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Development of Hand Movement Assistive Devices for Mild Stroke Patients Based on Arduino Uno

Dian Saadah[1], Siswiyanti[2], Eko Budiraharjo[3], Eko Budihartono[4]
Universitas Pancasakti Tegal, Indonesia [1,2,3]
Politeknik Harapan Bersama, Indonesia [4]
Email: diansaadah05@gmail.com, siswieyanti@gmail.com, ekobudiraharjo@yahoo.com, tara.niscita@gmail.com

Keywords:
Stroke, Hand Movement Tool, Arduino Uno.

Abstract: Stroke is one of the leading causes of physical disability worldwide, including in Indonesia. In the Tegal area, the number of stroke sufferers continues to increase, causing many individuals to experience difficulties in performing daily activities, especially impaired motor function in the hands. Rehabilitation is an important step in the recovery of stroke patients, but the facilities and rehabilitation aids available in the Tegal area are still limited and expensive. This study aims to design and develop an Arduino Uno-based hand motion aid that is affordable and easily accessible to stroke patients in the Tegal area. The research method includes anthropometric methods with the results taken as the largest percentile, namely P95 in cm Lij (2.4), Pij (6.6), Ljt (2.1), Pjt (8), Ljtg (2.1), Pjtg (8.7), Pjm (2.1), Ljm (8.2), Pjk (1.9), Ljk (6.2), Pt (19.5), Ptt (10.9), Ltmk (9.1), Ltij (11.8), Ttij (6.5), Ttm (3.3), Tij (1.9), Tj (1.6), Ltm (10.9), Ptm (13.8), Jjk (20.6), Dgmak (6.6), Dgmin (4.5), Tgkt (6.7), Lkt (11.1). Testing on ten mild hand stroke patients aged 30-70 years, as well as evaluation of effectiveness through the distribution of questionnaires. The results of the study showed that the developed assistive device significantly improved the patient's hand motor function, with 40% of respondents agreeing that the device is easy to install and remove, and 30% agreeing that it can be used independently. The device also received positive responses regarding its comfort and effectiveness, with 50% of respondents agreeing that the device responded well to hand stimulation. In conclusion, the Arduino Uno-based hand motor aid has great potential for use in the rehabilitation of stroke patients in Tegal, and can be an effective solution to improve their quality of life.

INTRODUCTION

Stroke is one of the leading causes of physical disability worldwide, including in Indonesia. In the Tegal area, the number of stroke sufferers continues to increase, causing many individuals to have difficulty in carrying out daily activities, especially impaired motor function in the hands. Rehabilitation is an important step in the recovery of stroke patients, but the facilities and rehabilitation aids available in the Tegal area are still limited and expensive. Rehabilitation is an important step in the recovery of stroke patients, especially to restore hand motor function. However, the facilities and rehabilitation aids available in the Tegal area are still limited. The problem of stroke in Indonesia does require serious attention because the number of cases continues to increase and has a high mortality rate. Almost 85% of people are likely to have a stroke, but by overcoming the risk factors that occur, the number of stroke patients can be reduced (Fauzan et al., 2022).

THEORETICAL BASIS

Stroke

Stroke is the second most deadly disease in the world according to WHO. Sufferers experience injury to the nervous system. Because of this, health experts, especially in the field of nursing, need special attention. Because stroke in Indonesia has an increasing number of cases and has a high mortality rate (Byna & Basit, 2020). Stroke is a serious medical condition that occurs when the blood supply to part of the brain is disrupted or reduced, causing brain tissue to lack oxygen and nutrients. Within minutes, brain cells can begin to die. Stroke can cause permanent damage to the brain and can result in disability or death if not treated immediately (Aurelius Lami & Sonalitha, 2019).

Forearm

The dimensions of the human forearm can vary depending on factors such as the age, gender, and height of the individual. In general, the forearm consists of two main bones, namely the ulna and radius, which stretch from the elbow to the wrist (Subito M et al., 2021).

Lower Arm Muscle Structure

The muscles that affect human skeletal movement are called striated muscles, which have unconscious and irregular properties because their activity depends on the will of the perpetrator. The working principle of striated muscles or motor muscles is broadly the same as the heart muscle, the difference is that motor muscles do not have automatic properties where the trigger for stimulation comes from the brain and is then distributed through the nerves (Sukmanawati et al., 2019).

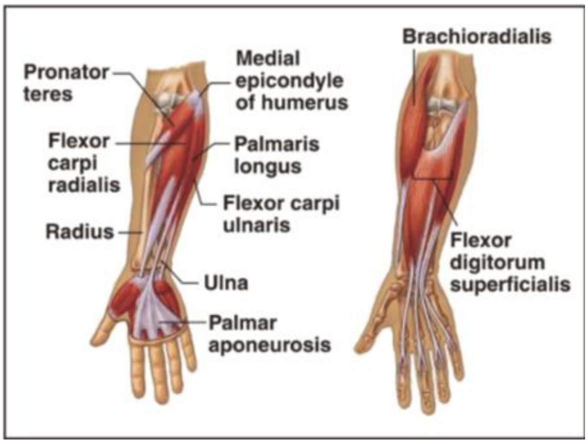


Figure 1. Lower Arm Muscle Structure

Arduino Uno

Arduino Uno R3 (as a software and hardware control tool) is a microcontroller-based board on the ATmega 328 which is used in this study as a control center for lower arm hand movements (Samsugi et al., 2020).

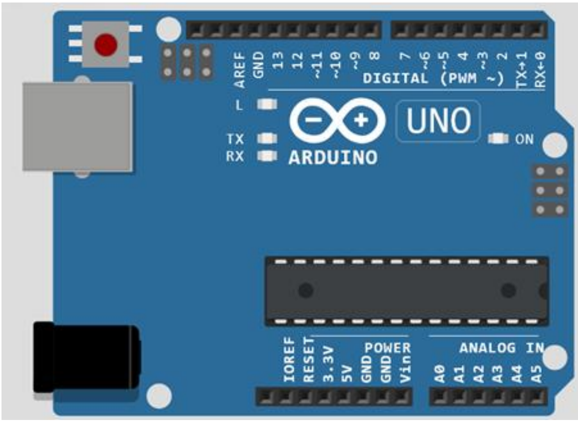


Figure 2. Arduino Uno hardware

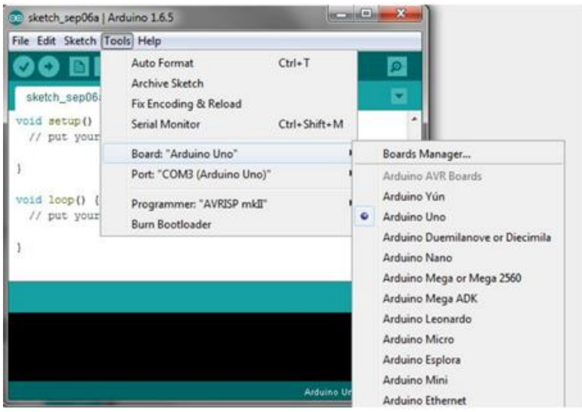


Figure 3. Arduino Uno software

Design

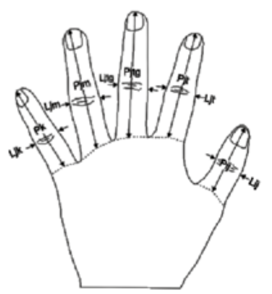
According to Soetam Rizky (2011: 140) design is a process to define something that will be done using various techniques and involves a description of the architecture and details of the components and also the limitations that will be experienced in the process of working on it. Design is the process of determining the data and steps needed for a new system. This system design stage is useful because it provides a complete picture as a guide for programmers in developing applications. In accordance with the system components that will be computerized, what needs to be designed in this stage includes hardware and software, databases, and applications.

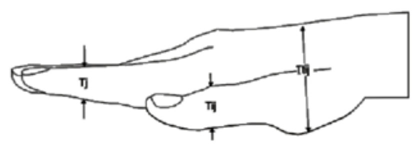
MSI Method

The successive interval method is the process of changing ordinal data into interval data. Why should ordinal data be changed into interval form? Ordinal data is actually qualitative data or not actual numbers. Ordinal data uses numbers as symbols of qualitative data. In many statistical procedures such as regression, Pearson correlation, t-test and so on, interval scale data is required. Therefore, if we only have ordinal scale data; then the data must be converted into interval form to meet the requirements of these procedures, unless we use procedures, such as Spearman's correlation that tests ordinal scale data; then we do not need to change the existing data (Sarwono et al., 2022.)

Anthropometric Method

Anthropometric method is a method of measuring the physical dimensions of the human body for the purpose of understanding variations in body dimensions in a population, which is important for various fields such as product design, ergonomics, and occupational safety. Anthropometry involves measurements such as height, weight, length and circumference of body parts, and various body indices (Tomia et al., 2023). Anthropometry is a science that deals with measuring the human body, especially regarding body dimensions. Anthropometry is divided into two main categories, namely static anthropometry and dynamic anthropometry (Siswiyanti, 2013).





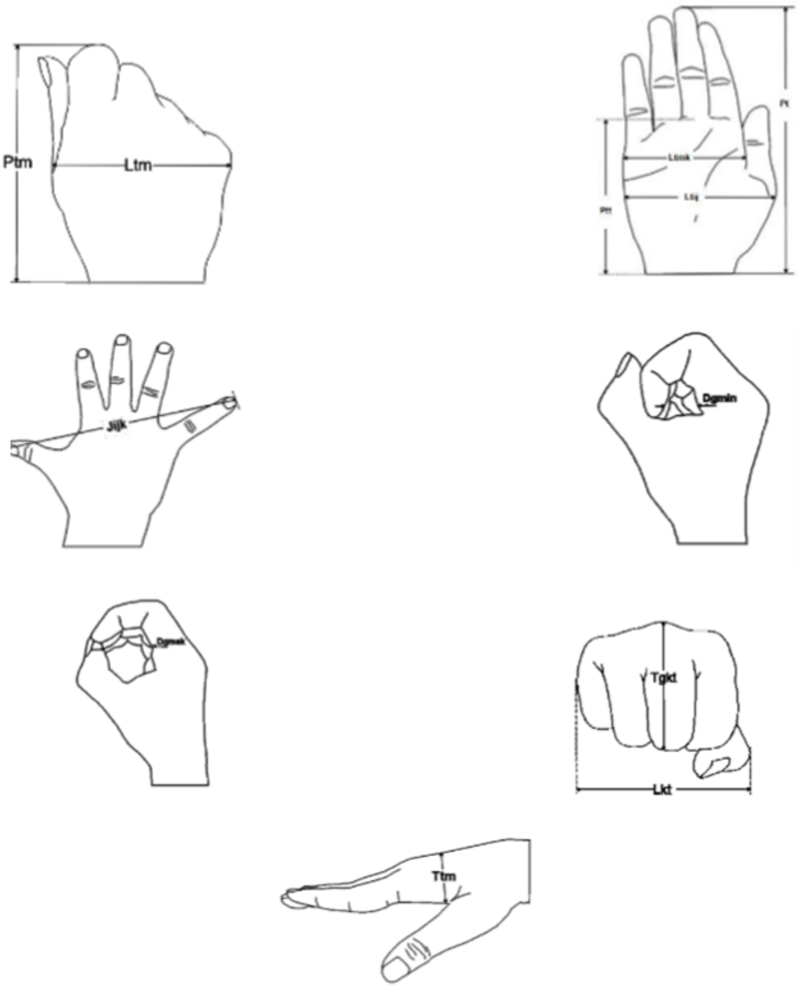


Figure 4. Hand Anthropometry

METHOD

The research method used in this study is a qualitative method, a study conducted in the field specifically only on several respondents or information in the need for in-depth interviews. And using the Successive Interval Method (MSI) is the process of changing ordinal data into interval data. Why should ordinal data be changed into interval form? Ordinal data is actually qualitative data or not actual numbers. Ordinal data uses numbers as symbols of qualitative data. The anthropometric method is a method of measuring the physical dimensions of the human body for the purpose of understanding variations in body dimensions in the population, which is important for various fields such as product design, ergonomics, and occupational safety. Anthropometry involves measurements such as height, weight, length and circumference of body parts, and various body indexes.

RESULT AND DISCUSSION

Data Collection

Hand Anthropometry Calculation to design Hand Mobility Assistance Devices for Mild

Stroke Patients. With a sample of 10 patients. Here is a summary of the calculations with the following dimensions: Thumb width (Lij), Index finger width (Ljt), Middle finger width (Ljtg), Ring finger width (Ljm), Little finger width (Ljk), Thumb length (Pij), Index finger length (Pjt), Middle finger length (Pjtg), Ring finger length (Pjm), Little finger length (Pjk), Metacarpal hand thickness (Ttm), Thumb hand thickness (Ttij), Thumb thickness (Tij), Finger thickness (Tj), Gripping hand length (Ptm), Gripping hand width (Ltm), Hand length (Pt), Palm length (Ptt), Metacarpal hand width (Ltmk), Hand width to thumb (Ltij), Distance from thumb to little finger (Jjk), Maximum grip diameter (Dgmak), Minimum grip diameter (Dgmin), Fist width (Lkt), Fist height (Tgkt).

No	Dimensi	Perempuan					Laki-Laki				
		1	2	3	4	5	6	7	8	9	10
1	Lij	1,9	2,1	2	2	2	2	2,3	2,2	2,3	2,2
2	Pij	6,2	5,3	5,1	6,1	5,4	5,8	6,2	5,2	6	6,3
3	Ljt	1,7	1,8	2	1,7	1,6	1,8	2	1,8	1,6	1,9
4	Pjt	7,4	5,9	6,2	7	6,2	6,6	7,5	7	7,7	7,4
5	Ljtg	1,7	1,6	2	1,6	2	1,8	2	1,8	2	1,9
6	Pjtg	8	6,3	7	7,4	6,6	7,3	8,4	7,6	8,4	7,8
7	Pjm	1,9	1,6	1,8	1,7	1,8	1,8	2	1,5	1,8	1,8
8	Ljm	6,8	6,1	6,3	7,1	6,4	6,8	7,8	7,1	7,9	7,5
9	Pjk	1,4	1,5	1,7	1,3	1,8	1,7	1,8	1,5	1,5	1,7
10	Ljk	5,4	4,8	5,1	5,8	5,4	5,5	6,1	5,6	5,8	6
11	Pt	16	15	17	17	16	18	19	18	19	18
12	Ptt	6,7	9,5	6,9	9,8	8	11	10	10	11	10
13	Ltmk	6,5	7	8,5	7,2	8,1	9	8,3	8,7	8,5	8,7
14	Ltij	8,2	8,5	9	8,6	9,6	10	11	6,5	10	8,5
15	Ttij	4,5	4	4,5	4	4,7	4,2	4	6,4	3,9	5,2
16	Tij	1,9	1,5	1,1	1,3	1,4	1,7	1,8	1,4	1,6	1,6
17	Ttm	1,2	1,4	0,9	1,1	1,2	1,5	1,4	1,4	1,2	1,5
18	Tj	1,2	1,4	0,9	1,1	1,2	1,5	1,4	1,4	1,2	1,5
19	Ltm	9	9,5	8,5	8,3	9	11	11	9,5	9,5	10
20	Ptm	11	11	11	13	10	11	14	11	13	12
21	Jjk	16	15	19	17	17	16	19	18	18	18
22	Dgmak	5,5	5	5	5,5	5,3	5,8	6,5	5	5,5	5,8
23	Dgmin	2,3	2,5	2,5	3,5	2,1	4,5	3,5	3	3,5	3
24	Tgkt	5,2	5,4	5,6	5,7	5,8	6	6,5	5,5	6,2	6,2
25	Lkt	8,5	7,5	9	9,3	7,5	6,5	11	8,5	8,3	9,5

Figure 5. Summary of Anthropometric Calculations (cm)

Data Normality Test

Based on the analysis of the data normality test that has been carried out using the Shapiro-Wilk test, all measured variables show significant values greater than 0.05. This means that the data from each variable, including measurements such as finger width and length, as well as other dimensions such as hand length, hand width, and grip diameter, follow a normal distribution. The following are the results of the calculation of anthropometric data with the 5th percentile (P5), 50th percentile (P50) and 95th percentile (P95) and Standard Deviation (SB) in the following table:

Results of the calculation of P5, P50, P95, SB

Female Data (Lij): 1.9 : 2.1 : 2 : 2 : 2

P5 = 5/100 x (5-1) = 0.3

P5 value = 1.9 + 0.3 x (2-1.9) = 1.9 etc.

P50 = 50/100 x (5+1) = 3

P50 value = 1.9+3x(2-1.9) = 2 etc.

P95 = 95/100x(5+1) = 5.7

P95 value = 2.1+0.7x(2.1-2) = 2,1 etc

SB = √0.014 = 0.1 etc

No	Dimensi	Perempuan (5)				Laki-laki (5)			
		P5	P50	P95	SB	P5	P50	P95	SB
1	Lij	1,9	2	2,1	0,1	2	2,2	2,4	0,1
2	Pij	4,8	5,6	6,4	0,5	5,2	5,9	6,6	0,4
3	Ljt	1,5	1,8	2	0,2	1,6	1,8	2,1	0,1
4	Pjt	5,5	6,5	7,6	0,6	6,5	7,2	8	0,4
5	Ljtg	1,4	1,8	2,1	0,2	1,7	1,9	2,1	0,1
6	Pjtg	6	7,1	8,2	0,7	7,1	7,9	8,7	0,5
7	Pjm	1,6	1,8	1,9	0,1	1,5	1,8	2,1	0,2
8	Ljm	5,9	6,5	7,2	0,4	6,7	7,4	8,2	0,5
9	Pjk	1,2	1,5	1,9	0,2	1,4	1,6	1,9	0,1
10	Ljk	4,7	5,3	5,9	0,4	5,4	5,8	6,2	0,3
11	Pt	15	16	18	0,8	17	18	20	0,7
12	Ptt	5,8	8,2	11	1,4	9,9	10	11	0,3
13	Ltmk	6,1	7,5	8,8	0,8	8,2	8,6	9,1	0,3
14	Ltij	7,9	8,8	9,7	0,5	6,4	9,1	12	1,6
15	Ttij	3,8	4,3	4,9	0,3	3	4,7	6,5	1,1
16	Ttm	2	2,5	3,1	0,4	2,2	2,7	3,3	0,3
17	Tij	1	1,4	1,9	0,3	1,4	1,6	1,9	0,1
18	Tj	0,9	1,2	1,5	0,2	1,2	1,4	1,6	0,1
19	Ltm	8,1	8,9	9,6	0,5	9,2	10	11	0,5
20	Ptm	9,4	11	13	0,9	10	12	14	1
21	Jjk	14	17	20	1,7	15	18	21	1,6
22	Dgmak	4,8	5,3	5,7	0,3	4,8	5,7	6,6	0,5
23	Dgmin	1,8	2,6	3,4	0,5	2,5	3,5	4,5	0,6
24	Tgkt	5,1	5,5	5,9	0,2	5,5	6,1	6,7	0,4
25	Lkt	7	8,4	9,7	0,8	6,2	8,7	11	1,5

Figure 6. P5, P50, P95 and SB values for women and men (cm)

Prediction Equation

The prediction equation of Pij, Pjt, Pjtg, Pjm, Pjk, Pt, Ptt, Ptm against Height (TB) is carried out. The calculation is as follows.

No	Dimensi	Perempuan			Laki-laki		
		Mean	Koefisien Korelasi	Persamaan Prediksi	Mean	Koefisien Korelasi	Persamaan Prediksi
1	TB	153	-	-	165,6	-	-
2	Pij	5,62	0,2208	-28,18+0,2208TB	5,9	0,1872	-25,1+0,1872TB
3	Pjt	6,54	0,2392	-30,16+0,2392TB	7,04	0,1888	-24,3+0,01888TB
4	Pjtg	7,06	0,2648	-33,54+0,2648TB	7,9	0,3168	-44,6+0,3168TB
5	Pjm	6,54	0,1456	-15,76+0,1456TB	7,42	0,2072	-26,9+0,2072TB
6	Pjk	5,3	0,096	-9,40+0,096TB	5,8	0,042	-1,1+0,0420TB
7	Pt	16,3	0,1192	-1,96+0,1192TB	18,3	0,2008	-15,0+0,2008TB
8	Ptt	8,18	1,224	-179,22+1,224TB	10,4	0,0176	7,5+0,0176TB
9	Ptm	10,9	0,5592	-74,86+0,5592TB	12,08	0,4576	-63,6+0,4576TB

Figure 7. Results of calculating the correlation coefficient and prediction equation.

The size of the correlation number determines the strength of the relationship between height (TB) and the dimensions of the palm. Based on the following correlation indicators (Sarwono, 2006).

1. 0-0.25: Very weak correlation
2. >0.25-0.50: Fair correlation
3. >0.50-0.75: Strong correlation
4. >0.75-1: Very strong correlation

Dimensions Pij, Pjt, Pjm, Pt, Pjk have fair correlation and Pjtg, Pt, Ptm have strong correlation. Thus, the data obtained from various dimensions of the palm correlate with height to conduct further research. For the design size, it is taken from the largest percentile, namely P95.

The result of the calculation of P95 plus an allowance of 25%

Lij = 2.4 + 25% = 2.4 + 0.6 = 3

Pij = 6.6 + 25% = 6.6 + 1.65 = 8.25 etc.

Table 1. Allowance Size (cm)

Dimensions	P95	Allowance 25%	Allowance Size
Lij	2.4	0,6	3
Pij	6.6	1,65	8,25
Ljt	2.1	0,525	2,625
Pjt	8.0	2	10
Ljtg	2.1	0,525	2,625
Pjtg	8.7	2,175	10,785
Pjm	2.1	0,525	2,625
Ljm	8.2	2,05	10,25

Pjk	1.9	0,475	2,375
Ljk	6.2	1,55	7,75
Pt	19.5	4,875	24,375
Ptt	10.9	2,725	13,625
Ltmk	9.1	2,275	11,375
Ltij	11.8	2,95	14,75
Ttij	6.5	1,625	8,125
Tij	3.3	0,825	4,125
Ttm	1.9	0,475	2,375
Tj	1.6	0,4	2
Ltm	10.9	2,725	13,625
Ptm	13.8	3,45	17,25
Jjk	20.6	5,15	25,75
Dgmak	6.6	1,65	8,25
Dgmin	4.5	1,125	5,625
Tgkt	6.7	1,675	8,375
Lkt	11.1	2,775	13,875

Data Processing

Operation Process Chart (OPC)

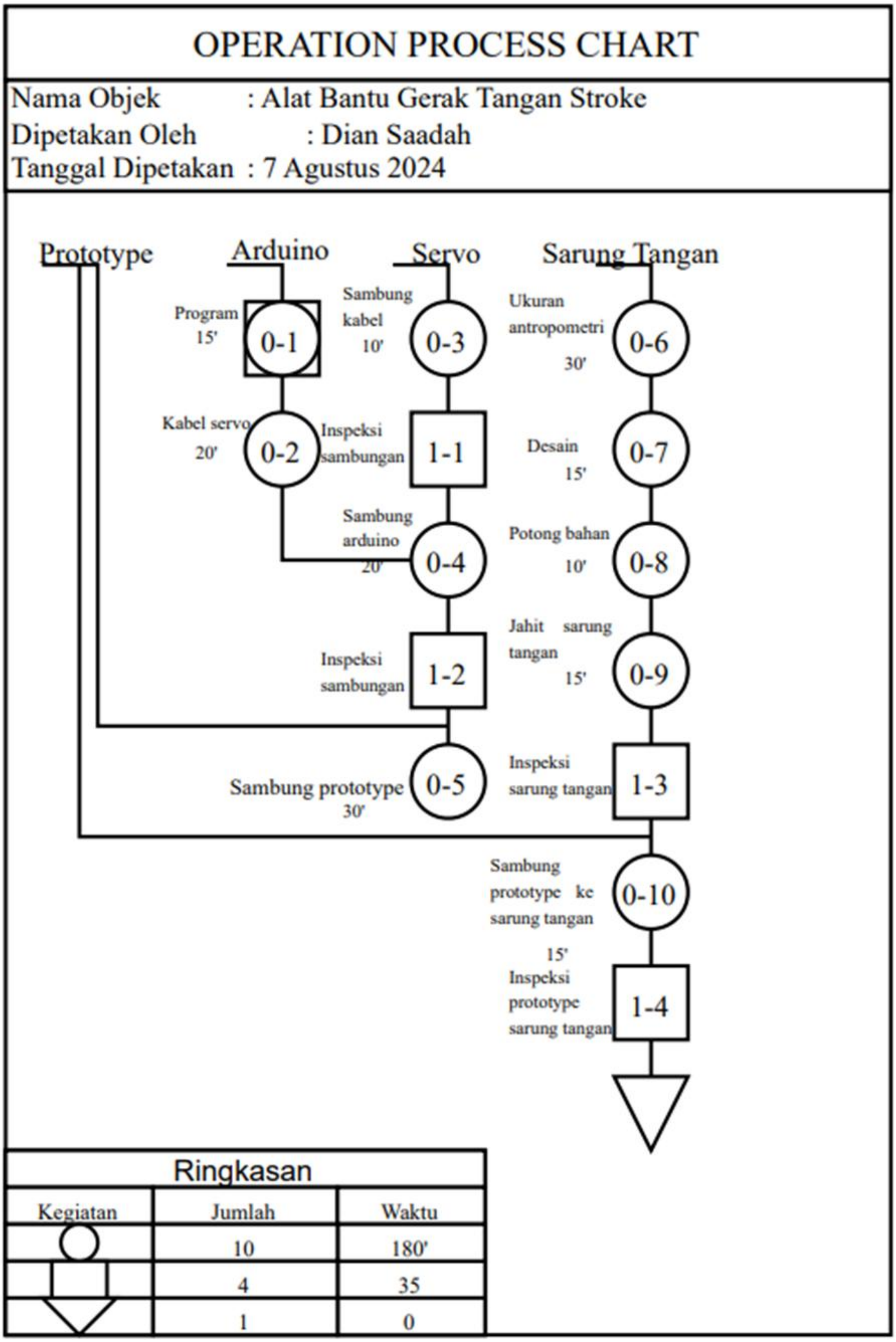


Figure 8. Operation Process Chart (OPC)

Glove Design

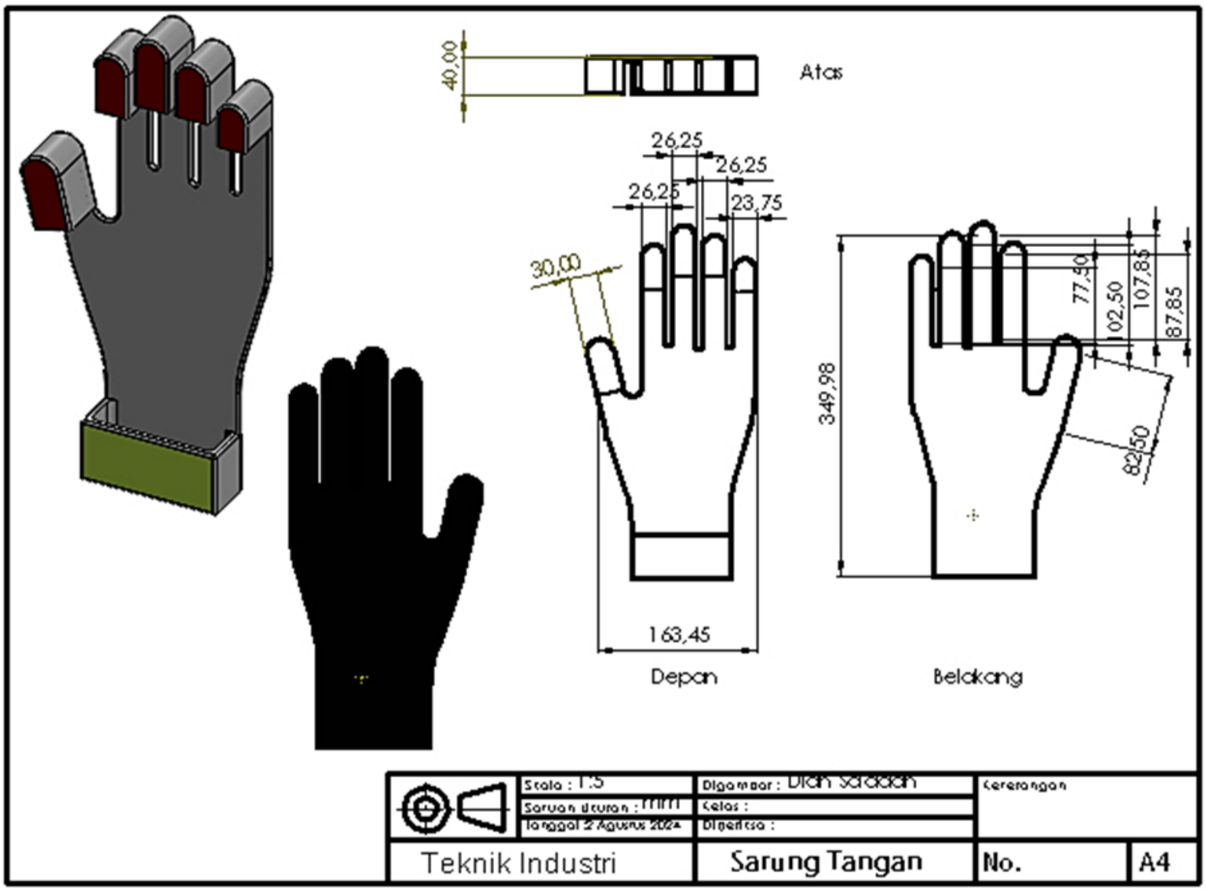


Figure 9. Glove Design

Tool Design

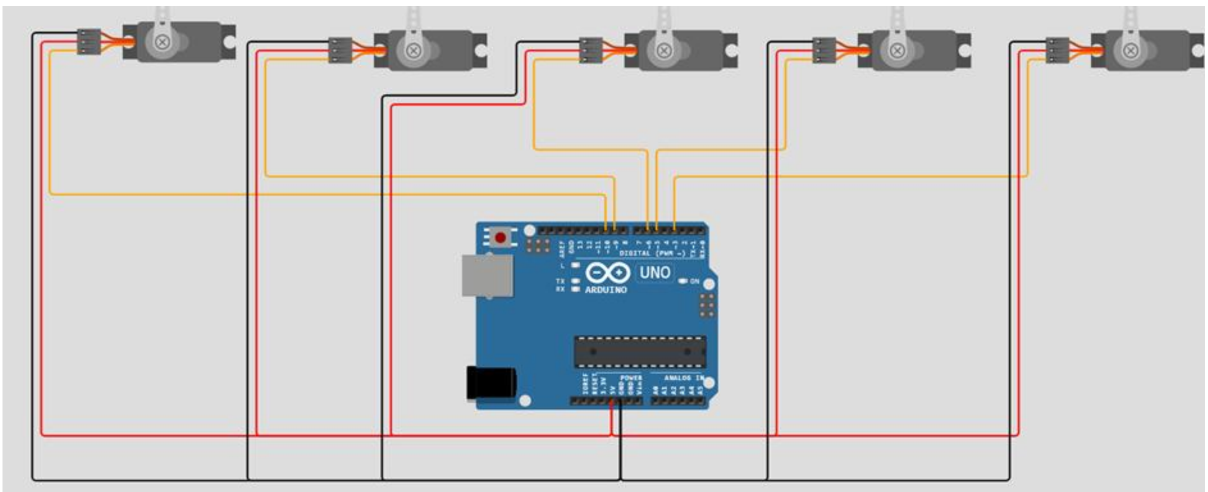


Figure 10. Arduino circuit

Arduino Systematic Circuit (DC)

The tool uses direct current (DC) with a power supply specification of 5V 3A which is divided into two streams with a total of 2.5V and 1.5A each. This shows the distribution of electrical loads that must be considered to maintain the stability of the device. Use of Dupont Cables: There are three dupont cables used, each for positive (+), negative (-), and signal flow to the Arduino. This configuration is standard in Arduino-based control circuits to ensure consistent power supply and proper signal control. Servo Control: The program used utilizes the Servo library in Arduino to control five servos. Each servo is connected to a specific pin on the Arduino and is set to move from a position of 0 to 180 degrees, then returns to its starting position.

Loop Implementation: The loop in the program is used to move the servo forward and backward, with a 50 millisecond delay between each movement. This ensures smooth and controlled servo movement.

Pin Usage: The choice of pins used (pins 3, 5, 6, 9, and 10) shows good planning to avoid pin conflicts on the Arduino, which is important to ensure that all servos can operate without interference.

Tool Implementation

Figure 11. Tool Implementation

Figure 12. Tool Implementation

Function Testing

Data obtained through the distribution of questionnaires about the response of mild stroke patients to stroke hand mobility aids below this table, it can be concluded that the average ease of use is around 3.5 indicating that the majority of respondents find this tool quite easy to use, comfort of use average score 4 indicating this tool is comfortable, effectiveness of users average score is 4 indicating this tool is effective, error in use average score around 3.7 indicating this tool has a low error rate, accessibility and information on the use of this tool get a score of 3.7 indicating this tool is quite easy to access.

Table 2. Questionnaire Questions

No.	Question (Q)
Facilities	
Q1.	Are hand mobility aids easy to put on and take off?
Q2.	Can you use it yourself?
Comfort	
Q3.	Do you feel comfortable using this hand mobility aid?
Q4.	Does this tool fit your finger size?
Effectiveness	
Q5.	Does this hand mobility aid successfully respond to your finger stimulation?
Q6.	Does this tool require a short time to use?
Error	
Q7.	There are no obstacles when using hand mobility aids
Q8.	There is no electrical leakage in this handheld mobility aid.
Accessibility and Information	

Q9.	Is there any information on how to use the product?
Q10.	Are you having trouble getting this hand mobility aid?

R	Gender	Usia	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	P	72	4	3	5	4	4	5	4	5	4	3
2	P	57	3	3	4	3	4	4	5	4	3	4
3	P	45	4	4	5	5	5	5	4	5	5	5
4	P	34	2	2	3	2	3	3	2	3	2	2
5	P	39	4	4	4	4	4	4	3	4	4	3
6	L	43	5	4	5	5	5	4	5	5	5	4
7	L	50	3	3	4	3	4	3	3	3	3	4
8	L	45	4	5	4	4	4	5	4	4	4	3
9	L	46	2	2	3	2	3	2	3	3	2	2
10	L	38	3	3	3	4	3	3	3	4	3	3

Figure 13. Summary of respondents filling out the questionnaire

Interval Data Validity Test

R	Gender	Usia	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
1	P	32	2,958	2,134	3,318	2,666	2,294	3,914	3,152	3,318	2,796	2,134	28,68
2	P	45	2,003	2,134	2,159	1,868	2,294	2,884	4,155	2,159	2,003	3,103	24,76
3	P	52	2,958	3,103	3,318	3,8	3,559	3,914	3,152	3,318	3,8	4,155	35,08
4	P	61	1	1	1	1	1	2,052	1	1	1	1	11,05
5	P	67	2,958	3,103	2,159	2,666	2,294	2,884	2,196	2,159	2,796	2,134	25,35
6	L	33	4,155	3,103	3,318	3,8	3,559	2,884	4,155	3,318	3,8	3,103	35,19
7	L	40	2,003	2,134	2,159	1,868	2,294	2,052	2,196	1	2,003	3,103	20,81
8	L	50	2,958	4,155	2,159	2,666	2,294	3,914	3,152	2,159	2,796	2,134	28,39
9	L	62	1	1	1	1	1	1	2,196	1	1	1	11,2
10	L	70	2,003	2,134	1	2,666	1	2,052	2,196	2,159	2,003	2,134	19,35

Table 14. Interval Data

1. Validity Test

   A validity test is carried out using SPSS on the interval data and it is said to be valid if the calculated r is greater than the table r. The results of the SPSS calculation above Total Pearcon Correlation > 0.5 then the results are Valid.

2. Reliability Test

Reliability Statistics

Cronbach's Alpha	N of Items
.967	10

Figure 15. Interval Data Reliability Test

CONCLUSION

The design of this hand mobility aid is produced from the results of measurements adjusted to the dimensions of the patient's hand to ensure that the designed tool fits the size of their hand. The design of the tool is made based on the anthropometric measurements that have been collected, with the selection of appropriate materials, shapes, and sizes. Arduino Uno is assembled and programmed to control the various sensors and actuators used in the tool. Gloves are made with the largest percentile size P95. And looking for strong but comfortable materials, designed to be easy to put on and take off by patients, and provide a good response to hand movements.

The data obtained through the distribution of questionnaires about the response of mild stroke patients to the stroke hand mobility aids below this table, it can be concluded that the average ease of use is around 3.5 indicating that the majority of respondents find this tool quite easy to use, comfort of use average score 4 indicating this tool is comfortable, user effectiveness average score is 4 indicating this tool is effective, error usage average score around 3.7 indicating this tool has a low error rate, accessibility and information on the use of this tool get a score of 3.7 indicating this tool is quite easy to access.

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