A DASH Diet Recommendation System for Hypertensive Patients Using Machine Learning

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***Abstract*— Hypertension is becoming a serious health issue in the world. People tend to have a busy lifestyle and to adopt unhealthy diets. Due to poor eating habits, the rate of Non Communicable Diseases (NCDs) such as hypertension together with the rate of death caused by such diseases are rising. In order to promote healthy eating habits in Mauritius, the paper proposes a DASH diet recommender system that recommends healthy Mauritian diet plans to hypertensive patients. The system consists of a recommendation engine that uses techniques such as content-based filtering along with machine learning algorithms to recommend personalized diet plans to hypertensive patients based on factors such as age, user preferences about food, allergies, smoking level, alcohol level, blood pressure level and dietary intake. The system makes use of a mobile application which is handy and quick to use. Based on a survey carried out, the application has helped users to control and reduce their BP level.**

Keywords—Hypertension, DASH Diet, Content-based filtering, Machine learning, Recommender System

I. INTRODUCTION

Hypertension is a non-communicable disease and according to the World Health Organisation (WHO), 17.7 billion of people around the world have died from the disease in 2015 [1]. It is a condition whereby blood vessels continually upraised pressure in the heart. It becomes difficult for the heart to pump blood when pressure in the heart is high [1]. Hypertension is known to cause health problems such as heart failure, strokes, eye diseases and kidney disease [2]. It additionally causes hypertensive retinopathy in the eye and doubles the risk of getting coronary heart disease in men [2].

Mauritius, having a population of approximately 1.3 million, is a pluri-cultural and multi ethnic society whereby its descendants originated mainly from Indian and African countries [3]. Hence, the Mauritian cuisines consist of a mixture of Indian, French, Chinese and European cuisine. Lately, there has been an increase in the rate of fast food adoption in the Mauritian culture [4]. The population has adopted the consumption of convenience, processed, fast-foods and more oily foods which are energy-dense foods [4]. Furthermore, these foods are not healthy on the long run as they contain a lot of artificial chemicals and salt [4]. Such unhealthy eating habits are thus impacting on the health of the Mauritian population. According to a survey published in 2017 by the World Health Organisation (WHO), the number of deaths caused by hypertension in Mauritius sums up to 268 [1]. The death rate per 100 000 is 18.41 and it is ranked 7 in the top 20 death causes in Mauritius [1]. Despite being a silent killer, it is an alarming situation for Mauritius and necessary actions should be taken to address the problem.

The government of Mauritius is doing much effort to remedy the situation. The Ministry of Health and Quality of Life has started the National Prevention Campaign against NCDs in April 2018 in association with the Ministry of Gender Equality, Child Development and Family Welfare [5]. The objective of this campaign is to educate the population about the causes, effects and the prevention of the NCDs [5]. Furthermore, as smoking is related to hypertension, the government is also encouraging the '*L'Ile Maurice sans Tabac*' campaign which started on May 2018 [6]. Moreover, a website will be launched to encourage people quitting smoking [7]. Talks are organized to educate people in community centers, district and village councils [6]. It is now prohibited to smoke in public places such as bus stops and it is a must to provide for pictorial awareness on the effects of smoking on packets of cigarettes. The government is also providing the necessary support in terms of free health care to hypertensive patients [6]. Additionally, the government is encouraging people to have a physically active lifestyle by setting up gyms in community centers and building health tracks around the country. Last but not least, campaigns are carried out on television and radios to encourage people to do physical exercises [6].

In order to promote a healthy lifestyle in Mauritius, the paper proposes a DASH diet recommender system. The rest of the paper is structured as follows: Section II explains what a DASH diet is and its importance. Related work is described in section III. Section IV presents the DASH diet recommendation system. Finally, section V concludes the paper and discusses future works.

II. DASH DIET FOR HYPERTENSION

DASH diet signifies Dietary Approaches to Stop Hypertension [8]. It is a healthy way of eating for people who want to treat or prevent themselves from getting hypertension. It is encouraged by the U.S-based National Heart, Lung, and Blood Institute. The aim of the DASH diet is to reduce the amount of salt (sodium) a person consumes. According to American Heart Association, an ideal limit of no more than 2,300 mg of sodium per day is recommended for non-hypertensive whereas for hypertensive people, the ideal limit is set to 1,500 mg per day [9]. DASH diet consists of meals which are composed of a lot of fruits and vegetables and are minimum in sugar and fat products [8]. Moreover, DASH diet prevents other diseases such as osteoporosis, cancer and stroke [10]. Furthermore, it has to be noted that the usage of DASH diet

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has lowered blood pressure among hypertensive patients who had stage 1 isolated systolic hypertension (ISH) [11]. According to a study carried out, after eight weeks of having DASH diet, the patients' blood pressure was lowered by <140 mg Hg as compared to those who had normal diets [11]. DASH diet can therefore help those who have hypertension to control their blood pressure and keep their blood pressure within the correct level. It also acts as a preventive measure to help people avoid the disease [12].

III. Related Work

This section describes some related work with respect to diet/DASH diet recommender system. A comparison of the different systems is made in Table 1.

A. System 1: Yum-Me [13]

Yum-Me is specialized in making food recommendations based on the user's preferences of fine-grained food items. It has also been designed to cater for nutritional and dietary requirements of individuals. The system consists of about 50,000 recipes and it also caters for those who follow a vegetarian, vegan, kosher and halal diet. The system is used in such a way that it does not require the dietary history of the person in order to make recommendation. The system makes use of an online learning framework that learns preferences of users.

B. System 2: SaltSwitch [14]

SaltSwitch is a mobile application available in UK and Australia. The application enables users to scan a product on their mobile phone and an instant message is received consisting of the nutritional information of the product. Moreover, suggestions on other similar food products that are lower in salt are also given to the user to make the best and healthier decision about which product is best to consume. The application forms part of FoodSwitch which uses improved algorithms to encourage people to have better choices of food items.

C. System 3: mHealth Behavior Change System [15]

The system consists of a mobile application and a web-based portal. It has as objective to investigate about behavioral changes in hypertension patients. The users can update their diet intake, blood pressure and weight data to the main server. There is a human coach who reviews information of patients and interacts with them to give advices on the coaching portal. It also provides users with training videos. The user is equipped with a Blood Pressure Cuff to input blood pressure reading, weighing scale, pedometer which all use Bluetooth to input data in the application. The system does not implement an intelligent agent as there is a human coach interaction.

D. System 4: Diet Recommendation System [16]

The system provides a customized diet to patients who are at risk of coronary heart diseases. It consists of a Nutrient Extraction Module which calculates required nutrients using an algorithm based upon vital signs and basal metabolic rate of the user. The vital signs of the user are recorded by a vital sign recorder which then sends the data to the server. The system also contains a Preference Configuration Module which stores the food likings of the users and recommends diets based on these likings. It also recommends diets based on the family history, personal data, health condition, how much food the user has taken and how much energy have been used and how active the user has been.

TABLE 1. COMPARISON OF EXISTING SYSTEMS

Features	System 1	System 2	System 3	System 4
Recommend food low in salt	×	✓	×	×
DASH diet	×	×	✓	×
Vital Signs	×	×	✓	✓
Cater for Nutritional Needs	✓	✓	✓	✓
User food Preferences	✓	×	×	✓
User Dietary Intake	✓	×	✓	✓
User Family History	×	×	×	✓
Intelligent Agent	✓	✓	×	✓
Human Interaction	×	×	✓	✓
Sensors	×	✓	✓	✓
Provide Recipes (list of menus)	✓	×	×	×
Accommodate different types of diets such as vegetarian diet	✓	×	×	✓
Other health benefits such as help in weight loss	✓	×	✓	✓
Mobile application	✓	✓	✓	×
Web-based	✓	×	✓	✓
Diet can be used by medical professional	✓	×	×	✓
Crowd sourcing	×	✓	×	×
Image analysis model	✓	×	×	×

The different existing systems have their particular functions. Most systems perform recommendation tasks. From Table 1, it can be deduced that the existing systems encourage people to have a healthy eating habit. However, not all the four systems have all the functionalities that a DASH diet should provide. Mobile applications have been used for systems 1, 2 and 3 which make them more accessible, easy and quick to use. Sensors are being used and vital signs are also being input in systems 3 and 4 to find out more details about the user current blood pressure. Only system 2 namely SaltSwitch is recommending food products low in salt by scanning food items. Nevertheless, these systems would not fit the Mauritian context as the foods being recommended are not Mauritian cuisines. The paper therefore proposes a system adapted for the Mauritian population.

IV. Proposed System

This section describes the proposed system (as illustrated by Fig. 1) along with the relevant factors that are considered by the system for DASH diet recommendation. The system makes use of a content-based filtering whereby the system recommends meals based upon the users' preferences [17], [18]. The different components of the system are described as follows:

A. Mobile Application and Data Storage

The application runs on the android mobile phones which enable users to interact with the user interface (UI),

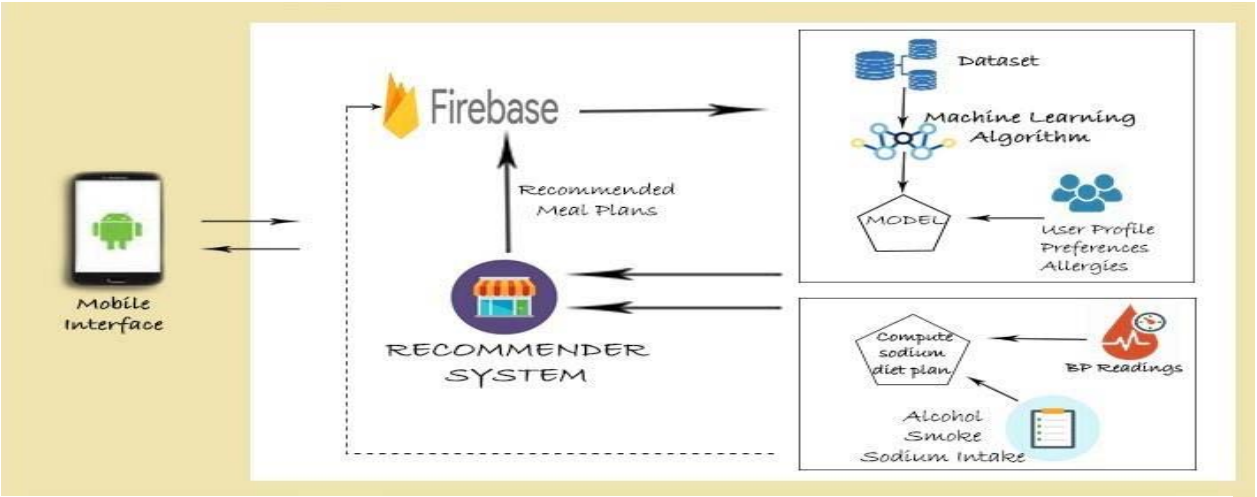

Fig. 1. Proposed System

input data to the system and also see the recommendations. The mobile phone is a better platform since it is handier and is an integral part of a person's life [19]. The system uses Firebase, a cloud-based database for data storage and authentication. The database contains all the structured data about user profiles, preferences and readings. Requests from the mobile application are processed by the server and recommendations are sent back to the client mobile phone.

B. User Profile

The user profile contains the explicit information provided by the user, stored in a NoSql format. The recommendation engine uses the user profile data in order to carry out recommendations. Examples of data stored in the profile are: personal details, food preferences, allergies.

C. DASH Diet Food dataset

The food database consists of food items, dishes and meal plans from the Weigh-Less book in order to cater for meals that are famous among Mauritians [20]. The Weigh-Less book has been chosen since it provides healthy food item and balanced diet meal plans that fits the Mauritian cuisine. However, Weigh-Less does not provide the sodium amount for each food item or meals, and it consists of many dishes that could have negative effect on blood pressure since the book mainly focus on weight loss diets. Some examples of food that can increase blood pressure include pickles, sausages and bacon [21].

To construct the dataset, the sodium amount per 100g of the food for each food has been obtained from the USDA Food Composition Database [22]. Sodium amount information for local food items have been collected from their label data as shown in the Fig. 2. The sodium content in food can be classified as low salt food which contains less than 120 mg of salt, medium salt food which contains between 120 mg and 600 mg of salt and high salt food which contains more than 600 mg of salt [29]. Food items that were high in sodium quantity are not considered in the dataset as they should not be recommended in a DASH diet [23]. The dataset consists of 1440 instances.

Fig. 2. Local Product Label

D. Factors for DASH diet recommendation

The following factors are considered for recommending diet plans to hypertensive patients.

1) Age: As one grows older, the risk of getting hypertension also increases [24]. However, the teen generation is also getting this disease due to bad eating habits and other factors such as stress. As from the age of 40, people have a higher risk of becoming hypertensive, hence a 1500 mg sodium diet plan should be recommended for them [25].

2) Food Preferences: Food preferences affect the way of eating of individuals [26]. People tend to eat their favorite food more frequently. Thus, before proposing meal plans, a user's personal taste is taken into consideration.

3) Allergies: It is important to consider allergies for diet recommendation as there exists some major consequences if not taken seriously such as headaches and eczema.

4) Alcohol: Alcohol is directly associated with blood pressure [27]. According to the website '*Alcohol Help Center*', the human body burns alcohol at the rate of 1 gram per hour for each 10 kilos of a person's weight [28]. The alcohol rate in beer, wine and spirits are approximately 5%, 12% and 40% respectively [30]. These alcohol drinks are the most consumed among Mauritians [1].

5) Smoking: According to [31], smoking more than 10 cigarettes per day can increase hypertension. The effect can stay for approximately 30 minutes after smoking a cigarette [32]. This factor is also considered when recommending meal plans.

6) BP level: The BP level is an important factor for recommendation since it is directly associated with DASH diet [8]. It is used to know the current health status of the user.

7) Dietary Intake (On a daily basis): High sodium intake has a direct effect on the human blood pressure [33]. The amount of sodium intake from the previous meals is calculated on a daily basis prior to meal recommendation. The person's previous sodium intake is compared with the adequate intake level and the tolerable upper intake level to be able to recommend the suitable sodium diet plan [34].

E. Recommendation Engine

The recommendation engine consists of three major components: Estimation Module, Food Classifier model, Content-based filtering Module.

1) Estimation Module: This component consists of three main calculators: Alcohol calculator, smoke calculator and sodium intake calculator.

The alcohol calculator calculates the blood alcohol content (BAC) of the user and classifies it into levels according to the range provided in *Alcohol Help Center* [28]. Based on the type of alcohol drink consumed and the amount, percentage of alcohol is computed. The human body burns alcohol at the rate of 1 gram per hour for each 10 kilos of a person's weight [28]. It is found that the BP level can increase by 1 mmHg for every 10g of alcohol intake [36]. Taking into consideration the hours elapsed since last drink, the *BP_rise* value representing rise in BP level is calculated. Based on this value, the user is assigned a level ranging from 1 to 4. A user who does not drink alcoholic drink is assigned level 1. If the *BP_rise* value is less than 5, he will be assigned level 2. If the *BP_rise* value lies between 5 and 10, he is assigned level 3. Otherwise, he is assigned level 4.

The smoke calculator calculates the effects of cigarette smoking in the user's body, which is classified into 3 levels according to the number of cigarettes smoked and hours elapsed since last cigarette smoked. If a person smokes a cigarette, his blood pressure will be high in the next 30 minutes. He is thus assigned the highest level which is 3. If he has smoked more than 10 cigarettes and more than 30 minutes has lapsed, he is still assigned level 3. However, if a person smoked less than 10 cigarettes but more than 30 minutes has lapsed, he is assigned smoke level 2. Otherwise, if he does not smoke, he is assigned level 1.

The sodium intake calculator calculates sodium intake based on foods consumed by a user the previous day. The user chooses the foods consumed from a list of available food items along with their servings. The sodium intake is then computed.

Based on values generated from these three calculators and parameters such as age, diastolic blood pressure and systolic blood pressure, the system then decides whether to allocate 1500 mg sodium meal plans or 2300 mg sodium meal plans. Users having smoke or alcohol levels above 2 are automatically advised 1500 mg sodium meal plans. If the sodium intake calculator reveals a sodium intake greater than 2300 mg for the previous day, it is advised a 1500 mg sodium meal plans. Additionally, if systolic and diastolic blood pressures are greater than normal blood which is 140 and 80 respectively, the user is advised a 1500 mg diet plans. Otherwise, in case the three calculators reveal satisfactory results and the systolic and diastolic blood pressures are normal, users are advised 2300 mg diet plans. This estimated value of sodium (1500 mg or 2300 mg) from the *Estimation Module* is used as input in the food classifier model to recommend for a relevant meal plan.

2) Food Classifier Model: The food classifier model uses a machine learning algorithm namely Multilayer Perceptron algorithm as classification technique. Multilayer Perceptron algorithm is a feed-forward artificial neural network [35]. The neural network consists of the input nodes, hidden nodes and output nodes. The attributes namely preference of the user for each food category, the sodium content of the food, allergies of the user, estimated sodium meal plan from the dataset are passed into the input nodes and then to the hidden nodes as shown in Fig. 3.The model uses all nominal attributes for classification. The attributes label and values are as follows:

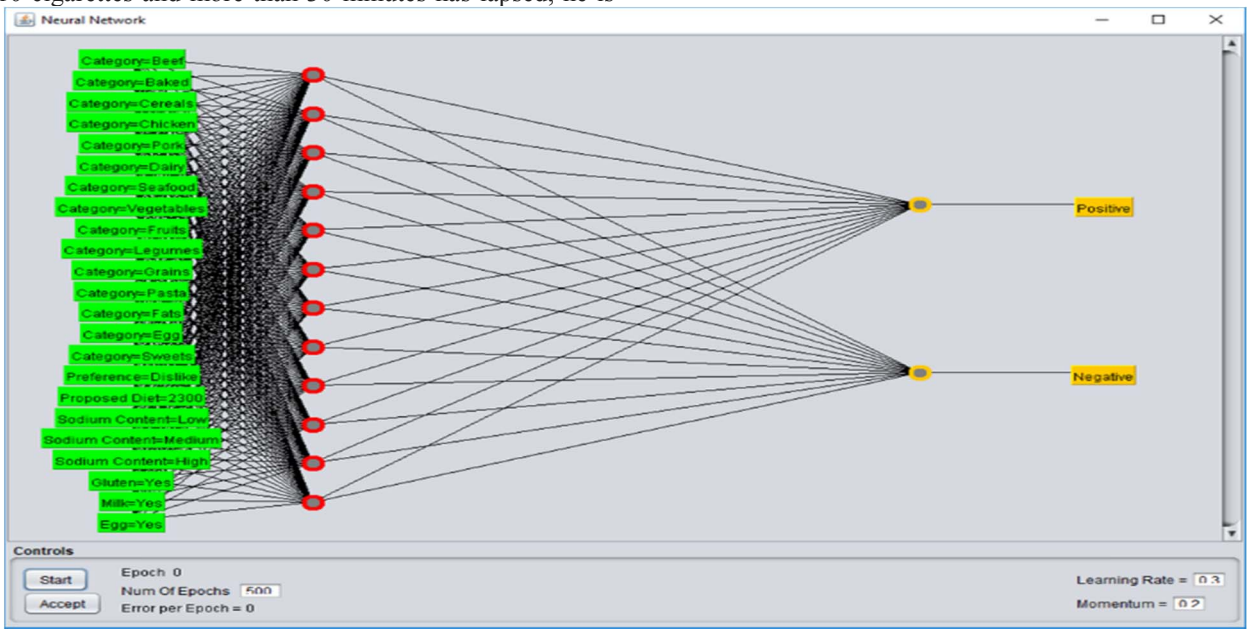

Fig. 3. Food Classifier Model

Category {Beef, Baked, Cereals, Chicken, Pork, Dairy, Seafood, Vegetables, Fruits, Grains, Pasta, Fats, Egg, Sweets}, Preference {Like, Dislike}, Proposed Diet {1500, 2300}, Sodium Content {Low, Medium, High}, Gluten {No, Yes}, Milk {No, Yes}, Egg {No, Yes}, Decision {Positive, Negative}. In USDA Food Composition Database [22], food has been classified into food categories whereby a food can fall into more than one category. An attribute preference is used and it states whether the user likes or dislikes a particular category. The result of the model is in the output node as positive or negative. The 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 %.

3) Content-based filtering Module: The content based filtering module uses all the positive classified food from the food classifier model to recommend meal plan with the highest score based on the standard DASH serving sizes for food group and the number of days since the user has last consumed a particular meal plan [23]. The amount of servings recommended are according to [23] to enable an individual to obtain the correct amount of nutrients in the food consumed. The content-based filtering module automatically adjusts the serving sizes of food according to their previous food intake and standard serving size. Then the module calculates the score between each meal plan's serving size and the recommended serving size for the user using cosine similarity formula. The module decrements a meal plan's score by 1 if the number of days since the user has last eaten a particular meal plan is less than 7 in order to avoid repetitive recommendations during a week. The highest scored meal is recommended to the user.

V. System Prototype

The system has been developed using android studio which is a mobile application development platform. It uses Java which is very popular and easy to use programming language. Weka has been used to implement the diet classification model as it is open-source. Fig. 4 shows DASH diet plans proposed for a person with the specifications (set of values 1) in Table 2. The diet plan changes as illustrated in Fig. 5 when one attribute, for example, age changes (set of values 2). The system also generates a chart as shown in Fig. 6 to track the user's BP level over several days. For the purpose of the user acceptance test, a group of 10 hypertensive patients (above the age of 40) have been introduced to the application. After the usage of the application for a period of one week, a post-test survey questionnaire was distributed to the users to obtain feedback on the application. 70% of the users claim that the application meets their eating requirements as a DASH diet application. 90% of the users claim that the application help them control and reduce their BP level. All users claim that the BP and food consumption charts help them track their BP level and amount of food they are consuming.

TABLE 2. USER DETAILS

CRITERIA	VALUES 1	VALUES 2
Age	33	55
Allergies	None	None
Preference	Dislikes beef and pork	Dislikes beef and pork
Height	170cm	170cm
Weight	75kg	75kg
Systolic BP	116	116
Diastolic BP	75	75
Smoking	Does not smoke	Does not smoke
Alcohol	No alcoholic drinks	No alcoholic drinks
Sodium intake	2106 mg	2106 mg

Fig. 4. Meal Plan 1

Fig. 5. Meal Plan 2

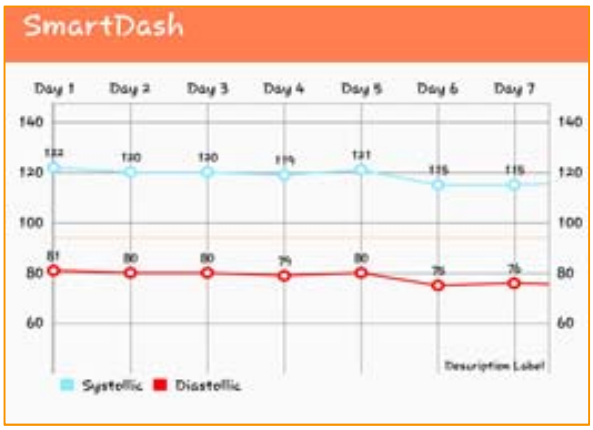

Fig. 6. Chart Monitoring BP level

VI. Conclusion And Future Works

Hypertension is one of the main causes of death in Mauritius. Proper eating habits and diets can help to remedy the situation in the country. The paper therefore proposes a DASH diet recommendation system to recommend healthy menus and dishes. The recommended dishes aim to help not only a hypertensive person to control his diet but also benefit a normal user to prevent him from getting health complications. The system considers a number of factors such as allergies, BP level, age, weight, smoke/alcohol intake, dietary intake and food preferences to make proper recommendations based on machine learning and content-based filtering techniques. The system has been evaluated with a group of hypertensive patients and has proved to be satisfactory. Relevant charts are projected to display the different blood pressure readings of the user over a certain period. As future works, the system will be used to identify and analyze the eating pattern of the user. Thus, the progress of the user can be monitored.

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