CHAPTER 4 – RESULTS AND DISCUSSIONS

4.1 Measurement of Children's Height and Elbow Height Results

As the anthropometric data is significantly affecting the overall system of the model, an experiment by measuring children's body and elbow height manually is conducted to prove that the data is accurate and to get more data. Later, both of the data will be compared to determine the best solution to find the variable percentage for the program system. Elbow height is inserted into the calculation as it is almost the same with hand height in a comfortable position for hand washing.

Table 1. Anthropometric Data

Data Variable	Body Height (cm)	Elbow Height (cm)	Variable Percentage (%)	Ages
5^{th}	102.67	62.00	60.39	7 years old
50^{th}	116.14	70.26	60.50	
95^{th}	129.61	81.90	63.19	
5^{th}	92.96	61.00	65.62	8 years old
50^{th}	114.96	71.26	61.99	
95^{th}	136.95	81.43	59.46	
5^{th}	112.89	67.92	60.16	9 years old
50^{th}	122.47	75.46	61.62	
95^{th}	132.05	83.01	62.86	
5^{th}	116.43	68.97	59.24	10 years old
50^{th}	127.27	79.22	62.25	
95^{th}	138.11	89.46	64.77	
5^{th}	121.25	68.84	56.78	11 years old
50^{th}	133.31	82.03	61.53	
95^{th}	145.36	95.23	65.51	

5^{th}	119.62	75.57	63.18	12 years old
50^{th}	137.67	88.02	63.94	
95^{th}	155.72	100.48	64.53	
5^{th}	104.57	62.44	59.71	7-12 years old
50^{th}	125.04	77.50	61.98	
95^{th}	145.51	92.57	63.32	

The table above shows the anthropometric data taken from the source and arranged into a specific age that is used as a reference in the adjustment height program system. Data variable is the percentile of the total general population, including the lowest and highest percentile, hence 5^{th} and 95^{th} is shown. The variable percentages are taken based on the ratio of both heights from the data.

Table 2. Actual Body Measurement

No. Variable	Body Height (cm)	Elbow Height (cm)	Variable Percentage (%)
1	163	97	59.51
2	177	105	59.32
3	160	95	59.38
4	158	88	55.70
5	157	99	63.06
6	167	103	61.68
7	156	94	60.26
8	155	96	61.94
9	175	103	58.86
10	163	101	61.96

From the table above, 10 participants measure their body height and elbow height. Most of the participants were from junior high school where their height levels were closer compared to the adults. Their body and elbow height were measured by tape measure. Variable percentage also taken based on the same formula on Table 1.

It can be seen that actual measurement data with the anthropometric data has identical variable percentages for the ratio of body height and elbow height. Therefore, it is concluded that the variable percentage for the program is 60% to get the required height for the sink, as it is almost equal with the elbow height for comfortable hand washing.

4.2 Sensor Accuracy Testing Results

To find out that both of the sensors can detect the distance to an object properly and accurately, multiple testing are required. After the data is taken, accuracy calculation had to be done to determine if the sensors can be used into the system. Graphs and tables data are shown below.

Table 3. Both Sensors Accuracy Data

1st Ultrasonic Sensor			2nd Ultrasonic Sensor		
Measure Manually (cm)	Measure Automatically (cm)	Accuracy (%)	Measure Manually (cm)	Measure Automatically (cm)	Accuracy (%)
20	20.31	98.45	20	20.11	99.45
40	40.78	98.05	40	40.51	98.73
60	60.44	99.27	60	60.89	98.52
80	80.37	99.54	80	80.49	99.39
100	100.84	99.16	100	101.23	98.77
120	121.32	98.90	120	121.89	98.43
135	135.67	99.50	135	136.12	99.17
160	161.72	98.93	160	160.85	99.47
180	181.92	98.93	180	181.21	99.33

To obtain the data above, both of the sensors are tested individually before being attached into the roof and the sink by measuring a test object in a specific distance by measuring tape and the sensor. Accuracy results for both sensors are pretty good as expected before, which are above 98% for all of the data.

Table 4. Sensors Measurement Value at 100 cm in 10 seconds

Time (second)	Sensor 1	Sensor 2
	Measurement value (cm)	Measurement value (cm)
0	100.78	100.58
1	101.45	101.62
2	100.78	100.58
3	101.45	100.46
4	101.45	101.21
5	100.53	100.58
6	100.78	101.21
7	100.56	101.35
8	101.32	100.95
9	100.78	101.06
10	100.78	100.58
Average	100.99	100.96
Standard Deviation	0.3511	0.3738

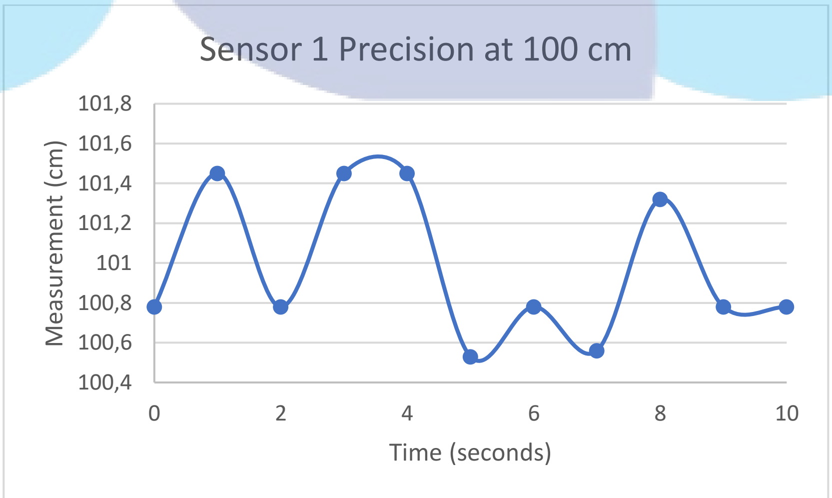

Figure 39. Sensor 1 Precision at 100 cm for 10 seconds

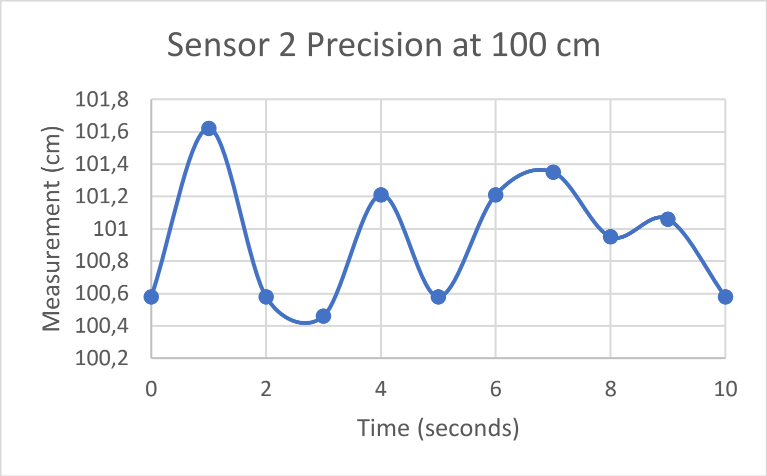

Figure 40. Sensor 2 Precision at 100 cm for 10 seconds

As for other data taking, both of the sensors are tested to find out their constant value of the measurement. As can be seen from Table 4, during the 10 seconds window, sensor 1 and sensor 2 does not detect the object distance smoothly. Their readings were going upward and downward as can be seen on Figure 39 and Figure 40 However, the value from the measurement has small difference with the projected distance, therefore, it does not cause significant problems into the system.

4.3 Motor Testing Results

This motor testing is to test the capabilities of the Dunkermotoren GR63X25 DC motor to make sure that it works properly. In theory, the more the load is given into the motor, the current that is taken into the motor will be increased. Therefore, a load test is carried out.

Table 5. Motor Load Test

Load (kg)	Ampere (A)	Rated Speed (RPM)
0	0.25	144
1.41	0.32	132
2.75	0.41	132
3.87	0.49	135
5.11	0.52	135
6.35	0.58	129
7.62	0.62	129

8.56	0.68	131
9.49	0.71	128
10.32	0.75	126

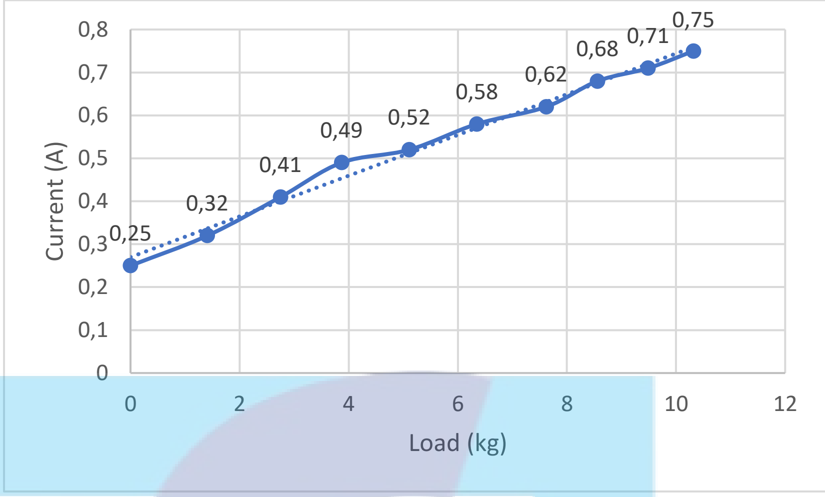

Figure 41. Load vs Ampere input of the motor

From the table and figure above, it can be observed that as the motor is subjected to a greater load, the current increases linearly. Additionally, the rated speed of the motor also decreased slightly when the load was getting bigger. To verify this graph, the current input of the motor was measured while the sink moved upward. For a 7.5 kg sink, the measured value was 0.6 A, thus confirming the result of this graph test. However, when the sink moves downward, the measured current was 0.38 A. This is due to the fact that when moving upward, the sink is against the gravitational force, and when moving downward, it goes with the gravitational force.

Table 6. Running Time of the Sink Movement

Distance	Time (seconds)	Speed (cm/s)
Upward Movement (30 cm)	28.12	1.06686
	27.44	1.09329
	27.41	1.09449
	27.98	1.07219
	28.05	1.06952
Downward Movement	27.10	1.10701

(30 cm)	26.51	1.13165
	26.84	1.11773
	26.32	1.13982
	26.79	1.11982

The table above illustrates the time required to move the sink by 30 cm in upward and downward direction on the model. According to the data, the upward movement took an average 27.8 seconds, while the downward movement took an average of 26.71 seconds. The reason for the faster downward movement compared to the upward movement is attributed to the influence of gravitational force. When it moves downward, it follows the direction of gravitational force, which assists in descent and reduces the time required to cover. On the other hand, when it moves upward, it goes against the gravitational force, which acts a resistance and increases the time required.

4.4 Motor Analysis

According to the motor testing results, it appears that the motor is capable of running in the model. However, in chapter 3.6.2 Motor Selection, it is mentioned that the motor is unsuitable for the model due to several reasons. First, the current model motor is already aging, making it insufficient to operate properly. Additionally, the rated speed of the motor is not fast enough to meet the requirements of the target users, who are elementary children between the ages of 7 to 12 years old. Considering their natural behaviors of being impatient and highly active, a faster motor is necessary.

To accommodate these concerns, it is recommended into changing the motor into

4.5 Experimental Procedures

To test the overall performance of the system, it needs to be tested in real world application. However, because it was very difficult to find participant heights that were almost equivalent to elementary school children's heights, adult participants were used as a reference for obtaining user acceptance tests. Some of the tests will use an "artificial mannequin" whose height can be adjusted and is almost the same as the height of elementary school children, whose body and hand height data have previously been measured manually using a tape measure. Then from the test, the taken data will be matched with data taken from manual measurements.

4.6 Overall System Testing Results

Table 7. Data Overall Result for Adults

Manually Measured			Sensor Measured		Accuracy (%)
Body Height (cm)	Sink Height (cm)	Target (cm)	Body Height (cm)	Sink Height (cm)	
178	103.5	106.8	178.83	104.43	97.78
168	97.5	100.8	167.69	97.74	96.96
164.5	102	98.7	161.14	102.27	96.38
174	103	104.4	172.84	102.34	98.03
168.5	103.5	101.1	168.87	103.38	97.74
181	104.5	108.6	181.13	104.99	96.68
180	105.5	108	179.25	105.34	97.54
175	104.5	105	174.58	104.57	99.59
163	95.5	91.8	153.9	93.32	98.34
161.5	96	96.9	162.39	96.14	99.22

Based on the table above, it can be seen that the accuracy from the target height with the sink height from the sensor measured has an average of 97.83 percent. The accuracy value compared with Table **3** value has a small difference by 0.17%. Factors that can be assumed from the inaccuracy value input are vibration from the motor, sound disturbance, etc. Time taken to move the sink does not include in the data since the motor is not fast enough, therefore time value is unnecessary.

Table 8. Mannequin Testing Results

Manually Measured			Sensor Measured		Accuracy (%)
Body Height (cm)	Sink Height (cm)	Target (cm)	Body Height (cm)	Sink Height (cm)	
125	74.5	75	125.89	73.49	98.64
146.5	62	60	100.43	63.1	98.23
130	65.5	66	111.21	66.81	98

To test the overall result for shorter user’s height that resembles children’s height, an “artificial mannequin” is being used as a model to test the overall result for shorter user’s height, resembling children’s height. While it is uncertain whether the height will match since the mannequin does not have the appropriate hand height, the sink height can be considered close when considering anthropometric data and supporting data from Table **1** and Table **2**. Accuracy value was at 98.29 percent, which is higher than the adult's testing results. This can be analyzed if the sensor is more accurate when measured closer rather than further away. However, both results indicated that the system works properly.