Design and Implementation of a Body Mass Indicator (BMI)

Team members

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Abstract

Height, Weight and the Body Mass Index (BMI) are among the common medical parameters measured upon a patient's visitation to a medical facility. The Body Mass Index is a ratio of the weight (in kilograms) to the square of the height (in meters) of a patient. The BMI is widely considered as an indicator of the body fatness of a person. It is grouped into four categories namely; underweight, normal, overweight and obesity. This project design basically measures the height and weight of the patient, computes them to obtain the body mass index of the patient and displays these important measurements. It also displays appropriate recommendations that correspond to the patient's or user's BMI.

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1.0 Introduction

The body mass index is an anthropometric measurement which involves a ratio of the weight (in kilograms) to the square of the height (in meters) of a person, thus kg/m^2. The BMI in humans varies among individuals of different ages, genders, races, professions, etc. Like all other anthropometric measurements, it is only a surrogate indication of body fatness but is widely used as a factor for the development of or the prevalence of several health issues. In addition, it is widely used in determining public health policies. The BMI has been useful in population-based studies by virtue of its wide acceptance in defining specific categories of body mass as a health issue[1]. Measuring of the BMI is not that complicated as it can be computed after obtaining the weight and height of the patient. See *Table 1* for various categories and ranges for BMI.

Table 1 Body Mass Indexes and their categories for Children and Adults [2]

BMI Categories for Children and Adolescents	**BMI-for-Age and Gender Percentiles for Ages 2-20**	**BMI Categories for Adults**	**BMI for Adults (kg/m^2)**
Obese[‡]	≥95th	Obese	≥30
Overweight[‡]	≥85th and <95th	Overweight	≥25 and <30
Normal	≥5th and <85th	Normal	≥18.5 and <25
Underweight	<5th	Underweight	<18.5

2.0 Objectives

The projects objectives were:

1. To determine the height, weight and body mass index of a patient in an autonomous way.
2. To indicate the body mass status of the patient and give recommendations corresponding a particular index.
3. To make it time-efficient by making it faster and minimize the workload of health personnel (work-efficient).

3.0 Equipment

1. Load cell with HX711 amplifier

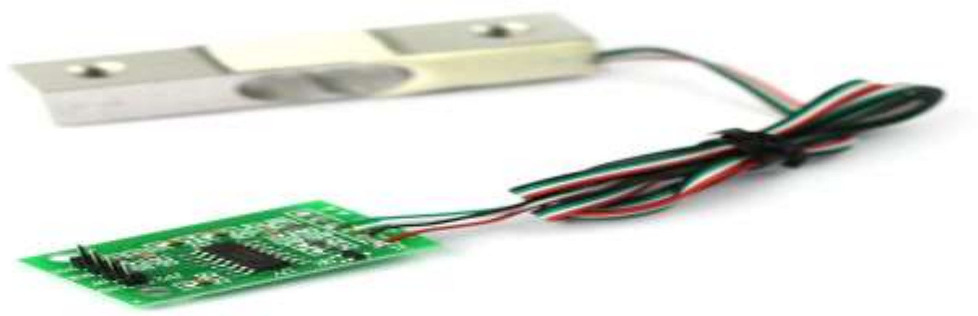


Figure 1 Load cell with HX711 amplifier

2. 16*2 LCD with I2C module

Figure 2 16*2 LCD with I2C module

3. Ultrasonic sensor

Figure 3 Ultrasonic Sensor

4. Arduino Uno Board

Figure 4 Arduino Uno Board

5. Jumpers/Connectors

Figure 5 Jumper wires/connectors

6.LEDs

Figure 6 Light Emitting Diodes (LEDs)

7.Resistors

Figure 7 Resistors of different resistance

8. 3D printed model case/cover

Figure 8 A 3D printed model case/cover

9. Arduino Integrated Development Environment for writing sketch/code

10. Wooden Stand/Support

4.0 Methodology

With little knowledge in arduino programming and its hardware implementation, the first few weeks of our time range involved intense learning of introduction to arduino, its hardware implementation and code writing. The entire project methodology was partitioned into four stages namely; the height stage, weight stage, BMI stage and display stage.

4.1 The Height Stage

The height stage involved writing of a code and implements a design using the ultrasonic sensor to measure the height of a patient. The ultrasonic sensor has four terminals, VCC, TRIG, ECHO and GND, which were all connected to the arduino board. The terminals with the corresponding pins they were connected to on the arduino board (see *table 1* and *figure 9* below)

Table 2 Terminals and Pin connection on Ultrasonic Sensor

Terminals on Ultrasonic sensor	*Pins on Arduino board*
VCC	5V
Trig	Digital pin 4
Echo	Digital pin 3
GND	GND

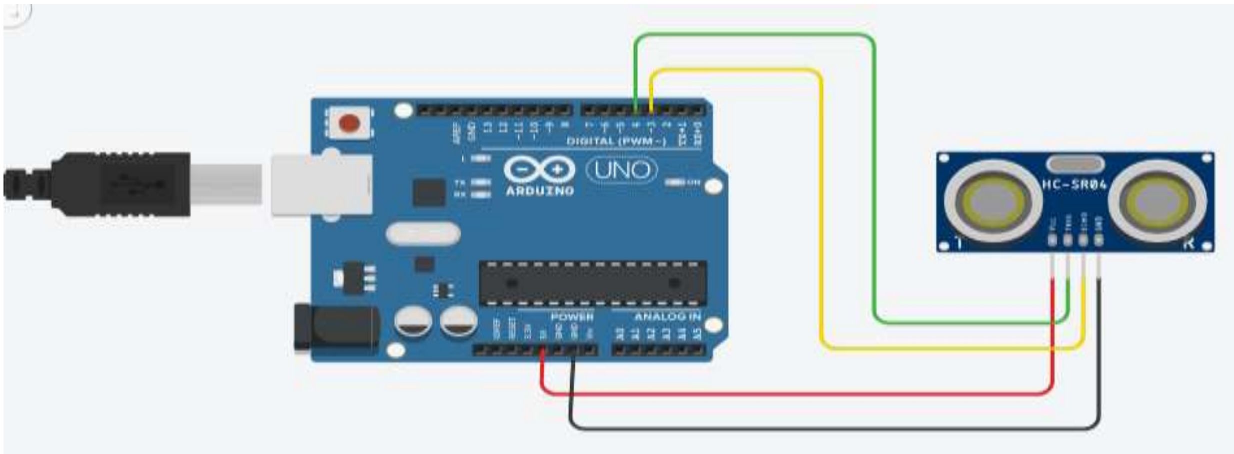


Figure 9 Ultrasonic connection to Arduino Board

In the code, the trig pin is set to high to produce ultrasound waves for some microseconds and set back to low. The echo pin is then set to detect the reflected ultrasound waves and compute the time duration the ultrasound took before reflected using the *pulseIn* function. The duration is further converted to distance in inches and stored in a variable *gapLengthInInches*. The fixed distance between the ultrasonic sensor and the base of the wooden stand was measured and saved in the variable *fullLength*. The height of the patient is then obtained by subtracting the *gapLengthInInches* from the *fullLength.* This entails how the height of the patient was obtained.

4.2 The Weight Stage

For the next stage which was the weight part, where a weight measuring scale was designed using the load cell with an HX711 amplifier and a code was written to run it. The output of the load cell is very minimal, hence the need for an HX711 amplifier to amplify that output into a significant value. The Load cell was used to construct a weighing scale together with some wooden supports. The four wires of the load cell were connected to the excitation terminals (E+ and E-) and output terminals (A+ and A-) on the HX711 amplifier. The VCC, GND, DT, SCK terminals on the amplifier were then connected on to the arduino board. The terminal and pin connection between the load cell, amplifier and arduino board is shown below. (See *Table 2* and *Figure 10*)

Table 3 Terminals and Pin connections between load cell, Hx711 amplifier and Arduino board

Terminals	*Pins connection on amplifier*
Red wire	E+
Black wire	E-
White wire	A-
Green wire	A+
Pins on terminal	*Pin connection on arduino board*
VCC	5V
GND	GND
DT	Digital pin 6
SCK	Digital pin 5

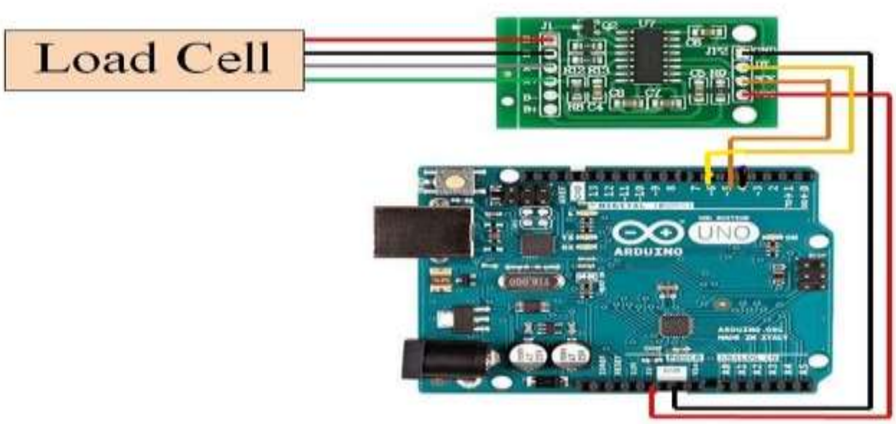


Figure 10 Load cell with HX711 and arduino board connection

Before the load cell can be implemented, a calibration code has to written to determine the calibration factor of the weighing scale's load cell. The calibration factor caters for the weight of the wooden support on the load cell and other external factors which causes minimal but significant changes in the load cell. We came up with a calibration factor of -101. Calibration code can be found in the link at the end of the report (*See Appendix A*). Using the calibration factor, a code was written to run the load cell weight scale in order to measure the weight in grams from the weighing scale using the *scale.get_units* function. The value obtained in grams is divided by 1000 to convert to kilogram. The weight in kilogram is then both displayed and used in BMI computation.

4.3 The BMI Stage

To achieve the objectives of this project, computation of the body mass index was a necessity and it was accomplished at this stage using the height and weight values obtained in earlier stages. The formula for calculating BMI is the ratio of weight in kilograms (kg) to the square of the height of the patient in meters (m^2), thus $BMI = \frac{Weight(kg)}{Height^2(m^2)}$. The height which was originally obtained in inches was converted to meters using a user-defined function called *InchesToMetres*. The computation of the BMI is done using the expression *patientWeightInKg/pow(patientHeightInMetres,2)* and stored in the variable *patientBMI*. Henceforth, the height, weight and BMI value of the patient is ready to be displayed.

Figure 11 Body mass index calculation

4.4 The Display Stage

For the final stage, it basically involved displaying the parameters obtained. A 16*2 LCD with an I2C module for simpler connection was used for this function. The terminals on the module were connected to pin outs on the arduino board. The connections are shown below. (See *Table 3* and *Figure 12*)

Table 4 LCD terminal and Pins connection on Arduino board

Terminals	*Pins on Arduino board*
VCC	5V
GND	GND
SDA	Analog pin A4
SCL	Analog pin A5

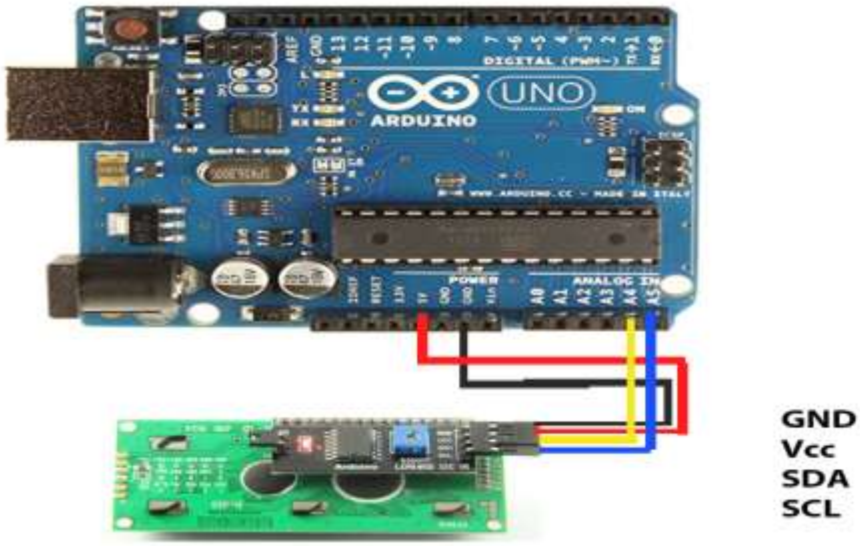


Figure 12 LCD with I2C module connection with Arduino Board

Because of the small number of rows of the LCD, the display of the parameters is in three steps/displays. This was achieved by initializing the screen periodically and using loop functions. The height and weight of the patient is shown in the first display and delayed for some time, afterwards the screen is initialized and the BMI value and status of the patient, either underweight, normal, overweight or obesity are displayed in the second step. Based on the BMI, it gives recommendations corresponding to these statuses in the third display before the LCD screen is cleared for the next measurement.

Also LEDs, whose colors are significant in visual communication, were implemented in the design. Each of the four LEDs used, blinks in correspondence to a particular BMI status. All the LEDs were connected to a 220Ω resistor. (See *Table 4* and *Figure 13*)

Table 5 Led Pins and connections on Arduino board

LED color	*Digital pin connection*	*Color code interpretation*
Red	Pin 10	Danger(Underweight)
Green	Pin 11	Normal
Yellow	Pin 12	Warning(Overweight)
Red	Pin 13	Danger(Obesity)

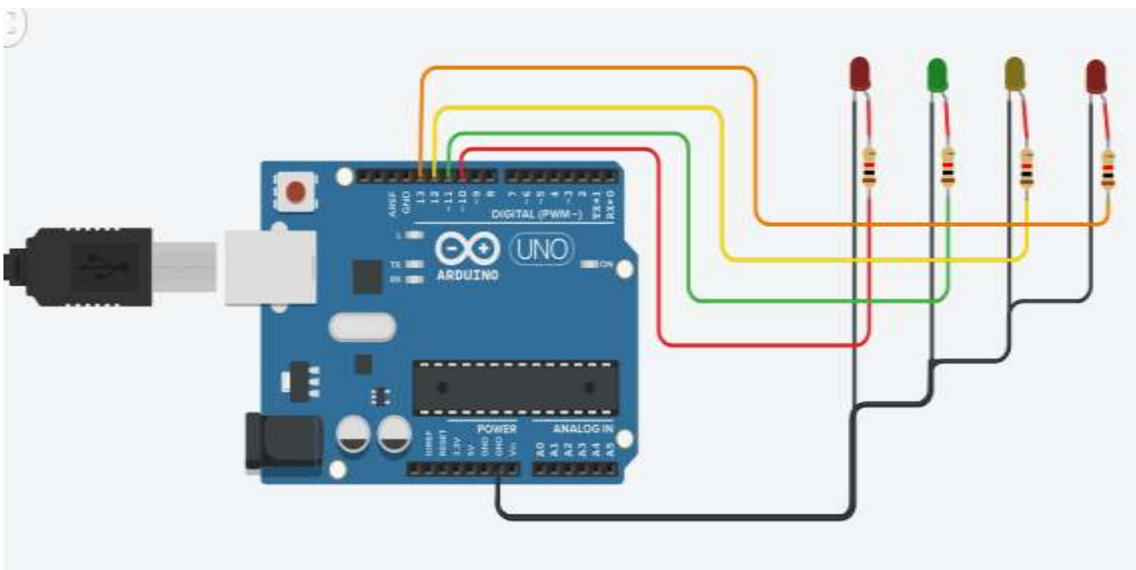


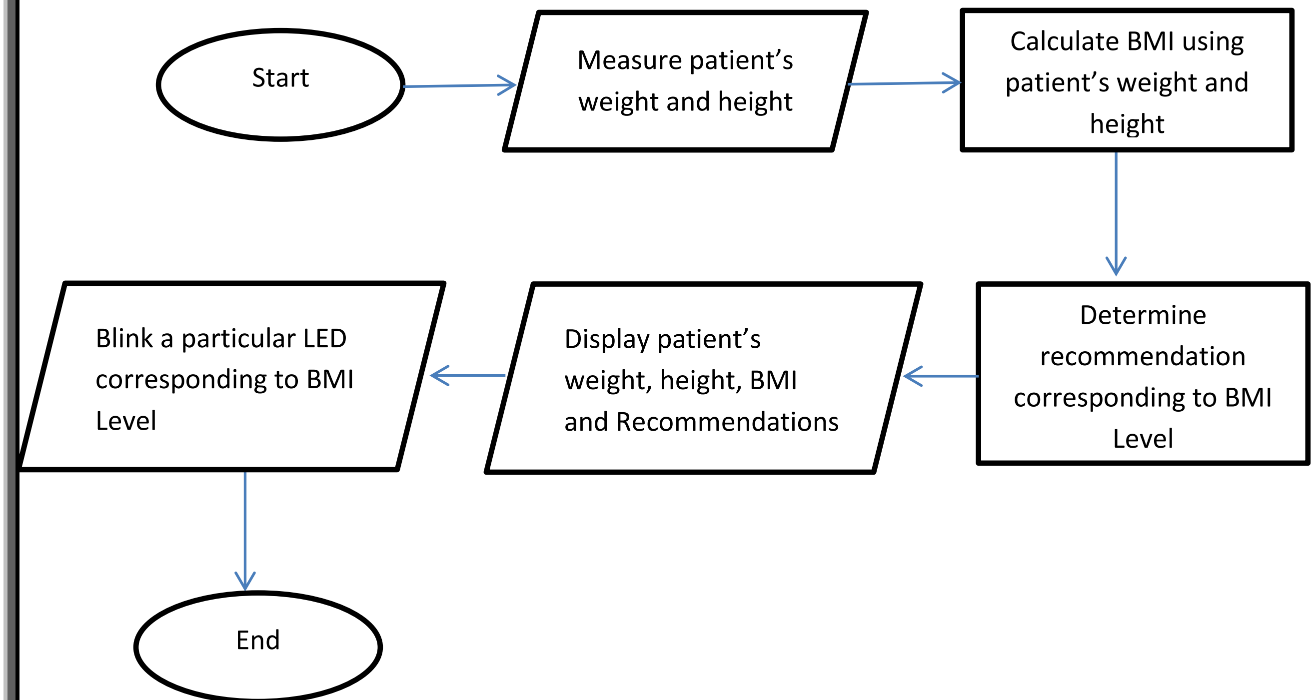
Figure 13 LEDs connection

In completion of the design, some of the components used in the various stages were connected together and fixed in the 3D-printed casing. A final code was written to achieve the task of implementing all the various functions together in a few seconds (See *Appendix B*). With the code uploaded unto the arduino board, the 3D casing with all the connections done inside was sealed. The 3D print case together with the ultrasonic and load cell weighing scale was assembled on the wooden stand.

Our final design implemented is shown in *Figure 14* below;

Figure 14 An image of the design implementation

4.5 Flow chart for working principle of project design



5.0 Conclusion

The objectives of the project were achieved as the project design is able to measure the height, weight and compute the BMI in an autonomous way, thus enabling it to be work or energy efficient. It also displays these measurements for recording by the health personnel. Finally the measurement of these parameters of a patient occurs under 30seconds, hence making it time efficient.

6.0 Challenges

Few challenges were encountered during the building of the hardware design. At the height stage, an issue was encountered whereby the reading obtained for the height was inaccurate. After troubleshooting, it was found out that the ultrasonic was faulty, which could not detect the reflected ultrasonic waves and there were some breaks in the jumper wires initially used. Resolving this issue, a new ultrasonic sensor and new yards of flexible wires were used to replace the old ones entirely. One has to be careful when implementing such designs.

Few bugs were also encountered while writing the program, which we resolved by debugging and fixing the errors.

7.0 Recommendations

1. A temperature measuring unit/sensor such as the infrared sensor can be included in the project design to determine the temperature of the patient.
2. A RadioFrequency module can also be included to transfer these measured vitals wirelessly to the hospital/clinic's database system making the design an Internet on Thing (IoT) system.

8.0 References

1. [1] F. Q. Nuttall, "Body Mass Index Obesity, BMI, and Health: A Critical Review," 2015. doi: 10.1097/NT.0000000000000100 128.
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5. Arduino scale with load cell and HX711 amplifier https://www.instructables.com/Arduino-Scale-With-5kg-Load-Cell-and-HX711-Amplifi/
6. Pictorial presentation of Body Mass Index calculation https://www.w3resource.com/python-exercises/python-basic-exercise-66.php

9.0 Appendices

Appendix A: Link to code used to calibrate load cell and determine its calibration factor:

https://github.com/CollinsSam10/Body-Mass-Indicator/blob/main/Load%20cell%20calibration%20code.ino

Appendix B: Link to final code/sketch implemented in project design:

https://github.com/CollinsSam10/Body-Mass-Indicator/blob/main/Main_code.ino