Design and build a head circumference measurement system for toddlers

Kurniawan Teguh Martono1,*, Oky Dwi Nurhayati1, Erwan Yudi Indrasto1, Satryo Adhy2
1Computer Engineering Department - Engineering Faculty, 2Informatics Department - Science and Mathematics Faculty (Diponegoro University, Tembalang Semarang Indonesia)

E-mail: *k.teguh.m@live.undip.ac.id

Abstract. Growth and development are events that every living thing will experience. These events are two events, namely growth, and development. These two events are related to one another, where growth refers to a change in the shape of the body, or cell size and effect change an organ or limb's function in its operation. Every parent must consider child development because this will significantly determine and influence how the child develops in the future. Measurement of height, weight, or head circumference is carried out at the Posyandu to aim that the development of children under five in an area can be monitored and make it easier to determine policies. The results of this measurement will later be recorded on a card called the "Kartu Menuju Sehat" (KMS). Technological developments bring about considerable changes in the world of health. This paper discusses the design of a head circumference monitoring system. The use of a rotary sensor is an option in designing a head circumference gauge. The measurement results using a rotary sensor show that the measurement accuracy is 100%. Testing the system with a black box shows that 100% of the structure built is acceptable and according to the design scenario.

1. Introduction
The age of five years and under is a crucial period for child development. This is important because, at this time, the maximum stimulation will affect and determine the child’s development in the future. The process of growth and development are two processes that occur in human life, where there is a process of growth and development where these two processes are different from one another but are influential and related. The process of growing is changing the physical form of cells, organs, or bodies in children. The development or development process is the process of increasing the structure and function's ability to grow, which becomes more complicated. The early stages of child development will include several aspects, namely motor, social, language, and emotional factors. The process of monitoring child development in Indonesia is carried out using various models, and one of them is the integrated service post (posyandu) activity. This activity is an activity carried out by the community, the community, and the community. The activities carried out at the posyandu consist of measuring body weight, measuring body height, nutrition education, giving vitamins, and measuring head circumference. Posyandu is a community-based activity supported by at least health personnel from the puskesmas level.
Officers at the posyadu are referred to as posyandu cadres. The center of posyandu activities is at the lowest level, carried out at the RW (neighborhood unit) level.

Measurement of height, weight, or head circumference is carried out at the posyandu to aim that the development of children under five in an area can be monitored and make it easier to determine policies. The results of this measurement will be recorded on a card called the "Kartu Menuju Sehat" (KMS). The information in KMS is in the form of weight and height data expressed in a graph. Also, other information is the identity of toddlers and parents. In addition to KMS, the monitoring process for children’s growth and development is also carried out by measuring the circumference of the head, where the results of this measurement will again be entered on a card whose output is displayed in graphic form.

Based on the above study, the need for data on child development is critical, and therefore a level of accuracy is required in reading or entering measurement data. The result of technology helps humans in overcoming problems in various fields, especially in the health sector. This paper will discuss the design of a system that can be used to measure and monitor head circumference in toddlers by utilizing rotary sensor technology and information and communication technology. With this system, the measurement process becomes easier in reading data, and the input process into the system becomes more manageable.

2. Literature Review

2.1. Child Development

Growth and development are events that every living thing will experience. These events are two events, namely growth, and development. These two events are related to one another, where growth refers to a change in the shape of the body, or cell size and effect change an organ or limb’s function in its operation. Every parent must consider child development because this will significantly determine and influence how the child develops in the future.

In assessing a child’s growth, several ways can be used to detect children’s growth and development, including anthropometric measurements. These anthropometric measurements include bodyweight measurements, height (body length), head circumference, and upper arm circumference [1]. Head circumference is one of the characteristics of the growth process, where the size of the brain in humans changes. Measuring head circumference is very important because it reflects the size and growth of a child’s brain. According to the American Academy of Pediatrics recommendations, regular monitoring of head circumference should be performed, primarily until two years [2,3]. Figure 1 shows a graph of the development of head circumference in boys and girls.

![Figure 1: (a) Male Head Circular Graph, (b) Female Head Circular Graph [5]](image)

The measurement of head circumference is done by wrapping a flexible measuring tape made
of inelastic material through the most prominent part of the back of the head (protuberantia occipitalis) and forehead (glabella). It is a good idea to measure the side of the tape that shows the centimeter is on the inside to increase the probability of measuring subjectivity [7]. Figure 2 shows how to measure head circumference in children.

![Figure 2: How to measure head circumference](image)

2.2. Microcontroller
A microcontroller is a chip composed of a processor, memory, and I / O integrated into a single unit that functions as an electronic circuit controller. Microcontroller applications commonly used to build and design a control system are Arduino Uno, Arduino Nano, and Arduino Mega. On the Arduino Uno and Arduino Nano, the microcontroller used is ATmega328P, while in the Arduino Mega, the microcontroller used is ATmega 2560. Arduino is a microcontroller system that has hardware and software parts. Arduino software is used to develop programs or code that will be implemented on the Arduino microcontroller. Simultaneously, the hardware from Arduino is a set of devices consisting of CPU, IO, and memory [8,9].

2.3. Rotary Sensor
Rotary encoders generally use optical sensors to generate a series of pulses, which can be interpreted into motion, position, and direction. The angular position of a rotating object shaft can be processed into information in the form of a digital code by the rotary encoder to be forwarded by the control circuit. Rotary encoders are composed of a thin disc having holes in the disc’s circular portion [10]. An incremental rotary encoder is one type of sensor that can be used to calculate distance. This sensor’s working principle is that when the shaft rotates, a row of pulses will appear on each channel at a frequency proportional to the rotational speed. In contrast, the phase relationship between channels A and B produces the direction of rotation. By counting the number of pulses that occur against the dish resolution, the process can be measured so that the distance traveled can be known [11].

2.4. Information System
An information system is a system in an organization that brings together the needs of daily transaction processing that supports the organization’s operations’ managerial functions with the strategic activities of an organization to be able to provide certain outsiders with the information needed for decision-making. The development of information systems has led to significant changes in the patterns of decision making by management both at the operational level. This development has also led to changes in the roles of managers in decision making. They are always required to be able to obtain the most accurate and up-to-date information. Information
is data that is still raw material if it is not processed or processed. Data will be useful and produce reports through a model.

2.5. Framework
The framework can be defined as a collection of functions/procedures and classes for specific purposes that are ready to simplify and speed up a programmer's work without having to create a function or class from scratch. The framework is a reusable system design. In it, there is an interaction with a certain set of objects. The framework describes how these objects’ relationships and interactions along with their interfaces and return flow between these objects. There are three main characteristics of object-oriented programs in the Framework: data abstraction, polymorphism, and inheritance. CI is a framework for developing web-based applications using PHP scripts. PHP is a popular script in web-based application development. PHP used 81.7% of web-based applications at this time [13,14].

3. Method
The monitoring system design uses the software development life-cycle method with the waterfall model. The use of the waterfall model is intended to obtain optimal results. The stages carried out in designing this system are as follows:

(i) Needs Analysis
At this stage, the process carried out is to collect the complete needs then analyze and define the requirements that must be met by the program to be built. This phase must be done entirely to produce a finished design. In this study, a needs analysis was carried out at a posyandu in Semarang, Central Java, Indonesia. The first step is to discuss with posyandu cadres, where the results will be used to create a system design.

(ii) Design
At this stage, it is necessary to translate the needs analysis results into a form that can be understood in system development. The design includes two steps, namely hardware design, and software design. Hardware design is a design for making a head circumference measuring system. The system is built using a rotary encoder and Arduino Uno.

(iii) Implementation
The stage where the entire design is converted into program code. The resulting program code is still in the form of modules integrated into a complete system. In this study, the software used in the implementation uses the Arduino IDE and Visual Studio Code.

(iv) Testing
This test is done to determine whether the hardware or software that is made is in accordance with the design and function. There is an error. In this research, hardware testing was carried out in two models: in the laboratory and then at the posyandu. Testing in the laboratory using a comparison tool in the form of a ruler. This comparison tool is used for reference in determining the distance used in determining the head circumference in children. Testing software using the black-box testing method, this test is done to see the functionality of the system being built.

4. Result
The results obtained from this study is a system used for monitoring head circumference in children. The system consists of hardware used to measure head circumference and software used as an information system in monitoring children’s head circumference. Rotary sensor testing uses a ruler as a comparison tool. Initial testing is carried out in the laboratory by moving the rotary sensor beside the comparator. Tests carried out ten times the distance reading. The results of sensor testing and distance comparison are shown in Table 1.
Table 1: Test results of head circumference gauges

| No. | Comparator output value (cm) | Sensor output value (cm) | Difference (cm) |
|-----|-----------------------------|--------------------------|-----------------|
| 1   | 5                           | 5.1                      | -0.1            |
| 2   | 10                          | 10.3                     | -0.3            |
| 3   | 15                          | 15.4                     | -0.4            |
| 4   | 20                          | 20.2                     | -0.2            |
| 5   | 25                          | 25.5                     | -0.5            |
| 6   | 30                          | 30.3                     | -0.3            |
| 7   | 35                          | 35.5                     | -0.5            |
| 8   | 40                          | 40.7                     | -0.7            |
| 9   | 45                          | 45.8                     | -0.8            |
| 10  | 50                          | 50.7                     | -0.7            |

Table 2 shows the research result that there is a difference between the comparator’s value and the value issued from the sensor. The calculation of the percentage of error and the percentage of accuracy using Equation 1 and Equation 2. The parameter $e_n$ represents the percentage of error, parameter $A_n$ represents the percentage of accuracy, parameter $Y_n$ represents the result of the benchmark measuring instrument, and parameter $X_n$ represents the result of the measuring instrument designed [15].

\[
\text{Percentage of errors } (e_n) = \frac{Y_n - X_n}{Y_n} \times 100\% \quad (1)
\]

\[
\text{Percentage of accuracy } (A_n) = 100 - \left( \frac{Y_n - X_n}{Y_n} \right)x100\% \quad (2)
\]

A linearization process is required to improve the measurement results from the system output to reduce the value or distance obtained. The linearization process is carried out using a simple linear regression equation. The regression equation has a formula, namely $Y = a + bx$. Equations 3 and equation 4 are used to get the values $a$ and $b$. Parameter $a$ states a constant, parameter $b$ represents the regression coefficient/slope of the resulting response magnitude, parameter $Y$ represents the response/effect variable (dependent), and parameter $x$ represents the predictor/cause variable (independent).

\[
a = \frac{(\sum y)(\sum x^2) - (\sum x)(\sum xy)}{n(\sum x^2) - (\sum x)^2} \quad (3)
\]

\[
b = \frac{n(\sum xy) - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2} \quad (4)
\]

Table 2 shows the results obtained after the system was treated by entering a linear equation. After linearizing or calibrating the rotary sensor, the difference is obtained. The percentage error value and accuracy are accurate, with an average error percentage value of 0% and an accuracy value of 100%.

Tests carried out on this software using black-box testing, and testing is emphasized on the user side of the posyandu cadres. Table 3 shows the results of the black box test on the login page.

Table 3 shows that black box testing results can be accepted because the application’s output is under the expected results. The next stage is testing on the data management page by posyandu cadres. The details of this test are shown in Table 4.
Table 2: Test data table with linearization

| No. | Comparator output value (cm) | Sensor output value (cm) | Difference (cm) |
|-----|-----------------------------|--------------------------|-----------------|
| 1   | 5                           | 5                        | 0               |
| 2   | 10                          | 10                       | 0               |
| 3   | 15                          | 15                       | 0               |
| 4   | 20                          | 20                       | 0               |
| 5   | 25                          | 25                       | 0               |
| 6   | 30                          | 30                       | 0               |
| 7   | 35                          | 35                       | 0               |
| 8   | 40                          | 40                       | 0               |
| 9   | 45                          | 45                       | 0               |
| 10  | 50                          | 50                       | 0               |

Table 3: Black Box test results on the Login Form

| Task | Expected value | Observation | Result          |
|------|---------------|-------------|-----------------|
| Enter username and password | Users can enter the main page and the menu that is displayed according to user settings | When the user has successfully logged in, the system display is under the user’s settings | succeed |
| Entering username and password with wrong data | An error notification appears on the username or password | An error notification appears | succeed |

5. Conclusion
The conclusions from the results of this study are as follows: Implementation of rotary sensors for measuring head circumference in toddlers or children has been successfully tested and successfully tested in posyandu activities. To reduce the sensor’s difference value, a linear equation is needed, where the final result will make the value generated by the sensor equal to the value on the comparator. Rotary sensor test results show that the sensor output has an accuracy value of 100% and the resulting error is 0%. The system test results with the black box testing model show that 100% of the functionality of the system has been running according to the initial scenario.

Acknowledgments
This research was funded by RKAT Engineering Faculty Diponegoro University 2020.

References
[1] R. D. Sanitasari, D. Andreswari, and E. P. Purwandari, “Sistem Monitoring Tumbuh Kembang Anak Usia 0-5 Tahun Berbasis Android,” J. Rekursif, vol. 5, no. 1, pp. 1–10, 2017.
[2] R. Shabariah, F. Farsida, and I. Prameswari, “Hubungan Ukuran Lingkar Kepala dengan Perkembangan Anak Usia 12 - 36 Bulan Berdasarkan Skala Denver Development Screening Test-II (Ddst-II) di Posyandu RW 03 Mustika Jaya Bekasi Timur November 2016,” J. Kedokt. dan Kesehat., vol. 15, no. 1, p. 46, 2019.
[3] “Recommendations for Preventive Pediatric Health Care Bright Futures,” American Academy of Pediatrics, 2020.
| Task                        | Case and test results                                                                 |
|-----------------------------|---------------------------------------------------------------------------------------|
| Entering parent and child data | Posyandu cadres can enter parent and child data and will serve as master data         |
| Enter measurement result data | Posyandu cadres, after measuring the head circumference, then enter the measurement data into the system |
| Entering Immunization data | Posyandu cadres, after collecting immunization data, then enter the data collected into the system |
| Display posyandu participant data | Posyandu cadres can display the data according to what they are looking for          |
| Displays a graph of the head circumference measurement | Posyandu cadres can display a head circumference measurement chart according to their search |
| Displays child development data | Posyandu cadres can display child development data according to the search           |
| Parent and child data       | The data from the measurement of circumference will be successfully entered into the system |
| Immunization data collection results are successfully entered into the system |                                                    |
| Posyandu participant data can be displayed according to the search |                                                   |
| The head circumference chart can be displayed according to the search |                                                   |
| Child development data can be displayed according to search |                                                   |

[4] Available: https://downloads.aap.org/AAP/PDF/periodicity_schedule.pdf.
[5] “KURVA PERTUMBUHAN WHO,” IDAI, 2015.
[6] Available: https://www.idai.or.id/professional-resources/growth-chart/kurva-pertumbuhan-who.
[7] A. Sishadi and A. Purwanti, “Hubungan Lingkar Kepala Dengan Perkembangan Anak Sindrom Down,” J. Kedokt. Diponegoro, vol. 4, no. 4, pp. 437–446, 2015.
[8] G. Barbon, M. Margolis, F. Palumbo, F. Raimondi, and N. Weldin, “Taking Arduino to the Internet of Things: The ASIP programming model,” Comput. Commun., vol. 89–90, pp. 128–140, 2016.
[9] D. Prihatmoko, “Perancangan Dan Implementasi Pengontrol Suhu Ruangan Berbasis Mikrokontroller Arduino Uno,” Sitrinis J. Tek. Mesin, Elektro dan Ilmu Komput., vol. 7, no. 1, p. 117, 2016.
[10] M. Tresanchez, T. Pallejá, M. Teixidó, and J. Palacín, “The optical mouse sensor as an incremental rotary encoder,” Sensors Actuators, A Phys., vol. 155, no. 1, pp. 73–81, 2009.
[11] “Lpd3806-400bm-G5-24c Ab Two-Phase 5-24V 400 Pulses Incremental Optical Rotary Encoder.” Available: https://www.made-in-china.com/showroom/jn-syjm/product-detailmBkEiChUXjWg/China-Lpd3806-400bm-G5-24c-Ab-Two-Phase-5-24V-400-Pulses-Incremental-Optical-Rotary-Encoder.html.
[13] D. P. Pop and A. Altar, “Designing an MVC model for rapid web application development,” in Procedia Engineering, 2014.
[14] N. Prokofyeva and V. Boltunova, “Analysis and Practical Application of PHP Frameworks in Development of Web Information Systems,” Procedia Comput. Sci., vol. 104, no. December 2016, pp. 51–56, 2016.
[15] K. T. Martono, E. D. Widianto, and Y. Bahctiar, “Performance analysis on the arduino uno microcontroller-based weight measurement system for toddler,” J. Theor. Appl. Inf. Technol., vol. 97, no. 7, pp. 1914–1925, 2019.