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JITK (JURNAL ILMU PENGETAHUAN DAN TEKNOLOGI KOMPUTER)

RTOS-BASED SYSTEM FOR TODDLER NUTRITIONAL STATUS DETECTION

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Abstract—*Determining the nutritional status of toddlers is essential for monitoring growth and preventing long-term health problems. Manual assessment requires significant time and is prone to human error; therefore, an automatic detection system based on height and weight parameters is needed. This study aims to develop a Real-Time Operating System (RTOS)–based system to detect the nutritional status of children aged 24–60 months, capable of managing task priorities, ensuring timely execution, and preventing race conditions using semaphores. The system employs an ultrasonic sensor to measure height, load cell sensors to measure body weight, and a web-based interface to input gender and age. Nutritional classification is determined through Z-score calculations using WHO reference data. Tests conducted on 200 children in various locations showed that the ultrasonic sensor achieved an average absolute error of 0.39 cm, a relative error of 0.409%, and an accuracy of 99.59%, while the load cell sensor achieved an average absolute error of 0.22 kg, a relative error of 1.587%, and an accuracy of 98.41%. The average execution times for the measurement and Z-score computation tasks were 4014.4 ms and 11.31 ms, respectively. The nutritional status classification results showed accuracy levels of 99.5% for Weight-for-Age (W/A), 99.5% for Height-for-Age (H/A), and 97.5% for Body Mass Index-for-Age (BMI/A) compared with manual assessments. The developed system demonstrated reliable performance in measurement and classification, with results consistent with conventional methods, indicating its potential as an efficient and accurate tool to assist healthcare workers in monitoring toddler nutrition status.*

Keywords*: nutritional status, RTOS, toddler, Z-score.*

Intisari—*Penentuan status gizi balita sangat penting untuk memantau pertumbuhan dan mencegah masalah kesehatan jangka panjang. Penilaian manual memerlukan waktu yang signifikan dan rentan terhadap kesalahan manusia; oleh karena itu, sistem deteksi otomatis berdasarkan parameter tinggi dan berat badan diperlukan. Studi ini bertujuan untuk mengembangkan sistem berbasis Real-Time Operating System (RTOS) untuk mendeteksi status gizi balita berusia 24–60 bulan yang dapat mengelola prioritas tugas, memastikan eksekusi tepat waktu, dan mencegah kondisi balapan menggunakan semafor. Sistem ini menggunakan sensor ultrasonik untuk mengukur tinggi badan, sel beban untuk mengukur berat badan, dan antarmuka berbasis web untuk memasukkan jenis kelamin dan usia. Klasifikasi gizi ditentukan melalui perhitungan Z-score menggunakan data referensi WHO. Uji coba yang dilakukan pada 200 balita di berbagai lokasi menunjukkan bahwa sensor ultrasonik mencapai kesalahan absolut rata-rata 0,39 cm, kesalahan relatif 0,409%, dan akurasi 99,59%, sementara sensor sel beban mencapai kesalahan absolut rata-rata 0,22 kg, kesalahan relatif 1,587%, dan akurasi 98,41%. Waktu eksekusi rata-rata untuk tugas pengukuran dan perhitungan Z-score masing-masing adalah 4014,4 ms dan 11,31 ms. Hasil klasifikasi status gizi menunjukkan tingkat akurasi sebesar 99,5% untuk berat badan menurut umur (BB/U), 99,5% untuk tinggi badan menurut umur (TB/U), dan 97,5% untuk indeks massa tubuh menurut umur (IMT/U) dibandingkan dengan penilaian manual. Sistem yang dikembangkan menunjukkan kinerja yang andal dalam pengukuran dan klasifikasi status gizi, dengan*

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sebagian besar hasil konsisten dengan metode konvensional, sehingga berpotensi digunakan sebagai alat bantu tenaga kesehatan dalam memantau status gizi balita secara efisien dan akurat.

Kata Kunci*: status gizi, RTOS, balita, z-score.*

INTRODUCTION

In Indonesia, assessing the nutritional status of toddlers is an important aspect to support their growth and development, considering that this period experiences rapid increases in weight and height [1]. The toddler period is recognized as a golden phase that requires special attention to nutritional adequacy, as nutritional deficiencies during this stage are difficult to recover from and may hinder brain development, particularly in the cognitive domain [2]. However, some communities still have limited literacy in understanding and interpreting child nutritional status tables, which makes it difficult for them to accurately monitor nutritional intake [3]. Therefore, parents need to have a good understanding of how to assess a toddler's nutritional status. In Indonesia, toddler nutritional status assessment generally refers to anthropometric indicators, namely Weight-for-Age (W/A), Height-for-Age (H/A), and Body Mass Index-for-Age (BMI/A) for children aged 24 to 60 months, using the Z-score approach [4]. Determining nutritional status based on these indicators is very important to ensure toddlers receive adequate nutrition for their body development [5].

To ensure that the three indicators can be measured quickly and synchronously, an automated system based on a Real-Time Operating System (RTOS) is required, capable of executing tasks in a scheduled manner based on task priority [6]. To obtain the nutritional status of children, the necessary parameters are height and weight. To acquire these parameters, a load cell sensor is used for weight measurement and an ultrasonic sensor for height measurement [7]. Therefore, a child nutrition detection device that uses RTOS is needed. Thus, nutritional status results based on the indicators weight-for-age (W/A), height-for-age (H/A), and body mass index-for-age (BMI/A) can be obtained through grouping of scheduling and task prioritization, allowing data to be collected quickly and synchronously without race conditions occurring [8].

The nutritional status detection device for toddlers utilizes two primary sensors: an ultrasonic sensor for measuring height and a load cell sensor for measuring weight. An RTOS is employed to manage the scheduling and prioritization of all tasks, ensuring that each task is executed within a defined time frame [9]. In this system, RTOS is responsible for determining the execution schedule and priority of each task within the device. Task prioritization defines the importance and execution order, which can be static, remaining constant during runtime, or dynamic, adjusting based on system conditions such as deadlines [10]. This study performs two main tasks, namely measurement and calculation. The use of RTOS is very important because sensor measurements and nutritional status calculations must be performed on a scheduled basis without interfering with each other [11]. By leveraging RTOS, the system can manage both tasks in a structured and synchronized manner, allowing accurate and timely acquisition and processing of anthropometric data for nutritional status assessment.

The previous study discussed Nutritional Status Detection Based on Child Anthropometric Standards [12]. In that study, the anthropometric standards were used to assess the growth and nutritional status of children based on the parameters of height, weight, and age. An ultrasonic sensor was utilized to measure height, while a load cell sensor was used to measure weight. The results showed that the ultrasonic sensor used for measuring height achieved an average success rate of 99.7% and an average error rate of 0.3%. Meanwhile, the load cell sensor used for weight measurement demonstrated an average success rate of 96.7% and an average error rate of 3.3%.

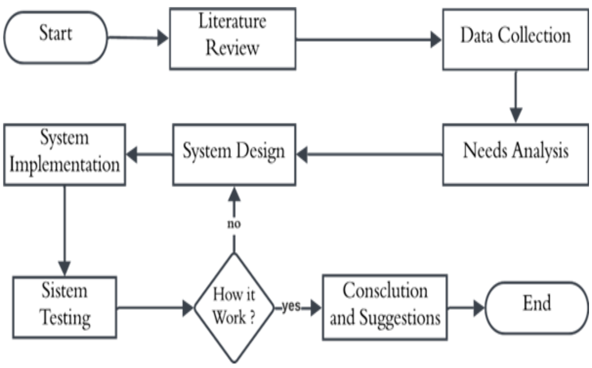
Another related study focused on designing an Arduino-based device to measure height and weight, processing the data using a fuzzy logic method. This device utilizes an ultrasonic sensor to measure height and a load cell sensor to measure weight, which is then processed to calculate the Body Mass Index (BMI). The resulting BMI is classified into categories such as underweight, normal, overweight, and obese, with the classification displayed on an LCD screen. A comparison with manual measurements showed an error rate of just 0.34% for weight and 0.0159% for height, indicating that the system has a high level of accuracy [13].

A previous study investigated the application of an RTOS for bridge monitoring, where FreeRTOS was used to manage three tasks on an Arduino Uno: monitoring load, displacement, and strain. The system architecture integrated a load cell with an HX711 module, an accelerometer, and an ultrasonic sensor to measure these respective parameters and transmit the data to a computer. Testing on a bridge prototype with incremental loads of 0 kg, 5 kg, and 10 kg demonstrated the RTOS's efficiency. The average execution times with FreeRTOS were 956.3 ms, 8413.6 ms, and 12884 ms for the three load levels, respectively, proving significantly faster than the 1918.6 ms, 8843 ms, and 15255 ms recorded on the system operating without an RTOS [11].

Based on related studies, research has been conducted on a detection tool for the nutritional status of preschool children using an RTOS. This research aims to assist healthcare workers in determining nutritional status based on anthropometric standards, including W/A (Weight-for-Age), H/A (Height-for-Age), and BMI/A (BMI-for-Age). The implementation of an RTOS manages task scheduling and priorities for the system's two main functions: sensor measurement and data calculation. The measurement task utilizes an ultrasonic sensor for height and a load cell sensor for weight, while the calculation task processes this data to derive the z-score, which serves as the final indicator of the child's nutritional status.

MATERIAL AND METHOD

This research consists of several stages, starting with a literature review, data collection, and requirement analysis, which are conducted before the design phase of the research tool. Once these initial stages are completed, the process proceeds with system design, implementation, and testing. Following the testing phase, a verification process is conducted to ensure the tool functions properly. If the tool fails to operate as expected, the process returns to the system design stage for necessary improvements. Conversely, if the system performs successfully, the research continues with drawing conclusions and providing recommendations based on the findings. The flowchart of this research process is illustrated in Figure 1.

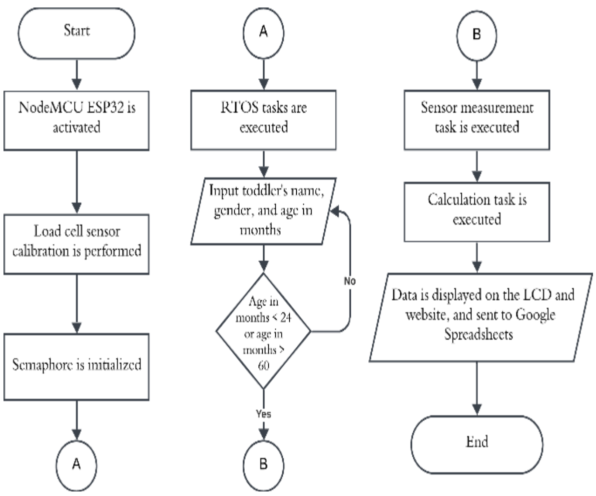


Source : (Research results, 2025)

Figure 1. Research Flow Chart

This research began with a literature review to gather information from journals, books, and scientific articles related to the application of the RTOS in embedded systems, as well as the use of ultrasonic and load cell sensors for measuring height and weight, including nutritional status indicators in toddlers. Next, data collection was carried out, including reference data for height, weight, and median BMI. The needs analysis stage was conducted to determine the components used, such as the ultrasonic sensor, load cell (HX711), NodeMCU ESP32, Arduino IDE, web server, Google Spreadsheet, and the FreeRTOS library.

At the system design stage, a comprehensive plan was developed covering both hardware and software architecture. The hardware design included determining the configuration of the ultrasonic and load cell sensors, the ESP32 microcontroller circuit, data communication modules, and the measurement display unit. The software design included program code development, RTOS task arrangement, task synchronization using semaphores, and the algorithm for z-score calculation to determine toddlers' nutritional status. To provide a clearer overview of this stage, the system design flowchart is presented in Figure 2.



Source : (Research results, 2025)

Figure 2. System Design

At the implementation stage, the system was realized according to the design and divided into hardware and software implementation. Testing was then carried out to ensure the system's functionality and accuracy, including sensor testing, data transmission, RTOS task execution, z-score calculations for (W/A), (H/A), and (BMI/A), as well as nutritional status classification. The final stage involved drawing conclusions and providing

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recommendations based on the test results, including suggestions for future system development.

The child anthropometric standards in Indonesia refer to the WHO Child Growth Standards for ages 0–5 years and the WHO Reference 2007, as stated in the Regulation of the Minister of Health of the Republic of Indonesia Number 2 of 2020 concerning Child Anthropometry Standards [4]. These standards are used to determine a child's nutritional status by comparing the measured weight and height with reference values. Nutritional status is an important indicator for evaluating growth and is assessed through three anthropometric indices: (W/A), (H/A), (BMI/A). The classification of nutritional status can be seen in Table 1.

Table 1. Nutritional status classification and Z-score thresholds

Index	Nutritional status	Z-Score
Weight for Age (W/A)	Severely Underweight	<-3 SD
	Underweight	-3 SD to <-2 SD
	Normal Weight	-2 SD to +1 SD
	Risk of Overweight	> +1 SD
Height for Age (H/A)	Severely Stunted	<-3 SD
	Stunted	-3 SD to <-2 SD
	Normal Height	-2 SD to +3 SD
	Height	> +3 SD
BMI for Age (BMI/A)	Severely Wasted	<-3 SD
	Wasted	-3 SD to < -2 SD
	Normal BMI	-2 SD to +1 SD
	At Risk of Overweight	> +1 SD to +2 SD
	Overweight	> +2 SD to +3 SD
	Obese	> +3 SD

Source : (Al-Rahmad and Fadillah, 2020 [4])

An RTOS is an operating system designed to manage the execution of multiple tasks on time, based on predetermined priorities and scheduling mechanisms [14]. In an RTOS, scheduling is performed using a preemptive priority-based scheduling algorithm, which ensures that higher-priority tasks are executed first by temporarily interrupting lower-priority tasks that are currently running [15]. To support task switching, RTOS uses semaphores as a synchronization mechanism to control access to shared resources, thereby preventing conflicts between tasks [16].

The system testing phase is carried out after the design process is completed to evaluate the overall performance of the device according to the predetermined specifications. At this stage, the system is operated under real conditions to verify the function of each component, such as the ultrasonic sensor for measuring height, the load cell sensor for measuring weight, and the LCD for displaying measurement results. The obtained results are then recorded and analyzed to ensure that the system operates accurately and in accordance with the initial design.

If the system functions properly and as designed, the testing phase is considered complete and the system is ready for use. However, if discrepancies or malfunctions are found, the process will return to the design stage for corrections and improvements. This cycle is repeated until the system fully meets the expected performance standards.

Absolute error is the difference between the measured value and the actual value, indicating the magnitude of deviation in the measurement [17]. Relative error can be expressed as a percentage by comparing the difference between the measured value and the actual value, then multiplying it by 100% [18]. Accuracy represents the degree of closeness between the measured value and the actual value, which is calculated by subtracting the percentage error from 100% [19] . In addition, classification accuracy can be calculated by comparing the number of correct classifications to the total number of sample data [20]. Meanwhile, execution time refers to the duration required by a program or task to complete all of its instructions from start to finish, and it is a crucial parameter in real-time systems to ensure that each task is completed within the required time [21]. The formulas used can be seen in Equations 1 through 5.

$$AE = |M - A| \quad (1)$$

$$RE\ (\%) = \left(\frac{|AE|}{A}\right) \times 100\% \quad (2)$$

$$SA\ (\%) = 100 - RE \quad (3)$$

$$CA\ (\%) = \left(\frac{N_{correct}}{N_{total}}\right) \times 100 \quad (4)$$

$$T_{exec} = T_{end} - T_{start} \quad (5)$$

Description :
AE = Absolute Error
M = Measured Value
A = Actual Value
RE = Relative Error
SA = Sensor Accuracy
CA = Classification Accuracy
$N_{correct}$ = Number of correct classifications
N_{total} = Total number of data
T_{exec} = Execution Time

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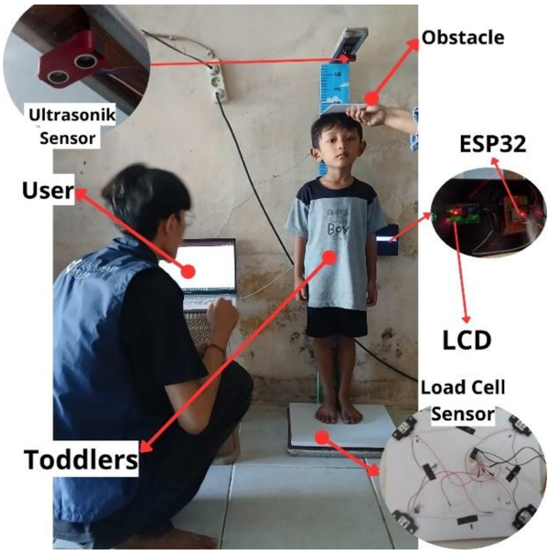
RESULTS AND DISCUSSION

The hardware design results of the child nutrition status detection system show successful integration of key components: four load cell sensors, an ultrasonic sensor, an LCD, an ESP32 microcontroller, an HX711 module, and a laptop as a web-based interface. The load cell sensors measure body weight by detecting pressure, converting it into analog signals, and digitizing them via the HX711 module. Arranged in a full-bridge configuration, the four load cells ensure balanced measurements when the child stands on the platform. The ultrasonic sensor measures height by calculating the travel time of ultrasonic waves between the sensor and the child's head. Measurement results, including weight, height, BMI, and z-score values, are displayed on the LCD, while the laptop provides a web interface for entering the child's name, gender, and age.

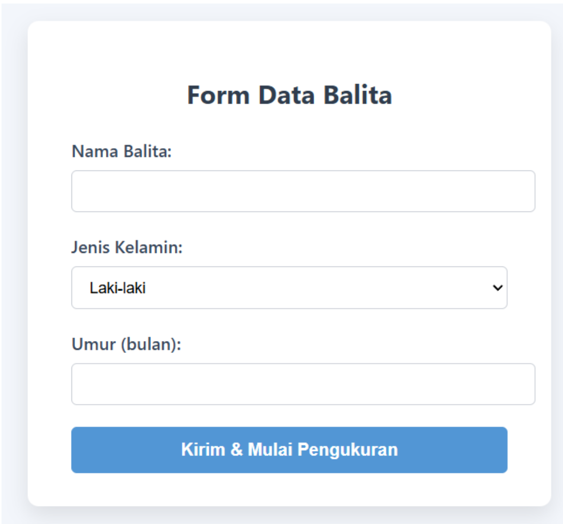
The system operation begins with an initial calibration process in which the load cell sensors are adjusted using a digital scale as a reference. After the calibration is completed, the child is positioned on the measurement platform to ensure stable weight detection. The system automatically resets the load cell readings to zero and performs calibration based on the reference weight input. Once the calibration process is finished, the system proceeds to the child data input stage, where identity and age information are entered through a web-based interface. The child is then positioned under the ultrasonic sensor for height measurement, after which the system automatically executes the measurement sequence until all parameters height, weight, and nutritional status — are successfully obtained.

The measurement results and nutritional status calculations are automatically transmitted and stored in a Google Spreadsheet, which functions as the system's final data repository. This spreadsheet-based storage enables real-time data access and facilitates the monitoring and analysis of child growth and nutritional development. To ensure data security and privacy, access to the spreadsheet is restricted to authorized personnel such as healthcare workers or researchers. Furthermore, personal data such as the child's name and age are stored with appropriate protection measures to maintain confidentiality and prevent potential data misuse. The child nutrition status detection device is shown in Figure 3, while the web interface is presented sequentially in Figure 4 Load Cell Sensor Calibration Page, Figure 5 Toddler Data Input Page, Figure 6 Measurement and Calculation Process Page, and Figure 7 Toddler Nutrition Analysis Results Page.



Source : (Research results, 2025)
Figure 3. Hardware Design Results

Source : (Research results, 2025)
Figure 4. Load Cell Sensor Calibration Page



Source : (Research results, 2025)
Figure 5. Toddler Data Input Page

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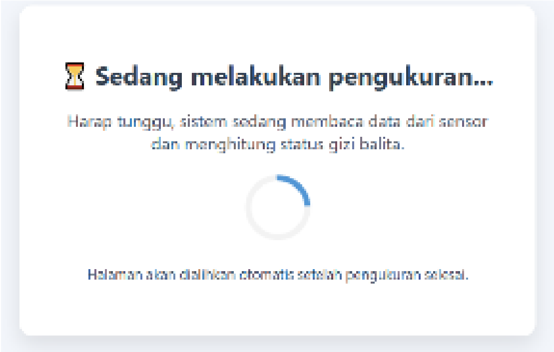
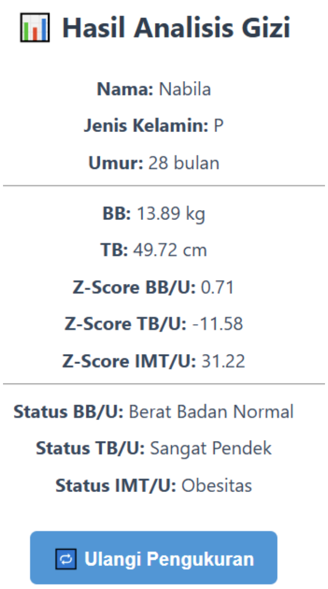


Source : (Research results, 2025)

Figure 6. Measurement and Calculation Process Page

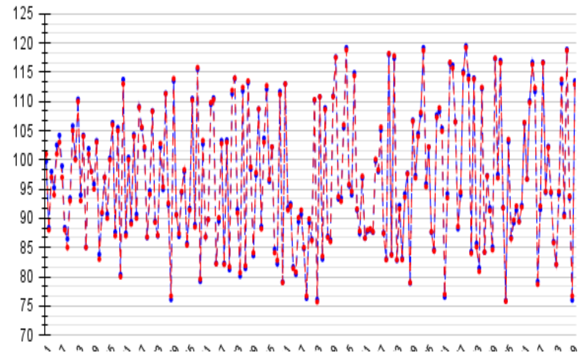


Source : (Research results, 2025)

Figure 7. Toddler Nutrition Analysis Results Page.

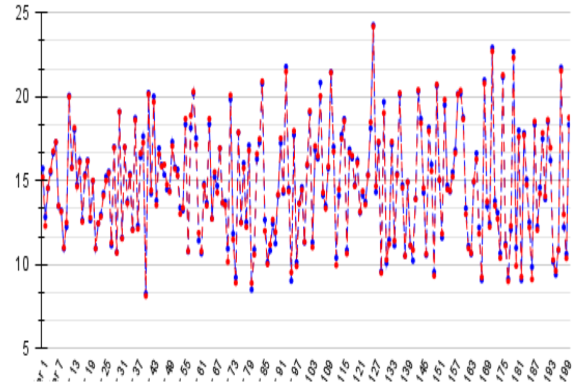
Based on the test results, the ultrasonic sensor and load cell sensor showed excellent performance in measuring the height and weight of toddlers. The ultrasonic sensor produced an average absolute error of 0.39 cm with a relative error of 0.409% and an accuracy rate of 99.59%. These values were obtained by comparing the sensor readings with reference measurements using a standard measuring device installed on the nutrition status detection device pole. Meanwhile, the load cell sensor recorded an average absolute error of 0.22 kg, a relative error of 1.587%, and an accuracy rate of 98.41%, with reference values obtained from a calibrated digital scale.

During the data collection process, the load cell sensor was calibrated periodically to ensure the stability of the measurement results, so that the values obtained remained close to the reference values. The absolute and relative error values were caused by several factors, such as the shift in the position of the object during measurement, vibrations or movements of the toddler's body, changes in ambient temperature that affected the sensitivity of the sensor, and the limitations of the sensor's resolution in reading small changes in value. However, the deviations that occur are small and insignificant to the final nutritional status calculation results. The comparison of the high values between the measuring device and the ultrasonic sensor is shown in Figure 8, while the comparison of the weight values between the digital scale and the load cell sensor is shown in Figure 9.



Source : (Research results, 2025)

Figure 8. Comparison of Height Values from Measuring Device and Ultrasonic Sensor



Source : (Research results, 2025)

Figure 9. Comparison of Weight Values between Digital Scales and Load Cell Sensors

In the execution of tasks within the RTOS system, the start and finish times of two main tasks namely the sensor measurement task and the calculation task were recorded. This recording aims to calculate the execution duration of each task and ensure compliance with the specified deadlines. The sensor measurement task has a deadline of 5000 ms, while the calculation task has a deadline of 1000 ms. The execution duration of each task was calculated using the following equation, by applying Equation (5) to determine the task execution time.

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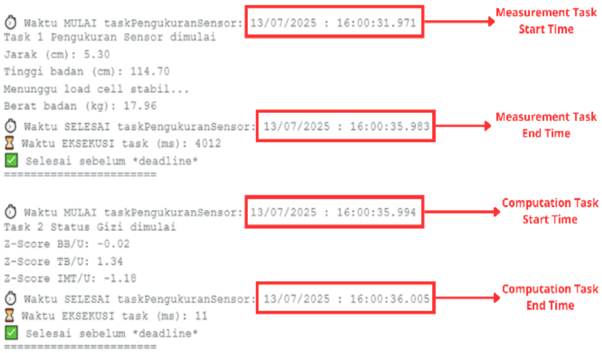
$$T_{exec} = T_{end} - T_{start}$$

$$T_{task\ 1} = 35.983\ ms - 31.971ms = 4012\ ms$$

$$T_{task\ 2} = 36.005ms - 35.994ms = 11ms$$

Based on the measurements, the execution time was 4012 ms for the sensor measurement task and 11 ms for the calculation task. The predetermined time limits were 5000 ms for the sensor measurement task and 1000 ms for the calculation task. From these data, it can be concluded that both tasks were completed within the specified time limits. The execution process of both tasks is illustrated in Figure 10.

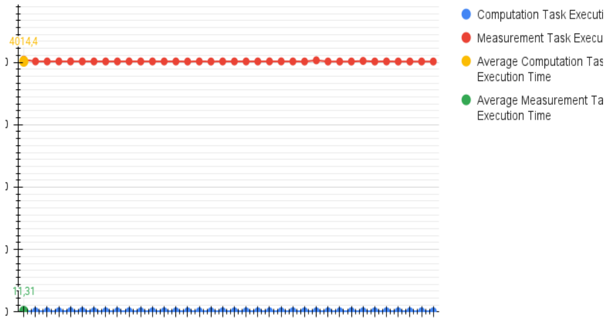


Source : (Research results, 2025)
Figure 10. RTOS Task Execution Process

Based on the results of 36 experiments, the average execution time for the sensor measurement task was 4014.4 ms, while the average execution time for the computation task was 11.31 ms. The experimental results indicate that both tasks were executed without exceeding their predefined deadlines, which were 5000 ms for the sensor measurement task and 1000 ms for the computation task.

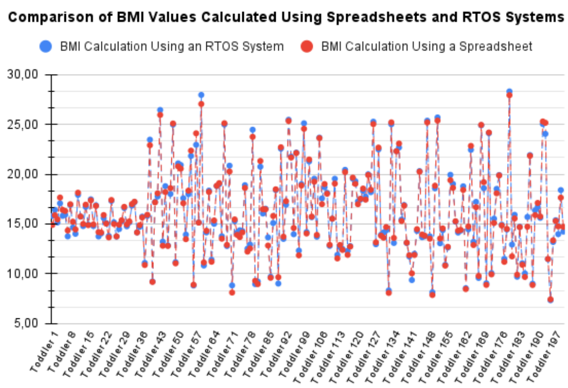
The system employs a preemptive priority-based scheduling mechanism, in which the higher-priority task namely, the sensor measurement task is always executed first. This mechanism ensures that, although both tasks run on a single-core processor, the system can still manage their execution alternately while meeting the specified deadlines.

In addition, the implementation of FreeRTOS contributes to the overall energy efficiency of the system. Through its priority-based scheduling mechanism and processor idle state management between task executions, the system minimizes unnecessary active time. Consequently, the use of FreeRTOS not only ensures precise timing performance but also helps reduce overall power consumption during the measurement and computation processes. The execution time graph of each task is presented in Figure 11.



Source : (Research results, 2025)
Figure 11. Task Execution Time on RTOS Systems

The Body Mass Index (BMI) test was conducted to determine the Z-score, where BMI values were obtained from body weight and height data. For validation purposes, the results calculated by the RTOS-based system were compared with manual calculations using Google Spreadsheet. A total of 200 subjects were tested, and the comparison results are presented in Figure 12. The calculation patterns from both methods showed a high level of consistency. The obtained BMI values produced an average absolute error of 0.281 kg/m^2, a percentage error of 1.821%, and an accuracy rate of 98.83%.



Source : (Research results, 2025)
Figure 12. Comparison of BMI Values from Manual Spreadsheet Calculation and BMI Calculation from RTOS

The differences in error and accuracy values were influenced by several factors, including minor discrepancies in readings from the ultrasonic and load cell sensors, latency between tasks in the RTOS system, and rounding effects during BMI computation on both the microcontroller and the spreadsheet. In addition, slight variations in the child's body position during height and weight

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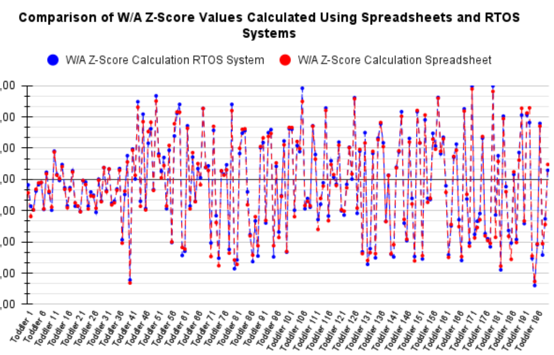
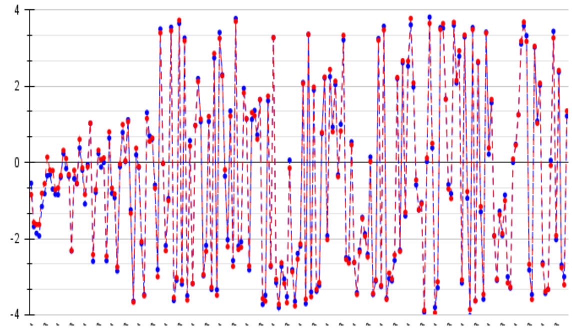
measurements may cause small fluctuations in the recorded data. Despite these differences, the deviations remained within acceptable measurement tolerances, indicating that the system maintained a high level of accuracy. The resulting BMI values were then used to calculate the Z-score (BMI-for-age) based on WHO reference standards.

The Z-score (Weight-for-Age, W/A) calculation was performed using the Z-score formula, considering the variables of age, gender, and body weight of each child. The computation was carried out manually using Google Spreadsheet and automatically through the RTOS-based system, and the results from both methods were compared to evaluate system consistency. From the 200 child datasets tested, Z-score values and nutritional status classifications based on W/A were obtained for each individual. These Z-score values served as the basis for determining the nutritional status category of the children. The test results showed an average difference of 0.12 in W/A Z-score values between the spreadsheet and RTOS system calculations. The comparison of W/A Z-score values computed using both methods is presented in Figure 13.



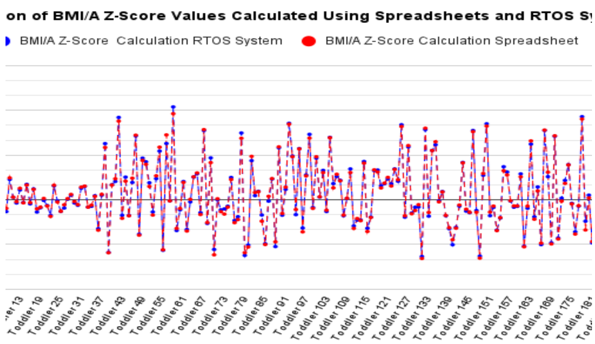
Source : (Research results, 2025)
Figure 13. Comparison of W/A Z-Score Values Calculated Using Spreadsheets and RTOS Systems

The Z-score (Height-for-Age, H/A) calculation was performed using the Z-score formula by considering the variables of age, gender, and the child's height. The calculation process was carried out manually using Google Spreadsheet and automatically through the RTOS-based system. The results from both methods were then compared to evaluate system consistency. From the 200 child datasets tested, Z-score values and nutritional status classifications based on the H/A parameter were obtained for each individual. The test results showed an average difference of 0.1 in the H/A Z-score values between the spreadsheet and the RTOS system calculations. The H/A Z-score values served as the basis for determining the nutritional status classification of each child. The comparison of H/A Z-score values calculated using both methods is presented in Figure 14.



Source : (Research results, 2025)
Figure 14. Comparison of H/A Z-Score Values Calculated Using Spreadsheets and RTOS Systems

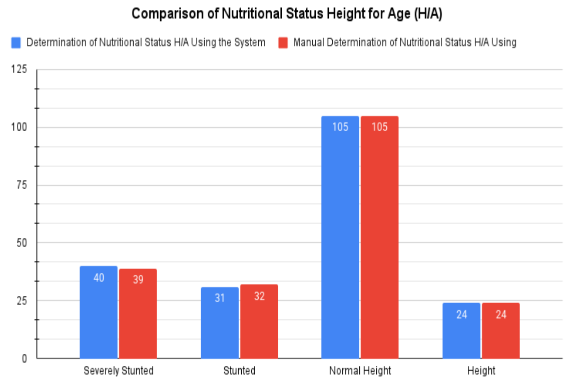
The comparison of Z-score values (Body Mass Index-for-Age / BMI/A) between manual calculations using Google Spreadsheet and automatic calculations through the RTOS-based system showed a similar pattern with relatively small differences in values. The testing was conducted on 200 child datasets, and the analysis results indicated an average difference of 0.230 in BMI/A Z-score values between the two methods. These findings demonstrate that the system achieved a fairly high level of accuracy in calculating BMI/A Z-scores. The obtained Z-score values were subsequently used as the basis for determining the nutritional status classification based on the BMI/A parameter. The comparison of BMI/A Z-score values obtained from both methods is presented in Figure 14.



Source : (Research results, 2025)
Figure 14. Comparison of BMI/A Z-Score Values Calculated Using Spreadsheets and RTOS Systems

The classification of nutritional status based on the Height-for-Age (H/A) parameter was conducted to compare the results between manual calculations and those generated by the Real-Time Operating System (RTOS)-based system. The evaluation was performed on a dataset of 200 children categorized into four groups: severely stunted, stunted, normal height, and tall. Based on the results, the RTOS-based system demonstrated a very high level of consistency compared to the manual method. The system classified 40 children as severely stunted, 31 as stunted, 105 as normal height, and 24 as tall. Meanwhile, the manual method produced nearly identical results, with 39 children classified as severely stunted, 32 as stunted, 105 as normal height, and 24 as tall.

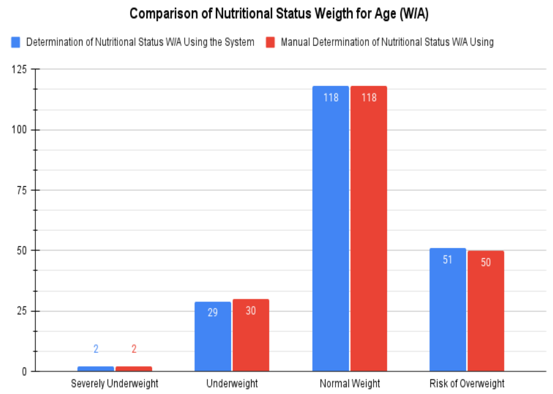
The minor discrepancies observed between the two methods were primarily caused by slight differences in ultrasonic sensor readings compared to manual measurements, which influenced the calculated Z-score and final classification. Nevertheless, the comparison results indicate that the system achieved an accuracy rate of 99,5% in determining nutritional status classification based on the H/A parameter. This finding confirms that the RTOS-based system is capable of performing precise and reliable calculations and classifications of nutritional status, making it suitable for field implementation in child nutrition monitoring. The comparison of nutritional status classification results between the two methods is illustrated in Figure 15.



Source : (Research results, 2025)
Figure 15. Comparison of Nutritional Status Height for Age (H/A)

The classification of nutritional status based on the Weight-for-Age (W/A) parameter was conducted to compare the results between manual calculations and the system based on the Real-Time Operating System (RTOS). The evaluation was carried out using 200 child datasets categorized into four groups: severely underweight, underweight, normal weight, and risk of overweight. Based on the experimental results, the RTOS-based system demonstrated a very high level of consistency compared to the manual method. The system classified 2 children as severely underweight, 29 as underweight, 118 as normal weight, and 51 as at risk of overweight, while the manual method produced nearly identical results, with 2 children classified as severely underweight, 30 as underweight, 118 as normal weight, and 50 as at risk of overweight.

The minor discrepancies observed between the two methods were attributed to variations in load cell sensor readings compared to manual weighing measurements, which slightly affected the computed Z-score values and final classifications. Nevertheless, the evaluation results showed that the system achieved an accuracy rate of 99,5% in determining nutritional status classifications based on the W/A parameter. This finding indicates that the RTOS-based system is capable of performing nutritional status calculations and classifications with high accuracy, making it a reliable tool for automatic and efficient child nutrition monitoring. The comparison of nutritional status classifications based on the W/A parameter between the two methods is presented in Figure 16.



Source : (Research results, 2025)
Figure 16. Comparison of Nutritional Status Weight for Age (W/A)

The classification of nutritional status based on the Body Mass Index for Age (BMI/A) parameter was conducted to compare the results between the manual method and the Real-Time Operating System (RTOS)-based system. The evaluation was performed on 200 child datasets categorized into six groups: severely wasted, wasted, normal, possible risk of overweight, overweight, and obese. Based on the results, the RTOS-based system demonstrated a high level of consistency compared to the manual method. The system classified 30 children as severely wasted, 7 as wasted, 83 as normal, 18 as at possible risk of overweight, 19 as

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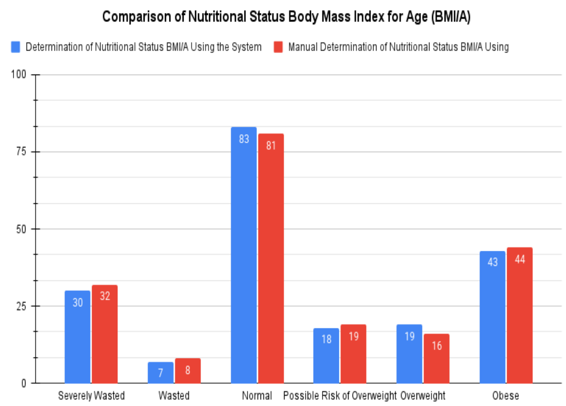
overweight, and 43 as obese. In comparison, the manual method classified 32 children as severely wasted, 8 as wasted, 81 as normal, 19 as at possible risk of overweight, 16 as overweight, and 44 as obese.

The minor discrepancies observed between the two methods were primarily due to variations in the Body Mass Index (BMI) values resulting from load cell and ultrasonic sensor readings, which slightly affected the Z-score computation and the final nutritional classification. Despite these small differences, the system achieved a high accuracy rate of 97,5% in determining nutritional status classifications based on the BMI/A parameter. These findings indicate that the RTOS-based system possesses reliable capability in performing automatic nutritional status calculations and classifications, making it a practical and accurate tool for nutritional monitoring in children. The comparison of BMI/A-based nutritional status classifications between the two methods is presented in Figure 17.



Source : (Research results, 2025)

Figure 17. Comparison of Nutritional Status Body Mass Index for Age (BMI/A)

The Real-Time Operating System (RTOS)-based child nutrition status detection system developed in this study demonstrated reliable performance in performing automatic measurement, computation, and nutritional classification processes. Through the integration of four load cell sensors, an ultrasonic sensor, an ESP32 microcontroller, and an HX711 module, the system was able to accurately measure both body weight and height. The preemptive priority-based scheduling mechanism implemented in the RTOS ensured that each task particularly the sensor measurement task was executed on time without conflict, guaranteeing system reliability in real-time conditions. This implementation also confirmed that the system can efficiently manage multiple tasks, even when operated on a single-core processor, maintaining stable and consistent execution timing.

The system was tested across various locations, including households with toddlers and several posyandu (community health posts), involving 200 children as research subjects. Based on the test results, the ultrasonic sensor achieved an average absolute error of 0,63 cm with a relative error of 0,659% and an accuracy rate of 99,34%, while the load cell sensor achieved an average absolute error of 0,11 kg with a relative error of 0,788% and an accuracy rate of 99,21%. The average execution times for the sensor measurement and computation tasks were 4014,4 ms and 11,31 ms, respectively, both remaining well within their specified deadlines of 5000 ms and 1000 ms. In addition to ensuring precise timing, the implementation of FreeRTOS also contributed to energy efficiency by managing the processor's idle state to minimize power consumption. However, in real-world conditions, slight vibrations while the child stood on the platform and ultrasonic wave reflections from uneven surfaces introduced minor variations in sensor readings, which contributed to the observed measurement errors.

Furthermore, the calculation of Z-score values for the Weight-for-Age (W/A), Height-for-Age (H/A), and Body Mass Index-for-Age (BMI/A) parameters revealed minimal differences compared to the WHO reference values. The classification accuracy rates were 99,5% for W/A, 99,5% for H/A, and 97.5% for BMI/A, indicating that the system achieved a high level of precision in determining the nutritional status of toddlers automatically. All measurement results and computed nutritional classifications were automatically transmitted and stored in Google Spreadsheet, which functioned as the system's final data repository. This spreadsheet-based data storage enabled real-time monitoring by healthcare professionals while ensuring data security through access restrictions limited to authorized personnel. Personal information such as the child's name and age was stored with appropriate confidentiality measures to prevent unauthorized access and potential data misuse.

For future research, the system is planned to be integrated into a large-scale national health information network, enabling centralized use across both posyandu centers and household-based monitoring environments. In addition, data security will be further enhanced through the implementation of data encryption, user authentication, and secure gateway–based access management to strengthen privacy protection and

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system reliability. These improvements are expected to support the development of a more secure, energy-efficient, and sustainable Internet of Things (IoT)–based child nutrition monitoring system that can be adopted nationally as part of the digital transformation of public healthcare services.

CONCLUSION

The Real-Time Operating System (RTOS)–based child nutrition status detection system developed in this study performed well in automatically measuring height, weight, and classifying nutritional status. The system utilized four load cell sensors, one ultrasonic sensor, an ESP32 microcontroller, and an HX711 module to obtain measurement data. Based on the test results, the ultrasonic sensor showed an average absolute error of 0,63 cm, a relative error of 0,659%, and an accuracy rate of 99,34%, while the load cell sensor showed an average absolute error of 0,11 kg, a relative error of 0,788%, and an accuracy rate of 99,21%. The average execution time for the sensor measurement task was 4014,4 ms, and the computation task required 11,31 ms, both remaining within the system's specified limits. The calculated Z-score values for Weight-for-Age (W/A), Height-for-Age (H/A), and Body Mass Index-for-Age (BMI/A) parameters showed results close to the WHO reference standards, with classification accuracy rates of 99,5%, 99,5%, and 97,5%, respectively. The implementation of FreeRTOS also supported efficient task scheduling and contributed to energy savings by managing the processor's idle state. Overall, the system was able to perform measurement and classification processes effectively in real-world conditions, both in household and posyandu (community health post) environments, although minor variations were observed due to platform vibration during measurement and ultrasonic wave reflections from uneven surfaces.

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