Arduino-Based Development of Automatic Body Posture Measuring Device for Rapid Entire Body Assessment Method

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Abstract

Workers from various industries can be exposed to musculoskeletal disorders (MSDs) risks in the workplace. Most cases of MSDs happen because of the accumulation of repetitive bad postures. Postural analysis can be done to implement changes that minimize MSDs risks in the workplace. The rapid entire body assessment (REBA) method provides an easy and fast measurement to analyze various postures. The accuracy of REBA assessments from observations is not good enough due to the limitations of human vision. The input of photo-based postural analysis also has a lot of error potential and takes up even more time. Therefore, this study aims to design a tool to do body posture measurements accurately and quickly. The Arduino-based postural analysis tool measures the position of several body segments, which are then used as the input of REBA in real time. The acceleration of each body segment recorded by the MPU6050 will be processed as displacement data and used to analyze the posture. The posture measurements detected by the tool is then used as input for REBA assessment. The device's accuracy was tested by comparing the photo-based postural analysis result to the postural analysis result of the tool. The reliability of the device was tested by Cronbach's Alpha method. The Cronbach's Alpha value of normal standing posture is 0.692, and the extreme posture's Cronbach's alpha value is 0.537. Multiple postures can be recorded at once using the tool. The tool can capture and assess multiple postures in approximately 6 minutes.

Keywords: Arduino, Motion Capture, MPU6050, Musculoskeletal Disorder (MSDs), Rapid Entire Body Assessment (REBA).

I. Introduction

Musculoskeletal disorders (MSDs) are abnormalities of the muscles, nerves, tendons, ligaments, joints, cartilage, and spinal discs that are not caused by slips, trips, falls, motor vehicle accidents, or other similar accidents [1]. A lot of musculoskeletal disorders are usually caused by the repetitive use of limbs with accumulated injuries [2]. Workers from various industries may be exposed to MSDs risks in the workplace by doing work such as lifting heavy items, bending over, grabbing overhead items, pushing or pulling heavy loads, holding awkward postures for an extended period, and performing the same tasks over and over again [3]. The cost of MSD's compensation is complained to reduce both profit and productivity [2]. Bureau of Labor Statistics study in 2013 showed that musculoskeletal disorders are the most significant contributors to workplace injuries and are responsible for nearly 30% of the entire cost of worker compensation [3], [4].

MSDs risks caused by awkward and incorrect body postures can be used as a significant basis to implement changes to the work environment [5]. Posture analysis is a good technique to assess the activities of a job. Rapid Entire Body Assessment (REBA) is one of the postural analysis methods that can be used easily. REBA method provides easy and quick measurements to assess the MSDs risks of different postures [6]. Different industries have different ways of working, resulting in unpredictable working postures. REBA was developed to cater to the sensitivity to various working postures [5].

Postural assessment of the REBA method can be carried out by direct observation or photo analysis. However, the accuracy of direct observation assessment is considered unsatisfactory due to human visual limitations. Photos analysis can improve the accuracy, but it still has many potential errors in its input taking, such as non-sagittal photos and errors in drawing auxiliary lines to measure the body part angle.

Input-taking errors will decrease the accuracy of the posture analysis. The body angle generated from photo analysis is limited to the angle in its sagittal plane. The results of the posture analysis might show a worse or even better score than in reality. The photo-based postural analysis also takes a longer time.

Some applications can automate the process of calculating REBA scores, such as ErgoPlus, ErgoIntelligence, and ErgoFellow 3.0. Unfortunately, these applications still require user analysis to determine the input of the body segments' angle. Users are expected to have known the angle of each body part so that the application can calculate the REBA score of the posture. Thus, the use of these applications can not significantly improve the accuracy of the postural analysis. Therefore, the novelty of this research is to design an automatic posture-measuring device for the REBA method.

II. METHOD

The designed automatic posture measuring device uses the REBA method to do posture assessments. The REBA method analyzes the angles of six body segments when a person demonstrates a posture: neck, trunk, legs, upper arms, lower arms, and wrists [5].

Each body segment's angle required for REBA assessment can be measured by calculating the angle between two vectors. For example, the angle of the trunk is the angle of the vector $\overrightarrow{\text{L3/L4,neck}}$ and $\overrightarrow{\text{Z body's axis}}$ [5].

Vectors' magnitude and direction can be searched when the position of each vector's base point and the endpoint is known [7]. Once the magnitude and direction of both vectors are obtained, the resulting angle of the two vectors can be calculated [7], [8]. Therefore, the relative position of each related body part is needed to find the angle of each body segment.

People always move when working; thus, the body's position changes over time. The position of a point can be tracked through its displacement. Displacement is a vector whose magnitude reflects how far an object moves from its initial position [7], [8]. It is essential to know the displacements that happened to find the targeted position of the assessed posture.

The displacement vector can be calculated by integrating the velocity vector [7], [9]. The velocity vector can be calculated by integrating the acceleration vector [7], [9]. In other words, the displacement of a point can be approached when the value of its acceleration is known.

Thus, calculating the angle needed for REBA assessment starts by taking acceleration data at the base point and end point of the required vectors. The acceleration data will then be integrated twice to obtain the displacement data. Displacement vectors are used to obtain the magnitude and direction of the body segments' vector. Once the vectors of the body segments are obtained, the angle of each body segment required for REBA can be calculated. Fig. 1 is the algorithm for obtaining body segments' angles from acceleration data.

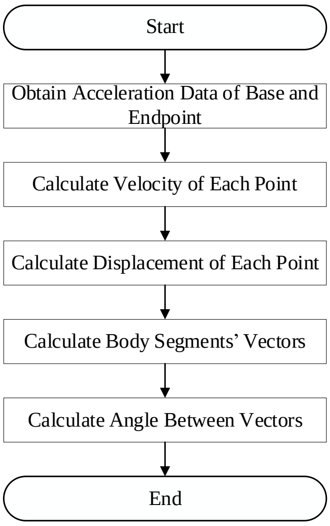


Figure 1. Obtaining Body Segments' Angle Algorithm.

Reference [5] illustrates the vectors needed to measure each body segment's angle. Table 1 lists all the vector's points needed to measure every body segment angle based on [5].

TABLE I. VECTOR'S POINT FOR EACH BODY SEGMENT

Body Segment	Vector's Point
Neck	Crown of head
	Thoracic T1/T2
	Lumbar L3/L4
Trunk	Thoracic T1/T2
	Lumbar L3/L4
Leg	Hip
	Knee
	Ankle
Upper arm	Hip
	Shoulder
	Elbow
Lower arm	Shoulder
	Elbow

Body Segment	**Vector's Point**
	Wrists
Wrists	Elbow
	Wrists
	Back of the hand

III. RESULTS

A. Design and Prototype

The device consists of a microcontroller, an accelerometer sensor, and a battery. The body measuring device takes acceleration data from the operator's body and sends it to the computer.

The device consists of a Wemos D1 R1 board, an MPU6050 module, and a 9V battery to power the device. Jumper cables connect the Wemos D1 R1 board and MPU6050. The 9V battery is connected to the Wemos D1 R1 board with battery clips. Fig. 2 shows the assembled device.

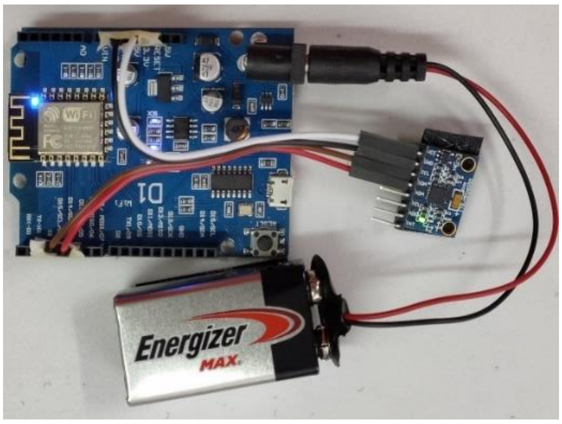
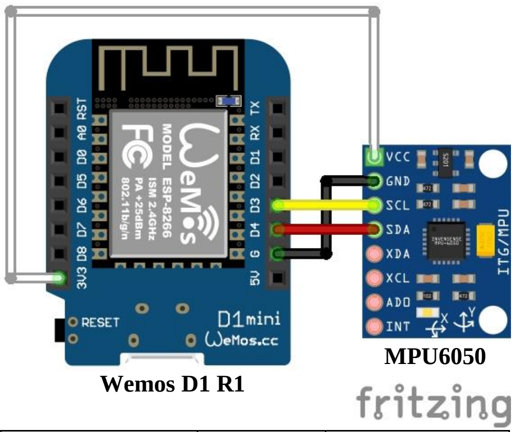


Figure 2. Assembled Device

The Wemos D1 R1 is used as a microcontroller of the device, as well as a Wi-Fi module to transmit data wirelessly to the computer. The MPU6050 accelerometer contributed as an acceleration detection sensor. The 9V battery acted as an electrical power source for the device. All components in the body circuit are connected to the wiring system, as shown in Fig. 3.



Wemos D1 R1	MPU6050	Battery
3V3	VCC	
GND	GND	
D3	SCL	
D4	SDA	
Battery Jack		*Battery Clip*

Figure 3. Device's Wiring System

Wemos D1 R1 data transmission is carried out over a Wi-Fi network so data can be received directly by the PC using the MQTT communication protocol [10].

The measuring device is attached to the operator using aid devices. The aid devices are designed using a 95th percentile size so that most people can use them. Hook and loop fasteners (Velcro) are applied to the aid device so the operator can adjust the size according to their own. The operator wears the aid device, and the measuring device is attached to the fasteners provided. Fig. 4 illustrates the aid device.

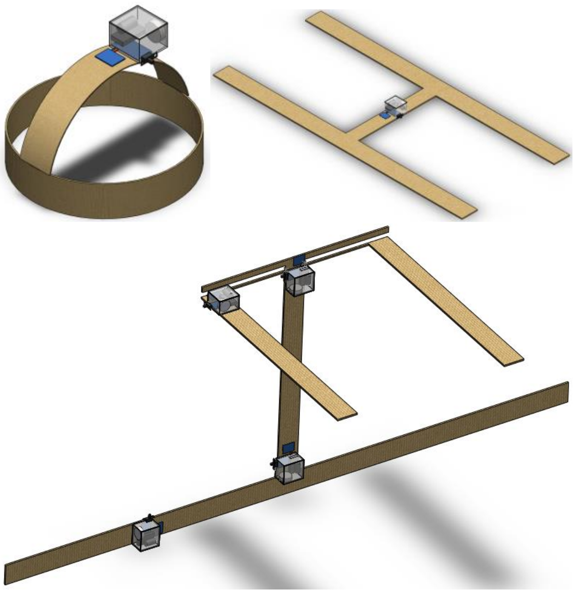


Figure 4. Aid Devices' Design.

Table 1 indicates that there have to be at least ten measuring devices to do REBA analysis. Thus, ten devices must be placed at the crown of the operator's head, thoracic T1/T2, lumbar L3/L4, hip, knee, ankle, shoulder, elbow, wrist, and the back of the hand. The data from one measurement device can be used for multiple body segment angle calculation. Fig. 5 illustrates the placements of the measuring devices.

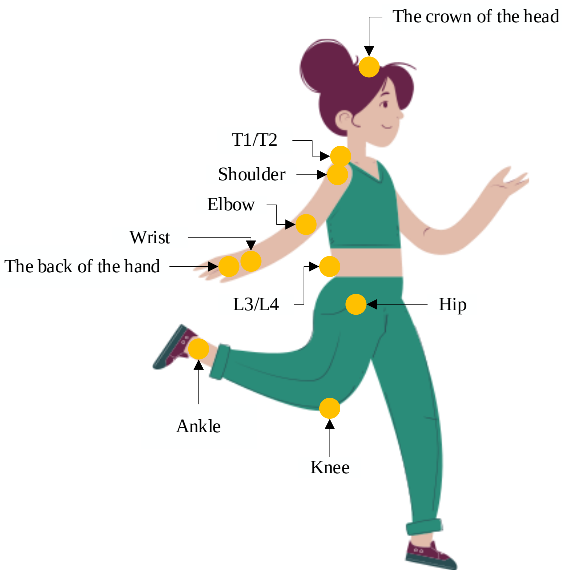


Figure 5. Measuring Device Placements Illustration.

This device uses three sets of codes: the Wemos D1 R1 Arduino code, the Python code to retrieve data using MQTT communication, and the MATLAB code to process the data into REBA scores. The Arduino code uploaded to Wemos R1 D1 is designed to retrieve acceleration data and transmit it to the computer. The algorithm used for the Arduino code is shown in Fig. 6.

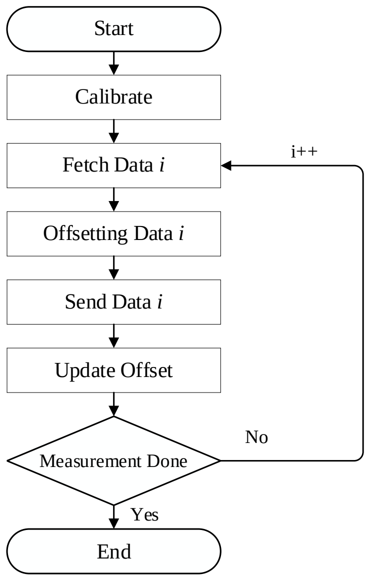


Figure 6. Measuring Device Algorithm.

Each device must first be calibrated before being used for data retrieval. The initial calibration is done by turning on all devices at approximately the same time and place. Initial calibration is performed to ensure that the starting point of each device is in the same place. Differences in starting points of each device will produce irrelevant acceleration data to measure the body segments' angles [7]. Therefore, all devices should be turned on at the same time and place.

After turning it on at the initial place, the device will perform several setups, such as checking the sensor and connecting to the Wi-Fi. The second stage of calibration will then begin to calculate the first offset. The flickers of Wemos' LED signal the end of calibration. The device is ready to be worn by the operator and used for data retrieval only after the calibration ends.

The device retrieves acceleration data using the MPU6050 sensor. The sensor produces three-axis acceleration data: X, Y, and Z. The MPU6050 sensor detects both the static acceleration due to the earth's gravitational force and the dynamic acceleration when the sensor moves. The magnitude and direction of the body part only needed dynamic acceleration when the sensor moved. Therefore, the acceleration data needs to be checked and offset first. Offset is performed to eliminate the static acceleration from the data.

Offset is performed by comparing the current acceleration value (a_t) with the average of the previous three acceleration values $(a_{t-1}, a_{t-2}, a_{t-3})$. If the value of a_t is around the average value of the previous three accelerations, a_t will be considered a static acceleration and be omitted.

This offset technique is used considering the nature of the data retrieved from MPU6050. The MPU6050's datasheet shows that the magnitude of acceleration detected by the MPU6050 should be (0;0;16,384) for each X, Y, and Z axis under normal idle circumstances when the sensor is placed on a flat floor surface. The acceleration of the Z axis has the value of 16,384 at rest due to the sensor's sensitivity of 16,384 LSB/g, and 1 g is 9.80665 m/s^2. In other words, the accelerometer sensor will only detect the gravitation acceleration of the earth at rest on a flat floor surface. Table 2 shows the sample data of acceleration at rest conditions.

TABLE II. ACCELERATION DATA SAMPLE AT RESTING CONDITION

Data *i*	**Axis**		
	X	**Y**	**Z**
1	308	-1556	13980
2	508	-1444	13980
3	368	-1556	14040
4	500	-1544	14128
5	360	-1520	13936
6	540	-1600	13988
7	460	-1568	14084
8	188	-1688	14012
9	356	-1648	13960
10	552	-1596	14024

Even though the accelerometer sensor is at rest, the acceleration data recorded by the sensor varies. The sensor's noise causes the static acceleration data to vary even when the sensor does not move. Based on several attempts, it was noticed that the acceleration noise typically ranges from 200 to 350 when the sensor is at rest. When the sensor moves, the recorded acceleration data will change drastically and typically over the size of 350. Thus, tolerances by the amount of 350 are given in the offset to accommodate the sensor's noise.

The offset process averaged $a_{t-1}, a_{t-2}, a_{t-3}$ and considered the noise range of 350. If the current acceleration a_t is within the range of $\bar{X}_{a_{t-1},a_{t-2},a_{t-3}} \pm Tolerance$, it will be considered as static acceleration and omitted. Else, if the current acceleration a_t is outside of the range, it will be considered dynamic acceleration and recorded. The offset will be updated every time the sensor detects new acceleration data, as shown in Fig. 6.

The computer runs the second set of codes to retrieve data sent by the device. Each device has its own network of MQTT topics. The computer receives data from every device until the posture assessment is completed. When the data recording is done, the device will send the message "exit" to end the data retrieval. The is then recorded into CSV files. Fig. 7 shows the algorithm of the data retrieval process.

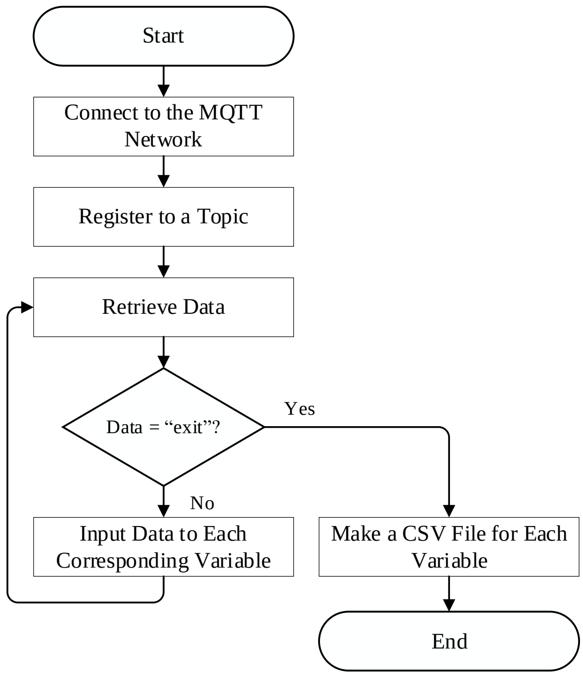


Figure 7. Data Retrieval Algorithm

Postural assessment starts after data retrieval is completed. The MATLAB code will read the data from the CSV files and begin the data processing. The acceleration data from CSV files is the input to measure the body segments' angles.

REBA posture assessment method also needs a load/force score, coupling score, and activity score [5], which cannot be obtained from the measuring device. Thus, the MATLAB program will ask users to manually enter the load/force score, coupling score, and activity score when running. After all the inputs are obtained, the program will process the REBA assessment, as shown in Fig. 8.

Start
↓
Input Load Score
↓
Input Coupling Score
↓
Input Activity Score
↓
Convert Acceleration Unit
↓
Calculate Velocity
↓
Calculate Displacement
↓
Calculate Offset Multiplier
↓
Calculate Neck Angle and Score
↓
Calculate Trunk Angle and Score
↓
Calculate Leg Angle and Score
↓
Calculate Upper Arm Angle and Score
↓
Calculate Lower Arm Angle and Score
↓
Calculate Wrist Angle and Score
↓
Calculate Table A Score
↓
Calculate Score A
↓
Calculate Table B Score
↓
Calculate Score B
↓
Calculate Table C Score
↓
Calculate REBA Score
↓
Generate an Excel Report
↓
End

Figure 8. Data Processing Algorithm

B. Implementation and Evaluation

The designed measuring device was tested to assess two posture samples: the regular standing and the extreme posture, as shown in Fig. 9. Evaluation was carried out to assess the measuring device's accuracy, reliability, and process time.

Figure 9. Posture Samples: (a) Standing, (b) Extreme

The measuring device evaluation compared the device's REBA scores to the photo analysis. Table 3 shows the approximation angles measured from the photo analysis of Fig. 9.

TABLE III. BODY SEGMENTS ANGLES OF PHOTO ANALYSIS

Body Segment	Standing	Extreme
Neck	6°	3°
Trunk	10°	106°
Leg	22°	72°
Upper Arm	4°	63°
Lower Arm	16°	120°
Wrist	5°	33°

The measuring device was used to assess five replications of each posture. The process of data collection was done randomly between each posture sample. For convenience, the first to fifth replication is reserved for the standing posture, and the remaining is the extreme posture.

The accuracy of the device's measurement is tested by comparing the angles measured by photo analysis to the device's. The device's accuracy is considered good if the measured angles of both methods do not differ significantly. Table 4 compares the measured angle of both techniques for each body segment.

TABLE IV. BODY SEGMENTS ANGLES COMPARISON

Body Segment	Standing Posture						Extreme Posture					
	Photo Analysis	Measuring Device Replication					Photo Analysis	Measuring Device Replication				
		1	*2*	*3*	*4*	*5*		*6*	*7*	*8*	*9*	*10*
Neck	6	19.47	13.13	14.70	27.59	4.73	3	60.20	6.22	70.00	22.68	20.55
Trunk	10	7.83	4.76	5.49	16.30	6.24	106	6.67	4.38	46.35	8.29	8.46
Leg	22	21.36	21.76	21.90	21.98	22.06	72	71.92	72.09	71.89	71.88	71.48
Upper Arm	4	42.22	31.32	23.36	31.62	27.42	63	80.74	74.87	83.55	80.48	86.71
Lower Arm	16	44.77	29.60	24.01	23.60	29.86	120	70.84	86.42	78.29	62.66	56.20
Wrist	5	16.81	20.77	4.38	14.05	5.84	33	44.70	6.67	64.14	10.76	73.14

The measuring device produced similar angles to the trunk and leg segment of the photo analysis. The resulting angle of the neck, upper arm, lower arm, and wrists are significantly different. The measuring device produced a random angle value for each replication, with the third and fifth replication being very close to the photo analysis. For each replication, the wrist angle differs, while other body segments have similar angles. A similar comparison is made to the extreme posture.

The measuring device produces significantly different angles from the photo analysis for the neck, trunk, upper arm, lower arm, and wrist. The leg was the only segment with a similar angle to the photo analysis. For the extreme posture, the neck angle differs randomly for each replication along with the wrist. Based on the comparison results, the posture-measuring device's accuracy is still relatively low. Some of the angles measured tend to differ randomly and significantly.

The angle measured by the device is then input into the program to do the REBA assessment and produce the REBA score. Each body segment has its own score, contributing to the final REBA score [5]. Table 5 shows the score of each body segment and the final REBA score.

TABLE V. BODY SEGMENTS AND REBA SCORE COMPARISON

Body Segment	Standing Posture						Extreme Posture					
	Photo Analysis	Measuring Device Replication					Photo Analysis	Measuring Device Replication				
		1	*2*	*3*	*4*	*5*		*6*	*7*	*8*	*9*	*10*
Neck	2	1	1	1	2	1	1	2	1	2	2	2
Trunk	2	2	2	2	2	2	4	2	2	3	2	2
Leg	1	1	1	1	1	1	3	3	3	3	3	3
Upper Arm	2	2	2	2	2	2	3	3	3	3	3	3
Lower Arm	2	2	2	2	2	2	2	1	1	1	1	2
Wrist	1	2	2	1	1	1	2	2	1	2	1	2
REBA	3	2	2	2	3	2	10	6	6	9	7	9

The difference in angle measured by each technique also generates a difference in the REBA score. Table 5 shows that the standing posture assessment results in a more similar REBA score than the extreme posture. REBA scores of two and three are in the same risk level category, which is low [5]. However, the extreme posture assessment results in significantly different REBA scores. The REBA score of six and seven are on the medium-risk level, while the REBA score of eight, nine, and ten are on the high-risk level [5].

A reliability test is carried out by comparing the results of angle measurements from each posture. The device is considered reliable if the measurement of each replication of the same measurement is similar. The test is performed for each posture.

The reliability test was carried out using Cronbach's Alpha method. Cronbach's alpha test was performed to test the consistency of the device when used multiple times to measure the same posture[11]. The test was conducted using SPSS software. Table 6 shows the reliability test result for each posture sample.

TABLE VI. MEASURING DEVICE RELIABILITY TEST

Posture Sample	**Cronbach's Alpha Value**
Standing	0.692
Extreme	0.537

The standing and extreme posture Cronbach's alpha values were under 0.7, the acceptable standard of indicator value for new measures [11]–[13]. This shows that the automatic posture measuring device is unreliable enough to produce the same result of the same measurement. Nonetheless, Cronbach's alpha of the standing posture is approaching 0.7, showing that the device captured the standing posture better than the extreme one.

Even though the accuracy and reliability of the device need to be improved, the device cuts process time off of posture measurement and assessment. The photo analysis based on the REBA assessment done in the implementation stage takes about 25 minutes for each posture. The 25-minute duration is an estimate of photo taking, auxiliary line drawing, the measurement of angle, and the REBA assessment.

On the other hand, the calibration of ten measurement devices takes about two minutes. The installation of the devices on the operator takes another three minutes. This estimated time was obtained through the results of the implementation. It is worth noting that one person carried out the installation of the devices in the implementation stage. The installation time can be even faster if several people assist it.

The devices will record acceleration data as long as the operator does their job. The data collection will stop after the targeted posture is carried out during the activity. After the data retrieval is complete, the acceleration data received by the computer will be processed into CSV files. These CSV file generation can be completed in less than 10 seconds.

The first running time of the MATLAB program required two minutes. The subsequent runs take up a shorter time, about a minute. The running time includes every process shown in Fig. 8. Thus, the approximate time required for body posture assessment using the device is about seven minutes. The estimated time was obtained from the implementation stage using a laptop with an Intel Core i7-6700 processor, 4GB RAM, and 1 TB HDD. It is worth noting that the device can measure and assess multiple postures at one run, while regular observation and photo analysis can only assess one posture at a time.

The photo analysis assessment of REBA Each posture in the operator's activity can be recorded and assessed into a REBA score. Therefore, the posture measurement device can speed up the assessment process compared to traditional assessment.

IV. DISCUSSION

A. *Accuracy of the Posture Measurement Device*

Many factors interfere with the accuracy of the automatic posture measurement device. The leading cause of the inaccuracy is the ability of the MPU6050 to retrieve data. The MPU6050 acceleration data values tend to be random. When the sensor moves towards the X-axis, the acceleration data on the Y and Z axes also moves significantly. A repeated trial at the prototyping stage showed that a movement of 5 cm towards the positive X-axis often results in movements of the Y and Z-axis data as well. When the data is integrated, the resulting displacement data will show displacement at all three axes, although the accelerometer only moves on one axis. This phenomenon affects the accuracy of the device significantly.

In addition, each accelerometer sensor produces different values of acceleration. The acceleration data generated by the MPU6050 not only differs between replications but also differs between sensors. Each sensor has a different amount of noise. The amount of noise will increase over time. The movement of the sensor will affect its orientation and distort the resulting acceleration data. This causes the retrieved acceleration data to be inconsistent and inaccurate.

The accelerometer MPU6050 is also very sensitive to vibration. The accelerometer MPU6050 detects acceleration through vibration, so the presence of vibrations around a stationary sensor will cause the sensor to detect acceleration. Unnecessary vibrations and movements will significantly affect the accuracy of the angle. The sensor can detect movements as small as 1 cm.

The duration of data collection also affects the accuracy of the angle calculation. The longer the data retrieval time, the more acceleration data is retrieved. The acceleration data will be integrated twice to approach the displacement data. The integration process is affected by time. The more data there is to be integrated, the greater the value of integration will be. This noise will continue accumulating and result in increasingly inaccurate displacement data.

When the device is attached to the operator after calibration, the device's orientation has to be adjusted. The device can not be used without keeping the orientation in mind. Adjusting the device's orientation takes time, and the acceleration data during this process is also recorded. The acceleration data during this process is unwanted because the sensor does not actually move. The sensor is adjusted not to tilt, but the position remains the same. However, the MPU6050 cannot distinguish this adjustment from the actual movement. The sensor detects the vibration resulting from the shift as movement and generates acceleration data as if the sensor was in motion. Even if the offset is used, the value of these shifts sometimes slips out of the offset process and gets recorded as dynamic acceleration.

B. *Reliability of the Posture Measurement Device*

The reliability of the automatic posture measurement device is low due to unreliable data from the sensor. A trial was done at the prototyping stage to move the sensor 5 cm to the positive X-axis multiple times. The value of the acceleration data obtained varies with each replication. The difference between replication comes not only from the acceleration's magnitude but also from the other axes.

When the sensor moves 5 cm away towards the positive side of the X-axis, the sensor also captures the acceleration on the Y and Z-axis. The displacement data obtained showed that the sensor moved on three axes after. The result was different when the sensor only moved toward the positive X-axis. Unfortunately, the magnitude of this unwanted acceleration is also different for each replication, so it is not easy to offset.

C. *Limitations of the Posture Measurement Device*

The automatic posture measurement device cannot measure postures with side bending, twisted, and abducted positions. This limitation is due to the orientation of the sensor. The MPU6050 reads orientation based on itself. The acceleration data required for REBA assessment are from the body's X, Y, and Z axes. However, the sensor can only read the axes according to its position. This limitation also results in the need to adjust the device's orientation when attached to the operator.

Under normal circumstances, the sensor should have been placed in a horizontal state, parallel to the ground. The normal position of the MPU6050 consists of the positive Z-axis facing up, the positive Y-axis facing front, and the positive X-axis facing right. However, the placement of the ideal orientation condition is challenging in automatic posture measurement.

The X-axis acceleration data are detected from movements to the right or left sides of the sensor. The Y-axis acceleration data are detected from movements to the front or rear sides of the sensor. Similarly, the Z-axis acceleration data are detected from the upward or downward movements of the sensor. This self-orientation tendency prevents the sensor from distinguishing the body's X, Y, and Z axes. This nature also forbid the sensor from detecting 180-degree changes in orientation, such as turning around.

The devices installed on the hand of the operator will be in the vertical position due to the hand's shape. Thus, the movement of the Z-axis of the body will be detected by the Y-axis of the accelerometer. The hand's ability to move freely in many directions makes the orientation of the movement not easy to be tracked using the MPU6050. This reason also leads to the more significant difference of angles measured for upper arm, lower arm, and wrists body segments.

Side bending and abducted postures can be detected by the presence of a body tilt towards the Y and Z axes of the body. These postures are highly dependent on the axis of the operator's body which is undetectable by the device. In addition, the device also can not distinguish flexion from extension movement. The state of flexion and extension is marked by the body's inclination toward the X-axis of the body, which the sensor can not distinguish.

V. CONCLUSION

The automatic posture measurement device mechanism starts by capturing acceleration data at body parts. The acceleration data is sent by the device and retrieved by the computer. The data is then processed into displacement data to calculate the body segments' angles. The angle of each body segment is then used as input for REBA assessment and results in the REBA score.

Evaluation of the device is carried out on the accuracy, reliability, and process time of the device's measurement. The device's accuracy is not good due to the large amount of noise generated by the sensor. Offset has been done, but it still is not enough to approach the actual angular value measured. The device's reliability was tested using Cronbach's alpha method, and the result showed that the device was unreliable. The regular standing posture reliability was 0.692, while the extreme posture reliability was 0.537. The duration required to assess postures can be reduced to 7 minutes.

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