A Personalized Food Recommendation Application using a Hybrid Collaborative Filtering Approach

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Abstract- With the increase of workloads, the usage of recommendation platforms for purchasing meals has increased. The diet patterns of individuals are influenced by a multitude of factors including age, health conditions, pregnancy, culture, religion, and location. Existing applications recommend restaurants to the user depending on the user's ratings and locations. However, these apps do not consider personal traits of a user during the recommendation process, so they cannot provide effective suggestions that match the user. None of the existing apps recommend individual food items that suit the user's preference. This research aims to provide a smart solution to this common issue encountered during online food purchases. Through the development of a personalized food recommendation system, the time spent on selecting food items can be decreased. This model will be implemented in 2 sections- a mobile application that allows the users to order food items based on the recommendations, and a web platform that can be used by restaurant owners to maintain their restaurant's profile. The customized recommendation process is implemented by using a hybrid collaborative filtering model, by addressing the data sparsity and scalability issues associated with the content-based and traditional collaborative filtering approaches.

Keywords*: *personalized, food recommendation, hybrid collaborative filtering

I. INTRODUCTION

Food, being a fundamental human need, provides energy for humans to steer through the day and supplies the vital nutrients that are essential for growth. It is of utmost importance that people take a balanced diet that matches their preferences, nutritional needs and their physiological conditions. People seek for more convenient ways to perform their regular activities, such as dining out instead of preparing their meals at home, to keep up with the increasing workloads. This led to an increase in the number of restaurants and fast-food places in the 21st century. This is backed up by statistical evidence, which states that the predicted increase in the number of restaurants that provide limited services is 8%, during the year 2021 (Moon *et al.*, 2015).With the advent of automation technologies, online ordering platforms have become increasingly popular (Saad, 2020). Most modern restaurants will provide the facility to order food online via their website. A major underlying issue encountered would be the inconvenience of choosing food items over a wide range of restaurants, which would be time intensive. Apart from this, these systems are not constantly updated. Thus, food recommendation technologies were introduced to allow cross comparison of meals between multiple websites. Existing recommendation apps like Uber Eats, PickMe Food and OpenTable recommend restaurants to the user, and allow users to compare restaurants using a single platform. Based on the location of the user and the restaurant, restaurants will be recommended and the list of food items available will be displayed. These systems generally use location filters. This will allow the users to pick meals that suit their preference. The recommendations are made based on users' ratings; higher the ratings, more likely it is for the restaurant to be recommended. Due to the added convenience, the usage of online ordering systems to order food has increased by 300%, since 2014. By the year 2020, third party food purchasing applications were predicted to become a $38 billion-dollar industry (Trang Tran *et al.*, 2018).

A. Factors affecting the food preference

Anatomical, social, economic and environmental differences between individuals have created a variation in their food preferences. Around 119

cuisines have been identified around the world, which includes Korean, Chinese, Italian and Sri Lankan cuisines. According to popularity scoring surveys, Italian food received a popularity score of 84% and Chinese food received a score of 78%. Local ingredients which suit the palate of local citizens, might not suit the taste of individuals from other countries, which will prevent them from purchasing food items containing these exotic ingredients.

Moreover, with the increasing number of ethical issues, more people have resorted to vegetarian and vegan diets. Apart from this, some people have dietary restrictions due to innate physiological conditions.

Gluten intolerance, lactose intolerance and allergies are a few among them. Variations in age will also lead to changes in the dietary patterns of humans. Progressive deterioration of the human body will alter the requirement of nutrients (Bartkiene *et al.*, 2019), which will make older individuals increase the protein content in the meals. Pregnancy would also be another factor affecting the nutritional needs of an individual, since the mother will intake more nutrients for the healthy growth of the baby.

Another crucial factor that should be taken into consideration while choosing a meal would be the presence of non-communicable diseases. Genetic and environmental changes can result in conditions like cardiovascular diseases, hypertension, diabetes mellitus and cancer. It is evident that these diseases can be controlled by a dietary change; a 30% reduction in the intake of sodium has proven to mitigate the number of diabetic patients (Ge, Ricci and Massimo, 2015). These diseases have a direct link with the imbalance in diets, thus people suffering from non-communicable diseases will take carefully controlled diets in contrast to other individuals. Apart from this, economic, geographical and cultural differences affect the food preferences as well. Food items which are prepared using expensive and rare ingredients cannot usually be afforded by poverty-stricken individuals. If the restaurant is distal to a user's current location, they will be reluctant to order food from it, due to the added cost and delivery time. Religions like Buddhism will encourage its followers to adopt plant-based diets and Muslims generally prefer Halal food items, leading to variations in food patterns between different religious groups. Combinations of two or more of the aforementioned factors will affect the dietary patterns of an individual. Thus, it can be concluded that no two individuals have an identical choice of food, although similarities can be found between the choices of individuals who share common genetic traits and environmental conditions.

B. Drawbacks of the existing systems

To provide effective recommendations to the user, their attributes must be carefully studied, to ensure that the food items recommended match the user's preference. However, none of the existing applications take traits of the users into consideration. Thus, none of the existing recommendation systems can provide personalized food recommendations to the user. Instead they will be provided with generalized predictions, based on the highest user ratings and location filters. (*Food Discovery with Uber Eats: Using Graph Learning to Power Recommendations | Uber Engineering Blog*, no date) If key factors like age, health conditions and gender are excluded from the recommendation process, the user's preferences cannot be identified, and this will yield unsatisfactory results. A major problem encountered when ordering food items online would be that a method of cross comparison, for a particular food item, across multiple sites is not yet available. The main purpose of a recommendation system would be to add ease and comfort by reducing the time invested in selecting a food item. This cannot be fully achieved by the existing recommendation apps, since they do not provide a platform to compare an individual item, though they allow comparison of restaurants. Apart from this, recommending food items based on the user ratings would mean that the unrated restaurants will not be included in the selection process, and they are less likely to be recommended. This would affect certain small businesses, which have received low ratings though they provide high quality meals that complements an individual's taste.

C. Current recommendation approaches

The most popular recommendation systems that currently exist are YouTube, Uber Eats, Netflix and Amazon. Most of the applications will make suggestions based on the past behavior of the user. Using various machine learning techniques and AI algorithms, these systems will make predictions based on the behavioral patterns of a

user. Effective recommendation systems employ filtering techniques to filter and classify the vast amount of data that is received continuously. The major machine learning algorithms in a recommendation system can be classified based on the filtering approaches used, which are content-based filtering, collaborative filtering and hybrid filtering techniques (Salehi, 2013). Collaborative filtering does not require the items and users to be individually known and prevents overspecialization of a user's profile. Based on a similarity index, suggestions will be made to the user. The ratings provided by a user for different food items can infer the similarity between these items. For an active user, the predictions are provided by ratings calculated on this weighted average of similar users. (Kumar and Fan, 2015) This will provide effective recommendations for food combinations that will suit the user's preference.

D. Proposed solution

The aim of this proposed initiative is to resolve the issues that are faced by people who order food online. This app will provide personalized food recommendations by analyzing the end user's food patterns. This will take factors like the age, gender, religion and general health issues into consideration. To identify these factors, a preliminary survey was conducted. This system will be established as two sections: a mobile application that can be used by the user to place an order and a web platform which will allow the restaurant owners to update their menus. The mobile application is trained to provide customized recommendations to the user by deploying a hybrid collaborative filtering approach. The user's interest can be predicted, conditioned to the rating data of users with common interest as the target user. The recommendations are made, and the user will purchase food items from the set of alternatives. Food items which are compatible with the one that was purchased will also be recommended; for instance, if multiple users who bought a burger also bought fries, the current user who bought a burger will be notified about this. This will allow the users to purchase meals with compatible food combinations. Once the purchase is made, the respective restaurants will be notified through their web application. This vendor platform allows the owners to add new food items and modify their prices on their profile. They will be allowed to monitor their customer base to identify their preferences. This will be a highly useful tool for all customers and vendors, since this system provides the user with ideal meal recommendations that suit their attributes. No resources will be wasted on providing ill-fitting recommendations. This can be used to alleviate non-transmissible diseases including CVDs and will provide maximum satisfaction to the user.

II. METHODOLOGY

A. Preliminary studies

To ensure the effectiveness and feasibility of this research, the target customer base and their traits were initially identified. This was deduced based on the data collected by a Google form. 300 data samples were collected by random individuals to list the attributes that will vary across them, including the frequency of using recommendation applications for food purchases, age groups of the users, common dietary restrictions (vegan, vegetarian, halal, gluten free), preferred tastes (sweet, sour, spicy, salty bitter), and health information that leads to varying food patterns. The common application users were identified to be within the age group of 15 to 30. The data collected also demonstrated that most people dined outside instead of cooking at home. Preliminary studies lead to the conclusion that parameters like age, country, location, and health condition affects the food patterns of an individual. Out of these variables, health conditions had a significant effect on the diet compared to other factors. The feasibility of this app was predicted to be high since 84.8% of the participants consumed meals from outside and 94.3% of the participants were in favor of a personalized food recommendation app. The following results depict some factors that were taken into consideration in order to develop the application.

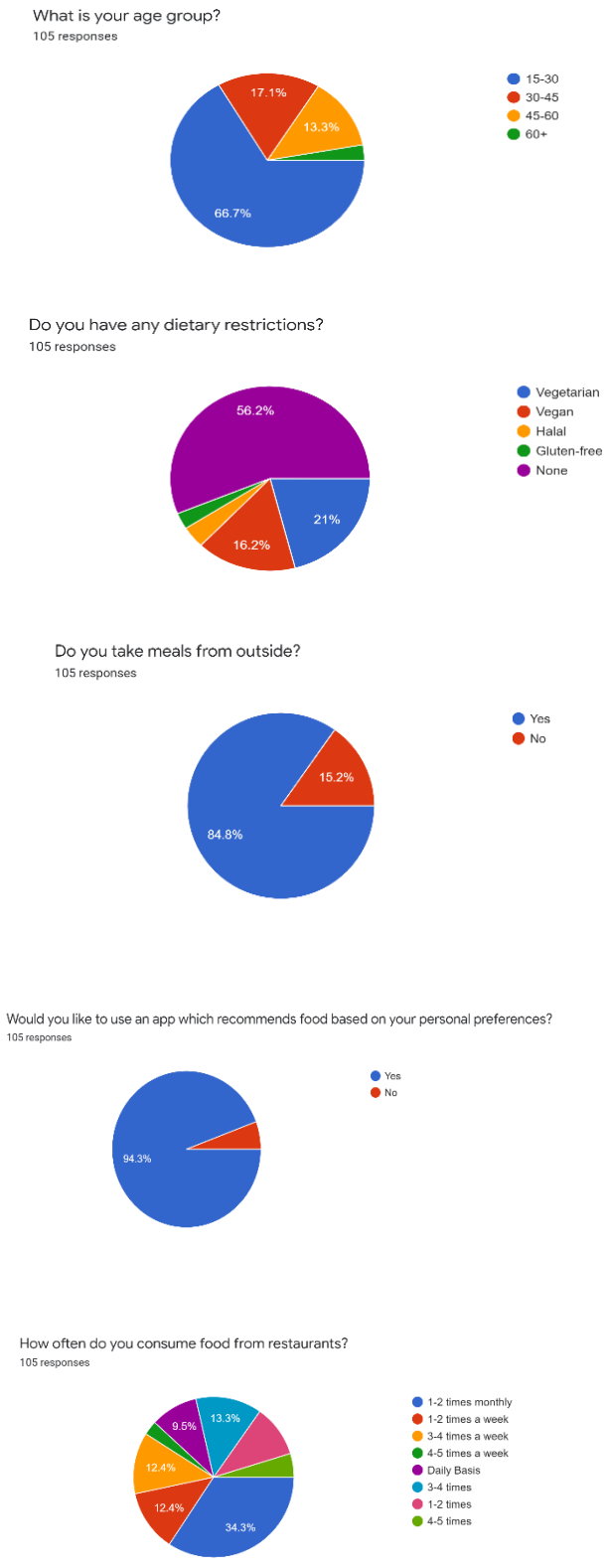

Figure 1. Selected results of the preliminary survey

B. Hybrid collaborative filtering

This research will follow a collaborative filtering approach due to its effectiveness and ease. Collaborative filtering technique generally follows two approaches- user based and item based. Due to the data sparsity, scalability and cold start complications associated with the traditional CF approaches, a novel approach was employed to develop this system. An approach merging the user and item clusters, called hybrid collaborative filtering approach, detects the similarity between the average users and the active user and locates the immediate neighboring clusters of the active user. (Hu and Lu, 2006) To resolve the data sparsity issue, the incomplete cells in the user matrix are filled by deducing that similar users will rate items similarly, thus will require a similar result. The unrated food items are rated based on the ratings provided by similar users. (Safran and Che, 2017) The scalability issue was resolved by clustering users with similar traits. This reduces the number of users considered during the prediction process. Following this, the item clusters are used to make accurate recommendations, using the closest neighboring cluster.

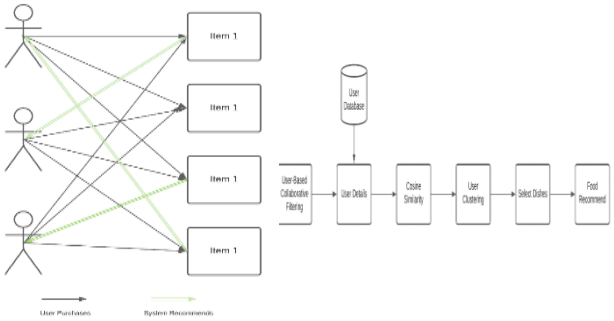

Figure 2. User-based CF

C. System Design and Architecture

The proposed system consists of two ends, namely the mobile and the web platforms. The authorized parties (system administrators and restaurant owners) will be allowed to feed in data to the database. The system administrator has different privileges when using the web platform, compared to the restaurant owners. This includes adding and deleting stores to the system, handling the complaints of customers and managing the users. The restaurant owners are allowed to add new food items to the system and monitor their sales. On the other end, users can use the mobile application to log into the system in order to obtain their personalized food recommendations. The web and the mobile

platforms are connected to a single database, hosted by the cloud. This links the two systems.

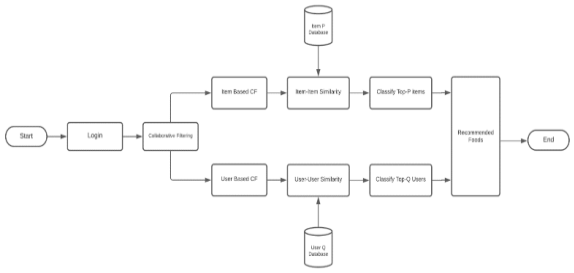

Figure 3. The system design

The mobile and the web platform are built using the same technologies- ReactJS, NodeJS and MySQL. ReactJS, which is a commonly used front-end library currently, is used to build interactive, attractive, dynamic and high-performance user interfaces with many functionalities. The UI will be fragmented into a collection of reusable sub components, each having unique attributes and functions. (ShravanG, 2020) In this project the front end of the system (the mobile application and the website) was developed using ReactJS front end library. The backend functionalities of the system were developed using NodeJS. This will also be a JavaScript based open-source platform. (Chhetri, no date) The database for the system was implemented by the MySQL database service, which is an open-source database management platform, built using SQL. Large number of data entries to the system will be effectively managed by the relational database.

The user is required to register using the mobile application initially. During the registration process, the system requests the user to input personal data, including the name, age, email address, telephone number, food preferences (vegetarian, vegan, non-vegetarian, halal, high or low salt diets, etc.), location and health conditions. After the registration is successfully completed, the system requests the user to set up credentials including the username and a password. Once the user logs in to the system using the respective username and password, the system will automatically identify the user by matching the user credentials with the database. Once the authentication process is complete, the user will be allowed to access the system.

Since the model is trained with continuous input of data, the initial shortage of data will lead to inaccurate predictions. To overcome this cold start issue, the initial recommendations are made based on the data that was input to the system during the registration. The initial recommendations will be based on the user's age, food preference, gender, location and the health conditions. This application requires the geo location of the device to filter proximal restaurants and include them in the recommendations. If the location cannot be accessed by the system, it will use the most recent location stored on the database. When a user logs into the system for the first time, their preference can also be predicted based on the history of other users. This information is also included in the initial recommendation process to obtain the best possible outcome. The only limitation posed when employing this technique to make predictions is that 3% of the users will receive recommendations that will not suit their preferences.

After the user has successfully purchased a food item, the system records the user's preferences. Following 4 to 10 purchases, the system starts to make accurate predictions. The accuracy of the system is fully dependent on the number of purchases made by the user. Each record will be uploaded to the database, which will then make predictions based on the data stored. The hybrid collaborative filtering algorithm will then be applied by the system to generate similar users and items from the database. A deep learning neural network was used to implement the hybrid CF model. An item-item model and a user-user model serve as inputs, which is used to build the layers of the neural network. A dummy data set was fed into the model in order to train it and the output layer was built. This will allow the app to recommend frequently purchased food combinations by similar users to the active user. The user is also allowed to rate the item on a scale of 1 to 5 stars. The ratings, along with the number of times that the items are added to the cart, will also be used to provide an accurate recommendation.

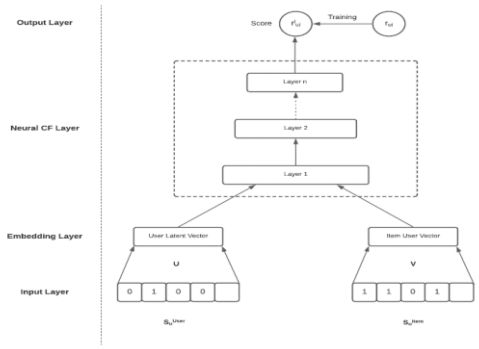

Figure 4. The hybrid collaborative filtering model

Based on the likes and the dislikes of the users, predictions will be made by the system. If the user wants to select a food item apart from the recommended items in the list, they are provided with a search functionality. Once the item is selected, the user will be allowed to view the ingredients involved in making the dish, its price, related food items and purchase it.

III. RESULTS

During the registration process, the user will be asked to enter personal details and the food preferences, by checking off the boxes, as displayed below. This will be a two-step process as the personal information and login credentials must be established.

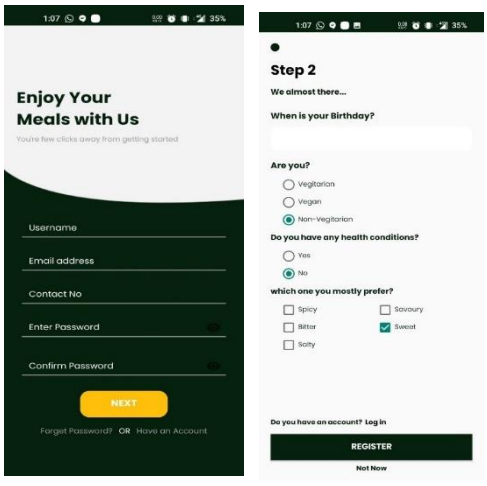

Figure 5. Registration and login interface

Once the user logs in to the mobile phone application, a request will be sent to the server. The server accepts the request and performs the necessary validation operations. After the operations are successfully executed, the processed data is sent back to the mobile application. Any issues with the connectivity will be notified by an error message in the app.

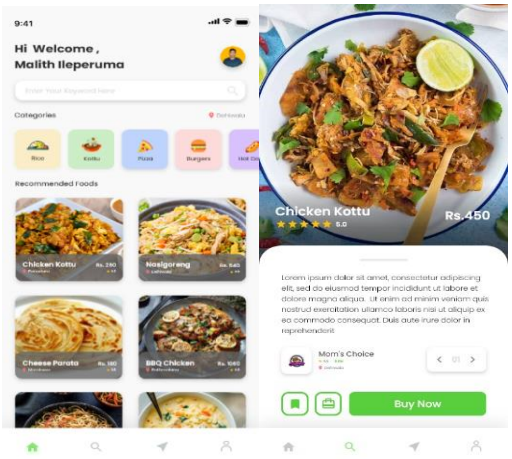

Figure 6. Recommended products

This application has three potential stakeholders-the end user, restaurant owner and the system administrator. The system administrator is responsible for updating new items to the system, as shown in the following image.

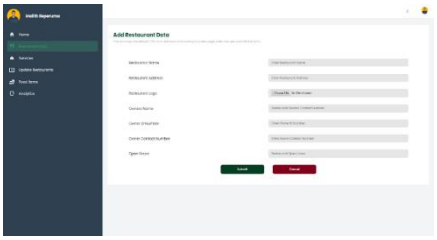

Figure 7. Web platform for the administrator

Restaurant owners will manage the web application end of the system, through which new dishes are added. The ingredients available in the food items and their prices will be added through this. The vendors can view, update and delete items from their menu as well. This web platform will allow the restaurant owners to monitor the sales and the status of their items.

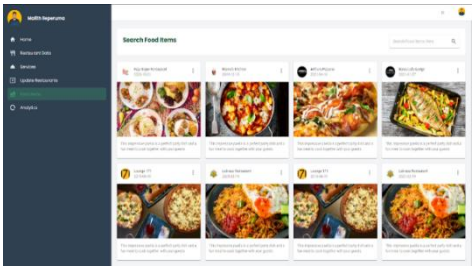

Figure 8. Web platform for the restaurant owners

IV. DISCUSSION AND CONCLUSION

This project exemplifies the ease of using the hybrid collaborative filtering technique over other filtering approaches. This also resolves the common issues that users commonly face while purchasing food online. To reduce the time spent on selecting food, this system provides a smart and realistic solution, where the recommendations are customized according to the user's preference.

Using the data from preliminary studies, it was concluded that 83.8% of the users are below the age of 35. Thus, the application interfaces were designed and developed to increase the usability and to attract members of the above age group. In the first stage of the development, training datasets were collected. A prototype was developed, using which raw data was collected. This was used to create a dataset which trained the collaborative filtering model. The model was trained with different datasets and parameters to achieve the best possible output. During the initial training sessions, new layers were added with different parameter combinations to compare the training and validation accuracies. By breaking the product development into cycles, a fast and hassle-free development was ensured.

With an increasing number of purchases the accuracy of the system increases. Thus, more personalized recommendations will be made to the user. A common issue that is encountered would be that the users' preferences are subjected to constant change. Making predictions based on their preferences would not be valid for a single trial. This will be an iterative process that has to be performed regularly. The application's database is hosted in a cloud and all the data of the users will be stored in it. Thus, cellular network is a mandatory requirement for the application to connect with the database hosted by the cloud, in order to function properly.To access this system, a device that supports the functionalities of this application is a necessity. This is a limitation posed since this restricts individuals who do not have the income to afford, or the knowledge to operate a smartphone/PC. Technical literacy is another crucial factor to be considered, since the fundamental knowledge to read the predictions and handle the transactions should be present in the user. This will be a disadvantage for old people and those who lack technical knowledge. To overcome this issue a tutorial will be integrated with the system in the future, to educate the users about the features of the application.

In the future, this system will be advanced by ncorporating a profit prediction system, which can be used by the restaurant owners to predict their sales monthly and in different quarters of the year. This will be highly beneficial for the business and the economy, since necessary modifications can be made in order to compensate for any possible losses. To enable users from different countries and ethnicities to use this application, this will be developed into a multilingual system in the future. This system will also be integrated with other models to enhance the accuracy of the recommendation during the initial stages. This user-friendly system will indeed minimize the time spent on selecting food items and will provide customized food recommendations that will suit each user.

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