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Role of Machine Learning in Internet of Things Enabled Smart Cities

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***Abstract*—**This paper presents the idea of Internet of Thing (IoT) for the infrastructure of smart cities. IoT has been visualized as a communication prototype that incorporates myriad of digital services. The various components of the smart cities shall be implemented using microprocessor, microcontroller, sensors for network communication and protocols. IoT enabled systems have been devised to support the vision of smart city and to exploit the currently available precocious communication technologies to support the value-added services for function of the city. Due to volume, variety, and velocity of data, it requires analysis using Big Data concept. This paper presented the various techniques used to analyze big data using machine learning.

***Keywords*—**IoT, smart city, embedded systems, sustainable environment.

I. Introduction

IoT interfaces the objects of the real world to the virtual world. IoT enabled system allows non-living object to intact with each other with the help of data communication. IoT enabled system is able to communicate on real time basis as long as it is connected on network devices. Companies today are coping with the IoT, that is nothing but a large network of physical devices that encompasses devices, industrial equipment, sensors, and extended products that is way beyond the typical computer networks.

The Urban IoTs have been designed to support and implement the vision of Smart City. The urban IoT focuses on exploitation of latest communication technologies. This will help them to provide value-added services for a better administration of the city and comfort of citizens [1].

A smart city is comprehended to be a system of systems. The dynamic nature of a city can be depicted by an architectural model that illustrates the multifarious structure of elements. A smart city has been defined as an amalgamation of technology with economic growth and citizen welfare for a sustainable environment. A feasible smart city model should embody the multitude aspects of smartness. Hence, it is multi-dimensional and signifies the interaction across multiple domains.

In a smart city everyone including the authorities, administration and the citizens, all are provided with access to various real-time information about the environment and local objects on which the necessary decisions and actions are planned.

The physical virtual objects or 'Things' are integrated into an information network infrastructure. Such entities have distinct attributes, identities, personalities. They make use of intelligent interfaces so as to coalesce into an exhaustive network framework. These global networks boast of skills based on standard and interoperable communication protocols and reconfigurable computational techniques.

For sustainable development of smart city, there is a need of independent SC department (Smart City Department) like Special Purpose Vehicles (SPVs) in India, which will decouple the political element of the improved city servicing from the elemental technologies and traditional procurement processes.

Smart city application must be able to trust the data, which are coming in for analysis. These data shall be analyzed and developed as a useful information. A methodology shall be applied on these data to control various applications of smart cities; therefore, it is imperative for the data to travel without noises.

II. Major Smart City Services

Fig. 1 IoT services to smart city

Fig. 1 shows the major applications of IoT in Smart Cities. IoT needs to target following services to be delivered through it [3], [4]:

a. Smart building
b. Waste management
c. Air & noise pollution monitoring
d. Smart lighting
e. Water management
f. Traffic Congestion on control
g. Smart health care system
h. Smart energy consumption
i. Healthcare system

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A. Smart Buildings

A "Smart Structural Building" amalgamates major building systems onto a standard network and distributes the information and the services among systems to improve the building operations. The smart buildings contribute majorly in providing improved energy efficiency and upgraded operational effectiveness. Various sensor network applications are included in building for monitoring. They include power usage, ventilation, current monitoring, temperature and humidity controlling, air quality, leakage detection, air compressor system failures and leaks. The emergence of IoT has empowered perceptive data collection and processing thus enabling building monitoring systems

B. Waste Management

The way household waste is managed is also crucial. Therefore, IoT solutions using sensors and cameras to gauge fill levels and scheduling pick-ups autonomously have been proposed. These solutions will not only help in checking the household waste but also help the waste management companies to operate more efficiently. Also there are smart bins that are equipped with low cost embedded device/sensors which will help in monitoring the level of the garbage bins and a unique ID is designated to every smart bin in the city so as to easily identify which bin is full. When the level reaches a predetermined threshold limit, the device will transmit the garbage level along with the unique ID provided. This way the garbage can be collected easily.

C. Air and Noise Pollution Monitoring:

Air and noise pollution is an alarming issue these days. It is quintessential to monitor air quality in smart cities as the pollution levels are increasing at an alarming rate due to rapid urbanization. An appropriate sensor shall be deployed through wireless sensor network, which are enable with the help of micron roller and controlled by mobile devices.

D. Smart Lighting

Intelligent Lighting uses LEDs with connected controls to provide better lighting with more control. An all-in-one smart street-lighting system provides lighting control based on the darkness intensity on the street. This helps to reduce loss of energy and multifunctional communications enable to develop sustainable system.

E. Smart Parking

A Smart Parking System (SPS) based on IoT makes use of various sensors like video sensors etc. Therefore, with the help of SPS, a driver can find a nearest empty parking slot without much wastage of time and more importantly the fuel consumption which will further reduce the carbon footprints in an atmosphere. Hence, it is an eco-friendly scheme too. By using processors such as raspberry pi, MCU/MPU, network processor, hybrid processors such systems can be designed. These systems make use of technologies like GPS, RFID, Wi-Fi, BT/BTLE etc.

F. Traffic Congestion

The IoT plays an instrumental role in traffic decongestion. Various equipment, like car's GPS, mobile phones, road sensors and traffic cameras, are used to collect data. The data gathered are analyzed to perceive how the traffic flows and usage patterns that shall enable new ways to cultivate the most frequented roads and transportation means.

G. Water Management

IoT can be used for getting the right amount of water at the right destination for the right duration. It is a data-driven approach which is a result of wireless communication enabled by the IoT. IoT technology is beneficial in smart irrigation as well.

H. Smart Energy Consumption

The smart grid is a universally acknowledged and well-developed IoT based system. Smart meters are employed by smart grids to gather information. They communicate the information about the energy usage of a building to the server node for better utilization and resource allocation.

I. Healthcare System

The field of healthcare has been drastically revolutionized due to inclusion of IoT in medicine. Medical history of the population can be easily analyzed and appropriate medicine and doctors can be deployed through IoT system. Big data analytics is becoming good tool to analyze and predict the future requirement of the society [5]-[8].

III. IoT for Epidemic Tracking

The IoT is an amalgamation of software, communication network and embedded devices like sensors. This integration capacitates the objects to collect and interchange data. The usage of IoT for medical assistance leads to development of m-IoT, which revolutionizes the healthcare by improving the quality of services, granting better access to facilities and curbing the costs [9].

The emergence of the IoT is crucial for healthcare because of two reasons. Firstly, the data that were not accessible before can be now easily collected, recorded and analyzed. This has been possible due to the evolution in the field of embedded systems and communication technology. Secondly, since the sensors can gather the data on their own, the limitations that arise due to human-errors are also removed.

Technology cannot alone stop the spread of the epidemic but it can forecast, warn and enlighten the people vulnerable and those who need to be apprehensive of the scenario to reduce the impact. Hence, IoT can be quite helpful in tackling such menace.

Consider the case of Chikungunya in Delhi. Following the onset of monsoon, Chikungunya resurged in Delhi to put many lives at risk. Government of Delhi reported more than 5000 cases of Chikungunya in October 2016 [20]. IoT can play an instrumental role in tracking the outbreaks of diseases like Chikungunya.

IoT-driven wireless sensor-based systems are used nowadays. These systems are employed to extract and analyze patient's health-related data. Since these data were not accessible before, the people in need of care were deprived of proper treatment. To ensure superior implementation of IoT in healthcare, the sensor and microcontroller have been coupled to form a smart sensor. Such smart sensor can be exploited to monitor, accurately measure and analyze composite health status indicators.

IoT-driven non-intrusive follow-up and tracking system can be used to monitor the medical condition of ailing patients by employing sensors to get exhaustive fitness information. Such monitoring involves use of gateways and cloud computing techniques to scrutinize the information received and accumulate it before sending it to medical professionals for extensive evaluation and assessment [17]. Also, there are people belonging to marginalized communities residing in low-dwelling areas in the city who are deprived of basic healthcare facilities. The health of these people is adversely affected in case of epidemics. But now, through IoT enabled wireless solutions the effective monitoring comes to them instead of people reaching out. System implemented using IoT provides accurate and secure data transfer. Then complex algorithms are applied for data analysis. After the analysis, the data are wirelessly transmitted to the medical professional for further analysis.

IV. Proposed Framework for IoT Enabled Smart City

Fig. 2 shows the framework for IoT enabled smart city. Sensors are used to collect real time data and further forwarded to system through microcontroller for processing. ARM based microcontrollers are popular to be used in the IoT based system, due to their freeware open source application development environment. These devices have also inbuilt facility of TCP/IT protocol [21] and Wi-Fi enable device, which helps to communicate the captured data to server. A separate database server is used to store real time data, so that appropriate action can be initiated based on analysis [2].

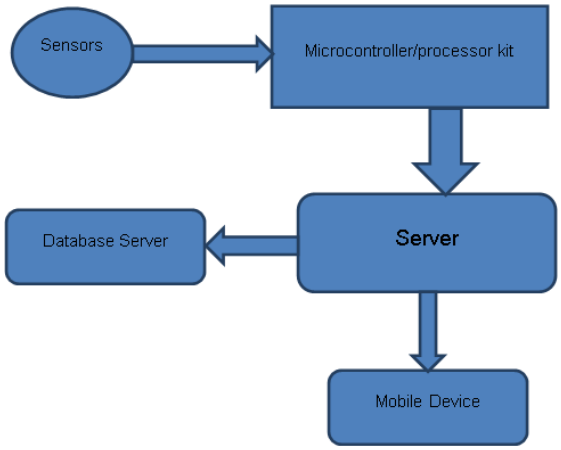

Fig. 2 Framework of IoT enabled Smart City

A control system is a very important component of the smart city environment. Due to enhancement of the easy life, mobile devices are used as controlling device to smart city. Therefore, an application shall be developed for mobile devices, so that user can easily monitor and control various appliance attached with the smart city system.

V. Data Management in Smart Cities

Large data travel from one device to another device in smart cities system. Though, most of the devices are connected with high-end microcontroller, large volume of data is managed with the help of high-end data storage devices. Due to variety of data at server thess data are called big data [22]. Analysis of big data needs analytics technique using machine learning and statistical techniques.

Machine learning help to clean the data and various techniques help to train the data. Trained data work as a learned system. These trained systems help to develop better smart cities, which are capable to predict need of resources to manage growing need of population [22]. These machine learning systems also help to deploy more numbers of public transport system to cater the growing need of passenger. This type transport systems are popularly known as intelligent transport systems [23].

Similarly, machine learning technique is popularly used in health care system. Better health care system is one of the important requirements of smart cities.

Due to growing population in the cities, environment pollution is growing very fast [10]. To develop the environment sustainable cities, it is imperative to develop the better data analytics technique, so that growing environmental pollutant can be checked at appropriate time [24]. Use of machine learning technique for environment has been demonstrated in technical report published by Wilcox et al. [11]. Technical report clearly stated how various machine learning techniques are used to assess the impact of environment. Hsieh had written a book on machine learning methods in the environmental science [12] and given various techniques which are useful for analyzing data. This analysis of data shall become very good tool for development of smart cities.

VI. Big Data for IoT

Many articles [13]-[16] have been published by researchers around the world for the data analytics of IoT. The features of big data are heavily used in IoT due to its features of volume and variety of data. IoT has a property to capture the variety of data due to its complex nature of sensors. Sensors are used to detect the input data and transmit to centralized system. The data captured through the sensors are in various varieties and its volume is also large. These data are used to control various features of smart cities. Therefore, as suggested by Chen [14], data analytics required machine learning approach to analyze big data generated through IoT. Machine learning help to train the system in place, for future unknown input and provide approximate output to system that will be helpful to smart cities.

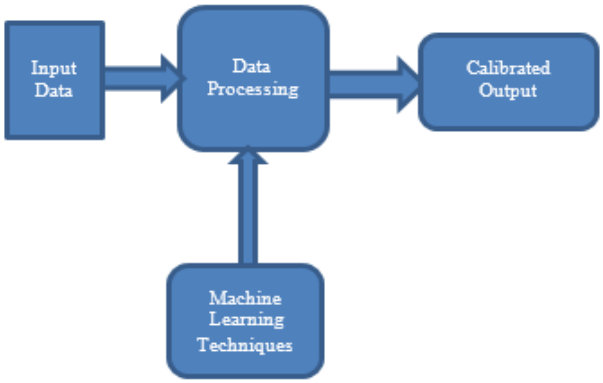

Fig. 3 Framework for data analytics of smart cities

Following properties of data required machine learning techniques for analysis purpose:

a. Volume of data
b. Variety of data
c. Value of data i.e. Real time data, which tends to changes it value
d. High velocity data i.e. speed of data capture by IoT system. IoT systems are implemented on high speed network; therefore velocity of data is very high.

Due to these properties, machine learning techniques are widely implemented to analyze the data. Few popular techniques are listed below:

i. K Means Clustering Algorithm.
ii. Support Vector Machine Algorithm.
iii. Logistic Regression.
iv. Decision Tree Machine Learning Algorith
v. Apriori Machine Learning Algorithm
vi. Artificial Neural Networks.

Artificial Neural Network (ANN) is a popular learning algorithms, which are used to develop robust system for training and reducing validation error. ANN helps the system to be trained with or without external training mechanism. Systems trained using ANN are capable to predict unknown input. ANN has a lot of potential in smart city data analytics due to its inherent features. Classifier and clustering algorithms are used depending on the types of data required to analyze using machine learning. So selection of appropriate algorithm also depends on the application of usage.

VII. Application of Cloud Computing

Due to heavy usage of social media like Facebook and Twitter by citizens, sentiment analysis is widely used for predicting traffic movement in the city [18]. IoT based network and usage of sensors in the cities, cloud based infrastructures are highly useful to develop smart cities. Most of the European cities have deployed intelligent system such as RADICAL (Rapid Deployment for Intelligent Cities and Living), EUROCITIES, OASC, FP7 CA FIREBALL to develop sustainable and intelligent system to achieve smart city. These applications are widely used by IT companies to deploy ICT enable sustainable system in smart city. Cloud based application help to strengthen the IT network of the city, which help to established IoT based smart cities.

Similar to RADICAL, few other cities have also developed IoT based solution to achieve smart cities concept. Few well known solutions are the European Platform for Intelligent Cities, Padova Smart City project, SMARTiP project, PERIPHÈRIA, Open Cities. These projects were implemented in various European cities, keeping in view of respective priorities of need. Aisopos et al. [18] analyzed various features of these projects and concluded that none of the solution is generic and fulfill the requirement of all the cities.

It was also reported in [20] that a specialized project is required to integrate the solution of industry and smart city for which GrowSmarter and Triangulum projects were studied and it has been found that IoT based system, which has variety of sensors network are very useful to develop robust smart cities. These projects help to integrate industry and cities to develop better solution in Energy, Infrastructure and Transport. Projects like Open cities and RADICAL helped citizen to improve data connectivity through fiber based network infrastructure. Based on needs and analysis, it has been reported in [21] that system based on sentiment analysis will help improve services in the cities, while project based industry integration helps develop better energy and transport infrastructure in the cities.

Sharma and Chandra [19] presented the use of social media to analyze Odd-Even policy in Delhi using sentiment analysis. In [19], author used hashtag of Twitter and reported the success of policy with the help of feedback given by citizen of Delhi. This is a classic example of development of the system for smart cities. This type of system can be easily extended for different applications.

VIII. Conclusion

It has been found in various literatures that IoT will help develop more sustainable city. IoT enable smart cities help distribute natural resources more appropriately. It also shows that machine learning tools are very helpful to analyze the data and predict the future need.

This paper reported the application using cloud based application to deliver services for smart cities. It has been concluded that development of smart cities is also dependent on the priorities of the city. IoT based smart cities is the future of the urban society, where more data analytics and sensor networks shall be used.

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