An IoT-Based Automated Nutrition Monitoring System with a Deep Learning Foundation: Smart-Log

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Abstract

It's crucial to balance your nutrient intake, especially for young children. Lack of vital nutrients in the body can result in major illness and organ degradation, which can have a major impact on an adult's health. For the sake of the infants' healthy growth, automated food content monitoring is necessary both at home and at childcare facilities. In order to meet this challenge, this article introduces Smart-Log, a novel fully automated nutrition monitoring system based on the Internet of Things (IoT) that will push the boundaries of smart healthcare. This research presents an accurate meal prediction method based on Bayesian Network and a unique 5-layer perceptron neural network for the Smart-Log implementation. A smartphone application that gathers nutritional information about food ingredients and WiFi-enabled sensors for food nutrition quantification make up the Smart-Log prototype, a consumer electronics product. An open IoT platform is used by the Smart-Log prototype for data analytics and storage. Based on 8172 food items for 1000 meals, the experimental findings demonstrate that Smart-Log has a 98.6% prediction accuracy.

Keywords:

Nutrition estimation, IOT based , Deep Learning , Smart- Log

Introduction

Keeping track of everyday food consumption is a pertinent and significant issue in healthcare. Smart healthcare monitoring systems are made with a healthy lifestyle in mind, with an emphasis on tracking caloric intake and output. Monitoring the amount of calories consumed is just as crucial as tracking the number of calories expended. The primary goal of these monitoring systems is to resolve nutrition imbalances, even though their focus could vary from tracking weight reduction to maintaining a healthy, balanced diet. Both undernourishment, in which insufficient nutrients are ingested, and overeating, in which an excessive amount of non-nutrient-rich food, especially high in fats and salt, are contributing

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factors to this condition. Overindulgence in food can result in obesity, a major health issue in today's affluent societies.

A compromised skeletal structure, bleeding gums, receding hairlines, compromised immune systems, and cognitive impairments are only a few of the adult manifestations of malnutrition in newborns and kids. The system is made to control the nutrients that a person consumes from meals and aids in preserving their health.

A person attempting to gain, decrease, or maintain weight should keep track of the nutrients they consume via their meals, according to their BMI. An Android application will be used to manage this record effectively. The application keeps a log that the user can view with information that reveals the specifics.

[1] introduces Smart-Log, an Internet of Things-based baby nutrition monitoring system. It makes use of a revolutionary 5-layer perceptron neural network and a meal prediction algorithm based on Bayesian networks. A smartphone app and WiFi sensors are included in the consumer electronics prototype of the system, which gathers nutritional data. According to experimental results, 8172 food items for 1000 meals had a 98.6% prediction accuracy. [2] In order to get accurate nutrition intake data from heterogeneous sensors, the article suggests a smart nutrition monitoring system that makes use of Internet of Things technology. The non-invasive approach does light-weight analytics and preprocessing using notions from fog computing. The system prototype improves dietary management of chronic diseases like obesity and type 2 diabetes by using cameras to generate 3D images for food volume estimate.[3] Health depends on nutrient consumption, therefore it's critical to keep an eye on the nutritional value of food. Two approaches to meal nutrient calculation are presented in this paper: image processing (convolution neural network) and IoT (Arduino and Loadcell). The Android application is used to enable the system's mobility in the external environment. [4] Using an RFID reader, weighing sensor, and smart dining table, researchers have created a fully automated diet tracking system. To determine portion size and intake, the system makes use of a camera and microphone. The technology gathers nutrition data on ingredients via a smartphone app and assesses food nutrition using Wi-Fi-enabled sensors. Food is categorised by the system according to its nutritional value, obesity, and the connection between dietary intake and nutrient shortages.[5] In order to understand user behaviour and make recommendations, this study integrates data from several devices to create a nutrition monitoring intake system using the Internet of Things. Semi-structured interviews with six participants were used to assess the system and identify its advantages and disadvantages. [6] An Internet of Things-based service system platform for tracking plant nutritional deficits and making fertiliser recommendations was created as part of the project. A chlorophyll metre was integrated with the platform, and JMeter software was used for testing. With a dependability value of 0.97, the platform demonstrated strong system confidence. The platform might be used to track nutrient shortages in plants, suggest fertilisation, save fertiliser prices, and possibly lessen pollution in the environment.[7] The safety of children is a serious concern because half of them have problems. IoT devices and sensors have the ability to track children's whereabouts, keep an eye on their surroundings, and notify parents of

unacceptable behaviour. Blood pressure monitors, smoking, and alcohol can all be used to spot abnormalities. Appropriate decisions to save children's lives can be made by analysing input data. [8] In order to forecast an excess or deficiency of nutrient content, the study suggests monitoring hydroponic plants in real time. Hydrogen potential and electrical conductivity are used to calculate nutritional value. Fuzzy logic and the Mamdani approach are applied to the NFT hydroponic system in order to anticipate PPM values. Accurate measurement findings are made possible by the hydroponic system's usage of remote sensing via the Internet of Things. This invention can help keep plants healthy and stop them from dying.

[9] focus on the needs of older adults seeking care are scarce, nevertheless. In addition to classifying current methods and presenting a hierarchical model for old-centered monitoring, this research investigates IoT-enabled systems for elderly monitoring. In order to enhance the quality of life for the elderly, the study intends to assess the goals and developments in IoT-based monitoring systems. [10] In order to fulfil the Sustainable Development Goals (SDGs) of the United Nations (which include eradicating hunger, promoting good health, and ending poverty), this article focuses on sustainable food systems in the chicken sector. It examines recently put out ideas for Internet of Things (IoT)-based remote poultry monitoring systems that make use of sensors, sound analysis methods, video/image surveillance, and algorithms. The purpose of this article is to support the research community in creating enhanced Internet of Things (IoT) systems that increase profitability and production while promoting the adoption of cutting-edge automated poultry monitoring technology. It also seeks to direct decision-making by policymakers.[11] In this paper, a service-based architecture that works with linked smart home devices to contrast and enhance food intake descriptions is presented. Its goal is to pinpoint and create the necessary services to automatically record and process natural language summaries of dietary intakes in connection with smart home appliances. In order to avoid the drawbacks of monolithic designs, the architecture makes sure that the functionality offered by these services can operate alone or in conjunction with downstream pipeline activities. [12] By facilitating ongoing monitoring and recommendations between patients and physicians, the Internet of Things (IoT) has completely changed the healthcare industry. using the help of data sharing, M2M connectivity, and interoperability offered by IoT, remote health tracking using fitness bands and smartwatches is made possible. This chapter highlights the contributions of researchers and identifies the key problems and challenges in many fields as it addresses the uses and challenges of IoT in healthcare.[13] Stress eating stimulates appetite and can result in a calorie-dense food addiction, which is one of the main causes of obesity. A system that combines wearable and non-wearable techniques to detect stress eating and track food intake is suggested. With 97% accuracy, the system can inform users about their eating habits. [14] Urban plant growth can be accomplished with hydroponics, although it does require controlled conditions, such as humidity and temperature. In order to solve this, a NodeMCU ESP8266 microcontroller-based Blynk-based nutrition monitoring system (IoT) with internet connectivity is required in order to save time and guarantee plant quality.[15] suggests ANDES, an Internet of Things-based hydroponic plant control system that lets users monitor and manage plants using a smartphone by using

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sensors and microcontrollers. Hydroponic plants can have their pH concentration, height, temperature, and humidity automatically adjusted by ANDES. If the temperature rises above 28°C, the system senses the water level and immediately turns on water pumps to raise the nutrition height and chill the space. This creative method aids in maintaining ideal nutrient levels and controlling plant fertility in hydroponic farming.

Proposed Methods

Fig.1 provides a summary of the suggested design for the smart food monitoring system. The system can be thought of as a product that comes with a smartphone application and a smart sensor board. There is a food weighing sensor on the sensor board. Under the control of a microprocessor integrated with a wireless module, the weight of the food product or ingredient is transmitted wirelessly to the cloud via the Internet. As a result, the suggested system is transformed into an Internet of Things "thing." Using the camera on a smartphone and an app, the corresponding nutritional information about the food item is obtained. The overall amount of nutrients consumed is then valued by the system. The user can utilise the smartphone application to view the predicted and computed nutritional values. Fig. 2 depicts the data flow of the suggested Smart-Log system.

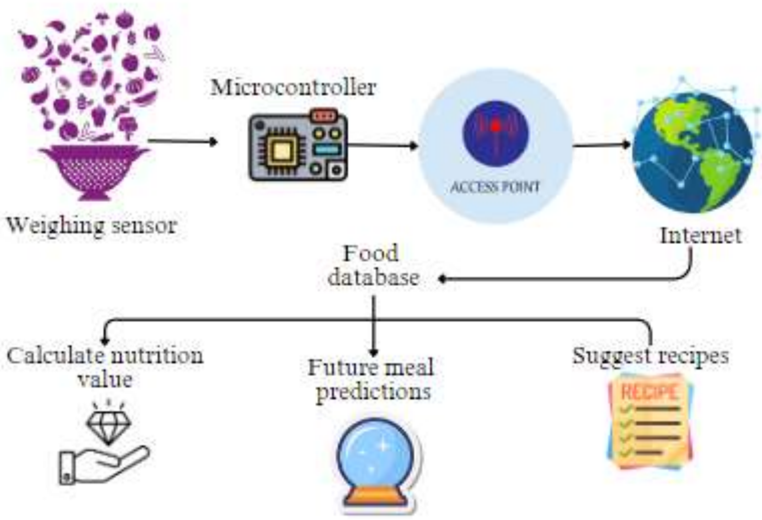

Fig. 1. Architecture of the Proposed IoT-Based Food Monitoring System.

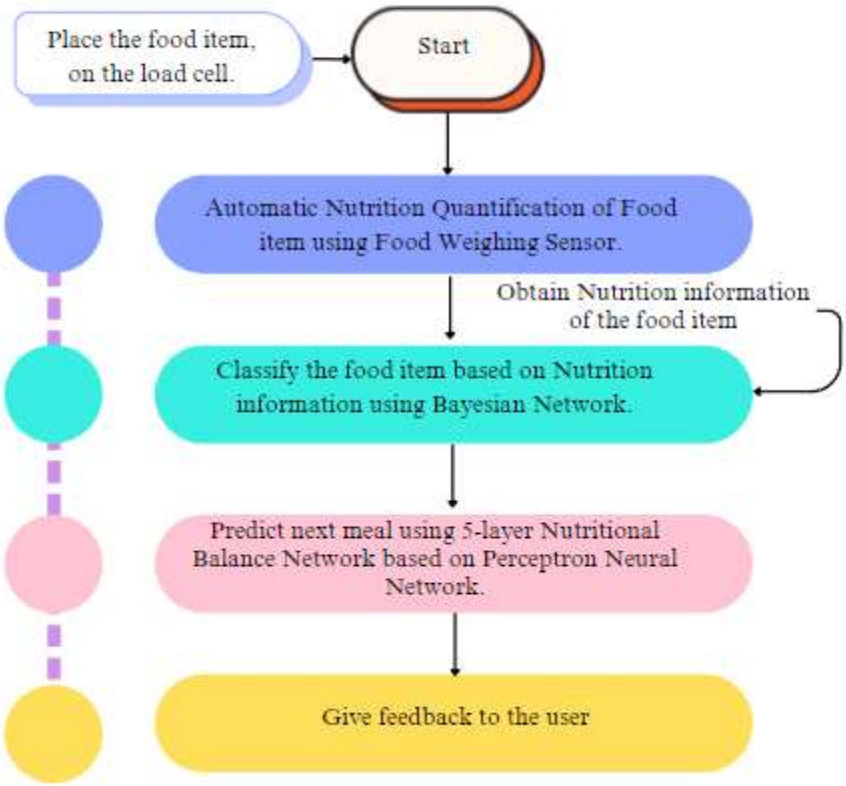

Fig. 2. Data flow of the proposed Smart-Log System.

Quantifying the amount of nutrients the user consumes is the primary goal of utilising the food weighing sensor in Smart-Log. The weight of the food ingredients placed on it and a time stamp should be the sensor's desired outputs. Determining the meal at which the food was consumed is aided by recording the time stamp and variations in food weight. Fig. 3 shows the schematic of the food weighing sensor, which is made up of load cells coupled with a microcontroller. Figure 4 explains the experimental setup of smart-log implementation.

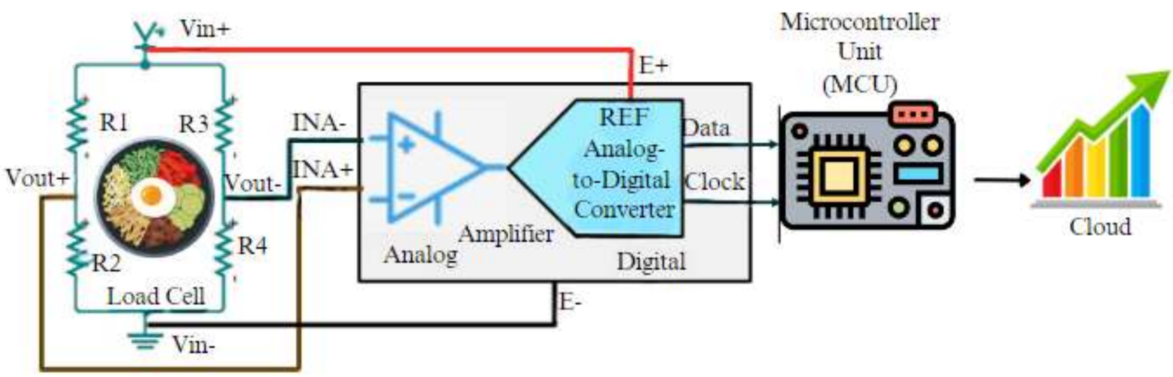

Fig. 3. Schematic Representation of the Food Weighing Sensor in Smart-Log

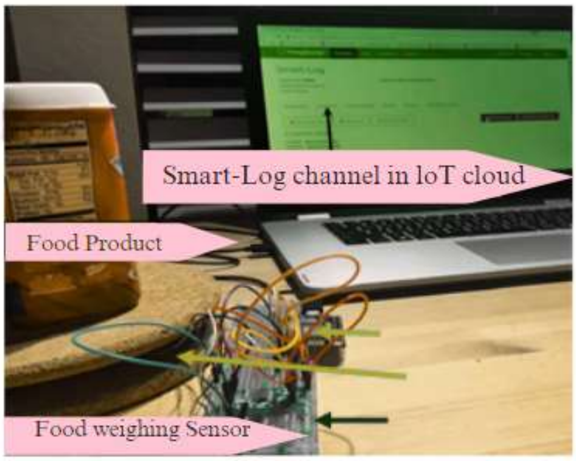

Fig. 4. Experimental Setup of the Smart-Log implementation.

Automatic Nutrition Quantification Method

As soon as the food is placed on the smart sensor board, the first step in Smart-Log is to measure the nutrient levels. The Smart-Log system's automatic nutrition measurement mechanism is depicted in Fig. 5. The load cells are used to calculate the weight of the meal.

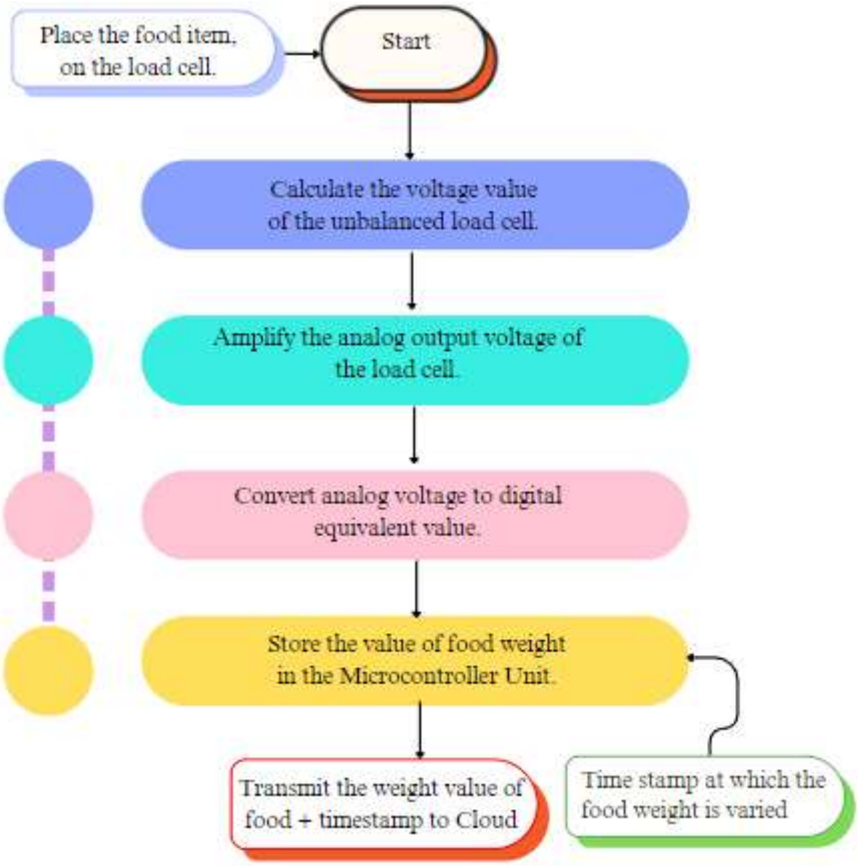

Fig. 5. Method for Automatic Nutrition Quantification.

Smart-Log Nutrient Data Acquisition Method

Compiling nutrient information is a crucial step after obtaining the food's weight and time stamp using the food weighing sensor board. Previous studies have prioritised computer vision methods and making use of pre-existing data. Two distinct approaches are employed in this study to get pertinent nutritional values. Optical Character Recognition (OCR) is one method that uses the phone's camera to extract information from the FDA-mandated Nutritional Facts Label, if accessible. The information is then put to a local database. The alternative method scans the food's barcode and uses open APIs to retrieve nutritional data from the Internet. Both strategies are shown in Fig. 6. The nutritional value of the food item is determined using the food weight and timestamp values after the nutritional content of the food has been determined. In a similar manner, all of the food ingredients that go into making the meal have their nutritional values determined. The nutritional data is recorded under the corresponding meal IDs, together with the weight and timestamp, so that the nutrient values for subsequent meals can be calculated. To identify if a meal is breakfast, lunch, or dinner, the timestamp is recorded.

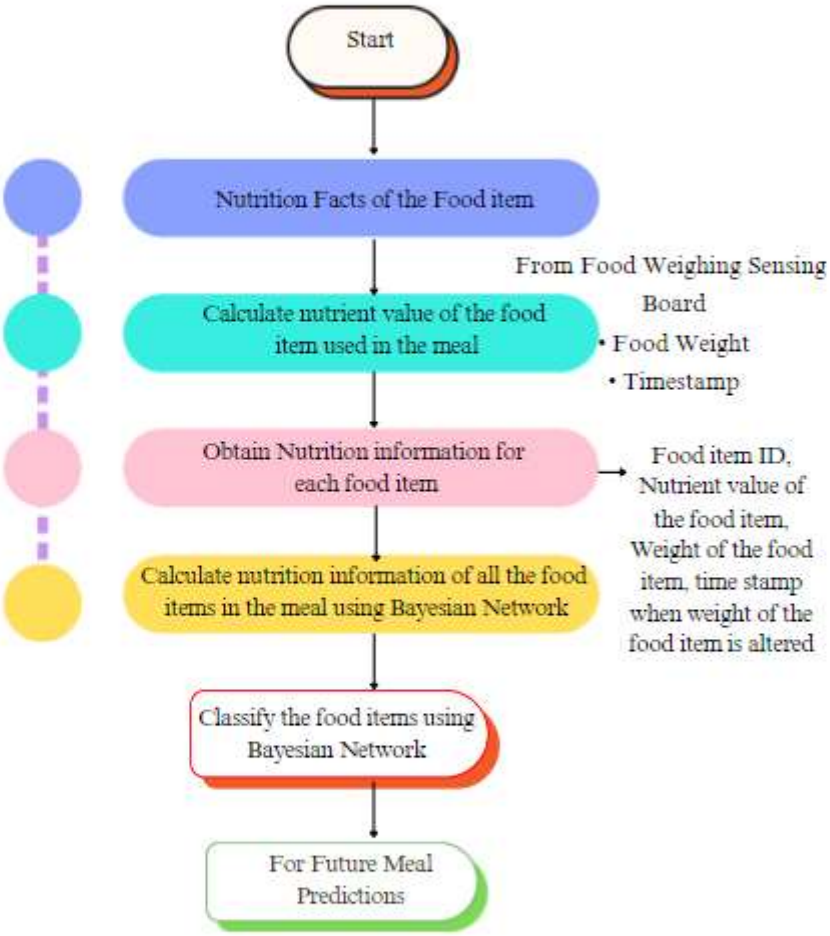

Fig.6. Proposed Data Acquisition Approaches of Smart-Log.

Method for future meal production

The suggested procedures to forecast the next meal based on user feedback and quantified food waste are displayed in Figure 7. The amount of nutrients squandered from each meal is measured by calculating the weight of the leftovers after consumption. This residual nutrient data is used with user input to determine whether a meal has achieved its objective. The goal of the meal—that is, whether it is a high-fiber, high-carb breakfast, a low-carb, high-protein lunch, etc.—is ascertained by user feedback. The amount of nutrients not absorbed throughout the meal is calculated using the weight of food that is discarded. Using the determined deficiencies in nutrients, the nutritional values for the next meals are calculated to ensure a completely balanced diet. Future meals are forecasted and recommended to the user as feedback based on these inputs.

Results and discussion

Data Acquisition for Smart-log system

The hardware design of the food weighing sensor and the extraction of nutritional features are involved in data collecting for Smart-Log, and they are covered in the sections that follow.

Smart Food Weighing Device: The food weighing sensor was implemented in hardware with the assistance of commercially available off-the-shelf (COTS) components. The load cell's sensitivity and resistance are the primary factors to take into account. The amount of output voltage, when the input (excitation) voltage is 1 mV, is the load cell's sensitivity (measured in mV/V). The manufacturer provides the sensitivity, resistance, and offset values for components that are sold commercially. A load cell with a 0–5 kg weight range was taken into consideration for the Smart-Log system. A 24-bit Analog-to-Digital Converter (ADC) intended specifically for weighing purposes was linked to the load cell's output. An internal oscillator, an analogue power supply regulator, and an on-chip programmable gain amplifier (PGA) make up the 24-bit ADC's architecture. Data Output (DOUT) and Serial Clock (SCK) are the ADC's outputs that need to be connected to the microcontroller in order to get data. Before the data are ready, the output at DOUT stays high and the SCK remains low according to the ADC's design for weighing applications.

During the Smart-Log design prototyping phase, the system's overall efficiency was evaluated by evaluating its compatibility and convenience of use, which are attributed to its reduced size, low power consumption, and fast processing speed. Two microcontrollers were taken into consideration for this purpose: one with an integrated wireless module and the other without. A comparison of the two microcontrollers is shown in Table 1. Since the primary function of the microcontroller in the Smart-Log design is to transfer data wirelessly to the cloud, Model 2 was taken into consideration for the final prototype. Additionally, given its dimensions, the Model 2 has a smaller form factor and is a simple addition to this IoT-based solution as a "Thing."

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TABLE 1 COMPARISON OF HARDWARE PROTOTYPES FOR SMART-LOG SYSTEM BASED ON 2 MICROCONTROLLERS.

Characteristics	Model 1	Model 2
Operating Voltage	5 Volts	**3.34- 5 Volts**
Built-in Wi-Fi module	YES	**NO**
Clock Speed	14MHz	**70 MHz**
Digital I/O pins	65	**22**
Dimensions of the board	**123.6 × 67.7 mm^2**	**45 × 33.8 mm^2**

<u>2) Nutrition Acquisition:</u> To gather nutritional values from the Internet, a Java programme was developed. Nutritional values were obtained from a freely available database of 8791 food products from the USDA [32]. Additionally, the US Department of Agriculture keeps up an API front-end website for its SR8 database, which uses the NDB number as a unique identifier to encode items. When using Smart-Log, the user is greeted with a webpage that asks questions about the meal's name and kind based on predetermined categories, such as "breakfast," "brunch," "lunch," "snack," and "dinner." Finding the nutrition value of each food item utilised in a meal is the primary problem in acquiring the nutrition information for that meal. The total nutritional content of the meal prior to ingestion is computed using the food weight recorded by the sensor board and the nutritional data downloaded from the cloud. Any remaining food is weighed again after the meal, and the meal's exact nutritional value is recalculated.

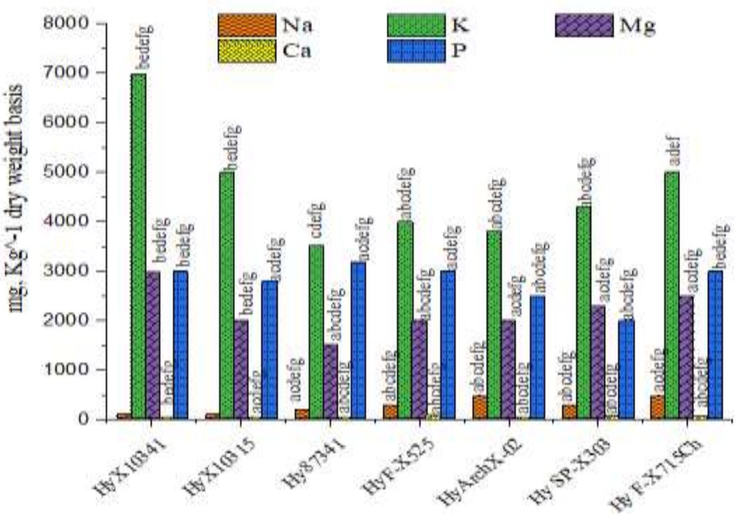

Figure 7 Nutrition Acquisition Data

<u>Smart-Log System Data Analysis</u>

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As was said in Section V, the Smart-Log system ought to keep track of the user's food intake on its own and provide effective forecasts. The Waikato Environment for Knowledge Analysis (WEKA) tool, which is used to categorise each food item into different classifications, was used to perform the data analytics in order to accomplish this. An attribute-relation file format (.arff) item created by the programme is sent to WEKA. A custom Java application shows the classifier's response on a webpage. WEKA has a large number of data analytics algorithms that are useful for predictive modeling. One thousand meal entries entered via the Smart-Log UI were contained in a.arff file that was fed into the system.

An Experimental Smart-Log System Prototype

Table 2 provides the general compositional properties of the Smart-Log system. In the phase of data acquisition, OCR, APIs, and databases were employed. OCR increases the system's processing complexity, which raises power consumption. It was disregarded from further consideration as a result.

TABLE 2

CHARACTERIZATION OF SMART-LOG SYSTEM.

Characteristics	Specifics
Accuracy (worst case)	98.6 %
Classifier	Bayesian Network
Data acquisition	API & Database approach
Data Analysis Tool	WEKA
Input Dataset	8954 instances
Sensor system	Food Weighing Sensor

Conclusion

This paper presents an automated food data logging system. With regard to diet monitoring, the adopted design is highly accurate and economical. After a careful examination of numerous classifiers using WEKA, two algorithms were proposed: one for nutrient feature extraction based on a Bayesian network and another for evaluating the nutritional balance after each meal. The technique for the former is based on a five layer perceptron neural network. Some products were logged more than once in the input dataset since an open food database was used. In order to get around this, the user is given more opportunities to fix a data entry in the event of redundancy, which increases the accuracy in the end. Apart from evaluating the nutritional value of the meal, the system recommends actions to lower the likelihood of an unbalanced diet. This system may end up being a need for use in the home or in nursery facilities. Although the current research illustrates the usage of Smart-Log in relation to infant feeding patterns, Smart-Log may also be extended to adults by growing the food database stored in its cloud storage. In order to accurately anticipate an adult's diet through automated means, Smart-Log will be combined with physiological monitoring systems in future study.

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