Machine Learning with Internet of Things: A Comprehensive Survey

Akanksha Kochhar[1], Prerna Sharma[1]

[1]Maharaja Agrasen Institute of Technology

Email: akankshakochhar@mait.ac.in

prernasharma@mait.ac.in

ABSTRACT

Rapid evolutions in the hardware and software that uses devices which are used in technologies in communications have introduced the concept of IOT that is Internet of Things. IOT involves the connection of devices with one another in such a way, so that they can share information with each other and gather large number of facts on daily basis. But the disadvantage involved in the analysis of the data collected, extraction of the information and creation of the applications is that all these require human interference. IOT devices must be intelligent which can create automated smart applications introducing the concepts of Machine Learning with IOT can led to huge improvements in the application.

In this paper a review is conducted on the existing work done by the researchers in using Machine learning with IOT which includes the application areas. Also the major challenges which are faced in using Machine Learning with IOT are briefly discussed.

The aim of this paper is to gain knowledge about how both the technologies are used together and applied in the smart environment.

Key words: Machine Learning, IOT, smart applications.

I. INTRODUCTION

IOT involves the connection of devices with one another in such a way, so that they may exchange data with each other and bring large number of information on daily basis. IOT devices are programmed to perform specific actions, it may be to trigger an action on the basis of previous feedback collected or on the basis of some predefined condition. But the disadvantage involved in the analysis of the data collected, extraction of the information and creation of the applications is that all these require human interference[1].

The work of IOT is to perform connections of devices and communicate with other devices with the human interference however this human interference must be replaced and these IOT devices must be autonomous.

Removal of human interference means the IOT devices have to take the decisions which are text based and experience from their collected data. This need where IOT devices must be autonomous is termed as cognitive IOT[21] . IOT devices must be intelligent which can create automated smart applications where allocation of resources, communication between devices, operating networks will be autonomous[20].

Introducing the concepts of Machine Learning with IOT can led to huge improvements in the application. Machine Learning can be applied in different fields. IOT devices depends on the information that is if we increase the IOT devices the information will also be increased. So IOT applications has to deal with Big Data. The old databases cannot handle the Big Data . Some different infrastructure is required to handle structured and unstructured data by analyzing them and applying different techniques.

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By the introduction of IOT has made our lives easier and have immensely became an important part of life. Many applications like smart city, transportation, smart healthcare have been developed. With the involvement of intelligence in IOT has become more useful. This combination of both the technologies will decide in future when you have to get up, at what time you should eat, at what time one should travel, when to work, when to sleep and all our daily routine work will be carried out by these technologies. Everything and anything will be determined by the use of these technologies.

IOT has changed the world to the smart world. World has head towards advancement where automatic learning3 from the data is done and adopting intelligence has given best results. The Learning process of Machine Learning techniques needs a lot of data and hence this work is done by IOT which generates data in large forms. Many goals can be achieved by integrating these techniques and has made the human life much simpler[4]. Integration of IOT with high capable process and reliable communicating objects is done. Machine Learning and IOT have both reached at hype and both are enhancing the human lives.

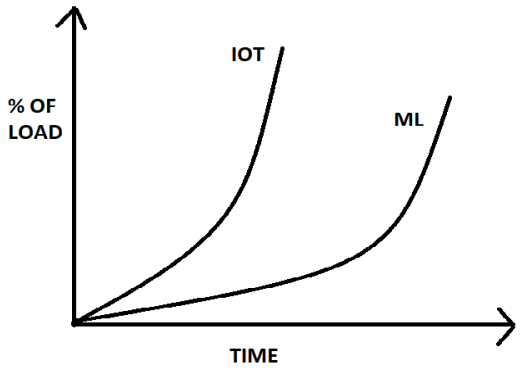

Fig1: Line graph showing the percentage of load of IOT and Machine Learning with respect to time[6]

Here, IOT is Internet of Things

ML is Machine Learning[6]

Machine Learning is the process of making new facts through analysis and development can be done using the learning process[30].

In the modern time the utilization of IOT has immensely growing with time. In order to have a smart environment IOT is implemented with Machine Learning. The usage of Machine Learning has increased recently with time. IOT devices are used to build up interaction between the devices and exchange data between real world objects. And in present time the applications based on human or machine interaction because different sensors and cameras are used for extraction of information[17]. So this information must be represent in human readable form. So Machine Learning mechanisms are implemented with IOT[31].

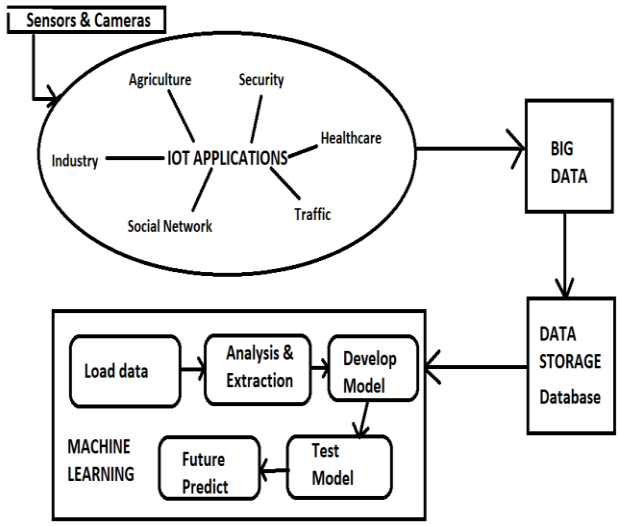

Fig2: Diagram showing the operation of Machine Learning with the IOT devices[6].

This figure shows how machine learning with IOT is operational. This system has three phases[6]:

- IOT Application: The sensors and cameras are firstly connected to the IOT applications. In this phase the data is collected and monitored through different areas with the help of sensors and cameras. IOT have applications in many areas which involves agriculture, security, health, traffic, industry, social networking, industry.

- Database: After the collection of data is done the analysis on the data starts and it changes the data into Big Data. The data which is analyzed that is the Big Data is

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then placed in the database or the cloud and this data is transferred into the third phase.

- Machine Learning: Machine Learning techniques are applied on the data which is stored in the database. Machine Learning operations take place in a way that first the data is loaded from the database and then the analysis and extraction of useful data is performed. After this a model is developed and then the testing of the model begins. When the model passes through the testing phase the prediction of future is done.

II. LITERATURE SURVEY

In many researches, the researchers have worked upon differant models, schemes and methods by using IOT applications using Machine Learning and improved the quality of work.

Meiden et al.[7] proposed a method in which the classification and identification of IOT devices in the network was done using supervised method of Learning. By using this method the network can be secured. Identification of IOT and non IOT devices in traffic environment was done using supervised Machine Learning algorithm. This technique involves the collection of trained data set. Threshold values and session sequence size was calculated through the dataset and identification of IOT and non IOT devices was done using this technique.

Joshi et al.[8] proposed a model which is used in agriculture, using IOT. Here, with the use of sensors, the soil and environment properties are sensed. Also the detection and prevention of weed and crop can be done using this model. A Machine Learning algorithm that is Bayesien statistical algorithm is used to estimate about how to protect the crop. Object Detection algorithm is performed where image processing is done by taking different images of weeds. Different images of weeds and soil are collected using different technique with the help of sensors to decide about how to prevent weed growth and helps in the farm maintenance.

Kumar et al.[9] has worked on the scheme where blind people can freely travel indoor and outdoor and can avoid the obstacles in the path, also they can recognize the person in front of them. This scheme involves first the smart navigation system and also the face recognition model. The navigation model is connected with the android based smart phone which is connected to the sensors. Smart phones with GPS helps in navigating the blind people to their destination and for that they can use Text to Speech(TTS) system so that it gives audio response. The sensors are connected with Bluetooth which can be used as microcontroller where sensor will collect the data and convert into speech. After that the face recognition can be used which uses the Artificial Neural Network(ANN) as the Machine Learning technique which can recognize the face on the basis of past data. This technique can learn the face of people and based on that the system will give audio response to blind people.

Truongi et al[10]. also proposed a model which makes use of IOT devices which contains the data stored in cloud. When this data is used with Machine Learning algorithm it is used in detection and prevention of fungi in the crop field. Data is stored in the IOT systems like air temperature, humidity, rainfall, wind speed. These algorithms are used to predict the presence of harmful fungal diseases present in the crop. In short, IOT devices collect the data and identifies the fungal in crop using Machine Learning algorithms.

Ghayvat et al[11]. developed a scheme for smart home. Smart home means that safe environment is provided for the well being of the people. Sensing technology can make home smart. The data is collected in the database and unwanted data is filtered out.

Elias et al[12]. developed a scheme which design and implements the wildlife monitoring system with the help of IOT, Machine Learning, and Image Processing. These techniques are used for Image Recognition. Images of animals are collected as training data. This system will be used to identify the animals using Machine Learning and IOT.

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Anjomshoa et al[13]. presented a scheme for identification of the social behavior of a person using Machine Learning. The behavior pattern of the person of social network is identified. With the help of smart phone sensors the person's usage of data, sessions starting and ending time, number of applications accessed are recorded in the cloud server and the data is trained using sliding window of data which is used for generating patterns about the behavior pattern of a person on social network.

Devi et al[14]. proposed a scheme in which a Machine Learning based congestion prediction algorithm is used. Cameras and seensors are used to performthe traffic analysis on the roads. After the analysis the congestion on roads is predicted using Linear Regression, a Machine Learning algorithm. The test data is collected in a way that if the mean speed of the vehicle is increased in comparison to the threshold value then the road is congestion free.

P.Kumar et al[15] proposed an IOT which is uses health monitoring system. In this the data is collected and then it is transferred to the database for storage and on the basis of past data prediction is performed using Logistic Regression. IOT devices are used to collect data from the human body and after storage Linear Regression algorithm is used to decide few parameters like blood pressure, body temperature, heartbeat of the person.

III. APPLICATIONS OF ML IN IOT

IOT has changed the world to the smart world. World has head towards advancement where automatic learning from the data is done and adopting intelligence has given best results[16]. The Learning process of Machine Learning techniques needs a lot of data and hence this work is done by IOT which generates data in large forms. Many goals can be achieved by integrating these techniques and has made the human life much simpler. Integration of IOT with high capable process and reliable communicating objects is done. Machine Learning and IOT have both reached at hype and both are enhancing the human lives.

Both these technologies are used in many application areas like:

1. SMART TRANSPORTATION

As the technology is heading towards advancement new applications are created just to make the lives of the people simpler and better. With the latest technological improvements the cities are getting smart. Also the introduction of IOT can be seen in the field of transportation and development of intelligence in transport leads to Intelligent Transport Systems (ITS). Smart cities have aimed for enhancement in transports and helped in areas like[1]:

(i) Route optimization or Navigation

Navigation is used to provide the best direction to reach at a location, in order to lessen the traffic congestion. By this both the travelling time and vehicles emission can be reduced. [22] As the number of vehicles are increasing the traffic congestion is subject to a common concern. By using route optimization one can estimates the time required to reach the destination, also it detects the traffic congestion on the road. It can provide the optimal route options in order to cut short the travelling time and reach the destination faster.

(ii) Parking Reservation System

This is a smart system which allows the parking of more number of cars by maximizing the parking lots availability and capacity. A smart parking approach is used which uses IOT based parking and a smart signboard which is used to carry related content.[23] This system also minimizes the searching time of the person to park the car. Smart cameras are used in parking lots to detect free parking space[24].

Ultrasonic sensors are used with embedded Wi-Fi art parking to communicate with the cloud server[25].

(iii) Smart Lights

Smart Street lights (SSL) are used to diminish the consumption of energy. A

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smart lighting system was proposed in which each lamp post will be connected with a Wi-Fi so that it can be used to send all the collected data to the server[26]. Smart Lights can be made by attaching a light sensor with the street lights. The light sensors will be able to detect sunrise and sunset and can switch the lamp on/ off. Also it can detect the cars or the passersby and light the lamp to lessen energy consumption.

(iv) **Avoid accidents**

Systems are designed which can help in detection of the surface anomalies on the roads. It can be detected on the basis of input data received from the sensors which are attached to the car or may be connected to driver's phone. An IOT cloud platform was proposed which was used to enable the traffic visualization and provide notifications about the slowdown of the traffic in order to prevent the accident[27]. Accidents can be detected, avoided or prevented by these sensors. Autonomous real time detection of accidents can be done by analyzing data which is obtained from road sensor using Regression tree Machine Learning algorithm[28].

(v) Intercommunication among vehicles

IOT devices are used in communication from one machine to another is also one of the most important application which is developed so that vehicles can communicate amongst each other and can transfer useful data in the vehicle social network.

2. HEALTHCARE

In Medicine the past and current practice is that the doctors prescribe the medicines on the basis of their experience according to the symptoms described by the patient. The drug adviced by the doctor according to his experience does not respond the same way for each person. For some it may lead to quick recovery or for some it might lead to side effects. In current trends of medication there may be many reasons like people are more cautious regarding medications and there side effects, growing culture of lack of confidence by the patients who suffered the side effects on the medical system[2].

Personalized healthcare is one solution which can raise the quality of care and also can diminish the cost. Mainly it can be used to predict the best therapy for the patients without any side effects[29].

One of the case study conducted in personalized healthcare with IOT is Personalized Diabetic Management. This case study deals with patients suffering from diabeties. Every person have different food habits and the food intake also varies from person to person.

Dietry advice must be provided to the patient suffering from blood sugar by the use of Bluetooth so that the patient is aware of the quantity of food that should be consumed and advice the patient through notifications on personal mobile phone through which the device is connected[19].

Personalized Healthcare plays another important role in hospital readmission. A survey was conducted in past which says one- fifth patients are readmitted to the hospital after the surgeries are conducted may be because of improper care. Out of those one-third readmissions can be stopped if proper healthcare planning is conducted for the patients.

Personalized Healthcare involves the use of both Machine Learning and IOT in:

- **Diagnostics Care**: In this field some diagnostics of the patients is carried out by bio module devices. These type of devices will help to overcome the drawbacks of not having well qualified doctors, pathological trainers, and proper medical instruments in rural and remote areas and in areas where accessibilty and availability of doctors is difficult. So using this instrument can help in the growth of personalized healthcare.

- **Assistive Care**: These services have a great impact on many lives as the technology is heading towards advancement . But this service will have to address the issue of usability, affordability and availability. Its drawback is that the devices

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are not secured so its leads to privacy and authentication issue and they can be hacked and altered if proper security is not provided.

- **Monitoring and Alarming**: The patients after they are released from the hospitals can be monitored by the use of personalized healthcare. Monitoring of health status can be done by the use of IOT devices. Also the health information of patient is put into the cloud server and then the predictive analysis can be performed and alarm the patients through phone or some device.

The BAN consist of sensor which collects the information about the patient's heart rate, ECG, sugar, pressure and collects it in the cloud server. The database is accessed by all the parties involved in it. And then the Machine Learning technique like decision making are used to determine the risk factor of patient, improvement in health and predicts the future on the basis of past experience. These algorithms can analyze the situation on the basis of dataset trained . Dataset can be used to predict future trend on the basis of past. But the data should not be noisy, dirty or incomplete as if it happens it won't give the accurate suggestions.

3. SMART WATER MANAGEMENT

India is a developing country which consists of 17.50% of the total world population. So in a developing country a trend of new technologies is flourishing towards the generation of smart cities. A smart city is one which uses the communication and information techniques and reduce the cost of resource consumption. As we are familiar with the fact that resources are limited . So essential urbanization is necessary[3].

Urbanization has led to increase in economies but there are some impacts which it creates on environment, water, transport and medical concerns. Environmental issues may include the increasing demand in usage of water, the quality of air and water is degraded, drainage issues, the frequency in the occurrence of the flood has immensely increased and the cost in the administration of city is also at its peak. These growing concern have led to the use of IOT in this field. Variety of objects like sensor devices can be attached to Internet and can transfer information with each other. As IOT is considered to be an emerging technology, it can be used in setting up the smart city.

The IOT sensor device will collect the data from the surroundings which may include the identification address of the sensor.

The data which is collected is analyzed by the application and knowledge is infer from it.

Necessary decisions are taken and information is transformed to all the devices which are connected. Now using of Machine Learning techniques will extract the data from IOT. This information will improve the system's performance

Smart city will have smart water management which will have

- Increasing demand of water : The management in the increasing demand of water can be optimized in cost effective manner by prediction algorithm. Forecasting can help in better planning to meet the demand of resources in future. Input parameters involves make use of models and collect information like temperature, humidity and rainfall.

- Detection of the water quality anomalies: It is very important to keep a check on the quality of water. Artificial Neural Network and fuzzy logic systems can help in determining that. The water quality can be measured by the turbidity level, content of chlorine present in it, ORP, nitrates, PH, temperature and conductivity Hybrid Model is used to predict the quality of water and the oxygen content present in it.

Anomalies are the faults which are present which makes the pattern of the data unusual like outlier. Clustering technique is used for detection of anomaly by finding the neighbor which is nearest and the gap to every data is measured. Data will form big

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clusters and anomaly will form little clusters.so using this Machine Learning algorithm we can find the anomalies in the content of the water.

4. SMART HOMES

A smart home is presented which is developed using the different Machine Learning techniques[32].

Home can also be made smart by the detecting the human presence, recognization of any activity, home appliances be self organized, air conditioning controller on the basis of the user's comfort are all enabled by the use of Machine Learning algorithm[33]. This in turns makes the home automated[5].

To recognize an activity it uses the embedded classification in order to operate the accelerometer data that is applied on the IOT device and not stored it cloud server[34].

Multi regression algorithms helps to forecast the load of heat in a building which can help in consumption of energy[35].

5. SMART AGRICULTURE

To reduce the maintenance cost and improve productivity in agriculture IOT has been used[5]. To detect the pests and diseases in plants a convolutional neural network is used[36]. The dataset of the images of plants can be captured using the smart phones and then they are uploaded on the server to conduct the classification. Linear vector classifier algorithm helps to identify the diseases present in the crop with the help of dataset[39]. In smart agriculture the diseases in the plants are detected and the environmental conditions like temperature, humidity, moisture content in soil can be maintained[37].CNN algorithm of Machine Learning helps to identify the flowers present in the dataset and is provided to the farm for monitoring of growth rate and environmental parameters. [38]

A case study was conducted on the grape plant when environmental parameters like temperature, humidity, leaf wetness was captured. The dataset is collected and the grape diseases are detected out and the farmer is informed about the crop disease.

IV. MAJOR CHALLENGES IN USING MACHINE LEARNING WITH IOT

The researchers face few challenges in using the IOT which consists of preparation and then the processing data. The threat of security can come from anywhere. The major challenges of IOT and Machine Learning are[4]:

1. **Standards and platforms**
   IOT systems requires the need of processed data and decision making with the IOT edge by the using ML algorithms. IOT devices have limited number of resources which involves computational capacity, memory, energy. So far a more compatible and efficient hardware is required to carry out the Machine Learning algorithm[40]. Also the algorithms which are used needs to be optimized so that power consumption , memory can be efficiently used[5].

2. **Increased computational cost**
   As the architecture of IOT has a hierarchical structure. The hierarchy starts from embedded devices then the gateway then the fog computer and lastly the servers. Every stage will carry out some computation. These computations when reaches the higher level will introduce a trade-off and the communication and computation cost will increase[18].

3. **Issue of privacy and security**
   The Machine Learning technique other than the reinforcement learning requires huge number of data to store in the cloud server[41]. The cloud server is accessible to all the servers which are connected to it so the privacy and security of data is at risk.

4. **IOT needs to develop with effective ML systems**
   IOT sensors simply help to collect the data but when they are used in combination with

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Machine Learning serves many advantages. But Machine Learning is itself a very broad field so the drawback that IOT device suffer is that they need to develop with learning systems which require different memory capacity , hardware and procedures.

5. **Enhancing the standards of IOT**
   IOT devices when used with different Machine Learning algorithms needs to improve the standards so that the compatibility of the devices matches with the Machine Learning algorithms[43].

6. **Trust on data**
   ML algorithms are performed on the facts collected by the IOT sensors[42]. So it is mandatory to trust the data and secure so that the machine learning algorithms can be applied efficiently.

V. CONCLUSION

This article reviews the use of IOT devices which is used for data collection and processing using the sensors but a need of human intervention is required. To remove that need the introduction of Machine Learning algorithms was done. Also both the technologies are at hype at the present era and by integrating them we can use them in many domains like smart transportation, smart cities, industry, healthcare, water management, supply chain management etc. all these applications requires the use of IOT devices and the Machine Learning algorithms.

Also the latest trends of IOT and Machine Learning was shown in the graph as they are rapidly increasing with time. The architecture which shows the used of both the technologies was designed.

The latest works of the researchers in this field was concluded and the challenges which the integration of both these technologies face have been discussed in detail.

To sum up we can say individually both these technologies are flourishing, and by integrating them we have enhanced the use of both of them.

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