Book Chapter

Machine Learning with Internet of Things

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Abstract- *The Internet of Things (IoT) is being used to develop smarter environments and simplified lifestyles by saving time, energy and money. IoT consists of a set of connected devices that can send data to each other to optimize performance. These actions occur automatically without human attention or input. The Internet of Things will generate massive amounts of data from millions of devices such as sensors, cameras and instruments that can be combined to provide unprecedented insights. Machine learning is powered by data and generates achievable insight from it. Machine learning uses the past behavior of IoT devices to identify patterns and build models that help to predict the future behaviour and events. Leveraging his IoT-based approach using machine learning has proven to be more accurate, sensitive, cost-effective and time-saving.*

Cities are constantly looking for services that improve 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) is a network of physical object "things" that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the Internet. Represents these devices range from common household items 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 embedded with sensors are connected to an IoT platform that integrates data from various devices, applies analytics and shares the most valuable information with applications designed for specific needs.

The Internet of Things generates big amounts of data from millions of devices. Machine learning is based on data and generates insights from it. Machine learning uses past behavior to identify patterns and implement models that help to predict future behavior and events.

Machine learning is a concept that allows machines to learn from examples and experience without being explicitly programmed. So instead of writing code, you feed data into a generic algorithm and the algorithm or machine builds logic based on the data you give it.

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 essentially smart devices that support internet connectivity, interact with other devices over the internet, and allow users remote access to manage the device as needed.

Basically, two things are needed to turn a regular device into a smart IoT device.

1. A device that can connect to the Internet in some way.

2. Devices integrated with technology such as sensors, functional software, some embedded technologies that support network connectivity, and actuators.

IoT device is formed by combining both these functionalities together. Until now, only simple watches were used to see the time and date, but the smart IoT watches can now display heartbeat rate, calories burned count, steps walked. [10]

Life cycle of IoT:

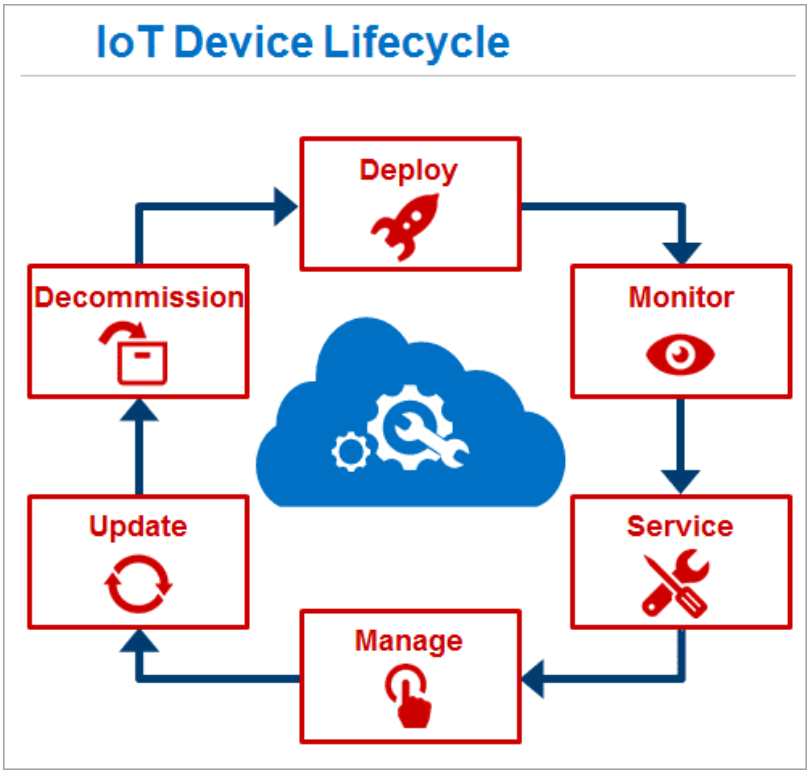

Fig. 1: IOT Device Lifecycle

Lifecycle of development is shown in figure 1 and it has following phases:

1. Deployment of each IOT device.
2. Monitoring - observe and check the progress or quality.
3. Servicing – Test and Maintain or repair if necessary.
4. Managing
5. Updates
6. Decommissioning

Four steps to collect the more values from IoT data:

In recent years IoT journey has evolved rapidly. Following four steps needs to execute every organization to get more useful data from IoT devices.

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 the patterns understand from data, visualization and increase value to the business is easier.

Step 3: Advance to analytics

IoT journey focuses on making data even smarter through analytics. Using Analytics, we can combine real-time IoT device data with existing, long-term and historic information. By spotting patterns and making predictions, and adopting new practices it is easy to avoid risk and avoid potential problems.

Step 4: Infuse with Artificial Intelligence

IoT uses Artificial Intelligence to find good insights from data. Machine learning will help you clean up the data, distil it down to the most relevant pieces, and find the seemingly desperate data sets that actually matter.

Using these steps, more synergies can be found from data. It also helps identify useful data and not useful data. As you refine the process helps to perform more sophisticated tasks like forecast models, apply predictive maintenance and anomaly detection. This means gain the right, rich context that helps to make sense. Problem solving is easier using these techniques and perhaps even identify new opportunities and business models.

Machine Learning:

Machine learning enables machines to make data driven decisions rather than being explicitly programmed to perform specific tasks. These programs or algorithms are designed to learn and improve over time as 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.

In recent, Machine Learning is a trending technique in the technology world and for good reason, it represents a major step forward in how computers can learn.

How ML Works?

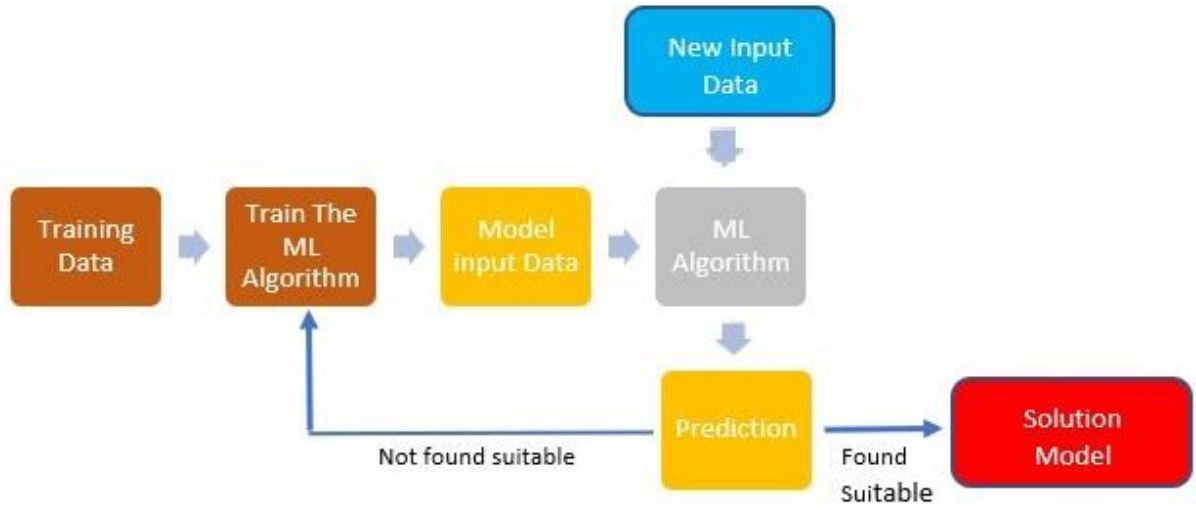

Fig. 2: Machine Learning Phases

Figure 2 shows the general machine learning phases. Each phase is explain below.

Training Data: Training data is a very large dataset used to teach machine learning models. Training data is used to train prediction models that use machine learning algorithms to extract features relevant to specific business goals.

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

Machine Learning 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 provision of massive data, it's far ultimately possible to build predictive Model that may learn and analyze complex data to find useful insights and deliver more accurate outcomes. Machine learning is important as it gives organizations a view of tendencies in purchaser behavior and operational business pattern, in addition to supports the development of recent products.

Why Machine Learning is so important?

1. **Increase in Data Generation:** Data is being generated in excess and we need a way to structure, analyze and gain useful insights from the data. Here is Machine Learning comes in picture. ML uses data for problem solving and finding solution to the most complex tasks that organizations faces.
2. **Improve Decision Making:** Machine Learning uses various algorithms for making better business decisions. Figure 3 shows the overall decision making process using machine learning.

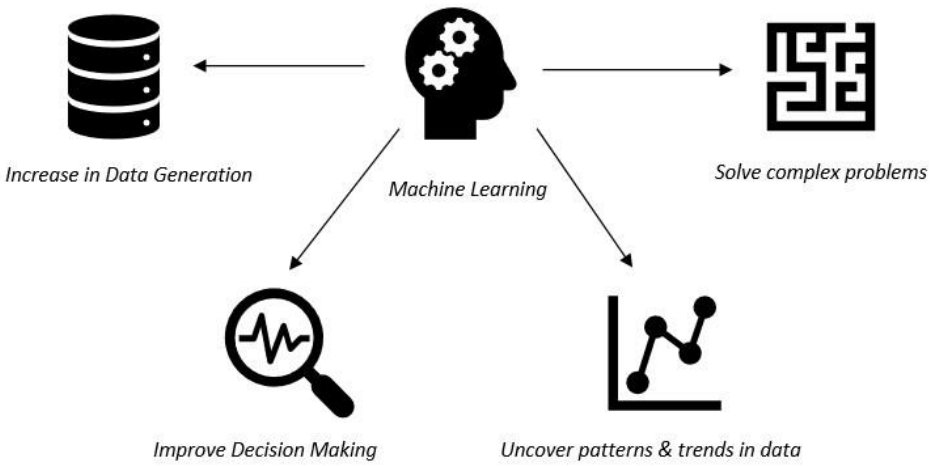

Fig. 3: Decision making using machine learning

3. **Uncover patterns & trends in data:** Machine learning is usually based on Finding hidden patterns and extracting key insights from data. Using Machine Learning dig we can explore the data at a minute scale by building predictive models and using statistical methods. Understanding data and extracting patterns manually is time consuming task, but Machine Learning algorithms can perform such complex and time-consuming computations in less than a second.

4. **Solve complex problems:** Machine Learning can be used to solve more complex problems by detecting the genes linked to the deadly ALS disease to building self-driving cars.

Types of Machine Learning

Figure 4 and table 1 shows types of machine learning algorithms. Machine learning is sub-categorized to three types:

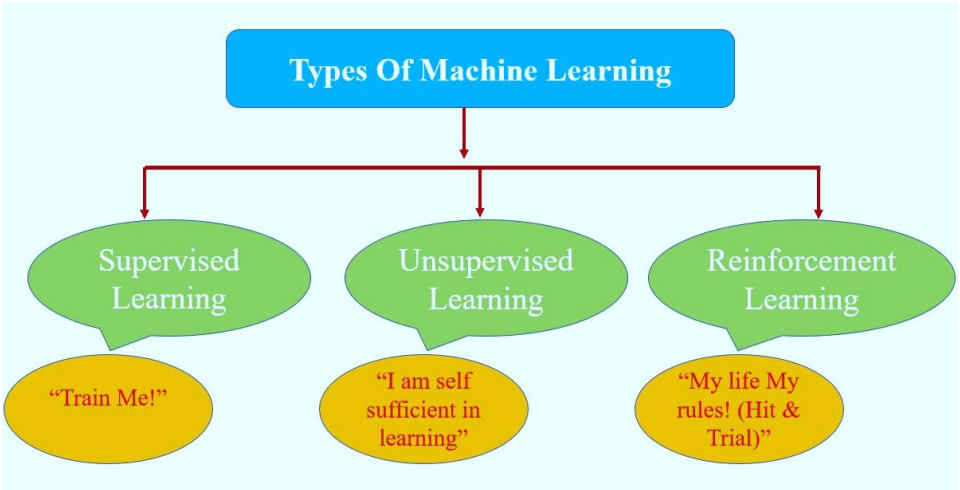

Fig. 4: Types of Machine Learning

Table1: Machine Learning Algorithms

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:

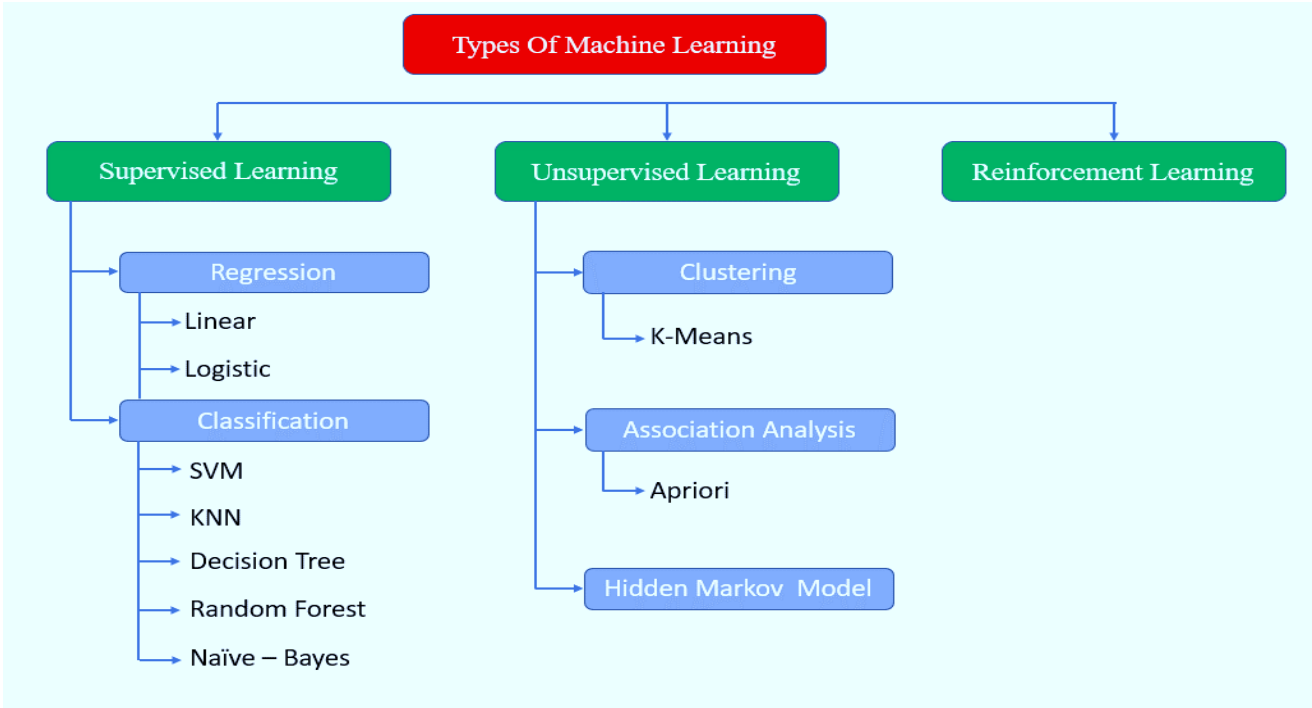

Fig. 5: Types of Machine Learning

1. Linear Regression

This algorithm used to estimate actual values based on continuous variables. Two kinds of variables, dependent variables and independent variables are correlate with each other by fitting straight line. This best fit straight line is called as the regression line and is represented by the equation in figure 6.

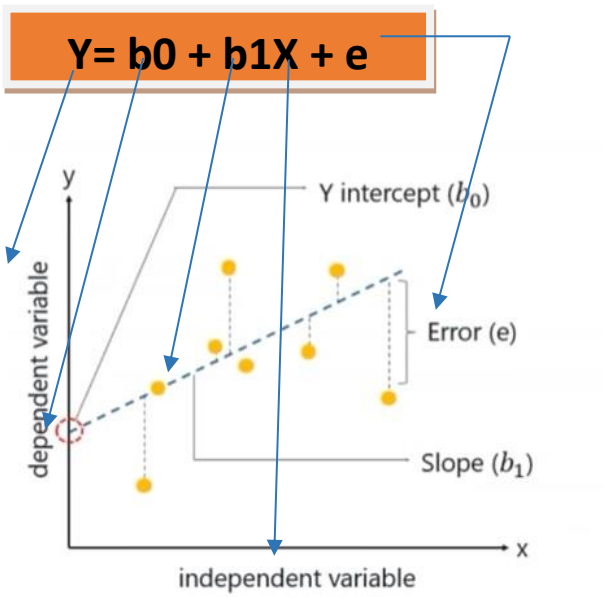

Fig. 6: Linear Regression

There are two types of linear regression:

1. Simple Linear Regression: In simple linear regression, there is relation established between one dependent variable and only one independent variable
2. Multiple Linear Regression: In Multiple Linear Regression relation established between one dependent and multiple (more than 1) independent variables.

2. Logistic Regression

Logistic regression is a binary classification algorithm. It is used to estimate output in binary form by using given set of the independent variables. We can also say that it used to predict the probability of occurrence of an event by fitting data to 0 and 1. Figure 7 shows the logistic regression.

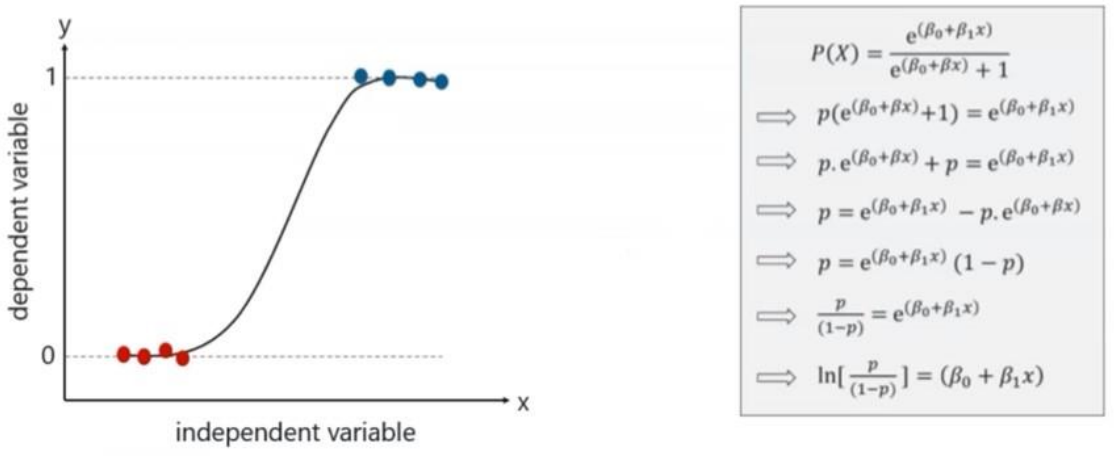

Fig. 7: Logistic Regression

3. Decision Tree

Decision tree algorithm is a supervised learning technique which is commonly used for classification problems. It can use for both categorical as well as continuous dependent variables. In this algorithm, the dataset is splits into two or more homogeneous sets. This is done based on the most significant parameters/ independent variables to form the most diverse groups possible.

As shown in figure 8 given below, children are classified into four distinct groups based on multiple parameters to know 'if children will play or not'. To split the dataset into different heterogeneous groups, it uses various techniques like Gini, Information Gain, Chi-square, and entropy.

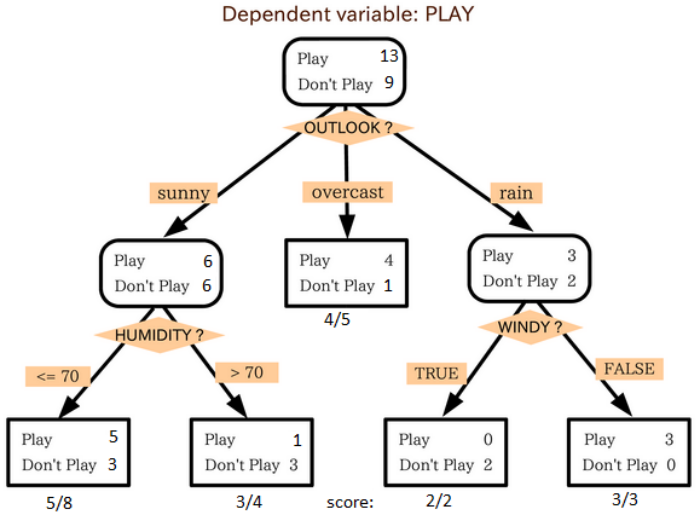

Fig. 8: Decision Tree

4. SVM (Support Vector Machine)

SVM is a classification technique used to plot each data item as a point in n-dimensional space with the value of each feature being the value of a particular coordinate. SVM is one of the best classification algorithms which is used to give best result on small amount of data.

For example, if we had only two characteristics such as an individual's height and hair length, we would first graph these two variables in two-dimensional space, where each point has two coordinates. These coordinates are called support vectors**.**

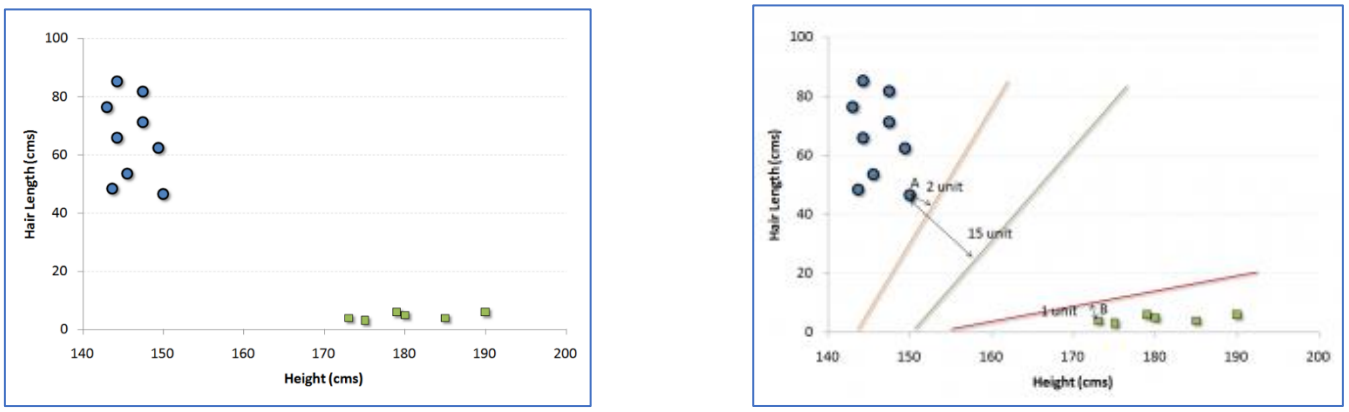

Fig. 9: SVM

Now, find a few lines that divide the data between two groups of different classified data. This will be the line such that the distance from the nearest point in each of the two groups is the furthest.

In the above example shown in the figure 9, the line that divides the data into two groups of different order is the black line, because the two closest points are furthest from the line. This line is our classifier. Then, depending on where the test data is on either side of the line, so, we can classify the new data into classes.

5. KNN (k- Nearest Neighbours)

KNN is used for both classification and regression. It is generally used in classification problems in the companies. KNN classifies and store the cases as per majority matching characteristics of its k neighbours. KNN measures distance using distance functions to specify the class to the new case.

The various distance functions used to calculate KNN distance are Euclidean, Manhattan, Minkowski which are used for continuous function and Hamming distances (Hamming) uses categorical variables. If K = 1, then the case is simply assigned to the class of its nearest neighbour. At times, choosing K turns out to be a challenge while performing kNN modelling.

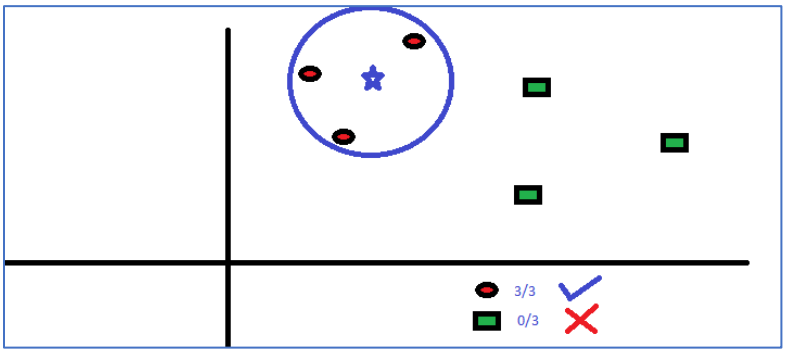

Fig. 10: KNN

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 an ensemble classifier that consists of many decision trees and outputs the class that is the mode of the class's output by individual trees. The method combines Breiman's "bagging" idea and the random selection of features. It introduces two sources of randomness: “Bagging” and “Random input vectors”. Bagging means each tree is grown using a bootstrap sample of training data and Random input vectors means at each node, best split is chosen from random sample of m try variables instead of all variables

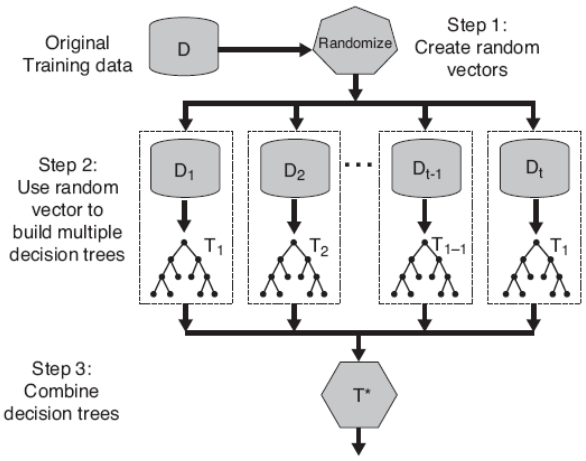

Fig. 11: Random Forest

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. Naive Bayes

Naïve Bayes classification technique is 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.

Bayes' Theorem finds the probability of an event occurring given the probability of another event that has already occurred.

Bayes' theorem is stated mathematically as the following equation:

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

Where A and B are events and P (B)! = 0.

Basically, we are trying to find probability of event A, given the event B is true. Event B is also termed as evidence. P (A) is the priori of A (the prior probability, i.e. Probability of event before evidence is seen). P (A|B) is a posteriori probability of B, i.e., probability of event after evidence is seen.

Bayes Theorem is basis for Naïve Bayes Classifier

$$P(y|X) = \frac{P(X|y)P(y)}{P(X)}$$

Where, y is class variable and X is a dependent feature vector (of size n) where:
$X = (x_1, x_2, x_3, ..., x_n)$

Naïve Assumption:

The fundamental Naive Bayes assumption is that each feature makes an:

1. Independent
2. Equal

Contribution to the outcome.

With above naïve assumption, we reach to the result:

$$P(y|x_1, ..., x_n) = \frac{P(x_1|y)P(x_2|y)...P(x_n|y)P(y)}{P(x_1)P(x_2)...P(x_n)}$$

Now, we need to create a classifier model. For this, we find the probability of given set of inputs for all possible values of the class variable y and pick up the output with maximum probability. This can be expressed mathematically as:

$$y = argmax_y P(y) \prod_{i=1}^{n} P(x_i|y)$$

So, finally, we are left with the task of calculating P(y) and P (xi | y).

P(y) is also called **class probability** and P (xi | y) is called **conditional probability.**

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:

Fig. 12: Machine Learning Algorithm Phases

- **Training Phase:** The process of training a Machine Learning model involves providing a 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 Machine Learning:

- **Traffic Alerts (Maps)**

Google Maps is an application used for directions and traffic assistance. But how does he know that?

This is a combination of people currently using the service, historical data of this route collected over time, and some tips obtained from other companies. Everyone who uses maps provides their location, average speed, and route, which helps Google collect massive traffic data, allowing them to predict oncoming traffic and adjust their behaviour. Your submission according to this data.

- **Social Media (Facebook)**

One of the most popular uses of machine learning is to automatically suggest tagging friends on Facebook or any other social networking platform. Facebook uses facial recognition and image recognition to automatically find a person's face that matches its database, and therefore recommends that we tag that person based on DeepFace.

- **Transportation and Commuting (Uber)**

Uber is one of the machine learning apps used for transportation and commuting. It uses a machine learning algorithm overlaid on historical trip data to make more accurate ETA predictions. With the implementation of machine learning, they saw 26% accuracy in shipping and receiving.

- **Product Recommendations (Amazon)**

When we search for a product even if we don't buy it, recommendations are always predicted on many websites related to your search. This happens because Google tracks your search history and recommends

ads based on your search history. It is one of the most interesting applications of machine learning. In fact, 35% of Amazon's revenue is generated from product recommendations.

- **Virtual personal assistants**

As their name suggests, virtual personal assistants help find useful information, when requested by text or voice. Some of the key applications of machine learning here are:

• Speech recognition

• Speech-to-text

• Natural language processing

• Text-to-speech

• Application-virtual- assistant-for-machine-learning

To answer a question asking the wizard, it searches for information or recalls your related queries to gather information. Recently, personal assistants used in chatbots are deployed in various food ordering applications, online educational websites and also in delivery applications.

- **Self-Driving Cars**

This is one of the coolest Machine Learning apps. Machine learning plays a very important role in self-driving cars. The leadership of this business and its current artificial intelligence is led by hardware manufacturer NVIDIA, based on unsupervised learning algorithms.

- **Dynamic Pricing**

Setting the right price for a good or service is an old problem in economic theory. There are countless pricing strategies depending on the desired goal. Whether it's movie tickets, plane tickets or taxi tickets, everything is priced flexibly.

Uber's primary use of machine learning comes in the form of price increases. If you're late for a meeting and need to book an Uber in a crowded area, be prepared to pay double the normal fare. Even for flights, if you go during the holiday season, chances are the price will be double the original price.

- **Google Translate**

Google's GNMT (Google Neural Machine Translation) is a neural machine learning technology that works across thousands of languages and dictionaries, using natural language processing to provide the most accurate translations for any given dictionary. any phrase or word. Since the tone of the words is also important, it uses other techniques such as POS Tagging, NER (Named Object Recognition) and Chunking. It is one of the best and widely used machine learning applications.

- **Video Streaming (Netflix)**

Netflix is one of the best machine learning apps.

The Netflix algorithm continuously collects huge amounts of data about user activity such as:

• When you pause, rewind or fast forward

• The day you watched the content and weekend movies

• Date and time you watched

• When you pause and leave content

• Rating given, Search

• Browsing and scrolling behaviour

And more. They collect this data for everyone to follow they have and use their recommendation system and many machine learning applications.

- **Fraud Detection**

Fraud detection is one of the most essential applications of machine learning. The number of transactions has increased due to the wide variety of payment channels - credit/debit cards, smartphones, multiple wallets, UPI and more. At the same time, many criminals have become adept at finding loopholes.

Every time a customer completes a transaction, the machine learning model thoroughly analyses their records for suspicious patterns. In machine learning, problems such as fraud detection are often presented as classification problems.

How to use Machine learning in IOT?

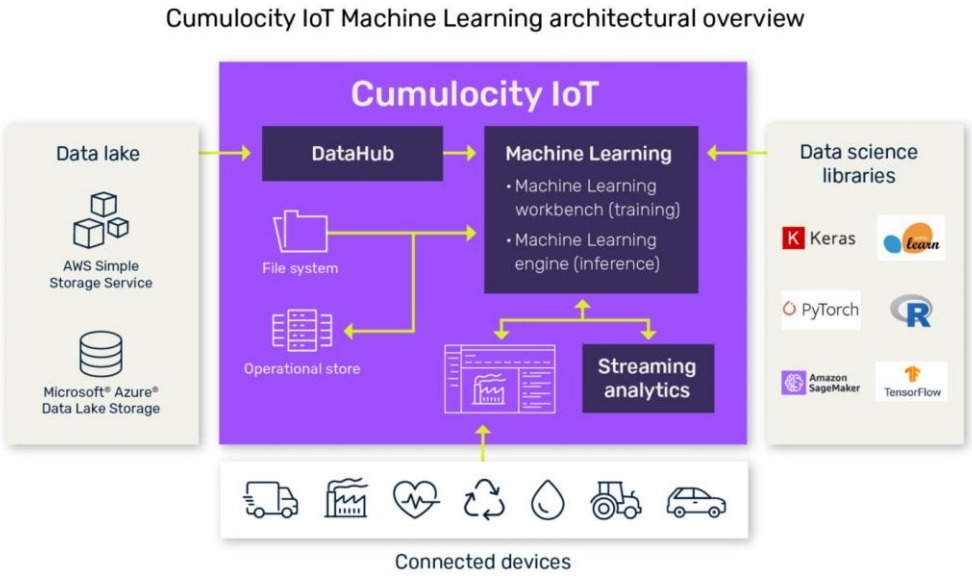

Fig. 13: Machine Learning with IoT

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

To understand which algorithm is best suited for processing and decision making on intelligent data generated from IoT objects, it is essential to consider the following three concepts.

1. IoT application

2. IoT data characteristics

3. Data-driven vision of machine learning algorithms.

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

There are eight main groups of algorithms that apply to IoT data. These algorithms are classified based on their structural similarity, the type of data they can process, and the amount of data they can process in a reasonable amount of time [9].

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

After looking at the real-world views on how IoT data is analysed by more than 20 authors, many important and profound findings have been revealed about the characteristics of the data. To better understand IoT smart data, samples must be extracted and the generated data interpreted. Cognitive algorithms take care of the interpretation and matching, just like the human mind. Cognitive IoT systems learn from previously generated data and improve when performing repetitive tasks. Cognitive computing acts as a prosthetic for human perception by analysing large amounts of data and answering questions humans may have when making certain decisions. Cognitive IoT plays an important role in enabling meaningful patterns to be extracted from the generated IoT smart data [9].

Application of IOT:

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

Table 2: IOT Applications with Machine Learning Algorithms

Sr No.	IOT Applications	IOT Devices/ Components	ML Algorithms and Techniques	Performance Measurement 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. Raspberry pi	1. Linear Regression, 2. SVM 3. Neural Networks		[3]

4	Health Care Monitoring System at war field	1. Adruino 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 was chosen as our main IoT use case for three reasons: First, of all the articles reviewed, 60% focused on the smart city sector. Second, smart cities cover many other IoT use cases. Third, there are many open datasets for smart city applications that researchers can easily access. In addition, the Support Vector Machine (SVM) algorithm is implemented on the smart traffic data of the city of Aarhus to predict the traffic hours of the day. By answering the above questions about IoT smart data and machine learning algorithms, we will be able to choose the best machine learning algorithm that can process the characteristics of IoT smart data. Unlike similar surveys on machine learning and IoT, readers of this article can gain an in-depth and technical understanding of machine learning algorithms, IoT applications, and the characteristics of IoT data, as well as engineering and simple [9].

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