Development of microcontroller based ultrasonic non-contact meter rule for height measurement

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DEVELOPMENT OF MICROCONTROLLER BASED ULTRASONIC NON-CONTACT METER RULE FOR HEIGHT MEASUREMENT

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ABSTRACT

The world is changing to an era of technological innovations, where things are now done automatically with ease and high accuracy. The use of manual length measuring instruments such as stadiometer, metric and imperial systems has a lot of defects like parallax, human error and insufficient length of measurement. This paper presents the design and development of a portable device that utilizes ultrasonic sensors to measure human height. The sensor scans to determine the height of the object/human under measurement and evaluate the actual height using the difference between the reference height of the device and scanned distance. It is designed to allow users to easily measure their heights on their own. The target is to improve on device performance and accuracy. The results show improved accuracy with a variation of ± 0.01m. The device can be alternatively used instead of the bulky and expensive height measuring products at home or doctor's offices.

1. INTRODUCTION

Human height and weight are considered as important health indicators. Some people always assume their height based on previously acquired measurements. The fastest growth rate for a human is during embryonic life. If sustained, it would provide 50-60 cm (close to 2 feet) of growth per year (Priya, 2016). This extraordinary rate of growth is largely independent of growth hormone. Growth hormone only begins to play a role in growth in the final weeks before birth (Deng, 2015). However, an inch alteration in actual height could be an important determinant to a person’s health status. It is necessary to check the growing rate of the children to determine whether they are growing or depreciating. In addition, with known height and weight, an individual body mass index (BMI) can easily be evaluated. An important commonly used indicator by medical doctors for diabetes and heart ailment is BMI. Therefore, accuracy and measuring time in height measurements are highly demanded whenever the measurement is directly linked to health challenges (Wiedemann et al., 2007). Currently, some approaches such as the use of a stadiometer to determine height and weight are traditional and mostly consume much time. Besides, in taking the measurement, it usually requires more than a person (John et al., 1991). The most commonly used devices are the tape measure or a stadiometer. The stadiometer is a device mounted on the wall with measurements written on its frame and includes a plank that comes down and rests on the user’s head to help determine the height. Microprocessor-based automatic height measurement is developed using sound output, a sound circuit coupled with a speaker for sound output is presented in (Erlita, 2015). However, their percentage error value is large. Hence, results from the use of these methods are often less accurate

Ultrasonic sensors provide a portable and easy-to-use solution for height measurement compared to the traditional methods. In a similar way for short for sound navigation and ranging (SONAR), an ultrasonic wave is sent off from the top of a person's head and measure the returned echo wave reflected off the floor (Nguyen et al., 2017). With the two ultrasonic sensors, two separate measurements could be made and the average reading is determined for a more accurate value. At the same time, it allows for compensation for non-level orientations. When designing the prototype, the consideration is how efficient is the device, how economical the components are, the ease of assembling and construction, and finally how friendly it is to the users. Though, there are a few products such as the stadiometer that are similar in theory but are very different in design. The two configured ultrasonic sensors make for robust design with improved performance and better accuracy. The study is organized and structured as follows: Section 2 presents the methodology which describes the operation of the components. Section 3 presents the results and discussion and the conclusion is presented in Section 4.

2. METHODOLOGY

Ultrasound technology also known as sonography is non invasive technique used in capturing objects by emitting sound waves at frequencies ranging between 1 and 10 MHZ (megahertz). The sound wave emitted reflects back after they bounce off the focus object. This device was designed using current ultrasound technology to measure the distance to the floor from the top of a person's head. The computed height is displayed on a liquid-crystal display (LCD) screen for easy viewing as illustrated in Figure 1. The portable height measuring device includes an arduino nano microcontroller, portable power circuit, ultrasonic sensors (HC-SR04), and a 20 by 4 inches LCD to display the height. The microcontroller is programmed to send a trigger signal to the ultrasonic sensors, which commands the ultrasonic sensors to send bursts of ultrasound that reflect off the floor and return to the receiver. When the sensors detected the return wave, it notifies the microprocessor with an echo signal. The time interval between the trigger and echo signal is the travel time of the ultrasound wave from sensors to the floor and back. The microprocessor measures this time interval and uses the speed of ultrasound to compute the round-trip distance. To avoid restriction base on different users' heights, a reference distance of 2.02m is incorporated in the program and the measured height which is the half of the round-trip distance is subtracted from the reference height. This reference distance is the maximum height that can be captured by this design. It is the distance from the tip of the sensing device to the foot stand. However, this reference height can either be increased or reduced in any other related designs but for this particular project, the value has been incorporated in the program hence, any alteration would influence the end result negatively.

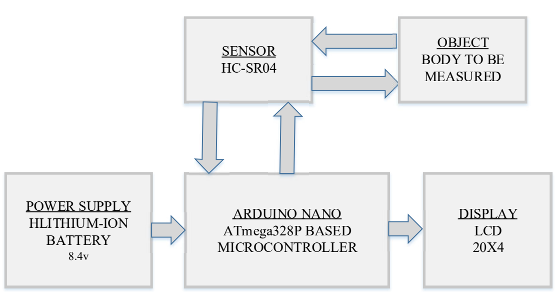

Figure 1: Block diagram of microcontroller based ultrasonic non-contact meter rule for height measurement

2.1 Ultrasonic sensor HC-SR04

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound. Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target).

In order to calculate the distance between the sensor and the object, the sensor measures the time it takes between the emissions of the sound by the transmitter to its contact with the receiver. The formula for this calculation as:

$$D = \tfrac{1}{2} T \times C$$

Where D is the distance, T is the time taken, and C is the speed of sound. As shown in Figure 2, the HC-SRO4 functions as it provides a non contact measurement of 2cm to 400cm with an accuracy of about 3mm (Zhmud et al., 2018). An ultrasonic transmitter, a receiver, and a control circuit are embedded in each HC-SR04 module. The HC-SR04 has only four significant pins which are: Vcc pin for power with input voltage range between 3.3V to 5V, Trig pin for Trigger, Echo pin for receiver, and GND pin for Ground. An additional control circuitry is incorporated in it in order to prevent inconsistency in its application.

Figure 2: Ultrasonic sensor HC-SR04

2.2 Power supply (Li-ion battery)

Figure 3 shows the lithium-ion battery, this is one of the most advanced rechargeable batteries that has been attracting much attention for a very long time. Noticeably, the increasing functionality of mobile electronics always demand for better Li-ion batteries. The power supply incorporated in this study is Lithium-ion battery or Li-ion battery. Two of the batteries are connected in series and rated 3.2V.

Figure 3: Li-ion battery

2.3 Arduino Nano (ATmega328P microcontroller)

The Arduino Nano is a portable and friendly board based on the ATmega328, that offers the same connectivity and specifications of the UNO board in a smaller form (Sanni et al, 2019). There are different types of microcontroller but ATmega328 was chosen due to many pins in its configuration with the ease of programming via Arduino Nano board. It is flexible with a wide range of applications. It is where all the progaramming codes, command and decision making of the device are written using Arduino IDE. Figure 4 show detail picture of the microcontroller.

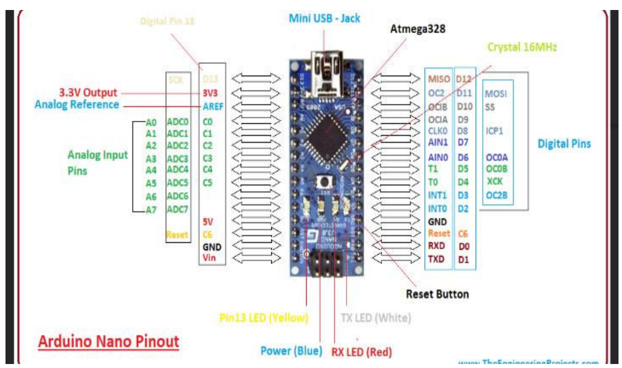

Figure 4: Arduino Nano (ATmega328 based microcontroller)

The analog pins are 0A to 07 which are used to calculate the analog voltage while the digital pins are 14 in number. The input voltage pin Vin is between 7V to 12V which can be powered through a USB port. The operating voltage is 5V and the GND is the ground pin of the board.

2.4 Liquid Crystal Display (LCD)

A liquid crystal disply (LCD) can be described as an electronic visual display flat panel that uses a double dimensional array of liquid crystal cells, each of this cells can be controlled electronically to modulate the transmission of light to display digital images (Gu & Yeh, 2015). This display is made of green LCD pixels, each one is been controlled to turn on or off by the controller chip. LCD is made up of two pieces of polarized glass (also called substrate) that contain a liquid crystal material between them. A backlight creates light that passes through the first substrate. Simultaneously, electrical currents cause the liquid crystal molecules to align and vary the levels of light that passes to the second substrate. The colors and images are then created. Figure 5 shows the liquid crystal display.

Figure 5: Liquid crystal display

3. RESULTS AND DISCUSSION

After the necessary connection of the circuit and fixing of ultrasonic sensor HC-SR04, ATmega328P microcontroller and LCD in their proper position on the height measuring system as shown in Figure 6. The developed height measuring device was tested to measure the height of different users by capturing twice to ascertain the consistency and accuracy of the system. The measurements were confirmed to be accurate with an uncertainty of ±0.01m and recorded. The following steps were taken to test the developed height meter:

i. the device is switched ON
ii. The START button is pressed to initiate the measurement.
iii. the user is prompted to stand in position to be measured
iv. the system displays the measured height
v. the measured value remains on the screen until another user captures another measurement.
vi. the device is powered off when users are no more available.

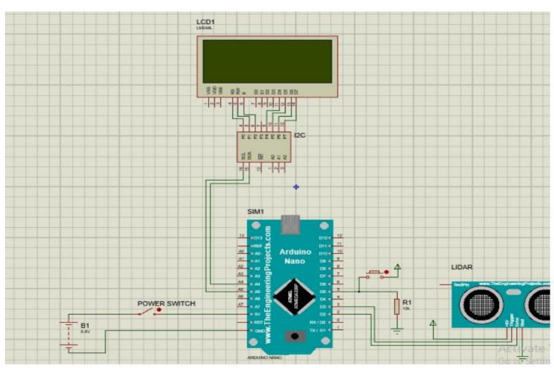

Figure 6: Complete system units with programmed microcontroller

Table 1 shows the height measurement of twenty users as captured. These measurements were double captured and well documented to avoid errors or mistakes.

Table 1: Results of height measurement from five users

S/N	Name	Capture 1(m)	Capture 2(m)	Difference (m)
1	USER A	1.75	1.75	0
2	USER B	1.73	1.72	+0.01
3	USER C	1.65	1.64	-0.01
4	USER D	1.12	1.13	+0.01
5	USER E	1.76	1.77	+0.01
6	USER F	1.45	1.46	+0.01
7	USER G	1.67	1.66	-0.01
8	USER H	1.53	1,54	+0.01
9	USER I	1.42	1.43	+0.01
10	USER J	1.76	1.75	-0.01
11	USER K	1.87	1.88	+0.01
12	USER L	1.42	1.42	0
13	USER M	1.13	1.14	+0.01
14	USER N	1.79	1.78	-0.01
15	USER O	1.59	1.60	+0.01
16	USER P	1.92	1.93	+0.01
17	USER Q	1.73	1.73	0
18	USER R	1.81	1.80	-0.01
19	USER S	1.48	1.47	-0.01
20	USER T	1.29	1.30	+0.01

The inspection on the Table 1 shows that the difference between capture 1 and capture 2 for all users is low, which indicates a good accuracy in results output. Table 2 shows the error analysis for USER A to USER E where x is the height measurement for the users, $\bar{x}$ is the mean value, σ denotes the standard deviation and N is the number the trial (10). The table shows a low standard deviation, which confirms accuracy in a good results output.

Table 2: Error analysis for USER A to USER E

Trials	USER A (x)	USER B (x)	USER C (x)	USER D (x)	USER E (x)
Trial 1	1.75	1.73	1.65	1.12	1.76
Trail 2	1.75	1.72	1.64	1.13	1.77
Trial 3	1.74	1.72	1.64	1.13	1.76
Trial 4	1.76	1.73	1.65	1.12	1.77
Trial 5	1.75	1.71	1.66	1.11	1.75
Trial 6	1.75	1.72	1.65	1.11	1.76
Trial 7	1.74	1.73	1.64	1.13	1.75
Trial 8	1.74	1.72	1.66	1.12	1.76
Trial 9	1.76	1.72	1.65	1.11	1.75
Trial 10	1.75	1.73	1.64	1.13	1.76
Mean deviation ($\bar{x} = \frac{1}{N}\sum_{1}^{N} x_i$)	1.749	1.723	1.643	1.121	1.759
Standard deviation (	0.000	0.00	0.000	0.0000069	0.0000049

$\sigma = \sqrt{\frac{\sum(x_i - \bar{x})^2}{N}}$)	0049	000 49	0056		

The height measuring device is developed to ease the process of measuring height and give the result in a digital form, making it more accurate than the previous analog height measurement methods. The need for health fitness devices and new-age products is extensive and massive. This device certainly has great prospects on such markets, with the only competitors being extremely costly.

Figure 7 and Figure 8 show the variance for USER A and USER B over the number of trial time within a lower error of 10^{-4}.

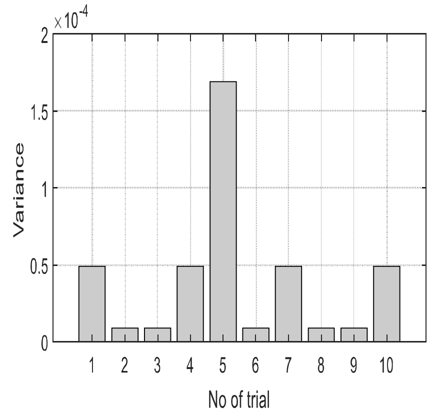

Figure 7: Variance in USER A measurement

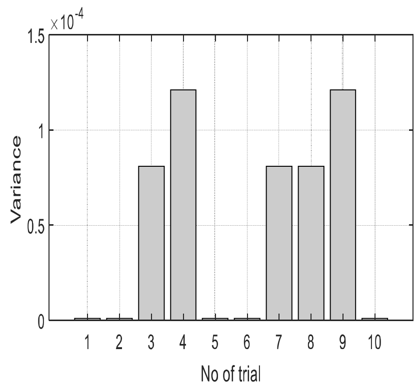

Figure 8: Variance in USER B measurement

4. CONCLUSION

The findings on height measuring devices with Ultrasonic distance meters have shown great potential for accuracy and reliable measurement of human height. Previous studies used technologies with different practice and methodological limitations such as stadiometer, metric and imperial systems which has a lot of defects like parallax, human error and insufficient length of measurement. This study improves on these limitations by developing a microcontroller based ultrasonic sensor non-contact human height measurement with improved performance. The measurements were confirmed to be accurate with an uncertainty of ±0.01m hopefully; Bluetooth technology will be added in the future, linking the height measurement to a mobile application and a Bluetooth scale. The mobile application will be configured to simultaneously determine the BMI calculations. Furthermore, temperature compensation can be added to improve accuracy since the temperature can affect the ultrasonic wave's travel speed and thus height measurements.

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