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MILK ADULTERATION DETECTION USING IOT AND ML TECHNIQUES

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ABSTRACT

Ensuring the purity of milk is paramount for public health, and the increasing instances of adulteration necessitate advanced detection methods. This paper presents a comprehensive approach to milk adulteration detection using a combination of Internet of Things (IoT) and Machine Learning (ML) techniques. The proposed system integrates pH, temperature, turbidity, TDS (Total Dissolved Solids) and conductivity sensors deployed across the milk supply chain to collect real-time data. These sensors monitor critical parameters, providing a rich dataset for analysis. The collected data is processed using a Support Vector Machine (SVM) ML algorithm, leveraging its capacity for efficient classification. SVM is trained on labeled datasets, enabling it to discern between genuine and adulterated milk samples based on the sensor readings. This model ensures robust and accurate detection of various adulterants, including those affecting pH levels, temperature, turbidity, and conductivity.

The integration of these sensors and SVM algorithm enhances the precision and reliability of milk adulteration detection. The proposed system emerges as a cost-effective and reliable solution, offering a practical tool to safeguard the safety and quality of milk products. By synergizing the strengths of IoT and ML techniques, our system empowers stakeholders to effectively combat milk adulteration and ensure consumer well-being.

KEYWORDS:- IoT (Internet of Things), pH Sensor, Temperature Sensor, Turbidity Sensor,

TDS sensor, Conductivity Sensor, ML (Machine Learning), SVM (Support Vector Machine) Algorithm.

I. INTRODUCION

Milk, a fundamental component of human nutrition, plays a vital role in ensuring public health and well-being. The Food Safety and Standards Authority of India (FSSAI) has established minimum requirements for the protein and nutrient content of milk to ensure its nutritional quality and consumer safety. According to the FSSAI regulations, milk must contain at least 2.5% fat, 3.0% protein, and 4.5% carbohydrate. These macronutrients provide essential energy and building blocks for the body's growth and maintenance.[1] However, the pervasive practice of milk adulteration poses a significant threat to consumer safety and undermines the integrity of the dairy industry. Milk adulteration involves the intentional addition of foreign substances, such as water, starch, urea, and maltodextrin, to milk, with the malicious intent to increase its volume or weight for fraudulent gain. The presence of these adulterants not only compromises the nutritional value of milk but can also lead to severe health consequences, including allergies, digestive issues, and even death.

Conventional methods for milk adulteration detection, such as lactometer testing and visual inspection, often prove to be time-consuming, labor-intensive, and prone to human error. These limitations necessitate the development of more sophisticated and reliable detection methods that can effectively combat the prevalence of milk adulteration.[2]

In recent years, the remarkable advancements in the Internet of Things (IoT) and machine learning (ML) have opened up new frontiers for milk adulteration detection. IoT- based systems offer real-time monitoring and analysis capabilities, enabling continuous surveillance of milk quality. These systems employ an array of sensors to capture various physical and chemical properties of milk, such as pH, temperature, conductivity, and turbidity. The sensor data is then transmitted to a central processing unit, where it is analyzed using ML algorithms to identify potential adulterants. ML algorithms, with their exceptional pattern recognition and classification abilities, are well-suited for milk adulteration detection. These algorithms can be trained on large datasets of sensor data and adulterant information to establish robust models for identifying adulterated milk samples. Several studies have demonstrated the effectiveness of IoT-based milk adulteration detection systems using ML algorithms.[3]

These studies underscore the immense potential of IoT- based milk adulteration detection systems using ML algorithms to revolutionize milk quality control practices. By providing real-time insights into milk adulteration, these systems can safeguard public health, ensure consumer protection, and promote economic fairness in the dairy industry.

II. LITERATURE REVIEW

Milk adulteration is a serious concern, and researchers are constantly seeking better ways to detect it. A literature review in this field would explore the different types of adulterants, their health risks, and the various detection methods available. Traditional methods like lactometers and chemical tests are covered, but the focus often shifts to newer, more advanced techniques like spectroscopy, chromatography, and DNA- based methods. Emerging technologies like IoT sensors and AI are also gaining traction. The review wouldn't just compare methods, but also discuss challenges like detecting low-level adulterants, improving accuracy, and making tools portable and affordable. It might even touch upon factors like geographical variations and economic drivers of adulteration. Ultimately, a good literature review helps researchers and policymakers understand the current landscape and chart a course for future advancements in milk safety. The outcomes of their research efforts in this area include the following results.

In 2022, a novel classification system was developed by Prashanth P Lal, Avishay A.Prakash and Kushal A Prasad to analyze common milk adulterants. The EC, pH, and temperature sensors were interfaced together with the Arduino Mega microcontroller to create the electronic tongue section of the project. These ranges formed the backbone of the Fuzzy classification system, where values outside these ranges were associated with the presence of adulterants in milk. Observing the pH and EC values at 1:1 part dilution of adulterant solution with milk produced the following results. The IoT feature was implemented to log measured milk parameters to the ThingSpeakTM cloud platform. It provided a graphical representation of the measured data concerning time and provide alternate cloud-based solutions for measurements.

In 2019, Aditya Dave, Dishant Banwari, Satyan Srivastasava have explored that there has become an ever increasing need for detecting good quality of milk against the bad one because of the vast number of methods now known and used for milk adulteration. Especially since India has a vast and thriving dairy industry committing an adulteration fraud can reap rich profits and exploit poor people if undetected. Traditional methods involve measuring the specific gravity (e.g. Lactometer). But if the weight after introducing the adulteration is kept constant, such methods fail. The ones that have overcome this flaw and are presently prevalent are contact based methods that involve contact with the milk samples and hence the samples cannot be used again. Such methods lead to large amount of wastage of milk since the reliability seen thus far does not guarantee accurate adulteration detection within short number of tests. This paper proposes a completely non-contact type method for detection of milk adulteration, preserving the consistency and quality of milk sample and making it reusable for testing again. About 500 raw milk samples were considered for the study and categorized into 3 categories namely Cow milk, Buffalo milk, and skimmed milk. Fresh samples obtained were from different dairies and commercial local brands like Saras, Anand, Amul etc. An embedded system consisting of AVR micro-controller integrated with the optical sensor, LCD and keypad was built. Refractive index was the principle parameter involved in detecting the adulteration. As the amount of water adulteration changed, the refractive index changed and these relations were used to configure the system for detecting adulteration of a random milk sample. The results obtained detected the adulteration with an accuracy of about 95 ± 1% which show an increase in misclarification accuracy of about 200% over traditional methods such as spectroscopy.

The research conducted by N Sowmya and Vijay Kumar introduces a novel approach to combat milk adulteration utilizing Artificial Intelligence alongside multispectral sensors. Their model successfully identifies four common adulterants: Hydrogen peroxide, sodium sulphate, dextrose, and Ammonium sulphate, as well as pure milk samples. Machine learning algorithms such as Naive Bayes, Linear discriminant analysis, support vector machine, decision tree, and neural network models are employed, achieving impressive accuracies ranging from 88.1% to 92.7%. Notably, the neural network's performance is enhanced to 100% through optimal parameter tuning via Genetic algorithm framework. Moreover, a dedicated IoT-enabled webpage is designed to allow users and authorized individuals to remotely visualize detected adulterants. Nonetheless, the model's efficacy may diminish if the sensor-to-sample distance exceeds one inch, and further research is warranted to explore additional potential adulterants not currently addressed.

III. Scope and Objective

- Determining the adulterant in milk at initial stages.
- It can be used as a portable device by each customer.
- To protect the interests of consumers by eliminating fraudulent practices.

- To protect the public from poisonous and harmful milk.
- To prevent the sale of substandard milk.

IV. System analysis

The system analysis of the Milk Adulteration Detection Using IoT and ML Techniques are crucial for understanding the model's performance and its implementation.

i. Existing system

Ensuring the purity and quality of milk is crucial for consumer safety and public health. Adulteration, the practice of adding inferior or unauthorized substances to milk, poses significant health risks and jeopardizes consumer trust. To combat this issue, various methods have been employed to detect milk adulteration.

Lactometer testing: A lactometer is a hydrometer specifically designed to measure the density of milk. Since pure milk has a higher density than water, a lactometer will float higher in pure milk compared to watered-down milk. Lactometers are relatively inexpensive and easy to use, making them a common choice for home testing. However, their accuracy is limited due to factors such as temperature fluctuations and the presence of non-water adulterants.

Visual inspection: Visual inspection of milk can also provide preliminary indications of its purity. Pure milk should exhibit a white or slightly yellowish color, maintain a uniform consistency, and be free from visible impurities. However, these visual cues are not always reliable, as certain adulterants can mimic the appearance of pure milk.

ii. Limitations of existing system

- **Inaccuracy:** Lactometers and visual inspection methods can be inaccurate due to factors such as temperature variations, the presence of non-water adulterants, and the type of milk being tested.
- **Limited scope:** These methods primarily detect water addition as the adulterant and may overlook other forms of adulteration, such as chemicals, starch, or urea.
- **Labor-Intensiveness:** Testing milk using a lactometer and visually inspecting it can be time-consuming and hard to handle.
- **Inconsistent visual cues:** Visual inspection of milk for signs of adulteration can be subjective and unreliable.

- No Machine Learning model is implemented.

iii. Proposed system

The proposed system consists of an Arduino UNO microcontroller and the sensors which are the pH sensor, Temperature sensor, TDS sensor, Turbidity sensor, and Conductivity sensor. Instead of manually noting the data, the data is stored in the Thinkspeak and through Machine Learning model the data is classified.

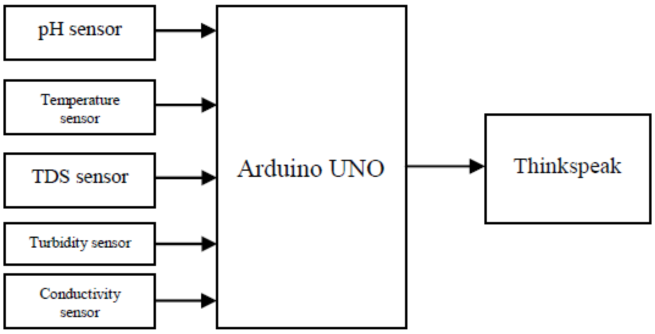

Fig. 4.1: Proposed system.

V. METHODOLOGY

The term "methodology" refers to a systematic and structured approach to conducting research or solving a problem. It outlines the steps involved in a process, the tools and techniques used, and the underlying principles that guide the investigation or solution development.[4]

In the context of Milk Adulteration Detection Using IoT and ML Techniques, the methodology encompasses the procedures and strategies employed to utilize IoT (Internet of Things) devices and machine learning (ML) algorithms for effective detection of milk adulteration. It encompasses the following key aspects:

i. Data collection

Data collection is the initial and crucial stage of developing a milk adulteration detection system using IoT and ML techniques. This stage involves gathering sensor data from both pure and adulterated milk samples to establish a comprehensive dataset that encompasses the diverse characteristics of both unadulterated and adulterated milk.

ii. Data preprocessing

Data preprocessing is an essential step in the development of machine learning models, as it ensures the quality and consistency of the data used for training and evaluation. This phase focuses on cleaning, normalizing, and transforming the sensor data to ensure its integrity, consistency, and suitability for machine learning analysis.

iii. Model training

This stage involves utilizing the SVM (Support Vector Machine) ML algorithm to learn the patterns and relationships within the preprocessed and engineered data, enabling the distinction between pure and adulterated milk.

iv. Model evaluation

This step assesses the performance of the trained SVM model on an unseen dataset to evaluate its classification accuracy, precision, recall, and F1-score.

v. Model Deployment and Monitoring

This stage involves integrating the trained SVM model into the IoT system, enabling real-time milk analysis and triggering alerts in case of adulteration detection. Additionally, continuous monitoring of the model's performance is crucial to maintain its effectiveness and adapt to potential changes in milk characteristics or adulteration practices.

VI. System architectural design

The design phase is a crucial stage in the project management lifecycle, responsible for transforming raw requirements into detailed and actionable plans. It serves as a bridge between the conceptualization of a project and its actual implementation, laying the foundation for a successful outcome. The goal is to create a comprehensive blueprint that clearly communicates the project's objectives, scope, and deliverables.

The enhanced system aims to detect milk adulteration with greater precision by employing additional sensors: pH, temperature, turbidity, Total Dissolved Solids (TDS), and conductivity. The collected data from these sensors is transmitted to a cloud platform for processing and analysis. The system utilizes the SVM machine learning algorithm to classify milk samples as either pure or adulterated based on the comprehensive sensor data.

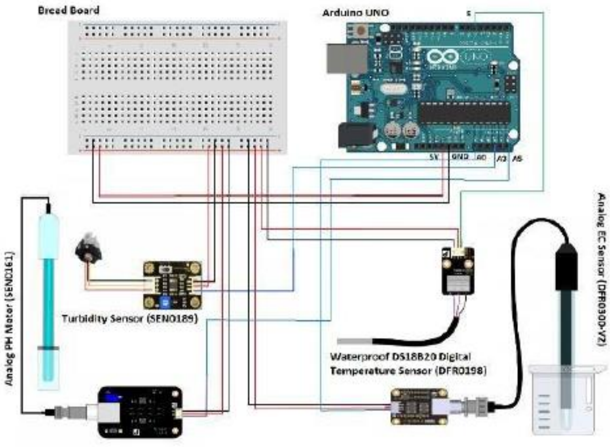

Fig. 6.1: System architecture design.

The system architecture comprises three main components

i. Sensor node

Sensor nodes play a crucial role in milk adulteration detection systems by continuously monitoring and measuring various parameters of milk quality. These nodes are equipped with sensors that can detect the presence of adulterants, such as water, starch, sugar, and harmful chemicals, in milk samples. By analyzing the sensor data, milk adulteration detection systems can flag contaminated samples for further investigation or immediate rejection.

Sensor nodes are often integrated into milk adulteration detection systems that combine sensor data with data from other sources, such as milk temperature, production date, and supplier information. This integrated approach provides a comprehensive assessment of milk quality and helps to identify potential adulteration patterns. The use of sensor nodes for milk adulteration detection is becoming increasingly prevalent as technology advances and sensor costs decrease. These nodes are playing a vital role in ensuring the safety and quality of milk products for consumers worldwide.

pH sensor: pH (Potential of hydrogen) is a measure of the hydrogen ion concentration in milk. This means is that for every tenfold change in hydrogen ion concentration, there is a one unit change in pH. pH is a numeric scale used to specify the acidity or basicity of an aqueous solution.

It measures the acidity of milk, which is an indicator of water adulteration. The pH of milk typically ranges from 6.4 to 6.8, with the ideal range being between 6.5 and 6.7.[5] A lower pH value indicates a higher acidity, which could be a sign of water adulteration. Milk with a pH below 6.2 is considered to be sour and undesirable.

Fig. 6.2: pH sensor.

Temperature sensor: Temperature sensors are devices that detect and measure coldness and heat and convert it into an electrical signal. Temperature sensors are utilized in our daily lives be it in the form of domestic water heaters, thermometers, refrigerators, or microwaves. Temperature Sensor is a piece of electronic equipment that detects the temperature of its surroundings and transforms the incoming data into electronic output data to control record or signal temperature variations. It measures the temperature of milk, which can deviate from normal levels due to preservatives or chemicals. The ideal temperature for drinking milk is between 15-20°C (59-68°F). This temperature range allows for optimal taste and nutrient absorption. Milk that is too cold can be unpleasant to drink and may numb your taste buds, while milk that is too hot can destroy some of its nutrients.[6]

Fig. 6.3: Temperature sensor.

Turbidity sensor: Measures the cloudiness of milk, increasing with foreign particles or impurities. The turbidity of pure milk typically ranges from 10 to 20 NTU (Nephelometric Turbidity Units).[7] An increase in turbidity beyond this range may indicate the presence of foreign particles or impurities, suggesting milk adulteration.

Fig. 6.4: Turbidity sensor.

TDS sensor: A TDS meter indicates the total dissolved solids like salts, minerals, and metals, in a solution. This parameter can be used to give you an idea of water quality and compare water from different sources. One of the main applications of a TDS meter is aquarium water quality monitoring.

Measures the total dissolved solids in milk, which may be elevated due to added salts or minerals. The total dissolved solids (TDS) content of milk typically ranges from 120 to 180 milligrams per liter (mg/L) or parts per million (ppm). Elevated TDS levels in milk may indicate the addition of salts or minerals, such as sodium chloride or calcium carbonate, which are common adulterants used to increase the milk's weight and appearance.[8]

Fig. 6.5: TDS sensor.

Conductivity sensor: Taste is something which is dependent on the pH and conductivity of particular substance as the adulterants added to the milk will have different conductivity. Conductivity of solution depends on the concentration of all the ions present. Greater the concentration greater will be the conductivity. Since pH is a measure of H+ ions, for an acidic solution PH will be lower [higher H+ ions], hence greater will be the conductivity. Similarly higher the pH lower will be the conductivity for basic solution.

It measures the electrical conductivity of milk, which can be altered by conductive substances. The electrical conductivity of pure milk typically ranges from 2.2 to 2.5 mS/cm (millisiemens per centimeter) at 25°C (77°F). This conductivity is primarily due to the presence of dissolved ions in milk, such as lactose, proteins, and minerals.

Fig. 5.6: Conductivity sensor.

ii. Data transmission

The Arduino Uno microcontroller can effectively transmit sensor data for milk adulteration detection. It gathers sensor readings, converts them to digital values, packages them into structured data packets, and transmits them using a wireless communication module. Modbus, Serial communication, Wi- Fi, and Bluetooth are common protocols, while XBee, ESP8266, HC-05, and SIM800L are popular modules.[9]

The Arduino Uno microcontroller acts as the sensor interface, data acquisition unit, and communication hub in the milk adulteration detection system. It collects sensor data, processes it into meaningful measurements, and transmits it to a cloud platform or data server for analysis and classification. The SVM machine learning algorithm utilizes this sensor data to identify patterns and distinguish between pure and adulterated milk samples.

Fig. 6.7: Arduino UNO.

iii. Thinkspeak (Cloud platform)

The cloud platform serves as the central hub for data storage, processing, analysis, and visualization in the milk adulteration detection system. It handles data ingestion, preprocessing, feature extraction, machine learning model training and deployment, real-time classification, and comprehensive visualization and analytics, ensuring effective milk quality monitoring and adulteration detection.

The Support Vector Machine (SVM) algorithm serves as the classification model in milk adulteration detection using IoT and ML techniques. It effectively distinguishes between pure and adulterated milk samples by finding an optimal hyperplane, a decision boundary that separates the data points into two classes.

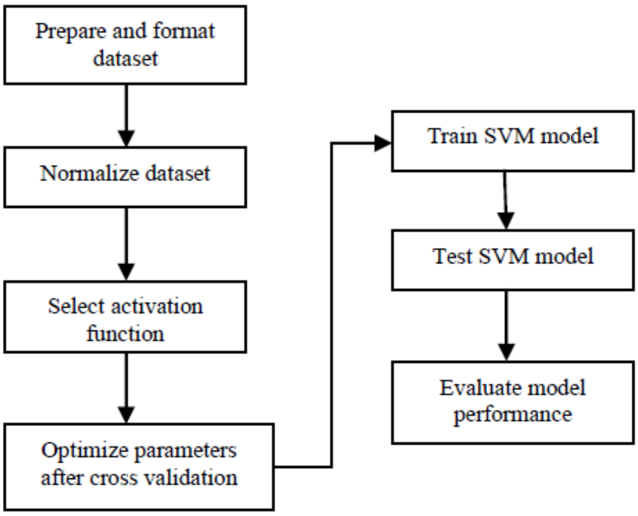

Fig. 6.8: Flowchart of SVM model.

SVM Algorithm

Begin

1. Initialized SVM parameter and structure
2. Generate an initial number of birthing lairs
3. L = (f = 1,2,3,…,n)
4. While (Stopping criterion)
5. If noise = false
6. Search in the proximity for a new lair by using a Brownian walk Else
7. Expand the search for a way for a new layer by using levy walk
8. End if
9. Evaluate the fitness of each new lair and compare with previous one

10. If
11. Leste > y bestk+1
12. Choose the new lair
13. Less = Lbestik
14. Else
15. Go to 4
16. End if
17. Rank the solutions;
18. Return the best lair
19. The global best lair is fed to SVM classifier Training the SVM classifier
20. End while
21. End

VII. CONCLUSION

The integration of IoT and ML techniques has emerged as a transformative approach to milk adulteration detection, offering a comprehensive and multifaceted solution to address this critical concern. By employing a network of sensors to gather real-time data on milk quality parameters, including pH, temperature, turbidity, TDS, and conductivity, the system enables continuous monitoring and early detection of adulteration attempts. This real-time surveillance capability empowers stakeholders to take immediate corrective actions, preventing the distribution of contaminated milk products and safeguarding consumer health. The system's effectiveness is further enhanced by the incorporation of advanced machine learning algorithms, specifically the SVM (Support Vector Machine) algorithm. SVM excels in pattern recognition and classification tasks, making it ideally suited for identifying adulteration signatures in the collected sensor data. The algorithm's ability to learn and adapt from continuously updated data ensures that the system remains effective in detecting even emerging forms of adulteration.

Beyond real-time monitoring and precision detection, the IoT-ML system offers valuable data-driven insights into milk quality trends and potential adulteration patterns. The cloud platform, serving as the system's central hub, facilitates data analysis, visualization, and correlation, enabling stakeholders to identify potential sources of contamination and implement targeted quality control measures. This data-driven approach empowers informed decision-making and continuous improvement of milk production and distribution practices.

In contrast to traditional laboratory testing methods, the IoT-ML system offers a more efficient and streamlined approach to milk adulteration detection. By eliminating the need for time- consuming and resource-intensive laboratory analyses, the system reduces processing time and costs, leading to significant economic benefits for milk producers and distributors. Overall, the integration of IoT and ML techniques into milk adulteration detection represents a paradigm shift in safeguarding milk quality and consumer health. By providing real-time monitoring, enhanced precision, data-driven insights, scalability, adaptability, and reduced reliance on traditional methods, this innovative solution plays a pivotal role in ensuring the integrity of the milk supply chain and fostering consumer trust.

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