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IoTCaloTrack: An IoT-Enabled Real-Time Calorie Tracking System

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Abstract: In today's health-conscious world and simultaneously the world of unhealthy and processed foods, managing what a person eats, how much a person eats and most of all how much it affects their body is getting harder as time goes on. In this paper, IoTCaloTrack, a novel Internet-of-Things framework for real-time calorie monitoring using a web frontend and Python FastAPI backend is introduced. This system integrates a microcontroller with a camera and load-cell sensor, a FastAPI server, and the Google Gemini AI for food recognition. In a typical workflow, a user triggers meal capture via the web interface; the IoT device then captures a photo of the food and measures its weight. The backend then uploads the image to the Gemini API, which identifies the dish. Knowing the food type and its measured weight, IoTCaloTrack computes caloric content by multiplying weight (in grams) by a nutrient database value. The result is stored and returned to the web client. Gemini's high accuracy (20% improved recognition over prior methods) ensures reliable identification. Experiments show that Gemini 2.5 processes images very quickly (≈1 second faster than earlier AI models), enabling near-instant calorie estimates. It is a comprehensive calorie management and tracking system where each user can independently store their nutritional data and access it conveniently.

Keywords: IoT, FastAPI, Web Frontend, Calorie Tracking, Food Recognition, Gemini API, Python.

1. INTRODUCTION

IoT has grown rapidly in recent years and has resulted in the development of smart systems that become part of everyday life of people, particularly in the field of health and nutrition. One of the major challenges in maintaining a healthy lifestyle is accurately and precisely tracking daily calorie intake, as traditional methods like manual food logging are time consuming and greatly prone to errors. To address this issue, IoTCaloTrack introduces an automated, real-time calorie tracking system that uses embedded sensors and leverages AI models available online. By using an ESP-32 camera and weight sensor (load cell), the system captures both the visual and quantitative aspects of food. AI models such as Gemini, then identify the food type, while its weight is used to calculate calorie content using established nutritional databases. This integrated approach helps in minimizing user effort and improves accuracy compared to standard, conventional methods. Cloud connectivity enables data storage, analysis, and real-time feedback through a website. Overall, the system shows how IoT can make diet tracking easier and how the Internet of Things can transform dietary monitoring into a smarter, more efficient, and user-friendly process.

1.1 Background and Motivation

Unhealthy, irregular eating habits and inactiveness have led to a rise in obesity and long-term health issues related to that worldwide.
Being overweight or obese has become a major health concern along with poor nutrition are major risks for both death and illness globally.
As a result, management of weight in an effective manner and prevention of long-term health issues depend heavily on tracking what we eat and how much energy we use.

People commonly use methods like keeping food journals by hand or using apps on their phones to track what they eat.

However, these methods have problems.

They can be time-consuming and people can make mistakes. It is hard to keep doing them consistently.

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Research has shown that writing down what you eat can be overwhelming, often leading to mistakes, underreporting and people giving up which results in poor estimates of how many calories people actually consume.
The growth of the Internet of Things offers a possibility by adding sensors, connections and smart processing to everyday items.
With more people using smartphones and wearables devices, systems that monitor diet using the Internet of Things are becoming popular as a way to automatically track calories and improve accuracy.
However, these systems still have issues with data privacy, reliable measurements. Not being too much of a burden, on users.

1.2 Problem Statement and Objectives

Tracking calorie intake accurately in real time is still a difficult task, especially when it depends on manual input from users. This project aims to solve this problem by developing an IoT-based system that can automatically monitor food intake without requiring users to log their meals manually. The goal is to create a smart solution that can both recognize what food is being consumed and determine how much of it is present.
To achieve this, the system is designed with several key objectives. First, it uses built-in sensors such as a camera and a weight sensor to capture information about the food. Next, machine learning techniques are applied to identify the type of food from the captured images. Once the food is recognized, its calorie content is estimated using standard nutritional data combined with the measured quantity. Finally, the system delivers instant feedback to the user through a mobile or web interface, making it easy to track dietary intake.
In addition, the solution is intended to work smoothly in everyday environments like homes or cafeterias. It is designed to be affordable, easy to use, and requires very little effort from the user, ensuring practicality for regular use.

1.3 Technical Challenges

- **Accurate Food Recognition:** Identifying food from images isn't as easy as it sounds. The same dish can look very different depending on lighting, angle, or how it's served, and sometimes parts of the food may even be hidden. To handle these challenges, we use deep learning models like Convolutional Neural Networks (CNNs), which can learn patterns from a wide variety of food images when trained on diverse datasets.

- **Volume/Weight +Estimation:** Knowing how much food is on the plate is just as important as recognizing it. To estimate the portion size, we use a load cell sensor with a 5kg capacity along with an HX711 amplifier to measure weight accurately. Once the weight is known, the calorie content is calculated by multiplying it with the food's calorie density.

- **Sensor Integration and Connectivity:**
The system brings together multiple components—camera, weight sensor, and communication module—into one coordinated setup. A microcontroller, such as a Raspberry Pi or ESP32, manages these components. It receives commands from a mobile app through MQTT, which triggers image capture and weight measurement seamlessly.

- **Data Management:** All the collected data, including images, weight readings, and calculated results, needs to be stored and organized. Initially, the data is saved locally on an SD card, and then it is uploaded to a cloud platform like ThingSpeak for long-term storage and further analysis.

- **Real-Time Feedback:** To make the system useful for users, it provides instant feedback. The estimated calorie information is quickly displayed on a smartphone app or web interface, allowing users to monitor their food intake in real time.

1.4 Contributions

- **IoT System Design:** We propose an IoT-based system for real-time calorie tracking for real-time dietary monitoring. The system integrates mobile or wearable interfaces, embedded sensing components, and cloud-based analytics to enable efficient and continuous calorie tracking**.**

- **Hybrid Algorithmic Framework:**
A combined approach is adopted by integrating a CNN-based food classification model with sensor data. Image-based recognition is used to identify food items, while weight measurements are utilized to estimate calorie content based on the relationship between caloric value and quantity.

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- **Prototype Implementation:** A functional prototype is developed consisting of a camera module, load cell sensor, microcontroller unit, and a mobile application. Communication between system components is established using MQTT, and the collected data is stored on the ThingSpeak cloud platform for further processing and analysis.

- **Empirical Evaluation:** The performance of the system is evaluated through experimental analysis, achieving an approximate food classification accuracy of 91%. The estimated calorie values are validated against reference data, demonstrating reliable and consistent results.

- **Comprehensive Study:** A review of existing IoT and computer vision–based dietary monitoring systems is conducted. The proposed approach extends prior work by emphasizing real-time operation and improved integration of system components.

2. RELATED WORK

2.1 IoT in Dietary and Health Monitor

IoT has increasingly been used in health and nutrition monitoring through wearable devices and sensors. Existing systems track physical activity and basic health metrics, while some combine cameras and weight sensors to estimate food intake. However, many solutions either depend on manual input or focus mainly on fitness tracking. The proposed system improves this by automating food recognition and integrating cloud-based data handling.

2.2 Computer Vision and Calorie Estimation

Computer vision techniques are widely used to analyze food images and estimate calorie intake. These systems typically involve detecting food regions, classifying them using deep learning models, and estimating portion size. While classification accuracy is generally high, portion estimation based only on images can be unreliable. This work addresses the issue by incorporating direct weight measurement for better accuracy.

2.3 Limitations of Existing Systems

Most calorie tracking applications rely on manual input, which can lead to errors. Some systems automate weight measurement but lack food identification, while wearable devices focus only on calories burned. Overall, existing solutions do not fully integrate food recognition and portion estimation. The proposed system overcomes this limitation by combining both within a single IoT framework.

3. SYSTEM ARCHITECTURE AND IMPLEMENTATION

Our IoT calorie tracker consists of three main components: (A) Data Acquisition Interface, (B) Embedded Processing Unit, and (C) Cloud Data and Analytics.

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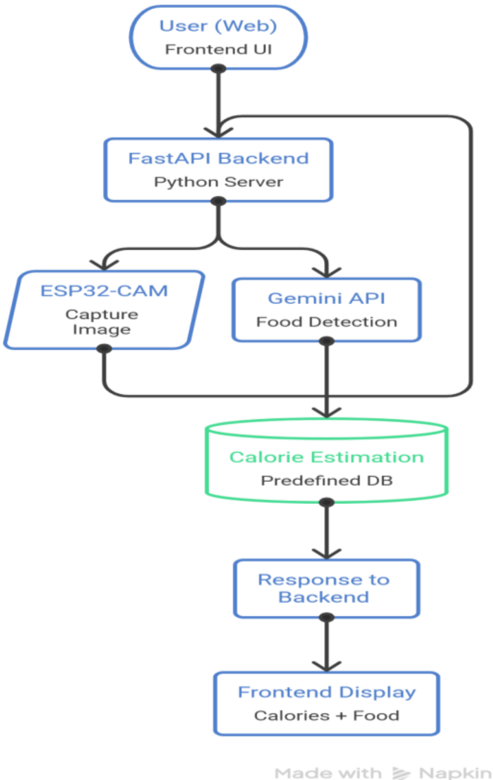

Fig. 1: System Architecture Design

3.1 Sensors and Data Acquisition

The system interface starts with a smartphone application, where the user logs in and selects the **"Capture Meal"** option. Once this action is triggered, the application sends a message using MQTT to a predefined topic (for example, iot/capture_food). The IoT device, such as an Arduino or Raspberry Pi, is subscribed to this topic and continuously listens for incoming signals.

After receiving the trigger, the device initiates two operations simultaneously:

- **Camera Capture:** A USB camera or Raspberry Pi camera captures an image of the food placed on the weighing platform.

- **Weight Measurement:** A load cell (with a capacity of approximately 5 kg), connected to an HX711 amplifier, records the weight of the food in grams. This measurement is also tagged with a timestamp.

The captured image and corresponding weight data are temporarily stored on the device before further processing. The use of MQTT enables fast communication between the mobile application and the IoT hardware, while also keeping the system design modular and independent of specific hardware implementations.

3.2 IoT Hardware and Communication

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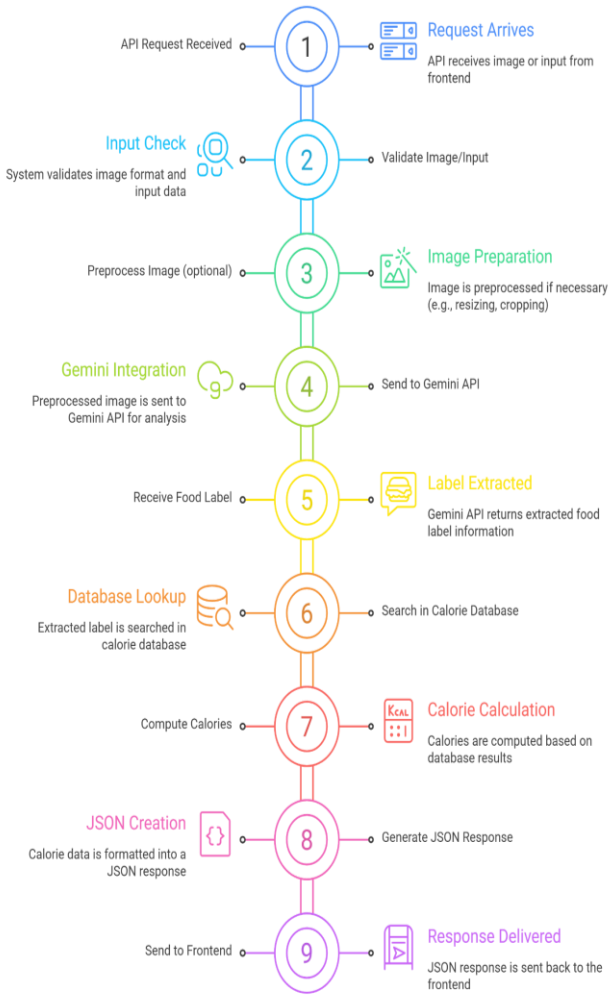

Fig. 2: Backend Processing Flow (FastAPI)

In IoTCaloTrack, a Raspberry Pi 3 acts as the central unit, running Python to manage sensors like the camera and HX711 weight module. It collects both image and weight data, which are first saved locally on an SD card to avoid any loss due to network issues.

Once data is captured, it is sent to the cloud (ThingSpeak or AWS) using secure protocols such as HTTPS or MQTT. This ensures that user data remains protected during transmission. The cloud platform stores the data and provides tools for further analysis and calorie estimation.

The system includes the following key components:

- **Web Application:** Allows users to trigger data capture and view calorie results from any browser, making the system easily accessible.
- **MQTT Broker:** Handles communication between devices in a lightweight and efficient way.
- **Raspberry Pi (Python):** Controls sensors, processes inputs, and manages data transfer.
- **Cloud Platform:** Stores data, performs analysis, and maintains backups.

This setup allows IoTCaloTrack to combine reliable local data handling with the flexibility of cloud-based processing.

4. IMPLEMENTATION AND RESULTS

4.1 Food Classification Results

The food recognition model performed well during testing, reaching an accuracy of around 91%. Most of the food categories were identified correctly, with both precision and recall staying above 90% in many cases.

Some mistakes did occur, especially between foods that look very similar, like white rice and mashed potato. These kinds of errors are expected since the model mainly relies on visual features. In a real-world scenario, this can be handled by giving users the option to correct the prediction if needed.

Overall, the model is reliable enough for practical use and provides a strong base for estimating calorie intake.

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4.2 Calorie Estimation Accuracy

To check how accurate the calorie calculation was, the system's results were compared with manually calculated values based on food weight and standard nutritional data.

Across 50 different meal samples, the average error stayed below 5%, which shows good accuracy.

Most of the small differences came from minor variations in weight measurement (around -2 or +2 g) and a few cases where the food was misclassified.

When the system correctly identified the food item, the calorie calculation was almost exact since it directly depends on weight and reliable nutritional values.

This shows that the overall method works effectively for calorie tracking, especially when the classification step is accurate.

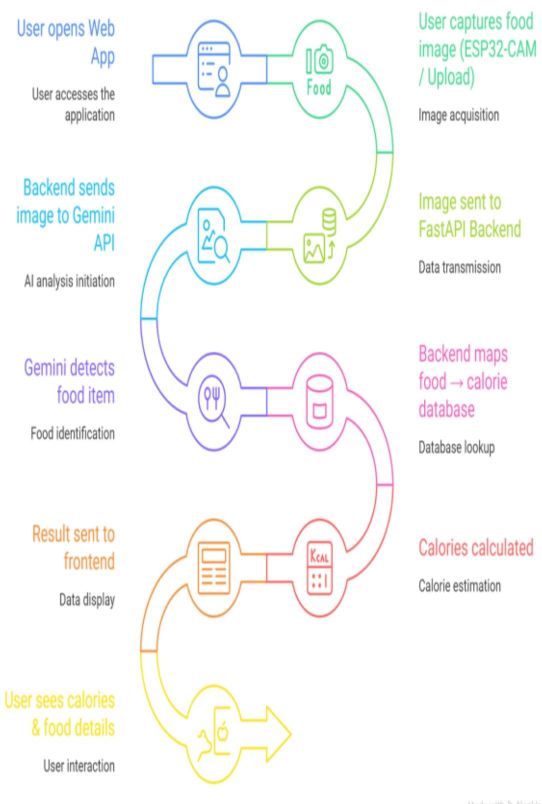

Fig. 3: Overall Workflow Flowchart

5. DISCUSSION

5.1 Key Findings

The system shows that calorie tracking can be automated with minimal user effort by combining a weight sensor and CNN-based food recognition. It provides quick results (under 1 second), making it practical for daily use. Cloud connectivity also allows easy data access and scalability, improving over manual food logging methods.

5.2 Limitations

The model currently supports only a limited set of foods, so it may not recognize unfamiliar items. Mixed or complex dishes can also reduce accuracy since the system uses single-label classification. Additionally, it assumes one food item is placed on the scale at a time, and the current cloud setup may need upgrades for real-world deployment.

5.3 Future Work

Future improvements include expanding the dataset, using advanced sensors for better portion estimation, integrating wearable devices, and allowing user corrections. Conducting user studies can also help evaluate its impact on dietary habits.

6. CONCLUSION

This project presented IoTCaloTrack, a smart system that makes calorie tracking easier using IoT technology. By bringing together a camera, weight sensor, and a machine learning model, the system can automatically identify food and estimate its calorie content without much effort from the user.

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The system performed well during testing, achieving a good amount of accuracy in recognizing food and giving dependable calorie estimates. This shows that such an approach can be useful for everyday diet tracking.
Overall, this work shows how technology can help people stay more aware of their eating habits. Moving forward, the system can be improved further and tested in real-life situations to understand its long-term impact.

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