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Using Data Analytics in Machine Learning for Performance Enhancement in Internet of Things

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ABSTRACT: Predictive analytics using machine learning (ML) involves two steps: building a model and refining it. This cycle is repeated multiple times until the best model is created and then deployed. In this article, we will explore how we can improve predictive analytics with ML in order to derive highly effective insights. Predictive analytics is a powerful technique that ‘predicts’ the future, in a sense. It can help answer key questions, such as how many products a business could sell in the next three months and how much profit it is likely to make. Using sales as an example, it’s essential to know past sales data in order to predict future sales. The past sales data and cleaned data from descriptive analytics are mixed to create a dataset to train an ML model. The built model predicts future sales, say, for the next few months. The predicted quantities sold and profits made are compared with the actual numbers sold and profits made. The actual profits could be more or less than what was predicted. The model is refined to overcome such limitations and improve the accuracy of predictions.

KEYWORDS: analysis, data, machine, learning, performance, enhancement, IoT, profits, accuracy

I. INTRODUCTION

There are four types of analytics: descriptive, diagnostic, predictive, and prescriptive.

- Descriptive analytics deals with the cleaning, relating, summarizing, and visualizing of given data to identify patterns.
- Diagnostic analytics deals with analyzing why something is happening. For example, investigating the reason behind the decline or growth of revenue.
- Predictive analytics involves predicting future outcomes or unknown events using machine learning and statistical algorithms.
- Prescriptive analytics uses descriptive and predictive sources to assist with decision-making.¹

There are many scenarios where there may be an abundance of data. However, there may be no algorithms available to train machines to perform certain tasks. In this case, we want the machines to learn from the data and apply the learning to unseen inputs. This is referred to as machine learning. For example, if we want to know employee churn rate, we can use a machine learning model that has been trained on past data to predict if an employee will leave.²

ML is used when we cannot explicitly estimate all the possible cases of an event occurring and write a piece of code for each. For example, what are the rules to predict if content posted on a video-hosting platform is for kids or adults? How do we predict the genre of a new show? There are millions of videos uploaded every day. Examining and analyzing

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each of them manually is impossible. This is where ML comes into play as the algorithms can process enormous amounts of structured (data in rows and columns) and unstructured (images, videos, text with emoticons, etc.) data.³

Step 1: Define the problem statement

We begin by understanding and defining the problem statement, and deciding on the required datasets on which to perform predictive analytics.⁴

Example: There is a grocery store. Our objective is to predict the sales of groceries for the next six months. Here, past sales data of how many groceries were sold and the resulting profits of the last five years will be the dataset.

Step 2: Collect the data

Once we know what sort of dataset is needed to perform predictive analytics using machine learning, we gather all the necessary details that constitute the dataset. We need to ensure that the historical data is collected from an authorized source.

Using the grocery store example, we can ask the accountant for records of past sales logged in worksheets or billing software. We collect data spanning the past five years.

Step 3: Clean the data

The raw dataset obtained will have some missing data, redundancies, and errors. Since we cannot train the model for predictive analytics directly with such noisy data, we need to clean it. Known as preprocessing, this step involves refining the dataset by eradicating unnecessary and duplicate data.⁵

Step 4: Perform Exploratory Data Analysis (EDA)

EDA involves exploring the dataset thoroughly in order to identify trends, discover anomalies, and check assumptions. It summarizes a dataset's main characteristics. It often uses data visualization techniques.

Step 5: Build a predictive model

Based on the patterns observed in step 4, we build a predictive statistical machine learning model, trained with the cleaned dataset obtained after step 3. This machine learning algorithm helps us perform predictive analytics to foresee the future of our grocery store business. The model can be implemented using Python, R, or MATLAB.⁶

- Hypothesis testing

Hypothesis testing can be performed using a standard statistical model. It includes two hypotheses, null and alternate. We either reject or fail to reject the null hypothesis.

Example: A new 'buy one, get one free' scheme is implemented where customers buy a packet of soap and get a face wash for free. Consider the two cases below:

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Case 1: Despite the scheme, sales of soap did not improve.

Case 2: After the scheme, sales of soap improved.⁷

If the first case is true, we fail to reject the null hypothesis as there is no improvement. If the second case is true, we reject the null hypothesis.

Step 6: Validate the model

This is a crucial step wherein we check the efficiency of the model by testing it with unseen input datasets. Depending on the extent to which it makes correct predictions, the model is retrained and evaluated.

Step 7: Deploy the model

The model is made available for use in a real-world environment by deploying it on a cloud computing platform so that users can utilize it. Here, the model will make predictions on real-time inputs from the users.⁸

Step 8: Monitor the model

Now that the model is functioning in the real world, we need to verify its performance. Model monitoring refers to examining how the model predicts actual datasets. If any improvement must be made, the dataset is expanded and the model is rebuilt and redeployed.

E-commerce/retail

Predictive analytics achieved through machine learning helps retailers understand customers' preferences. It works by analyzing users' browsing patterns and how frequently a product is clicked on in a website. For example, when we purchase a t-shirt on an e-commerce site, similar shirts are suggested the next time we log in. Sometimes, we may be recommended several specific items that are often purchased together for x amount of money. Such personalized recommendations help retailers retain customers. Predictive analytics also helps maintain inventory by foreseeing and informing sellers about stockouts.⁹

Customer service

Customer segmentation is performed based on insights by predictive analytics. Customers are placed into different segments depending on their purchase patterns. For example, book buyers will form one cluster while t-shirt buyers will constitute another. Tailored marketing strategies are then developed for each of the segments depending on their characteristics.

Predictive analytics using machine learning can also detect dissatisfied customers and help sellers design products aimed to retain existing customers and attract new ones.¹⁰

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Medical diagnosis

Machine learning models that are trained on large and varied datasets can study patient symptoms comprehensively to provide faster and more accurate diagnoses. Performing predictive analytics on the reasons behind past hospital readmissions can also improve care.

Further, hospitals can use predictive analytics to provide the best care by pre-determining increase of hospital bed availability or staff shortage. For example, if the number of COVID cases for the next month can be predicted and the rise in the number of severely infected can be forecasted, hospitals can make arrangements to deal with such a scenario more efficiently.¹¹

Sales and marketing

Predictive analytics of historical data of customer behavior and market trends can help businesses understand the demands of prospective customers. Companies can achieve higher targets by streamlining their sales and marketing activities into a data-based undertaking. Demand forecasting also helps businesses estimate the demand for certain products in the future.

Financial services

Predictive analytics using machine learning helps detect fraudulent activities in the financial sector. Fraudulent transactions are identified by training machine learning algorithms with past datasets. The models find risky patterns in these datasets and learn to predict and deter fraud.¹²

Cybersecurity

Machine learning algorithms can analyze web traffic in real-time. When an unusual pattern is observed, advanced statistical methods of predictive analytics foresee and prevent cyber-attacks. They also automatically collect attack-related data and generate useful reports on a cyber-attack, thereby reducing the need for manpower.

Manufacturing

Machine learning and predictive analytics help manufacturers monitor machines and notify them when crucial components need to be repaired or replaced. They can also predict market fluctuations, reduce the number of accidents, improve key performance indicators (KPIs), and enhance overall production quality.¹³

Human Resource Information Systems (HRIS)

Predictive analytics using machine learning identifies employee churn rate and keeps human resources (HR) departments informed of the same. Models can be trained with datasets that have details such as an employee's monthly income, allowances, increments, insurance, and so on. The models learn from past records of ex-employees and find patterns to understand the reasons for leaving. They then predict if new employees are likely to resign or not, empowering HR to minimize the risk.

Thanks to the development of software systems supported by predictive analytics and backed by ML, one-click forecasting has been fulfilled. However, there are certain challenges that need to be overcome. These include preparing

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and processing the right dataset, finding experienced professionals to deploy predictive models, the high cost of predictive analytics software and data processing, and the need to upgrade to newer ML algorithms due to the evolution of the technology.¹⁴

II. DISCUSSION

IoT devices are becoming increasingly popular and are being applied in uniquely creative ways every day. With their appeal of open-source software, secure wireless data transfer, and endless capabilities of applications, their appeal is obvious. As technology progresses, low-power data harvesting applications are being explored further every day. However, a common issue encountered with IoT devices is the short operating life of the battery powering them. When using a battery-powered IoT device, it's important to minimize the amount of required maintenance and maximize its operating life to avoid costly replacements. Batteries make this a challenge, given their short cycle life. Energy harvesting solutions, such as indoor solar cells, are growing in popularity, as is pairing supercapacitors with these energy harvesting technologies to significantly reduce the burden on the batteries. This is because supercapacitors excel at charging with very small levels of current, have a high cycle life, and can deliver large amounts of current in quick bursts to complement batteries. In certain applications, supercapacitors can even replace the batteries all together. Let's design an IoT device to monitor air temperature throughout a city. In this case, the city management wants IoT devices installed in select intersections throughout the city.¹⁵ The customer's key requirements are:

- No change / retrofit to any of city infrastructure
- Added sensors and enclosures must be discrete and not an eyesore
- Hourly temperature readings through the day and night
- Data transmission every three hours via cellular network
- Maintenance free, with a targeted 10-year operating life

The system requires 3.3V and will feature three modes of operation: sleep, read, and transmit. The system will primarily operate in its sleep mode, where very little energy or power is required. Read mode will run for 60 seconds every hour, during which the sensor will record the temperature and store that data in memory. Finally, the system will transmit its data (the air temperature readings) for 0.5 seconds once every three hours to its receiver.¹⁶

Mode	Voltage	Current	Length of Operation	Power Requirement
Sleep	3.3V	0.5mA	Continuous	1.65mW
Read		150mA	60 seconds	495mW
Transmit		750mA	0.5 seconds	2,475mW

Design Choices

Battery:

Using only a battery to power this design is the easiest way to go in terms of design simplicity, but it will not meet the customer's requirements. Either the battery must be so large so that it stores enough energy to power the system for 10 years without maintenance or it will regularly require replacements of smaller batteries. The peak power requirement may require a smaller battery to discharge at a higher C rate, which may be harmful to the battery.¹⁷

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PRO: Easy, simple design

CON: Very large batteries needed or costly frequent replacements of smaller batteries

Potential fix: Add solar cell energy harvesting to help support the battery during periods of sunlight

Solar + Battery:

A solar cell in this kind of design will reduce the burden of the battery by delivering power to the load, reducing the burden on the battery and may be able to recharge the battery during the system's sleep mode. It is a step in the right direction but does not perfectly satisfy the customer's requirements. If a large battery is used, it will recharge very slowly with the help of the solar cell. A solar cell could recharge a smaller battery faster, but that smaller battery would cycle faster, reducing the operating life. A battery may have a ~500 cycle life before significantly degrading in performance. If the battery is sized to provide 24 hours of operation on its own, it will likely need to be replaced every few years. Also, a smaller battery may be damaged during the high discharge rate seen in the transmit mode further shortening its life. If the battery is sized to provide 720 hours (approximately one month) of operation on its own, it may be too large to meet the discrete requirement set by the customer. It may also struggle to recharge with the small current provided by the solar cells. Even if the battery does meet the aesthetic requirements of the customer, a battery powering this device for one month and recharging by a solar cell will not meet the 10-year operating life requirement.¹⁸

PRO: Solar cell supports the battery during the day reducing the burden on the battery

CON: Still not likely to meet either the aesthetic requirements or service life requirement

Potential fix: Add supercapacitor to complement the system by recharging at small currents and powering transmit mode

Solar + Supercapacitor:

There are a few challenges batteries face in this kind of design. First, they struggle to charge with small current values from energy harvesting devices like a solar cell. Second, they have a short cycle life, making it riskier to use a smaller battery that can recharge faster with small current values. Third, they can be damaged by discharging at a high C rate, which means they are not well suited for the transmit mode of operation. A supercapacitor can solve these problems, but do not come without their own challenges. A supercapacitor features a high-power density, meaning it is well suited to charge with small currents and to respond to high power draws from the load (like the transmit mode). They also can be cycled hundreds of thousands of times without performance degradation, meeting the operating life requirements. The problems faced with supercapacitors, is that they cannot provide energy for long periods of time. While recharging quickly with morning light, a supercapacitor and solar cell will not power this system through the night. The only way to do this would be to add many supercapacitors to the design to increase the energy storage capacity, but this would increase cost and size of the system failing the customer's requirements.¹⁹

PRO: Long service life, easy low current recharging, high power mode for transmitting data

CON: Cannot power device at night, failing to meet customer requirement

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Potential Fix: Add a battery to power the system at night
Solar + Battery + Supercapacitor:

This hybrid design allows each component to do what it does best and what it is designed to do.

Solar cells provide energy through the day to power the device and recharge energy storage systems.

Supercapacitors act as a workhorse and handle peak power requirements for the system.

Batteries provide energy through the night.

With this approach, all the requirements set by the customer can be met. The one challenge will be the aesthetic requirement to be discrete. IoT products often have space constraints, making it difficult to find the space to use batteries and supercapacitors. There may only be space for one or the other without needing to make the design larger.²⁰

Capacitech's supercapacitor, the Cable-Based Capacitor (CBC), is a wire-like and flexible energy storage device. It is designed to help engineers add supercapacitors to their designs without being concerned about negative tradeoffs. Leveraging its form factor, the CBC offers engineers a placement advantage so that they can find space to add supercapacitors to their IoT designs by not being restricted to the printed circuit board where space is a premium.

Potential Design

One option to build a solar-battery-supercapacitor hybrid design is to embed the air temperature monitor into a flexible package to be wrapped around a streetlamp where it is out of sight, out of mind using flexible solar cells, flexible CBCs, a narrow pouch style battery, and a skinny circuit board that is vertically aligned with the pole. From power management devices offered by Texas Instruments, Analog Devices, e-peas, and others, we know that they often require <5V input from solar power and that passive components can be changed to select the charging voltage for the supercapacitor as well as the final output voltage to the load. For this scenario, a power management device will be calibrated to charge the CBCs to 4.5V, discharge them to 3.6V, and regulate the output voltage to be 3.3V.²¹

III. RESULTS

In recent years, home automation has become so popular due to its numerous advantages. The home environment has witnessed a rapid introduction of network enabled digital technology. This technology comes with new and exciting opportunities to increase the connectivity of different devices within the home for the purpose of home automation. This paper aims at designing a basic home automation system of controlling multiple appliances which can be monitored and accessed from anywhere in the world with very low cost. The technology incorporates Raspberry Pi and the web server. The Raspberry Pi and Arduino integrated with Nrf modules are used to monitor the home environment appliances, and the readings are passed to the web server designed. The parameters or commands sent through web page are monitored frequently and if any threats found the mobile connected to this web server is alerted through an alarm or message.²²The user can access this application from anywhere in the world. The result produced is low cost advantageous and absolute. Performance Analysis of different protocols (MQTT, HTTP and CoAP) is estimated using visualizations. The organization renders itself capable of lowering expenses and evaluating improvements in the job and expertise or abilities of workers using technology. IoT is a way to empower the interlinking and fuse of the corporal world what's more, the web. IoT systems allow users to get profounder computerization, examination and incorporation into a program. Technology may help to maximize profitability, performance, enhance coordination and communicate with the workforce. Technology has emerged with enormous growth in business organization. It helps

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business organization to reform the existing business process and work. Productivity tends to raise the quality of life of workers. Productivity and technology changes lead to growth in the earning. Technology has brought new fanciful future to the business organization where they can set their vision to complete into the competitive environment.²³

With the IoT (Internet of Things), we can obtain much more information more easily than ever before, and control devices in a much more seamless manner. However, compared to conventional systems, IoT systems have distinct characteristics and require multiple problems be solved in order to make the systems efficient and usable. These distinct characteristics include the heterogeneous nature of the connected devices, the huge number of devices in the network, the lightweight security system, the fact that such devices may have different communication protocols and message characteristics, various security levels, diverse management authorities and policies, etc. As an example, the main purpose of Fog computing is to provide IoT/cloud services, which were originally provided by the system server, directly in the vicinity of the things. By doing so, not only is the amount of data transmitted to the system server reduced, but latency and privacy problems can also be solved in certain application areas. Fog/Edge computing is just one of many attempts proposed to solve the problems involved in the IoT. It is quite evident that software plays a key role in overcoming the obstacles mentioned above. For this reason, it is meaningful to discuss what kinds of software solutions are needed for better IoT systems.²⁴

Topics of interest include (but are not limited to):

- Fog/Edge computing middleware for IoT systems
- Efficient IoT system frameworks from a software perspective
- Software for reliable IoT systems in hostile surroundings
- Efficient IoT software for specific application areas (i.e., Healthcare, Smart city, Transportation, etc.)
- Efficient software for managing a large number of heterogeneous devices/communication protocols for IoT systems
- Efficient security-related software for IoT systems
- Performance monitoring or Performance enhancement software for IoT systems
- Other topics related to the issue

IV. CONCLUSIONS

RESTfull service based processing is the real bottleneck in undertaking an IOT based processing. The Load on an IOT network must be considering the data that flows from bottom to TOP and the requests that floe from Top to Bottom. The flow of data happens in both the direction to answer the user requests initiated by the user. The response time greatly improves through implementing the RESTful services through High Performance computing.²⁵

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