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Internet of things-based digital scale to detect stunting symptoms in babies under two years of age

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ABSTRACT

Given the ongoing global challenge of stunting, characterized primarily by chronic underweight in infants under two years of age, a new approach leveraging digital scale and the internet of things (IoT) has been developed. This innovative system was designed to facilitate the early detection and continual monitoring of stunting symptoms caused by malnourishment. Key features include an IoT-enabled digital scale for precise weight measurement, a robust cloud platform for reliable data storage and comprehensive analysis, and an easy-to-use mobile app for user engagement. This system demonstrates its potential to simplify tracking fluctuations in baby weight and development progress related to stunting over time. Early trials demonstrated an impressive accuracy rate of 99.4% in body weight measurements and provided excellent conclusions in determining the body weight status of the infants. Overall, this IoT-based solution catalyzes the improvement of stunting detection methodologies and early intervention strategies, thus promising a better solution and a significant positive impact on global child health.

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1. INTRODUCTION

There has been growing concern in recent years about the problem of stunting in babies under the age of two. Stunting, defined as chronic underweight and stunted growth, is an essential indicator of long-term malnutrition. It can harm children's physical and cognitive development, including their susceptibility to disease, academic performance, earning capacity, physical strength, and chronic disease [1], [2]. Underweight is a significant factor influencing the incidence of infant stunting [3]. It is defined using z-scores of lessthan-2 standard deviation (S.D.) according to World Health Organization (WHO) weight standards based on age and sex [4]. In this study, a system was developed to determine the symptoms of stunting in infants based on an analysis of their body weight, age, and gender.

The internet of things (IoT) has pervaded various aspects of human life. In smart homes, IoT applications improve user comfort, optimize electrical energy consumption, and enhance security measures [5]. Similarly, in agriculture, it enables automated and real-time tasks such as weeding, spraying, and precise monitoring of temperature and humidity [6]. Furthermore, in healthcare, IoT enables patient monitoring, real-time medical data transmission, and connected health devices to enhance healthcare and medical diagnostics [7].

In IoT applications, microcontrollers play a pivotal role in monitoring and controlling devices [8]–[13]. Additionally, a range of communication technologies, including wireless fidelity (Wi-Fi) and the fourth generation (4G), establish connections between devices equipped with microcontrollers and servers [14]–[18]. Cloud technology is frequently used to upload data from devices or smartphones to servers and to retrieve essential data from servers to devices or smartphones [19]–[22]. Smartphones, on the other hand, are utilized for system setup and monitoring purposes [23]–[25].

Several researchers have previously developed an IoT application for monitoring body weight. This application monitors adults' body mass index (BMI) over time and aims to prevent obesity. This IoT application uses an IoT-based digital scale, cloud server, and smartphone [26]. In this research, the IoT application model was built similar to its predecessor but with different objectives. This IoT application is designed for early detection and progress monitoring of stunting symptoms in infants up to two years of age. Significant differences lie in the electronic components, data processing algorithms, and user feedback. The application provides four types of feedback: normal, underweight, mild stunting symptoms, and stunting symptoms. Through this feedback, medical staff can easily understand the condition of the weighed baby, whether it falls within the normal range or shows symptoms of stunting. Furthermore, medical staff can track the number of babies exhibiting stunting symptoms in their hospital within specific periods.

2. METHOD

In this research, software and hardware were created and utilized to build the system. Based on the block diagram in Figure 1, the smartphone and ESP32 microcontroller are connected through a cloud server using the internet. The ESP32 utilizes a load cell and HX711 to acquire body weight data, which is then transmitted to the cloud server for processing the user's request via the smartphone. The ESP32 also employs a liquid crystal display (LCD) to display body weight data and indicate data transmission status to the cloud. The power supply provides voltage to the ESP32, activating the LCD and HX711.

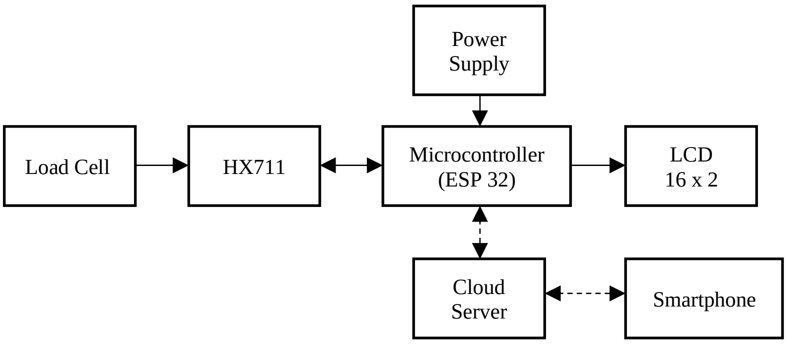

Figure 1. Block diagram of the system

The schematic diagram for the developed system can be seen in Figures 2 to 4, while the developed Android smartphone application can be seen in Figure 5. Figure 2 shows how the load cell is connected to ADC HX711. It can also be seen that in the IoT-based digital scale, four load cells are arranged in a Wheatstone bridge circuit, along with an analog-to-digital converter (ADC) HX711 specially designed for measuring the weight or force received from these load cells. The load cells serve as sensors to determine the baby's body weight, and the ADC HX711 is responsible for reading the analog signals from these load cells and converting them into digital data that a microcontroller can understand. Figure 3 shows how the HX711 is connected to the microcontroller, which processes and communicates the data received from the HX711 to the LCD and cloud database wirelessly via the internet network. Figure 4 illustrates how the LCD is connected to the ESP32.

Referring to the image above, here is a step-by-step explanation of the application's menu, starting from the top-left corner and moving towards the bottom-right corner as follows:

a. The cover menu is the first page of the application. This page has a 'login' button to access the main menu and a 'register' button to create a new hospital or public health center account.
b. The hospital registration menu is the page to create a new hospital/public health center account by providing necessary information like the hospital's name, address, province, city/regency, and a password for logging in.
c. The login menu is the page to access the main menu by entering the hospital name and password provided during the registration in the hospital registration menu.

d. The main menu is a page that accesses three other menus: patient registration menu, measure body weight menu, and monitor stunting status menu.
e. The patient registration menu is the page used to register a new patient. Essential details such as the patient's first name, last name, gender, birthdate, and mother's name are required. After entering the correct information, click 'submit' to save the data in the database server.
f. The body weight menu is a menu accessed after the patient registration process in the patient registration menu. On this page, the initial step for measuring the baby's weight begins by providing the baby's birthdate and then selecting the corresponding baby's name from the list provided by the system. The baby's name is added to the mother's name to distinguish babies with the exact birthdate and first and last names. After providing the correct name, the weight measurement can be done by clicking the 'measure' button.
g. The result menu is the page accessed after clicking the 'measure' button in the body weight menu. On this page, we can view the baby's weight measurement results and corresponding status, determined based on the baby's weight analysis from the past four months. We can also check the baby's weight history from this menu by clicking the 'view history' button.
h. The history menu is the page for viewing the baby's weight history, month by month; the history is displayed using a line graph. To view the history, users must provide the year they want to see. Months with no baby weight results will not be shown on the graph.
i. The stunting status menu is the page for knowing the percentage of baby weight status in a chosen year. From this menu, users can also obtain detailed information about the weight status of every baby in a specific hospital by downloading the file from the system.

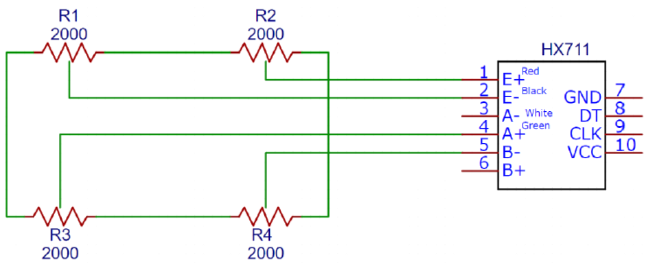

Figure 2. Schematic diagram of the load cell to HX711

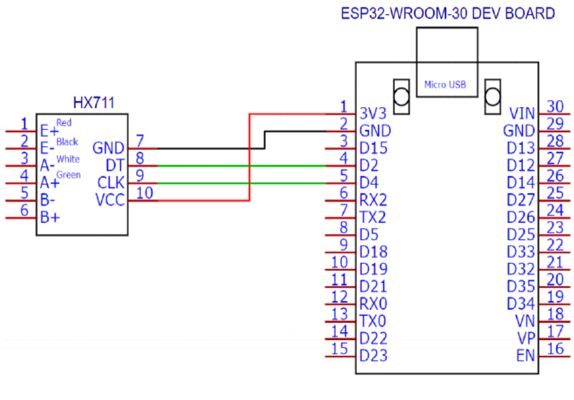

Figure 3. Schematic diagram of HX711 to ESP32

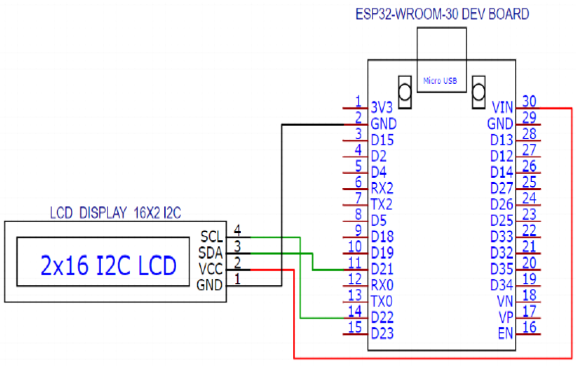

Figure 4. Schematic diagram of I2C LCD to ESP32

The decision-making process for assessing a baby's weight status consists of several vital steps. First, the average weight for each month is calculated. Next, based on the z-score, a status is assigned to each month; 'u' indicates underweight when the z-score is $\leq$ -2, 'n' signifies average weight when the z-score is > -2, and 'x' indicates no data for that month. Finally, the baby's overall weight status is determined by analyzing the baby's weight status for the last four months, referring to Table 1. This comprehensive procedure helps ascertain whether the baby's weight falls within a healthy range or if there are concerns about being underweight.

Figure 5. The developed android smartphone application

Table 1. The decision table of baby weight status

No	1st data	2nd data	3rd data	4th data	Decision
1	x	n	u	u	Mild stunting symptoms
2	x	n	n	u	Underweigth
3	x	n	x	u	Underweigth
4	x	u	u	n	Mild stunting symptoms
5	x	u	u	u	Stunting symptoms
6	x	u	n	u	Mild stunting symptoms
7	x	u	x	u	Mild stunting symptoms
8	x	x	u	u	Mild stunting symptoms
9	x	x	n	u	Underweigth
10	x	x	x	u	Underweigth
11	n	n	u	u	Mild stunting symptoms
12	n	n	n	u	Underweigth
13	n	n	x	u	Underweigth
14	n	u	u	n	Mild stunting symptoms
15	n	u	u	u	Stunting symptoms
16	n	u	n	u	Mild stunting symptoms
17	n	u	x	u	Mild stunting symptoms
18	n	x	u	u	Mild stunting symptoms
19	n	x	n	u	Underweigth
20	n	x	x	u	Underweigth
21	u	n	u	n	Mild stunting symptoms
22	u	n	u	u	Stunting symptoms
23	u	n	n	u	Mild stunting symptoms
24	u	n	x	u	Mild stunting symptoms
25	u	u	u	n	Stunting symptoms
26	u	u	u	u	Stunting symptoms
27	u	u	n	n	Mild stunting symptoms
28	u	u	n	u	Stunting symptoms
29	u	u	x	n	Mild stunting symptoms
30	u	u	x	u	Stunting symptoms
31	u	x	u	n	Mild stunting symptoms
32	u	x	u	u	Stunting symptoms
33	u	x	n	u	Mild stunting symptoms
34	u	x	x	u	Mild stunting symptoms

3. RESULTS AND DISCUSSION

In this study, the first test was conducted to assess the accuracy of the developed digital scale. In this test, the developed digital scale was compared to the reference digital scale to determine the accuracy of the developed digital scale. Ten experiments were carried out in this test, involving ten different babies. The average error percentage of the developed digital scale can be found in Table 2.

Table 2 shows that the average accuracy is 99.4%, with the highest error occurring at the lowest weight value. Additionally, it is evident that as the weight value decreases, the accuracy rate also decreases. This could impact babies with lower weight values. Based on the first test's results, the accuracy of the developed digital scale is approximately 99.4%.

The second test was conducted to determine the weight status of three infants after being weighed. The introductory data for this test is stored in the database server and can be seen in Table 3. Figure 6 shows the weight status of the three infants based on the data from the previous month. This status was obtained by using the decision-making process displayed in Table 4. The algorithm developed for this process functions smoothly and accurately, and as seen in Figure 6, it correctly determines the weight status of the three recently weighed infants.

Table 2. The accuracy of the developed digital scale

No	Reference digital scale	Developed digital scale	|Difference|	Error	Accuracy
1	6.4	6.4	0	0.0%	100.0%
2	7.8	7.8	0	0.0%	100.0%
3	6.6	6.6	0	0.0%	100.0%
4	5.5	5.4	0.1	1.8%	98.2%
5	8.3	8.3	0	0.0%	100.0%
6	7.2	7.2	0	0.0%	100.0%
7	8.5	8.5	0	0.0%	100.0%
8	5.7	5.6	0.1	1.8%	98.2%
9	4.9	4.8	0.1	2.0%	98.0%
10	9.3	9.3	0	0.0%	100.0%
Average					99.4%

Table 3. Weight data from measurements taken three months prior

Birthdate	First name	Last name	Gender	Mother's name	18/06/23	31/07/23	15/08/23	30/08/23
15/3/2023	Rich	Sanjay	Boy	Feronika	5.7	5.6	5.8	6.2
10/2/2023	Dena	Darwis	Girl	Anya	6.2	-	5.8	5.6
02/4/2023	Luis	Kohl	Boy	Diana	-	5.1	5.0	-

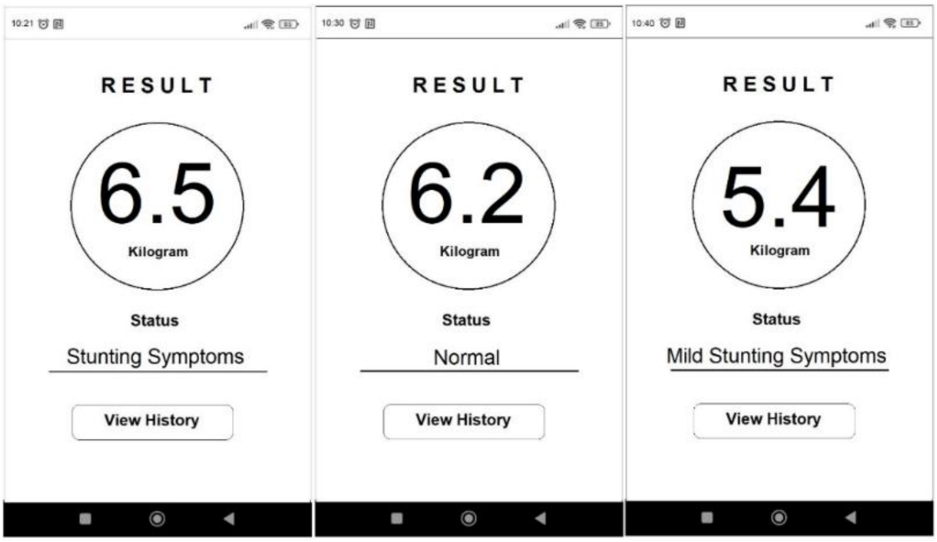

Figure 6. Result of weight measurement and body weight status of Rich, Dena, and Luis

Table 4. The decision-making process of body weight status of Reich, Dena, and Luis

Birthdate	First name	Last name	Gender	Mother's name	Jun	Jul	Aug	Sep	Decision
15/3/2023	Rich	Sanjay	Boy	Feronika	n	u	u	u	Stunting symptoms
10/2/2023	Dena	Darwis	Girl	Anya	n	-	u	n	Normal
02/4/2023	Luis	Kohl	Boy	Diana	-	n	u	u	Mild stunting symptoms

4. CONCLUSION

In conclusion, the first test in this study aimed to assess the accuracy of the developed digital scale. The results showed an average accuracy of approximately 99.4%, with the highest error occurring at the lowest weight value. Additionally, as the weight value decreases, the accuracy rate decreases, potentially impacting infants with lower weight values. The second test was conducted to examine the system's decision regarding the weight status of infants after weighing, and it demonstrated that the decision-making process operates smoothly, aligning with the developed algorithm and accurately determining the weight status of the recently weighed infants. Further research and fine-tuning of the digital scale's performance could lead to improved accuracy and more reliable weight status assessments.

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