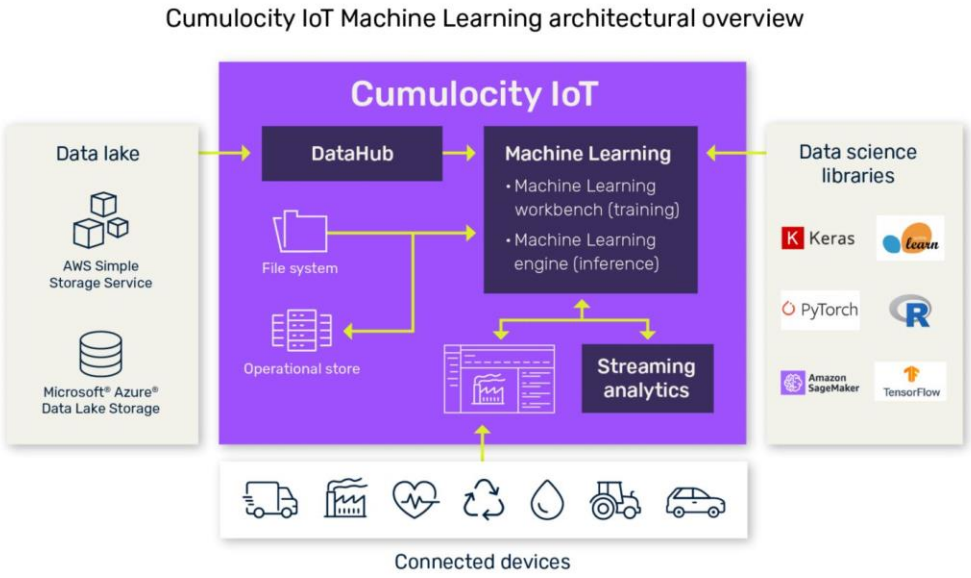
And a lot more. They collect this data for each subscriber they have and use their Recommender System and a lot of Machine Learning Applications. That's why they have such a huge customer retention rate.

Fraud Detection

Fraud Detection is one of the most necessary Applications of Machine Learning. The number of transactions has increased due to a plethora of payment channels – credit/debit cards, smartphones, numerous wallets, UPI and much more. At the same time, the amount of criminals have become adept at finding loopholes.

Whenever a customer carries out a transaction – the Machine Learning model thoroughly x-rays their profile searching for suspicious patterns. In Machine Learning, problems like fraud detection are usually framed as classification problems.

How to use Machine learning in IOT?



1. How can machine learning algorithms be applied to IoT smart data?[9]

To understand which algorithm is more appropriate for processing and decision-making on smart data generated from the things in IoT, it is essential to consider the following three concepts.

1. the IoT application

2. the IoT data characteristics

3. the data-driven vision of machine learning algorithms. [9]

2. What is the taxonomy of machine learning algorithms that can be adopted in IoT?

There exist eight major groups of algorithms applicable to IoT data. These algorithms are categorized according to their structural similarities, types of data they can handle, and the amount of data they can process in a reasonable time.[9]

3. What are the characteristics of IoT data in the real world?

Having reviewed the real-world perspective of how IoT data is analyzed by over 20 authors, many significant and insightful results have been revealed regarding data characteristics. To gain a deeper insight into IoT smart data, patterns must be extracted and the generated data interpreted. Cognitive algorithms undertake interpretation and matching, much as the human mind would do. Cognitive IoT systems previously learn from generated data and improve when performing repeated tasks. Cognitive computing acts as a prosthetic for human cognition by analyzing massive amount of data and responding to questions that humans might have when making certain decisions. Cognitive IoT plays an important role in enabling the extraction of meaningful patterns from generated IoT smart data. [9]

Application of IOT:

Applications of IOT in which Machine learning Algorithms are used to Analyse, predict or visualize data.

Sr No.	IOT Applications	IOT Devices/ Components	ML Algorithms and Techniques	Performance Measurment Parameters	References
1	Air Quality Monitoring System	1. MQ135 sensor 2. MQ7 sensor	Linear Regression	RMSE, MSE and MAE	[1]
2	Online Load forecasting	1.Arduino Uno 2. Node 3. MCUESP8266, 4. PZEM 004T 5. DHT 11 sensors	1. Linear Regression (LR) 2. Support Vector Machines (SVM) for regression 3.Ensemble Bagged (EB) regression 4. Ensemble Boosted (EBo) regression, 5. Gaussian Process Regression (GPR) 6. Fine Tree (FT)	RMSE, MSE and MAE	[2]
3	Flood Monitoring System	1. PCB, 2. Water- Float sensor, 3. Rain drop sensors, 4. Rasberry pi	1. Linear Regression, 2. SVM 3. Neural Networks		[3]

4	Health Care Monitoring System at war field	1. Arduino MEGA 2560 2. Heartbeat Sensor 3. Temperature Sensor 4. Humidity Sensor (DHT11) 5. Accelerometer (ADXL335) 6. Ethernet Shield (W5100)	K-Means Clustering		[4]
5	Waste Management Model	1.Arduino UNO microcontroller 2. Ultrasonic sensor 3. Moisture sensor buzzer 4. LED 5. Jumper wires	1. Random Forest Classifier, 2. CNN 3.R-CNN		[5]
6	Crop Protection against Animal Intrusion	1. PTZ (Pan-Tilt-Zoom) camera, 2. GSM module, Sensors, 3. Arduino UNO microcontroller	1. KNN (K-Nearest Neighbor) Algorithm, 2. Logistic Regression, 3. SVM (Support Vector Machine) Algorithm, 4. R-CNN	mAP	[6]
7	Smart Health Monitoring System	1. Heartbeat Sensor	1. KNN algorithm 2. Support Vector Machine 3. Naïve Bayes	Accuracy, Specificity, Sensitivity	[7]
8	Farm irrigation System	1.Arduino, 2. Rasberry pi, 3. Microcontroller, 4. Sensor	1. SVM , 2. Random Forest	F- score, p-value	[8]

A smart city has been selected as our primary use case in IoT for three reasons: First, among all of the reviewed articles the focus of 60 percent is on the field of the smart cities. Second, smart cities include many of the other use cases in IoT. Third, there are many open datasets for smart city applications that are easily accessible for researchers. Furthermore, a Support Vector Machine (SVM) algorithm is implementedon the Aarhus City smart traffic data to predict traffic hours during one day. By answering the above questions about IoT smart data and machine learning algorithms, we would be able to choose the best machine learning algorithm that can handle IoT smart data characteristics. Unlike similar surveys regarding machine learning and IoT, readers of this article would be able to obtain a deep and technical understanding of machine learning algorithms, IoT applications, and IoT data characteristics along with both technical and simple implementations.[9]

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