

Machine Learning-based Food Waste Management System

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Abstract—Our project aims to develop an engaging mobile application that serves as a ubiquitous platform for users to visualize available food resources in their local region and, as a result, acquire access to food, thereby addressing two key issues: hunger and food waste. We noticed the potential for mobile technology to help with food waste management and developed an Android app that allows businesses to donate and share leftovers with people in need. By reducing hunger and food waste, our activity has a significant influence on both healthcare and the environment. Apart from this, the application also provides analytics to the restaurants to reduce food wastage at their side using Machine Learning. Ensemble models like XGBoost and Random Forest are considered which will be beneficial in regularization for avoiding overfitting and also for inbuilt cross validation.

Index Terms— Food waste, waste Management, food saving application, food management.

I. INTRODUCTION

The wastage of food has turned out to be a major issue in today's world. It has gotten to be an extreme concern in our society which is affecting both poor and rich countries, and it has been estimated by the Food and Agriculture Organization (FAO) that over 1/2 of all meals produced will in no way be consumed. The time and energy that has been put to prepare the food goes to waste along with the natural resources and limited accessible agricultural land which may well be utilized in a more proficient and economical way. Waste has a substantial financial impact as well as an environmental impact, including overall greenhouse gas emissions.

At the end of the day, every restaurant has perfectly wonderful food that it cannot sell. A lot of this food is wasted and thrown away when it could have been used to feed someone who was hungry. Furthermore, increased food waste necessitates the construction of more trash disposal facilities, resulting in an unnecessary rise in energy usage. What if there was a platform that linked restaurants with organizations like food banks? Not only will food banks be able to feed more hungry people as a result of this platform, but restaurants will also have a useful avenue to distribute or dispose of excess food. It's a win-win situation in which corporations may make a significant contribution to a sustainable environment at the same time charities help fight food poverty.

II. LITERATURE SURVEY

The paper 'A Food Wastage Reduction Mobile Application' proposes to solve food wastage: a common problem faced by the society. In this paper the researchers have suggested the use of smartphones and built an application that allows restaurants to donate their leftover food to the needy. The app will have a dual authentication system

(User as well as Restaurants) consisting of registration and logging in/out. From the restaurant side the leftover food items can be added (images) along with the description and quantity. On the other hand, the user will log in on the application and will be shown the list of the food items by the respective restaurants from where he/she can select the food items and add it to cart followed by check out.

Limitations of the above applications are:

- i. There is no feature to discard the food after a period of time.
- ii. The app is only for Android Users.
- iii. GPS facility is absent. [1]

'FoodX, a System to Reduce Food Waste' the paper attempts to solve the problem of food wastage faced by Indonesia and also bring down the nation's hunger rate. In this paper the researchers are aiming to help people who are starving in Jakarta by connecting donors and humanitarian communities. This system has four different sorts of users: application managers, community managers, donors, and volunteers. The application manager features a part to supervise and oversee all exchanges from each community, benefactors, and volunteers. Community managers are in charge of regulating the distribution of food from donors and informing donors of the results of distribution. To donate food, donors must fill out an application. Because not every community has volunteers, the volunteer application is solely for those who want to assist in the process of picking up and delivering food.

Limitations:

- i. Application is not available on all platforms.
- ii. User interface needs more attention.
- iii. Applications are complex (Many types of users).
- iv. Only Indonesian Language is supported by the application. [2]

According to the paper 'Reduction of Food Wastage through Android Application – Make You Smile', which was published in 2019, creates an android application through which one can donate food and the other one can receive it. The application built in this system Admin, User, Driver. The admin verifies information, User can be anyone who wants to buy or donate food and the Driver is the one who picks up food from the source and delivers it to the destination. The issue with this application is that firstly the Tech Stack used are not the recent ones. This application uses XML to store data, which is difficult to parse. Secondly there is no verification of users that means no user will be verified and any security breaches can happen. Moreover, this application is only available for Android Smartphones.[3]

In this paper 'FOOD WASTAGE REDUCTION MOBILE APPLICATION', the developers have tried to create an android application using Java and XML to reduce the food reduction and redistribute the leftover food. In this application the admin collects the food from donors through their agents and then provides it to the nearest orphanages or poor people. The application basically consists of two systems. The first is Admin, who can add people to the list and once food is collected, he will send notification to all of his people. The second is the user who will get these notifications. The application UI is quite simple and easy to use. The application does not have major functionality such as verification of users, food item and quantity display, etc. The application also does not provide a GPS function. [4].

The paper 'Waste to Wealth- A Novel Approach for Food Waste Management' proposes to solve the problem through a garbage management system. This system uses an IR sensor, a microcontroller and also a Wi-Fi module. There are 3 IR Sensors on the surface of the dustbin which are placed at different levels showing the genuine level of trash contained in the bin. The quantity of trash or garbage in the bin is measured by using a weight sensor. Then this information is sent to the server with the help of a WIFI Module. The system cleans dustbins as soon as the waste level comes to its greatest. The goal here is to lower the overall cost of the waste collection by reducing the total number of trips of the vehicle. The limitation is that the system proposed for a smart garbage bin can be costly. This system works on IoT and if the components used stop working or malfunction then the accurate results cannot be provided. [5]

The paper 'SeVa: A Food Donation App for Smart Living' centres on developing an app called SeVa. Through this application the client can view all the local areas where food is available and can also acquire access to the food. The app's purpose is to function as a go-between the donor who donates food and the receiver who is in need of food. Both types of users mentioned above can login to the same applications and select the role suitable for them. SQLite is used to store the data. The app is made using android studio. Android is used on the frontend and Java is used on the backend to code the app's layout and functionality.

The following are the restrictions:

- i. SQLite is used to store the data, and it can only store a minimal quantity of data.

- ii. This app is only compatible with Android smartphones.
- iii. The app caters to a specific territory and clientele for food donations, primarily in the New Jersey-New York area. [6]

Classification Models is helpful for food catering organizations and local vendors of food. To serve the purpose, they have collected historical data from different organizations, and we have presented a comparative case study of two classification algorithms which are decision tree and naive Bayes. Dataset is mainly categorized into 'Age,' 'Gender,' 'Education,' 'Payment,' and 'Usage' are the four attributes and one class that make up the dataset. The average accuracy of the Naive Bayes method was 0.74, whereas the decision tree was 0.65. [7]

In another research model two independent convolutional routes were used that took the features of two images at different abstraction levels. At higher abstraction levels, convolutional layers extract higher-level features such as contours and forms, while lower convolutional layers extract low-level features such as edges and corners. The two convolutional routes are two examples of pre-trained VGG16 convolutional blocks trained on the Imagenet dataset. The authors made the weights of these two feature extraction paths non-trainable during the training phase. VGG16 is made up of five convolutional blocks. There are numerous convolution layers and a pooling layer in each convolutional block. The image representation is downsampled by the pooling layers. In VGG16 network's first two convolutional blocks have two convolutional layers, whereas the latter three convolutional blocks have three convolutional layers. For classifying food waste in waste bins, the authors used a deep convolutional neural network approach.

In this experiment, many objects of interest (food wastes) were successively placed to an observed scene (food waste bin). Because each image comprised numerous things of interest, image recognition networks were ineffective. Due to a lack of localization data, the authors were unable to use object detection networks. Furthermore, there was no segmentation data available. A single label was assigned to each image in the data set. Only the last food class tossed in the garbage bins was stated on the categorization labels.[8].

III. STATISTICS

A. Poverty Rate in India

Poverty is one of the most important factors while talking about Food Waste Management. Poverty defines the group of people who do not have the basic needs of life such as food and shelter which are required to live a quality life. India ranked 94th in the Global Hunger Index out of 107 countries in 2019. In 2020, India ranked 102nd out of 117 countries with 28% of the total population in poverty. A survey below shows the increasing rate of poverty in India.

TABLE I. 2018-2021 POVERTY RATES IN INDIA

Year	Poverty Rate Increase (%)
2018	5.7 %
2019	6.7 %
2020	9.2 %
2021	10.5 %

B. Food Waste in India

Food Loss and Food Waste are two major kinds of wasted food. There can be numerous reasons why food is wasted. A common example of food waste is cooking excess food. Humans generally cook and over produce food, and once they are not able to consume, they usually throw it away. Other reasons can include food deterioration, over-preparation, date label ambiguity, overbuying, and poor planning to buy food, etc. According to The United Nations Food and Agriculture Organization (UNFAO) more than 40% of the food that is manufactured is expended carelessly. According to a survey India wastes an average of 18.7 kilograms of food daily. The following table shows the food waste rate in India.

IV. EXISTING SYSTEM

A lot of developers have made an effort to bridge the gap between the party's wasting food and the party's donating it in order to reduce the food wastage problem. The applications which are developed till now use a

TABLE II. 2018-2021 FOOD WASTE RATES IN INDIA

Year	Food Waste Rate (Tons)
2018	52 million Tons
2019	59 million Tons
2020	67 million Tons
2021	79 million Tons

mobile or website application, through which parties log in and contact each other. The applications do not take into consideration the authentication and verification of users and NGO's. Moreover, the tech-stack used for the application is outdated which consists of a lot of vulnerabilities. Using such outdated technology also leads to delay in getting responses from the server.

Most of the applications have not been updated from their initial release date and hence no new functionality has been implemented. The User Interface of these applications are also not up to date. The below table shows a comparative study of 3 different applications.

TABLE III. COMPARATIVE STUDY OF 3 APPLICATIONS

Objective	Aahar	Zero Hunger	SeVa
App Release Date	6 Feb 2019	24 April 2020	Not deployed
Last Updated On	2 Feb 2021	24 April 2020	Not deployed
Locality App works on	Indore	Florida	New Jersey
Available on	Play Store and App Store	Play Store	None
Security	Only based on OTP	None	None
Rating Score as per users	4.0	3.5	None
Feature List	One Application Authentication on basis of OTP Old UI	Categories of donation item Posts of donations UI design is average	Not Interactive UI Uses IOT device which is not feasible

V. PROPOSED METHODOLOGY

A. Data Set

The features of the ML model are considered to be the number of people visiting the restaurant, day of the week, bank holiday, is the locality posh or crowded, restaurant stars, working hours and type of food. Along with these features, the quantity of food ordered and the quantity of food left is also taken into consideration for predicting the quality of food made on a specific day.

B. Machine Learning Model

To use ANNs, a good amount of data is required, otherwise, it will yield inaccurate results. Linear Regression is very sensitive and with a low number of samples it will overfit. And to handle extremely diverse data, ensemble learning algorithms are considered to be one of the best robust models. Ensemble Learning is a basic meta approach for ML which looks around for good predictive results by combining the predictions from several other models. Random Forest Regressor and XGBoost Regressor can assist in the development of the model, however, hyperparameter tuning should be done very carefully.

In Random Forest algorithm, fits a number of decision trees on sub-samples and averages the predictive accuracy and prevent overfitting. And the sub-sample size is tuned by the `max_samples` parameter, otherwise whole dataset is utilized to develop each tree. Along with this `max_depth` and `max_features` parameter also plays a crucial role in hyper parameter tuning and enhance the model. The Bayes optimal regressor is an ensemble in the hypothesis space of all the hypotheses. It assumes that the data is conditionally independent and hence it will be

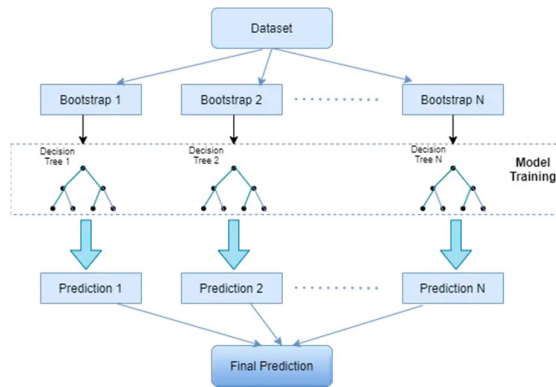


Fig. 1. Structure of an Ensemble Model

computationally feasible. A vote proportional is given to every hypothesis so that the training data would be sampled if that particular hypothesis is true. For training data of finite proportion, vote of the hypothesis is multiplied by the prior probability of that corresponding hypothesis. This can be expressed in the form of the following equation:

$$y = \operatorname{argmax}_{c_j \in C} \sum_{h_i \in H} P(c_j | h_i) P(T | h_i) P(h_i)$$

where y is the predicted class, C is the set of all possible classes, H is the hypothesis space, P refers to a probability, and T is the training data.

C. Application Module

Using Flutter and Firebase, we will be developing one application which will be communicating between restaurant management, the buyer and one who is hungry. The buyer can be an individual or an NGO.

Application Module 1: A portal for restaurant management to post information regarding all leftovers in the form of images.

Application Module 2: The posted information will be notified to the buyers via push notification and will be visible on this application from where the food item can be obtained.

Analytics are provided to help restaurants reduce their food wastage. Machine Learning is used to provide meaningful predictions about food wastage.

The software requirements include Cloud Fire Store for databaes and languages like Flutter,Dart and Firebase. The hardware requirements needed are OS: iOS 11+ | Android 9 Pie+, RAM: 4 GB, Minimum Free Space: 100 MB and Network Interface.

There are some unique features that our application provides. We will be creating our application for both the platforms that is, App store and Play Store. Regular updates to the application will be given. Authentication and Verification of users will be done. Authentication and Verification of NGO will be done. One combined application will be developed for Donor and the NGO. This application is the first ever project for Mumbai locality. Our application supports automatic removal of food after 12 hours. Our application provides a detailed description of how to manage waste food with statistical analysis.

D. Implementation

The application will start with a splash screen which will be showing the logo of our application. Next the users will be experiencing three onboarding screens. These screens will describe the application.

The next screen is "Choose Your Role", this screen will allow the user to choose their role as a Donor or as an NGO. The user can then login with their Email Address and Password. The login screen also has the option of Forgot Password where the user can request a password link. New users can also Sign Up using the Sign-Up Page.

Once logged in as the Donor user they are redirected to the Home Screen, where they will be able to see the Donation Requests made by the NGO. They can accept the donation, if available. The Donate button will allow the donors to create a donation post which will be visible on the NGO side of the screen. The history screen will show the donors donation history.

Once logged in as the NGO user they are redirected to the Home Screen, where they will be able to see the donation posts made by the donors. They can accept the donation, if available. The request donation button will allow the NGO to create a donation request post which will be visible on the donor's side of the screen. The history screen will show the donors donation history.

The above image shows the side menu bar which we get after clicking the hamburger button placed on the top right corner of our application. It also shows the ongoing orders list. All the orders that are under process and have not been completed yet fall under this list. Almost the same screen is used to show the My Posts page which shows all the posts created by the user. These features are offered for both the application modules.

The analytics screen is a unique feature provided by our application wherein the restaurant owner can see the amount of food to be made in order to reduce the wastage. This screen shows the graph of food predicted for the last 10 days along with the food left for the last 10 days.

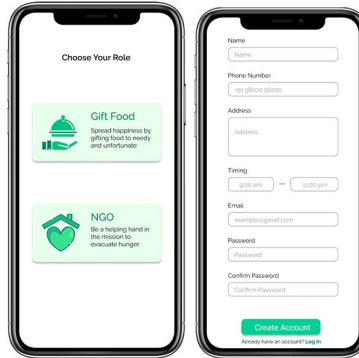


Fig. 2. Login and SignUp Screens

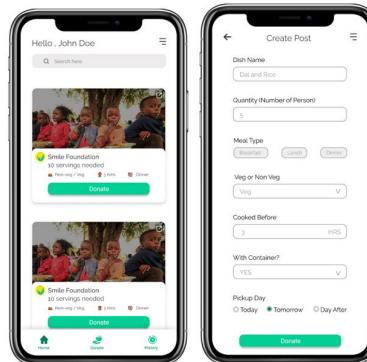


Fig. 3. Restaurant Home and Donate Food UI

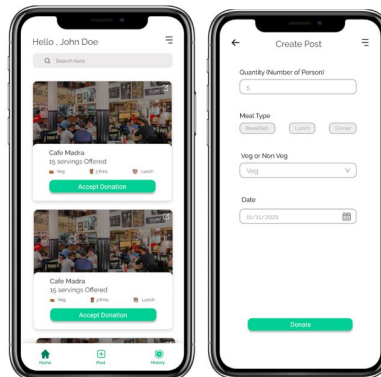


Fig. 4. NGO Home and Create Post UI

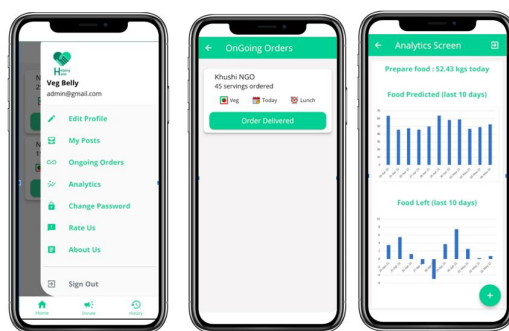


Fig. 5. Side Menu Bar and On Going Orders List and Analytics Screen

VI. RESULT ANALYSIS

Distribution analysis was done to get the idea of the dataset in terms of uniformity. Uniformity is a really sensitive component when it comes to Linear regression. The distribution found was almost uniform, however, with minimal outliers. With the preprocessed data till date, Linear Regression and SVR were trained on the selected features. The training and testing distribution was 80-20 %. With this we found that Linear Regression overfitted and yielded the regression score as 99.88 along with RMSE (Root Mean Squared Error) as 5.91 approximately. Further ahead, Random Forest Regressor and XGBoost Regressor were trained. Random Forest yielded 94.1% and XGBoost was 82.73% accurate. From here, Random Forest and XGBoost algorithms into consideration and techniques were explored to increase the accuracy and also the robustness in the event of outliers. After hyperparameter tuning in the Random Forest Regressor the accuracy score increased to 96.93%. Here, XGBoost didn't go well and the RMSE increased to 10.4.

TABLE IV. COMPARATIVE STUDY OF DIFFERENT REGRESSORS

Regressors	Accuracy	RMSE	R Squared
SVR	80.99	11.59	0.81
Linear Regression	99.88	5.91	0.95
XGBoost	82.73	10.45	0.36
Random Forest	96.93	4.66	0.97

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VIII. CONCLUSION

The purpose of creating this application is to bridge the gap between the donors and the receivers so that the food waste in restaurants, parties are donated to those who are in need and thus leading to overall decrease in food wastage and a better food waste management. Along with this, the analytics model provided to the restaurants is fine tuned to yield nearly accurate results with RMSE (root mean square error) of 1.6337 (Random Forest) and 7.423 (XGBoost). After fitting both the models Random Forest yielded an accuracy of 92.6% whereas XGBoost algorithms was around 73.9%. Random Forest is the algorithm chosen for this analysis since it is efficient and more accurate than any other model. And with more data it will yield better results utilizing sufficient resources.

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