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Development of an IoT-Based Anthropometry Tool with Area Mapping for Stunting Detection in Toddlers (Weight)

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ABSTRACT Stunting is one of the nutritional health problems affecting children in Indonesia. Children who experience stunting tend to have abilities below the average for their age group. The objective of this study is to develop a web-based infant and toddler nutrition monitoring system using z-score calculations and equipped with regional mapping in Gubeng Subdistrict. The weight module uses a load cell sensor as the weight sensor connected to the HX711 module as a converter and amplifier, and the ESP 32 as the microcontroller. The web system is equipped with regional mapping of Gubeng Subdistrict using the k-means method. This aims to facilitate and simplify the monitoring of stunting cases, particularly in the Gubeng Subdistrict area. Another feature is Gmail notifications that will automatically send emails to officials and parents as warnings about increasing stunting cases in a subdistrict within Gubeng Subdistrict. The research results show that this module and system are capable of measuring the weight of infants and toddlers and analyzing their nutritional status through calculations using the z-score method. The research results obtained an error value of 1.24%. The module and system are expected to assist health workers and health services in monitoring the nutritional status and growth of infants and toddlers. This is expected to prevent stunting cases in Indonesia. The limitation of this research focuses on the development of a weight module and web-based information system for infants and toddlers. The objective of this research is to develop an anthropometric tool using the z-score method. The benefit of this research is to help provide information on stunting data with regional mapping, thereby facilitating healthcare workers in collecting data.

INDEX TERMS Stunting, IoT, Z-score, Regional Mapping, *K-Means*

I. INTRODUCTION

Strengthening research and development of monitoring and evaluation is necessary in determining the direction of nutrition development in Indonesia [1] [2]. The depiction of stunting cases with regional mapping is useful for knowing the distribution pattern of stunting incidence through periodic height measurements in an area [3] [4] [5] [6] [7] [8]. Stunting is one of the nutrition problems among other nutrition problems such as wasting and obesity that are the focus of the current government [9] [10] [11]. The government is committed to addressing and reducing the prevalence of stunting by improving nutrition and conducting specific mapping and intervention programs involving various health sectors [12] [13] [14]. The intervention of the government and health workers as well as the local community is very important in handling stunting cases, which can be started from a small scope such as sub-districts [15]. With the digital mapping of the sub-district area, it is hoped that it can help optimize the work of the posyandu in monitoring the spread of stunting cases so that it can reduce the incidence of stunting in an area [16] [17]. There are still many cases of stunting in Indonesia. According to data from the Nutrition Status Monitoring (PSG) for the last three years, although stunting cases continue to decline until 2022 at 21.6%, stunting has the highest prevalence compared to other nutritional problems such as undernutrition, thinness, and fatness [15] [19] [20].

When compared to other countries, the stunting rate in Indonesia is still high at 30%-39%. Indonesia is ranked 5th in the world with the highest number of short children [21] [22] [23] . In East Java as of 2020, the achievement of stunting cases has decreased, which is 7.51% based on data from the Health Profile of the East Java Health Office. Stunting data is collected on children aged 0-59 months with nutritional status categories based on the index of Body Length According to Age (PB/U) or Height According to Age (TB/U) [24] . The highest case of stunting is Pasuruan city with a percentage of 15.71% and the lowest is Surabaya city at 1.01%[25]. The government continues to develop several programs to prevent stunting in children. One way to prevent stunting is by conducting routine checks in the form of regular monitoring of weight and height [26] [27]. Anthropometry was chosen as the measurement method because it has an easy procedure without special skills and equipment that is easy to file [28]. After taking measurements, the stunting data is then stored based on the measurement location in order to carry out appropriate treatment [29] [30]. Based on the data and literacy studies used in this research, in order to support government policies in addressing stunting cases, research related to stunting should be conducted in the form of graphical mapping (mapping) to facilitate spatial and regional analysis. Therefore, the author will conduct research aimed at addressing the shortcomings of previous studies. This device uses an ESP32 microcontroller, a Load Cell sensor, and an HX711 module to measure body weight. The results of the body weight measurements are displayed on a 16x2 LCD screen and also on a web-accessible platform. Additionally, the IoT system is equipped with regional mapping. Regional mapping uses the K-Means method, a data clustering technique that divides data into several clusters based on similarity, with the initial cluster centers randomly selected from a dataset located in various different regions. A notification feature via Gmail has been added to facilitate the documentation of stunting cases occurring in Gubeng subdistrict.

II. METHODS

A. *BLOCK DIAGRAM*

Figure 1 is a diagram block of the measurement module. The system starts working when measuring the weight of a toddler.

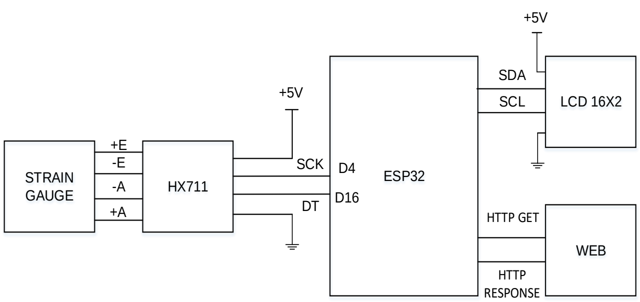

FIGURE 1 **Baby weight scale block diagram**

For the measurement of the baby's weight is done by laying the baby on the scales, while for the measurement of the weight of children over 1 year (already able to stand), the baby's manger can be removed and the child can directly stand on the scales. After that the load cell sensor reads the weight of babies and children in the form of analog data and then forwarded to the HX771 module to be processed into digital data and sent to ESP32, ESP32 will process the weight data and then display it on the display and send it to the web system to determine indications of stunting and regional mapping.

B. *FLOWCHART*

Figure 2 is a flowchart of the measurement module system. The initial process begins with the initialization of the Load Cell sensor. Then there is communication between ESP32 and the sensor marked by the sound issued by the buzzer. The initialization process will be repeated if ESP32 does not receive data from the sensor. Then ESP32 processes the Analog to Digital Converter data to get the weight value. Then the data will appear on the LCD and be sent to the WEB.

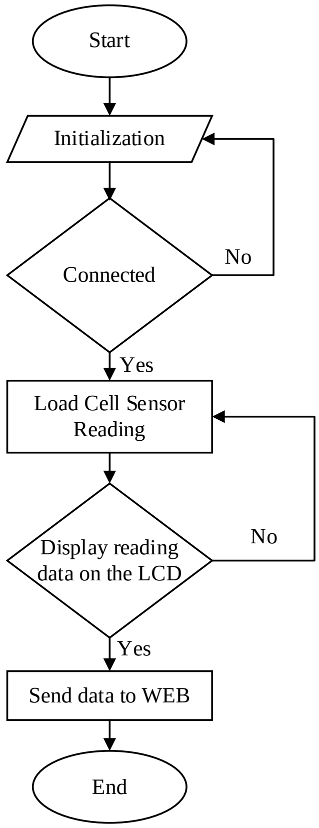

FIGURE 2 **Weight Data Transfer Flowchart to Web (SIPENTING)**

FIGURE 3 is a flow chart of the measurement module system on the website. The process starts with entering the patient's biodata such as name, date of birth, address, etc. manually and then receiving weight and height measurement data from esp32. After that, the data is processed to determine the patient's category (obesity, normal, stunting) by calculating Z-score. then processed and grouped using the *k-means* method which divides the data into 5 clusters, then poured into mapping the Gubeng District area which consists of six villages.

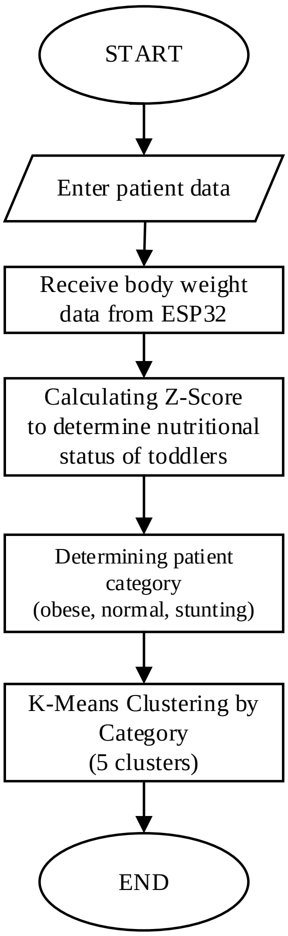

FIGURE 3 **Flow Chart of the Process of Patient Clustering and Region Clustering on the Web (SIPENTING)**

C. DATA ANALYSIS

Z-Score is used to evaluate how far a value is from the mean in a data set. The z-score calculation allows comparison between values from different data distributions, making it very useful. The use of anthropometric measurements and z-score calculations aims to assess the growth, nutritional status, and well-being of individuals. Interpretation of z-score values includes positive values indicating that the individual's score is higher than the mean. The greater the positive value, the further the individual is from the mean. Conversely, a negative z-score value indicates that the individual's score is below the mean. The smaller the negative z-score, the further the individual is from the mean. While a value of zero indicates that the individual's score is the same as the mean [31]. The Z-score is calculated using the following formula Eq. (1) :

$$Z = \frac{X - \mu}{\sigma} \quad (1)$$

Description:
Z = Z-Score
X = individual in the data set
μ = mean of the data set
ŏ = standard deviation of the data set

There are 2 conditions in this study, namely the first condition if the child's weight is <standard deviation of reference, using the equation formula Eq. (2). The second condition is if the child's weight is >standard deviation of reference, using the equation formula Eq. (3).

$$Z = \frac{\textit{Weight calculation} - \textit{Reference Standard Deviation}}{\textit{Median} - (\textit{Table} - \textit{1SD})} \quad (2)$$

$$Z = \frac{\textit{Weight calculation} - \textit{Reference Standard Deviation}}{(\textit{Table} - \textit{1SD}) - \textit{Median}} \quad (3)$$

The advantage of using z-score is its ability to compare different data distributions. Z-score can be used to identify values that are far from the mean as outliers, and also plays a role in standardizing data to compare variables that have different units.

The mean is a number that represents the entirety of the data observations. The mean is calculated by adding all the data and dividing it by the number of data. The term mean refers to the middle point of a set of data. The mean serves as a reference value that approximates the actual research results.

The average can be calculated using the following formula Eq. (4):

$$\text{Mean}\ (X') = \frac{x1+x2+x3+..+xn}{n} \quad (4)$$

Standard deviation is a measure that describes the distribution of data in a sample to determine how close the data values are to the average. One of the functions of the standard deviation is to provide an overview of the distribution of data relative to the average. The smaller the deviation value, the closer the data value is to the average. The standard deviation can be calculated using the formula Eq. (5):

$$Stdv = \frac{\sqrt{(x_1 - X')^2 + (x_2 - X')^2 + \cdots + (x_n - X')^2}}{n - 1} \quad (5)$$

The error value is the difference between the measured value and the actual value. The magnitude of this error can be calculated using the following formula Eq (6):

$$\%\ Eror = \frac{|X_n - Y_n|}{X_n} X100\% \quad (6)$$

III. RESULT

After collecting data, conducting research, and creating a weight measurement module, the results shown in FIGURE 4 were obtained, which is a weight measurement module equipped with a simple circuit in FIGURE 5

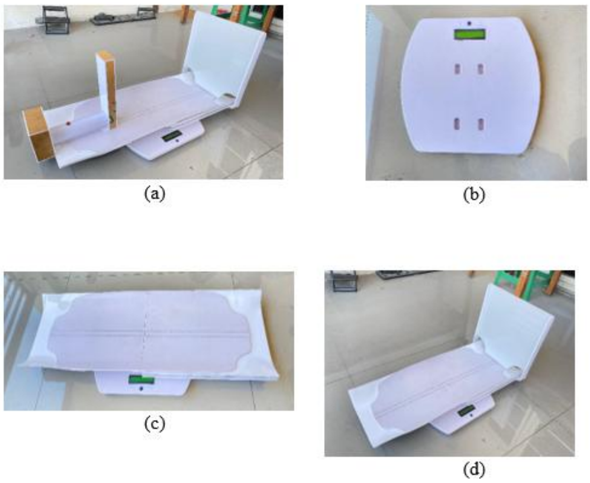

FIGURE 4 Baby weight scale box design in research

FIGURE 4 (a) is a picture of the device as a whole, consisting of a weight module, a manger, a baby foot barrier and a height module; Figure (b) is a weight module; (c) is a picture of a weight module with a manger that is used when measuring the weight of a baby who cannot yet stand; then Figure (d) is a picture of a weight module, a baby manger and a foot barrier that serves as a place to reflect the HCSR sensor when measuring the baby's body length. In addition, there is a picture of the overall circuit and of the weight module, which contains the components used.

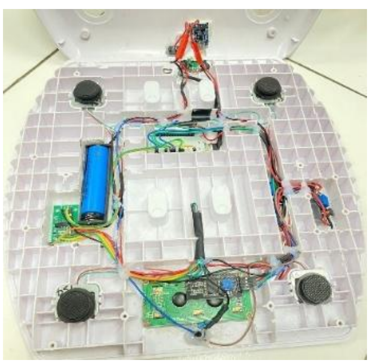

FIGURE 5 Inside view of baby weighing scale

Figure 5 is a inside view module. The body weight circuit consists of a load cell sensor, HX711, ESP32, 16x2 LCD plus I2C, battery, step down circuit, TCRT5000 infrared sensor, buzzer, and charger module.

TABLE 1
Load Cell Sensor Output Voltage Measurement Results

Weights (kg)	Load Cell sensor (kg)	Voltage (mV)
1.00	1.00	0.2
2.00	2.01	0.6
3.00	2.99	1.2
4.00	4.01	1.5
5.00	5.01	1.8

TABLE 1 is the data of the load cell sensor output comparison results to the voltage. From the test results, the voltage changes above are obtained from measurements at the output of the load cell. The relationship between the output voltage of the load cell sensor and the measured weight is generally linear. The greater the weight value, the greater the voltage generated.

TABLE 2
Measurement Results of Weighing Scales

Weights (Kg)	Module (Kg)	Standard Deviation (SD)	Error (%)
1.00	1.00	0	0
2.00	2.01	0.01	0.5
3.00	2.99	0.01	0.33
4.00	4.01	0.01	0.25
5.00	5.01	0.01	0.2

TABLE 2 is the result of comparing the weight module with the scales which are the standard of weight measurement. From the measurement results, the weight module shows output results that are close to the weight of the weights. The standard deviation in each measurement is low, indicating consistency in the measurement results. The error value shows a very small value, the largest is only 0.5%, proving that the tool used is quite accurate in measuring weight.

TABLE 3
Measurement Results on Baby Mannequins

Mannequins	Module (kg)	Error (%)
A (1 kg)	0.98	2
B (2.2 kg)	2.17	1
C (3 kg)	3.08	2.6

TABLE 3 is the mannequin measurement data using the weight module. From the measurement results, it is found that the results are close to the actual weight of the mannequin. The smallest error value of 1% is shown by mannequin B with a weight of 2.2 kg while the largest error value of 2.6% is shown by mannequin C with a weight of 3 kg.

TABLE 4
Measurement Results in Infants and Toddlers

No	Name/ Gender	Age (Month)	Measurement Result		
			Weight (kg)	Z-Score W/A	Nutritional status

					W/A
1	Respondents 1/M	29	11.31	-1.27	Normal
2	Respondents 2/F	38	12.41	-1.05	Normal
3	Respondents 3/M	29	17.7	2.70	Over Weight
4	Respondents 4/M	1	4.28	-0.36	Normal
5	Respondents 5/F	1	3.26	-1.56	Normal

TABLE 4 is the result of the weight measurement trial using the designed weight module. From the measurement results that have been obtained, calculations are then carried out using the z-score method to determine the nutritional status of toddlers.

FIGURE 6 Measurement Results in Infants and Toddlers

FIGURE 6 is a picture of baby measurements using the weight module. In addition to using z-score calculations, to determine the nutritional status of toddlers can be monitored through child growth charts (GPA). The value on the GPA is obtained from the results of periodic and repeated measurements so as to form a line diagram showing the growth chart in toddlers. The graph can be seen in the following figure:

FIGURE 7 is the result of a simulation of the child's weight growth graph that has been carried out during the measurement. The graph shows the weight growth of each child. The graph can be seen on the SIPENTING website.

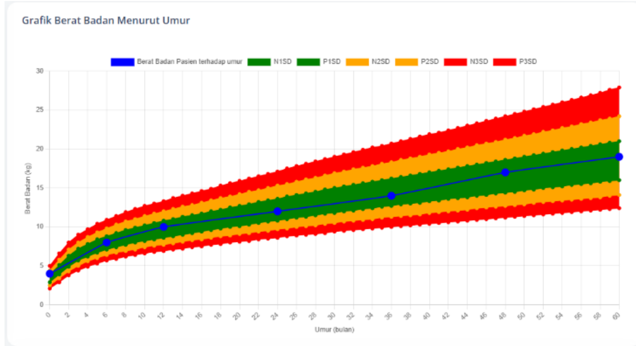

FIGURE 7 GPA results on the website display

The mapping area uses the k-means method. Analysis with this method to map the distribution of stunting cases with the division of 5 clusters based on WHO standards, namely cluster 1 (dark green zone) with a value < 2.5% which indicates areas with very low stunting cases; cluster 2 (light green zone) with a value of 2.5% - < 10% for low stunting cases; cluster 3 (yellow zone) with a value of 10% - < 20% for moderate stunting cases; cluster 4 (orange zone) with a value of 20% - < 30% for high stunting cases; and cluster 5 (purple zone) with a value ≥ 30% which represents areas with very high stunting cases [32] . The mapping results can be seen in the figure below:

(a) (b)

FIGURE 8 (a) Area Mapping, (b) Patient Information Menu

FIGURE 8 (a) is a mapping image of the Gubeng sub-district area which consists of 6 villages, namely Baratajaya Village, Pucang Sewu Village, Kertajaya Village, Gubeng Village, Airlangga Village, and Mojo Village. Figure (b) is the patient information menu. If you click on one of the neighborhoods, the menu will appear. This menu contains information on the number of patients in that subdistrict along with the number of stunting and obesity cases. Each urban village area is assigned a zone color according to the number of stunting and obesity cases in the area, which is called location management. FIGURE 9 is a Location management view containing patient information and stunting rates in six villages in Gubeng sub-district. Each is equipped with a zone status based on the number of stunted, obese and normal toddlers. The location management view is also outlined in the form of a bar chart with each village containing information on the number of stunted, normal and obese patients. the data used in the implementation of regional mapping is secondary data totaling 10500 data [29]. the implementation method used is the K-Means method.

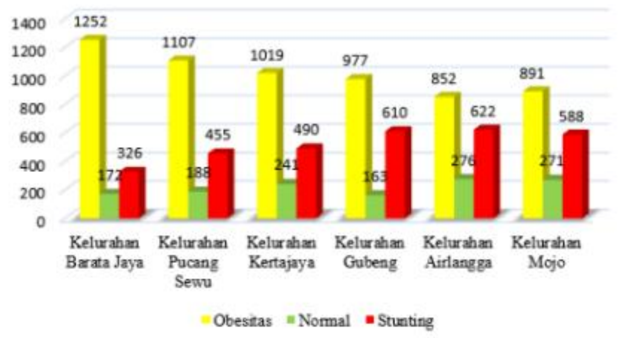

FIGURE 9 **Location management view**

This study used secondary data on toddlers totalling 10,500 data obtained from the Kaggle.com site [33]. The results of the clustering calculation with the K-Means algorithm are presented in TABLE 5 to show the distribution of areas based on the level of stunting risk. shows the results of the K-Means calculation obtained an average percentage error value of 1.24%. Based on the percentage error value, it can be concluded that the K-Means method has worked quite well in mapping the distribution of stunting in toddlers. The implementation of this mapping can be seen in the TABLE 5.

TABLE 5
K-Means Calculation Results

No	Region	Patient Category			Calculation of K- Means		Error %
		Obesity	Normal	Stunting	System	Manual	
1.	Barata Jaya	1252	172	326	18.63	18.63	0
2.	Pucangsewu	1107	188	455	27	26	3.85
3.	Kertajaya	1019	241	490	27	28	3.57
4.	Gubeng	977	163	610	34.86	34.86	0
5.	Airlangga	852	276	622	35.54	35.54	0
6.	Mojo	891	271	588	33.60	33.60	0

FIGURE 10 is a feature that automatically sends notifications via Gmail when very high stunting conditions are detected in an area or when an area enters the red zone category. This notification is sent with a maximum frequency of once per day for each similar condition or the same area. If there are other areas with high stunting conditions on the same day. additional notifications will be sent. The recipients of this notification email are operators or related health workers and parents of affected toddlers. The language used on the website is Indonesian to make it easier for users to navigate the site. The implementation of this feature can be seen in the image below.

FIGURE 10 **Gmail Notification of High Stunting Cases**

IV. DISCUSSION

Measuring the weight of infants and toddlers is done in different ways. For infants who cannot yet stand. they are placed in a demountable manger. while toddlers can stand directly on the weighing module. Weight measurement data is obtained from the readings of the load cell sensor connected to the HX711 module as a converter. which is connected to the RX2 and D4 pins on the ESP32. The measurement data will be sent to the 16X2 LCD display module. LCD functions to display height and weight data. Measurement results will automatically enter the web when we take measurements. The website can be used as a data storage area. So that it can be used to monitor the spread of stunting cases of infants and toddlers who have taken measurements every month. On the website. there is an automatic z-score calculation feature to determine the condition of the nutritional status of toddlers when measurements are taken which is equipped with a feature to display the Child Growth Graph (CPG). There is also a feature of mapping the distribution area of stunting cases using the K-Means method which is a data clustering method that divides data into several groups based on the similarity or similarity of the data. The web is also equipped with a notification feature to the Gmail of parents and users if an area indicates a high stunting case. In addition. there is also a print to pdf feature that allows parents to get a file of toddler measurement results. The file contains the toddler's biodata. GPA. and measurement history. Analysis is carried out to determine the accuracy of the load cell sensor reading results by conducting various trials. Starting with trials using loads of 1-5 kg and using mannequins. From these trials. the calibration constant value is obtained to correct or reduce sensor reading errors. The sensor reading results will then be sent to the website. Where from the results of the data transmission trial. there is no difference between the data sent from the module. and the data displayed on the website. It is concluded that sending data to the website does not experience data loss.

V. CONCLUSION

Based on the results of the research and development that has been carried out, it was concluded that the weight measurement module developed using a load cell sensor and an ESP 32 microcontroller successfully measured the weight of infants and toddlers with adequate accuracy, yielding z-score values of -1.27, -1.5, 2.70, -0.36, and -1.56. The BB/TB results are -0.21, -0.53, 0.36, -0.73, and 0.2. These results align with the manually calculated z-scores. The calculation yielded an error rate of 1.24%. This system is also capable of displaying data in the form of a Child Growth Chart (CGC). The automatic notification feature via Gmail provides information to users and parents of toddlers about the stunting rate in the Gubeng area. The implementation of this system in the field is expected to support health workers in monitoring and handling stunting cases in Indonesia, especially in areas that are difficult to reach by conventional health services.

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