DESIGN, CONSTRUCTION AND ANALYSIS OF MODIFIED AUTOMATIC BODY MASS INDEX SYSTEM FRAMEWORK

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Abstract

Body mass index diagnostic machine can be improved upon by including special additional features such as image capturing and data logging sub-systems with robust programmed software for prescription, as these would solve the problems of improper data documentation/referencing, user status monitoring, data incoherence and aftermath diagnosis. This study designed, constructed and analysed a modified automatic body mass index framework with additional features for solving problems beyond the conventional BMI machine. The materials for the design and construction are high density fibre (HDF) and acrylic casing for physical framework. The electronics components include ultrasonic sensor for user's height capturing, strain gauge load cell for measuring user's mass and raspberry pi 3B single-board computer with camera (input components), and smart screen for capturing user's image as output device, the raspberry pi SBC is used as microcontroller for coordinating all activities of sub-systems with python programming language for instruction. The system is powered with 2A/5V adaptor, and the 8 Mega pixel camera stand is adjustable to cater for various user's heights. The output live image of the user is displayed on 7inches raspberry pi smart screen of 1024 x 600 resolution capacity on GUI which contains all necessary button for parameters (height and mass) and stores it for future call. The system calculates the user's BMI, diagnose and give a prescriptive measure for normal/healthy mass. The system was calibrated, tested and analysed, and found to be efficient in terms of execution time, visual display quality, data retention and recall. It is recommended that these additional features should be included as modifications and improvement to conventional BMI machine to solve the existing problems.

Keywords: body mass index, graphical user interface, python, raspberry pi, diagnosis, single-board computer

Introduction

Human health is paramount and it is a major concern of monitoring that requires every aspect of science, technology and engineering for the success of every other sphere of life. One of the most importance health indices is the distribution of mass within matter (human body) which is an indication of obesity, underweight and normal or healthy body architecture (Meigs et al., 2006). This index is known as body mass index (BMI), it is about the mass, height and how matters within a sampling body are distributed all round. Body Mass Index (BMI) was formerly known as Quetelet index which is a measure for indicating nutritional status in adults based on mass acquisition and distribution within the volume of whole body (Varma et al., 2015). It is defined as a person's weight in kilograms divided by the square of the person's height in metres (kg/m^2) (Pfitzner et al., 2018). The summary of nutritional status based on body mass index for monitoring body's health status are classified in Table (1.1).

Table 1.1: Nutritional Status with Body Mass Index (Bailey & Ferro-Luzzi, 2015)

S/No	Body Mass Index	Nutritional/Health Status
1	Below 18.5	Underweight
2	18.5 – 24.9	Normal Weight
3	25.0 – 29.9	Pre-obesity
4	30.0 – 34.9	Obesity class I
5	35.0 – 39.9	Obesity class II
6	Above 40	Obesity class III

The BMI ranges are based on the effect excessive body fat has on disease and death and are reasonably well related to adiposity. BMI was developed as a risk indicator of disease; as BMI increases, so does the risk for some diseases. Some common conditions related to overweight and obesity include: premature death, cardiovascular diseases, high blood pressure, osteoarthritis, some cancers and diabetes (Ruth & Chan, 2010).

BMI is very easy to measure and calculate and is therefore the most commonly used tool to correlate risk of health problems with the weight at population level. It was developed by Adolphe Quetelet during the 19th century. During the 1970s report on the data from the seven countries study, researchers noticed that BMI appeared to be a good proxy for adiposity and overweight related problems (Ruth & Chan, 2010).

Based on the importance of BMI in human lives, it is therefore very crucial to realise an advanced system for monitoring this index as further indication and applications prevent and solve many health related issues. This health related machine can only be achieved by hybridization of discipline of concern; Physics with electronic and computer science. There should be inclusion of additional features as modification to conventional body mass index system, this is for usage beyond diagnosis but to prescribe monitoring, referencing and precautionary measures for safety health condition. Conventional BMI machine lacks user's data retention for documentation and monitoring, there is no provision for user's photographic image that can be used to convince doubting user and further analysis, and finally, there is no prescriptive measure for users that correspond to individual BMI status. Therefore, there is need for modification by including additional features that will cater for the above mentioned problems, features such as high resolution smart camera, a well robust computer programme that will calculate and prescribe solutions to abnormal body mass indices.

Body mass index requires some physical parameters in order to be estimated, these include height and mass of the user. Height is an important indicator of human health (positively or negatively). Most people may likely know their height up to a certain extent. But even being half an inch or an inch shorter could be a very important indicator to a person's health (Tunji et al., 2020). It is important to monitor the height of children that are growing at a healthy rate, and for the elderly it is important to monitor whether or not their height is decreasing or had decreased (Valarie, 2020). There are many devices developed to measure height but most comes with demerits such as technical-know-how, inaccuracy, tediousness. Among the tools used for measuring height are Meter rule, Horizontal length scale, Anthroprometric rod, Infantometer, Stadiometer, Oesteometric board (UNICEF SD. 2017; Deshmuk et al., 2017). All these mentioned devices need a trained personnel or someone with significant experience to carry out the height measurements.

Valerie (2020) in his study, "Digital height measurement sensor device" states that in order to achieve accurate height measurements, there must be some indication that the accelerometer on the device has reached a position that is parallel to the ground.

The use of this ultrasonic distance measuring device is useful in measuring the height. Instead of using devices such as a measuring tape, most of the traditional or old devices used for measuring are less reliable and requires more than one person to operate also take longer time (Rawaz, 2015).

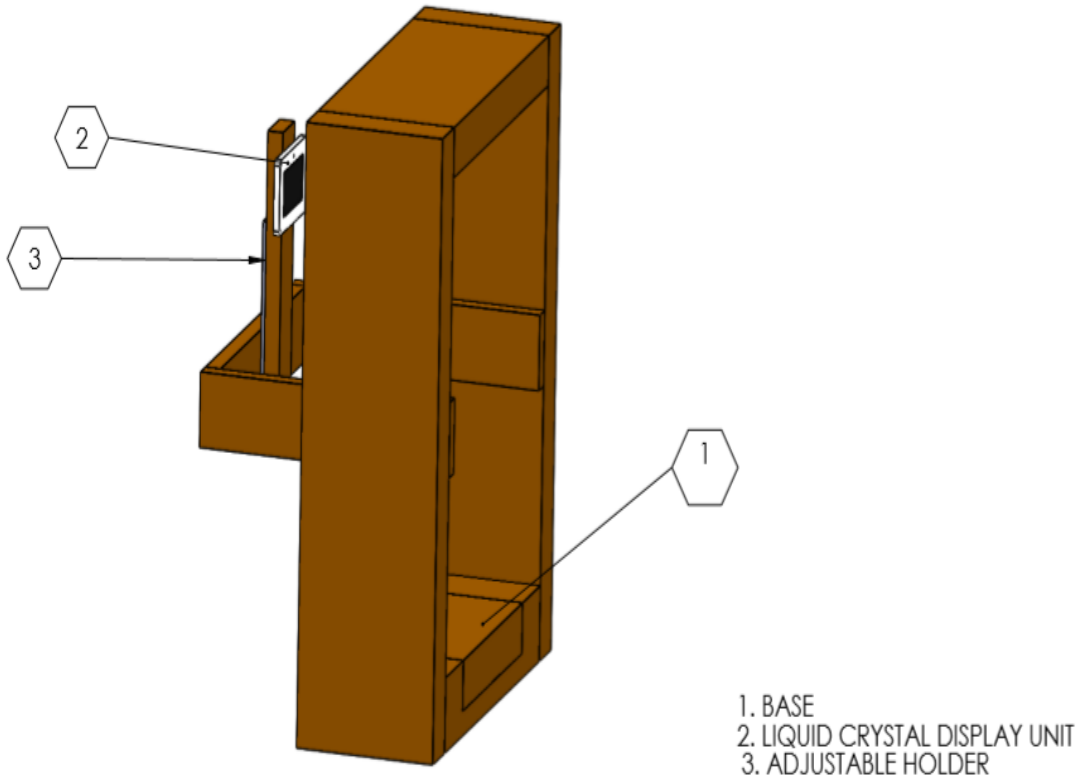
The problem of manual mass quantification by guessing material or object size (quantity of matter i.e. mass (kg) is a major problem that is prone to error. Available weighing balances and orthodox means of measurements are not accurate and memory retentive (Sandip et al., 2014; Akindele et al., 2018). Therefore, there is a need for careful design of a system that can accurately measure, classify, assign and retain measured data for further applications.

The manual or orthodox means of measuring objects height especially human is very tedious, time consuming and most of the time might be inaccurate. These manual methods are not retentive in terms of memory for future history check in case of monitoring human development, and are therefore prone to error (Pradeep et al., 2013). Therefore, there is essential need to design and construct an automatic height calculating system that is accurate, fast, robust, and memory retentive for proper monitoring of human development.

This study designs and analyses a modified automatic body mass index system framework which will automatically accepts user's input data (mass, height and image) through sensing, the input data will be assigned to individual user. Body mass index will be calculated for diagnosis purpose such as nutritional/health status classification, and finally, a comparative analysis will be done with standard BMI values for a prescriptive measure to be given in accordance with safety health conditions.

2. Methodology

This section of the study highlights the materials and describe the methodology used in achieving a modified BMI system. This involves the design of the system housing framework which was first designed in AutoCAD with appropriate dimension to accommodate user and other subsystem components. Figure (2.1) show the different views of the system, where the dimensions were carefully taken into consideration. The physical system was realised using High Density Fibre (HDF) material considering it strength to withstand various weight of the users. The base area dimension was 0.80m × 0.36 m, these dimensions were used to cater for different sizes of users.



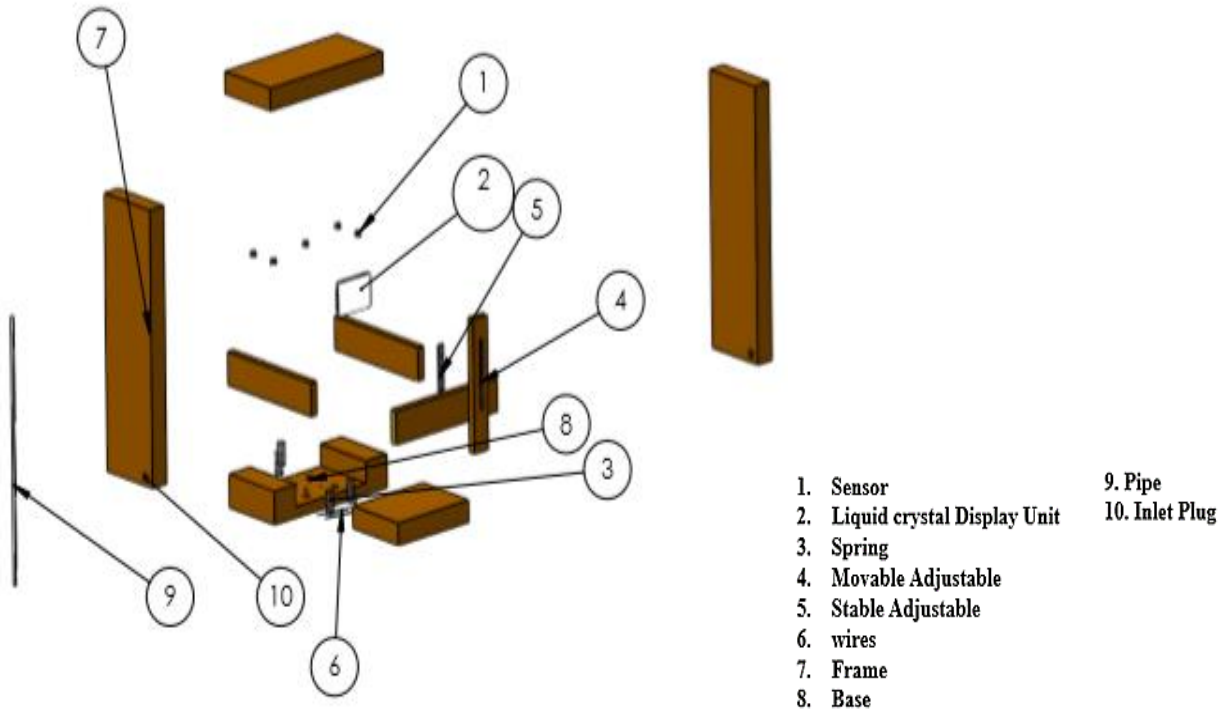


Figure 2.1: Isometric and Exploded View Modified BMI

The system as a whole has subsystems that measure each parameter needed in calculating the BMI.
The user's height is measured with HC-SR04 Ultrasonic sensor which interfaced with SBC raspberry pi 3 B. The ultrasonic sensor circuitry was designed and constructed on a Vero board before being mounted at the top of the frame above the user. Figure (2.2) shows the circuitry for measuring user's height.

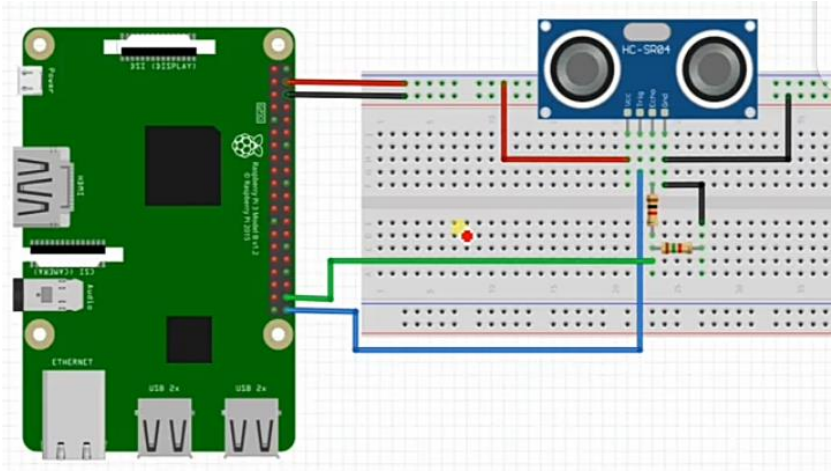


Figure 2.2: Interfacing HC-SR04 ultrasonic sensor with raspberry pi on bread board

User's Mass Analysis

Strain gauge load cell was interfaced with a driver (HX711) and placed beneath the user surrounded square by four spring that serves as absorber that dampen the forcing characteristics received by the load cell due to response from user's weight. Figure (2.3) shows the circuit diagram of the mass detector in connection with the raspberry pi.

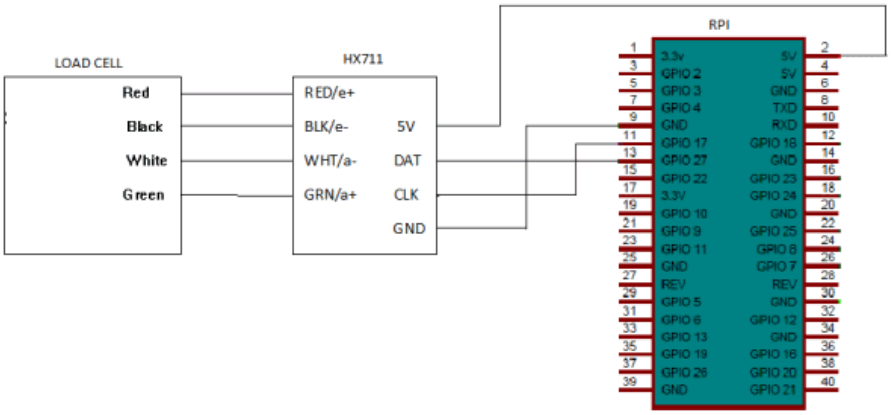


Figure 2.3: Circuit Diagram of interfacing load cell, Hx711 driver with Raspberry pi

Image Capturing

User's image could be captured by configuring a V2 camera that is embedded in the single board computer (raspberry pi). HDMI cable was used to connect the Raspberry Pi to the screen which serves as output device that displays the photographs captured by the Raspberry Pi camera. Figure (2.4) shows the raspberry pi V2 camera connected to the board.



Figure 2.4: V2 Raspberry Pi camera

The smart screen that displays user's BMI information (mass kg) is directly placed in front of the users with an adjustable stand ranging from (1.23m - 1.68m) The stand/base where the user stand is the dimension of (0.40m x 0.36m).

3. Results and Discussion

System Framework

This section of the study shows the modified body mass index machine after assembling various components and subsystems following the methodology designed earlier in this study. The system architecture framework was achieved with HDF material in which other subsystems are coupled. Figure 3.1 shows the constructed BMI system from the AutoCAD design.



Figure 3.1: Modified BMI Machine with Users

The dimension of systems full height and width is 2.14*m* where the base area dimension is 0.80m × 0.36 m, these dimensions were used to cater for different sizes of users. The maximum average human height is referenced to be 6feet which is equal to 1.829 m.

User's Mass Analysis

The smart screen that displays user's information (mass kg) is directly placed in front of the users with an adjustable stand ranging from (1.23m - 1.68m). The stand/base where the user stand is the dimension of (0.40m x 0.36m). Load cell was located beneath the basement which senses occupant mass, placed directly under occupant's foot. The load cell is surrounded by square MDF platform which contains four equidistantly spaced spring that serve as absorber that dampens the forcing characteristics received by the load cell due to response from user's weight. The force/spring constant of the spring was evaluated based on Hooke's law.

User's Height Analysis

The Ultrasonic sensor was placed above the user at the top of the system at a distance 2.14 m from the base/foot of user. When the transmitter side of the sensor sends signal out the receiver waits to get feedback by the process known as reflection as a result of the user's head which forms the obstacle. The distance between the user's head/obstacle to the sensor/top of BMI is evaluated and removed from the total height of the system in order to calculate user's height. The sensor measures the distance from the sensor to the barrier.

The distance measured by the sensor x speed of sound (3400 cm/s) = $\boldsymbol{H_a}$

The result 2 was converted to meter by dividing by 100 = $\boldsymbol{H_{am}}$

The maximum height ($\boldsymbol{H_{max}}$) = 7.021 ft = 2.14 m

The user's real height, $H_u = H_{max} - H_{am}$ (3.1)

System Image and GUI Analysis

A single-board computer (raspberry pi 3) is used as multifunctional component that accepts data from the electronics subsystems of the BMI (Ultrasonic, strain gauge load cell, and V2 camera circuitries) and processes it, assign, store, coordinate the activities of the system as a whole, and gives visual outputs which are displayed on a 7 inches' raspberry pi smart screen with the help of set of instruction written in python programming language. An interactive graphical user interface GUI was designed for user to access during use. Figure 3.2 shows a screenshot of the system interface during testing.



Figure 3.2: Modified BMI Interactive GUI during Testing

After powering the system, operating system boot to the desktop interface and the BMI application is launched. The GUI shows all the parameters (mass, height and image) needed for BMI evaluation as the user mounts the system for use. After a one time click on the "Capture Image" button the live video frame on the GUI would snap the user's image and store for further reference. Based on the user's acquired data the BMI is calculated; the BMI health/nutritional status would be displayed then a prescriptive interpretation would be offered after diagnosis.

4. Conclusion and Recommendations

This study has designed, constructed and analysed a modified body mass index machine., The machine included additional features from its conventional counterpart. It offers user's image analysis, data documentation and prescriptive advice for healthy life style.

The study was able to design and construct necessary subsystems circuitries that calculate needed parameters for BMI evaluation. User's height was measured with HC-SR04 ultrasonic sensor and functional circuitry; the sensor uses the principle of physics to send out signal through transmitter then the receiver waits for echo of the signal after obstruction by user's head. This process calculates user's height accurately without any human intervention.

The system is able to measure user's mass through strain gauge load cell of 100kg capacity. This was connected with HX711 driver and placed at the center of four spiral springs to reduce damping.

The physical image of the user is captured by V2 raspberry pi camera, the system is able to capture, display, and store image together with other BMI parameter with the help of python programmed scripts embedded in the SBC.

The subsystems were assembled to achieve a fully modified functional body mass index machine, which was tested and calibrated.

This study recommends that the designed modified body mass index system is ready for utilization for male and female with maximum mass less than 100kg to avoid overloading the load cell sensor. It can be used to monitor the nutritional and health status of individual.

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