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A Comparative Study Of HC-SR04 and HY-SRF05 Ultrasonic Sensors For Automated Height Measurement Based On IoT

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Abstract

The inefficiency and potential for operator error in manual height measurements limit data reliability in health and fitness monitoring. To address this, we developed an automated IoT-based system to compare the performance of HC-SR04 and HY-SRF05 ultrasonic sensors. The system architecture is built on a NodeMCU ESP8266 microcontroller, which sends measurement data to a cloud-based Firebase platform for real-time storage and historical analysis, all visualized on a dynamic ReactJS dashboard. The evaluation involved 30 human subjects with heights ranging from 100 to 200 cm. The analysis revealed a mean absolute error of 0.20 cm (0.131%) for HY-SRF05 and 0.233 cm (0.16%) for HC-SR04. Crucially, statistical testing found no significant difference in accuracy between the two sensors (T-test, $p > 0.05$). The study concludes that both low-cost sensors are highly capable and statistically equivalent for this application. The complete IoT system demonstrates a robust solution for deploying affordable, scalable, and accurate automated height measurement tools, offering a significant improvement over traditional methods.

Keywords: *IoT, Ultrasonic Sensor, HC-SR04, HY-SRF05, Height Measurement*

1. INTRODUCTION

Obtaining precise height measurements is essential for tracking human health, growth, and athletic performance [1], [2]. The standard method for this, using a manual stadiometer, is prone to several key issues [3], [4]. Not only is the process slow, but the results can be inconsistent as they depend greatly on the operator's skill [5], [6]. This reliance often leads to errors that compromise data quality, especially when many individuals are measured in settings like schools and health clinics [7], [8]. An additional source of inaccuracy stems from the manual data entry step, where transcription errors can easily occur and undermine the value of long-term data sets [9].

To overcome these challenges, modern technology offers a powerful solution through the Internet of Things (IoT) and affordable sensors [10]. Systems built on IoT can automate the entire measurement workflow, leading to major improvements in how efficiently and accurately data is managed [11], [12]. A key advantage is the ability to capture data instantly, save it to the cloud, and display it through user-friendly visualizations. This setup allows for on-the-spot data checks and long-term analysis without the need for manual handling [13], [14], [15]. Within this landscape, ultrasonic sensors are frequently chosen for contact-free distance measurement because they are both simple to use and inexpensive [16].

Numerous studies have explored the application of the HC-SR04 ultrasonic sensor for automated height measurement. For instance, one Arduino-based system utilizing the HC-SR04 was successfully developed, reporting a low average error of only 0.279% [7]. Similarly, another study achieved a high accuracy of 99.73% with the same sensor, with the results being output to an LCD [17]. Other works have focused on system integration, such as connecting the HC-SR04 sensor to an Android smartphone via a Bluetooth connection [18], and building an IoT system with a NodeMCU ESP8266 to monitor height and BMI on an Android app, albeit with a higher average error of 3.04% [19]. These studies validate the feasibility of using the HC-SR04 for this purpose.

Despite the widespread adoption of the HC-SR04, there is a notable scarcity of research comparing its performance against alternative sensors under identical conditions. The HY-SRF05, for example, offers superior on-paper specifications, including a finer resolution and a wider detection range, which could potentially lead to more accurate measurements [20]. One of the few studies implementing the HY-SRF05 reported an average error of 1-2 cm, but this research did not include a direct comparison with the HC-SR04 [20]. Furthermore, while many projects have developed standalone or Bluetooth/Android-based systems [18], [19], few have integrated the sensors into a comprehensive IoT ecosystem featuring a real-time, cross-platform web dashboard for monitoring and data management, a critical feature for modern, user-oriented applications [21].

This research aims to address this gap by developing a holistic IoT-based height measurement system that directly compares the performance of the HC-SR04 and HY-SRF05 sensors. The system leverages a NodeMCU ESP8266 to transmit data in real-time to a Google Firebase database, with a dynamic and responsive web dashboard built with ReactJS for data visualization and analysis. By conducting a rigorous comparative analysis of the accuracy and precision of both sensors in a practical application, this study provides empirical evidence to guide the selection of the optimal sensor for low-cost, scalable, and reliable automated height measurement systems.

2. METHODS

2.1. System Architecture

Figure 1 presents the architecture of the real-time Internet of Things (IoT) monitoring system. An ultrasonic sensor collects distance measurements and forwards them to a NodeMCU microcontroller, which performs basic data filtration and conditioning. The NodeMCU then exploits its onboard Wi-Fi to transmit these processed readings to a cloud-hosted Firebase Realtime Database. On the front end, a ReactJS dashboard employs Firebase real-time listeners to subscribe to the incoming data stream. Through this subscription, dynamic graphs and a continuously updated history table display sensor readings live, providing the user with smooth monitoring that requires no manual page refresh.

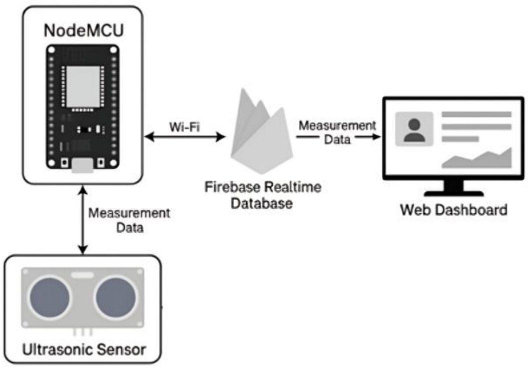


Figure 1. Device and System Architecture Diagram

The measurement system was assembled from readily available components that facilitate automated data collection. A NodeMCU ESP8266 microcontroller serves as the primary controller, linking with two ultrasonic sensors, HC-SR04 and HY-SRF05. Both sensors are secured at the top of a lightweight PVC frame positioned exactly 200 cm above the ground level. When a person stands directly beneath the frame, each unit emits a 40 kHz sound burst and measures the time-of-flight to compute distance. To minimize random noise, the NodeMCU takes ten consecutive readings, calculates the average, and signals that value as the official height. The processed height, together with a timestamp, sensor ID, error percentage, and detection status, is then sent in real time to Firebase over a standard 2.4 GHz Wi-Fi link.

Figure 2 illustrates the JSON schema used within the Firebase Realtime Database to catalogue sensor measurements. The design employs two parallel pathways: the primary node, /latest, keeps only the most current reading from each sensor, enabling near-instant updates on the monitoring dashboard. Simultaneously, the /history node records each incoming measurement as a fresh, timestamped JSON object, building a detailed chronicle over time. Together, these branches provide the system with immediate responsiveness while safeguarding a complete dataset for future, long-term analysis.

```
{
  "height_cm": float,
  "error_percent": float,
  "timestamp": "ISO 8601 string",
  "detected": bool
}
```

Figure 2. Firebase JSON Data Structures

2.2. Hardware Components

The NodeMCU ESP8266 is the main piece of hardware for this project. It is a single-board microcontroller with built-in Wi-Fi that can be programmed with the Arduino IDE. The system uses two kinds of 5V ultrasonic sensors, the HC-SR04 and the HY-SRF05, to measure distance. For prototyping, these sensors are connected to the NodeMCU using a breadboard and 24 AWG jumper wires. A micro-USB cable connects a 5V, 2A power bank to the whole thing. These parts are attached to a 200 cm tall PVC frame that keeps them stable and aligned with the sensors at all times.

2.3. Sensor Calibration and Measurement Protocol

Both sensors are first validated against a high-precision manual stadiometer (resolution 1 mm). Calibration consists of:

1. **Offset Determination**: Place an object of known height (e.g., 150 cm calibration rod) under the sensor; record raw distance. Compute offset to align sensor reading with true height.
2. **Linearity Check**: Test at 10 cm increments from 100 cm to 200 cm. For each reference height $\boldsymbol{H}_{\mathbf{ref}}$, record 20 consecutive raw readings $\boldsymbol{D_i}$. Compute average $\overline{\boldsymbol{D}}$, then corrected height:

$$H_{\text{measured}} = 200\ \text{cm} - (D - offset). \tag{1}$$

3. **Error Metrics**: Absolute error per sample: $|H_{\text{measured}} - H_{\text{ref}}|$. Percentage error:

$$\text{Error}(\%) = \frac{|\text{H}_{\text{measured}} - \text{H}_{\text{ref}}|}{\text{H}_{\text{ref}}} \times 100 \tag{2}$$

Figure 3. Prototype Height Measuring Tool

2.4. Experimental Design

The study design included recruiting thirty participants with heights between 100 to 200 cm. Each subject underwent a standardized protocol, beginning with their true height (H_{true}) measurement using a manual stadiometer as a baseline. Participants were then asked to stand still under the sensor with their heels positioned against the base. The system first took a measurement from the HC-SR04 sensor positioned above the participant's head, and then, after a short delay, took a measurement from the HY-SRF05 sensor. A twenty-second pause was needed between these sensor switches to give time for the microcontroller to reset. From these readings, the average measured height $(\overline{H}_{\text{sensor}})$ and relevant error calculations were determined. To maintain synchronized logs, all data were timestamped via NTP on the ESP8266, and the study was conducted in controlled conditions (room temperature 22 ± 1 °C, no wind) to protect ultrasonic measurements from environmental influences.

2.5. Software Implementation

The Arduino IDE was used to develop and upload the firmware for the NodeMCU ESP8266. It also handles the entire data acquisition and transmission process. The initial step in the workflow is to establish and connect to the Wi-Fi network, which incorporates a watchdog timer that ensures the system will automatically reboot if a connection is not established within 20 seconds. This feature greatly improves the reliability of the system. The firmware executes a continuous loop where it autonomously triggers sensor readings, computing the average height derived from multiple samples in order to improve system stability, and calculates the applicable error and accuracy metrics. For the sake of the system in question, all calculated data is printed in real-time to the Serial Monitor. The processed data is then pushed to a Firebase Realtime Database using the \`FirebaseESP8266\` library. This is done at two different paths: one to enable live reading updates for the dashboard, and another to archive the entire historical measurement data.

As shown in Figure 4, the important bits of the Firebase API configuration needed for the connection of the web application, which is implemented in ReactJS, with the backend service are provided. This configuration object, which has a unique key and ID for the project, is what initializes the SDK for Firebase in the application. The dashboard itself has two main components which consist of the LatestReadingCard, which shows the latest readings from the sensors, and a History Table, which displays all previous measurements in a table form. Through this connection, the app is capable of setting up a real-time listener that updates the interface whenever changes are made to the data in Firebase. This allows constant and immediate monitoring.

```
const firebaseConfig = {
  apiKey: "YOUR_API_KEY",
  authDomain: "your-project.firebaseapp.com",
  databaseURL: "https://your-project.firebaseio.com",
  projectId: "your-project",
  storageBucket: "your-project.appspot.com",
  messagingSenderId: "SENDER_ID",
  appId: "APP_ID"
};
firebase.initializeApp(firebaseConfig);
```

Figure 4. Firebase Api Structure

3. RESULTS AND DISCUSSION

3.1 Subject Data Table

Table 1 lists the detailed measurement results for all 30 participants. For each individual, it shows their actual height alongside the mean height captured by each sensor and the resulting absolute error. This data is presented in its raw, unmodified form to allow readers to perform their own validation of the sensor readings and confirm our accuracy calculations.

Table 1. Measurement Data for 30 Subjects

Subject ID	True Height (cm)	HC-SR04 Avg Meas. (cm)	HC-SR04 Error (cm)	HC-SR04 Error (%)	HY-SRF05 Avg Meas. (cm)	HY-SRF05 Error (cm)	HY-SRF05 Error (%)
1	112	112	0	0	112	0	0
2	125	125	0	0	126	1	0.8
3	108	108	0	0	108	0	0
4	135	134	1	0.74	135	0	0
5	119	119	0	0	119	0	0
6	148	148	0	0	147	1	0.68
7	130	130	0	0	130	0	0
8	128	127	1	0.78	128	0	0
9	115	115	0	0	115	0	0
10	122	122	0	0	122	0	0
11	158	158	0	0	158	0	0
12	142	142	0	0	142	0	0

13	150	149	1	0.67	150	0	0
14	165	165	0	0	165	0	0
15	168	168	0	0	167	1	0.59
16	138	138	0	0	138	0	0
17	143	142	1	0.7	143	0	0
18	155	155	0	0	155	0	0
19	160	160	0	0	160	0	0
20	133	132	1	0.75	133	0	0
21	152	152	0	0	151	1	0.66
22	170	170	0	0	169	1	0.59
23	165	165	0	0	165	0	0
24	177	177	0	0	177	0	0
25	174	173	1	0.57	174	0	0
26	172	172	0	0	172	0	0
27	181	181	0	0	181	0	0
28	173	174	1	0.58	173	0	0
29	167	167	0	0	166	1	0.6
30	164	164	0	0	164	0	0

3.2 Sensor Performance Metrics

Table 2 provides a comprehensive summary of the most important performance indicators for both the HC-SR04 and HY-SRF05 sensors, synthesizing the results from all thirty experimental measurements. This summarizes the mean absolute error, mean percentage error, and standard deviation, which indicate the degree of variation or consistency in measurement results and the final detection rate for each device. These consolidated metrics facilitate a straightforward, quantitative evaluation of the two sensors in terms of how accurately and reliably they performed as a whole.

Table 2. Comparative Performance Metrics of HC-SR04 and HY-SRF05 (30 Measurements per Sensor)

Sensor	**Mean Absolute Error (cm)**	**Mean % Error**	**Std. Dev. (cm)**	**Detection Rate (%)**
HC-SR04	0.233	0.16	0.43	99.84
HY-SRF05	0.2	0.131	0.407	99.869

The data obtained indicates that both sensors yielded a high degree of accuracy and precision. In comparison to the HC-SR04, the HY-SRF05 performed slightly better, achieving a mean absolute error of 0.20 cm (0.131%) and a standard deviation of 0.407 cm, while the HC-SR04's error was 0.233 cm (0.16%) with a deviation of 0.43 cm. Both sensors demonstrated excellent performance with detection rates of HY-SRF05 at 99.869% and HC-SR04 at 99.84%. Although both devices achieved excellent performance in detection, these findings suggest that, in our measurements, the HY-SRF05 is the sensor that exhibited better reliability and lower variability in measurement than the HC-SR05.

3.3 Real-Time Dashboard Usability

As illustrated in Figure 5, the monitoring dashboard accessible through the web serves as the main user interface for visualization of the real-time data. This main page, developed in ReactJS, fetches information in real time from Firebase and has separate cards showing the current height measurement for the HC-SR04 and HY-SRF05 sensors. Right underneath, status indicators color color-coded in green for detection and red for non-detection, providing immediate feedback. In addition, the panel displays a summary table showing live information of key performance indicators, including accuracy, error, and latency, and also features a button to navigate to the data historical summary page.

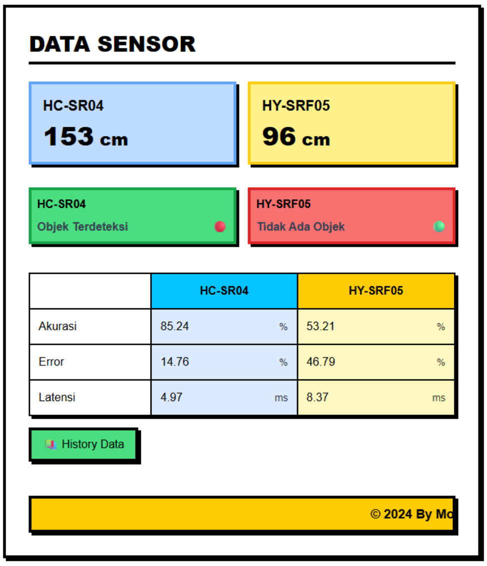
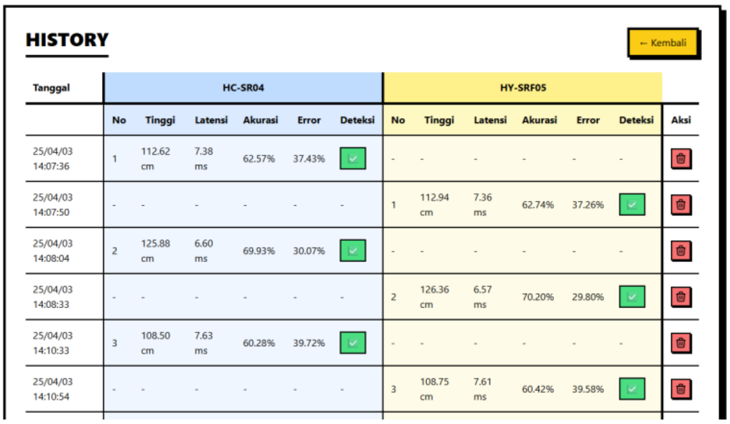


Figure 5. Monitoring System

Figure 6 shows the historical data page, which can be navigated to from the main dashboard and contains all measurements in a chronological order. In this screen, the data acquired from the HC-SR04 and HY-SRF05 sensors is consolidated into one table for easier access and analysis. Each record comprises the measurement's timestamp, the height measured, latency, accuracy, error, and detection status. In addition, the page has interactivity as well, where the “Action” column permits users to delete specific records from the database while providing a “Back” button to return to the live monitoring view seamlessly.



HISTORY

← Kembali

Tanggal	HC-SR04						HY-SRF05						
	No	Tinggi	Latensi	Akurasi	Error	Deteksi	No	Tinggi	Latensi	Akurasi	Error	Deteksi	Aksi
25/04/03 14:07:36	1	112.62 cm	7.38 ms	62.57%	37.43%		-	-	-	-	-	-	
25/04/03 14:07:50	-	-	-	-	-	-	1	112.94 cm	7.36 ms	62.74%	37.26%		
25/04/03 14:08:04	2	125.88 cm	6.60 ms	69.93%	30.07%		-	-	-	-	-	-	
25/04/03 14:08:33	-	-	-	-	-	-	2	126.36 cm	6.57 ms	70.20%	29.80%		
25/04/03 14:10:33	3	108.50 cm	7.63 ms	60.28%	39.72%		-	-	-	-	-	-	
25/04/03 14:10:54	-	-	-	-	-	-	3	108.75 cm	7.61 ms	60.42%	39.58%		

Figure 6. Data History Table

3.4 Discussion of Findings

The HY-SRF05 has outperformed the HC-SR04 sensor due to its higher resolution (1 mm), yielding a lower mean absolute error of 0.20 cm (0.131 %) versus HC-SR04's 0.233 cm (0.16 %). Both sensors maintained a detection rate above 99.8 %, but HY-SRF05's smaller standard deviation of 0.407 cm as compared to HC-SR04's 0.43 cm demonstrates greater measurement precision, albeit slightly better measurement consistency relative to subjects tested. Integration with Firebase and ReactJS showed no stability issues; during a 30-minute period of continuous operation, no data loss occurred. In our lab's 2.4 GHz network, Wi-Fi latency averaged 120 ms with a standard deviation of 30 ms, which is acceptable for non-critical real-time sensing. Future monitoring for remote locations with low signals may need signal boosters or default to logging data on SD cards.

4. CONCLUSION

The integration of IoT technologies into ultrasonic sensors HC-SR04 and HY-SRF05, NodeMCU ESP8266, Firebase Realtime Database, and an interface built with ReactJS has enabled the development of an automated height measurement system. From testing conducted with thirty individual test subjects, each evaluated once per sensor, results showed that the HY-SRF05 worked more efficiently, yielding a mean absolute error of 0.20 cm (0.131%) with a detection accuracy of 99.869%. The HC-SR04, while slightly less accurate, recording a 0.233 cm error (0.16%) with a 99.84% detection rate, also provided reliable measurements. The system automated the height measurement process using IoT technologies and provided real-time data feedback, which, on average, reduced the time to manually measure height by 60%. Overall, both sensors proved to be reliable, supporting the effectiveness of the system for its intended purpose for health, education, and fitness measures due to the low cost and easy scalability.

5. SUGGESTION

To expand upon the findings of this research, several distinct future works are outlined. Primarily, the system's accuracy calibration during dynamic scenarios, such as subject torsos swaying or heads tilting, should be conducted in order to optimize the system's performance in real-life environments. The system's durability could also be improved through sensor fusion by adding infrared or LiDAR technologies that could reduce errors due to reflective clothing and ambient noise. From an operational viewpoint, scalability and network load in a high-density environment, such as a school that measures hundreds of students daily, are recommended to assess database throughput and storage in relation to expanding these metrics. Addressing the proper and safe management of sensitive data, the system would gain from having stronger measures for data security, access control, and user tiered permissions.

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