# Smart-Log: An Automated, Predictive Nutrition Monitoring System for Infants Through the IoT


Prabha Sundaravadivel
Computer Science and Engineering
University of North Texas, USA.
Email: ps0374@unt.edu

Kavya Kesavan
Computer Science and Engineering
University of Texas Arlington, USA.
Email: kavya.kesavan@mavs.uta.edu

Lokeshwar Kesavan
Independent Researcher
Dallas, Texas, USA.
Email: lokeshwarkesavan@gmail.com

Saraju P. Mohanty
Computer Science and Engineering
University of North Texas, USA.
Email: saraju.mohanty@unt.edu

Elias Kougianos
Engineering Technology
University of North Texas, USA.
Email: elias.kougianos@unt.edu

Madhavi Ganapathiraju
Biomedical Informatics
University of Pittsburgh, USA.
Email: madhavi@pitt.edu



***Abstract*—Malnutrition is a condition where the body is deprived of important nutrients required to maintain healthy tissues and organ function. Maintaining the right balance in food intake is very important, especially in infants where tremendous growth occurs. Unlike adults, infants require someone's assistance in their food intake. In the modern world, where most of the infants are being sent to daycare, an automated food monitoring system helps in keeping track of their food intake. In this paper an automated food monitoring system with predictions to help a balanced meal is proposed. This sensor system consists of a piezo-based sensor board which can help in analyzing the weight of each meal and a smart phone camera to obtain nutrition facts of the ingredients.**



***Index terms*—** Internet of Things (IoT), Smart Healthcare, Smart Home, Optical Character Recognition


## I. Introduction

Malnutrition can occur either due to undernourishment or over-nourishment Under-nutrition occurs when enough nutrients are not consumed. Similarly, over-nutrition occurs when too many foods are fed which are not well balanced. Over-nutrition increases the risk of obesity which mainly is caused due to consuming food which is high in salt and fat. Malnourished children tend to have weakened immune systems and reduced IQ. Malnourishment can lead to nutritional disorders which can be characterized by symptoms such as anxiety, mood swings, tender bones, bleeding gums, thin hairline and so on.

The Internet of Things (IoT) helps in connecting real world sensor data to cloud based solutions. It is an inter-network of sensors deployed in the physical world and helps in exchanging data between these sensors and the cloud [1]. The IoT acts as a backbone of smart cities where sensors from different infrastructures such as hospitals, vehicles, and households are inter-connected [2]. The IoT acts as a virtual brain for wireless sensor networks which can be realized as mixed signal systems [3].

The rest of the paper is organized as follows: Section II discusses the novel contributions of this paper. Section III provides a broad overview of the sensor system. Existing related research work is discussed in Section IV. Section V gives a detailed explanation of the individual components involved in the sensor design along with the techniques for data acquisition. Section VI includes the implementation results of the sensor design. The conclusions and directions for future research are provided in Section VII.

## II. Novel Contributions

With an ever growing health-conscious trend amongst people, monitoring daily intake is necessary to reach one's fitness goals. Though there are many food logging solutions available, they require manually updating the mobile application each time, which might be erroneous if the values are not being updated regularly. This paper focuses in a nutrition monitoring system for infants where maintaining well balanced diet is extremely important. To overcome this, the following solutions are proposed:

- An automated solution which keeps track of the amount of food consumed along with the nutrition facts.
- A prediction method to analyze nutrient values of future meals based on wastage of food in the current meal.
- Feedback taken from the user each time to customize the meal plan according to the user's need.

With the above mentioned solutions for automated food logging, this method is novel and proves efficient especially for infants, where monitoring nutrient values is a high priority.

## III. Smart-Log: A broad perspective of the Smart Nutrition monitoring system through the IoT

Healthy lifestyle starts from having a well balanced diet. A well planned routine of diet and exercise can help in maintaining ideal body weight, which helps in preventing many weight-related disorders such as obesity, diabetes, high cholesterol etc. Developing healthy eating habits has to start from early childhood to make each individual health conscious. Most of the times, though parents try to give the best food in early childhood, due to lack of awareness, it is possible that a particular nutrient is never included in the food. Many children tend to be fussy eaters, where aversion of certain food stays forever in their life. In such cases, it is important to find a potential replacement of the concerned food item in order to maintain a well balanced diet.

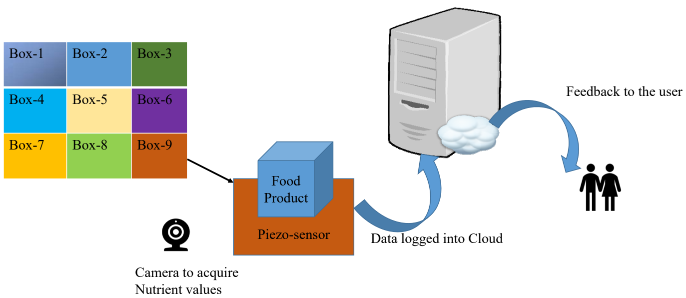


Fig. 1: Overview of IoT based sensor system for Smart-Log.

Figure 1 shows an overall architecture of the proposed food monitoring system. In this proposed system, a sensor board based on piezo-sensor is proposed which can be used to analyze the weight of the food products placed on this sensor board. With the help of a smart phone camera, the nutritional facts along with the weight information is provided to the system. The system uses this information and gives a value of the total nutrients consumed by the user. In addition to giving the total nutrition values consumed, based on the weight of the leftover food, predictions for future meals are provided.

## IV. Related Prior Research

An image based food recognition table has been proposed in [4] which was further improved to restaurant menu based food items in [5]. The main motivation behind these works was to have calorie control through food logging. Another image based analysis for food assessment has been proposed in [6] and [7]. A smart phone based image recognition system for dietary assessment has been proposed in [8] and [9]. A multiple kernel approach for image based food recognition is proposed in [10]. An extensive analysis of insulin therapy based on carbohydrate intake has been demonstrated in [11].

## V. System level modeling of Smart-Log System

### A. Smart sensor board

The proposed smart sensor system consists of piezoelectric sensors paired with a microcontroller. Piezoelectric sensors generate equivalent voltage signals for the applied weight or mechanical force [12]. Piezo-sensors are generally used as force or vibration sensing as they dynamically give a corresponding voltage value equivalent to the applied force. By using the piezoelectric sensors in weight sensing application as this, they can help in sensing the variations in the total weight and consumed weight of the product, which can be used to calculate the nutrient values. This equivalent voltage value can be read with the help of the microcontroller which also saves the obtained value along with the time stamp. The main reason behind using the microcontroller in this application is that it offers scheduling and easier integration into wireless modules, which helps in connecting the prototypes to the IoT.

### B. Data acquisition involved in Smart-Log System

Gathering information regarding food is the most important task in any food monitoring system. All the related prior research was focused on achieving this through computer vision and mapping it to already existing information. The time and weight of the food product is obtained through the piezoelectric based sensor board. In order to map the relevant nutrient values to these products, two approaches have been incorporated along with the sensor board. The nutrition information can either be captured as images through a smart phone and by using Optical Character Recognition (OCR) techniques, the appropriate information is stored in the database. OCR helps in identifying the printed characters in images. Another approach suggested is by linking open source Application Program Interfaces (APIs) through the barcode in order to obtain the nutrient values.

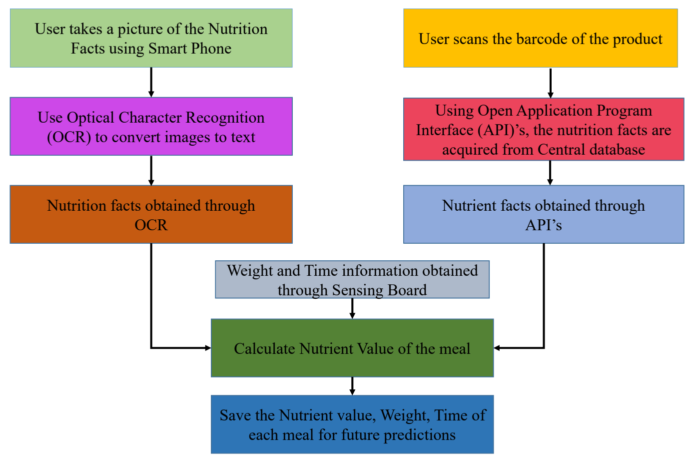


Fig. 2: Flow chart of data acquisition involved in the nutrition monitoring system.

Figure 2 shows the data flow of both methods involved in the data acquisition. When the user opts to use the OCR method, the user initially needs to take a picture of the nutrition facts label in that particular product. When the user opts to use the API approach, the barcode of the product is scanned using a smart phone. Along with the nutrient values obtained either through the OCR or API approach and the weight and time values obtained from the sensor board, the nutrient values for that meal are calculated.

### C. Future meal predictions

The main concern in infants is the amount of food wasted after each meal. In spite of getting the right formula, and making the best efforts to prepare a balanced diet everyday, the food can only offer all the benefits if it is being consumed. In order to have an accurate measure of the wasted food, the weight of the wasted food is calculated. By taking the weight of the wasted food, corresponding nutrient value is calculated.

The purpose of each meal may vary from person to person. For example, some would like to have high fiber in their breakfast and a carbohydrate rich lunch, whereas some would like to have carbohydrates in the form of fruits and increase protein in their breakfast and lunch. Getting feedback from the user about the goals of a particular meal is necessary to provide suggestions for future meals and to determine if the user has maintained a balanced meal in that day. The steps involved are shown in Figure 3.

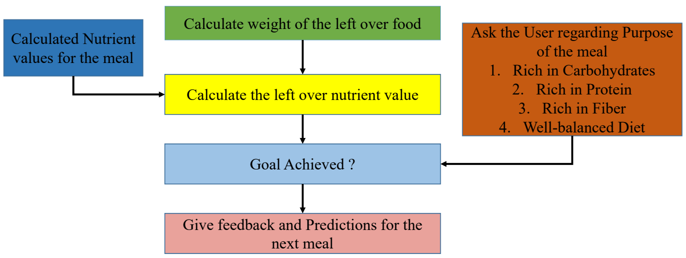


Fig. 3: Flowchart of steps invloved in calculating predictions for the next meal.

## VI. Implementation and Validation of Smart-Log System

The sensor system is implemented using Proteus and the data analysis to build an efficient prediction based system is done using WEKA [13], [14]. With the help of a JAVA program, the input and output of the classifier is displayed in a web page. The sensor system is required to possess the following functionalities: 1. Calculate the total weight of the product placed on the sensor board. 2. Calculate the weight of the product after the user consumes some quantity of it. 3. Log the weight values each time along with time stamps in order to give better predictions for each meal. An ARDUINO based piezoelectric sensor system for this purpose was developed using Proteus.

Figure 4 shows the prototype with four piezo sensors attached to the ARDUINO board in Proteus. The ARDUINO board helps in faster prototyping and the microcontroller can be programmed easily using C and C++. An LCD module was used in order to read the variations in voltage value in accordance to the weight of the elements. The data logging can be achieved through the USB port.

For acquiring nutrition values, a JAVA program was coded such that when the user inputs the name of a product, a large database is scanned and the relevant nutrient values are taken into consideration. A database of 8791 items consisting of both readily available and raw ingredients for baby food was taken from [15]. The SR8 database available through the US Department of Agriculture website, can also be analyzed using their API. The API provides a food report which gives a list of associated nutrient values for a particular food item and a nutrient report which gives an extensive list of food and their nutrient values for a selected amount of nutrients. Each food item entered in this database has an unique key called NDB number. This NDB number is used to access the food item and its relevant nutrient values.

Based on the priority, type of meal and other calculated values of nutrients, each food entry is assigned to one of the classes. Whenever a data entry is created by the user, an Attribute-Relation File Format (.arff) is created at the back-end, in order to give input to the Waikato Environment for Knowledge Analysis (WEKA) tool. ARFF files have a header and data section, where the header contains the relation and list of attributes and the data section contains the corresponding data of the listed attributes. Table I shows the accuracy of the classifier built based on different algorithms in WEKA. An input ARFF file with 1000 input instances, which were logged as input through the user interface were given to WEKA and by using different classifiers in WEKA, the efficiency is evaluated.

For data acquisition, OCR, API and DB approaches were used and it was observed that when OCR approach was used, additional computations were required in order to classify the values accordingly. Due to these limitations and considering the accuracy of the classifier as high priority, data acquired through the database approach were considered. A total of 8172 instances were considered as input to the system where the test file contained around 1000 instances. It was also observed that when a Bayesian classifier was used, the accuracy of the system was very high, ranging to 98.4 % in the worst case. Table II shows a comparison of the efficiency of this work with respect to related research. It should be noted that the research presented in [4], [5] and [10] was based on based models which makes it very different in terms of features considered for this work.

## VII. Conclusions and Future Research

In this paper an autonomous food data logging system has been proposed. Two approaches for data acquisition have been proposed and the results obtained have been analyzed using WEKA in order to build a better prediction model. It was observed that Bayesian classifiers provided better results. In the input dataset certain products were repetitive or logged more than once. Due to this, an additional option is given to the user in the user interface, where the user can customize the entry. This helps in improving the overall efficiency of the system. The proposed system can help in analyzing the nutrition consumed on an everyday basis and provide suggestions for the user to address malnutrition. With a cost effective sensor system and seamless data logging method, the proposed system can be an essential consumer electronic device used in child care.

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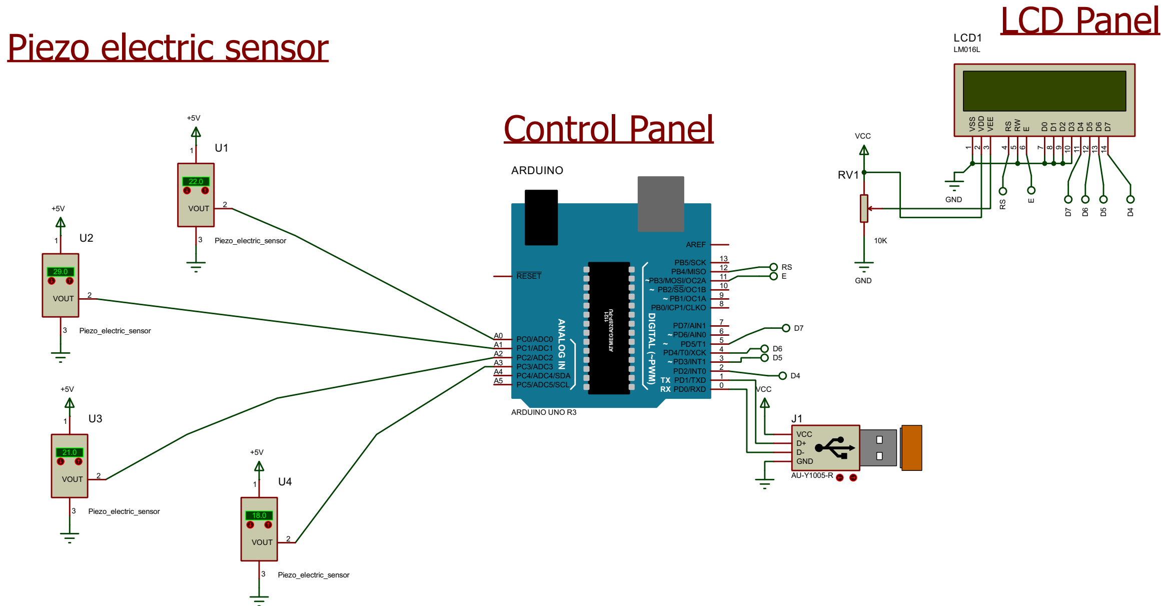


Fig. 4: ARDUINO based sensor module to monitor weight of individual box elements.

TABLE I: Classifier evaluation using WEKA.

| Classifiers | Mean Absolute error | RMS error | Relative absolute error % | Root Relative Squared error % |
|---|---|---|---|---|
| Naive Bayes | 0.0106 | 0.0179 | 2.65 | 3.98 |
| Bayes Net | 0.0052 | 0.0055 | 1.3108 | 1.2236 |
| Naive Bayes Updatable | 0.0106 | 0.0179 | 2.65 | 3.98 |
| Multilayer Perceptron | 0.0149 | 0.0179 | 3.72 | 3.99 |
| Decision Table | 0.0322 | 0.0363 | 9.06 | 8.63 |
| Simple Logistic | 0.1192 | 0.1192 | 33.55 | 22.28 |
| Naive Bayes Multinominal Text | 0.0354 | 0.0419 | 4.78 | 5.06 |

TABLE II: Performance comparison with related research on food recognition system.

| Research Works | Food recognition method | Efficiency (%) |
|---|---|---|
| Chen et al [4] | Image based feature extraction | 90.9 |
| Beijbom et al [5] | Image based feature extraction | 96.2 |
| Joutout et al [10] | Image based classification using multiple kernel learning | 61.34 |
| This Work | Mapping nutrition facts to a database | 98.4 |

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