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## PRECISION CARDIODIET: TRANSFORMING CARDIAC CARE WITH ARTIFICIAL INTELLIGENCE-DRIVEN DIETARY RECOMMENDATIONS

*The subject matter of this research revolves around addressing the escalating global health threat posed by cardiovascular diseases, which have become a leading cause of mortality in recent times. The goal of this study was to develop a comprehensive diet recommendation system tailored explicitly for cardiac patients. The primary task of this study is to assist both medical practitioners and patients in developing effective dietary strategies to counter heart-related ailments. To achieve this goal, this study leverages the capabilities of machine learning (ML) to extract valuable insights from extensive datasets. This approach involves creating a sophisticated diet recommendation framework using diverse ML techniques. These techniques are meticulously applied to analyze data and identify optimal dietary choices for individuals with cardiac concerns. In pursuit of actionable dietary recommendations, classification algorithms are employed instead of clustering. These algorithms categorize foods as "heart-healthy" or "not heart-healthy," aligned with cardiac patients' specific needs. In addition, this study delves into the intricate dynamics between different food items, exploring interactions such as the effects of combining protein- and carbohydrate-rich diets. This exploration serves as a focal point for in-depth data mining, offering nuanced perspectives on dietary patterns and their impact on heart health. The method used central to the diet recommendation system is the implementation of the Neural Random Forest algorithm, which serves as the cornerstone for generating tailored dietary suggestions. To ensure the system's robustness and accuracy, a comparative assessment involving other prominent ML algorithms—namely Random Forest, Naïve Bayes, Support Vector Machine, and Decision Tree, was conducted. The results of this analysis underscore the superiority of the proposed -based system, demonstrating higher overall accuracy in delivering precise dietary recommendations compared with its counterparts. In conclusion, this study introduces an advanced diet recommendation system using ML, with the potential to notably reduce cardiac disease risk. By providing evidence-based dietary guidance, the system benefits both healthcare professionals and patients, showcasing the transformative capacity of ML in healthcare. This study underscores the significance of meticulous data analysis in refining dietary decisions for individuals with cardiac conditions.*

**Keywords:** Diet Recommendation; Cardiovascular Diseases; Cardiac Care; Machine Learning; Personalized diet; Dietary patterns.

### Introduction

Cardiovascular diseases have surged to the forefront of global health concerns, accounting for a substantial portion of contemporary mortality rates [1]. As an escalating public health threat, these conditions demand innovative interventions to alleviate their impact [2]. Among these strategies, dietary modifications play a pivotal role in mitigating the risk factors associated with heart-related ailments [3]. This research stems from a profound motivation to develop a cutting-edge solution that not only addresses the urgent need for tailored dietary recommendations for cardiac patients but also leverages the power of machine learning (ML) algorithms to revolutionize cardiac care.

Traditionally, dietary recommendations for individuals with cardiac conditions have been broadly expressed and devoid of personalization [4]. These generic, one-

size-fits-all strategies frequently overlook the nuanced requirements of individual patients, potentially resulting in suboptimal health outcomes. The emergence of machine learning (ML) and data-driven insights presents an unparalleled prospect to revolutionize cardiac care through the delivery of highly personalized dietary suggestions. The recommender system anticipates users' preferences or past behavior to predict their interests [5]. Despite its considerable potential, the incorporation of ML algorithms into cardiac dietary recommendations remains a relatively underexplored domain.

The central objective of this research is to bridge the gap between the pressing need for customized dietary guidance for cardiac patients and the untapped potential of ML algorithms. By harnessing the capabilities of ML, we aim to develop a state-of-the-art diet recommendation system that caters to the specific needs and preferences of individuals dealing with cardiac concerns. Through

evidence-based guidance, this system aims to significantly enhance heart wellness and mitigate the risk of cardiovascular diseases.

The research approach combines advancements in ML techniques with the intricacies of cardiac care. Leveraging comprehensive datasets and sophisticated data analysis, the intention is to construct a robust diet recommendation framework. This framework will be driven by classification algorithms capable of categorizing foods into "heart-healthy" and "not heart-healthy" categories, aligning with the personalized requirements of cardiac patients.

By integrating ML with cardiac dietary recommendations, envision a future where healthcare practitioners and patients have access to a dynamic and data-driven dietary guidance system. This research aspires to set a new standard in cardiac care, where precision nutrition meets the potential of advanced technologies, ultimately contributing to better heart health outcomes and improved quality of life for cardiac patients.

## 1. Related Work

There have been many studies devoted to the topic of food recommendation, and the discipline is constantly growing and evolving today. Among the previous responsibilities are the following:

In their work, Phanich et al. [6], introduced a specialized Food Recommendation System (FRS) targeting the dietary needs of patients with diabetes. This system employs advanced food clustering analysis to suggest suitable alternative food options, considering both nutritional content and food-related characteristics. The methodology harnesses the power of Self-Organizing Map (SOM) and K-means clustering techniques, capitalizing on the inherent similarities among eight essential nutrients critical for individuals with diabetes. This innovative approach holds promise for enhancing dietary management and promoting healthier choices among individuals with diabetes.

Wahidah et al. [7] proposed a Cancer Patient Personalized Diet Recommendation System. The suggested system uses Case-based Reasoning, Rule-based Reasoning, and Genetic Algorithm for data mining. Case-based Reasoning suggests diet plans from the system's cases, whereas Rule-based Reasoning filters out irrelevant examples and selects the best case for the patient. The Genetic Algorithm customizes food menus according to each patient's health.

Mustaqeem et al. [8] used clustering and sub-clustering to provide improvised collaborative filtering. Angina, non-cardiac chest discomfort, silent ischemia, and myocardial infarction data were supervised using the suggested method. Once the disease classes are divided

into partitions, k-means clustering is applied to each partition. The outcomes of the experiments demonstrate that the recommender system, which is based on modular clustering, reduces the search space for a query patient and decreases the time required to generate relevant recommendations.

Bhat et al. [9] proposed a Diet Recommendation System (DRS) that uses ML techniques for diabetes diagnosis and diet recommendation. They developed a healthcare system that could predict and recommend diets for diabetic patients. Moreover, the supervised learning technique was employed to acquire knowledge about diabetes and develop a system for predicting diabetes diagnoses. Additionally, the dataset was prepared and features such as Age, Diagnosis Duration, Diastolic Blood Pressure, Cholesterol level, and Hemoglobin were selected using ML techniques.

Agapito et al. [10] introduced a system called DIES-TOS, which is an adaptive nutrition content delivery recommender that can help people who are healthy and those who have diet-related chronic diseases live better lives. The proposed method first generates a health profile for the user and then provides particular dietary recommendations for that user, considering both the user's tastes and the regional origin of the food.

A. Evwiekpaefe et al. [11] developed a personalized recommender system to suggest nutrient-dense meals for patients with various ailments. The system utilizes nutritional knowledge and analyzes dietary and user data to create tailored meal suggestions. This study considered physical traits, physiological data, and personal information to construct a general framework for daily eating plans. ML techniques, specifically K-means clustering and Random Forest classification, were employed to generate food recommendations that aimed to improve the health of the users. The model achieved an impressive accuracy of 95% using 100 decision trees.

A healthy eating system based on online data mining was proposed by Nandish et al. [12], which tracks dietary habits and recommends foods that promote health while discouraging foods that increase the risk of disease. The authors used data mining techniques such as classification, clustering, and association rules to extract pertinent information about people's eating patterns. The quantities of fat, energy, and vitamins in the dish were calculated after each food type's nutritional makeup was reviewed. The composition data were then assessed using the classification mining technique to determine whether or not the food was healthy. As a result, each person received a different set of recommendations.

## 2. Motivation for research

The relentless surge in cardiovascular diseases poses an urgent global health challenge, demanding in-

novative strategies to combat their pervasive impact. Within this context, dietary interventions are a cornerstone in reducing the risk factors associated with heart-related ailments. However, traditional approaches to dietary recommendations for cardiac patients have proven insufficient in addressing the intricate nuances of individual health profiles, often leading to suboptimal outcomes.

This research is driven by a compelling motivation to bridge this gap by harnessing the transformative potential of ML algorithms. Unlike the conventional "one-size-fits-all" approach, it is imperative to provide personalized dietary recommendations that consider each patient's unique physiological and dietary requirements. The integration of ML offers an unprecedented opportunity to deliver targeted, evidence-based dietary guidance that can significantly improve heart health outcomes.

Central to the research motivation is the choice of using classification algorithms in lieu of clustering methodologies. Classification algorithms promise to provide actionable insights by categorizing foods as "heart-healthy" or "not heart-healthy," aligning with the specific needs of cardiac patients. Unlike clustering, which groups items into categories without predefined labels, classification offers a more direct and interpretable framework for guiding dietary choices. This approach empowers healthcare practitioners and patients alike with clear and actionable information, fostering informed decision-making in dietary selection.

The use of classification algorithms addresses the limitations of previous clustering-based methods, which often lack specificity and clarity in dietary recommendations. By opting for classification, the precision and personalization of dietary suggestions is enhanced, facilitating a more intuitive and user-friendly experience for both medical professionals and patients.

### 3. Purpose and objectives of the study

The research is centered on technological advancements aimed at reshaping cardiac care. At the core of these contributions lies the development of an innovative diet recommendation system driven by cutting-edge ML algorithms. By tailoring this system explicitly for cardiac patients, we aim to provide personalized dietary strategies that harness the potential of extensive health data. This technological approach enables the prediction and management of heart health using data-driven insights to identify optimal dietary choices and mitigate cardiovascular risks. Notably, the superiority of classification algorithms is emphasized, ensuring precision in delivering dietary recommendations and enhancing decision-making accuracy. This research marks a pioneering step toward revolutionizing healthcare, seamlessly integrating

ML into dietary planning, and enhancing patient engagement and collaboration with healthcare providers. The data-centric approach not only contributes to evidence-based healthcare practices but also lays the foundation for a technologically empowered future in patient-centric cardiac care. Ultimately, this research strives to drive improved cardiac outcomes through the fusion of technology and medical expertise, ensuring tailored dietary interventions that align with individual health needs.

### 4. Proposed System

The proposed system introduces a novel paradigm in cardiac care by focusing on the intricate balance between essential and harmful nutrients in an individual's diet. Harnessing the capabilities of ML algorithms, this innovative platform is designed to provide personalized dietary recommendations tailored to each individual's specific cardiac health requirements. By leveraging comprehensive nutritional data, the system gains a comprehensive understanding of nutrient intake and its impact on heart health.

The core of the proposed system is nutrient profiling, where advanced algorithms meticulously analyze an individual's dietary choices to create a detailed nutrient profile. This profile forms the foundation for generating highly personalized recommendations that prioritize essential nutrients critical for heart health while strategically mitigating the intake of harmful nutrients. These recommendations are rooted in evidence-based nutritional science, ensuring that each dietary choice is informed by data-driven insights.

The system's process starts by considering the user's food preferences to extract the corresponding food ingredients. Subsequently, a meticulous nutrient analysis is conducted on the basis of these extracted ingredients based on lifestyle factors and metabolic data, leading to the identification of essential and harmful nutrients. Leveraging this nutrient profile, the system employs ML algorithms on its comprehensive database to evaluate the nutrient values. The outcome of this analysis forms the basis for personalized recommendations, indicating whether the specific food is considered safe for the user's consumption or not. This intricate process intertwines user preferences, nutrient analysis, ML, and nutrient values to provide actionable guidance on the safety of selected foods.

The system offers an intuitive and interactive user interface that allows individuals to input their dietary preferences, restrictions, and health goals. This dynamic engagement empowers users to actively participate in their cardiac care journey, fostering a sense of ownership over their heart health. A flow diagram of the proposed system is shown in Figure 1.

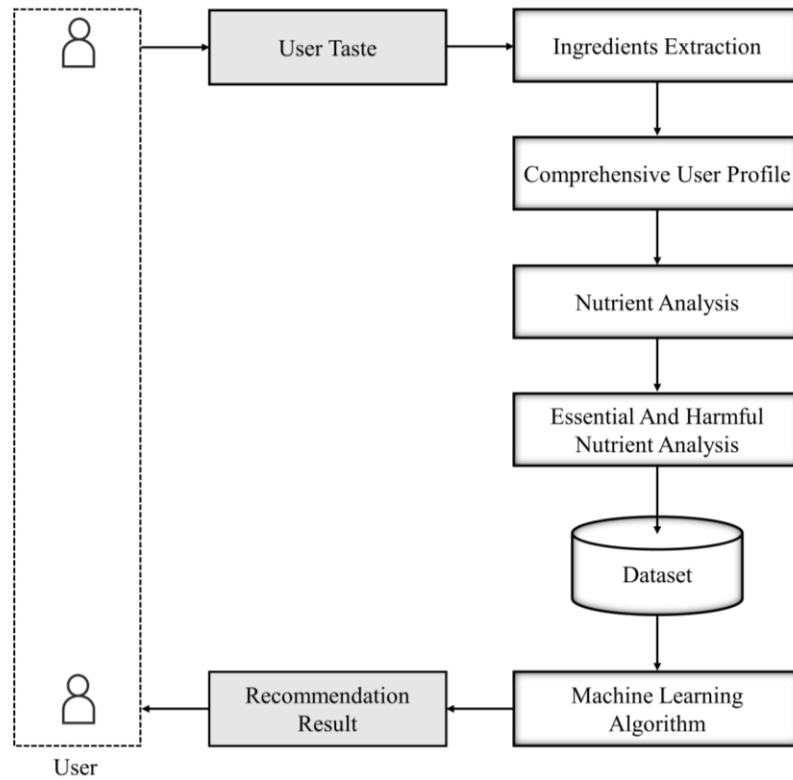


Fig. 1. Flow diagram of the proposed system

## 5. Dataset and methodology

The research methodology involves the collection and use of two distinct datasets, each contributing to the robustness and effectiveness of the proposed diet recommendation system tailored for cardiac patients. The compilation of these datasets ensures the accuracy and reliability of the system's insights and recommendations.

The first dataset, meticulously compiled by the Facebook research team, comprises a collection of food recipes, each accompanied by its respective ingredients. The team took careful measures to ensure the confidentiality and integrity of this dataset, safeguarding sensitive information. This foundational dataset serves as a crucial resource for the system, facilitating the extraction of ingredients based on individual user food preferences. With a diverse range of recipes at its disposal, the system can accurately discern the specific ingredients favored by users, allowing for personalized dietary recommendations tailored to individual tastes.

Simultaneously, the second dataset, sourced from the American food chart, contains a comprehensive compilation of nutritional information regarding a wide array of food ingredients. This dataset forms the basis for conducting nutrient analysis, enabling the identification of both essential and potentially harmful nutrients. The nutritional values provided in this dataset are instrumental in assessing the nutritional composition of each ingredi-

ent. Leveraging these nutrient values, the system employs a classification framework to recommend foods, considering the presence of both beneficial and harmful nutrients.

Both datasets are rigorously maintained to ensure representativeness and reliability and play integral roles in providing accurate, personalized, and balanced dietary recommendations for users. All measures are taken to ensure that these datasets are free from biases and uphold the integrity of the nutritional information used for the system's analyses and recommendations.

The validation and calibration of the nutrient values and classification parameters were undertaken in collaboration with Dr. Biswajit Mandal, an esteemed medical professional specializing in cardiology at Khulna Medical College Hospital, Khulna. Doctor Mandal's expertise ensures the accuracy of classifying foods based on their nutrient values and aligns recommendations with cardiac health considerations. This collaborative effort adds a crucial layer of credibility to the system's recommendations, ensuring that they are medically sound and aligned with best practices in cardiac care.

### 5.1. Dataset Preprocessing

The food recipes dataset, acquired from the Facebook research team, is presented in JSON format. The primary structure of the dataset is shown in Figure 2. To effectively utilize this dataset, a preprocessing phase

involving natural language processing Natural Language Processing (NLP) techniques is employed. The use of NLP serves as a pivotal steps in structuring and organizing the dataset, ensuring its coherence and compatibility with subsequent analyses.

```

{
  "id": "000095fc1d",
  "ingredients": [
    {
      "text": "yogurt, greek, plain, nonfat"
    },
    {
      "text": "strawberries, raw"
    },
    {
      "text": "cereals ready-to-eat, granola, homemade"
    }
  ],
  "instructions": [
    {
      "text": "Layer all ingredients in a serving dish."
    }
  ]
}

```

Fig. 2. Primary Structure of Recipe Dataset

Simultaneously, the nutritional dataset, which encompasses crucial information about food ingredients, is not exempt from challenges. This dataset presents issues such as structural errors, unwanted data, outliers, and occasional missing values. To address these intricacies and enhance the dataset's integrity, NLP techniques are again harnessed. By leveraging NLP, the nutritional dataset undergoes a transformation, rectifying inconsistencies, resolving missing values, and refining the overall quality of the dataset.

The integration of NLP into the preprocessing of both datasets signifies the versatility of NLP techniques. Beyond their conventional applications in text analysis, NLP methodologies are adept at harmonizing and refining datasets of diverse formats. This approach ensures that both the recipe and nutritional datasets are primed for subsequent analyses, facilitating accurate nutrient extraction, analysis, and the generation of precise dietary recommendations within the proposed system.

### 5.1.1. Natural Language Processing in Food Recipe Dataset

The preprocessing of the JSON-format food recipe dataset involves the systematic application of NLP techniques to refine and structure the textual data. This intricate process consists of several distinct stages, each contributing to the organization and usability of the dataset for subsequent analysis. Initially, the JSON dataset is parsed to extract essential textual elements such as recipe names, ingredients, preparation instructions, and user preferences. This parsing serves as a foundational step, segmenting the unstructured data into manageable components.

The following data extraction, tokenization comes into play, breaking down the extracted text into

individual words or phrases. Tokenization enables the conversion of text into distinct units, facilitating more granular analysis. Common stopwords, such as "and" or "the," are then removed to streamline the data further, focusing subsequent analysis on content-rich words. Text cleaning steps include addressing symbols, punctuation, and special characters to enhance text cohesiveness and readability [13].

Continuing the NLP process, part-of-speech tagging is applied to label each token with its corresponding grammatical role, enhancing contextual understanding [14]. Named Entity Recognition (NER) is then employed to identify and categorize entities within the text, such as ingredients, measurements, and units. Lemmatization and stemming transform words into base or root forms, minimizing redundancies and ensuring consistent representation.

The processed text is structured into data formats suitable for analysis, while vectorization transforms textual data into numerical vectors, enabling mathematical operations and integration with ML. This comprehensive NLP-driven preprocessing process ensures that the JSON food recipe dataset transitions from unstructured text to an organized and enriched resource. This transformation, which is vital for accurate nutrient analysis and subsequent dietary recommendations within the proposed system, underscores the importance of NLP in refining raw textual data for meaningful insights.

### FuzzyWuzzy Technique

FuzzyWuzzy is a string-matching library that employs various algorithms to calculate the similarity between two strings. One such algorithm is the Levenshtein distance, which quantifies the number of character edits needed to transform one string into another [15].

By leveraging FuzzyWuzzy with the Levenshtein distance, the preprocessing of the food recipe dataset is enhanced. For instance, when encountering ingredient names like "tomato," "tomatos," and "tomatoe," FuzzyWuzzy assesses their similarity based on Levenshtein distance. Levenshtein Distance mapping is shown in Figure 3.

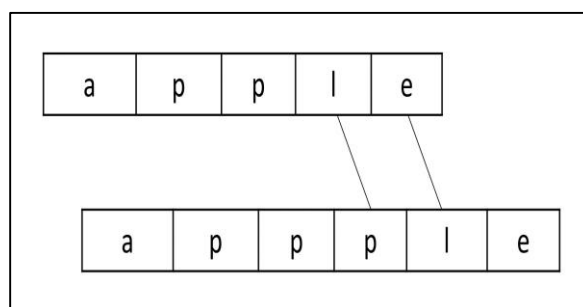


Fig. 3. Levenshtein Distance mapping

The Levenshtein distance quantifies the minimal number of character modifications required to align the strings. Consequently, strings that share a higher similarity score exhibit a closer match in terms of their content [16]. The equation to calculate Levenshtein distance between two strings  $a$ ,  $b$  (of length  $|a|$  and  $|b|$  respectively) is,

$$\text{lev}_{a,b}(i, j) = \begin{cases} \max(i, j), & \text{if } \min(i, j) = 0; \\ \min \begin{cases} \text{lev}_{a,b}(i-1, j) + 1 \\ \text{lev}_{a,b}(i, j-1) + 1 \\ \text{lev}_{a,b}(i-1, j-1) + 1 \end{cases}, & \text{in another case.} \end{cases}$$

If  $\min(i, j) = 0$  then the Levenshtein distance will be  $\max(i, j)$  otherwise it will be the min section.

In practical terms, FuzzyWuzzy allows the system to set a threshold for similarity scores, above which strings are considered matching or highly similar. This threshold is determined on the basis of the specific use case and the desired level of tolerance for variations [17]. When applied to ingredient names, FuzzyWuzzy assists in identifying and standardizing similar or near-identical ingredients.

In the proposed system, FuzzyWuzzy with Levenshtein distance optimizes the extraction of accurate and standardized ingredient information from the dataset. This refinement ensures that nutrient analysis and subsequent dietary recommendations are rooted in precise data, mitigating variations and enhancing the overall reliability of the system's insights.

### 5.1.2. Natural Language Processing in the nutritional dataset

In the context of a nutritional information dataset, NLP unveils its adaptability beyond its primary role in processing natural language text. By creatively adapting NLP techniques, specific data preprocessing challenges inherent to tabular datasets can be effectively addressed [18]. First, for textual descriptions or labels associated with food items, NLP tools such as tokenization and stop-word removal prove invaluable. These techniques facilitate the extraction of relevant information while filtering out non-informative words, resulting in a streamlined dataset devoid of extraneous textual content.

Moreover, NLP's application extends to rectifying structural errors present within text columns [19]. Beyond linguistic nuances, NLP can identify and rectify discrepancies such as misspellings or formatting irregularities in food names and nutrient labels. This proactive approach ensures data accuracy and cohesiveness, which contributes to the overall reliability of the dataset. In ad-

dition, while NLP is not inherently designed for numerical outlier detection, its analytical capabilities can be adapted to identify outlier-like patterns in textual representations. In cases where nutrient values display inconsistencies in their portrayal, NLP can serve to identify such anomalies, thereby enhancing the integrity of the dataset [20].

Furthermore, NLP's competency lies in handling missing data instances. By discerning patterns within textual indicators of incompleteness, such as "N/A" or "Not available" denoting nutrient values, NLP techniques can systematically address and manage these instances. This holistic approach enhances the robustness of the dataset and ensures comprehensive treatment of missing data. The interdisciplinary application of NLP in preprocessing this nutritional dataset exemplifies its versatility, demonstrating how NLP techniques, originally designed for language understanding, can be creatively adapted to optimize data quality, structure, and utility within the context of tabular datasets. The steps involved in Data Cleaning with NLP are shown in Figure 4.

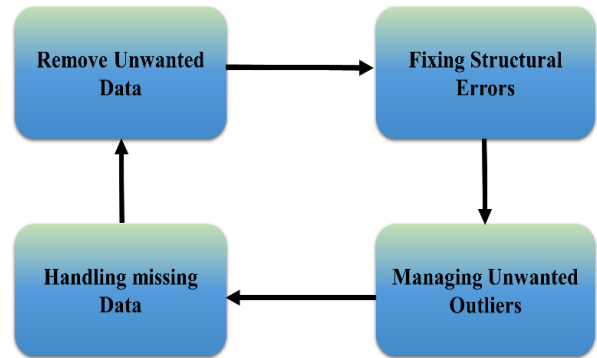


Fig. 4. Nutritional Value Dataset Cleaning Process

## 5.2. Ingredients Extraction

When a user provides their desired taste preference for a type of food, the input is processed by converting it to lowercase to ensure case-insensitive matching. The system then iterates through a dataset of recipes, each represented as a dictionary with a recipe name and a list of ingredients. For each recipe, the recipe name is converted to lowercase, and a comparison is made to check whether the user's taste preference is present in the recipe name. If a match is found, the associated list of ingredients is extracted and added to a collection of extracted ingredients. Once all recipes have been processed, duplicates are removed from the collection to ensure a clean list. However, if no matching recipes are found, the user is informed that no recommendations can be provided based on their input. The extraction process is shown in Figure 5.

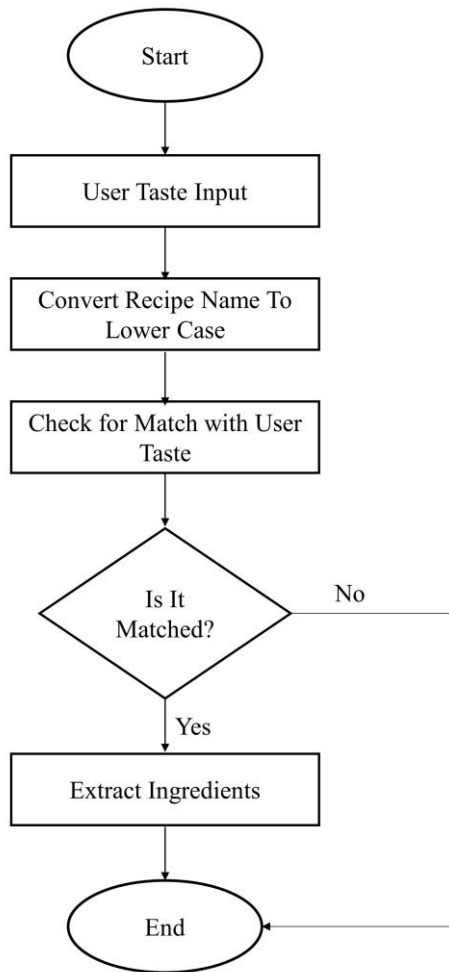


Fig. 5. Ingredients Extraction Process

### 5.3. Comprehensive User Profile

The system starts by merging lifestyle data and performing metabolic profiling, acquiring a wealth of information covering the individual's physical activity, stress management, sleep patterns, and daily routines. Lifestyle data collection involves employing various tools and questionnaires to gather details on physical activity levels, stress indicators, sleep patterns, and additional lifestyle factors, thus painting a comprehensive picture of the individual's daily habits and their potential impact on the dietary requirements for cardiac health. Simultaneously, the system conducts analyses of metabolic markers pivotal for cardiac health, including cholesterol levels, glucose levels, C-reactive protein (CRP) levels, hormone levels, and nutrient levels. These insights shed light on how the metabolic characteristics of the body influence cardiac health. This integrated profile, in conjunction with taste preferences and genetic information, forms the foundation for crafting personalized dietary recommendations. These recommendations are designed to address individual lifestyle and metabolic needs, thereby optimizing strategies for managing cardiac health effectively.

### 5.4. Nutrient Analysis

The nutrition analysis process is a pivotal component that evaluates the nutritional content of foods to determine their suitability within the dietary context of individuals with cardiac concerns. This process unfolds through several key steps. Initially, the system draws upon an extensive nutrient database, housing comprehensive information about the nutritional makeup of a wide array of foods, including macronutrients, micronutrients, calories, fiber, and more.

The system starts by considering the user's taste preferences, which are obtained through a detailed assessment of preferred cuisines, ingredients, dietary restrictions, and culinary choices. This taste profile informs the selection of ingredients and food items that align with the user's liking, ensuring that the suggested nutritional components are palatable and enjoyable for the individual.

The analysis further integrates lifestyle data, encompassing factors such as physical activity, stress levels, sleep patterns, and metabolic information such as lipid profiles, glucose levels, inflammatory markers, and heart function indicators. This comprehensive dataset helps in understanding the user's overall health context and metabolic characteristics. It plays a crucial role in identifying specific nutritional requirements tailored to the individual's health needs and influencing factors such as blood sugar management, cholesterol levels, and inflammatory responses related to cardiac health.

The system performs a nutrient analysis considering the amalgamation of taste preferences, lifestyle, and metabolic data. It tailors nutrient recommendations by aligning them with user preferences and health requirements. For instance, it might suggest foods rich in specific nutrients that cater to the individual's metabolic needs while appealing to their taste inclinations. This analysis might include recommendations for adequate intake of essential nutrients, such as omega-3 fatty acids, antioxidants, fiber, and heart-healthy vitamins and minerals, while considering the user's metabolic and lifestyle factors.

The outcome of this analysis is the generation of personalized dietary suggestions that strike a balance between the user's taste preferences and the necessary nutrients tailored to support cardiac health. By combining taste preferences, lifestyle, and metabolic information, the system provides dietary recommendations that are both nutritionally beneficial and aligned with the user's individual health context, thereby facilitating improved cardiac health management.

### 5.5. Recommendation using ML

After the nutrient analysis stage, the system integrates machine learning techniques to develop personalized dietary recommendations. This process involves the

use of a diverse dataset containing nutritional information gleaned from the nutrient analysis of various food ingredients. Machine learning algorithms then scrutinize the data, considering individual health profiles, specific nutritional requirements, and taste preferences collected from users. Through this analysis, the system determines the optimal combination of food items that align with an individual's nutritional needs, aiming to maximize the intake of beneficial nutrients while minimizing potentially harmful ones. The machine learning-driven framework assesses these complex relationships between nutrients and user preferences, ultimately generating tailored dietary suggestions. These recommendations account for an individual's unique health considerations, ensuring a more personalized and effective approach to promoting cardiac health through dietary choices.

## 6. Results and Discussion

This section delves further into the comprehensive analysis of outcomes resulting from extensive classification experiments, which are a pivotal part of the innovative diet recommendation system. The focal point of these experiments was the rigorous assessment of the effectiveness of various ML algorithms. Notably, this involved the intricate implementation and evaluation of algorithms such as Neural Random Forest, Support Vector Machine (SVM), Decision Tree (DT), and Naive Bayes.

Neural random forest is an ensemble learning technique that was developed by Gérard Biau [21] and colleagues. They adapted Breiman's random forest [22] technique into a neural network context, forming what they term "neural random forests." This adaptation combines the advantageous features of random forests with neural network methodologies, resulting in two distinct hybrid procedures.

### 6.1. Result Analysis

The primary objective was to identify an algorithm that excelled at precisely categorizing foods as either "safe" or "unsafe" for individuals with cardiac concerns. To conduct a thorough performance evaluation, the

dataset enriched with essential nutritional attributes and corresponding classifications was subjected to these diverse algorithms. By meticulously analyzing predictive accuracy and reliability, we aimed to pinpoint the algorithm that consistently demonstrated the highest performance levels. This robust selection process ensures the accuracy and dependability of tailored dietary recommendations for patients with cardiac conditions. A comprehensive breakdown of the comparative outcomes and key performance metrics for each algorithm can be found in Table 1, which summarizes the findings.

The table succinctly encapsulates the quantified performance metrics for each algorithm, revealing the Neural Random Forest as a consistent frontrunner across all parameters. Notably, Neural Random Forest showcased the highest accuracy, precision, recall, and F1 score metrics, unequivocally establishing its prowess effectively classifying foods for individuals with cardiac health considerations.

This supremacy of Neural Random Forest can be attributed to its inherent capability to decipher intricate patterns and correlations within the dataset. The architecture of multilayered neural network excels in comprehending complex interactions, making them ideal candidates for the nuanced task of dietary recommendation.

While the SVM, DT, Random Forest, and Naive Bayes demonstrated commendable performances, their limitations in capturing the intricacies of relationships and nuances within the dataset became more conspicuous when compared with the capabilities of Neural Random Forest.

Figure 6 depicts the accuracy and loss curve of the Neural Random Forest, the accuracy and loss curve of the Neural Random Forest is depicted, showcasing the performance trend over epochs. This curve provides insights into how the accuracy of the Neural Random Forest model evolves with each training cycle.

In addition, Figure 7 presents the accuracy and loss curve of the Neural Random Forest evolves with each test cycle. This curve illustrates the diminishing of the model accuracy and loss function over test cycles, indicating the network's optimization progress.

Table 1  
Performance of Different Classification Algorithms

Model	Accuracy	Loss	Precision	Recall	F1-score
Neural Random Forest	99.44	0.55	0.99	1.00	0.99
SVM	97.08	2.92	0.99	0.99	0.99
Random Forest	98.17	1.83	0.98	1.00	0.99
Decision Tree	93.16	6.84	0.99	1.00	0.99
Naive Bayes	92.16	7.84	0.99	0.97	0.98



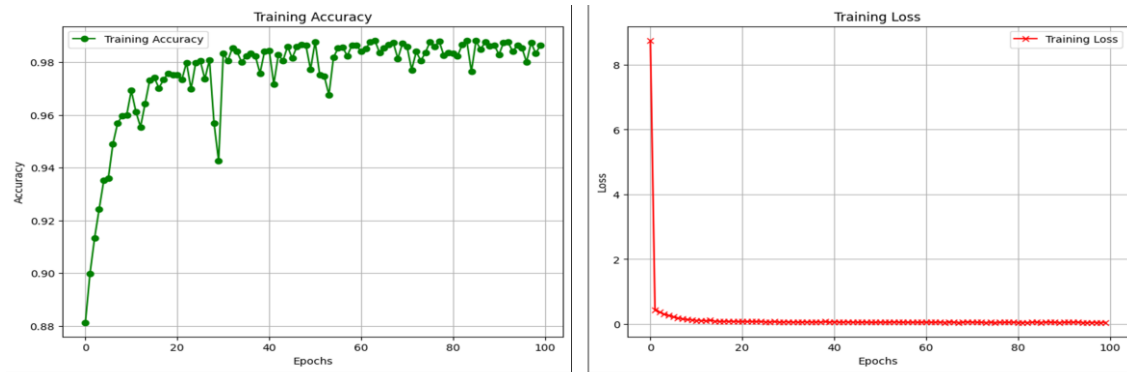


Fig. 6. Model Accuracy and loss in Neural Random Forest with each training cycle

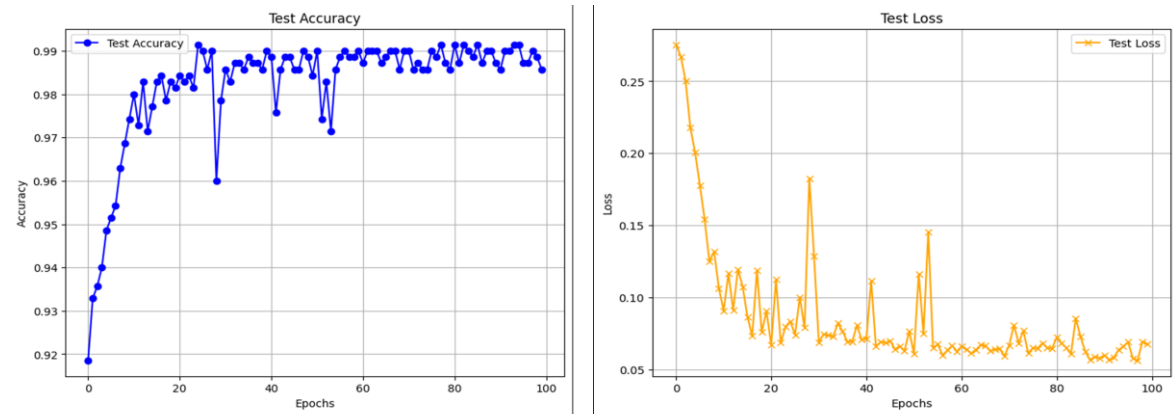


Fig. 7. Model Accuracy and loss in Neural Random Forest with each test cycle

Figure 8 offers a comprehensive comparison by juxtaposing the accuracy and loss curves in a single graph. This graph provides a visual representation of the trade-off between accuracy improvement and loss reduction as the Neural random forest undergoes training iterations. The interplay between accuracy enhancement and loss minimization is pivotal in assessing the Neural random forest convergence and overall model performance. By presenting these visualizations, valuable insights into the learning dynamics and convergence patterns of the

Neural random forest within the diet recommendation system are gained.

In summary, the outcomes emphatically underscore the pivotal role of the Neural random forest within the diet recommendation system. The precision, accuracy, and predictive abilities emphasize its potential to offer highly personalized dietary guidance to individuals with cardiac health concerns, underscoring the influential impact of ML in healthcare.

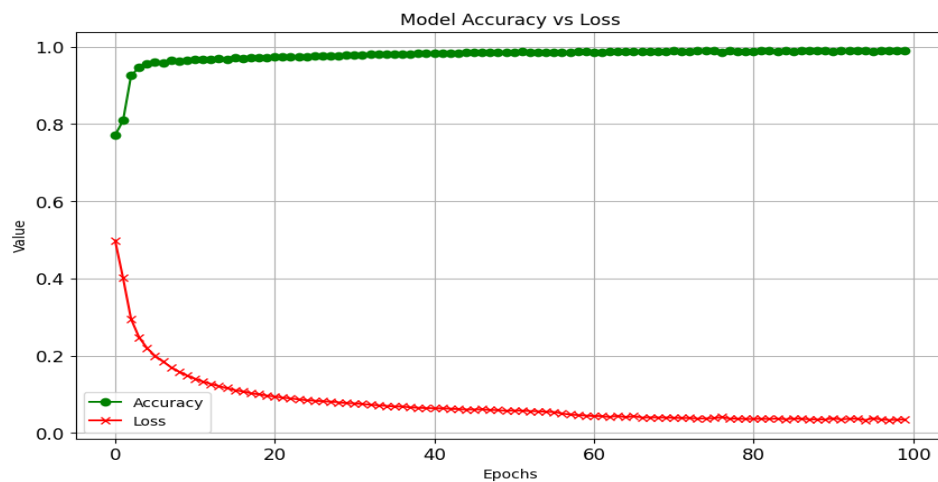


Fig. 8. Comparison of model Accuracy and Loss in Neural Random Forest

## 6.2. Implementation

The implementation of the system's recommendations involves pilot testing with a selected user group to observe their adherence and experiences. Longitudinal studies monitor health parameters over time, comparing the group following the system's recommendations with a control group. Data on health metrics such as blood pressure, cholesterol, and weight are collected before and after implementing the recommendations. User feedback regarding satisfaction, taste, and ease of implementation was gathered. Safety is a priority, with continual monitoring of adverse effects. Based on observations and feedback, the system's recommendations are refined to better suit user needs. Ethical guidelines are strictly followed to ensure privacy and confidentiality. This implementation process allows for validation of the system's effectiveness, safety, and user satisfaction, leading to continuous improvements for better cardiac health management.

## Conclusions

The researched method stands out as a groundbreaking approach to enhancing dietary recommendations for cardiac health, demonstrating quantifiable benefits and increased accuracy compared with traditional methods through a machine learning-driven framework. The fusion of neural network-based classification with nutrient analysis represents a key scientific breakthrough, resulting in a more comprehensive understanding of individual dietary needs and providing highly accurate, personalized suggestions. The system's trustworthiness is upheld by stringent data protection measures, ensuring user information confidentiality. Beyond its technical prowess, the method adopts a sophisticated and holistic approach by integrating diverse datasets, including food recipes, ingredients, and nutritional information. This enables the system to tailor recommendations based on users' tastes and health needs, identifying both beneficial and harmful nutrients. The meticulous curation of datasets, advanced classification methodologies, and commitment to user safety position this method as a revolutionary advancement in personalized dietary guidance for cardiac health, offering a comprehensive and innovative solution to enhance overall wellness.

Future endeavors could entail algorithm parameter fine-tuning for optimized performance, integrating user feedback for refinement, and incorporating continuous health monitoring for dynamic recommendations.

**Contribution of authors: Shahadat Hoshen Moz** took the lead in coding, conducted extensive data analysis, and played a pivotal role in drafting the manuscript;

**Md. Apu Hosen** authored the research proposal, conducted a thorough coding analysis, and made substantial contributions to manuscript development; **Md Noornobi Sohag Santo** executed the coding, collected and validated data, and played a crucial role in drafting the manuscript; **Sk. Shalauddin Kabir** assumed overall responsibility for manuscript oversight, conducted meticulous revisions, and contributed significantly to the document's drafting; **Md. Nasim Adnan** oversaw the manuscript's progress, conducted comprehensive revisions, and made significant contributions to drafting; **Syed Md. Galib** provided invaluable supervision, conducted rigorous editing, and served as a mentor throughout the entire article development process.

All authors have read and agreed to the published version of this manuscript.

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## ТОЧНА КАРДІОДІЄТА: ТРАНСФОРМАЦІЯ СЕРЦЕВОГО ДОГЛЯДУ ЗА ДОПОМОГОЮ ДІСТИЧНИХ РЕКОМЕНДАЦІЙ НА ОСНОВІ ШТУЧНОГО ІНТЕЛЕКТУ

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Предметом цього дослідження є вирішення проблеми глобальної загрози здоров'ю, яку становлять серцево-судинні захворювання, які останнім часом стали основною причиною смертності. Метою дослідження є

розробка комплексної системи рекомендацій щодо дієти, спеціально розробленої для серцевих пацієнтів. Основним завданням є допомога як лікарям, так і пацієнтам у розробці ефективних дієтичних стратегій для боротьби із серцево-судинними захворюваннями. Для досягнення цієї мети дослідження використовує можливості машинного навчання (ML), щоб отримати цінну інформацію з великих наборів даних. Підхід передбачає створення складної системи рекомендацій щодо дієти з використанням різноманітних методів машинного навчання. Ці методи ретельно застосовуються для аналізу даних, визначення оптимального вибору дієти для людей із захворюваннями серця. У пошуках дієвих дієтичних рекомендацій замість кластеризації використовуються алгоритми класифікації. Ці алгоритми класифікують продукти як «корисні для серця» або «нездорові для серця», відповідно до конкретних потреб серцево-судинних пацієнтів. Крім того, це дослідження заглиблюється в складну динаміку між різними харчовими продуктами, досліджуючи такі взаємодії, як наслідки поєднання білкової та вуглеводної дієт. Це дослідження слугує центром для поглибленого аналізу даних, пропонуючи тонкі погляди на схеми харчування та їх вплив на здоров'я серця. Основним методом у системі рекомендацій щодо дієти є впровадження алгоритму Neural Random Forest, який слугує нарізним каменем для створення індивідуальних дієтичних пропозицій. Щоб забезпечити надійність і точність системи, проводиться порівняльна оцінка за участю інших відомих алгоритмів машинного навчання, а саме: випадкового лісу, наївного Байєса, опорної векторної машини та дерева рішень. Результат цього аналізу підкреслює перевагу запропонованої системи на основі нейронного випадкового лісу, демонструючи вищу загальну точність у наданні точних дієтичних рекомендацій порівняно з аналогами. На завершення це дослідження представляє розширену систему рекомендацій щодо дієти з використанням ML, яка потенційно може значно знизити ризик серцевих захворювань. Надаючи рекомендації щодо дієти на основі доказів, система приносить користь як медичним працівникам, так і пацієнтам, демонструючи трансформаційну здатність ML в охороні здоров'я. Дослідження підкреслює важливість ретельного аналізу даних для уточнення дієтичних рішень для людей із захворюваннями серця.

**Ключові слова:** рекомендації щодо дієти; серцево-судинні захворювання; догляд за серцем; машинне навчання; персоналізована дієта; харчові звички.

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