

DESIGN AND CONSTRUCTION OF MODIFIED FRAMEWORK FOR AUTOMATIC BODY MASS INDEX SYSTEM

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ABSTRACT

Body mass index machine is an essential diagnostic tool for monitoring body mass distribution and corresponding health risks in humans but the conventional design does not give room for additional features for advance diagnosis, documentation and prescriptive measures. Therefore, the embodiment of conventional and additional subsystems requires modification in terms of system framework. This study designed and constructed a modified BMI framework beyond a conventional means of evaluating and monitoring human health which makes provisions for user's image capturing, automatic mass and height quantification subsystems. The system architecture framework was designed with computer aided design software, AutoCAD and constructed from locally made high density fibre, HDF. Through drilling, cutting and fitting all necessary subsystems/components within spatial locations were provided in the modified system. The load cells which sense the user's mass were placed within four springs in a square arrangement at the basement of the system for damping and absorbance characteristics analysis. The system accommodate all the proposed additional diagnosis features and users of different size/height for improvement. The ultrasonic sensor which is placed above the user at the top of the modified BMI to automatically measure user's height and the side of the system was calibrated to form meter rule for verification. All measured BMI parameters are displayed on raspberry pi smart screen which is fixed on adjustable hanger to cater for different user height, in front of the user for image capturing and parameters visualisation. All subsystems within the BMI worked properly, and the system was found to accommodate user irrespective of mass and height. It is recommended that this modified BMI system hardware should be complemented with robust application software for further advances advanced sophistication.

Keywords: AutoCAD, body mass index, conventional, framework, high density fibre.

1. INTRODUCTION

The state of well-being of any living organism is refer to as heath status, these conditions are being determined by many factors that result from what the body consumes weather in terms of perception, oral consumption and many more that have direct impact or contact with organism system. Therefore, health is the condition of body that requires proper monitoring for safety. The response of body system to any of the above mentioned parameters could be observed physically, mentally and medically where an important indication of physical response is body mass index. Body mass index (BMI) is a measure of

body mass quantification which gives an estimated value of how the body mass is distributed, a means which can be used to diagnose many health related issues such as obesity, kwashiorkor and malnutrition (Meigs *et al.*, 2006). 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/m²) (Pfitzner et al., 2018) as shown in equation (1.1)

$$BMI = \frac{\text{Mass (kg)}}{[\text{Height (m)}]^2} \quad (1.1)$$

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 and Chan, 2010).

In order to calculate BMI, measurement of physical parameters such as height and mass of the body are required but these are for conventional BMI machines. This study adopts the design and construction of modified body mass index machine framework based on additional features for diagnosis and prescriptive processes.

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 (Jayeoba & Olaifa, 2022). 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, and a corresponding framework that will accommodate these additional features should be properly designed and constructed.

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, Anthropometric rod, Infantometer, Stadiometer, Osteometric 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 designed and constructed a modified automatic body mass index system framework which will accommodate both conventional features and modified features.

2. METHODOLOGY

This section of the study highlights the materials and describe the methodology used in achieving a modified BMI system framework. 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 to 2.3, 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 its 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

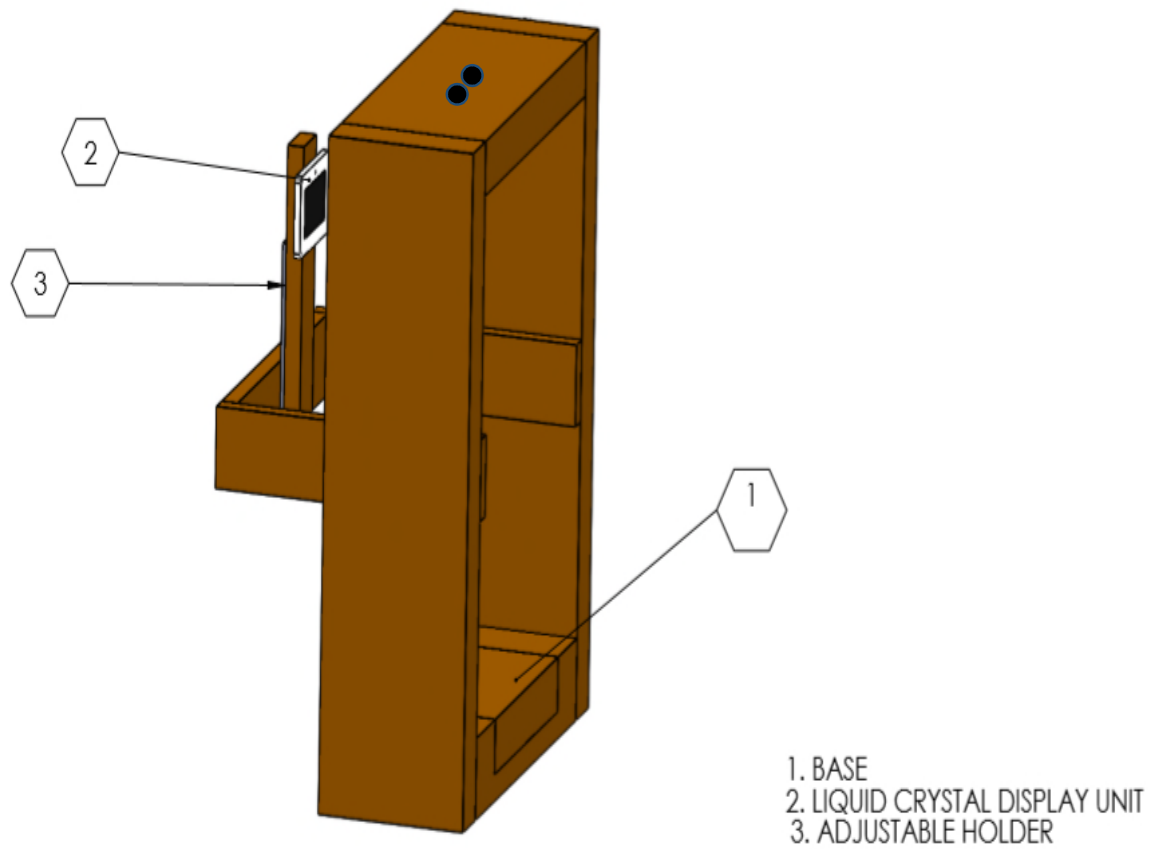


Figure 2.1: Isometric View Modified BMI

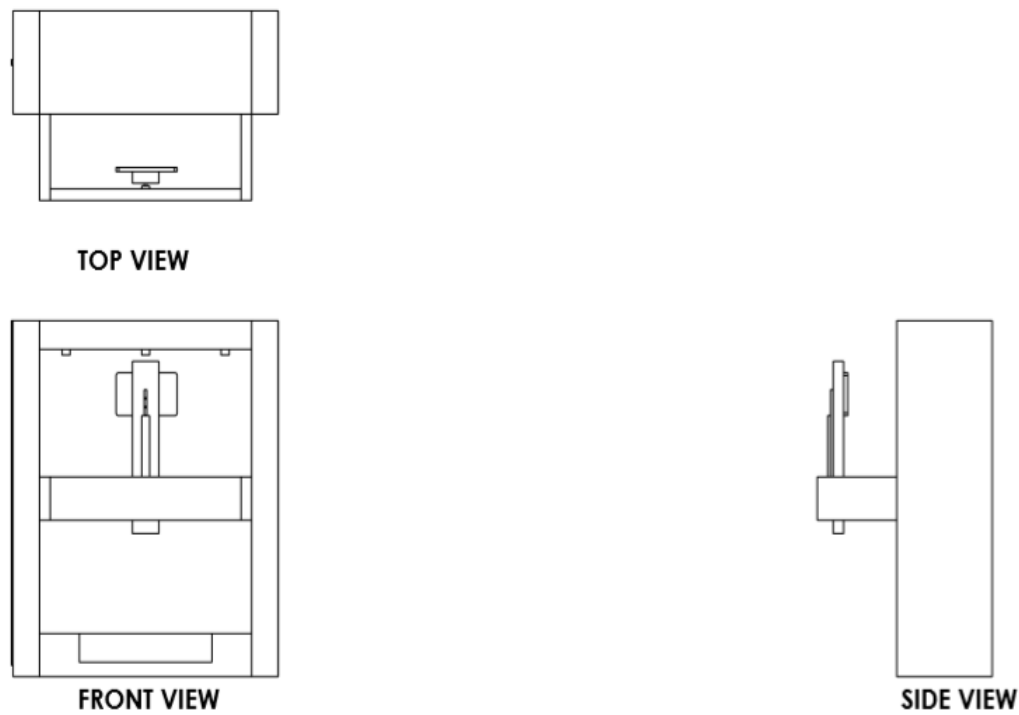
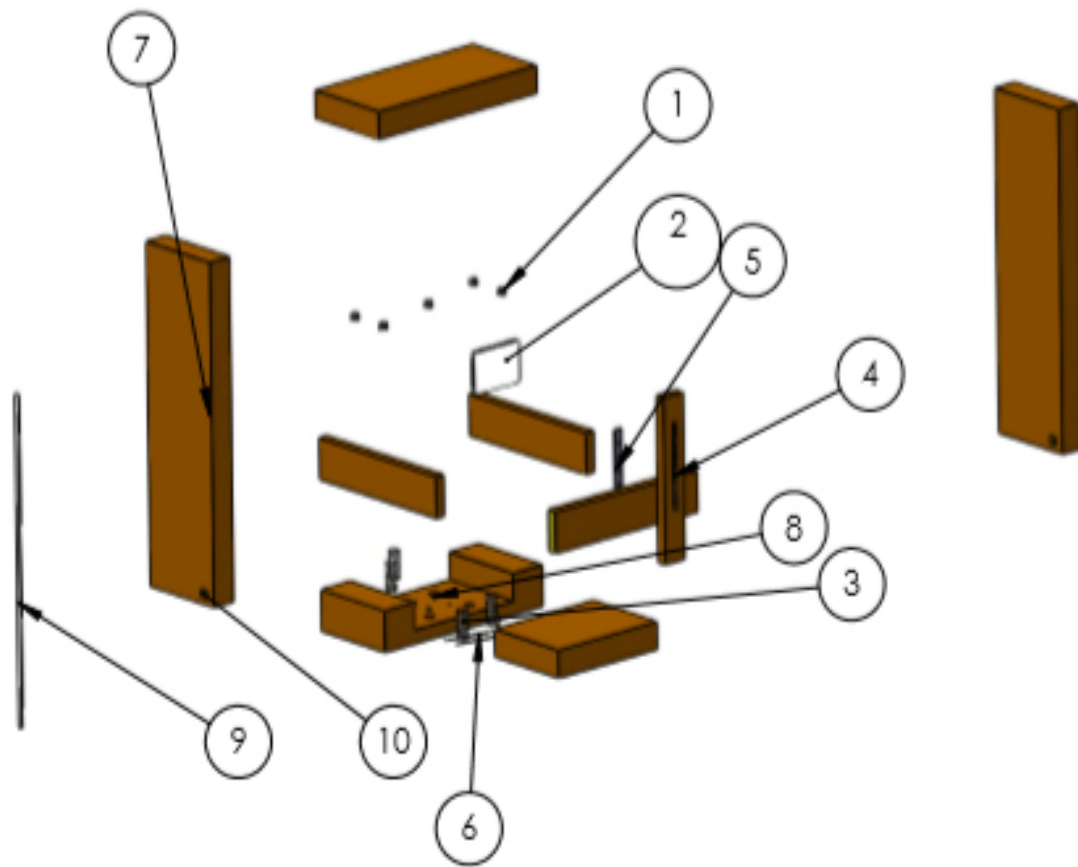


Figure 2.2: AutoCAD Orthographic View of the BMI System



- | | |
|--------------------------------|----------------|
| 1. Sensor | 9. Pipe |
| 2. Liquid crystal Display Unit | 10. Inlet Plug |
| 3. Spring | |
| 4. Movable Adjustable | |
| 5. Stable Adjustable | |
| 6. wires | |
| 7. Frame | |
| 8. Base | |

Figure 2.3: Exploded View Modified BMI

2.1 Height Measuring Subsystem

The design creates room to accommodate subsystems that measure and capture each parameter needed in calculating the BMI. The user's height can be measured automatically with HC-SR04 Ultrasonic sensor which is placed above the user as he steps in the BMI framework system. It was carefully constructed to accommodate user of various height. The height sensor is wired to be interfaced with Single Board

Computer, SBC raspberry pi 3 B for real-time status monitoring.

2.2 Mass Quantification Subsystem

Mass of the user can be sensed and measured by strain gauge load cell which was interfaced with a driver (HX711) and placed in a special base designed/constructed beneath the user. The load cell is surrounded square by four (4) springs that serve as absorber to dampen the forcing characteristics received by the load

cell due to response from user's weight. The load sensor data obtained from the user would be sent as input signal through a wired network to the SBC and finally sent

as output signal to graphical user interface for display and visualisation. Figure 2.4, shows the subsystem design and construction for mass quantification

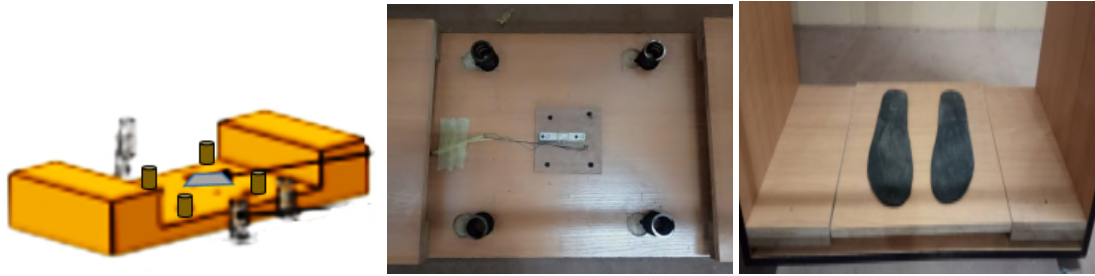


Figure 2.4: User mass quantification subsystem at BMI Basement

2.2 Image Capturing BMI Subsystem

User's image could be captured as an additional feature 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 2.5, shows the raspberry pi V2 camera connected to the board.

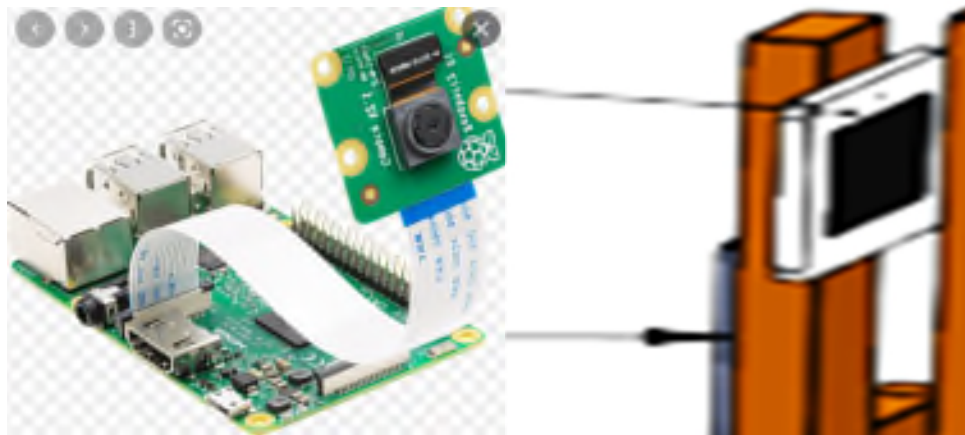


Figure 2.5: Image Capturing subsystem V2 Raspberry Pi camera SBC.

The smart screen that displays user's BMI information (mass kg) is directly placed in front of the users with a vertical adjustable hanger having degree of freedom ranging from (1.23m - 1.68m) to cater for users of different heights category for full image capturing. The stand/base where the user stand is the dimension of (0.40m x 0.36m).

3. RESULTS AND DISCUSSION

3.1 System Framework

This section of the study shows the modified body mass index machine

framework 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 were coupled.

The framework was designed and constructed to accommodate additional features in conjunction with conventional BMI, Figure 3.1, shows the constructed BMI system framework following the AutoCAD design.



Figure 3.1: Modified BMI Machine with User

The constructed framework majorly comprises of three subsystems; the base of the system contains the mass quantification unit where load cell is placed and covered with HDF slab that is supported by four square springs beneath the user.

The dimension of systems full height and width is 2.14m 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.

3.2 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 HDF 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.

3.3 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 considering the maximum user's height to be 1.83 m. This was carefully designed and constructed with appropriate gap between user's head and the height sensor for measurement purpose. The ultrasonic sensor uses the principle echo (reflection of signal) to measure the distance between user's head and sensor (2.14m) in order to calculate the user's height from the base of the system. User's height (H_u) is calculated by equation 3.1:

$$H_u = H_{max} - H_{hs} \quad (3.1)$$

Where: H_{hs} is the distance between user's head and ultrasonic sensor,

H_{max} is the maximum of the system (2.14m).

The system can therefore accommodate users of different height (short or tall).

3.4 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 instructions. 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

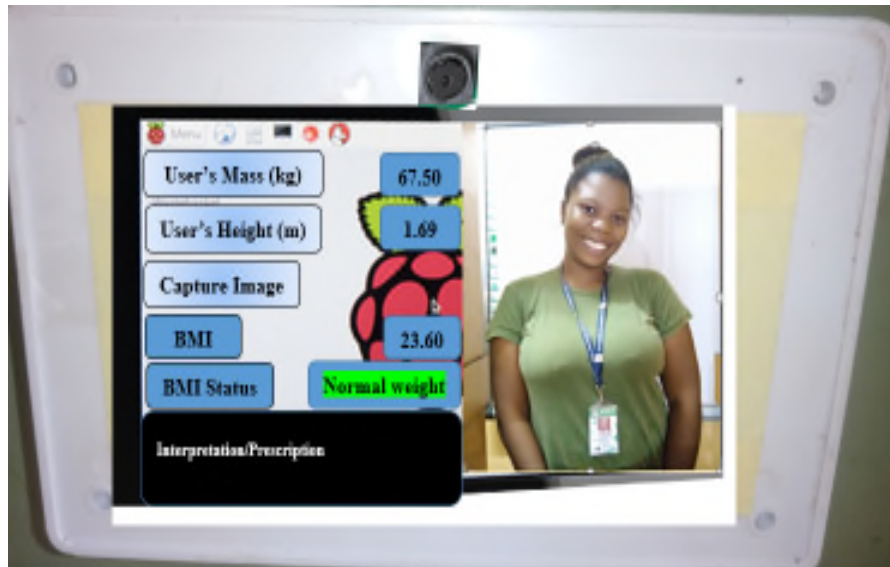


Figure 3.2: Modified BMI Interactive GUI during Testing

The SBC which serves as the power house is packaged and fitted into a rectangular casing made from acrylic material. The complete display box was hung on the adjustable hanger attached to the BMI framework.

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 and constructed a modified body mass index machine framework. The machine included additional

features from its conventional counterpart. It offers user's image analysis, data documentation and prescriptive advice for healthy life style. It was designed and constructed to accommodate additional subsystems.

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 well placed above the user; 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 can measure user's mass through strain gauge load cell connected with HX711 driver and placed at the centre 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. The system is stable and can accommodate user of any size depending on the load cell capacity. The subsystem housing the GUI box is collapsible for portability purpose. This study recommends that the designed modified body mass index system framework can be adopted to cater for additional features. It is ready for utilization for male and female with a flexible components utilisation. It can be used to monitor the nutritional and health status of individual.

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