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Development of Automated Body Mass Index Calculation Device

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Abstract-
The purpose of this study is to calculate the weight and height measurement and display its BMI measurement automatically upon entering in the system jamb and save the BMI measurement in the system's database. The proponents designed a circuit that combined the functions of the ultrasonic proximity sensor and weight sensor in one system and developed software embedded in two microcontrollers which control and manipulate the whole system of the design project. The design utilized the hardware tools which include ultrasonic proximity sensor, weight sensor, Gizduino ATMEGA328 and sensor Amplifier while for the software requirements include Windows 7, SQL Server Management Studio, Microsoft Visual Studio(.NET), Microsoft Visual Studio, and Arduino (software). After several testing of program to the gizDuino, the proponents distributed the software programs to Microcontroller Unit (MCU). After uploading the software it was interfaced to the hardware to test its functionality. Series of tests were conducted and it reveals accurate results compared to manual computation of BMI. The design has some limitations that the system is not suitable for person weighing 90kg and above; this can only accommodate one person at a time; this not suitable for people with dwarfism and this is not suitable for people with mannerism movement.

Keywords: Automation, Body Mass Index, Gizduino, Microcontroller

Introduction

In this generation, there are many existing technologies that help to distinguish healthy from unhealthy persons. Many software developers created an application that monitors man's proper weight according to height. These include BMI calculators that exist on application stores that can be downloaded through internet. This software requires height and weight to measure the body fat. It provides correct information of the body that you can track on a consistent basis. It determines exactly what size you should be for your specific build.

Before 1980, doctors generally used weight-for-height tables, one for men and one for women that included ranges of body weights for each inch of height. These tables were limited because they were based on weight alone, rather than body composition. BMI become an international standard for obesity measurement in the 1980s. The public learned about BMI in the late 1990s, when the government launched an initiative to encourage healthy eating and exercise [1].

The body mass index (BMI) is a measure of relative weight based on an individual's mass and height. In the nineteenth century, a Belgian statistician named Adolphe Quetelet came up with the Quetelet Index of Obesity, which measured obesity by dividing a person's weight (in kilograms) by the square of his or her height (in inches) [2].

While the formula previously called the Quetelet Index for BMI dates to the beginning of the 19th century, the new term "body mass index" for the ratio and its popularity date to a

paper published in the July edition of 1972 in the Journal of Chronic Diseases by Ancel Keys, which found the BMI to be the best proxy for body fat percentage among ratios of weight and height [3]. BMI provides a simple numeric measure of a person's thickness or thinness, allowing health professionals to discuss overweight and underweight problems more objectively with their patients.

Nowadays, Body Mass Index (BMI) is calculated manually through measuring tape and weighing scale. There are charts and graphs that show the ratio of proper weight according to height measurement to determine whether a person has too much body fat. This takes time and effort to calculate the body fat. The calculation of BMI occurs in hospitals and use by health professionals to determine healthy weights and risky weights. It is also used by schools to diagnose students in their various weight classification (Underweight, Normal, Overweight, and Obese) when conducting feeding programs. Some universities utilized this calculation in physical examination and medical purposes. Also, fitness gyms used BMI calculations to evaluate their clients and help them reach their proper weight. Pediatricians employ BMI percentile screening for health monitoring including children, teenage and adult, those working in a hospital or medical school, and those with fewer patients on public insurance. Parents often wondered if their children are overweight, underweight or just right. Using body mass index calculator can figure out if the child is in an appropriate weight for his or her height [4]. Dinsdale [5] stated that BMI provides a good indicator for levels of body fat, and it is known that having a BMI that is either too low or too high is associated with an increased risk of ill health in life.

The proponents developed a system that detects height and weight of a person that passed through the device and calculates their various weight classifications. This classification includes Underweight or those human whose body weight is considered too low to be healthy, Normal, And Overweight or person who has some excess body fat relative to bone structure and height and Obese or those individuals who has a lot of excess body fats. Through this system, the result will be given in just few seconds. The purpose of conducting this study and the intention of the proponents to pursue the designed project is to automate the BMI calculators in the hospitals to lessen the jobs of the nurses and to make a faster response to the patients; in the school feeding program and survey to save time and to make it easier for the staffs to determine which students are included in the program and needed health assistance. And for the fitness gyms, to help out the clients to easily check their health status. The study also helped in surveying the health status of a certain community.

The advantages of this technology are easy to use in practice, noninvasive, associated with no harm, accurate and consistent measurement, reliable equipment, fast calculation if many persons are in queue, inexpensive, easy maintenance, and less effort in doing the activity. It obtains information faster than doing it manually. The system will be a useful tool for quickly assessing weight classification. While it does not directly measure body fat, it is more accurate at approximating degree of body fatness than weight alone [6]. It can last for a long period of time.

Lustig [7] stated that the childhood obesity epidemic has taken the globe by storm, and it has slowly made its way into the lifestyles of Filipinos. Obesity rates in the U.S. are reaching disturbing proportions, and the Philippines is beginning to follow suit. This study helped the proponents on calculating BMI health status suitable for the Filipinos.

O`Brien [8] stated that the weighing scales should be calibrated monthly using the 80kg calibration weights. Any calibration drifts should be recorded in the calibration record book. Subsequent subject weights should be adjusted according to the calibration drift. A calibration record should be maintained in the calibration record book. Height measurements should be taken and adjusted according to the calibration drift. This study helped the proponents in calibrating the exact weight measurement. Bray and Gray [9] stated one current school of thought is to let nature takes its course with regard to body weight.

The project entitled BMI calculator with LCD display [10] aimed and developed a BMI (Body Mass Index) calculator which plays a major role in alerting the risk of diseases due to overweight. The proposed system not only shows the calculated value through LCD display. The Controlling device of the whole system is a Microcontroller.

People who are obese (BMI of 30 or above) almost always have a large amount of body fat in relation to their height. There are exceptions, of course and it varies depending on body fat. Big athletes with lots of muscle might have a BMI over 30, but may still have a healthy body composition. They would not be considered obese from the perspective of health risk [11].

The proposed design used a sensor amplifier that is related to the project which is entitled Temperature Sensor Amplifier. The entire system constructs and tests an amplifier circuit that increased the output voltage of a temperature sensor. This project determined how changing external component values effects the output of the circuit. The proponents gathered data from this project to apply it to the load cell which uses an amplifier to amplify the voltage signal [12]. Strain gauges are sensors which are used in variety of physical measurements. They change resistance when they are stretched or compressed. Because of this property, strain gauges often are bonded to a solid surface and used for measuring acceleration, pressure, tension and force [13].

The system will be a great help in various hospital instances; first, in the hospitals, in the admission department for faster health care and services and when admitting pregnant women. Checking BMI is very important because pregnant woman with high BMI has higher risk of disease. Second is when identifying malnutrition of patients in acute hospitals. Also, it helps hospitals for faster recording of the BMI. It shows the number of the patients of the hospitals who need more nutrients in body and to those who need to gain weight. The system also will help schools and universities when having feeding program for faster distinguishing of unhealthy students. Some subjects also need BMI calculator like Physical Education, Medical diagnosis and etc.

Another help of the design is in fitness gyms. Body builders, fitness enthusiasts, and weight lifters need to check the participants' BMI for their target weight according to their height. The importance of having this device is its inexpensiveness. It saves a lot of money. The other tests for obesity estimation or fat assessment like bioelectrical impedance and isotope dilution are expensive and require highly trained professionals. BMI calculation system stands out to be easily affordable by everyone [14].

Another importance of the project is it is also a good predictor of serious ailments like cardiovascular diseases. High BMI indicates high levels of cholesterols and triglycerides. High BMI also poses potential risks of breast cancer, colon cancer, endometrial cancer and respiratory problems. It's a rough indicator of current health status and disease risk, based upon weight and degree of obesity.

To the future researchers, the design served as a reference for them in making their own design. This system served as a guide to those persons who are health conscious and have health problems. Through this, in a certain community, monitoring of health status will be easy. It will also be possible to decrease the number of underweight and obese person in that area so that there will be no excuse to be unhealthy.

Objectives of the Study

To design and develop an Automated BMI calculation that will display the BMI through height and weight measurement of a person.

There are specific objectives that this project aimed to analyze the manual calculation of BMI and automating it; to design a circuit that will combine all the functions of the weight sensor and proximity sensors and microcontroller; to develop software embedded in the microcontroller; and to test, implement and evaluate the proposed design.

Hardware and Software Design

This section presents the requirements analysis and specification, hardware and software design of the system.

Design Process

The proponents chose embedded system design process model because it has the step by step process which the proponents need and work on.

The process has requirement analysis wherein the design must first meet its requirement before flowing through specifications, going through system architecture which has three (3) processes, the software design in which the design must need application, compiler and especially the operating system, interface design which has software and hardware drivers and the hardware design that is composed of architecture, compiler and synthesis which are lastly connected into the integration and testing.

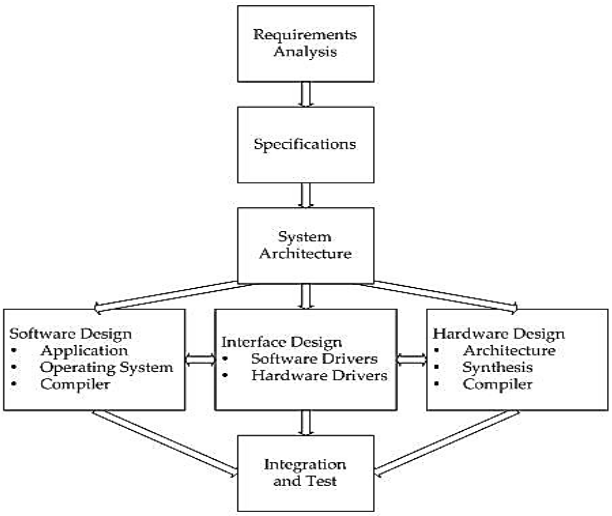

Figure 1: Embedded Systems Design Process

Requirements Specification

The system design's functionality is useful for clinics and schools in which they are maintaining their student's health. It is also economic friendly for it is not releasing smoke and it does not damage environment. The proponents' system design energy consumption is just up to 12V for the sensor amplifier it does not consume large amount of power. If it were to be manufactured, it would be inexpensive because it doesn't require many materials.

The table 1 shows the marketing requirements of the design project. It includes also the engineering requirement which involve its accuracy and speed of the system.

Table 1: Marketing Requirement

Marketing Requirements	Engineering Requirements	Justification
2,3,4,	1. The Accuracy of the BMI system calculation will be between 96% and 99%	The proponents test it by trial and error with the system can achieve a 96% up to 99% of accuracy.
3,4	2. The time to read the height and weight of the subject and calculate its BMI measure should not exceed to 60 seconds.	The system needs to provide convenient use by just entering into the system hardware.
1,4,5	3. The system should automatically store it in the system database.	The outputs of the calculated BMI should be imposed in the system database where it is saved and can be viewed upon the user login.

Marketing Requirements: (1) System should be able to store it in the database; (2) System should provide clear and accurate outputs; (3) System should be able to read automatically; (4)

System should be able to fit for obese and underweight; (5) System should be easy to use.

Hardware Requirements

In the designed system, in order to meet the objectives and functions of the proposed system, the team considered using the following hardware tools: Ultrasonic Proximity sensor, Weight Sensor, Gizduino ATMEGA328 and Sensor Amplifier**.**

Software Requirements

The minimum software requirements of the Automated BMI Calculation Prototype are: Windows 7, SQL Server Management Studio, Microsoft Visual Studio(.NET), Microsoft Visual Studio, and Arduino (software).

Platform

It is a weighing-machine or balance with a flat scale or platform for the support of the object to be weighed. The height of the jamb from the top surface of the platform is seven (7ft.) seven (7in.) and the inner width of it is six (6) ft.. The microcontroller is located at the upper right side of the jamb and the proximity sensor is located at the center of the jamb to get the height of the person. The height of the platform from the ground to the top surface of it is five(5) inches and supported by eight(8) springs. It is located at the center bottom of the jamb. There is also a foot prints to indicate where they can put their feet for proper reading of weight.

Installation/Training Plan

1. First, the jamb and the platform must be placed in a level-surface floor to have an exact measurement in height measurement.
2. Connect the gizduino cable in the laptop and plug in the power into the outlet.
3. For the software installation, user needs to have an SQL database and Visual Basic Studio. Install SQL Database and Visual Basic Studio and then upload the code in the Visual Basic Studio.
4. Synchronize the database and the Visual Basic Studio by using the back up file.
5. Check the serial port of the laptop and in the code if it has the same serial port number.
6. Run the program.
7. The user must first register the user who needs to measure the BMI status.
8. After the registration, the user must login his/her account and then the user can now enter into the system jamb.
9. After entering into the system jamb. There will be calculation of the height and weight of the person as displayed in the laptop. And then the user should click calculate button to display the result of the BMI.
10. The result must be saved and collected into the database for history checkup.

Admin

1. The user shall register into the system's database by entering the user's name, gender and indicate if child or adult.
2. After the registration is completed, the user can enter into the proponent's jamb and step into the weighing platform. After the user stepped on the jamb, it will automatically display the person's height in terms of inches and weight in terms of kilograms and the admin will start the calculation of the person's BMI status. When the system is done calculating, the BMI status of the person, the result will be displayed on the laptop whether the person's BMI is underweight, normal, overweight or obese. And when it's done, the admin will save it for future use.

Hardware Design

Figure 2 shows how the components are connected in transferring data. The ultrasonic proximity sensor and weight sensor sent the analog data into the microcontroller and the program in the microcontroller transmits received data from analog to digital to the computer using digital signal processing. The system will process the result, then the gathered data will be displayed in the computer. The user can now easily manipulate the data.

The micro-based BMI system is composed of five (5) modules, consisting of ultrasonic proximity sensor, sensor amplifier, load cell and two Arduino microcontrollers. Load cell reads the weight of the test subject sending its collected data into sensor amplifier to amplify the voltage to be transmitted into the microcontroller while the ultrasonic proximity reads and collects the data coming from analog and sends the gathered data to the another microcontroller in which the laptop will display the BMI status.

The functionality of the first microcontroller controls the proximity sensor that sends 5V output into the proximity sensor and collects the data coming from the proximity sensor. The Rx of microcontroller transmits data to the other module and the Tx for receiving data from the proximity. The microcontroller manipulates the data coming from proximity sensor that will be computed as height measurement.

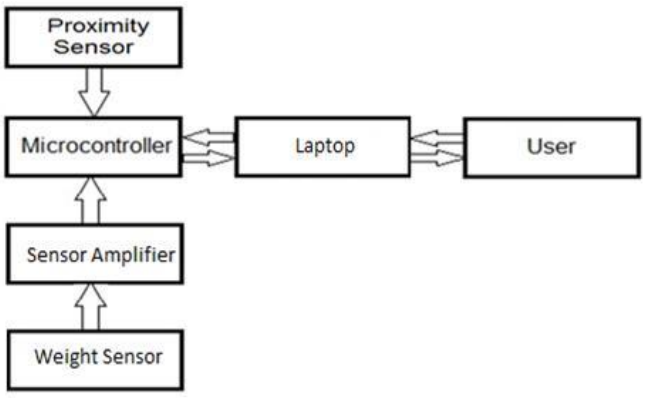

Figure 2: System Block Diagram

Software Design

The proponents used the waterfall development method in developing the software part by which the analysts proceed sequentially from one phase to the next.

The advantage of this method is that the system requirements were first identified before the programming begins and the changes in the requirements were minimized as the project proceeds. The phase by which the proponents conducted a research to have an idea on what design to choose for the proposal was in the planning phase. The proponents identified the problem that will be solved by the design. Then, the proponents constructed the title suited for the design description. The analysis phase was done after the planning. In the analysis phase the proponents should determine the users and the function of the system. The proponents analyzed the problem finding out that people want to enhance the way of measuring their BMI by automating it. Next, requirements were gathered to know the functions needed in building the design project. They also gathered information on what programming language to use in doing the system. After gathering the information needed, the proponents proposed the design to the Adviser as well as to the panel.

When the proposed design was approved by the panel, the proponents did the next phase which was the Design phase. This phase decided how the system will operate and what to use in terms of software development. In the Design Phase, the proponents chose a design strategy to work out with the team and come up with the deadline of the design project. This phase includes the development of the software as well as the coding of program. After several testing of program to the gizDuino, the proponents distributed the software programs to MCU. After uploading the software it was implemented to the hardware to test its functions if it will work or not to the hardware.

The last phase was the Implementation phase where, the installation of the design was completed. After installation, the proponents did the testing to check the accuracy and functionality of the design. For the reliability of the design, the proponents chose five users to evaluate the design. By this waterfall development-based methodologythe designers got the output "Automated BMI Calculation**"** with working and tested functionalities.

Figure 3 shows the flow diagram of the system. It represents the initialization of the software which will determine who will be the user. The registered account could add BMI. Admin system has the capability to display, open, update and delete all the BMI of the patients being examined by the system.

Software Drivers

The following drivers are needed in order to run the system software:

1. Net Framework 4.0 for Microsoft Visual Studio. The.NET Framework is an application development platform that provides services for building, deploying, and running desktop, web, and phone applications and web services. It consists of the common language runtime (CLR), which provides memory management and other system services, and an extensive class library, which includes tested, reusable code for all major areas of application development.
2. Microsoft JDBC Driver for Microsoft SQL. The Microsoft JDBC Driver for SQL Server is a Java Database Connectivity (JDBC) 4.1 compliant driver that provides robust data access to Microsoft SQL Server databases. The JDBC driver can access many of the features introduced in SQL Server 2005, including database mirroring; the xml, user-defined, and large-value data types; and it supports the new "snapshot" transaction isolation. In addition, the JDBC driver also supports the use of integrated authentication.

Hardware Drivers

The following drivers are needed in able to run the hardware:

1. GizduinoATMega328 driver for Arduino. It is an open source computing platform based on a simple input/output (I/O) board and the use of standard programming language; in other words, it is a tool for implementing a program you have designed. Gizduino is programmed using the IDE (Integrated Development Environment).
2. Arduino 1.5.8 Serial Monitor Driver. Use for faster response of the serial monitor in Arduino.

Design Implementation, Testing And Evaluation

Software Development

Figure 4 is a sample output of the homepage of the system that composed of Register wherein the user can register if the user does not have existing account, Exit button for exiting the program and Login button if the user have an existing account.

Figure 5 is a sample output of Admin page where the accounts are listed into the database. It is composed of four buttons, Open to view the person's details, Delete to delete a certain username together with the details, Delete All to delete all the stored data in the database and the Logout button for logging out the admin user.\

Microcontroller Unit Testing includes the test case name, description and tester information. The testing confirmed that the MCU is functioning and accurately giving the desired output. As a result, the reliability of the microcontroller is verified.

Weight Unit Testing. The testing showed that the load cell is being tested using executed codes for weight sensor. In overall test result, it is indicated that the unit testing for load cell is passed.

Proximity sensor unit testing. It includes test case name, description of the unit, tester information, action and result. Proximity sensor is connected to the MCU to see if there is an output. It should give the analog reading into microcontroller. For testing, the command is executed to the proximity sensor. As a result, the reading of the sensor satisfied the expected output.

Table 5 shows the summary of testing with ten (10) persons with different height and weight. Four(4) normal person, four(4) overweight and two(2) underweight. The expected result for person's BMI should be overweight for the first

testing based on manual measurement. The actual result for the testing showed that the BMI of the person is Normal. It is indicated that the first testing failed. Second testing showed that the BMI testing also failed. On the third to tenth testing, it showed that the person's BMI reading all passed. The integration testing appears that the system is working properly.

Table 6 shows the evaluation of the Automated BMI Calculator. The proponents chose five (5) persons to evaluate the project. The user rated the accuracy, effectiveness and compatibility of the system. The highest mean range of the evaluation is 4.5-5.0 and interpreted by Linkert Scale as excellent followed by 3.5-4.49 as very good, 2.5-3.49 as Good, 1.5-2.49 as Fair and 1.0-1.49 as Poor. As the result, the reading accuracy of height and weight of the person and plugging it in any outlet are rated as excellent. Turning off of the system, measurement of person's BMI, receiving the output of the system and accessing the system have the mean average of 4.8 and also interpreted as excellent. The evaluators also used manual BMI process for them to see if the output of the project is similar to the reading of manual process.

Figure 4: Home Page

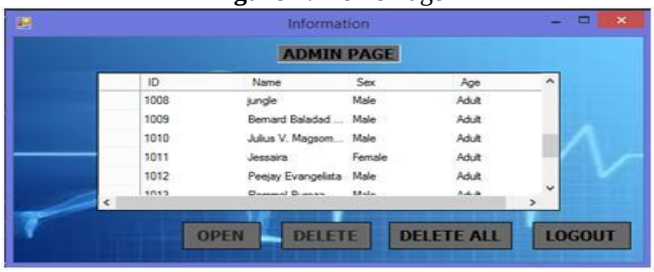

Figure 5: Admin Page

Table 5: Integration Testing

Test No.	Hgt (ft)	Wgt (kgs.)	Actual BMI result	Expected BMI result	Result
1	5'6	80	Normal	Overweight	Failed
2	5'	68	Normal	Overweight	Failed
3	5'9	55.3	Underweight	Underweight	Passed
4	5'6	86	Overweight	Overweight	Passed
5	5'5	50.9	Underweight	Underweight	Passed
6	5'7	63.33	Normal	Normal	Passed
7	5'6	64.6	Normal	Normal	Passed
8	5'5	58.04	Normal	Normal	Passed
9	5'4	61.6	Normal	Normal	Passed
10	5'6	68.9	Overweight	Overweight	Passed

Table 6: Acceptance Testing of Automated BMI Calculator Prototype

Accuracy	**WM**	**VI**
1. The height and weight reading is accurate.	5	Excellent
2. Turning on and off of the program is accurate.	4.8	Excellent
3. BMI measurement is accurate.	4.8	Excellent
Compatibility		
1. The Systems application program is easy to use.	4.8	Excellent
2. The systems hardware can be plugged in any outlet.	5.0	Excellent
Functionality		
1. There is no delay in receiving the output of the system.	4.8	Excellent
2. The user can easily access the system.	4.8	Excellent

Scale: 4.5-5.0: Excellent (E); 3.5-4.49: Very Good (VG); 2.5-3.49: Good (G); 1.5-2.49: Fair (F); 1.0-1.49: Poor (P)

Conclusion and Recommendations

The technology nowadays converted manual into automatic process, which becomes more efficient in everyday usage. Also, it is helpful for them because PCs now are needed at the workplace. The proponents used this as an advantage in monitoring the health status of patients or students.

The purpose of this study is to calculate the weight and height measurement and display its BMI measurement automatically upon entering in the system jamb and save the BMI measurement in the system's database. The proponents developed an embedded system which composed of two microcontrollers; holding the ultrasonic proximity sensor for the measurement of height and loading cell for the measurement of the weight of the test subject. The proponents have combined this function by gathering the data coming from each module to come up with the needed result.

The proponents have analyzed, automated the BMI and designed the circuit that combined all the functions of the weight and proximity sensors and developed the software embedded in the microcontroller. The proponents conducted different series of testing. This includes unit testing, integration testing and acceptance testing.

In general, the proponents developed the device to provide and maintain the health status of the test subjects and to encourage person to have a proper diet for their health. The proponents analyzed the manual BMI calculation and automated it. The proponents designed a circuit that combined the functions of the ultrasonic proximity sensor and weight sensor in one system and developed software embedded in two microcontrollers which control and manipulate the whole system of the design project.

The proponents recommended that their system design project is to be used in clinics and institutes that needs BMI measurements for an easy calculation of their patient's BMI; the height stand must be folded or extendable for portable usage; and the platform in height stand for safety purposes should be attached.

Limitation

The designed project has the ability to display the height and weight of a person and their weight classifications together with the target weight if he/she is obese or underweight. The design is programmed to calculate the person's height and divide it by the ratio to his/her weight that determined body fat. The device can be set according to the gender of the person that will enter. Also, the device calculates the number of persons that entered into the proponents system with the list of person showing underweight, normal, overweight and obese for survey purposes. This system helps the attending nurse, physician or doctor to lessen their job and to monitor patient's health. The proponents build the hardware suitable for children of any weight and height. Proponents ensure safety of any person that will enter through the device.

On the other hand, there are some limits that the system is not capable of which include not suitable for person weighing 90kg and above; this can only accommodate one person at a time; this not suitable for people with dwarfism and people with disability and this is not suitable for people with mannerism movement.

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