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Mathematics and Internet of Things Plays a Crucial Role in Revolutionizing the Wine Industry

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Abstract:

In Industry 4.0 generation, Industrial Internet of Things (Industrial IoT) is revolutionizing various industries, and wine industry is no exception. Mathematical and statistical analysis for Data Acquisition, Sensor Calibration, series Analysis, Process Optimization and Control, modelling. Sensor data, temperature, humidity, alcohol, Brisk levels, etc.is inherently noisy. Statistical methods like mean, median, outlier detection and, standard deviation are used to clean and pre-process the data. Sensors calibration is needed to provide accurate readings. Mathematical models linear, exponential, etc. are used to create calibration curves that map raw sensor readings to actual values. Data collected over time, temperature, brisk, humidity, alcohol changes in fermentation tanks is analysed using time series techniques. Mathematical models e.g. differential equations etc. are used to simulate and understand the complex biochemical reactions during fermentation to optimize and Control temperature, yeast addition, and oxygen levels for optimal results. Real time data of winery, collected by sensors is sent to the cloud for advanced data analysis and publish as an open source. The Mathematical analysis and statistical representation are done with the help of MATLAB software present on cloud. The application of these mathematical tools is transforming the winemaking process, improve the wine quality and consistency, control, and ultimately, the production of superior wines. It reduces the production cost, increase the efficiency, improve safety and security of winery.

Keywords: Winery, IoT, Mathematics and Statistics, MATLAB.

Introduction:

Traditional Process of Wine Making:

Traditional winery produces wine using time-honoured methods and techniques, reflecting the cultural heritage and practices of the region where it is located. These wineries are located in regions with a favourable climate for grape growing, typically known as wine regions, in Maharashtra most are located in Nashik region. Wineries cultivate specific grape varieties that are native or historically significant to the region. For example, Chardonnay, cabernet sauvignon Syrah, pinot in Nashik. Grapes are typically hand-harvested to ensure quality. The time of the grape harvest is crucial, as it impacts the sugar, acidity, and overall flavour and colour of the wine. After harvesting, depending on the type of wine whether it is red or white, grapes are crushed and pressed to separate the juice from the skins. The grape juice known as "grape must" is allowed to ferment using wild yeasts naturally present on the grape skins or the cultured yeast externally added in the winery environment to convert sugar into alcohol. The yeasts begin to metabolize the sugars in the must, producing alcohol and carbon dioxide. Fermentation is often carried out at ambient temperatures, which can lead to varying fermentation rates and it also varies complexity in Flavors. Although fermentation can be less predictable than

using cultured yeasts, winemakers closely monitor the process for signs of fermentation activity, such as bubbling and temperature changes. Wines are often aged in oak barrels; the aging period can vary greatly depending on the wine type.

Overview of IoT and IIoT:

1. Internet of Things:

The Internet of Things (IoT) refers to the network of physical objects, devices, "things" that are embedded with sensors, software, and connectivity capabilities to collect and exchange data over the long distance by using the internet. IoT enables these objects to communicate with each other and with centralized systems, leading to enhanced data collection, analysis, automation, and improved user experiences. The "things" in IoT, which can range from simple sensors to complex devices. Examples include smart thermostats, wearable health monitors, industrial machinery, connected home appliances etc. Devices use various communication protocols to connect to the internet or to each other. Common technologies include Wi-Fi, Bluetooth, Zigbee, cellular networks (like 4G and 5G), and LPWAN (Low-Power Wide-Area Network) technologies. Data collected from IoT devices needs to be processed. This can occur locally (edge computing) on the device itself or sent to centralized cloud systems for analysis. End-users interact with IoT systems through applications or dashboards that display collected data and provide control over devices. This can include mobile apps, web interfaces, and voice-activated systems.

2. Industrial Internet of Things:

IIoT refers to the extension and use of the Internet of Things (IoT) in industrial sectors and applications. IIoT involves the integration of sensors, machines, devices, and data analytics in manufacturing and industrial environments to improve efficiency, productivity, and safety. IIoT is a transformative approach that leverages digital technology to enhance industrial processes, leading to smarter manufacturing and operational efficiency. The massive amounts of data generated by these connected devices can be analysed to gain insights, optimize operations, and predict maintenance needs (Predictive Maintenance). IIoT enables greater automation of industrial processes, which can lead to reduced costs and increased efficiency. Operators can monitor processes remotely, allowing for quicker responses to issues.

Role of Mathematics and statistics in the Internet of Things (IoT):

Enabling data analysis, optimization, modelling, and the design of algorithms that drive IoT applications is possible due to the mathematics and statistics. Linear Algebra is essential for handling multidimensional data, transforming data sets which can represent sensor readings and other IoT data. Graph Theory helps in understanding and analysing relationships between devices in a network, optimizing the topology of sensor networks, and routing data effectively. Optimization, involves minimizing costs, such as energy consumption in networked devices, or maximizing efficiency in data transmission and storage. Descriptive Statistics, summarizes and describes the features of a dataset, including measures of central tendency (mean, median) and measures of dispersion (variance, standard deviation), which help in understanding sensor data. Concepts like Bayesian probability are used in decision-making processes in IoT systems. Time Series Analysis, critical for analysing temporal data collected by IoT devices over time, enabling predictive analytics, anomaly detection, and trend analysis. Machine Learning and Data Mining, involves algorithms and models to identify patterns and make predictions based on data collected from IoT devices.

1. Useful Mathematical and statistical Tools and Technologies in IoT:

Python, R, and MATLAB are popular for statistical analysis and machine learning in IoT applications. Tools like Tableau, Power BI, or libraries like Matplotlib and Seaborn (in Python) to visualize IoT data. SQL and NoSQL databases for storing large volumes of time-series data generated by IoT devices. Apache Hadoop, Spark for processing and analyzing large datasets.

MATLAB and IoT integration:

MATLAB, short for "MATrix LABoratory," is a high-level programming language and interactive environment used primarily for numerical computation, data analysis, algorithm development, and visualization. Developed by MathWorks, MATLAB is widely utilized in engineering, scientific research, and mathematics due to its powerful computational capabilities and extensive built-in functions. It has numerous specialized toolboxes that extend its functionality for various applications. MATLAB provides strong graphical capabilities to create 2D and 3D plots, which help in analysing data and presenting results. It features an interactive environment that allows users to execute commands and see results immediately, which is useful for prototyping and exploratory analysis. It can interface with other programming languages like C, C++, Java, and Python, and it can communicate with hardware and devices for real-time data acquisition and control. MATLAB is a powerful programming environment that can be utilized for various Internet of Things (IoT) applications. It provides a range of tools for connecting and analysing data from IoT devices. We can interface with sensors, gateways, and cloud services. We can work with the components: Data Acquisition**,** Signal Processing**,** Machine Learning**,** Visualizations**.**

IoT based Wine Fermentation Monitoring System:

Here's a brief outline of a IoT based wine fermentation monitoring system

a. Components: ESP 32 with a temperature and humidity sensor (DHT 11), alcohol sensor MQ3

b. Data Collection: Collect temperature, humidity and alcohol data periodically.

c. Data Processing: Analyse or process the data for trends.

d. Visualization: Create a graphical representation of temperature, humidity and alcohol over time.

e. Reporting: Send alerts if temperature, humidity and alcohol exceeds a certain threshold.

1. Data Acquisition:

IoT sensors (temperature, humidity, alcohol, etc.) are used to monitor the wine fermentation. These sensors are deployed to collect real-time data. Controller connected to these sensors used to retrieve data, primary edge computing and processing of data is done by the C program written in the controller chip. Further it is communicated to with IoT devices through gateways using protocols like MQTT or HTTP.

2. Data Analysis and Visualization:

Think speak cloud developed by Math Works in which MATLAB is integrated as mathematical tool is used for conducting exploratory data analysis to identify trends or anomalies in the collected data. MATLAB's plotting functions are used for the visual representation of the data. This help in understanding the conditions in the fermentation over time, such as temperature, humidity and alcohol variations.

3. Automation and Control:

This mathematically processed data is served to the app developed by IFTTT to provide alerts and significant controls. Winery uses these alerts for automation (temperature or humidity controllers), MATLAB help to design algorithms that initiate actions based on sensor data (e.g.,

turning on cooler when temperature rises above a certain threshold).

4. Wine Quality Control:

Wine colour and wine test are the most sensitive parameters in wine production. Gather data from fermentation tanks using sensors and analyze it using MATLAB to ensure consistency and quality in wine production.

5. Reporting and Decision Support:

Generate automated reports on fermentation conditions, equipment status, and predicted outcomes for decision-makers in the winery using MATLAB's reporting capabilities is possible. Decision support tools that assist winery managers in making informed decisions based on data analytics is done with the help of Mathematical and statistical analysis.

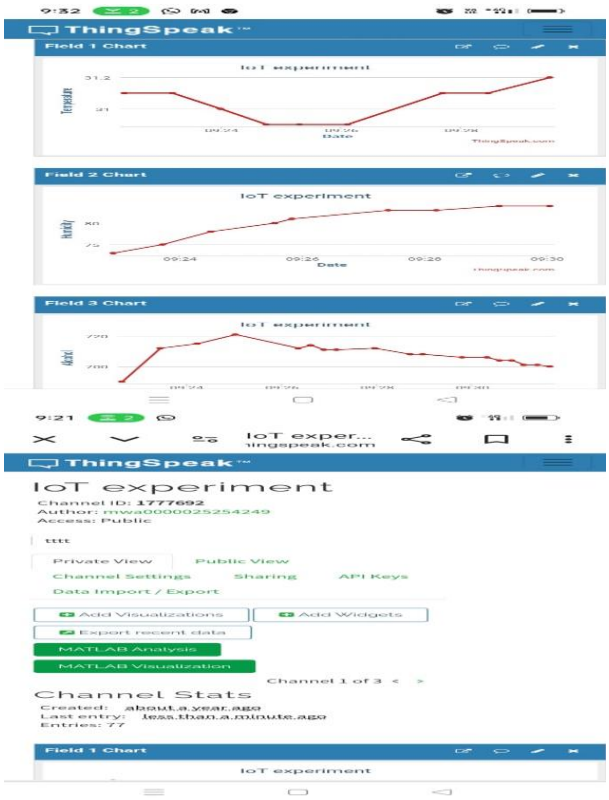

Figure: 1 Visual representation of data generated at wine fermentation by using thingspeak cloud with the help of MATLAB.

Conclusion:

Using MATLAB's Mathematical and Statistical Tool we can predict outcomes based on historical data. Predicting the time for fermentation or identifying potential risks such as wine colour or aroma is essential in winemaking. IoT is revolutionizing the industrial automation and to achieve this mathematics and statistical analysis plays vital role.

Future Scope:

a. Integration of AI can enhance data analysis, enabling smarter decision-making based on IoT data.

b. The rollout of 5G networks promises faster and more reliable connectivity, which can support a higher number of connected devices with lower latency.

c. Processing data closer to where it is generated can reduce latency, improve response times, and reduce bandwidth usage.

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