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A Review Paper on Machine Learning for Internet of Things

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Abstract

Rapid developments in hardware, software, and communication technologies have allowed the emergence of Internet-connected sensory devices that provide observation and data measurement from the physical world. By 2020, it is estimated that the total number of Internet-connected devices being used will be between 25-50 billion. As the numbers grow and technologies become more mature, the volume of data published will increase. Internet-connected devices technology, referred to as Internet of Things (IoT), continues to extend the current Internet by providing connectivity and interaction between the physical and cyber worlds. In addition to increased volume, the IoT generates Big Data characterized by velocity in terms of time and location dependency, with a variety of multiple modalities and varying data quality. Intelligent processing and analysis of this Big Data is the key to developing smart IoT applications.

1. Introduction

The entire world is going bonkers over data, IoT and Artificial Intelligence. Tons of articles have spoken about the amount of data we generate every single day and numerous statistics have shown how much data we would generate by the year 2025. On this post, however, we are going to deviate a little from data generation and discuss how algorithms or concepts from other technologies would be applied to IoT data for optimizations. On one of our previous posts, we discussed Data Science algorithms with IoT data and today, it will be Machine Learning.Machine Learning became a household term when Facebook shut down it's Artificial Intelligence wing when one of its bots

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discovered a whole new language. With Elon Musk commenting on it and netizens indicating an I-Robot in the future, most of us understood what Machine Learning is all about. On a very basic sense, machine learning in technology today is the process of elimination of human intervention wherever possible. It is allowing the data to learn patterns by itself and take autonomous decisions without a coder having to write a new set of codes. If you use your Siri, for instance, you would notice that its responses are more polished and appropriate as you keep using it. That is one of the basic applications of Machine Learning. But when it comes to a complex concept like IoT, how would Machine Learning make things better for the Internet of Things? Every time the IoT sensors gather data, there has to be someone at the backend to classify the data, process them and ensure information is sent out back to the device for decision making. If the data set is massive, how could an analyst handle the influx? Driverless cars, for instance, have to make rapid decisions when on autopilot and relying on humans is completely out of the picture. That's where Machine Learning comes to play with its To determine which algorithm has to be used for a particular set of task, we need to first define the task. Some of the tasks include finding unusual data points, structure discovery, predicting categories and values, feature extraction and more. Classifying the data sets into different tasks would make it easier for a beginner to understand the right algorithm application. For instance, to work on data structure discovery, clustering algorithms such as K-means could be used. K-means is designed to handle massive chunks of data including diverse data types. Quoting another example, the application of One-Class Support Vector Machines and PCA-based Anomaly detection algorithms are best for training data from unusual data points or data with high noises.

2. Internet of Things.

In IoT terms, every connected device is considered a thing. Things usually consist of physical sensors, actuators, and an embedded system with a microprocessor. Things need to communicate with each other, creating the need for Machine-to-Machine (M2M) communication. The communication can be short-range using wireless technologies such as Wi-Fi, Bluetooth, and ZigBee, or wide-range using mobile networks such as WiMAX, LoRa, Sigfox, CAT M1, NB-IoT, GSM, GPRS, 3G, 4G, LTE, and 5G [2]. Due to the massive usage of IoT devices in all kinds of everyday life applications, it is essential to keep the cost of IoT devices low. Additionally, IoT devices should be able to handle basic tasks like the data collection, M2M communication, and even some pre-processing of the data depending on the application. Thus, it is mandatory to find a balance among cost, processing power, and energy consumption when designing or selecting an IoT device. IoT is also tightly attached to "big data", since IoT devices continuously collect and exchange a great amount of data. So, an IoT infrastructure usually implements methods to handle, store, and analyze big data [3]. It has become a common practice in IoT infrastructures, to use an IoT platform such as Kaa, Thingsboard, DeviceHive, Thingspeak, or Mainflux in order to support the M2M communication, using protocols like MQTT, AMQP, STOMP, CoAP, XMPP, and HTTP [4]. Additionally, IoT platforms offer monitoring capabilities, node management, data storing and analyzing, data driven configurable rules, etc. Depending on the application, it is sometimes essential that some data processing takes place in the IoT devices instead of some centralized node as it happens in the "cloud computing" infrastructure. So, as the processing partially moves to the end network elements, a new computing model is introduced, called "edge computing" [5]. However, since those devices are most of the times low-end devices, they may not be suitable to handle intense processing tasks. As a result, there is a need for an intermediate node, with sufficient resources, able to handle advanced processing tasks, physically located close to the end network elements, in order to minimize the overload caused by massive sending of all the data to some central cloud nodes. The solution came with the introduction of the "Fog nodes" [6]. Fog nodes help IoT devices with big data handling by providing storage, computing, and networking services. Finally, the data are stored in cloud servers, where they are available for advanced analysis using a variety of ML techniques and sharing among other devices, leading to the creation of modern added value smart applications. IoT applications have already emerged in many aspects the so called, smart city. We could group the most important applications in the following categories.

2.1 Smart Homes:

This category includes traditional home devices, such as fridges, washing machines, or light bulbs, that have been developed and are able to communicate with each other or with authorized users via internet, offering a better monitoring and management of the devices as well as energy consumption optimization. Apart from the traditional devices, new technologies spread, providing smart home assistants, smart door locks, etc.

2.2 • Health-care assistance: New devices have been developed in order to improve a patient's well-being. Plasters with wireless sensors can monitor a wound's state and report the data to the doctor without the need for their physical presence. Other sensors in the form of wearable devices or small implants, can track and report a wide variety of measurements, such as heart rate, blood oxygen level, blood sugar level, or temperature.

2.3• Smart Transportation:

Using sensors embedded to the vehicles, or mobile devices and devices installed in the city, it is possible to offer optimized route suggestions, easy parking reservations, economic street lighting, telematics for public means of transportation, accident prevention, and autonomous driving.

2.4 Environmental Conditions Monitoring: Wireless sensors distributed in the city make the perfect infrastructure for a wide variety of environmental conditions monitoring. Barometers, humidity sensors, or ultrasonic wind sensors can help to create advanced weather stations. Moreover, smart sensors can monitor the air quality and water pollution levels across the city.

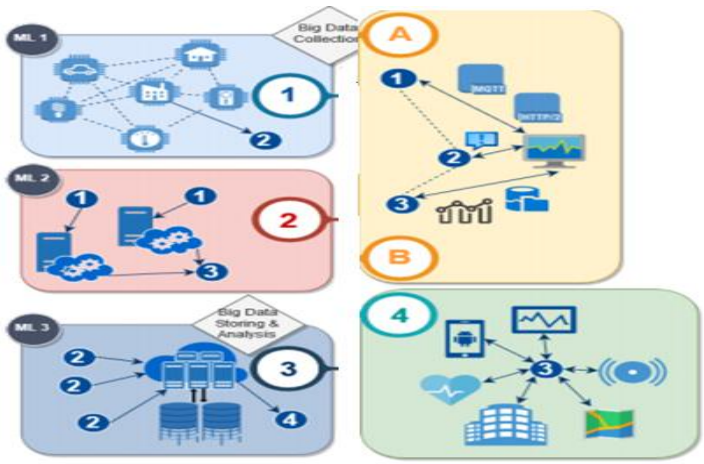

Figure 1. Key elements of the Internet of Things (IoT) infrastructure.

Figure 1 is organized by separating the infrastructure key elements in numbered blocks. Each block depicts a representative image of the described element, and arrows are linking the images with numbers, indicating how each element interconnects with the other blocks. Additionally, text blocks are included, giving the most important aspects of each key element in bullets. The IoT infrastructure consists of: (1) IoT nodes, namely the IoT devices (sensors and actuators) at the edge of the network. (2) The Fog nodes, servers that assist IoT devices by providing computing, storage, and advanced networking capabilities. (3) Cloud nodes that consist of data centers, which handle data storing, computationally intense data analysis using ML techniques, data sharing, etc. (4) IoT applications that use the collected and analyzed information to create services for the end user. Points (A) and (B) symbolize the IoT platforms, which have the orchestrator's role and support the elements throughout the infrastructure in various ways as described in the figure. Moreover, Figure 1, presents the role of ML in the IoT infrastructure. ML techniques can be applied at the IoT nodes, the fog nodes, or the cloud nodes, depending on the application needs.

2.5 Machine Learning (ML)

It is not a new concept. ML is closely related to Artificial Intelligence (AI). AI becomes feasible via ML. Through ML, computer systems learn to perform tasks such as classification, clustering, predictions, pattern recognition, etc. To archive the learning process, systems are trained using various algorithms and statistical models to analyze sample data. The sample data are usually characterized by measurable characteristics called features and an ML algorithm attempts to find a correlation between the features and some output values called labels [8]. Then, the information obtained during the training phase is used to identify patterns or make decisions based on new data. ML is ideal for problems such as regression, classification, clustering, and association rules determination. Depending on the learning style, ML algorithms can be grouped into four categories: • Supervised Learning: Supervised learning deals with problems involving regression such as weather forecasting, estimating life experience, and population growth prediction, by using algorithms like Linear Regression or Random Forest. Additionally, supervised learning addresses classification problems such as digit recognition, speech recognition, diagnostics, and identity fraud detection, by using algorithms such as Support Vector Machines, Nearest Neighbor, Random Forest, and others. There are two phases in supervised learning. The training phase and testing phase. The data sets used for the training phase need to have known labels. The algorithms learn the relationship between the input values and labels and try to predict the output values of the testing data [9]. • Unsupervised Learning: Unsupervised learning deals with problems involving dimensionality reduction used for big data visualization, feature elicitation, or the discovery of hidden structures. Moreover, supervised learning is used for clustering problems such as recommendation systems, customer segmentation, and targeted marketing. Contrary to supervised learning, in this type, no labels are available. Algorithms in this category try to identify patterns on testing data and cluster the data or predict future values [9]. • Semi-supervised Learning: This is a combination of the previous two categories. Both labeled data and unlabeled data are used. It works mostly like the unsupervised learning with the improvements that a portion of labeled data can bring [8]. • Reinforcement Learning: In this learning style, the algorithms try to predict the output for a problem based on a set of tuning parameters. Then, the calculated output becomes an input parameter and new output is calculated until the optimal output is found. Artificial Neural Networks (ANN) and Deep Learning, which will be presented later, use this learning style. Reinforcement learning is mainly used for applications like AI gaming, skill acquisition, robot navigation, and real-time decisions. [9]. When using ML techniques, there are two major parameters to consider; how computationally intense and how fast a given technique is. Depending on the application type, the most appropriate ML algorithm is chosen. If there is a need for real-time analysis for example, the chosen algorithm should be fast enough to track the changes of the input data and produce the desired output in a timely manner.

2.6 Machine Learning in IoT

With IoT, devices are connected with each other, communicate with each other and collect an enormous amount of data every day. In many applications, IoT devices may also be programmed to trigger some actions based either on some predefined conditions or on some feedback from thecollected data. However, in order to analyze the collected data and extract meaningful information and create smart applications, human intervention is required. IoT devices need not only to collect data, and communicate with other devices, but also to be autonomous. They need to be able to take context based decisions and learn from their collected data. This need led to the creation of the term “Cognitive IoT” (CIoT) [10]. Also, there is a necessity for Intelligent IoT devices, able to create automated smart applications with automated resource allocation, communication, and network operation. Deploying ML algorithms in an IoT infrastructure can introduce significant improvements in the applications or the infrastructure itself. ML can be applied for network optimization, congestion avoidance, and resource allocation optimization, but also for real-time or offline data analyzing and decision making. Moreover, as the number of devices increases, the amount of the collected data increases as well. Having to deal with “big data” is very common in IoT applications. Big data cannot be handled properly with conventional databases. Special infrastructure is needed to handle the great volume of structured and unstructured data and special techniques to analyze them [11]. There are many ML algorithms like "Ensemble", or Artificial Neural Networks (ANN) that can help dealing efficiently with big data, and they will be discussed in the following sections.

3. Machine Learning and IoT in Smart Transportation

Smart Transportation is a very popular area of research, since it encounters many everyday problems, with a huge footprint in a modern smart city. Additionally, the nature of the problems it deals with favors the use of both IoT and ML technologies. This review aims to both identify the current trend in the use of ML and IoT in smart transportation, and examine the research coverage ineach one of the smart transportation categories. For this reason, the review focuses on the most recent research works, which address the smart transportation categories (route optimization, parking, lights, accident detection/prevention, road anomalies, and infrastructure), using IoT and/or ML techniques.

- **ML and IoT Applications in Smart Transportation**

we review and summarize based on the type of the Smart Transportation problems they deal with. We have identified six major categories of Smart Transportation challenges, and we will present the methods approached by the authors using IoT technology and ML algorithms. Following groups all the researches in the six aforementioned categories, indicating also whether an ML technique is used or not in the respective research. The ML supported methods have been extensively discussed in the previous section. For the sake of completeness and to avoid repetition, these methods will be just referenced in the respective category and we will elaborate on the non ML approaches.

- Route Optimization
- . Parking
- . Lights
- Accident Detection/Prevention
- Road Anomalies Detection
- Infrastructure

4. Conclusions

A review on Machine Learning and Internet of Things techniques exploited for smart transportation applications has been presented. This study highlighted the fact that a wide variety of Machine Learning algorithms has been proposed and evaluated for Smart Transportation applications, indicating that the type and scale of IoT data in these applications is ideal for ML exploitation. On the other hand, given the current applications and infrastructure regarding IoT and ML, a comparatively smaller ML coverage for the smart lighting systems and parking applications is detected. Therefore, there is a definite need for supplementary coverage in those areas, from the ML perspective, in the future. Regarding the IoT approaches for the ITS application categories, route optimization, parking, and accident prevention/detection have proven to be the most popular among them. Considering the problems that the smart transportation applications address, some common points of interest have been identified from this review. These are: environmental precautions, transport finance, human safety, and time saving. Additionally, the great progress which has already been achieved in the field of smart transportation with the help of IoT and ML became evident, while an even better advancement in this topic is expected in the upcoming years. As the number of IoT devices rises, the data diversity and volume scale up, therefore, ML can create many meaningful applications.

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