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Spoilage detection and shelf life prediction of food using Internet of Things and Machine Learning

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Abstract:

Food spoilage is a crucial problem everyone is facing in the world. Every year about 48 million cases of food-borne illness are reported across the world. This is due to the consumption of spoiled food. Spoiled food contains several volatile organic compounds which are harmful to health. So, it is necessary to develop a system that can detect food spoilage before even the signs of spoilage are visible. The system aims at detecting spoiled food using appropriate sensors and by monitoring gases released from food. Different sensors are used to detect different parameters of food such as pH, moisture, oxygen level, ammonia gas, methane, and ethylene. The microcontroller takes readings from sensors. These readings are used as input to the machine learning model which will determine whether food is spoiled or not. If food is not spoiled, then the ML model will also predict the lifespan of food. This would help consumers to consume fresh food and avoid food-borne illnesses. With the help of this gadget, human mistakes that occur during the inspection can also be avoided. As in this system, the work of humans has been taken by the sensor, due to which there is no chance of human errors. That's why its accuracy has increased. The device gets the accurate results while detecting food spoilage. Time and money consumption can be reduced due to the high efficiency of the system, which will be profitable for large industries.

IndexTerms - **Arduino Uno, Internet of Things, Machine Learning, Sensors, Spoilage detection.**

I. INTRODUCTION

In today's world, food spoilage is crucial problem in food industry as consuming spoiled food is harmful for human's health. About 351,000 people die of food poisoning globally every year. The freshness of food can be detected manually but manual detection in a large scale industry is almost impossible and also may led to human error and environmental defects. So it is necessary to develop a device that can detect the freshness of food and also the lifespan. Proposed system will detect the spoiled food using biosensors[7] which is used to monitors the gases released by particular food items and ML technologies such as KNN[6] algorithm. Biosensor plays a vital role to detect the food spoilage. Based on the combination of the sensors outputs of the food items should be detected.

II. LITERATURE SURVEY

Food spoilage can be detected manually by checking color, tasting it or by smelling it. But manual checking is time consuming, less efficient and expensive due to human errors, environmental defects as checking color or taking smell sometimes gives wrong results. Various food quality monitoring systems and food spoilage detection systems are made using various technologies.

To analyze the images of food item, image processing[3] technique is used. The color, texture and shape are analyzed using computer vision algorithms in order to classify the food based on the color, size, maturity, defects etc. Fuzzy Logic is used to handle the fuzzy information and rule-based inference to construct decision support in real life applications. To estimate the expiration of food commodities, fuzzy set theory is used [5].

eFresh[7] is a device developed with biosensors that measures pH, moisture, and ethanol level of food item. The user can input the food to be checked from Android mobile application, the selection of food item from application gives command to Arduino Uno with communicating through Bluetooth module and microcontroller takes the reading from sensor and decision is made based on predefined algorithm and output is displayed on LCD.

A unique method is introduced for detecting food deterioration by combining picture classification with machine learning techniques and artificial intelligence [1]. They have used AI, deep CNN networks, computer vision, and ML

techniques such as the k clusters method[1] for color classifications in pictures and its HSV values for spoiling detection to identify food rotting.

To determine whether the food is spoilt or not, machine learning train the model using some sample datasets (training data). The information from MQ gas sensors is fed to PCA[6] to reduce the data and KNN is used for classification of food. The fruit type and quality is determined using convolutional neural networks[8].

UHF RFID[2] sensor for detecting food quality has been described in a research. This sensor is based on inter-digital capacity found in an RFID antenna, onto which a coating of vegetal biopolymer has been placed. Electromagnetic coupling between the capacity and the biopolymer is, therefore, employed to vary the adaption coefficient between the chip and the antenna of the RFID tag based on food deterioration. Experimental measurements of an RFID-sensor exposed to a genuine food gas environment in the process of deterioration.

The paper [3] presents categorization of the date fruits into two types as eatable and non-eatable. The methodology involves three phases that is Image processing, Features extraction and Classification. The fruit feature fusion considered includes color, texture and shape. The extraction of feature is done using Scale Invariant Feature Transform (SIFT)[3]. The classification technique used is SVM classifier using linear Kernel function. The result shows that SVM method performed with 100 percent of accuracy.

MIT team has done research on detection of spoilt meat items by developing a sensor to detect spoiled meat. But since it only detects a particular gas, it can have a lot of false negatives.

An MQ4 gas sensor used to detect the methane gas in the atmosphere which shows the freshness of the food and UV sensors[10] were used to track the food quantity. This model detects the quality of food and when the food started degrading it alerted instantly.

III. SYSTEM ARCHITECTURE

This system consists of two modules – namely IoT and Machine Learning. Different sensors are used to measure pH level, moisture content, and ethanol level of the food. The system comprises of Arduino uno microcontroller, ESP8266 Wi-Fi module, pH sensor, gas sensor, moisture sensor. The food items must be placed inside the sensing range to capture the more precise values of elements. Sensor senses the food items and then with the help of microcontroller the signal is transferred to the Wi-Fi module esp8266. After that the sensor data is fed to the machine learning model for further predictions. Based on the freshness level of sustenance, the result is displayed as “Good to eat” or “Ready for bin (Spoiled)”. In this system the elements like pH, moisture, ethanol, and gases are constantly monitored to make real-time predictions.

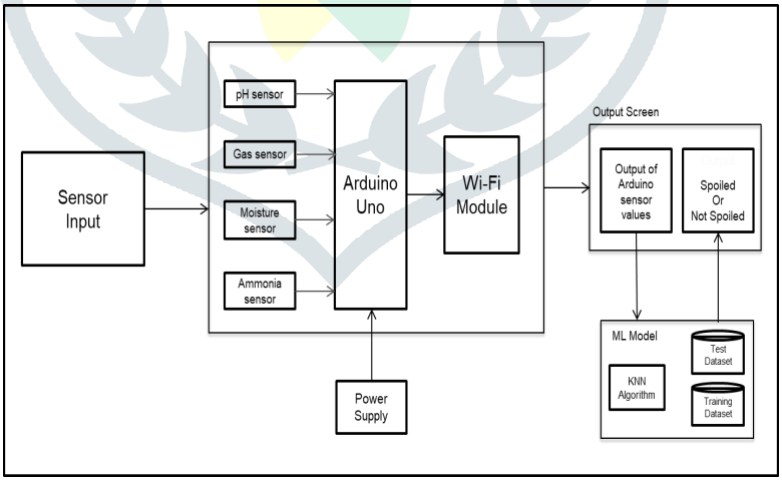


Figure 1: Architecture diagram

IV. PROPOSED METHODOLOGY

The main aim of the project is to make a device which can detect the freshness of food and food spoilage. Different sensors are used which measures different parameters of food such as oxygen level, ammonia gas, pH, moisture, etc. The device consists of Arduino Uno, Wi-Fi module esp8266, sensors like pH sensor, gas sensor, etc. This sensors measure the oxygen and ammonia content in the particular food item. PH of dairy products is measured using pH sensor. The real time values of the sensor are communicated to laptop using microcontroller. Machine Learning model uses trained model to predict whether the food is spoilt or not on the real time data.

A. ***Arduino Uno***

The Arduino UNO is ATmega328 based **microcontroller** board. It is IoT based device and is a popular prototyping board. It is interfaced with various sensors to monitor pH, humidity, etc. Arduino is connected to different arduino shields for Wi-Fi and Bluetooth network connectivity.

Figure 2: Arduino Uno

B. ***Wi-Fi Module***

Wi-Fi controller is used to send and receive messages to Arduino with ESP8266 wifi module using TCP/IP protocol. Add IP address and port of device for device connectivity.

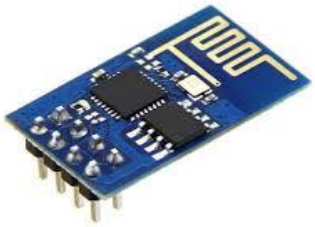


Figure 3: ESP8266

C. **pH Sensor**

A pH sensor used for measurement of pH level of liquids, specifically dairy products like milk, curd, etc. It measures the amount of alkalinity and acidity with a value ranges from 0 to 14.

Figure 4: pH Sensor

D. ***Oxygen Sensor***

Oxygen promotes food spoiling process such as microbial growth and protein decomposition. Therefore, an oxygen sensor let the consumers know if food is safe to eat or ready for bin. The sensor turns blue in excess oxygen indicating to the consumer that the food should be thrown away.

Figure 4: Oxygen Sensor

E. ***Moisture Sensor***

There are different types of moisture sensors for different types of food or grains. The moisture sensor tests the humidity of grain products and fruits.

Figure 5: Moisture Sensor

F. ***Ammonia Gas Sensor***

Ammonia has been used as an important marker to indicate the event of food spoilage. Ammonia detector works on electrochemical principle. The electrochemical sensors are electrochemical measuring transducers for measuring the partial presence of gases under atmospheric conditions.

Figure 6: Ammonia Sensor

V. SYSTEM ANALYSIS AND DESIGN

System uses Machine Learning to predict the results of food item, this system involves following components to make predictions.

Figure 7

A. Data Collection

System detects spoilage of more than 5 food items at a time. These food items include Milk, Chilly sauce, Soft drinks, Meat, Prawns, Fish, etc. The real time input values which are extracted from sensors, using these values the dataset has been created which contain Ammonia, Oxygen and pH values of food Item, as shown in table 1 and table 2.

TABLE I
SAMPLE DATASET 1

Item	pH	Result
Milk	6.4	1
Chilli sauce	4.8	1
Curd	3.3	1
Milk	4.8	0

Curd	2.4	0
Soft drink	5.6	0
Chilli sauce	3.7	0
Milk	4.2	0
Soft drink	3.5	1

TABLE III
SAMPLE DATASET 2

Items	Ammonia(mV)	Oxygen	Result
Meat	700	30	0
Fish	100	80	1
Meat	300	85	1
Prawn	500	20	0
Fish	450	25	0
Meat	250	90	1
Prawn	150	30	1
Fish	150	90	1
Meat	650	40	0

B. Data Cleaning

As ML efficiently works with numerical data, so column containing textual values should be removed, Dummy Variable concept is used to convert the data into numerical dataset.

	pHvalue	lifespan	result	Chillisauce	Curd	Softdrinks
0	6.4	6	1	0	0	0
1	3.4	0	0	0	0	0
2	2.0	0	0	0	0	0
3	6.8	7	1	0	0	0
4	4.7	2	1	0	1	0
5	4.5	2	1	0	1	0
6	6.0	2	0	0	0	0
7	4.5	0	0	1	0	0
8	4.2	0	0	1	0	0
9	5.5	3	1	0	1	0
10	6.5	0	0	0	0	1

Figure 8

C. Data Frame Table

To predict the output K-Nearest Neighbor which is most popular algorithm of ML is used. KNN algorithm stores all the available data and classifies a new data point based on the similarity. This means when new data appears then it can be easily classified into a well suited category by using KNN algorithm.

D. Model Training

In this graph, red data points belong to spoiled category whereas green data point belongs to not spoiled category.

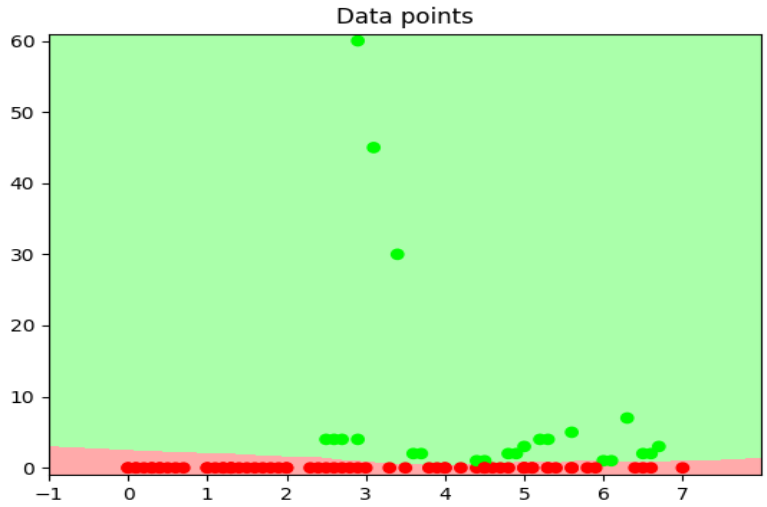


Figure 9

VI.RESULTS AND DISCUSSIONS

After applying KNN algorithm to our Machine Learning Model we are getting output with 98% of accuracy. Confusion Matrix and Classification Report of ML model is given below:

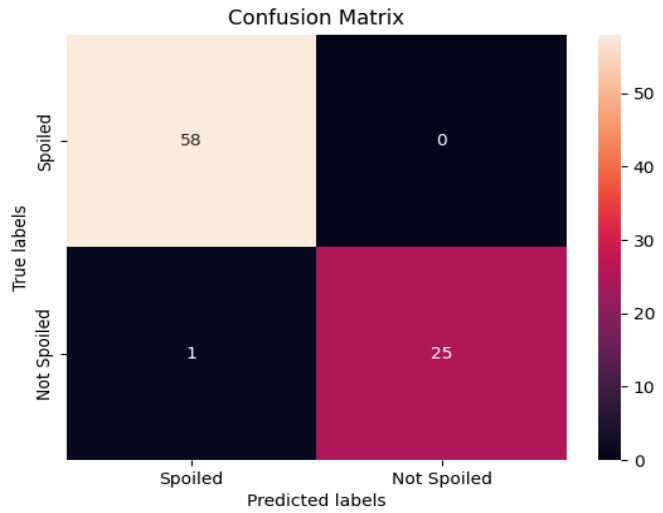
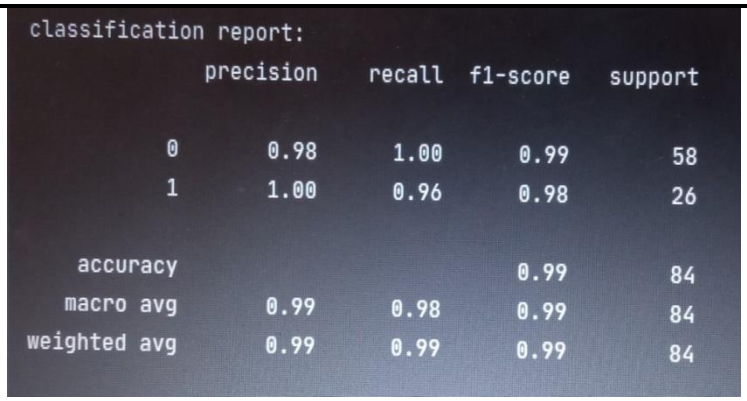


Figure 20

In confusion matrix;

- 58 indicate **TRUE NEGETIVE (TN)**, which means that 58 data points are correctly predicted and belongs to spoiled category.
- 25 indicate **TRUE POSITIVE (TP)**, which means that 25 data points are correctly predicted and belongs to not spoiled category.
- 0 indicates **FALSE POSITIVE (FP)**, which means there is no data point which is incorrectly predicted.
- 1 indicates **FALSE NEGETIVE (FN)**, which means that there are 1 data points which belongs to soiled category but predicted as not spoiled.



classification report:

	precision	recall	f1-score	support
0	0.98	1.00	0.99	58
1	1.00	0.96	0.98	26
accuracy			0.99	84
macro avg	0.99	0.98	0.99	84
weighted avg	0.99	0.99	0.99	84

Figure 31

Classification Report:

It is a performance evaluation metric in Machine Learning which is used to show Precision, Recall, and F1-score, Support score of trained classification model.

Precision: What Percent of predictions were correct?

Precision is nothing but accuracy of positive prediction. Here accuracy of positive prediction is 1, which means all the data points which belong to Not Spoiled category were correctly predicted. And accuracy of negative prediction is 0.98 means 98 percent of data point which belong to Spoiled category were correctly predicted.

Calculations for precision:

1. Data points which belongs to Not Spoiled category:
   Precision=TP/ (TP+FP) => 25/ (25+0) => 1
2. Data points which belongs to Spoiled category:
   Precision=TN/ (TN+FN) => 58/ (58+1) =>0.98

Recall: What percent of positive cases did you catch?

Recall is fraction of positive cases that were correctly identified.

Calculations for recall:

1. Data points which belongs to Not Spoiled category:
   Recall=TP/ (TP+FN) => 25/ (25+1) => 0.96
2. Data points which belongs to spoiled category:
   Recall=TN/(TN+FP) => 58/(58+0) =>1

F1-Score: What percent of positive prediction were correct?

F1-score is a weighted harmonic mean of precision and recall such that best score is 1.0 and worst score is 0.01.

F1-Score = 2*(recall*precision)/ (recall + precision)

= 2*(0.96*1)/ (0.96+1)

F1-score = 0.98

Support Score: Support is the number of actual occurrence of the class in the dataset. Here 58 occurrences actually belong to Spoiled category whereas 26 occurrences belong to Not Spoiled category.

VII. CONCLUSION

The proposed method uses various sensors to extract the various values of food item like pH and other gases using IoT and then Machine Learning model is used to detect the freshness of food whether it is spoilt or not and predict the lifespan of that food item. Now we are testing few food items but in future we are planning to extend a scope of a project.

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