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# Development, Implementation and Usage of an Automated Body Mass Index (ABMI) System

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**ABSTRACT**: Body Mass Index (BMI) is a non-invasive method employed to measure the body fat accumulation using the individual's weight and height. The obesity is therefore the major public health risk in the world. This is associated with a lot of disease such as hypertension, type-2 diabetes mellitus, kidney disease, respiratory problems, degenerative joint disease, cardiovascular disease etc. The purpose of this work was to design and fabricate a locally made Arduino based automated Body Mass Index (BMI) machine with Liquid Crystal Display (LCD), that works on the principle of Hooke's law and acoustic ultrasound waves, that is affordable, accurate, rugged, accessible for individuals for regular check of obesity status. The hardware of the project consists of 4-load cells for the weight and an ultrasonic sensor for the height measurement, while the Arduino microcontroller circuitry does the automatic computation of the BMI. The machine was used in the calculation of the BMI of sixty randomly chosen ABUAD students made up of 22 males and 38 females. The heights and weights of the same students were also measured manually as reference. The values obtained from manual and designed automated BMI machines are relatively agreed with standard errors of 0.01, 0.35, 0.12, for height, weight and BMI respectively.

KEYWORDS: Automated, Body Mass Index, Obesity, Microcontroller, Morbidity

### 1. Introduction

The global epidemic of overweight and obesity is termed "globesity" [1]. Obesity is broadly referred to the excess body fat [2][3]. It is the major public health problem in developed as well as developing world. Recent study conducted among young adults in Nigeria showed that more than one in every eight young adults was either overweight or obese [4]. Overweight and obesity accounted for 15-30% of deaths in coronary heart disease and 65-75% of new

cases of type-2 diabetes mellitus. Overweight and obesity resulted from an energy surplus over the time that is stored in the body as fat [5]. Body mass index (BMI) is the measure of a person's weight in kilograms divided by the square of his height in meters.BMI is an approximate measure of overweight or underweight of the body; which is calculated by dividing the weight of the body in kilograms by the square of height in meters. That is:

$$BMI = \frac{weight \ (kg)}{square \ of \ height \ (m^2)}$$
(1)

BMI could also be defined as an estimation of the proportion of body weight that is accounted for by fat [3]. It is commonly used as an indicator of obesity which is an attempt to quantify the amount of tissue mass (i.e. muscle, fat, and bone) in an individual and then categorize the person as underweight, normal, overweight or obese based on the value obtained. Other devices used before include skinfold [7] thicknesses, bioelectrical impedance [8], underwater weighing, dual energy x-ray absorptiometry [9], waist circumference (WC) and waist hip ratio (WHR) [10] in determining overweight and obesity. Similarly, World Health Organization (WHO) provides general cut off points, in which BMI could be used to classify individuals into four major categories; underweight (< 18.5 kg/m<sup>2</sup>), normal (18.5-24.9 kg/m<sup>2</sup>), Overweight (25-29.9 kg/m<sup>2</sup>), and obese ( $\geq 30$  kg/m<sup>2</sup>) [4]. A researcher further classifies obesity into three categories as tabulated below: (Reference)?

Classification	BMI (kg/m <sup>2</sup> )	Risk of Co-Morbidities
Underweight	<18.5	Low
Normal range	18.5-24.9	Average
Overweight	25.0-29.9	Increased
Obese class I	30.0-34.9	Moderate
Obese class II	35.0-39.9	Severe
Obese class III	>40	Very severe

Table 1.1: Classifications of overweight and obesity in adults

The classifications of overweight and obesity in adults shown in Table 1.1 according to BMI help us to know the different types of obesity and their morbidity [11]. BMI is calculated the same way for Adults and Children, but the results are interpreted differently [14]. For adults, BMI classifications do not depend on age or sex. For children and adolescents between 2 and 20 years old, BMI is interpreted relative to a child's age and sex, because the amount of body fat changes with age and varies by sex. Percentiles, specific to age and sex, classify underweight, healthy

weight, overweight, and obesity in children. The BMI-for-age determined for an individual indicates the relative position of the child's BMI value among children of the same sex and age.

#### 1.1 USAGE

BMI is very simple, inexpensive, and non-invasive surrogate measure of body fat. BMI could be an approximation for determining potential weight problem but not as a diagnostic tool. Studies have shown that BMI levels correlate with body fat and with future health risks [12]. High BMI predicts future morbidity and death. Through BMI measurements and values, physicians can recommend different health risk related to weight, for instance, skin fold measurements and fitness of a person. Nutritionist can decide the diet of a person and other screening related to personal health. BMI can be generally used as a statistical device for means of correlation between groups and estimation of adiposity [13]. This general correlation is particularly useful for consensus data regarding obesity and other various conditions.

#### 2. Work Methodology

The block diagram consists of the following elements as shown in Figure 2.1 below.

- a. Weighing bridge machine or Load cell with Amplifier.
- b. Load cell instrumentation amplifier/Calibration circuit.
- c. Height ultrasonic sensor.
- d. Arduino-Uno (ATmega328P) microcontroller
- e. LCD display.
- f. Buzzer with driver
- g. Power supply



Fig. 2.2: Block diagram of ABMI System



Fig. 2.3: The isometric view of the ABMI System

The development of an Arduino-Uno microcontroller-based ABMI machine consists of a load-cell in a Wheatstone bridge configuration to measure the weight of the subject ranging from 2 to 150kg. The electrical resistance of the Wheatstone bridges changes on the direct application of a force on the load cell and thus generates electrical output in millivolts (mV). The small output signal is later amplified with the use of instrumentation amplifier, and the calibration circuit converts the mechanical signal to electrical signal and then connected to Arduino Uno (AT mega 328p microcontroller) where the signal is converted into digital signal for processing. The object's weight is calculated using equation 2.1, where W is the weight of the object (Load or Force) in kg,  $V_m$  is the measured output voltage in millivolt by the application of the load (or force) on the Load Cell and the offset voltage,  $V_o$  is in millivolt as well. It is found to be  $\approx$  525.05mV.

$$W = gain * (V_m - V_o) \tag{2.1}$$



Fig. 2.3: The circuit diagram of ABMI

For the height measurement of the subject person, an ultrasonic sensor (PING ultrasonic sensor) is used, connected to  $RC_1$  and  $RC_2$  pins of the microcontroller. The sensor transmits ultrasonic waves on the application of a high

pulse on the sensor trigger input resulting in echo generation once it strikes the subject. The time it takes for the echo pulse to return back to the sensor after reflection from the object's head is calculated by the microcontroller to measure sensor-head the distance (see Fig. 2.2) using the Equation (2.2).

$$d_{os} = t * (0.0174) \tag{2.2}$$

where distance,  $d_{os}$  is in metres and t is in seconds.

The ultrasonic sensor is 2.135 metres from the load cell. The height of the object is simply calculated using equation 2.3, where height, h, is in metres and the  $d_{os}$  represent the distance between the head of the object and the ultrasonic sensor. The calculated height was computed in metres using equation 3.4 and the BMI was calculated using equation (2.2)

$$h(m) = 2.135 - d_{os} \tag{2.3}$$

The computed BMI data of an individual person involved is then automatically displayed on Liquid Crystal Display (LCD) connected to the appropriate port of the microcontroller along with the height (m) and weight (kg) data.

In order to determine the accuracy of the designed instrument, the subject data was compared with the data obtained from an existing commercial floor-type manual weighing machine (i.e. analog weighing machine) as well as the manual height. The measurement was performed on 60 healthy randomly selected students at Afe Babalola University, Ado Ekiti, Nigeria, comprising 38 females and 22 males with the ages ranging from 16 to 50yrs. MATLAB Programming was used to determine the correlation of the automatic and manual height, weight and the BMI measurement while MS-Excel was used to perform the appropriate statistical analysis that includes calculation of the Mean, Standard deviation and Standard error of mean, for the 60 students. The Fig. 2.4 is the Flowchart of the calculations involved.



Fig. 2.4: Flow chart of the design and calculations

## **3. RESULTS AND DISCUSSION**

The results of the design and development of an automatic automated BMI system constructed as well as manual BMI calculated values.



Fig. 5: Correlation of automatically and manually measured weight, height and BMI for 60 students of ABUAD



Figure 6: An error of automatically and manually measured weight, height and BMI for 60 students of ABUAD



Fig. 7 (a): The Bar chart of automated and manual height for 22 male students of ABUAD



Fig. 7 (b): Bar chart of automated and manual height for 38 female students of ABUAD



Fig. 8 (a): Bar chart of automated and manual weight for 22 male students of ABUAD



Fig. 8 (b): Bar chart of automated and manual weight for 38 female students of ABUAD



Fig. 9 (a): Bar chart of automated and manual BMI for 22 male students of ABUAD



Fig. 9 (b): Bar chart of automated and manual BMI for 38 female students of ABUAD

The BMI system has been successfully designed, tested and used for data collection and comparison for system authentication. The Manual and automated data comparison for 60 students, that is, 22 males and 38 females were illustrated in the graphs above. The difference in the bar-chart correlation for each data between the manual and automated value is as a result of improper positioning of the object and the human error in reading the stadiometer and weighing balance.

#### **4. CONCLUSION**

The BMI of a person helps to maintain the healthy lifestyle and indicates the serious health diseases. Many studies said that BMI machine is a health indicator. The designed ABMI is found to be very accurate because it has been used and compared with manual system. The adoption and use of electronic principle of ABMI machine will reduce the hustling and errors which may due human during the operation of manual device and calculation. The ABMI can also be applied as a statistical device to determine the human health related status.

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