IoT based body weight tracking system for obese adults in Indonesia using realtime database

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Abstract. Obesity has become a serious issue in many countries with increasing prevalence every year. People with obesity has higher risk for several serious health complications and on a larger scale, this could bring negative implications for economic growth and human wellbeing of a nation. Many studies have been conducted to overcome this issue and some suggested that regular self weighing could promote weight loss and weight maintenance. Based on those findings, a body weight tracking system is made as an approach from technological side. The purpose of this system is to raise health awareness by using easy-to-use technology to monitor user weight from time to time. The system consists of a realtime database, a smartphone application, and a modified digital weight scale. The weight scale is tested to have more than 99% accuracy and can active for estimated 40 hours of usage, while the realtime database storage for this implementation is adequate for more than half a million users.

Keywords: weight tracking, IoT, realtime database, obesity.

1. Introduction

Obesity is a medical condition where excess body fat is accumulated and often lead to serious health problem. Obese individual has higher risk to suffer serious illness, such as hypertension, heart attack, stroke, diabetes, gallbladder disease, and cancer compared to normal weight individual. Based on 2018 basic health research (Riskesdas) by Indonesian Ministry of Health, the prevalence of obese adults in Indonesia is 21.8% [1] and Indonesia was ranked 10th place in terms of country with the most prevalence of obesity [2]. The research also shows an increasing prevalence of obesity adults where it is nationally recorded 10.5% in 2007, then 14.8% in 2013, and 21.8% in 2018 [3]. Many research has been made to further investigate this issue and the results confirm that obesity has become a serious public health problem in Indonesia [4] [5] [6]. All the stakeholders including the government and researchers are required to take an immediate action to combat this epidemic.

The most commonly used measure for overweight and obesity is the Body Mass Index (BMI) which is defined as the weight in kilograms divided by the square of the height in meters (kg/m²). BMI as an indicator of obesity is being used by WHO as a population-level measure of overweight and obesity. Although BMI is generally used to estimate an ideal weight of an individual, different region has a different cut-off points for categorization. Weisell in his article mentioned that some country has developed their country-specific cut-off points for BMI instead of using a more general WHO BMI cut-off points in order to fit their region situation [7]. In this case, Indonesian Ministry of Health has...
issued BMI cut-off points as a standard for Indonesia citizen based on clinical experience and research on some developing countries [8]. The comparison between WHO and local cut-off points are displayed in Table 1a and Table 1b. Both BMI classification has similar cut-off points for normal range category, but local BMI classification generally has lower cut-off points. Local BMI classification will be used in this research as it adapt to local population.

This research aims to give a technology-based solution to combat increasing obesity prevalence by raising awareness to obese individual about their current weight and health condition. There are numerous research that support the idea that regular self-weighing promotes weight loss [9]. Other reports 77.9% successful weight reduction from 35,921 participant only by using mobile phone application to track daily progress [10]. Based on those findings, we propose a system with combination of digital weight scale controlled by smartphone application to replace conventional analog weight scale. The proposed system is designed to be easy to use, reliable and response fast, so that the whole weighing process does not waste much time. Current popular smart scales available in the market use bluetooth technology to connect to user’s smartphone [11] [12]. This requires additional effort to pair the device and sometimes proven unreliable when being used in public with many users trying to connect to a single device. This research tries to use IoT concept as a solution to the problem.

| BMI     | Nutritional Status     | BMI     | Nutritional Status     |
|---------|------------------------|---------|------------------------|
| < 18.5  | Underweight            | < 17.0  | Severe Underweight     |
| 18.5 – 24.9 | Normal Range          | 17.0 – 18.4 | Mild Underweight    |
| 25.0 – 29.9 | Preobese               | 18.5 – 25.0 | Normal Range          |
| 30.0 – 34.9 | Obese class I         | 25.1 – 27.0 | Mild Overweight       |
| 35.0 – 39.9 | Obese class II        | > 27.0  | Obese                  |
| >= 40.0 | Obese class III        |         |                        |

2. Design and Implementation

The diagram block of the whole system was shown in Figure 1. A digital weight scale is the main component of the system to provide weight data. The digital weight scale consists of four single strain-gauge load cell connected to a combinator board in which the load cells are arranged in a wheatstone bridge configuration. Weight information is obtained by reading the voltage resulting from the load cell multiplied by a calibration factor. In order to process the voltage information, it is needed to be converted into digital form using an Analog to Digital Converter chip. A 24-bit ADC from Avia Semiconductor is used in this implementation. The mini WiFi board is based on ESP8266 chip which has a microcontroller in it. It also has embedded WiFi module and capable to connect to the internet. The conversion from voltage level data into weight information is processed by the microcontroller. The digital weight scale is powered by a Li-Ion battery which can also be recharged.
The system is designed to be controlled through smartphone application either in Android or iOS. The whole user process are described through simple flowchart in Figure 2. Initially, new user will have to create an account using Google mail. Upon signed in, user will be taken to home page. The home page of the application is displayed in Figure 3 at the top left figure. There are three menu selection that user can choose. The weighing menu will take the user to the QR code scanning page in which the user should point their smartphone to the QR code provided on top of each weight scale unit. The QR code contains unique ID for the weight scale. The generation of the ID is done manually based on production date of the weight scale and the number of unit produced. When the QR code scanning complete, the particular weight scale is notified to start reading weight as soon as the user step on it. The weighing page is displayed in Figure 3b at the top right figure. Following the second menu, the user can see the history of their weight in the form of chart. The history view is displayed in Figure 3 at the bottom left figure. Lastly, in edit profile menu, user can provide information of their height which is then combined with their last weight information to get classification of their BMI category. The edit profile page is shown in Figure 3 at the bottom right figure.
The weight scale being used in this experiment can be modified from common digital weight scale of any type. The first modification is within the ADC unit, where HX711 from Avia semiconductor is used. It features a precision 24-bit ADC and support large gain of 128 to accommodate small input signal from sensors. The next modification is the removal of numerical display to provide enough space to attach the QR code on top of it, since the weight information will be sent to user’s smartphone. The last modification is also an upgrade to the weight scale, where a low-cost WiFi microcontroller is integrated to the system. The WiFi microcontroller being used in this implementation is Wemos D1 mini because of its small size which can easily fitted inside the weight scale unit. The whole process inside the weight scale unit is described in Figure 4. The weight scale unit will send weight information to realtime cloud database which will distribute the data to user’s smartphone or supported Android / iOS devices. The cloud database being used in this implementation
is Firebase Realtime Database which is a part of Google Cloud Platform. The database is free to use up to 10 GiB monthly bandwidth and total of 1 GiB stored data, which is considered to be abundance for small to medium number of user base. The information stored to the database are scale ID, user ID, username, time information, weights and height. The organization of the data inside the database is shown in Figure 5.

![Project Level](image)

Figure 4. Flowchart of Weight Scale Unit

Figure 5. Data Organization in Database

3. Results and Discussion

The final product of the weight scale unit can be seen in Figure 6, where modifications have been made to common digital weight scale. The dimension of the weight scale unit is 36 cm x 26 cm. The WiFi microcontroller board and a rechargeable Li-ion battery are placed inside the white box. The QR code were enlarged to enable scanning from smartphone camera while the user is in standing position. Table 2 shows the accuracy of the weight scale in measuring different kind of calibrated objects. The instruments being used are from PASCO mass and hanger set [14]. It is officially stated that the mass objects has tolerance of ± 1% each. The weight scale has tare function which will set initial weight to zero at the beginning of operation. Despite being calibrated and zeroed out, there are 0.01 kg offset which occurs when there is no object placed on the weight scale. This is caused by imbalance of the inner sensors placement. However, those value can be eliminated by further substract the measurement.
with an offset constant value. Subsequent measurements are affected by the offset value and mass inaccuracy. The offset value is consistently around 0.01 kg to 0.02 kg across different weights. The largest weight tested in this experiment is 20 kg, thus conclude that the noise value is 0.4% for a 20 kg object and will get smaller for a heavier object.

![Weight Scale Unit](image)

**Figure 6. Weight Scale Unit**

| Table 2. Weight Scale Measurement Data |
|----------------------------------------|
| 1\textsuperscript{st} trial | 2\textsuperscript{nd} trial | 3\textsuperscript{rd} trial | 4\textsuperscript{th} trial | 5\textsuperscript{th} trial |
| No Weight | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 |
| 0.01 kg | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| 0.05 kg | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| 0.1 kg | 0.10 | 0.10 | 0.11 | 0.11 | 0.10 |
| 1.0 kg | 1.02 | 1.03 | 1.02 | 1.02 | 1.02 |
| 1.5 kg | 1.52 | 1.52 | 1.52 | 1.52 | 1.53 |
| 5.0 kg | 5.02 | 5.02 | 5.02 | 5.02 | 5.02 |
| 20.0 kg | 20.02 | 20.02 | 20.02 | 20.02 | 20.02 |

The power consumption on the weight scale is 80 mA on the average with WiFi activated. The power consumption is considered large for a battery powered application. Unfortunately, switching between power saving mode is not an option, since the device needs to listen to signal from cloud database any time the user wants to use it. The battery used in this application is a Li-ion battery which has rated energy of 2600 mAh and produce 3.7 Volts output. By using rated energy information divided by current consumption, the active time of the weight scale can be estimated to be around 32.5 hours. However, this is only a rough estimation consider the real rated energy of battery usually lower than the specification, and also the current consumption is an average data. In order to estimate the active time more precisely, a series of battery voltage data was taken with an interval of 1 hour (Table 3). When fully charged, the battery is measured at 4.2 Volts and there is an additional circuit which protects the battery from over-discharging and cut off the supply power at 2.5 Volts. Using the battery voltage data from Table 3, the active time of the weight scale can be estimated before it is automatically cut off. The average discharge rate is calculated to be 0.041 Volts/hour by averaging the voltage differences from Table 3. Using equation 1, we get an estimate data of 40.24 active hours.
Table 3. Battery Discharging Data

| Start | 1h   | 2h   | 3h   | 4h   | 5h   | 6h   | 7h   | 8h   | 9h   |
|-------|------|------|------|------|------|------|------|------|------|
| V     | V    | V    | V    | V    | V    | V    | V    | V    | V    |
| 4.15  | 4.10 | 4.06 | 4.02 | 3.98 | 3.94 | 3.9  | 3.86 | 3.82 | 3.78 |

4.1 Conclusion

This research demonstrate a successful implementation of IoT based body weight tracking system to raise health awareness. The weight scale unit is designed to be portable yet compact with a size of common notebook computer. By using a realtime cloud database, the weight scale unit can be used anywhere with internet access and user can track their weight history easily on their smartphone. The weight scale unit can detect an object as low as 0.01 kg of weight with accuracy more than 99%. The weight scale unit is powered by a single rechargeable Li-ion battery which can run for estimated 40.24 hours of usage. The ideal usage of this implementation is in hospital or health center where people can monitor their weight as well as their BMI classification and consult with their doctor or medical specialist.

Acknowledgement

This project is financially supported by Binus University.

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