Autonomous height measurement system for smart health monitoring

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Abstract. Height measurement considered as an important parameter for health monitoring. The increasing demand for telemedicine services requires a robust and affordable height measurement system. In addition, the system should have the ability to interact with a remote destination. Unfortunately, existing height measurement tools are incompatible with telemedicine services. In this paper, a low-cost autonomous height measurement system has been proposed. Moreover, the system utilizes an ultrasonic sensor to measure the human height and processes the sensor’s data through a Micro Controller Unit (MCU). Finally, the MCU communicates with the remote terminal through a Bluetooth module. A special wearable prototype has been developed to deploy the hardware for real-life applications. The experiment results demonstrate that the results obtained by the proposed system are reliable with a mean error rate of 0.02%.

Keywords: Height measurement, smart health monitoring, telemedicine, microcontroller, ultrasonic sensor, Bluetooth module


1. Introduction

Telemedicine services seem to be the futuristic alternative of confronting medical diagnosis and treatment. Having widespread usability, these services gradually getting popularity among mass users. Typically, telemedicine services are designed to reduce physical afford to meet physicians. In minor or follow up cases it can help the patients to get a preliminary diagnosis. In contrast, telemedicine services are also useful in emergency cases for getting a quick response from a remote physician, particularly when it is tough to arrange a sudden face to face meeting. As consequences, telemedicine services are becoming a trendy and convenient alternative to traditional follow-up and emergency appointment approaches. By taking advantage of recent technologies, many developed countries already introduced several telemedicine services. Following the trend, developing countries also become enthusiastic about their adaptation. However, making a robust and efficient telemedicine system depends on several evaluation factors such as patient outcomes, management decisions, access to care, user satisfaction, and cost-effectiveness and so on [1,2,3]. Moreover, all telemedicine services do not follow a common operating procedure as well. Depending on their service types, the telemedicine services can be clustered into three basic categories: store and forward data to a remote device, quick service (home-based services) and remote help station based [4] systems. Regardless of different operation procedures, the main purpose of telemedicine services always remains unchanged.

In most common cases, telemedicine services are incorporated with few basic parameters such as height and weight measurement. Among these basic parameters, body height measurement is appraised as one of the crucial factors for many disease diagnoses. For a quite long period of time, height is widely used in physiology and clinical medicine. Typically, it used to generalize the biological function with the respect of body size and conformation [5]. For tracking an infant or child’s health and growth, a full or a partial height measurement system [6] plays an important role. In addition, height is also considered as a mandatory parameter for a human body mass index (BMI) calculation, which again directly effects on women reproduction system [7]. Thus, in adulthood or childhood, height measurement considered as an essential parameter for inspecting the health
of a woman body as well as their reproduction system. Due to the several diagnosis and treatment procedures, height measurement tools drawn the attention of the researcher of that particular domain.

Apart from the widespread importance of height measurement, a robust, simple, affordable height measurement system is still missing. In addition, the existing height measurement tools are incorporated with local actuators only. They don’t permit a typical user to send their examined height to another remote system or a smartphone app. To sum up, these devices are not compatible with telemedicine services.

In this work, an affordable and low-cost height measurement system has been introduced. The proposed device uses an ultrasonic sensor and Micro Controller Unit (MCU) to calculate human height. The proposed system will automatically redirect calculated heights to a remote system or a smartphone app through the Bluetooth connectivity. Additionally, it also allows the user to control the hardware from a remote device. In the end, a wearable prototype has been developed to house the hardware. This paper is organized as follows: Section II emphasizes on the similar works, Section III describes the proposed system architecture, hardware setup, and experiments. In Section IV, results and findings have been discussed. Finally, section V concludes this work.

2. Similar works

Height measurement tools have several real-life applications. Particularly, they are very useful in disease diagnosis. However, making an automatic height measurement tool introduces many barriers such as accuracy and affordability. Thus, in the past two decades, many height measurement tools have been introduced in search of a robust system. Caleb et al. [8] invented a height measurement system to measure the height in a typical home environment. The system incorporated with a slide rack configured for mounting to a vertical wall surface. The tools also have a slide mount portion, which again mounted on a slide track. Apparently, the slide mount portion was configured in such a manner that it could travel parallel to the vertical surface. Furthermore, the height measuring gauge has a gauge plank and it can be movable between two plank positions. That system also includes a backing sheet configured for mounting along a length of the backing sheet on the vertical wall surface and between the height measuring gauge. The backing sheet indicates the measured height in the vertical wall surface.

A smarter solution for height measurement has been proposed by [9]. On their work, they have introduced another mechanical slide carrying height measurement tool, where the tools have a measuring arm. The measuring arm is capable to move on a vertical scale. Typically, when a human body stands straight underneath the measurement tool, the measuring arms search for the person’s head and read out the measured value through an audio output module. Apart from being accurate in height measurement, that system doesn’t offer any feature of sending data to a remote place for further analysis. Scot et al. [10] invented another height measurement system to categorize incoming guests of a theme park for allowing them into some particular rides. On that system, an ultrasonic sensor was fixed on a single point. Thus, it could emit signals to a reflection surface. According to the difference of signal sending and receiving time, an approximate height was measured through the device. Though the device was able to categorize the guests in various groups, apart from that the system requires a fixed reflection surface which may not attach to the head of the incoming guests. A similar height measurement approach has been taken by [11]. On their height measurement tool, they also used an ultrasonic sensor to measure the human height. That system additionally offers portability and usage different concepts for calculating the human heights. In addition, they have mounted their sensor on the sun visor and a switch in the inner part of a baseball like a cap. When the head of the person wearing the cap touches the switch, it triggers the ultrasonic sensor to emits signals. This portable height measurement system is capable of outputting data through the different actuators, which again set on the crown of the cap. Despite output data through the actuators, this device is unable to send the output to a remote device. Thus, it also could not be integrated into a telemedicine system.

A different height measurement approach has been taken by Jeges et al. [12]. On that study, they have used a calibrated camera to measure the height of the human body. Their height measurement system was prepared for the surveillance system and used an intelligent system in order to measure the human height through a video height measuring sensor. However, this intelligent system only searches for a height range in order to reduce the suspect elements for identifying suspicious humans coming from a blind point to a camera sight. Apparently, this measurement system is not compatible with any kind of telemedicine services.

Most of the existing height measurement systems are incorporated with complex mechanical structures or inconvenient to the mass use. Some existing devices are an exception to these problems and can yields output in digital interfaces. Apart from
that they are also unable to team up with a telemedicine system. Thus, in this work, a simple and portable device has been introduced to optimize all existing problems through a single device.

3. Present work

The present work is incorporated by proposing a smarter solution for height measurement. In addition, it has been designed especially for teaming up with a telemedicine system. In this work, an HC-SR04 (an ultrasonic sensor) [13], an Arduino-Micro Controller Unit (MCU) [14,15], an HC-05 (Bluetooth module) [16] and laser diode has been used to measure human height precisely. Moreover, the hardware prototype allows users to measure and send calculated height to another Bluetooth enabled remote device or a system. Figure 1 giving a glance at the system architecture. According to the overview, the proposed system will collect height related raw data from an ultrasonic sensor. After then, the MCU unit will convert the sensor’s raw signals into human-readable data. A laser diode has been implanted in the middle of the ultrasonic sensor. Therefore, it can help a typical user to understand the reflection surface. The laser diode will monitor the ultrasonic sensor’s performance as well. After conducting a successful height measurement, the MCU will redirect all data to another remote device or a smartphone app. Thus, the remote system or app can store or forward the result to another destination or a telemedicine system [17]. Additionally, the proposed hardware prototype is configured in such a manner that it could receive external command like re-initiating, showing history, conducting a new height measurement experiment right from a Bluetooth terminal.

3.1. Hardware setup

Figure 2 illustrates the schematic diagram of the proposed hardware. The MCU has been performing as a power source for the sensor, module as well as for the diode. Thus, the ground pin of all modules and diode has been shorted with the Arduino’s ground pin. Additional pins from both: the ultrasonic sensor (Echo, Trigger) and Bluetooth module (RX, TX) have been
configured in the user define digital pins at the Arduino board. Arduino serial output is disabled while configuring the hardware.
In this work, the default Arduino terminal has been replaced by a third-party Bluetooth terminal, which baud rate is set to 9600. Between each sampling and right after a successful data transmission, delays have been introduced. Thus, it could not interrupt the data transmission or sampling procedure during conducting an experiment. However, the hardware is capable to take at least one sample per second. Note that the MCU itself has to be powered up with an energy source. Here, a 9V lithium-ion battery has been used to power up the hardware. However, any kind of energy source that can provide a power around 9 ~ 12V, 1mA can be used to power up the MCU.

3.2. Software integration

![Image of Bluetooth terminal](image-url)

Figure 3: Actual cost to develop the proposed device

The proposed system is aims to send calculated data to a remote destination. Moreover, the data transfer has to be autonomous and it shouldn’t require any user interaction. As smartphones are the most available and convenient solution for the mass user, this study utilized the Bluetooth terminal of the smartphone. An open free Bluetooth terminal, which is available in the android play store has been used to monitor the output of the experiments. Furthermore, the Bluetooth terminal also used for sending the command (i.e. history, start, timestamp and so on) to control the hardware prototype. Figure 3 shows the sample screenshot of the used Bluetooth terminal. Note that any kind of Bluetooth terminal can be used to interact with the proposed system. Moreover, this work will allow third-party software developers to integrate the proposed hardware in their respective applications.

3.3. Height Measurement

The developed hardware is designed to measure height accurately. However, the accuracy of the measured height highly depends on sensor placement. To find out the appropriate position of sensor placement, two different methods have been studied. The methods are as follows:

**Method-I:** The height measurement sensor has been placed in a fixed position. It targets the correspondence skull as a reflection surface.

**Method-II:** A special wearable prototype has been developed. The hardware has been attached to the wearable prototype such as it can be placed like a cap.

3.3.1. Method-I

Figure 4 demonstrates the basic setup for the Method-I. As the figure shows, the height measurement procedure with Method-I begins with the initiating hardware in a static location. For the first time when the hardware powered up, the ultrasonic sensor begins to emit signals and tries to initiate it in a floor or reflective surface. In addition, the device initial position is not a fixed value. It can be re-initiate from the connected smartphone or remote terminal as per user requirement. After initiating, the
system will wait for the command from a remote control for measuring height. When it receives any user command of height measurement, it will begin the search for finding another reflection surface, which is less than the initial position. Typically, the device takes a person’s skull as the reflection surface and calculate the actual height of correspondence as follows:

\[ AH = IP - RS \]

Where, \( AH \) = Actual Height, \( IP \) = Initial Position, and \( RS \) = Reflection Surface

### Algorithm 1 Finding Initial Point

```plaintext
sensorData
FilteredData[i]
while i ≠ 20 do
  if sensorData > 0 and sensorData < 3000 then
    FilteredData[i] ← sensorData
  end if
  i ← i + 1
end while
```

Note that in Method-I an initial point has to be selected. The following algorithm has been developed to find the appropriate initial point: During initializing the hardware prototype, it’s very common to receive garbage data. However, the initial point must have to be precise in order to measure accurate height. The algorithm (1) has been introduced to initiate the device:

![Figure 4: Overview of Method-I](image)

#### 3.3.2. Method-II

For method-II, a wearable prototype has been developed. Apparently, the wearable has been designed as a baseball cup. Thus, it can be placed into the user’s head. Figure 6 demonstrates the top and bottom view of the wearable prototype. Moreover, the MCU, power source, Bluetooth module, circuit connection has been placed into the crown. It has been tried to make the circuit connection invisible from the user. A stand has been attached to the top of the wearable in such a manner that it can hold the ultrasonic sensor and the laser diode. The overall hardware configuration remains unchanged. However, the height measurement strategy has been changed for method II. As Figure 5 shows, in Method-II the ground has been considered a reflection surface. Subsequently, it doesn’t require any initial point as method I. Here, the initial point has been set to 0.
3.4. Data sampling and processing

Depending on the method, steps for the height measurement can be different. In contrast, every method follows a common procedure for data sampling and finding the final result. For each data pointing (calibration and human height calculation), the data samples have been taken from the sensor. Furthermore, data samples have been stored in an array. The garbage values have been filtered out from the sample data. In addition, most appeared value has been considered as the final sample value for determining the initial point (Method-I) or the human height. Finally, the calculated height has been sending through the Bluetooth module to a remote device. Figure 7 illustrating the data flowchart that has been used in this work.
3.4.1. Data sampling

The body movement and uneven surface can have an effect on data sampling. To compute the accurate height, a set of data samples (D) has been considered. The algorithm (2) has been developed to measure the height of a correspondence. For data sampling, the measurement unit is fixed in millimeters.

Algorithm 2 Data Sampling

\[
sensorData \\
sampleData[i] \\
while i \neq 20 do \\
    sampleData[i] \leftarrow sensorData \\
    i \leftarrow i + 1 \\
end while
\]

3.4.2. Garbage filtering

HC-SR04 can produce garbage values due to several issues such as: sending and receiving signals, transmission delay, fluctuation of reflection surface and so on [18]. Moreover, these garbage values can directly affect the final outcomes. Thus, the algorithm (3) has been developed to filter out the garbage values from the raw data. Note that a threshold value has been set to omit the garbage from the sample data. For Method-I threshold is equivalent to the initial point. For Method-II threshold value is set to 3000 (mm).
3.4.3. Finding the final height

This step has been designed to determine the final heights from the filtered data. However, it heavily relies on the garbage filtering strategy. To measure the final height of a correspondence the filtered data has been considered. In addition, the final height has been calculated with the algorithm (4). In a nutshell, the most appeared value has been considered as the final height.

Algorithm 3 Garbage Filtering

```
sampleData
FilteredData[i] = threshold
while i ≠ 20 do
    if sampleData[i] > 100 and sampleData[i] < threshold then
        FilteredData[i] ← sampleData[i]
    end if
    i ← i + 1
end while
```

4. Experiments and results

The proposed hardware setup has experimented with different measurement methods. To test each method, two target samples F and M have been considered. Here, F and M is the sample set of female and male correspondence, respectively. Each sample set is comprised of 15 persons with different heights.

4.1. Results

Table 1 shows the hardware performance for each method. Apparently, results indicate that the method-II is more consistent than Method-I for both sample sets (F and M).

Figure 8 shows the error comparison for both methods. Apparently, the error graph for both male and female demonstrates that the error rate of method-II is much stable. Moreover, the error for method-I is less than 1% cm. In contrast, the error rate of Method-I is varying between 3 cm to 5 cm. Table 2 shows the mean error rate of both methods. It is to be noted that, Method-I much higher than method-II. Moreover, it has been affected by the reflection surface, which again considered as the top of the skull. Due to the interference of hair, the measured height with Method-I seems to be inaccurate.

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```
Table 1: Experiment results of Method-I and Method-II

<table>
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<tr>
<th>Person</th>
<th>Actual (cm)</th>
<th>Method-1 (cm)</th>
<th>Method-2 (cm)</th>
<th>Person</th>
<th>Actual (cm)</th>
<th>Method-1 (cm)</th>
<th>Method-2 (cm)</th>
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Figure 8: Error comparison of Method I and Method II

(a) Error for male attendance

(b) Error for female attendance

Table 2: Mean error rate of Method-I and Method-II

<table>
<thead>
<tr>
<th>Method</th>
<th>Gender</th>
<th>Mean Error Rate (%)</th>
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<td>Female</td>
<td>1.40</td>
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<tr>
<td>Method-II</td>
<td>Male</td>
<td>0.02</td>
</tr>
<tr>
<td>Method-II</td>
<td>Female</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Table 2: Mean error rate of Method-I and Method-II
4.2. Cost analysis

The proposed work aims to develop an autonomous height measurement system at a low cost. Thus, it could be affordable by the mass user. Figure 9 shows the approximate cost of developing a single prototype. The overall cost for the hardware development and deployment kept under USD 15 (approximately). However, this cost should significantly drop during the mass production phase.

![Figure 9: Actual cost to develop the proposed device](image)

5. Conclusion

In this study, an autonomous height measurement system has been proposed. Moreover, the proposed system utilizes an ultrasonic sensor to measure human height. A laser diode has been used to help the user to locate the reflection. Apparently, an MCU has been used to process raw data. To the end, the measured data has been transferred to a remote terminal for further processing. Thus, it can team up with any kind telemedicine services. To study the feasibility of the proposed autonomous height measurement system, two methods have been studied. Moreover, a special wearable prototype has been developed to reduce measurement errors. In addition, the cost for developing the hardware prototype was kept under USD15 (approx.). Moreover, the experiment results demonstrate that the newly developed wearable prototype helps the hardware to measure accurate heights. The mean error rate of the proposed system observed under 0.02%. In foreseeable future, the proposed system will be extended with several body sensors (i.e. heart rate, body temperature and so on.) for further improvement. It has been planned to develop a smartphone application for user convenience.

Conflicts of interest. There is no conflict of interest.

References


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