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Automatization of Weight and Height Measurement Using Ultrasonic Sensors HC-SR04 and Load Cell Based on Arduino UNO at Integrated Services Posts (Posyandu)

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Abstract

An automatic instrument for measuring weight and height has been realized using the HC-SR04 Ultrasonic Sensor and Arduino Uno-based load cell. This study aims to facilitate the weight and height measurement system to make data collection more efficient and accessible. The instrument is assembled by a frame made of PVC pipe to form a 112 cm high pole. The instrument's top is mounted with an Ultrasonic Sensor to detect height. At the bottom of the instrument, there are four load cells which are assembled with the principle of Wheatstone bridge and then connected to the HX711 module as a signal amplifier to the Arduino to detect weight. The measurement results are displayed on the LCD and the application interface created with Microsoft Visual Studio. The results showed that the instrument could measure and display the results of measuring weight and height well. The error value and accuracy of the Ultrasonic Sensor are 1.09% and 98.913%, respectively. The error values and load cell accuracy were obtained at 1.4% and 98.6%.

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Abstract

Telah direalisasikan instrumen otomatis pengukuran berat dan tinggi badan menggunakan Sensor Ultrasonik HC-SR04 dan load cell berbasis Arduino Uno. Tujuan penelitian untuk memudahkan sistem pengukuran berat dan tinggi badan agar lebih efisien dan lebih mudah dalam pendataan. Instrumen dibuat dengan merangkai rangka yang terbuat dari pipa PVC membentuk tiang setinggi 112 cm. Bagian atas instrumen dipasang Sensor Ultrasonik untuk mendeteksi tinggi badan. Bagian bawah instrumen terdapat 4 load cell yang dirangkai dengan prinsip jembatan wheatstone kemudian dihubungkan dengan modul HX711 sebagai penguat sinyal menuju Arduino untuk mendeteksi berat badan. Hasil pengukuran ditampilkan pada LCD dan aplikasi antarmuka yang dibuat dengan Microsoft Visual Studio. Hasil penelitian menunjukkan yaitu instrumen dapat mengukur dan menampilkan hasil pengukuran berat dan tinggi badan dengan baik. Nilai error dan akurasi Sensor Ultrasonik diperoleh 1,09 % dan 98,913 %. Nilai error dan akurasi load cell diperoleh 1,4 % dan 98,6 %.

1. Introduction

Health is one of society's basic needs, which is the right of every citizen protected by the Constitution (Khariza, 2015), be it physical or mental health. Many factors affect human health, such as the economic, social, and physical environment and individual characteristics. Age can influence the body's immune system, especially cell-mediated immunity or what is commonly called Cell-Mediated Immunity (CMI) (Noviyanti & Sarbini, 2010). Children under five years of age (toddlers) are vulnerable to health and nutrition, while the immune ability of the elderly group and the speed of immune response against infectious diseases will decrease with age.

One of the health problems that are often found in toddlers is nutritional problems. Nutritional status in toddlers can affect several aspects. Malnutrition in toddlers harms physical and mental growth, hindering learning achievement (Rahim, 2014). Physical indicators (*anthropometry*) of undernutrition can be indicated by low weight

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and short body (less height at average age). The incidence of undernutrition or short nutrition has become a global nutritional problem (Rahayuh et al., 2016). For that, nutritional status needs to be known early on through health efforts, one of which is Posyandu.

The existence of Posyandu is vital in the community because it is a forum for community empowerment in transferring information and skills from officers to the community and bringing primary health services closer to the community (Zuniawati, 2019). The benefits of carrying out activities at Posyandu are health services for mothers and children, family planning (KB), immunization, nutrition control, and prevention of diarrhea in children. At Posyandu, routine measurements of weight and height are carried out once a month. One way to assess nutritional status in community groups is by measuring the human body, known as anthropometry, which is presented as an index associated with other variables. These variables include age, weight, and height (Fidiantoro & Setiadi, 2013).

Measuring instruments are tools that humans can use to assist in the process of determining a parameter. There are several measurement parameters, including height and weight measurements. Measurable variables such as age, weight, and height can be identified through analog measuring devices. However, most tools are still analog and done manually (Dwiyatno & Prabowo, 2017). Changing the measurement process from manual to automatic can make it easier for humans to carry out measurement activities. This research aims to create an automated tool for measuring weight and height using the HC-SR04 Ultrasonic Sensor and a 50 kg *load cell* based on Arduino UNO as a tool at Posyandu.

Previously, many similar studies have been carried out related to the automation of weight and height measurements, such as those conducted by Dwiyatno and Prabowo (2017) but using the Delphi 7 *interface*. For weight measurement, the *load cell* used is of different types of mass capacity that can be weighed, as in the study of Kusriyanto and Saputra (2016) using a Mavin brand *load cell* of the NA4 type with a capacity of 200 kg. The type is type GP2Y0A02YK0F. The advantage of this research with previous research is that the measurement results can be displayed on a PC (*Personal Computer*), and measurement data can be stored automatically. The sensors used can be found on the market as more affordable than other types.

2. Research methods

The research is divided into instrumentation system design, tool testing, and data processing. The system design of this instrument is generally shown in the block diagram in **Figure 1**

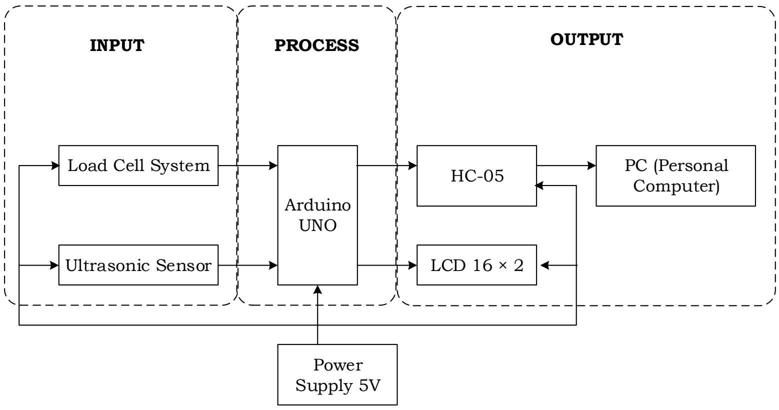

Figure 1. block diagrams.

Generally, a series of built systems include reading parameters, processing, sending data in Visual Studio applications, and storing data in Microsoft Excel. On reading the physical parameters, height and weight will be captured by the Ultrasonic Sensor, and the *load cell* is then converted into electrical quantities (analog signals). The analog signal is then converted into a digital quantity (digital signal) using the Arduino Uno processor. The digital value converted from the Arduino Uno will then be displayed using a 16x2 LCD. The data will be sent to a PC via a *wireless network using the HC-05 Bluetooth* module and displayed with an interface created with Microsoft Visual Studio *software.* The measurement results will be saved in a *file* in Microsoft Excel containing name, age, height, and weight measurement results. The electric current source of this instrument uses a 5V power supply obtained from a rechargeable battery placed on the battery shield and connected to a circuit scheme with a voltage of 5 V.

The design phase of this automated measurement instrumentation system is divided into four parts as follows.

a. Circuit schematic

The schematic of the automatic measurement instrumentation circuit can be seen in **Figure 2**, with the scheme consisting of the following:

1. *Load cells* 50 kg in as many as four pieces
2. HX-711. Module
3. Arduino Uno
4. Power supply
5. Ultrasonic Sensor HC-SR04
6. HC-05. Bluetooth module
7. 16 x 2 LCD

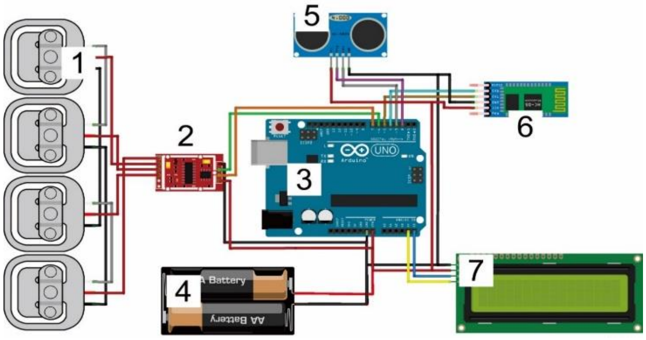

Figure 2. Schematic of the system circuit

b. Arduino Controller Program
The controller program on the Arduino Uno Microcontroller was created using the Arduino IDE software. The program to be created contains commands to carry out the functions of the controller circuit. In general, the design of the control program is shown in the flow chart in **Figure 3**.

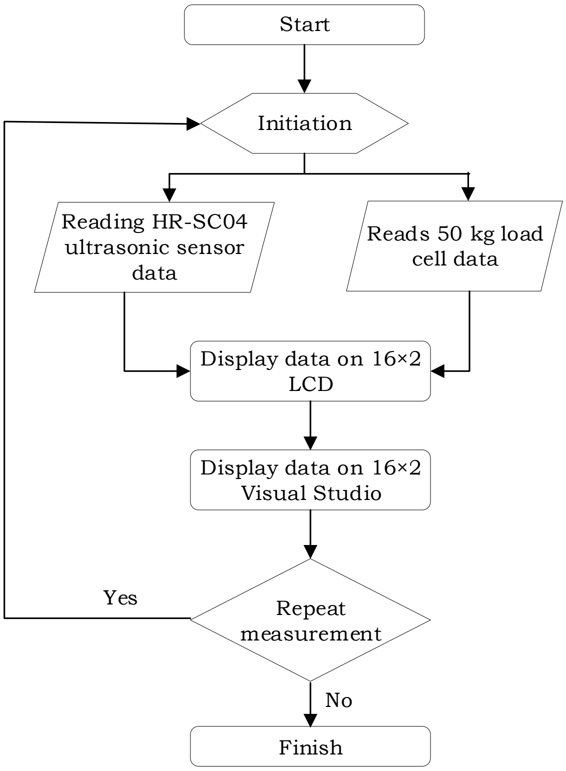

Figure 3. Flowchart of the control program design.

c. Tool design
The tool design created is shown in **Figure 4**. The framework uses PVC pipe with a height of 1.12 meters to place the Ultrasonic Sensor as a height-measuring sensor. The footrest below is placed in a *load cell* coated with an aluminum box to measure body weight. In the middle is a box containing Arduino UNO, a power supply, *a Bluetooth module,* and an LCD as a temporary display of measurement results.

Figure 4. Tool design.

d. Visual Studio Interface Software
Visual Basic is a programming language that is easy for beginners because it is a simple language that uses commonly used words (Wiliani & Fahmi, 2017). In this study, Visual Studio is used as a monitoring system application. The application is designed to display data in the form of distance and mass parameters and can be used to store measurement data in the form of Microsoft Office Excel files. The interface also provides a column for the name and age of the child to be measured to facilitate data collection to be carried out. The application receives the measurement results that Arduino has processed.

The next stage of testing the measurement instrumentation system includes calibrating the instrument's tools. Calibration is carried out so that the sensor measurement results are known whether the measurement value is valid according to the comparison instrumentation. The test data results are then used to calculate the percentage of relative error, accuracy, and precision. Tests were carried out on the LCD, interface applications made with Visual Studio, and data storage systems.

After testing the instrumentation, the system will be implemented to measure children under five at the Posyandu to find that the system is running well. Data collection was carried out on ten toddlers. The nutritional status of the measured children is also attached, reviewed based on the anthropometric standards used by the Ministry of Health, namely a review in terms of age, height, and weight.

3. Results and Discussion

1. Tool Realization.
The realization of the automation instrument for measuring weight and height is shown in **Figure 5**. The instrument displays measurement data value *output* on LCD and PC with Visual Studio interface *wirelessly*. Measurement result data is saved automatically with Microsoft Excel. The instrument frame is made with a 112 cm high PVC pipe as a place for the Ultrasonic Sensor and an iron body as a *load cell* in the lower box of the instrument frame with a height measuring 35 cm x 35 cm. The middle box contains the Arduino Uno components, *Bluetooth module*, power supply, and LCD.

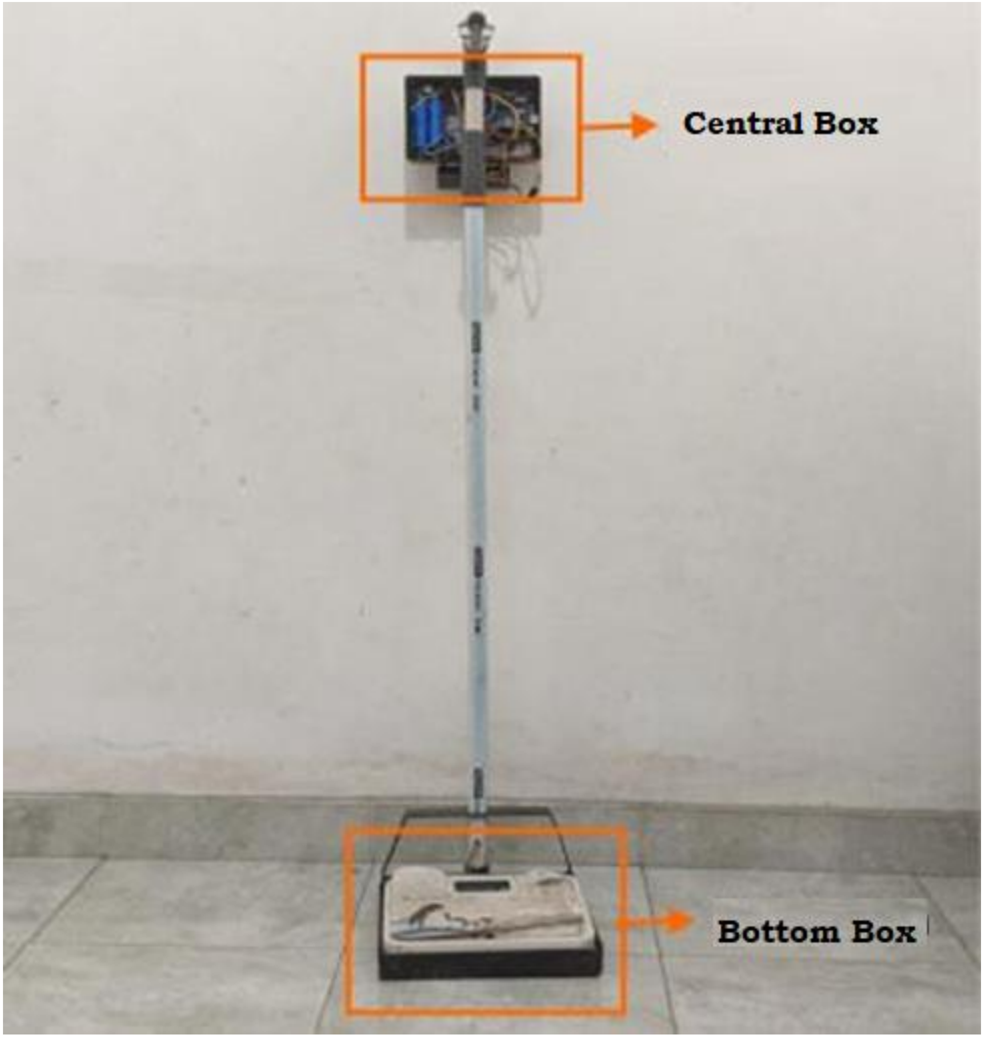

Figure 5. Realization of automatic weight and height measurement instruments

2. Liquid Crystal Display (LCD) Testing
The test program contains a command to display the instrumentation system name when the instrument is powered on. Then the LCDs are the measurement results obtained from the sensor, namely from the Ultrasonic Sensor and *load cell*. This test is carried out to ensure that the LCD can function properly and be used to display measurement values from Ultrasonic Sensors and *load cells*. The following LCD test results can be seen in **Figure 6**.

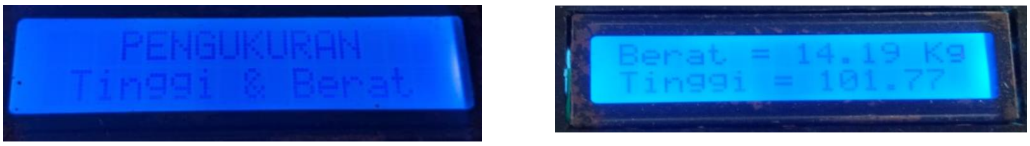

Figure 6. The LCD shows the instrument name and measurement data

3. Ultrasonic Sensor Test
Ultrasonic sensor testing against standard tools is shown in Figure 7. This action is needed to determine the level of *error* or error in the sensor used. The test is carried out by measuring the distance of an object with a flat surface using an Ultrasonic Sensor, then compared with measuring the distance of an object using a standard tool. The supporting media used are "GEA Medical" brand height measurement, LCD, power supply, and various objects whose height is known.

Figure 7. Testing of Ultrasonic Sensors against standard tools "GEA Medical."

Height scales are mounted on a wall at 2 m from the floor. The height measuring sensor is assembled according to the design drawing on the instrument. The samples used were 15 children with a height range of 66,7-108.8 cm (adjusting to the child's height), with each measurement of the Ultrasonic Sensor repeated three times. The results of distance testing using Ultrasonic Sensors against measurement results using standard tools are shown in **Table 1**.

Table 1. Ultrasonic Sensor test results against "GEA Medical" standard tools

No	Standard tool height (cm)	Ultrasonic Sensor (cm)			Average (cm)
		1	2	3	
1	66.7	66.35	66.32	66.29	66.32
2	68.4	70.96	70.79	71.00	70.91
3	76.2	77.47	77.37	77.44	77.42
4	81.2	82.40	82.35	82.42	82.39
5	86.2	87.16	87.06	87.11	87.11
6	90.0	90.77	91.21	91.82	91.26
7	93.0	94.27	94.63	94.00	94.30
8	94.5	95.79	95.71	95.10	95.53
9	95.2	96.56	96.53	96.51	96.53
10	96.0	97.31	97.70	97.30	97.43
11	96.8	97.00	97.58	97.70	97.42
12	98.6	99.96	99.04	99.44	99.48
13	106.0	105,92	105.90	105.11	105.64
14	108.0	107.65	107.77	107.95	107.79
15	108.8	109.07	108.70	108.79	108.85

The graph of the results of distance testing using an Ultrasonic Sensor to measurements using standard tools is shown in **Figure 8.** The graph shows the R^2 value obtained is 0.9969, and the linearity equation obtained is shown in **Equation 1**.

$$y = 3{,}1957 + 0{,}9743x \tag{1}$$

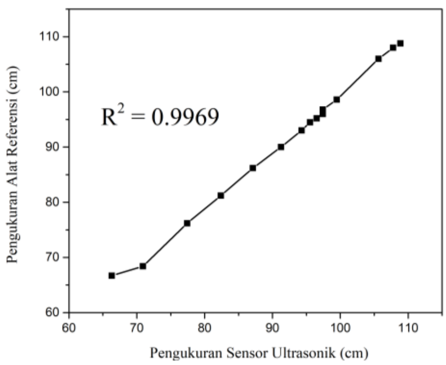

Figure 8. Graph of Ultrasonic Sensor test results against standard tools.

The percentage *error* of the Ultrasonic Sensor obtained is 1.09%, so the average percentage accuracy value obtained is 98.913%, and the percentage value for the precision of the Ultrasonic Sensor is 91.895. The results followed research conducted by (Akbar, 2015) which obtained an *error value* of 1.14% with an instrument as high as 200 cm, and measurements were made in the height range of 163-172 cm. The *error* value obtained is almost the same, with a difference of 0.05%.

Load Cell Testing
The load cell is used to measure body weight. This *load cell* is equipped with an HX711 module which functions as a valued reader for the *load cell* by converting the measured changes in the voltage resistance to be forwarded to the Arduino. The supporting media is a 5 V power supply, LCD, and a weight reference measuring instrument, a Xiaomi brand digital scale of the "Mi Body Composition Scale" type. The series of *load cell* testing on standard equipment is shown in **Figure 9**.

Figure 9. Testing *load cell* 1 against standard tools.

The load cell to be tested is a unified system in which four *load cells* of type G with a capacity of 50 kg are assembled using the principle of a *Wheatstone bridge*. The *load cell* is connected to the HX711 signal amplifier module to the Arduino Uno. The linearity test mechanism between the *load cell* and the weighing scale is carried out to obtain accuracy and precision between the *load cell* and the reference scale. Linearity testing is carried out using a *load cell* given a load that has been measured previously using a reference scale with a range of 9-18 kg. Then the measurement was repeated three times. The test results between *load cells* and reference scales are shown in **Table 2**. The graph of the *load cell* test results against the reference body weight is shown in **Figure 10**.

Table 2. The results of *load cell* testing against standard equipment

No	Standard tool height (kg)	*Load cells* (kg)			Average(cm)
		1	2	3	
1	10.15	9.43	9.35	9.37	66,32
2	12.15	12.17	12.26	12.51	70.91
3	12.20	11.93	12.18	12.30	77.42
4	12.95	13.18	13.33	13.24	82.39
5	13.55	13.39	13.94	13.87	87.11
6	15.00	14.38	14.85	15.02	91.26
7	15.65	16.09	15.91	15.86	94.30
8	16.90	16.94	16.98	17.02	95.53
9	16.95	16.69	17.08	17.02	96.53
10	17.35	17.53	17.65	17.89	97.43

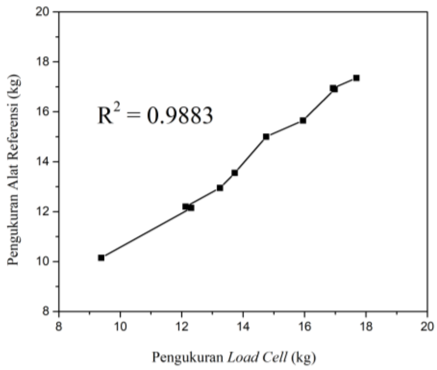

Figure10. Graph of *load cell test results* on digital body scales

The graph above shows the R^2 value of 0.9883, and the linearity equation obtained is shown in **Equation 2**.

$$y = 1{,}0719x - 1{,}0019 \quad (2)$$

The percentage of the average value of the measurement *error* obtained based on the calculation is 1.40%. The percentage of average *load cell accuracy is* 98.6%. The results obtained following the previous tests on measuring weight with a *load cell* in the study of Afdali et al. (2018). The *error value* obtained is 0.96%, and the accuracy value obtained is 99.04 %. The result of the measurement difference is 0.08%.

3. Application Interface

This study's interface application (*user interface*) was made using the Visual Studio 2019 application on a PC (*Personal Computer*). The design of this interface application consists of a monitoring display and a *data logger display*. The *monitoring display* reads sensor values, as shown in **Figure 12**.

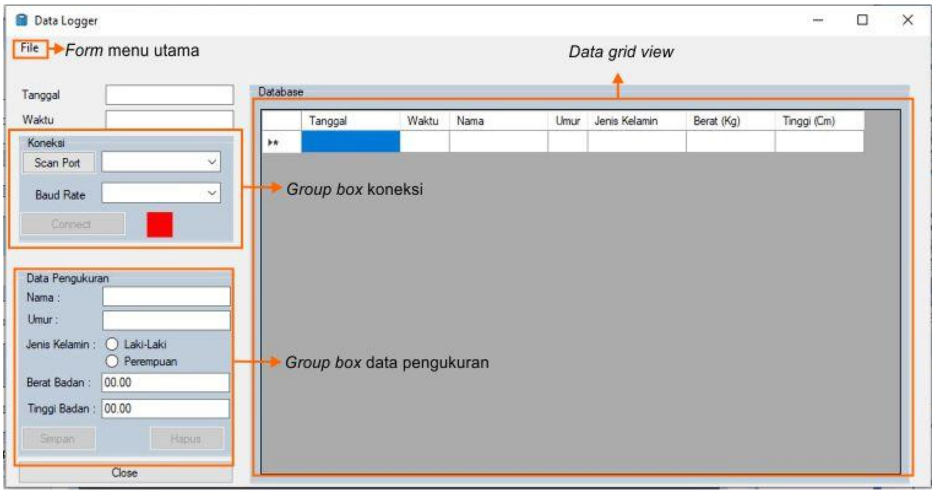

Figure 11. *Monitoring* menu display made with Visual Studio.

Figure 11 is a monitoring menu display consisting of the main menu form. The main menu form contains a page that displays the menus in the application interface. This program has one menu, " *file*", which consists of exporting data to *excel*, deleting data, and opening data. The *data logger display* displays sensor measurement data in tabular form. Measurements on the *data logger table* can be started by pressing the *connect button* on the "Connection" group box, where the *data logger process* will start, as shown in **Figure 12**. Then after pressing *connect*, the measurement date and time will start automatically. The indicator light that was initially red will turn green. The sensor value that is read will be displayed on the LCD and in the "weight" and "height" *text boxes*. After that, select *the port* and click *connect* so that the Arduino Uno is connected to the application interface.

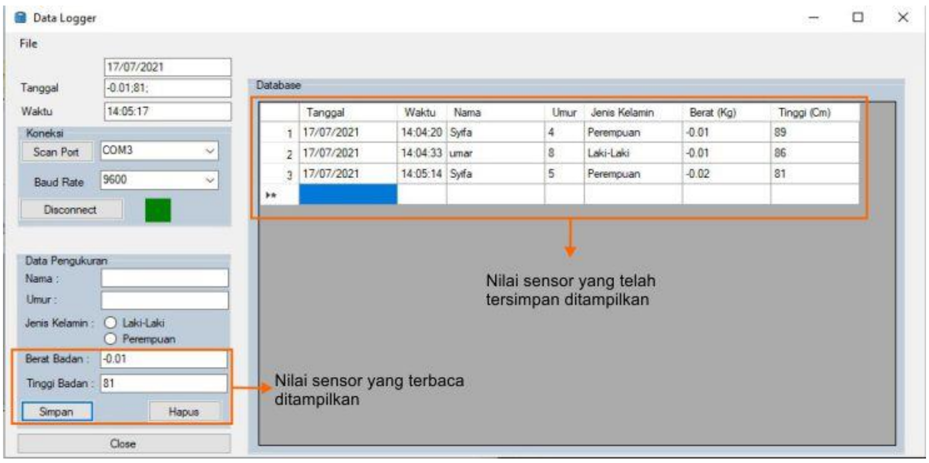

Figure 12. Display of sensor value readings on *data grid view.*

When taking measurements, the "measurement data" *group box* is filled with data on the person whose height and weight will be measured, such as name, age, and gender. Then *the data logger* will start running after the "*connect" button is* pressed, then the weight and height measurement values will appear. If a stable number appears, press the save *button to enter the measurement data in the data logger*. The data stored in *the logger* can then be saved to Microsoft Excel. However, the auto-save that was designed does not work. Storage is done by copying the numbers from the *data logger* to Microsoft Excel. If we want to restart the measurement and delete the previous *data logger* by pressing the " *File " menu bar and* then selecting the "delete data" button, then automatically, all measurement data in *the grid view data table* will be deleted.

4. Data Collection and System Analysis

Data collection and system analysis were carried out to apply the tool directly to the weight and height measurement of toddlers so that the overall performance of the instrument that had been made was known. Data collection was carried out at *Day Care* Al Muhsin Purwosari on August 24, 2021. The collection was carried out with toddlers as the object of measurement, as many as ten toddlers. The realized system is shown in **Figure 13**.

Figure 13. Realization of automatic weight and height measurement system.

To start fetching data, the object to be measured stands on the *load cell.* Then the object's weight and height values will be read through the Ultrasonic Sensor above the object's head and the *load cell* on the lower footrest. Furthermore, the device is connected to the PC *wirelessly* using *Bluetooth* for data transmission to the interface application on the PC, and the height and weight measurement begins. In the application interface, *the serial port* and *baud rate* are selected according to the system's use. The COM5 serial port and *baud rate in this system is* 9600. After the connection is successful and the indicator light changes color from red to green, the value read by the sensor will enter automatically in the application interface. They were supporting data that needed to be included in the name, age, and sex of the toddler being measured. The system measurement results displayed by the interface application can be seen in **Figure 14**.

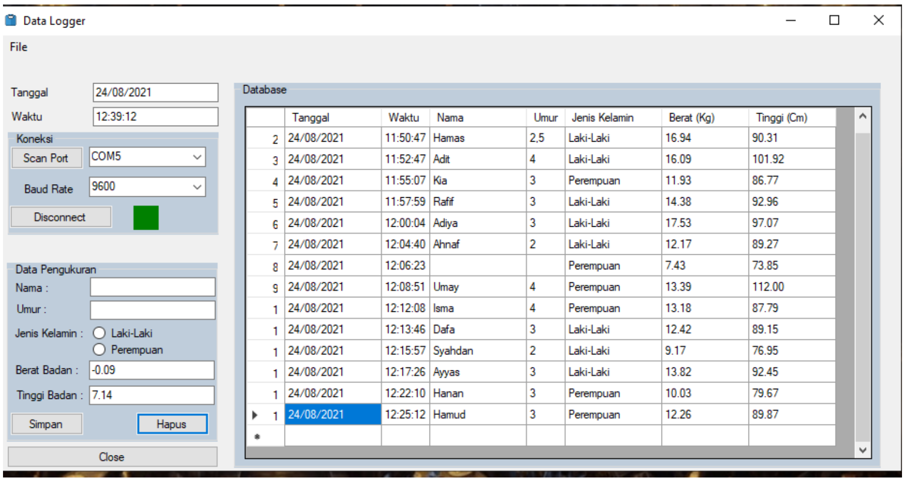

Figure 14. The measurement results are displayed on the application interface.

Figure 14 above is the result of measuring the weight and height displayed on the application interface. The measurement results on the system indicate that the interface application that has been made can read and display the weight and height values from the sensor correctly. The measurement value is also displayed on the 16 x 2 LCD, which is placed on the top side of the black box, which aims to make it easier for others to see the measurement results from the instrument. The display of measurement results by LCD is shown in **Figure 15**. The measurement results on the LCD are displayed correctly and follow the values displayed on the application interface. Then the measurement results are stored in Microsoft Excel 2016, shown in **Figure 16**.

Figure 15. The measurement results are displayed on the LCD

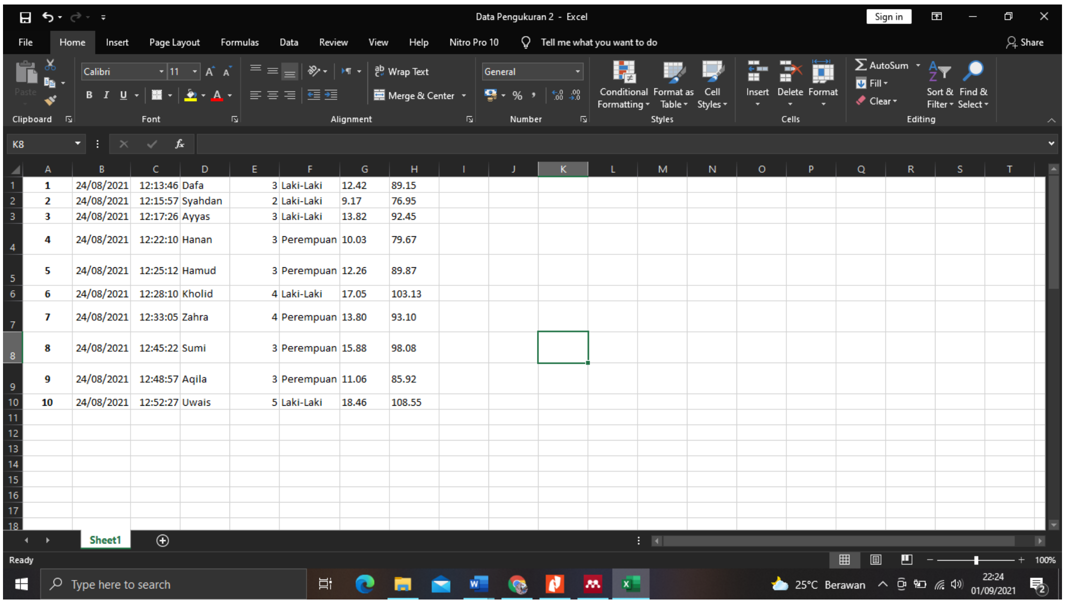

Figure 16. Measurement results are saved in Microsoft Excel.

Figure 16 shows the measurement results displayed and stored in the Microsoft Excel 2016 application. The measurement results displayed in Microsoft Excel show that the instrument is connected and can transmit the measurement values properly, and the measurement results can be displayed in Microsoft Excel. From this data retrieval, the height and weight measurement data obtained in tables that have been processed from the storage system are shown in **Table 3** as follows.

Table 3. Data measurement of weight and height.

No	Name	Age (yr: month)	Gender	Body weight (kg)	BB Status	Height (cm)	TB Status
1	Shahdan	1:4	L	9.17	Normal	76.95	Normal
2	Hanan	1:10	L	10.03	Normal	79.67	Short
3	Aqila	3:2	P	11.06	Normal	85.92	Short
4	Acid	3:7	L	12.26	Normal	89.87	Short
5	Dafa	2:5	L	12.42	Normal	89.15	Normal
6	Zahra	3	P	13.80	Normal	93.10	Normal
7	Ayyas	2:7	L	13.82	Normal	92.45	Normal
8	Sumi	4:8	P	15.88	Normal	98.08	Normal
9	Khalid	2:8	L	17.05	Normal	103.13	Tall
10	Uwais	5	L	18,48	Normal	108.55	Normal

Information:
L: boy
Q: girl

Table 3 is the result of measuring the weight and height of 10 toddlers. The measured age range is 2-5 years, and the table shows a toddler's weight range from 9.17 to 18.48 kg and a toddler's height from 76.95 to 108.55 cm. Information on nutritional status in terms of TB (Height) for age and BB (Weight) for age in toddlers who are categorized based on a list of anthropometric standards of weight and height based on a list of anthropometric standards of ideal weight and height of toddlers in the Minister of Health Regulation (PMK).) RI Number 2 of 2020.

4. Conclusion

Based on the research that has been done, it is concluded that the instrument that has been made can run well, with a *load cell* test *error value* of 1.4% and an accuracy value of 98.6%. The ultrasonic sensor test *error* value is 1.09%, and the accuracy value is 98.913%. The serial port communication between the PC and the instrument runs well, as evidenced by the interface program operated using a PC.

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