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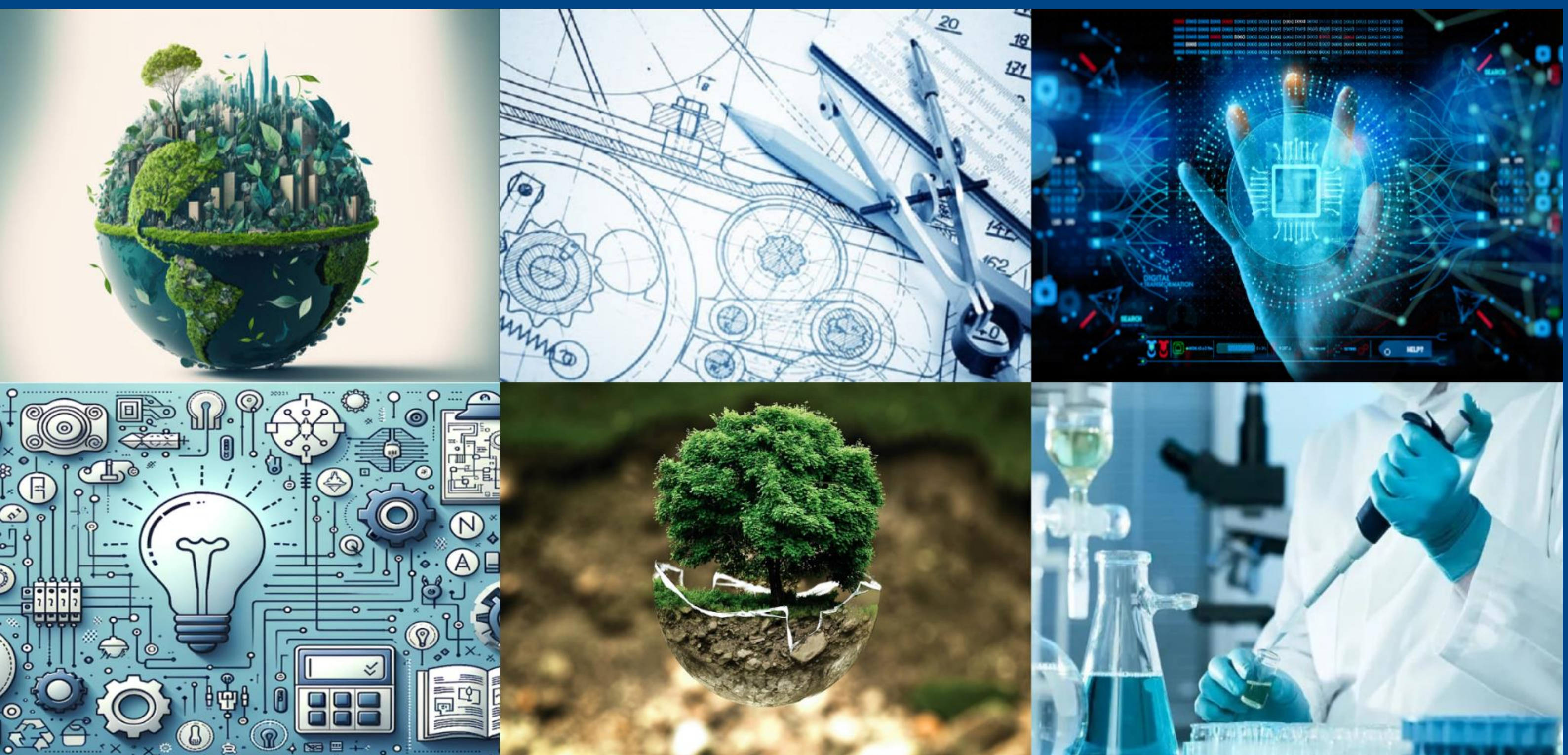

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Advanced Food Calorie Estimation and Bmi Prediction Leveraging Machine Learning

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ABSTRACT: Obesity remains a significant global health challenge, fundamentally tied to the consumption of surplus calories. Consequently, precise food calorie estimation and Body Mass Index (BMI) prediction are vital for effective obesity management and prevention. Traditional methods, such as self-reported food diaries, are prone to inaccuracies stemming from human error and biases. Leveraging recent advancements in computer vision and machine learning, this project aims to revolutionize calorie tracking by introducing an innovative system for food calorie estimation and BMI prediction. The proposed system employs deep learning techniques, specifically convolutional neural networks (CNNs), to analyze a dataset of food images alongside their calorie information, enabling accurate food recognition and calorie estimation. Furthermore, the system integrates demographic data—including age, gender, height, and weight—to predict BMI through sophisticated regression models. Evaluations using mean absolute error and root mean square error metrics will substantiate the models' accuracy. This project underscores the potential of deep learning and machine learning methodologies to transform nutrition and healthcare, facilitating individuals in monitoring their calorie intake and managing weight with greater precision and ease.

KEYWORDS: Machine Learning, Obesity, Deep Learning and Body Mass Index.

I. INTRODUCTION

Obesity poses a significant global health challenge, with the World Health Organization (WHO) linking 20% of worldwide deaths to dietary imbalances [1]. In 2016, 39% of adults were overweight and 13% obese, outstripping undernutrition-related mortality in many regions [1]. This epidemic, driven by excess caloric intake over expenditure, heightens risks of chronic diseases like diabetes and cardiovascular disorders, underscoring the need for precise tools to monitor food consumption and assess health metrics such as Body Mass Index (BMI). Traditional methods, like self-reported food diaries and static BMI calculations, are unreliable due to human error and lack of personalization, highlighting a critical gap in effective obesity management.

The advent of artificial intelligence, particularly deep learning and machine learning, offers a transformative solution. The project, *"Advanced Food Calorie Estimation and BMI Prediction Leveraging Machine Learning,"* harnesses these technologies to develop an automated system that redefines dietary and health monitoring. Inspired by *Caloriemeter* [6], which used Faster R- CNN for calorie estimation, our system employs Convolutional Neural Networks (CNNs) to analyze food images from a dataset of over 100 items (App.py), estimating caloric content with high accuracy. It also integrates regression models and facial recognition to predict BMI with precision, deployed via a Flask-based web application for seamless accessibility.

Building on prior research, this initiative synthesizes advancements like Wang et al.'s (2015) CNN-based food recognition [7] and Gutiérrez et al.'s (2019) 82.9% accurate BMI prediction [9]. While Caloriemeter [6] achieved low-error calorie estimation for limited food types, it lacked broader dietary scope. Our system addresses these gaps by combining real-time calorie tracking with individualized BMI prediction, validated by metrics like Mean Absolute Error (MAE) and Root Mean Square Error (RMSE), offering a comprehensive tool that transcends manual methods' limitations.

This project promises significant applications in healthcare, nutrition, and fitness. By automating calorie estimation, it empowers users to track intake effortlessly, while personalized BMI predictions enable tailored health interventions. Accessible via a web interface, it bridges advanced technology with everyday wellness, contributing to obesity prevention through data- driven insights.

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1.1 MOTIVATION

Our motivation emerges from a synergy of technological passion and societal necessity. As Computer Science Engineering students, we are driven to apply our expertise to address real-world challenges. The alarming rise in obesity—coupled with the inefficiencies of manual tracking methods—ignited our ambition to innovate. Witnessing machine learning's success in fields like computer vision and diagnostics, we drew inspiration from works such as Caloriemeter [6], which achieved low-error calorie estimation, to envision a system that brings similar precision to nutrition and health monitoring. Our goal is to bridge advanced technology with everyday wellness, offering a practical solution to a pervasive health issue.

1.2 PROBLEM DEFINITION

This project tackles a dual challenge rooted in the deficiencies of current health monitoring practices. First, calorie tracking remains labor-intensive, relying on manual inputs prone to errors in portion estimation and omissions. Second, BMI assessments are static, using basic height and weight data without capturing individual variability, thus limiting their utility. These shortcomings result in unreliable data, undermining obesity management efforts. Building on insights from Caloriemeter [6], which addressed calorie estimation limitations, our system automates (1) food calorie estimation from images using deep learning and (2) BMI prediction with personalized precision via regression and facial recognition, eliminating human error and enhancing health insights.

1.3 OBJECTIVE OF THE PROJECT

The primary objective is to design and deploy an integrated system that seamlessly combines advanced food calorie estimation and precise BMI prediction. Using CNNs trained on a dataset of over 100 food items (as in App.py), we aim to accurately identify and estimate caloric content from images. Concurrently, regression models and facial recognition, augmented by demographic data, will predict BMI with individualized accuracy. Deployed as a Flask web application, the system prioritizes accessibility and real-time performance. Inspired by Caloriemeter's automation [6], our goal is to deliver a scalable, user-centric tool that empowers individuals, nutritionists, and healthcare providers to combat obesity effectively, validated by MAE and RMSE metrics.

II. LITERATURE SURVEY

An Improved Traceability System for Food Quality Assurance and Evaluation Based on Fuzzy Classification and Neural Network

Currently, the food safety incidents happened frequently in China and the customer confidence declined rapidly, then the problems related to food quality and safety have attracted more and more social attention. Considering the concern with regard to food quality assurance and consumer confidence improvement, many companies have developed a traceability system to visualize the supply chain and avoid food safety incidents. In this paper, we proposed an improved food traceability system which can not only achieve forward tracking and diverse tracing like the existing systems do, but also evaluate the food quality timely along the supply chain and provide consumers with these evaluating information, to mainly enhance the consumer experience and help firms gain the trust of consumers. For the food quality evaluation, the method of fuzzy classification was used to evaluate the food quality at each stage of supply chain while the artificial neural network was adopted to derive the final determination of the grade of food quality according to all the stage quality evaluations. A case study of a pork producer was conducted, and the results showed that the improved traceability system performed well in food quality assurance and evaluation. In addition, implications of the proposed approach were discussed, and suggestions for future work were outlined.

Food Safety Traceability System Based on Blockchain and EPCIS

In recent years, food safety issues have drawn growing concerns from society. In order to efficiently detect and prevent food safety problems and trace the accountability, building a reliable traceability system is indispensable. It is especially essential to accurately record, share, and trace the specific data within the whole food supply chain, including the process of production, processing, warehousing, transportation, and retail. The traditional traceability systems have issues, such as data invisibility, tampering, and sensitive information disclosure. The blockchain is a promising technology for the food safety traceability system because of the characteristics, such as the irreversible time vector, smart contract, and consensus algorithm. This paper proposes a food safety traceability system based on the blockchain and the EPC Information Services and develops a prototype system. The management architecture of on-chain & off-chain data is proposed as well, through which the traceability system can alleviate the data explosion issue of the blockchain for the Internet of Things. Furthermore, the enterprise-level smart contract is designed to prevent data

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tampering and sensitive information disclosure during information interaction among participants. The prototype system was implemented based on the Ethereum. According to the test results, the average time of information query response is around 2 Ms, while the amount of on-chain data and query counts are 1 GB and 1000 times/s, respectively.

The Egg Traceability System Based on the Video Capture and Wireless Networking Technology
With the global food safety problems increasing, food safety problems of egg products get more and more attention of consumers in China. With the development of internet of things IOT, food traceability system can let the consumer participate in the whole process of the supervision of food production. Thus, the consumers can understand information behind the food. The existing egg traceability systems are lack of unified standard, and they are not practical and not popular. The data sources are not intelligent, timeliness and advantages enough. This paper puts forward an egg traceability system based on video capture and wireless networking technology. In this paper, the authors put forward the general structure of the egg traceability and develop the platform based on the sensor network.

Future Challenges on the Use of Blockchain for Food Traceability Analysis
The steady increase in food falsification, which has caused large economic losses and eroded consumers' trust, has become a pressing issue for producers, researchers, governments, consumers and other stakeholders. Tracking and authenticating the food supply chain to understand provenance is critical with a view to identifying and addressing sources of contamination in the food supply chain worldwide. One way of solving traceability issues and ensuring transparency is by using blockchain technology to store data from chemical analysis in chronological order so that they are impossible to manipulate afterwards. This review examines the potential of blockchain technology for assuring traceability and authenticity in the food supply chain. It can be considered a true innovation and relevant approach to assure the quality of the third step of the analytical processes: data acquisition and management.

An Intelligent Value Stream-Based Approach to Collaboration of Food Traceability Cyber Physical System by Fog Computing
Good advanced food traceability systems help to minimize unsafe or poor-quality products in food supply chain through value-based process. From the emerging technologies forthcoming for industry automation, future advanced food traceability system must consider not only cyber physical system (CPS) and fog computing but also value-added business in food supply chain. Accordingly, this study presents a novel intelligent value stream-based food traceability cyber physical system approach integrated with enterprise architectures, EPCglobal and value stream mapping method by fog computing network for traceability collaborative efficiency. Furthermore, the proposed intelligent approach explores distributive and central traceable stream mechanism in assessing the most critical traceable events for tracking and tracing process. Successful case study, software system design and implementation demonstrated the performance of the proposed approach. Furthermore, experiment shows the better results obtained after the simulation execution for intelligent predictive algorithm.

Study on the Traceability System Establishment of Safety Objective-Oriented Food Logistics Supply Chain
Due to food safety issues, traceability is becoming a method of controlling food safety and connecting suppliers and consumers. The aim of this study is to build up a food logistics supply chain traceability system which can control food safety and connect suppliers and consumers. This paper discusses the establishment of traceability system based on the Structured Query Language (SQL) Server, uses the failure mode and effect analysis to assess key indicators of the system. The result shows, the largest Risk Priority Number (RPN) is the precision risk of information. Moreover, with fuzzy synthetic evaluation model and intensity weighted average method, this paper ranks the importance of the three factors of the food logistics supply chain traceability system and finds that the depth is the most important factor.

II. SYSTEM ANALYSIS

1.4 EXISTING SYSTEM

In this system, a deep learning model is trained on a large dataset of food images and their associated calorie information. The model is then integrated into a mobile app, which allows users to take a picture of their food and receive an estimate of its calorie content based on their BMI. The app uses the front- facing camera on the mobile device to capture an image of the food, which is then processed by the deep learning model. The model uses a combination of convolutional neural networks (CNNs) and recurrent neural networks (RNNs) to analyse the image and predict the calorie content of the food. This Project provides a convenient and accurate way for users to estimate the calorie content of their food based on their BMI, using state-of- the-art deep learning techniques.

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1.4.1 DISADVANTAGES OF EXISTING SYSTEM

The existing systems for food calorie estimation and BMI prediction have limitations and disadvantages, such as accuracy, cost, limited scope, user engagement, and privacy concerns. Addressing these limitations can lead to the development of more accurate, user-friendly, and privacy- preserving systems

1.5 PROPOSED SYSTEM

The proposed system for food calorie estimation and BMI prediction using deep learning and machine learning aims to overcome the limitations of existing systems. The system will use advanced deep learning algorithms such as CNNs to accurately estimate the calorie content of various food items. Additionally, machine learning algorithms such as logistic regression and random forest will be used to predict the BMI of an individual using relevant input features such as age, weight, and height. To overcome the issue of limited scope, the system will be trained on a large dataset of food images and individual health data, which will enable it to estimate the calorie content of a broad range of food items and predict BMI accurately. The system will also be designed to be user-friendly and easy to use, allowing users to input their data quickly and understand the system's recommendations easily. Privacy concerns will also be addressed by ensuring that user data is kept confidential and that data is stored securely. The proposed system will be cost-effective, leveraging open-source software and publicly available datasets to minimize costs. Overall, the proposed system for food calorie estimation and BMI prediction using deep learning and machine learning has the potential to revolutionize the way people manage their health and wellbeing. By providing accurate and personalized recommendations, the system can help individuals maintain a healthy lifestyle and prevent obesity-related health complications

1.5.1 ADVANTAGES OF PROPOSED SYSTEM

The proposed system for Food Calorie Estimation and BMI Prediction using Deep Learning and Machine Learning has several advantages over existing systems. These advantages include:

Accuracy: The proposed system leverages advanced deep learning algorithms such as CNNs to accurately estimate the calorie content of various food items and machine learning algorithms such as logistic regression and random forest to predict BMI. This ensures that the system provides accurate recommendations to users.

Scalability: The proposed system can be trained on a large dataset of food images and individual health data, which will enable it to estimate the calorie content of a broad range of food items and predict BMI accurately. This makes the system highly scalable and able to accommodate a large number of users.

User-friendly: The proposed system is designed to be user-friendly and easy to use, allowing users to input their data quickly and understand the system's recommendations easily. This encourages user engagement and increases the likelihood that users will adopt healthy lifestyle changes.

Cost-effective: The proposed system leverages open-source software and publicly available datasets to minimize costs. This makes it an affordable solution for individuals, healthcare providers, and other organizations.

Privacy-preserving: The proposed system ensures that user data is kept confidential and that data is stored securely. This addresses privacy concerns that users may have about sharing their personal health data with third-party systems.

In summary, the proposed system for food calorie estimation and BMI prediction using deep learning and machine learning has several advantages, including accuracy, scalability, user-friendliness, cost- effectiveness, and privacy preservation. These advantages make it a promising solution for improving the health and wellbeing of individuals and communities.

1.6 MODULES

This project consists of several key modules that facilitate the food calorie estimation and BMI prediction system. Each module plays a crucial role in data processing, model training, and real-time predictions to ensure accurate results.

1.6.1 Upload Food Dataset

The first step in developing the system involves gathering and uploading a diverse food dataset. This dataset consists of food images and their respective calorie information, ensuring the model learns from a wide variety of food items. Additionally, demographic data such as age, gender, height, and weight is collected for BMI prediction.

Data is preprocessed before being used for training. This involves:

- Collecting food images from various sources.
- Assigning corresponding calorie values to each food item.
- Ensuring data diversity by including multiple cuisines and cultural backgrounds.
- Organizing demographic data for BMI prediction.

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1.6.2 Preprocess Dataset

Data preprocessing is a critical step to improve the efficiency and accuracy of the models. The preprocessing includes:

3.3.3 Image Preprocessing:

- Resizing images to a uniform shape (299x299 pixels) for CNN processing.
- Normalizing pixel values to a range of [0,1].
- Converting images into arrays for model input.

3.3.4 Data Cleaning and Transformation:

- Sorting food items and assigning them their respective calorie values.
- Encoding gender data for BMI prediction (e.g., Male = 1, Female = 0).
- Splitting data into training and testing sets for machine learning models.

3.3.5 Train Machine Learning Model

Once the dataset is preprocessed, machine learning models are trained to perform food recognition and BMI estimation**.**

3.3.6 Food Calorie Estimation:

- A Convolutional Neural Network (CNN) model is trained to classify food images and estimate their calorie values.
- The model is trained on a large dataset containing labeled food images.
- The CNN architecture ensures accurate recognition of food items, overcoming limitations of manual calorie tracking.

3.3.7 BMI Prediction:

- Regression models are used to estimate BMI based on demographic inputs.
- Face recognition is leveraged to extract features for predicting height and weight.
- The BMI model is trained using a dataset containing height, weight, gender, and corresponding BMI values.
- Standard scaling and support vector classification (SVM) are applied to categorize individuals into different BMI groups (e.g., Underweight, Healthy, Overweight, Obese).

3.3.8 Upload Test Data & Predict Calories and BMI

- Once the models are trained, the system can take real-time inputs for prediction.

3.3.9 Food Image Prediction:

- Users upload a food image.
- The CNN model processes the image and identifies the food item.
- The system retrieves the estimated calorie value based on the prediction.

3.3.10 BMI Estimation:

- Users upload a facial image for height, weight, and BMI prediction.
- The model extracts facial features and applies machine learning models to estimate the user's height, weight, and BMI.
- Alternatively, users can manually enter height, weight, and gender to determine their BMI category using the SVM classifier**.**

Through these modules, the system provides an end-to-end solution for accurate calorie tracking and BMI assessment, contributing to improved health monitoring and obesity management.

IV. SYSTEM DESIGN

The system design outlines the architecture and modeling of the proposed food calorie estimation and BMI prediction system. It provides insights into how different components interact to ensure efficient functioning. This section also includes Unified Modeling Language (UML) diagrams to depict various aspects of system behavior and structure. The system integrates deep learning techniques, machine learning models, and web-based interfaces to deliver a seamless and accurate health monitoring solution. The architecture of the system is designed for efficiency, scalability, and accuracy. The deep learning model for food image recognition is trained using a large dataset containing various food items along with their respective calorie values. The CNN model classifies images into predefined categories and

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estimates calorie content based on learned patterns. Meanwhile, the BMI prediction module employs regression techniques to predict BMI based on demographic factors such as age, gender, height, and weight. This modular approach ensures that each component operates independently while contributing to the overall system functionality.
The system also incorporates a recipe recommendation module, which suggests healthy food options based on user preferences and dietary goals. By allowing users to select specific dietary preferences such as low-calorie or high-protein diets, the system provides personalized recommendations. The backend utilizes Flask for seamless integration with machine learning models, ensuring smooth data processing and result generation. Additionally, the database stores essential information, including food calorie data, user inputs, and health records, enabling future enhancements such as user history tracking and trend analysis. The implementation of this system follows a structured approach to guarantee reliability and accuracy. Rigorous model evaluation is conducted using performance metrics such as accuracy, mean absolute error (MAE), and root mean square error (RMSE). The use of a diverse dataset ensures that the system generalizes well across different food types and user demographics. Security measures, such as secure data storage and access control, are also incorporated to protect user privacy. Overall, the system is designed to be a comprehensive, user-friendly, and efficient tool for calorie tracking and BMI estimation, helping users make informed health decisions.

4.1 SYSTEM ARCHITECTURE

The system is built using deep learning and machine learning techniques, leveraging convolutional neural networks (CNNs) for food image recognition and regression models for BMI prediction. The architecture consists of the following key components:

1 User Interface: A web-based interface developed using Flask, allowing users to upload food images or input demographic details for BMI estimation.
2 Food Image Recognition Module: Utilizes a pre-trained CNN model to classify food images and estimate calorie content based on a predefined dataset.
3 BMI Estimation Module: Uses a trained machine learning model to predict BMI based on user demographic data such as age, gender, height, and weight.
4 Recipe Recommendation Module: Provides healthy food recommendations based on selected dietary preferences.
5 Database and Data Processing: A dataset containing food images, calorie values, and demographic health data is used for training and predictions.
6 Backend Processing: Flask routes handle user requests, process images, and interact with machine learning models to generate results.

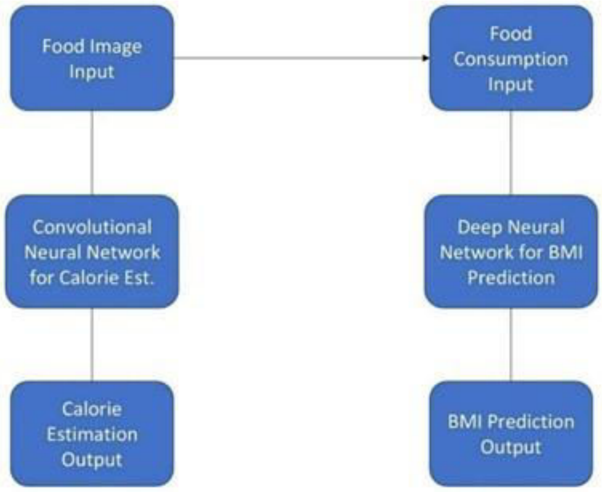

Fig 1: System Architecture

4.2 UML DIAGRAMS

UML stands for Unified Modeling Language. UML is a standardized general- purpose modeling language in the field of object-oriented software engineering. The standard is managed, and was created by, the Object Management Group. The goal is for UML to become a common language for creating models of object oriented computer software. In its current form UML is comprised of two major components: a Meta-model and a notation. In the future, some form of

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method or process may also be added to or associated with, UML. The Unified Modeling Language is a standard language for specifying, Visualization, Constructing and documenting the artifacts of software system, as well as for business modeling and other non-software systems.

UML was created as a result of the chaos revolving around software development and documentation. In the 1990s, there were several different ways to represent and document software systems.

The UML represents a collection of best engineering practices that have proven successful in the modeling of large and complex systems. The UML is a very important part of developing objects oriented software and the software development process. The UML uses mostly graphical notations to express the design of software projects.

4.2a GOALS:

The Primary goals in the design of the UML are as follows:

1. Provide users a ready-to-use, expressive visual modeling Language so that they can develop and exchange meaningful models.
2. Provide extendibility and specialization mechanisms to extend the core concepts.
3. Be independent of particular programming languages and development process.
4. Provide a formal basis for understanding the modeling language.
5. Encourage the growth of object oriented tools market.
6. Support higher level development concepts such as collaborations, frameworks, patterns and components.
7. Integrate best practices.

V. RESULTS

The following figures present the sequence of screenshots of the results.

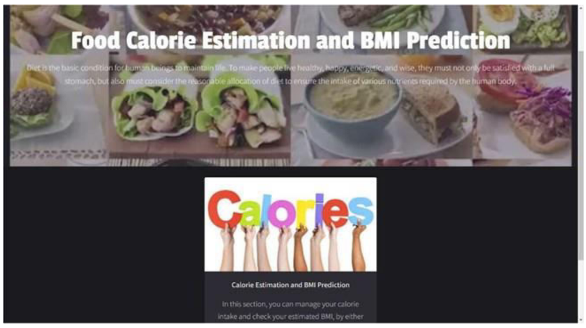

Fig 2a: Home Page

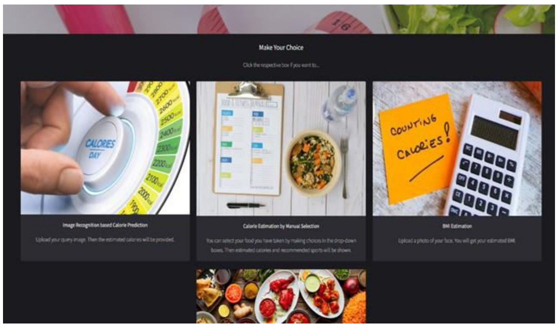

Fig 2b: Modules in application dashboard

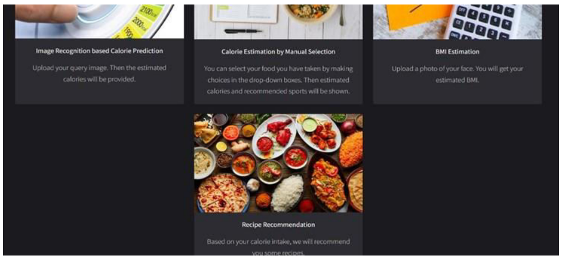

Fig 2c: Modules in application dashboard

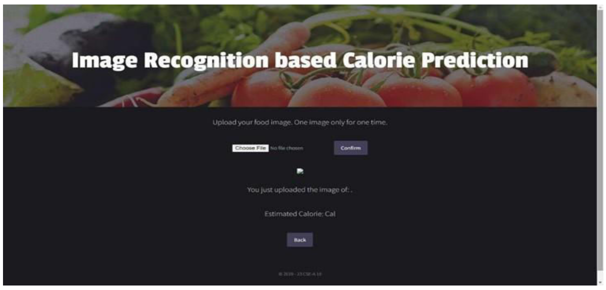

Fig 2d: First Module, Calorie estimation through the image

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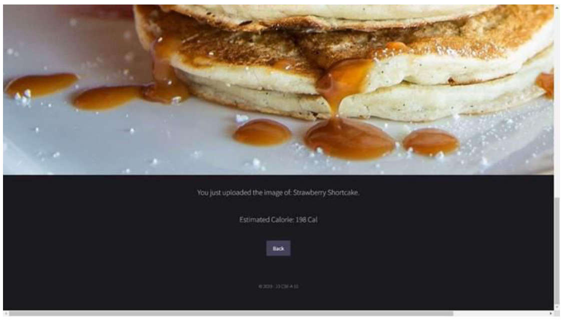

Fig 2e: Output of first module

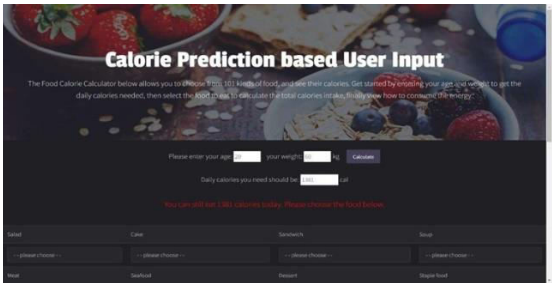

Fig 2f: Second Module, Daily calories a person needs

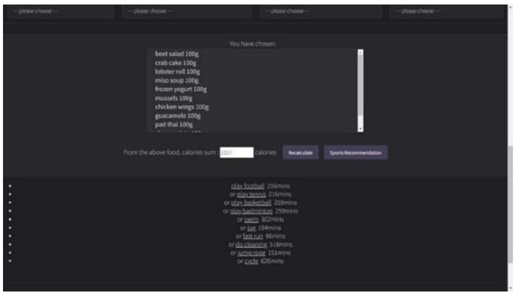

Fig 2g: Output of second module

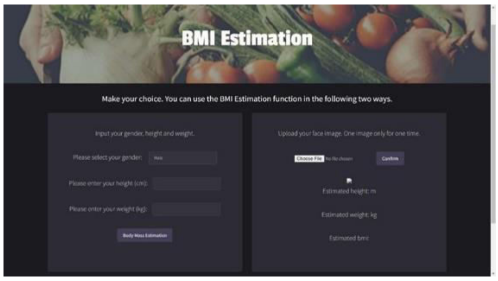

Fig 2h: Third Module, BMI Estimation

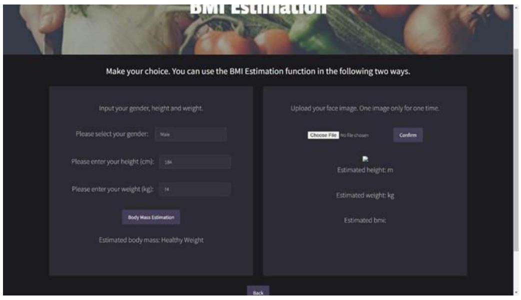

Fig 2i: Output of the third module

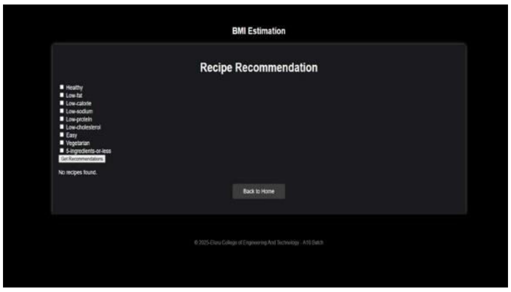

Fig 2j: Fourth Module, Recipe Recommendation.

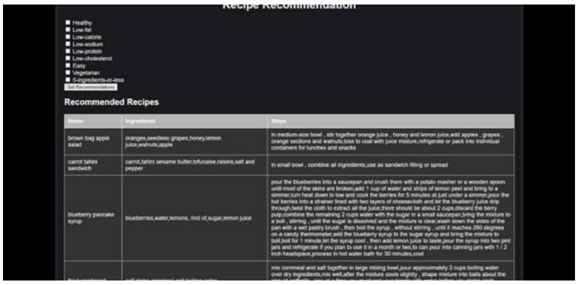

Fig 2k: Output of the Fourth module

VI. CONCLUSIONS AND FUTURE WORK

6.1 CONCLUSIONS

In this paper we successfully integrates deep learning and machine learning techniques to provide an advanced system for food calorie estimation and BMI prediction. By utilizing convolutional neural networks (CNNs) for food image recognition and regression models for BMI calculation, the system offers a precise and automated approach to nutritional tracking. Unlike traditional methods such as self-reported food diaries, which are often inaccurate, this AI-

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driven system ensures reliable calorie estimation and health assessment with minimal user effort.

The robustness of the system is enhanced through training on a diverse dataset encompassing various food items from different cuisines and cultural backgrounds. This ensures that the model generalizes well to real-world scenarios, making it applicable to users with diverse dietary habits. Additionally, the incorporation of demographic factors such as age, gender, height, and weight further refines BMI predictions, providing a personalized health assessment for each user. The accuracy of the system is validated using standard error metrics, ensuring its reliability and effectiveness.

Beyond individual use, this project holds significant potential for healthcare professionals, nutritionists, and fitness experts. The ability to accurately estimate calorie intake and BMI can aid in designing personalized diet plans, monitoring obesity trends, and supporting preventative healthcare measures. Furthermore, integrating face recognition technology for BMI prediction introduces an innovative, contactless approach to health monitoring, improving accessibility and ease of use.

Future enhancements to the system could include expanding the food image dataset for improved recognition accuracy, incorporating real-time food portion estimation, and integrating additional health parameters such as activity levels and metabolic rates. With continuous advancements in AI and machine learning, this project paves the way for more intelligent and accessible health monitoring solutions, ultimately contributing to global efforts in combating obesity and promoting overall well-being.

6.2 FUTURE WORK

The proposed system has demonstrated significant potential in enhancing food calorie estimation and BMI prediction through deep learning. However, future improvements can further refine its accuracy and expand its capabilities. One major enhancement is the incorporation of real-time portion size estimation. While the current system accurately recognizes food items, it does not consider variations in portion sizes. By integrating depth estimation techniques using LiDAR sensors or stereo vision-based image processing, the system can more precisely calculate the volume of food, leading to more accurate calorie predictions.

Another important area for improvement is the integration of multimodal data sources to provide a more comprehensive health analysis. Currently, the system relies on food image recognition and demographic details for BMI prediction. Future enhancements could incorporate data from wearable fitness devices that track physical activity, heart rate, and metabolism, offering a real- time calorie balance estimation. Additionally, integrating nutritional intake history and personalized dietary habits would enable the system to provide more customized health recommendations.

Expanding the dataset to include a wider variety of global cuisines and homemade meals is another key aspect of future work. Many current food recognition datasets primarily focus on restaurant-style dishes, which may not reflect everyday eating habits across different cultures. Encouraging user participation through crowdsourced labeled datasets can significantly improve the diversity and generalizability of the model. Additionally, incorporating OCR-based ingredient recognition for packaged foods can enhance the system's usability by allowing users to scan nutritional labels directly.

Finally, deploying the system as a mobile application or cloud-based API would make it more accessible to a wider audience. A user-friendly app with real-time food scanning, BMI tracking, and AI-driven dietary recommendations would be a valuable tool for individuals, dietitians, and healthcare providers. Future developments could also integrate conversational AI assistants that offer personalized meal suggestions, weight management advice, and interactive fitness tracking. By implementing these advancements, the system can evolve into a comprehensive AI-powered nutrition assistant, contributing to improved public health and better weight management strategies.

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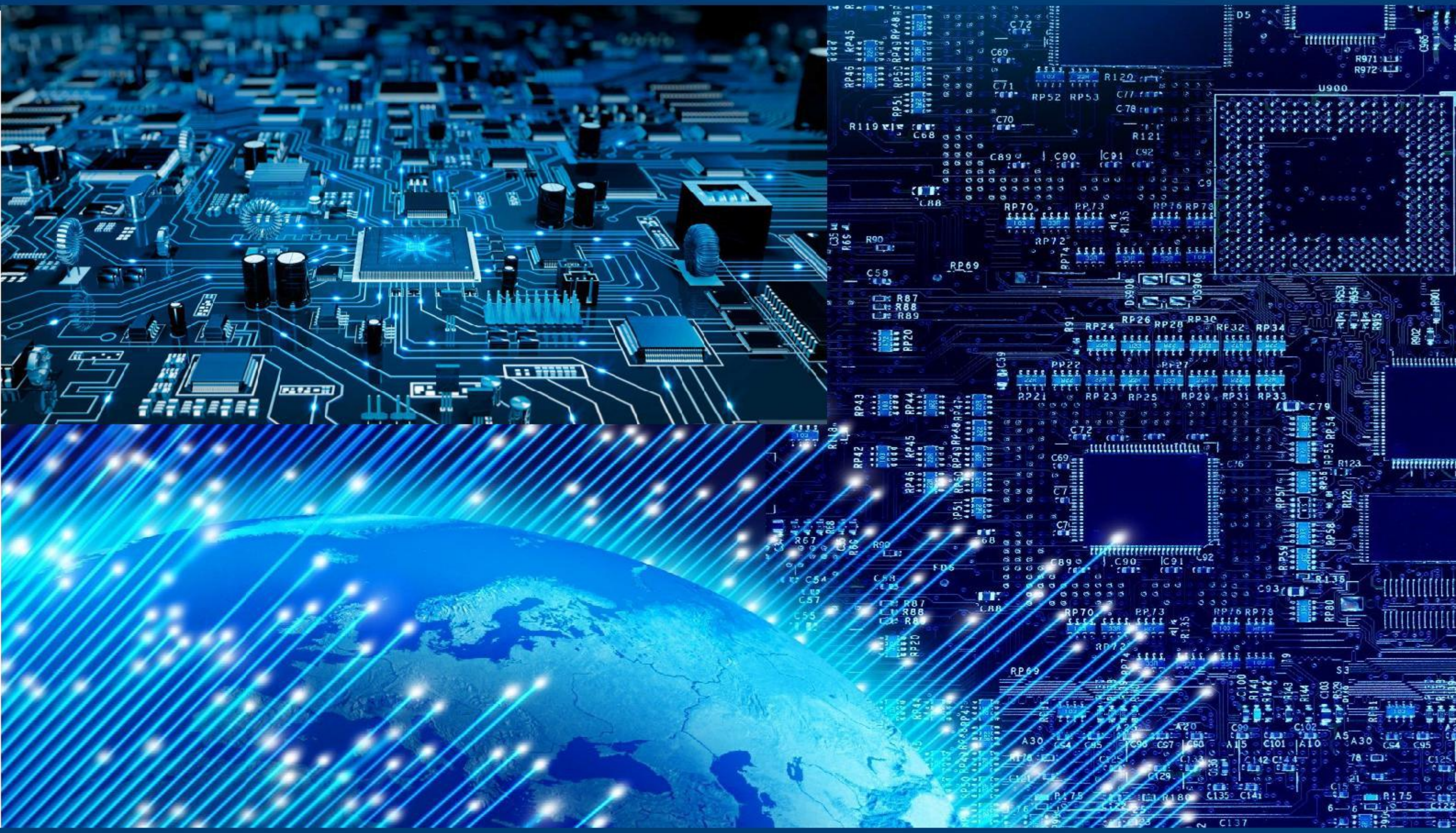

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