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Polycystic Ovarian Syndrome Diet Recommender System using K-means and Random Forest Algorithm

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ABSTRACT

Polycystic Ovary Syndrome (PCOS) is a medical condition which causes hormonal disorder in women in their adolescent age. Women with PCOS have other comorbid conditions, such as anxiety, depression, and body image issues, they also have metabolic issues such as obesity, insulin resistance, metabolic syndrome, prediabetes, type 2 diabetes, cardiovascular risk factors, and increased risk for sleep apnea. In the proposed model build a diet recommender system for PCOS diagnosed women which will help reduce the effect of the above-mentioned problems. When a person diagnosed with PCOS inputs the meal she had, our diet recommender system identifies the calories and nutrients consumed and suggests food based on the remaining nutrients she must consume in order to maintain a healthy diet. K-means algorithm is used for clustering the nutritional dataset. Using the Body Mass Index, we will calculate the number of calories that person should include in her diet from the dataset, and our code subtracts the number of calories she already had from the total calories she needs to have. Our diet recommender system will then suggest a proper diet plan particularly for PCOS patients for the remaining calories using Random Forest Classification. In our proposed model we made our own data set for diet recommendation where we include diet according to gynaecologist and dietician inputs.

Keywords- Diet Recommender System, K means clustering algorithm, Polycystic Ovary Syndrome (PCOS), Random Forest Classifier.

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I. INTRODUCTION

The most common endocrine disorder in women of adolescent age is polycystic ovarian syndrome (PCOS). PCOS occurs due to hormonal imbalances. In this disorder, the ovaries develop small collections of fluids called follicles (cysts) and fail to release eggs, which is why women suffering from PCOS tend to have complications in conceiving. A lot of women have PCOS, but do not get diagnosed with it at an earlier stage. In a study, 69 to 70 percent of women did not have a pre-existing diagnosis.

The basic symptoms of PCOS are:

- Cysts in ovaries.
- High levels of hormone: androgen.
- Irregular Periods
- Excessive body hair growth
- Weight gain especially around the belly

The clinical implications of PCOS diagnosis in adolescents remain unclear [12]. Hence, in this study we developed a diet recommender system which is an effective way to reduce the effect of problems caused by PCOS using K-

means clustering algorithm and random forest classifier. In the modern era, there are several new technologies available to recommend a healthy diet and one of them is Machine learning algorithms because they are exposed to new data and self-learning. These algorithms learn from past experiences to produce reliable and repeatable decisions.

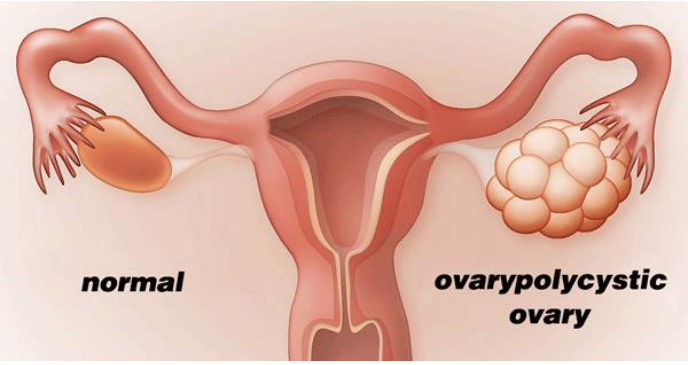


Fig. 1: Comparison of ovaries of normal people and PCOS diagnosed person [11]

II. RELATED WORKS

In this paper [1] they have proposed a DASH diet recommender system that recommends diet plans to hypertensive patients. The system includes a recommendation engine that recommends personalised diet plans to hypertensive patients based on factors such as age, food preferences, allergies, smoking level, alcohol level, blood pressure level, and dietary intake. The system employs a mobile application that is both convenient and quick to use. DASH (Dietary Approaches to Stop Hypertension) focuses on the amount of salt a person consumes. When compared to those who followed a normal diet, those who followed the DASH diet had lower blood pressure by 140 mHg after Eight weeks. The DASH diet recommendation system employs content-based filtering. Meals are suggested based on the user's preferences. The mobile application allows the user to enter data so that the system can recommend a diet to follow. The system uses Firebase which is a cloud-based database for the data storage and authentication. The dataset's sodium content per 100g of each food was compiled using data from the USDA Food Composition Database. Information about the sodium content of regional foods has been gathered from label data. and categorised them as being less, medium, or more salt. Consequently, the system shouldn't be able to suggest items with more salt. This model used **Multilayer perceptron algorithm** for food classification. It's a feed-forward ANN. The result of the model is either positive or negative. This model is trained using 85% of the dataset and tested using 15% of the dataset. Then the model is imported in the mobile application. The classifier has an accuracy of 99 %. This research paper [2] develops an automated tool that uses machine learning techniques to assess the patient's kidney function. This tool will help the doctors anticipate chronic kidney disease and provide a more effective course of treatment. Machine learning can classify the severity of CKD in a person using extracted features. Th diet recommendation is done according to potassium zone which is calculated using blood potassium level. Following data collection, data pre-processing is started, during which missing value searches and data transformation are carried out. Later, the Prediction module is completed, which includes the feature selection and prediction algorithm. Finally, a machine learning-based diet recommendation module is implemented (logistic regression, Support Vector Machines, Decision trees classifier and K-nearest neighbours). Overall, this system finds and suggests diets that are helpful to both patients and doctors. In this [3] they have proposed a system that aims at improving the health of the patients suffering from various diseases by recommending them healthier diet and exercise plans by analysing and monitoring health parameters and the values from their latest reports related to the disease consider patients suffering from either Diabetes or Blood pressure or Thyroid. The system can be essentially useful for the doctors to recommend diet and exercise based on their latest reports and personal health details.

Decision tree is the algorithm that is used to suggest a suitable diet and exercise programme. It determines if a particular food item and exercise should be given to a particular individual or not with respect to our customized datasets. Four different algorithms (k-nearest neighbours, Support vector machine, Random Forest, AdaBoost) were used and among this Random Forest gave more accuracy and score than other three, i.e., 60 to 70 % for health monitoring that checked the patient's ECGs suffering from LQTS genetic disorder and identified patients

with a high risk of cardiac events. Three different algorithms (random forest, gradient boosting, logistic regression) were used, and among this logistic algorithm gave more accuracy and score than others, i.e., 87%. which monitored and authenticated the Fitbit credential of a user. Diet data set includes 102 food items with calorie counts and takes the user's preference for vegetarian or non-vegetarian options into account. Here, a person's BMI is calculated to determine their daily caloric intake. Chronic Kidney Disease (CKD, also known as the Chronicrenal disease) is a communal problem to the public with an escalating in either technologically advanced or advancing countries. 10% of the populations internationally are diagnosed with the disease of chronic kidney disease (CKD), and many deaths each day because of poor access to proper treatment or absence of awareness. If necessary, precaution is not taken at the right time the treatment gets complicated and possibly reach the final stage. Thus, to provide a better dietary solution our paper proposes a model to basis of their potassium level in blood. In this research paper [4], Classification of the patients is implemented recommend food for patients suffering from kidney disease on the using **WEKA** and then further using **query-based** matching they recommended food for the identified levels based on the seriousness of the disease. This paper [5] proposes a deep learning solution for health base medical dataset that automatically detects which food should be given to which patient base on the disease and other features like age, gender, weight, calories, protein, fat, sodium, fibre, cholesterol. This research framework is focused on implementing both machine and deep learning algorithms like, logistic regression, naive bayes, Recurrent Neural Network (RNN), Multilayer Perceptron (MLP), Gated Recurrent Units (GRU), and Long Short-Term Memory (LSTM). The medical dataset collected through the internet and hospitals consists of 30 patient's data with 13 features of different diseases and 1000 products. Product section has 8 features set. The features of these IoMT data were analysed and further encoded before applying deep and machine and learning-based protocols. The performance of various machine learning and deep learning techniques was carried and the result proves that **LSTM** technique performs better than other scheme with respect to forecasting accuracy, recall, precision, and F1-measures. We achieved 97.74% accuracy using LSTM deep learning model. Similarity, 98% precision, 99% recall and 99% F1-measure for allowed class is achieved, and for not-allowed class precision is 89%, recall score is 73% and F1 Measure score is 80%. A recommendation system would be a useful tool if we can make it for diabetes patients. As diabetes, patients need to follow diet plans and work out strictly. Diabetes patients need to control blood sugar in his or her bloodstream to stay healthy. Using machine learning for recommend food and workout plan is an effort to make a precise recommendation system for Bangladeshi diabetes patients.

Various classification algorithm is use in this system [6] to detect diabetes risk of the user as per his or her input. Such as, **Decision tree, Naive Bayes** and **Support vector machine**. After classify the diabetes risk the system will suggest some best diet plan and workout routine by query selection method. The six steps of this methodology—Experimental dataset, Processing the Original Data, Level Selection, Data Scaling, Model Building, and Final Output—lead to the completion of the research. The data was collected from 300 individuals in Bangladesh. They have used various python libraries to process the dataset and give it a new shape. Then **SVM** is used for classification. After determining whether the user is at risk for diabetes or not, it is time to make dietary and exercise recommendations based on the findings. Accuracy after evaluating are Support Vector Machine – 64%, Naïve Bayes – 68%, **Decision Tree – 96%**. The food that we eat supplies nutriments to the body. A balanced diet full of essential vitamins and minerals in adequate amount will help an individual reach their full growth potential especially children because a proper diet results in an increase in the learning ability, stamina and strength. It even has a positive impact on their behaviour. To offer an efficient method regarding food intake, in this paper [7], we proposed a **Nourishment Recommendation Framework (NRF)** where we take user input from children, analyse the data and finally an output is generated that presents an improved diet plan. It provides children from 8–13 years with healthy meals according to their age, growth, gender and health records. In this paper [8], automated methods of food classification using deep learning approaches are presented. SqueezeNet and VGG-16 **Convolutional Neural Networks** (CNN) are used for food image classification. Even with fewer parameters, SqueezeNet is able to achieve quite a good accuracy of 77.20%. Convolution Neural Network has basically three layers: convolution layers, pooling layers and fully connected layers. Convolution layer assigns learnable weights and biases to input image. Pooling layer down-samples the input data by summarizing the features thus reducing trainable parameters. At the end fully connected layer is present having full connections to all neurons. Softmax activation function calculated the probability of the image belonging to a particular class. Classical machine learning algorithms like support vector machine (SVM), random forests and artificial neural networks can also be implemented for image classification with lesser accuracy compared to deep learning methods. Deep learning techniques allow for the easy identification of deep and complex features, improving recognition tasks. The dataset contains 101,000 images of 101 categories, each category of food containing 1000 images. In this dataset, 30% of training data is used for validation to help to prevent overfitting. The result

proposed **VGG-16** has achieved much better performance and was able to classify food images more accurately with higher accuracy of **85.07%.**

In this paper [9] they have taken Indonesian food as data-set. Her the database development collected data for Sumantra traditional food, and also built a model for image classification. It classifies some features like colour and texture, which is further seen in classification using 5 classical machine learning models. **Convolutional Neural Network (CNN)** is also used in research for food classification. The experiments were carried out using 435 images, which were divided into 8 classes. Data Training is carried out using several classical machine learning models. Models used include Logistic Regression, Linear Discriminant Analysis (LDA), Decision Tree, and Random Forest. Logistic Regression is a classification calculation that is based on the linear regression formula. Accuracy is calculated as (Correctly classified data/Total Data). Accuracies of Logistic Regression, LDA, Decision Tree, Random Forest are 77.01%, 67.81%, 98.85% and 100% respectively. In this research paper [10], computer vision methods have been applied to food logging to automate image classification for monitoring dietary intake. In this work we applied pretrained ResNet-152 and GoogleNet **Convolutional Neural Networks** (CNNs), initially trained using ImageNet Large Scale Visual Recognition Challenge (ILSVRC) dataset with MatConvNet package, to extract features from food image datasets; Food 5K, Food-11, RawFooT-DB, and Food-101. Deep features were extracted from CNNs and used to train machine learning classifiers including **Artificial Neural Network** (ANN), support vector machine (SVM), Random Forest, and Naive Bayes. Results show that using ResNet-152 deep features with SVM with RBF kernel can accurately detect food items with 99.4% accuracy using Food-5K validation food image dataset and 98.8% with Food-5K evaluation dataset using ANN, SVM-RBF, and Random Forest classifiers. Trained with ResNet-152 features, ANN can achieve 91.34%, 99.28% when applied to Food-11 and RawFooT-DB food image datasets respectively and SVM with RBF kernel can achieve 64.98% with Food-101 image dataset. From this research it is clear that using deep CNN features can be used efficiently for diverse food item image classification.

III. PROPOSED METHODOLOGY

A. Problem Statement:

Polycystic Ovary Syndrome is a very common disease in women especially in teenagers. There is no cure for PCOS. Hence in order to reduce the long-term effect of symptoms caused due to PCOS and to control insulin levels and weight issues, a nutritious diet is crucial. Most experts agree that change in diet that includes high protein and low carbohydrate and proper exercise is the only possible way. Hence in this proposed system we mainly focus on recommending a healthy diet plan dedicated to people suffering from PCOS.

B. Preliminary Analysis

K-means algorithm:

It is an unsupervised Machine learning algorithm used for clustering unlabelled data input into different clusters where each cluster is associated with a centroid. All the data points get assigned to k-centers and those data points which are near to the particular k-centre, create a cluster.

Random-Forest Classification:

Random Forest is a supervised machine learning algorithm which contain decision trees on various subsets of the given dataset and takes the prediction from each tree and based on the majority votes of predictions, predicts the final output.

C. Proposed Approach:

i. Preparation of Questionnaire:

We also carried out a poll on PCOS and asked respondents the following questions:

a. How old are you?
b. Do you know about PCOS?
c. At what age did your first menstrual period occur?
d. Do you experience irregular periods?
e. What symptoms do you experience during your periods?
f. Do you take any measures for prevention of symptoms and if yes, what are the measures taken?
g. How effective are the prevention measures?
h. Do you follow any personal diet?
i. Would you be interested in a diet recommender system?

These are the responses:

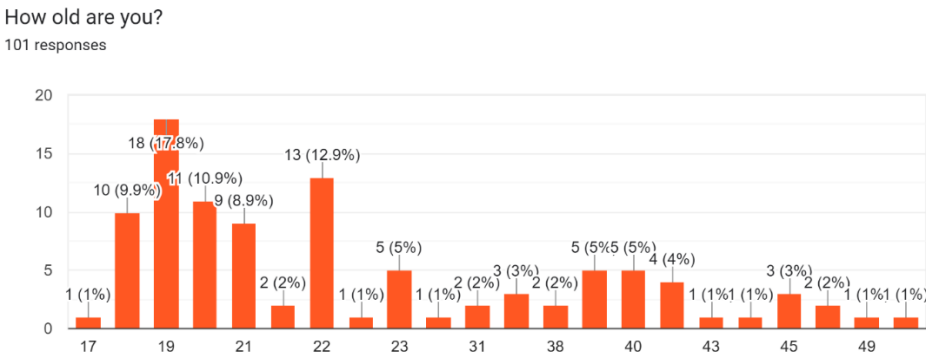


Fig. 2

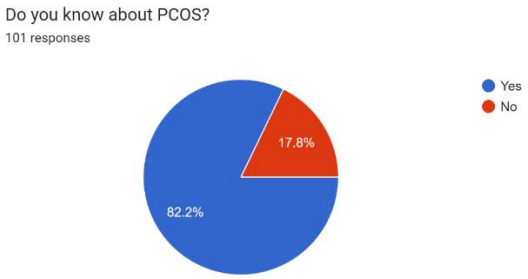


Fig. 3

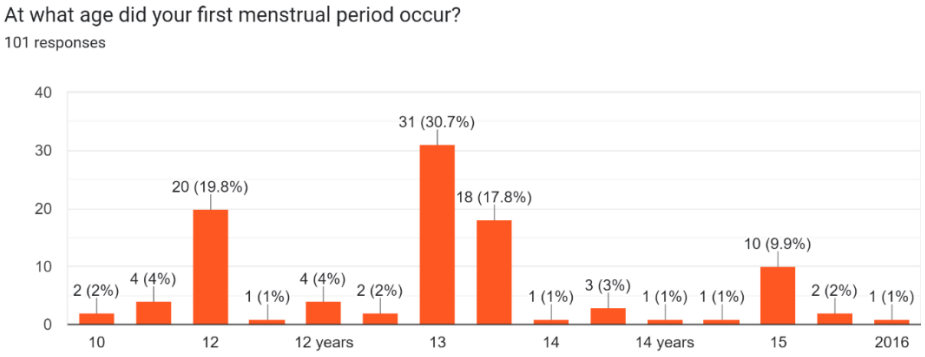

At what age did your first menstrual period occur?
101 responses
40
30
20
10
0
2 (2%)
4 (4%)
20 (19.8%)
1 (1%)
4 (4%)
2 (2%)
31 (30.7%)
18 (17.8%)
1 (1%)
3 (3%)
1 (1%)
1 (1%)
10 (9.9%)
2 (2%)
1 (1%)
10
12
12 years
13
14
14 years
15
2016

Fig. 4

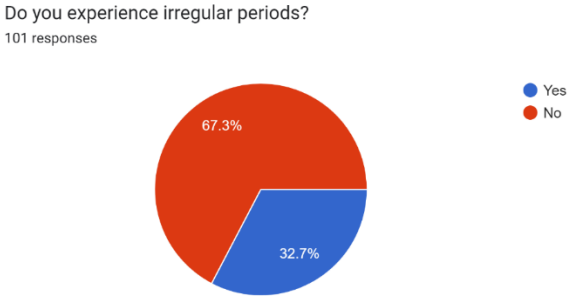

Do you experience irregular periods?
101 responses
Yes
No
67.3%
32.7%

Fig. 5

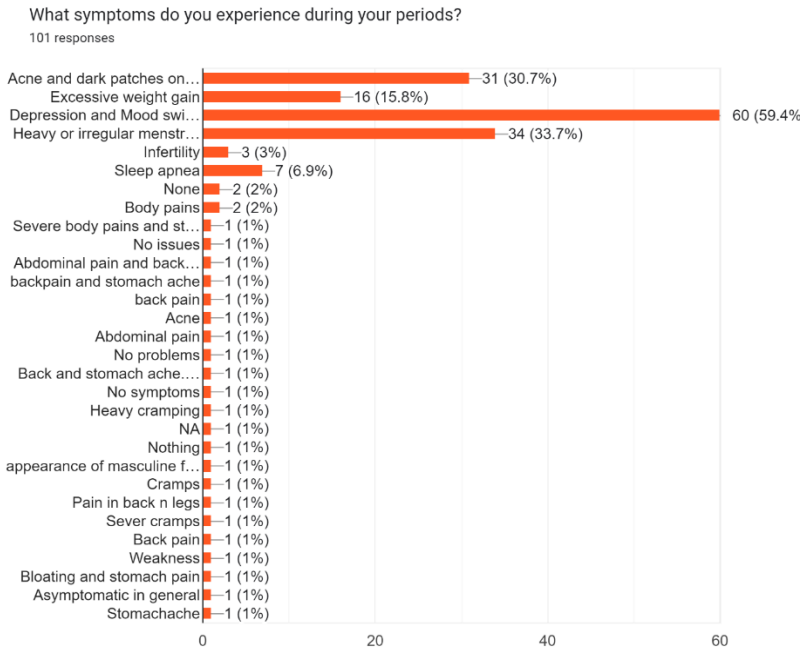


Fig.6

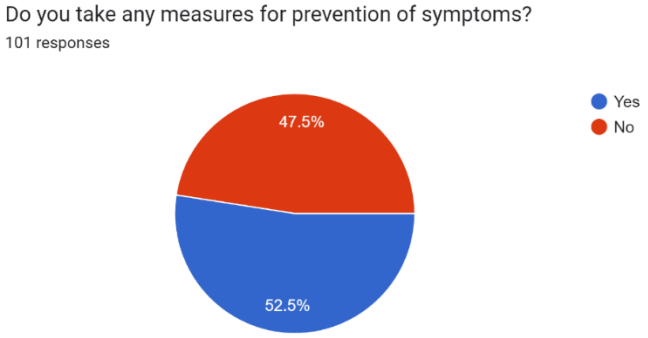
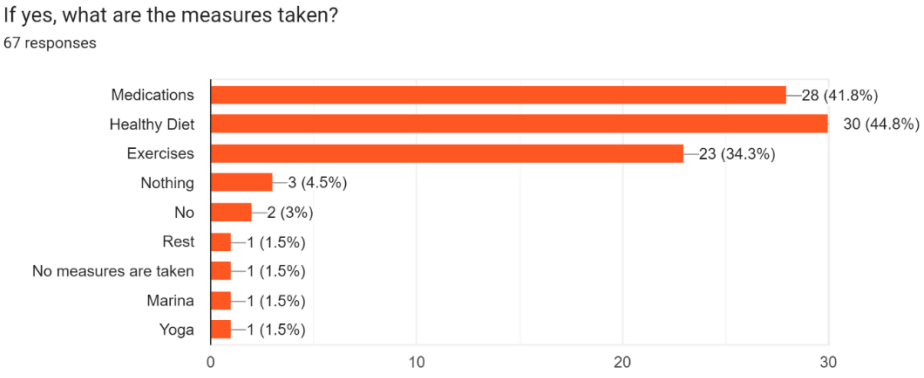


Fig. 6



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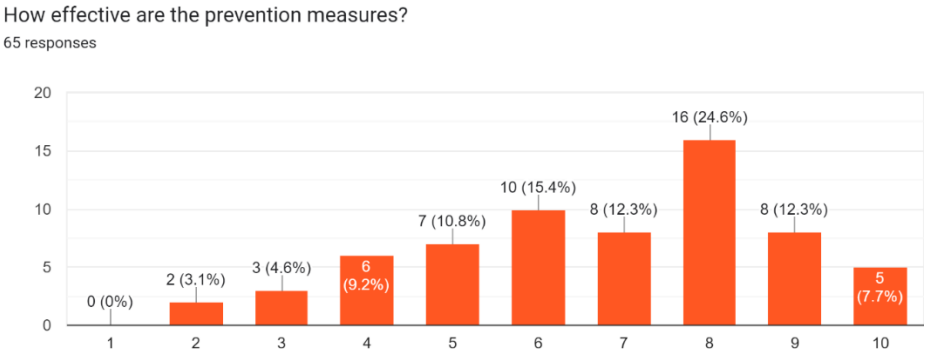

Fig. 8

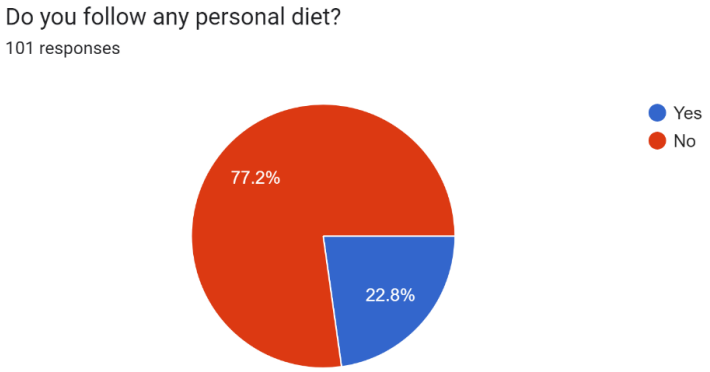

Fig. 9

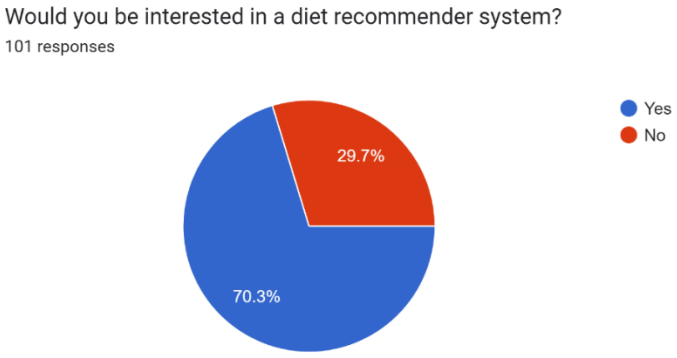

Fig. 10

Fig.2-Fig 11: Output of the results of the questionnaire conducted

ii. Gynaecologist inputs:

> **What is the cause of PCOS?**

Hormonal Imbalance

> **What are the symptoms for getting PCOS?**

Lack of bleeding during periods, irregular periods, high insulin levels compared to a healthy human body, excessive facial hair, and glucose intolerance

> **What are the diseases that one can be diagnosed with because of PCOS?**

Infertility, type 2 diabetes, increased cardiovascular disease, and obesity.

> **Is there any cure for PCOS?**

There is no cure for PCOS

> **Would you advise a diet plan, prescription drugs, or exercise for those with PCOS?**

She advises making changes to the diet, such as reducing the intake of animal fat and stressing the importance of getting regular, aerobic exercise. She recommends vitamins in the form of tablets if the condition is long-term or people don't show interest in doing exercises. She stated that everyone, even those who are obese, should maintain a healthy diet.

> **Which diet would you advise for people with PCOS?**

More consumption of vegetables with green leaves generally. More protein should be consumed daily, while fewer carbohydrates and fats should be included in the diet. But this also largely depends on the patient's weight and BMI. Based on their weight and BMI, calorie intake can be suggested.

> **How well do medications work for PCOS?**

Not very efficient. Just that vitamin tablets (Vitamin-D) are advised for those who cannot exercise or receive little sun exposure.

> **How common is PCOS in women?**

It’s quite common. These days, more than 20% of people have PCOS diagnosed.

> **How seriously should PCOS be taken?**

People may try to ignore changes in their menstrual cycle because they believe PCOS is not a serious illness. But it's crucial to get checked, and if PCOS is diagnosed, to work to lessen its effects. PCOS is the primary factor in infertility in women.

iii. Flowchart

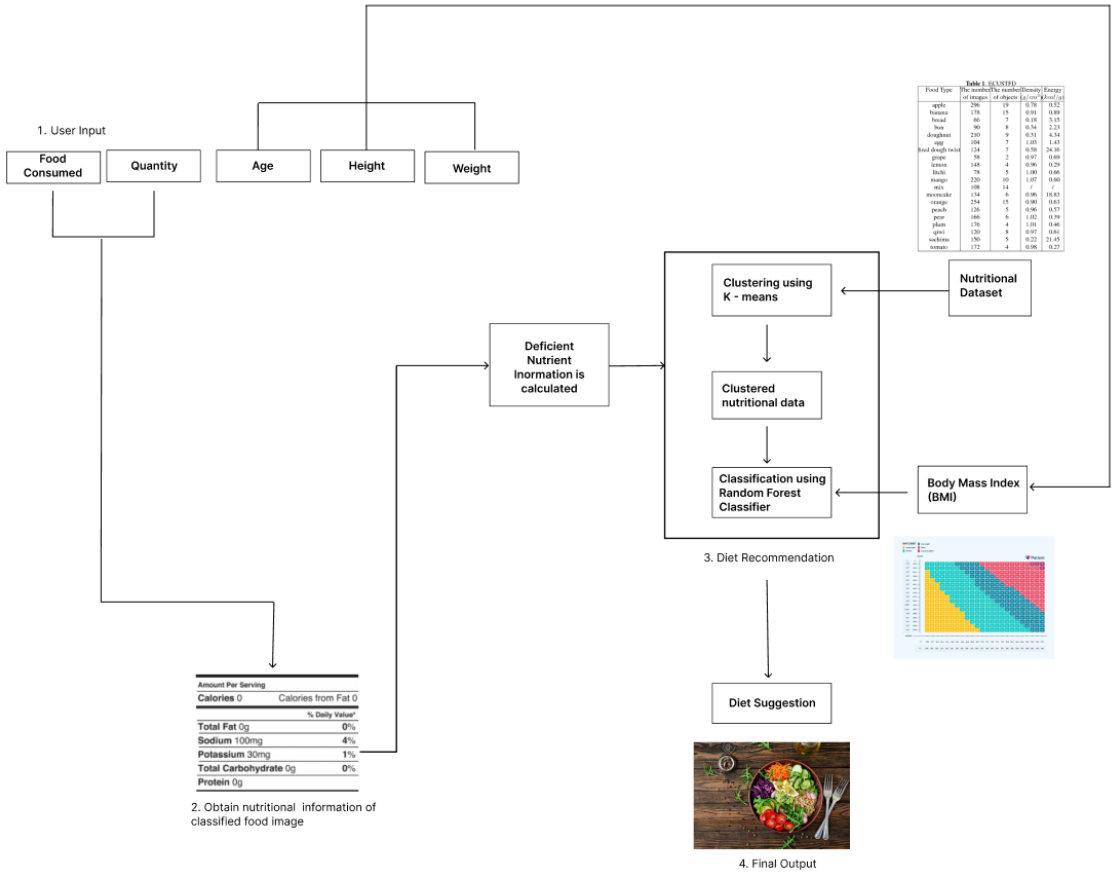

Fig.12: Flowchart of proposed algorithm

iv. Algorithm

Input Input sent from the user,

Food consumed by the user "Food_consumed",

Quantity of the food consumed "Quantity_consumed",

Height of the user "User_Height",

Weight of the user "User_Weight",

Age of the user "User_Age"

Output Personalised Diet Recommendation for the person

Steps

1. Collect food items consumed by the user and its quantity "Food_consumed", "Quantity_consumed"

2. Collect user details: "User_Height", "User_Weight", "User_Age"

3. Health_condition = calculateBMI (User_Height, User_Weight)

   //Health condition is determined the BMI, which in turn is calculated by the height and weight of the user

4. Procure the dataset, Food-PCOS

5. Classify the data items in terms of Breakfast, Lunch and Dinner

6. Find the total calorie per serving unit volume along with protein/unit, fat/unit, carbohydrate/unit, calorie/unit.

7. Find the average quantity of the food and get the corresponding calories along with protein, fat and carbohydrate.

8. Calculate User_Calorie_Requirement based on user parameters like User_Height, User_Weight, User_Age.

9. Calculate the deficient amount of nutrients

    Recommended_Calories = User_Calorie_Requirement – Calories_Consumed

10. Procure nutritional dataset.

    //Nutritional dataset contains various food items with its nutritional information

11. Use K-means clustering algorithm to cluster the nutritional dataset.

    //The algorithm clusters the dataset based on its proximity to Recommended_calories, Recommended_Proteins, Recommended_Fat, Recommended_Carbohydrates. It divides the dataset 'X' of 'N' food items with 'd' dimensional properties into k clusters.

12. Obtain the food_item cluster closest to the recommended values.

13. Decision_Value = random_forest_classifier(parameters)

    //The random forest classifier is trained with preloaded data, to classify whether the food is recommended based on the nutrition history of the user. The parameters for the classifier are BMI restrictions, User_Calorie_Requirements. Other parameters such as calories, proteins, fats and carbohydrates.

14. if decision value = "yes" then

      Recommended_Diet += Food_Item += 'x' grams of Food_Item

    Else

      Continue

15. Return Recommended_Diet

16. Repeat Steps 8-15 for every meal i.e., Breakfast, Lunch, Dinner

17. Stop

IV. RESULTS AND DISCUSSION:

A. Dataset and Working Environment

i. Dataset

The dataset used for the proposed model has been manually prepared using inputs from gynaecologist.It includes many parameters regarding nutrients such as calories, fats, proteins, carbohydrates, calcium, iron, potassium, sodium, fibre, sugars for 1gram of each food item.

ii. Working Environment

The first step to building our model is to import our libraries and datasets into our Jupyter Notebook.

- Pandas: The most popular python library that is used for data manipulation and analysis. In our proposed system, it is primarily useful for data frame manipulation.
- NumPy: A python library that provides support for large, multi-dimensional arrays and matrices, and has high-level mathematical functions to help operate on and manipulate these arrays.
- Matplotlib.pyplot and seaborn: Used for data visualization.

B. Performance Measures

Classification report

- **Precision** is a measure of how many of the positive predictions made are correct (true positives).
- **Recall** is a measure of how many of the positive cases the classifier correctly predicted, over all the positive cases in the data. It is sometimes also referred to as Sensitivity.
- **Specificity** is a measure of how many negative predictions made are correct (true negatives).
- **F1-Score** is a measure combining both precision and recall. It is generally described as the harmonic mean of the two. Harmonic mean is just another way to calculate an "average" of values, generally described as more suitable for ratios (such as precision and recall) than the traditional arithmetic mean.

We compared the samples for breakfast, lunch, dinner and calculated precision, recall, F1-score, Support and accuracy.

Performance Measure	Sample 1					Sample 2					Sample 3				
	C1	C2	C3	Macro Average	Weighted Average	C1	C2	C3	Macro Average	Weighted Average	C1	C2	C3	Macro Average	Weighted Average
Precision	1.00	0.60	0.89	0.83	0.93	0.93	0.67	0.50	0.70	0.79	0.60	0.96	1.00	0.85	0.85
Recall	0.89	0.86	1	0.92	0.90	0.56	1.00	0.91	0.82	0.68	0.94	0.69	1.00	0.88	0.78
F1-score	0.94	0.71	0.94	0.86	0.91	0.70	0.80	0.65	0.72	0.69	0.73	0.80	1.00	0.84	0.79
Support	37	7	8	52	52	25	2	11	38	38	16	32	3	51	51
Accuracy	90.0%					68.0%					78.0%				

Table 1: Comparison of Samples of Breakfast, lunch and dinner

C. Result and Discussions

Elbow Method

The elbow method is a heuristic used in determining the number of clusters in a data set. The method consists of plotting the explained variation as a function of the number of clusters and picking the elbow of the curve as the number of clusters to use.

Silhouette Coefficient

The silhouette plot shows how close each point in one cluster is to points in neighbouring clusters and thus allows you to visually assess parameters like the number of clusters.

KMeans Cluster Formation

The plot shows Cluster Formation. It is a NxN plot, but we have made it 2x3 for visual purposes.

Confusion Matrix

A Confusion matrix is a N x N matrix used for evaluating the performance of a classification model, where N represents the number of target classes. The matrix compares the actual target values to the machine learning model's predictions.

BREAKFAST

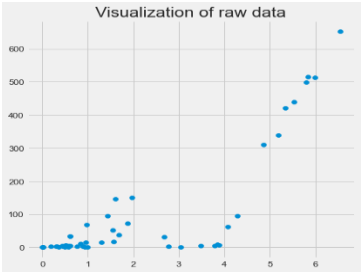

Fig.13

LUNCH

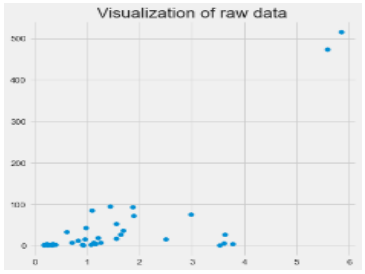

Fig.14

DINNER

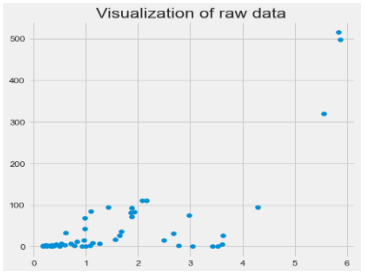

Fig.15

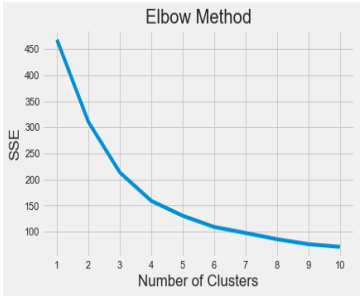

Fig.16

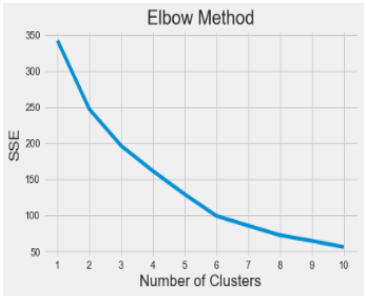

Fig.17

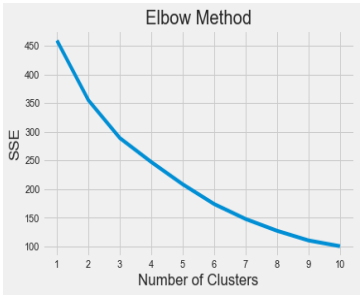

Fig.18

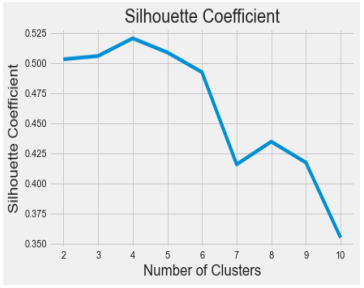

Fig.19

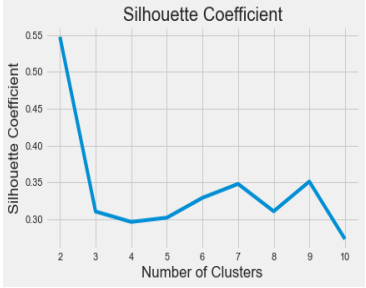

Fig.20

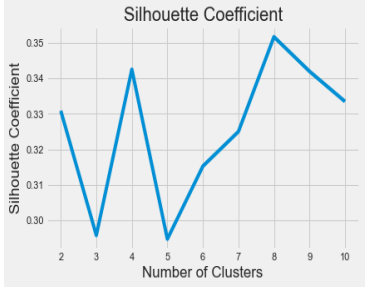

Fig.21

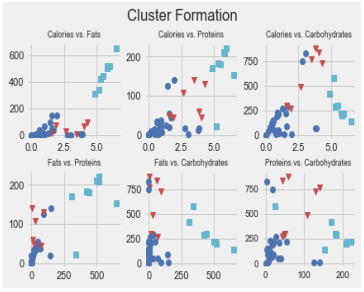

Fig.22

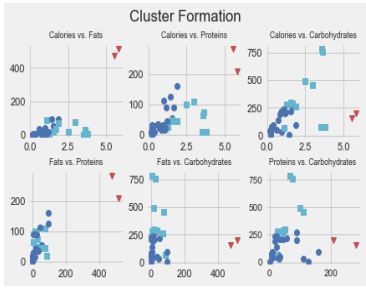

Fig.23

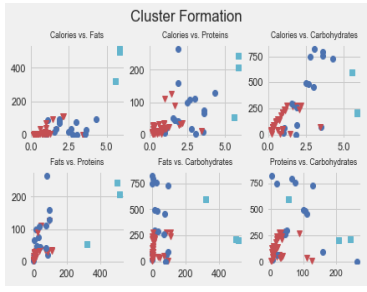

Fig.24

33	4	0
0	6	1
0	0	8

Confusion matrix

Fig.25

14	1	10
0	2	0
1	0	10

Confusion matrix

Fig.26

15	1	0
10	22	0
0	0	3

Confusion matrix

Fig.27

HEAT MAPS FOR BREAKFAST, LUNCH AND DINNER

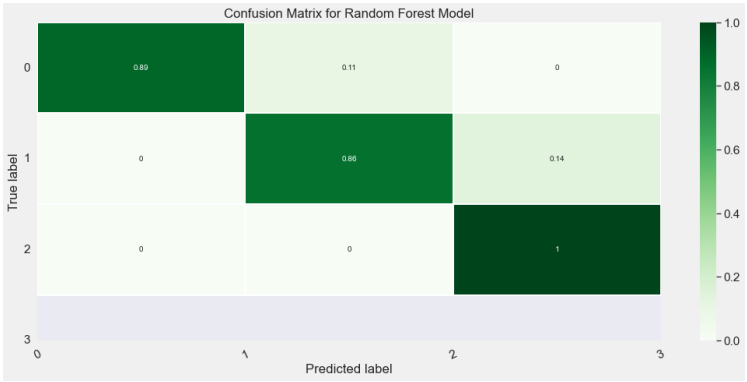

Fig.28: Heat Map for Breakfast dataset

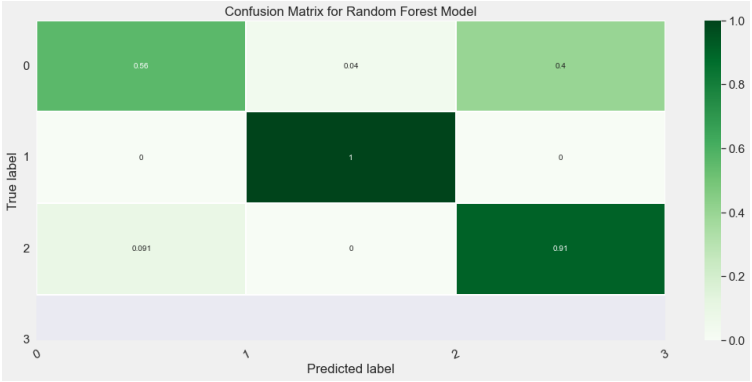

Fig.29: Heat Map for Lunch dataset

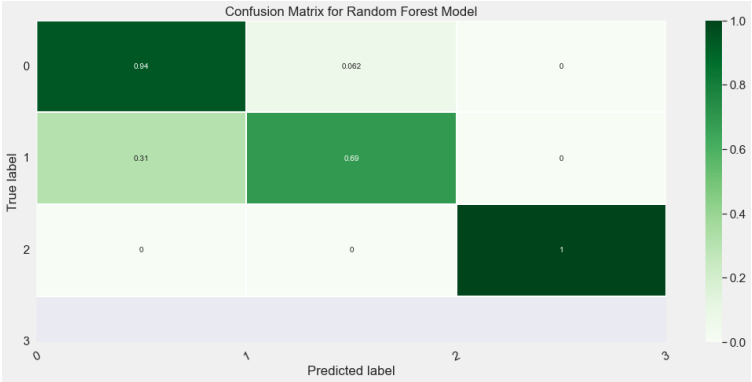

Fig.30: Heat Map for Dinner dataset

OUTPUTS:

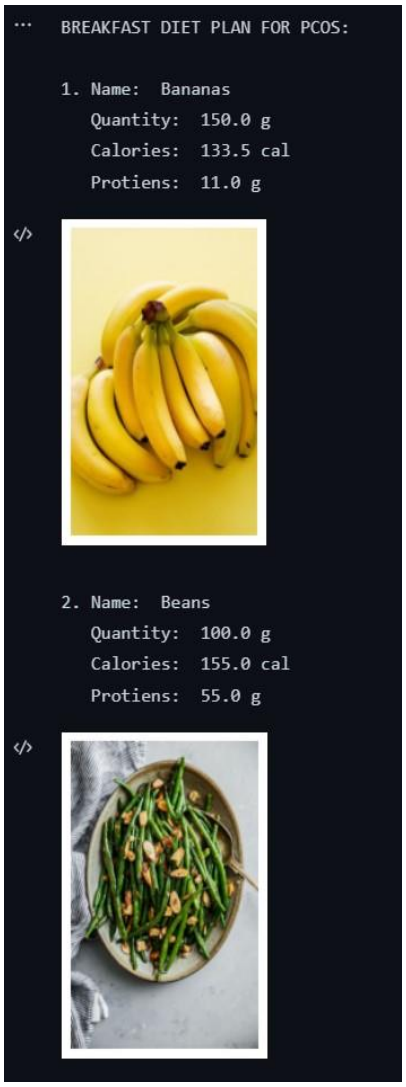

Fig.31

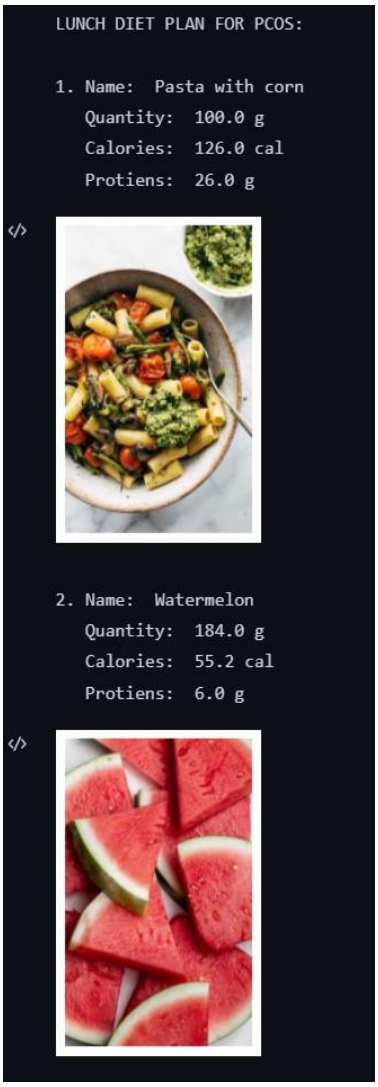

Fig.32

Fig.33

Fig. 31-Fig. 33: Output of the proposed model for breakfast, lunch and dinner respectively

D. Conclusion and Future scope

Polycystic Ovarian Syndrome (PCOS) is a disease without any permanent cure. The diet recommender system built by us has been able to recommend appropriate diets for people suffering from polycystic ovarian syndrome. The proposed system uses a combination of K-Means Clustering and Random Forest Classifier for diet recommendations taking various parameters such as height, weight, age and the food already consumed into account. The dataset used in this model is manually prepared by collecting the nutrients for each food item that must be consumed by PCOS patients in order to reduce the effect of symptoms caused by PCOS. Furthermore, the algorithm has been evaluated using various metrics and has been used to generate recommendations with acceptable values of accuracy. In future, there may be models on usage of predefined dataset exclusively for PCOS, usage of different hybrid algorithms to improve accuracy and studies on expanding dataset with more cuisines and food items to suit different ethnic groups.

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