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Intelligent Food System: Generative AI for Smarter, Healthier Choices

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Abstract
In the modern era, maintaining a healthy lifestyle has become increasingly challenging. Ensuring food safety and making informed dietary choices are crucial due to the rising threats of food adulteration and health-related concerns. Our research focuses on developing a Generative AI-based model capable of tasks such as ingredient analysis, food adulteration detection, nutritional assessment, and personalized dietary guidance. Leveraging cutting-edge Generative AI technologies, including Large Language Models (LLMs), Bidirectional Encoder Representations from Transformers (BERT), and Generative Adversarial Networks (GANs), the system delivers accurate and real-time evaluations. The approach involves assessing nutritional content, identifying adulterants, interpreting ingredient lists, and providing tailored dietary suggestions. The system employs advanced AI tools like GANs for precise food recognition and adulteration detection, LLMs for processing ingredient information, and BERT with cross-attention mechanisms for comparing product ingredients. By offering reliable and actionable insights, this approach promotes healthier eating habits. The methodology marks a significant step forward in enhancing overall well-being.
Keywords: *Adulteration Detection, Food Analysis, Generative AI, Nutritional Assessment, Generative Adversarial Networks (GANs), Large Language Models (LLMs)*

1. Introduction
Food is one of the basic needs of humans. Food is essential for both sustaining general health and enabling daily human activity. However, the extensive use of chemicals, artificial colorants, and preservatives in packaged foods, along with poor eating habits and a lack of nutritional awareness, present serious health risks in today's fast-paced society. Despite improving food products' flavor, look, and shelf life, these additives frequently have negative side effects, such as causing allergies, hormone imbalances, and serious illnesses like cancer. The widespread practice of food adulteration, which involves adding harmful ingredients like artificial coloring, poisonous chemicals, and non-edible oils, makes these worries even worse. Chronic illnesses, obesity, and nutritional deficits are just a few of the health issues that are exacerbated by such tainted meals. Public health initiatives emphasize the importance of informed dietary decisions, yet consumers face difficulties in making healthy food choices. Hazardous compounds are difficult to identify since ingredient labels sometimes use complicated wording and difficult-to understand chemical names. A lot of makers of packaged foods exacerbate this problem by using deceptive marketing strategies to hide dangerous components, which may be listed on packaging in small print or under technical names. It is difficult for customers to determine the actual nutritional worth of their food because of these activities, which also contribute to disinformation. In order to compute caloric values, Sarode et al. [1] use PostgreSQL as the backend to store annotated input photos that are then trained on models based on Deep CNN algorithms. Food101 and EDA food databases are used as input by Nivedhitha P. et al. [2], who create a system that uses

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the YOLOv4 (You Only Look Once version 4) algorithm to identify foods [2]. When compared to other CNN algorithms, the YOLO method produces faster results [2]. For accurate Thai food detection, Sombutkaew R. et al. [3] use the Mask-RCNN (Mask Region-based Convolutional Neural Network) algorithm. By offering more information like food area estimation and depth analysis, the Mask-RCNN algorithm improves calorie and nutrient estimation [3]. We can better comprehend these techniques and their evaluation measures by comparing different CNN models [9].

1.1. Motivation

This research proposes a generative AI-based system designed to empower individuals to perform comprehensive analyses of food products, addressing existing gaps. The system integrates four key functionalities into a unified platform: personalized dietary recommendations, ingredient analysis, food adulteration detection, and nutritional content evaluation. Unlike traditional methods that focus on isolated tasks, this system provides a holistic solution. By leveraging advanced technologies such as transformer-based models like BERT, Generative Adversarial Networks (GANs), and Large Language Models (LLMs), the system ensures accurate and real-time analysis. Users can interact with the system through a user-friendly interface, where they can upload images of food or ingredient lists for assessment. The system performs tasks such as food identification, nutritional value assessment, and detection of harmful additives or allergens. A dual-BERT model with cross-attention mechanisms enhances ingredient comparison, offering detailed insights into product similarities and differences. Additionally, the system encourages healthier and more informed food choices by recommending alternatives tailored to users' dietary preferences.

1.2. Literature Survey

Estimating the calorie amount of the meal being consumed is the first step in providing users with an accurate nutritional analysis. The health of users may be enhanced by calorie-specific dietary choices [1]. Current systems use a variety of approaches for estimating calories, the majority of which use object identification and neural network algorithms [8]. In order to produce nutritional analysis results, these systems usually take a systematic approach that involves gathering input photographs, creating a dataset, and training the image data using models based on CNN (Convolutional Neural Networks) and object detection algorithms The system's next feature focusses on combining nutritional analysis with ingredient analysis and adulteration detection. Important details regarding the nutritional value, allergies, and additives of commonly consumed food are provided by ingredient analysis [6]. The body's metabolism is greatly influenced by ingredients [7]. The "FoodProX" method is proposed by Giulia Menichetti et al. [6] to assess the level of food processing. To provide results, this technique uses a Multi-Class Random Forest classifier in conjunction with Fpro-scores. Furthermore, Erban Alexander et al. [7] do genetic analysis using a Random Forest classifier and metabolomic annotated dietary data. Saranya P. et al. [5] investigate CNN-based adulteration detection by applying a variety of image processing techniques, such as Digital Image Processing (DIP), and contrasting the outcomes of CNN-based models.Agrawal U. et al. [4] design a model for spice adulteration detection using feature extraction methods like Histogram Oriented Gradient (HOG) and Local Binary Patterns (LBP) [4]. These studies offer valuable insights into adulteration detection. Sudharson K. et al. [8] explore a personalized nutritional system powered by advanced AI, analyzing the performance and functionalities of various AI-based models for nutritional analysis. M. Kuzlu et al. [11] propose a Streamlit-driven AI platform aimed at NextG applications, marking a notable advancement in Artificial Intelligence. Xu Guo et al. [10] investigate cutting-edge research in LLM (Large Language Models) and synthetic data generation, which serves as the foundation for the proposed system.

2. Methods

The food analysis methodology begins with image capture and preprocessing. An image of the food item is captured and subjected to preprocessing steps, which may involve Gaussian blurring for noise reduction using a denoising autoencoder and contrast enhancement through AI-driven CLAHE. The

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preprocessed image is then analyzed by the Google Gemini Pro API, which utilizes vision transformers to identify the food item. If the model is uncertain about the identification, it raises a flag for manual review, and the generative model proposes potential matches. Next, nutritional information is extracted using transformer-based natural language processing (NLP). Simultaneously, the ingredient list is analyzed through optical character recognition (OCR) to extract text and NLP to interpret the ingredients.

2.1. System Model

A Bayesian predictive model is employed to flag potential health risks, such as allergens or harmful substances. Adulteration detection is performed using AI-powered pattern recognition techniques, and if adulterants are identified, an adulteration flag is raised. Finally, if necessary, AI-augmented decision models generate a comparison table of similar products or healthier alternatives. The results of the analysis, including nutritional data, health risks, adulteration status, and product comparisons, are presented to the user. This systematic approach ensures thorough food analysis and effective detection of risks and adulterants. Figure 1 shows Architecture of System.

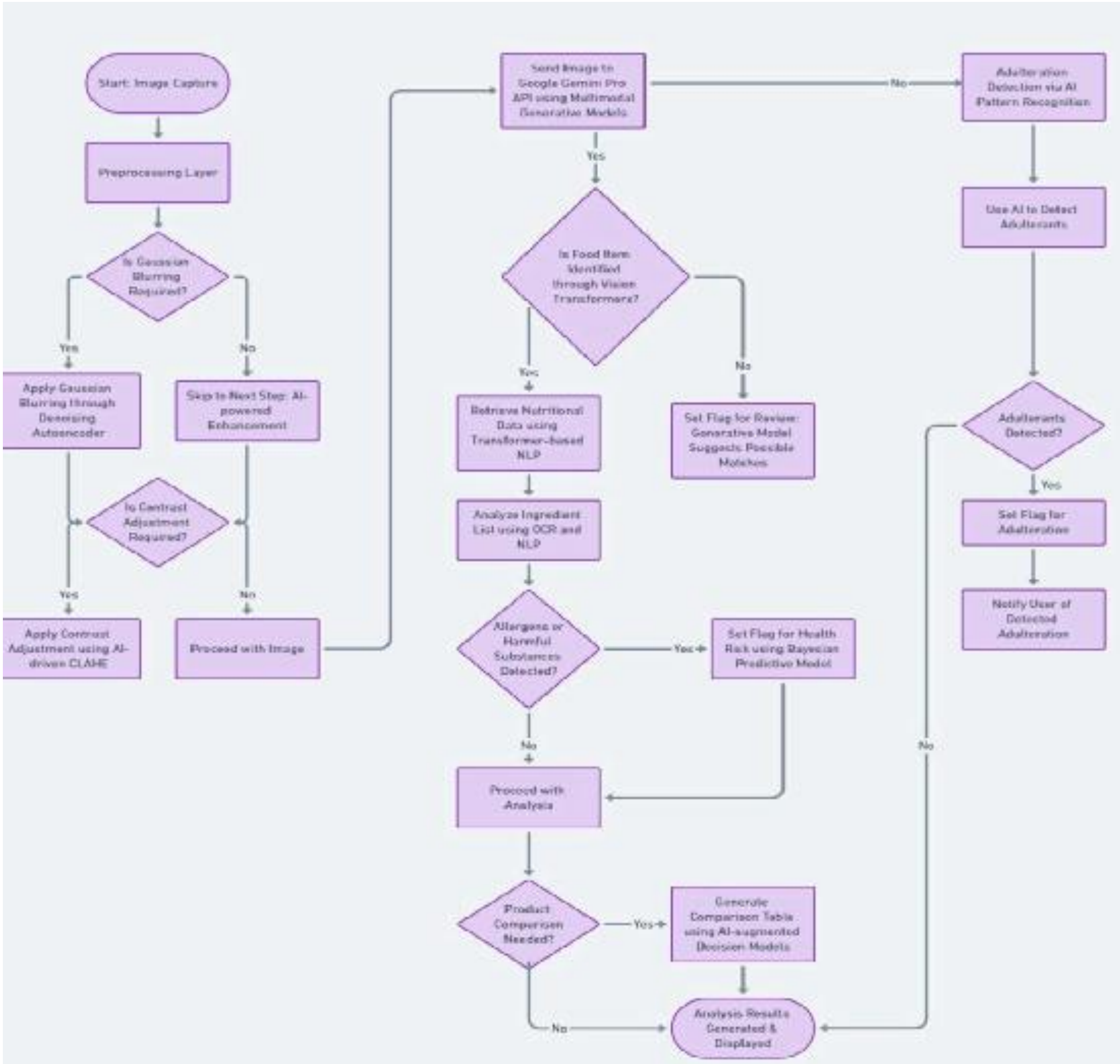

Figure 1 **Architecture of System**

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3. Results and Discussion

3.1.Results

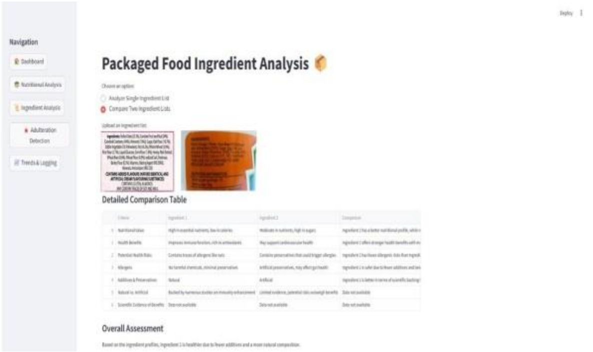

Figure 2 Ingredient Analysis

Figure 3 Comparison of Ingredients

Figure 4 Nutritional Analysis

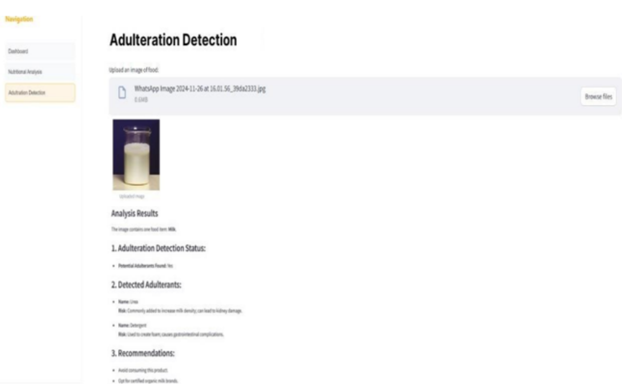

Figure 5 Adulteration Detection

3.2.Discussion

The ingredient list for a single product is the subject of Figure 2. A deeper comprehension of the product's composition is made possible by the analysis, which offers comprehensive insights into the safety and nutritional value of these constituents. Conversely, Figure 3 compares two ingredient lists, emphasizing the variations in terms of products' nutritional value, health advantages, allergies, and additives. Because Ingredient 1 has fewer additives and a more natural makeup, it is the healthier option in this comparison, providing unambiguous guidance for choosing healthier foods. The method raises consumer awareness by offering practical insights and encouraging well-informed decision-making, according to the assessments taken together. The figure 4 demonstrates a system capable of identifying food items and providing detailed nutritional information. In this example, a red apple is analyzed. The system delivers comprehensive nutritional data, including calories, sodium, protein, fat, carbohydrates, and sugar per serving. This functionality allows consumers to gain a better understanding of the nutritional content of the foods they consume, contributing to informed dietary choices. Figure 5 shows a system that checks food for harmful substances. In the example, milk is tested for adulterants like detergent and urea. Detergent can cause stomach problems, and urea may harm the kidneys. The system warns about these risks and advises not to consume tainted products, helping to ensure food safety

Conclusion

There are three fundamental necessities for human survival, and food is one of them. In today’s world, making informed food choices, avoiding junk and contaminated foods, and finding healthy alternatives can be challenging due to a lack of awareness. This often makes it difficult to maintain a balanced and nutritious diet on a daily basis. To tackle these issues, we are developing a comprehensive system with the following primary objectives: identifying the nutritional composition and caloric content of foods, detecting food adulteration, creating personalized diet plans, and suggesting healthier food options. The proposed approach leverages advanced generative AI technologies, such as Generative Adversarial Networks (GANs), Large Language Models (LLMs), LangChain, and other generative AI models, to ensure accurate calorie calculation, adulteration detection, and personalized recommendations.

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