Scalar Product in Acquiring Angle for Mimicking Robotic Elbow using Two Tri-Axial Accelerometers

Charlene A. Alcira, Mayraquel G. Balla, Nanette A. Burgos, John Paul O. Bilon, Mark Anthony M. Baris, Roselito E. Tolentino

Abstract—Most of the robotic arm is controlled using accelerometer by capturing different gestures and postures wherein the movement of the robotic arm is only limited on the given gestures, which doesn't mimic the human arm correctly. This paper presents a method to acquire angle in mimicking robotic elbow using two low cost and small tri-axial accelerometers. These accelerometers are attached to the upper arm and forearm of the user. To find out the angular position of the elbow joint, scalar product is applied in the computation. The communication between human hand and robotic arm has been established using Arduino microcontroller. The result is that the robotic arm's movement is synchronous with human arm's movement. The system has been developed in Arduino IDE platform and Lab VIEW Robotics. In conclusion, the application of scalar product is effective in acquiring the value of user's elbow angle.

Index Terms—Accelerometers, Elbow Angle, Robotic Elbow, Scalar Product

I. INTRODUCTION

ROBOT mimicking has been a hot research topic in the previous years and is an important application area for robotic systems. Likewise, robot mimicking is a convenient way to teach the robots the operations they are to perform [1].Robotic arms are very important in almost all the industries because they perform various different tasks such as trimming, picking and placing etc. In addition, the biggest advantage of these robots is that it can work in hazardous areas which cannot be accessed by the human [2]. Therefore, new and more advanced ways are required to control robotic arm.

In the robotics field, several researches used different controllers and sensors to mimic human arm such as flex sensor and potentiometer. But as the time goes by, accelerometer-based gesture recognition methodology has become increasingly popular in mimicking and controlling robotic arm in a very short span of time [6]. The low moderate cost and relative small size of the accelerometers are the two factors that make it an economical and effective tool to detect and recognize human body gestures [3]. But, most of the accelerometer-based gesture controlled robotic arm only capture different gestures and postures. The problem is that the movement of robotic arm is only limited on the given postures and gestures, which doesn't mimic human arm correctly and doesn't acquire the actual elbow joint angle.

However, in this paper is proposed the application of scalar product for acquiring angle in mimicking robotic elbow using two tri-axial accelerometers. The controller is made up of two tri-axial accelerometer attached to the upper arm and forearm of the user. Robotic elbow will move as the sensors measure elbow angle. The system has been developed in Arduino IDE platform. Data is gathered for the evaluation of response and a graph is created using Lab VIEW Robotics. This paper shall help industries by introducing a low-cost, easy-to-use and reliable way of mimicking angle using only two tri-axial accelerometers as a sensor [4]. This paper can also be used in the medical field. It will help rehabilitation doctors and physical therapists to come up with a more accurate way of getting the elbow angular joint measurements. Finally, several tests are done to evaluate the proposed system. The results of the performed tests are presented and discussed.

Revised Version Manuscript Received on March 10, 2016.

Roselito E. Tolentino is with Polytechnic University of the Philippines – Santa Rosa Campus and De La Salle University - Dasmarinas as part time Instructor.

Charlene A. Alcirais a graduate of Polytechnic University of the Philippines Sta. Rosa Campus.

Mayraquel G. Ballais a graduate of Polytechnic University of the Philippines Sta. Rosa Campus.

Nanette A. Burgos is a graduate of Polytechnic University of the Philippines Sta. Rosa Campus.

John Paul O. Bilonis a graduate of Polytechnic University of the Philippines Sta. Rosa Campus.

Mark Anthony M. Barisis a graduate of Polytechnic University of the Philippines Sta. Rosa Campus.

II. METHODOLOGY

A. System Description

The system is composed of a robotic arm equipped with Arduino microcontroller, and actuated by a servo motor mounted at the elbow of the robotic arm. Also, it is composed of a wearable device with two tri-axial accelerometers to measure acceleration due to gravity in different axis. This wearable device also serves as measuring device because it comprises of potentiometer mounted on a 1-DOF mechanical joint that is used to know the actual elbow angle produced by the user. The individual accelerometers are placed in upper arm and forearm of the user respectively. They are located near the elbow joint. Lastly, it is also composed of a computer running the program.

The accelerometer used in this study is ADXL345 Digital accelerometer. This sensor is physically rated to measure accelerations over a range of at least +/-16g, with a sensitivity of 4mg/LSB. The accelerometers communicate with the computer by using Arduino microcontroller. It is coded in Arduno IDE (Integrated Development Environment), a programming environment that is capable to upload programs in any Arduino boards (microcontrollers) [7] [8].

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

Fig. 1 Wearable Device and Robotic Arm

B. Methodology

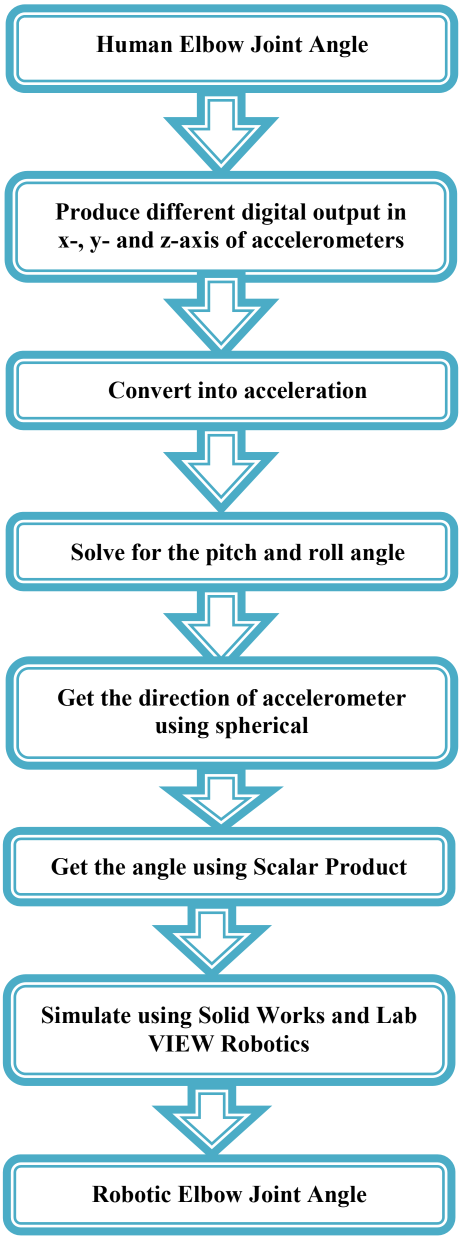

Fig. 2Conceptual Framework

Fig. 2 shows the explanation of how the system works. The accelerometers are used as the main sensor of the robotic arm and are attached to the upper arm and forearm of the user. The proponents used Arduino and Lab VIEW software for the interfacing of program. The input signals coming from the accelerometer sensor is fed to the Arduinomicro controller using serial communication.

1. Acquisition of Elbow Angle

The accelerometer has digital output in the range from -256 to +256 through 180° of tilt. The output in every axis (x-,y- and z-axis) is minimum if the axis is pointing downward, on the other hand, it has maximum value if it is pointing upward.

The proponents used these outputs to compute the acceleration due to gravity in different axes experienced by the accelerometer attached to the upper arm.

$$G_{X1} = \frac{DO_{X1}}{S} \qquad (1)$$

$$G'_{Y1} = \frac{-DO_{Y1}}{S} \qquad (2)$$

$$G_{Z1} = \frac{DO_{Z1}}{S} \qquad (3)$$

where:

S= sensitivity of the accelerometer
Gx1 = acceleration from the x- axis of the accelerometer
Gz1 = acceleration from the z- axis of the accelerometer
G'y1 = acceleration from the y- axis of the accelerometer
DOx1 = digital output from the x-axis of the accelerometer
DOy1 = digital output from the y-axis of the accelerometer
DOz1 = digital output from the z-axis of the accelerometer

Afterwards, the proponents determine the value of acceleration due to gravity in different axes of the accelerometer attached to the forearm.

$$G'_{X2} = \frac{-DO_{X2}}{S} \qquad (4)$$

$$G_{Y2} = \frac{DO_{Y2}}{S} \qquad (5)$$

$$G_{Z2} = \frac{DO_{Z2}}{S} \qquad (6)$$

Where:

S= sensitivity of the accelerometer
Gy2 = acceleration from the y- axis of the accelerometer
Gz2 = acceleration from the z- axis of the accelerometer
G'x2 = acceleration from the x- axis of the accelerometer
DOx2 = digital output from the x-axis of the accelerometer
DOy2 = digital output from the y-axis of the accelerometer
DOz2 = digital output from the z-axis of the accelerometer

After getting the value of acceleration due to gravity, tilt angles are acquired using (7) and (8) for the pitch angles of two accelerometers and (9) and (10) for the roll angles of two accelerometers. The force of gravity is used as an input to determine the orientation of object by calculating the tilt

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

angle.

The accelerometer experienced acceleration in the range from -1g to +1g through 180° of tilt. The value of -1g and +1g in any axis is aligned with the Earth's downward and upward gravitational field respectively.

$$\emptyset_1 = \tan^{-1}\left(\frac{G'_{Y1}}{G_{X1}}\right) \quad (7)$$

$$\emptyset_2 = \tan^{-1}\left(\frac{G_{Y2}}{G'_{X2}}\right) \quad (8)$$

$$\theta_1 = \tan^{-1}\left(\frac{G_{Z1}}{\sqrt{(G_{X1})^2 + (G'_{Y1})^2}}\right) \quad (9)$$

$$\theta_2 = \tan^{-1}\left(\frac{G_{Z2}}{\sqrt{(G'_{X2})^2 + (G_{Y2})^2}}\right) \quad (10)$$

where:

θ_2 = roll angle of the accelerometer (forearm)
ϕ_2 = pitch angle of the accelerometer (forearm)
θ_1 = roll angle of the accelerometer (upper arm)
ϕ_1 = pitch angle of the accelerometer (upper arm)

Using the tilt angles acquired from the previous computation the direction of the two accelerometers with respect to the upper arm and forearm are acquired using spherical coordinates to find the equivalent Cartesian coordinates. From the orientation and position of accelerometer, the value of roll and pitch angle correspond to the value of azimuth and zenith angle in spherical coordinates respectively.

Finding the direction of two accelerometers using (11) and (12),

$$\vec{A} = [(\sin\emptyset_1)(\cos\theta_1)]\hat{x} + [(\sin\emptyset_1)(\sin\theta_1)]\hat{y} + (\cos\emptyset_1)\hat{z} \quad (11)$$

$$\vec{B} = [(\sin\emptyset_2)(\cos\theta_2)]\hat{x} + [(\sin\emptyset_2)(\sin\theta_2)]\hat{y} + (\cos\emptyset_2)\hat{z} \quad (12)$$

where:

$\vec{B}$= direction of accelerometer attached to the forearm
$\vec{A}$= direction of accelerometer attached to the upper arm

Afterwards the proponents used the components of each vector of the two accelerometers mounted on the user's forearm and upper arm to compute the magnitude of each vector.

$$|A| = \sqrt{[(\sin\emptyset_1)(\cos\theta_1)]^2 + [(\sin\emptyset_1)(\sin\theta_1)]^2 + (\cos\emptyset_1)^2} \quad (13)$$

$$|B| = \sqrt{[(\sin\emptyset_2)(\cos\theta_2)]^2 + [(\sin\emptyset_2)(\sin\theta_2)]^2 + (\cos\emptyset_2)^2} \quad (14)$$

where:

|A| = magnitude of vector A
|B| = magnitude of vector B

Using (11), (12), (13), and (14), the elbow angle is acquired by applying Scalar Product.

$$\beta = \cos^{-1}\left(\frac{\vec{A}\cdot\vec{B}}{|A||B|}\right) \quad (15)$$

where:

β= value of computed elbow angle

2. Evaluation of the System

The proponents devised a wearable device which comprises of potentiometer mounted on a 1-DOF mechanical joint and two accelerometers which are attached to the human arm. The computed angle was read by the Arduino microcontroller. The proponents also used potentiometer in their wearable device to compare data from accelerometers. The proponents also devised a potentiometer-mounted robotic elbow to get the robotic elbow angle. The angular values were sent through serial communication into a computer and then were inputted into Lab VIEW's waveform chart feature using NI VISA.

The proponents used servo motor as an actuator to control robotic arm. The movement of servo motor is dependent to the value of computed angle. The proponents plot the graph in Lab VIEW to monitor the response. The plotted response of the system is the extracted into an Excel Worksheet and used these data to determine if there is significant difference between them.

The proponents set the significance level to the standard value of 5%. Knowing the area, they used the z-test table and found the critical value as 1.96.The computed z value will become the basis of the proponents if they will accept or reject the hypothesis. To be able to verify if the robot can mimic the human elbow angle, the researchers used z-test:

$$z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{(\sigma_1)^2}{n_1} + \frac{(\sigma_2)^2}{n_2}}} \quad (16)$$

where:

z= z-test result
$\bar{x}_1$ = mean of the first group
$\bar{x}_2$ = mean of the second group
n_1 = no. of samples in the first group
n_2 = no. of samples in the second group
σ_1 = standard deviation of the first group
σ_2 = standard deviation of the second group

III. RESULTS AND DISCUSSION

A. Acquisition of Elbow Angle

From the different orientation made by the user, the proponents obtained the data coming from the two accelerometers. To analyze and interpret the computed angle, the proponents gathered raw data through varying the orientation of the human elbow in many trials.

Table 1 shows the digital output in three different axes of accelerometer which is attached to the upper arm, acceleration due to gravity in every axis and the tilt angles.

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.*

This vector is the orientation of the accelerometer in the upper arm with respect to the elbow of the user.

Table 1. Data Obtained from the Accelerometer Attached to the Upper Arm

Elbow Angle	Orientation	Accelerometer Attached to the Upper Arm							
		Digital Output of Accelerometer (Upper Arm)			Acceleration due to gravity (Upper Arm)			Tilt Angles	
		DO_{X1}	DO_{Y1}	DO_{Z1}	G_{X1}	G'_{Y1}	G_{Z1}	ϕ_1	θ_1
60°	1	41	-262	-5	0.16016	1.02344	-0.01953	81.11	-1.08
	2	23	-170	170	0.08984	0.66406	0.66407	82.30	44.74
	3	-15	-261	-16	-0.05859	1.01953	-0.06250	93.29	-3.50
	4	-233	-35	-83	-0.91016	0.13672	-0.32422	171.46	-19.41
	5	-37	-218	113	-0.14453	0.85156	0.44141	99.63	27.07
	6	242	-140	-25	0.94531	0.54688	-0.09766	30.05	-5.11
90°	1	9	-260	-17	0.03516	1.01562	-0.06641	88.02	-3.74
	2	-1	-184	156	-0.00391	0.71875	0.60938	90.31	40.29
	3	-113	-228	15	-0.44141	0.89063	0.05859	116.36	3.37
	4	-245	-5	-14	-0.95703	0.01953	-0.05469	178.83	-3.27
	5	-120	-176	119	-0.46875	0.68750	0.46484	124.29	29.19
	6	195	-191	27	0.76172	0.74609	0.10547	44.41	5.65
120°	1	-19	-255	9	-0.07422	0.99609	0.03516	94.26	2.016
	2	10	-121	202	0.03906	0.47266	0.78906	85.28	58.99
	3	-172	-182	9	-0.67188	0.71094	0.03516	133.38	2.06
	4	-212	-119	10	-0.82813	0.46484	0.03906	150.69	2.36
	5	8	-254	47	0.03125	0.99219	0.18359	88.20	10.48
	6	193	-197	4	0.75391	0.76953	0.01563	45.59	0.83
150°	1	8	-262	-22	0.03125	1.02344	-0.08594	88.25	-4.80
	2	59	-78	219	0.2	0.27	0.84	53	68
	3	-83	-244	-26	-0.32422	0.95313	-0.10156	108.79	-5.76
	4	-207	-130	-39	-0.80859	0.50781	-0.14523	147.87	-9.07
	5	-48	-207	116	-0.18750	0.80859	0.45312	103.06	28.63
	6	247	-97	65	0.96484	0.37890	0.25391	21.44	13.76
180°	1	13	-256	18	0.05078	1	0.07031	87.09	4.02
	2	33	-182	159	0.12891	0.71094	0.62109	79.72	40.68
	3	-192	-162	-17	-0.75	0.63281	-0.06641	139.84	-3.87
	4	-245	-2	-40	-0.95703	0.00781	-0.15625	179.53	-9.27
	5	-139	-235	-8	-0.54297	0.91797	-0.03125	120.60	-1.68
	6	149	-172	71	0.58203	0.67188	0.27734	49.10	17.33

Table 2. Data Obtained from the Accelerometer Attached to the Forearm

Elbow Angle	Orientation	Accelerometer Attached to the Forearm							
		Digital Output of Accelerometer (Forearm)			Acceleration due to gravity (Forearm)			Tilt Angles	
		DO_{X2}	DO_{Y2}	DO_{Z2}	G'_{X2}	G_{Y2}	G_{Z2}	ϕ_2	θ_2
60°	1	-241	96	16	0.94141	0.375	0.0625	21.72	3.53
	2	-152	64	191	0.59375	0.25	0.74609	22.83	49.19
	3	-214	144	5	0.83594	0.5625	0.01953	33.94	1.11
	4	92	238	-59	-0.35938	0.92969	-0.23047	111.13	-13.02
	5	-162	138	144	0.63281	0.53906	0.5625	40.43	34.08
	6	-225	-135	-5	0.87891	-0.52734	-0.01953	-30.96	-1.09
90°	1	-257	-10	4	1.00391	-0.03906	0.01563	-2.23	0.89
	2	-177	5	175	0.69140	0.01953	0.68359	1.62	44.66
	3	-224	119	42	0.875	0.46484	0.16406	27.98	9.4
	4	-6	260	12	0.02344	1.01563	0.04688	88.68	2.64
	5	-177	122	140	0.69141	0.47656	0.54688	34.58	33.07
	6	-179	-189	42	0.69922	-0.73828	0.16406	-46.56	9.17
120°	1	-232	-114	27	0.90625	-0.44531	0.10547	-26.17	5.96
	2	-94	-66	220	0.36719	-0.25781	0.85938	-35.07	62.43
	3	-249	60	36	0.97266	0.23438	0.14063	13.55	8
	4	-219	128	38	0.85547	0.5	0.14844	30.31	8.52
	5	-212	-136	66	0.828125	-0.53125	0.25781	-32.68	14.68
	6	-67	-257	16	0.26172	-1.00391	0.0625	-75.39	3.45
150°	1	-118	-240	-3	0.46094	-0.9375	-0.01172	-63.82	-0.64
	2	11	-100	230	-0.04	-0.34	0.91	-97	69
	3	-188	-184	-4	0.73438	-0.71875	-0.01563	-44.38	-0.87
	4	-257	-22	-14	1.00391	-0.08594	-0.05469	-4.89	-3.11
	5	-142	-167	130	0.55469	-0.65234	0.50781	-49.63	30.67
	6	173	-193	74	-0.67578	-0.75391	0.28906	-131.87	15.93
180°	1	17	-261	32	-0.06641	-1.01953	0.125	-93.73	6.98
	2	32	-187	174	-0.125	-0.73047	0.67969	-99.71	42.53
	3	-197	-182	4	0.76953	-0.71094	0.01563	-42.73	0.85
	4	-265	-16	-8	1.03516	-0.0625	-0.03125	-3.46	-1.73
	5	-137	-254	11	0.53516	-0.99219	0.04297	-61.66	2.18
	6	158	-168	80	-0.61719	-0.65625	0.3125	-133.24	19.13

Table 2 shows the digital output in three different axes of accelerometer which is attached to the forearm, acceleration due to gravity in every axis and the tilt angles. This vector is the orientation of the accelerometer in the forearm with respect to the elbow of the user. From each orientation, the value of acceleration due to gravity in different axes, pitch and roll angles pitch and roll angles are different from the other orientations. It only shows that the user is moving from one orientation to another. The proponents applied tangent functions to solve for the value of pitch and roll angles.

Table 3. Magnitude of Three Vectors and Values of Computed and Actual Elbow Angle

Elbow Angle	Orientation	|A|	|B|	A·B	Actual Elbow Angle	Computed Elbow Angle	Average Difference
60°	1	1	1	0.50806	60	59.47	0.106667
	2	1	1	0.50696	60	59.54	
	3	1	1	0.507946	60	59.47	
	4	1	1	0.494251	60	60.38	
	5	1	1	0.507156	60	59.53	
	6	1	1	0.485234	60	60.97	
90°	1	1	1	-0.00416	90	90.24	0.283333
	2	1	1	0.022722	90	88.7	
	3	1	1	0.025873	90	88.52	
	4	1	1	-0.00278	90	90.16	
	5	1	1	0.003989	90	89.77	
	6	1	1	-0.01585	90	90.91	
120°	1	1	1	-0.50544	120	120.36	-0.45333
	2	1	1	-0.50424	120	120.28	
	3	1	1	-0.4984	120	119.89	
	4	1	1	-0.50729	120	120.48	
	5	1	1	-0.51174	120	120.78	
	6	1	1	-0.51396	120	120.93	
150°	1	1	1	-0.88116	150	151.78	-2.138
	2	1	1	-0.30004	150	149.68	
	3	1	1	-0.88994	150	152.87	
	4	1	1	-0.88888	150	152.73	
	5	1	1	-0.88799	150	152.62	
	6	1	1	-0.89328	150	153.15	
180°	1	1	1	-0.99857	180	176.93	3.126667
	2	1	1	-0.99945	180	178.1	
	3	1	1	-0.9975	180	175.95	
	4	1	1	-0.99864	180	177.01	
	5	1	1	-0.9975	180	175.95	
	6	1	1	-0.99889	180	177.3	

Table 3 shows the magnitude and scalar product of two vectors needed to acquire the elbow angle by applying Scalar Product. The magnitude of vector A and B is always equal to one because they are unit vectors. It also shows the results of computed angles from different orientations, its corresponding actual angle and the average difference for each angle.

The proponents observed that angle of 180˚ has the largest average difference because when the user performed this angle, one of the axes of the accelerometer is aligned with gravity and point upwards or downwards. Thus, the value of acceleration due to gravity is only concentrated to one axis and its reducing the value being measured from other two axes. Another factor is that an accelerometer is most sensitive to tilt when its sensitive axis is perpendicular to the force of gravity. At this orientation its sensitivity to changes in tilt is highest. When the accelerometer is oriented on axis to gravity, the change in output acceleration per degree of tilt is negligible. It means that as the tilt of an accelerometer increases, the sensitivity of this sensor decreases the given results to smaller error [5].

The proponents also observed that angle of 60˚ has the lowest average difference because with this angle, the

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

accelerometer is tilted and none of the axes is aligned with gravity thus, the value of acceleration due to gravity is distributed to all axes. It implies that angle of 60˚ is the most accurate angle for mimicking user's elbow angle compare to other angles.

The proponents also observed that as the angle being mimicked increases, its average difference also increases. It implies that mimicking capability of the system is better if the user performed an angle less than 90˚.

A. Response of the System

In the experiment, the user measured different sets of angle in different orientation with the human elbow angles from 43̊ to 180̊. The response of the system is shown below.

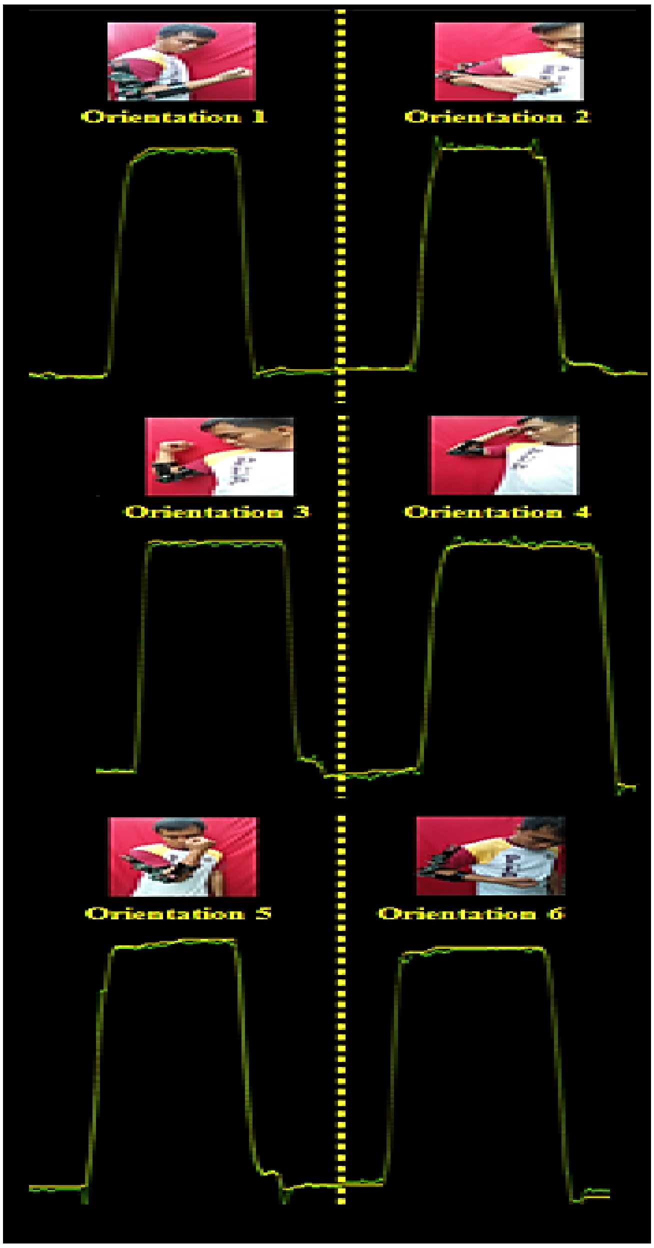

Fig. 3LabVIEW panel showing the human elbow angle and the robotic elbow angle based on the user's orientation and elbow movement. (Note: The labeled figures above the graph and the yellow broken lines are not part of the graph seen on the actual panel of the Lab VIEW.)

The figure shows the response of the system between the human and robotic elbow angle in different orientation. The graph shows the angle measured from the wearable device (yellow line) and the robotic elbow angle (green line). The value of the human and robotic elbow angle are almost equal or coincide in the graph when the user performed transition from flexion to extension or vice versa.

However, when the user steadies his arm in a specific position, there is a small discrepancy between two angles. It also shows that the value of robotic elbow angle is slightly unstable compared to the human elbow angle.

B. Significant difference between user and robotic elbow angle

The proponents measured different human and robotic elbow angles in different orientation. From the data, the proponents computed the value of standard deviation and mean of each sample.

Table 4. Z-test result for every tilt angle

Orientation	Human Elbow Angle			Robotic Elbow Angle			Result of z-test	Comment
	n_1	$\bar{x}_1$	σ_1	n_2	$\bar{x}_2$	σ_2		
1	100	102.42	33.8012	100	102.71	36.1091	-0.0586	Null Hypothesis is Acceptable
2	100	113.99	52.3594	100	113.73	55.4619	+0.0341	
3	100	98.5	51.2388	100	98.99	53.3075	-0.0663	
4	100	112.65	39.1135	100	118.24	45.9922	-0.9259	
5	100	112.3	53.2779	100	112.91	53.7169	-0.0806	
6	100	115.94	48.6228	100	117.65	51.0696	-0.2425	

Table 4 shows the number of samples (n_1 and n_2), the mean of the samples ($\bar{x}_1$ and $\bar{x}_2$), the standard deviation of the samples (σ_1 and σ_2) and the z-test result. All of the z-test result shows that z value is within the range of $-1.96 \leq z \leq 1.96$. Therefore, there is no significant difference between the robotic elbow angle and human elbow angle.

The proponents observed that orientation two has the lowest value of z-test result which is equal to +0.0341 because all of the axes of accelerometer in this orientation is not concentrated or not aligned with the gravity, thus the total value of acceleration due to gravity is distributed to all axes. It implies that this orientation is the best orientation in mimicking the human elbow.

The proponents also observed that orientation four has the largest value of z-test result which is -0.9259. It is primarily due to the alignment of one axis of accelerometer with the gravity that results to decrease of sensitivity of accelerometer.

IV. CONCLUSION

The proponents came with this findings based on the gathered data. Accelerometers outputs are used to measure the angle between the human's upper arm and forearm, and set as the triggering or controlling device of a one degree of freedom robot arm. Those outputs are used by the proponents to compute the angle obtained by the human. Since those outputs are the values of the acceleration due to gravity in different axis, pitch and roll angles obtained from the two accelerometers varies in different angle and orientation, but it will be arrived with the angle closed to the human's elbow angle. The pitch and roll angle values are set as the angle components in the spherical coordinate system. The proponents used the spherical coordinates to find the equivalent Cartesian coordinates - vectors of the two accelerometers with respect to the upper arm and forearm.

The findings of the proponents, suggests that the system and the method proposed were effective in acquiring the

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.

value of user's elbow angle. The proponents used spherical coordinates to find the equivalent Cartesian coordinates - vectors of the two accelerometers with respect to the upper arm and forearm. The value of the resulting elbow angle from the angle of 150˚ to 180˚ acquired larger angle difference. This is caused by the alignment of one axis with the gravity of an accelerometer which can decrease the sensitivity of the sensor in getting tilt angles. The angle of 60˚ has the lowest average difference, which means that it is the most effective angle for mimicking human's elbow.

RECOMMENDATION

Since the proponents observed that there are small discrepancies between the human and robotic elbow angle in different orientations, the proponents recommend using additional sensors for the improvement of the response of the system when it comes to the alignment with gravity. The proponents also suggest improving the proposed method for acquiring angle where the alignment of axis with the gravity cannot affect the computation, since average angle difference is caused by the alignment of any axis of the accelerometer with the gravity. This is for the purpose of having more precise mimicking angle.

REFERENCES

1. Algan Uskarci. (2004). Human Arm Mimicking using Visual Data. Middle East Technical University Available from http://www.eee.metu.edu.tr/~alatan/PAPER/MSalgan.pdf
2. Aggarwal, Love, Varnika Gaur and Puneet Verma. (2013).Design and Implementation of a Wireless Gesture Controlled Robotic Arm with Vision. International Journal of Computer Applications, Vol.79. Available fromhttp://research.ijcaonline.org/volume79 /number 3/pxc3891906.pdf
3. Khajone, Saurabh, Dr. S. W. Mohod and V.M. Harne. (2015). Implementation of a Wireless Gesture Controlled Robotic Arm. International Journal of Innovative Research in Computer and Communication Engineering, Vol.3 Issue 1. India: SantGadge Baba University. Available from http://www.rroij.com/open-access/implementation-of-a-wireless-gesturecontrolled-robotic-arm.pdf
4. Neto, Pedro, J. Norberto Pires and A. Paulo Moreira. (2009)Accelerometer-Based Control of an Industrial Robotic Arm. Japan: The 18th IEEE International Symposium on Robot and Human Interactive Communication. Retrieved from: http://arxiv.org/ftp/arxiv/papers/1309/1309.2090.pdf
5. Pedley, Mark. (2013)Tilt Sensing Using a Three-Axis Accelerometer. Freescale Semiconductor Inc. Available fromhttps://cache.freescale.com/files/sensors/doc/app_note/AN3461.pdf
6. Verma, Shamsheer. Hand Gestures Remote Controlled Robotic Arm. India: Research India Publications, Volume 3, 2013. [pdf file] Retrieved from: http://www.ripublication.com/aeee/80_pp%20%20%20%20601-606.pdf
7. E-gizmo. Digital Accelerometer. Available from http://www.egizmo.com/KIT/ADXL345.html
8. Analog. ADXL345 specification. Available from http://www.analog.com/en/products/mems/mems-accelerometers/adxl345.html#product-overview

Charlene A. Alcirawas born in Santa Rosa City, Laguna, Philippines on March21, 1995. She received the degree of Bachelor Science in Electronics and Communications Engineering from the Polytechnic University of the Philippines Santa Rosa Campus Laguna in 2016 under the scholarship of DOST-SEI. She was a part of ON Semiconductor, Carmona, Laguna, Philippines as a team member of Product Engineering department for her On-The-Job training in 2014. She was a member of Institute of Electronics Engineers of the Philippines and Association of Electronics and Communication Engineering Students. She was alsoa former National Quizzer and representative of PUP-Santa Rosa on the 36th IECEP National Inter-Scholastic Quiz Show.

Mayraquel G. Balla was born in Binan, Laguna, Philippine son May 2, 1995. She received the degree of Bachelor Science in Electronics and Communications Engineering from the Polytechnic University of the Philippines Santa Rosa Campus Laguna in 2016. She was a part of Continental Temic Electronics (Phils.) Inc.,San Vincente, La Mesa, Calamba City, Laguna Philippines as a team member of Test Engineering department for his On-The-Job training in 2014. She was a member of Institute of Electronics Engineers of the Philippines and Association of Electronics and Communication Engineering Students

Nanette A. Burgos was born in Pola, Oriental Mindoro, Philippines on February 12, 1994. She received the degree of Bachelor Science in Electronics and Communications Engineering from the Polytechnic University of the Philippines Santa Rosa Campus Laguna in 2016. She was a part of Nidec Copal (Phils.) Inc., Bo. Diezmo, Cabuyao, Laguna, Philippines as a team member of Quality Assurance department for her On-The-Job training in 2014. She was a member of Institute of Electronics Engineers of the Philippines- Laguna Chapter and Association of Electronics and Communication Engineering Students. She was alsoa former National Quizzer and representative of PUP-Santa Rosa on the 36th IECEP National Inter-Scholastic Quiz Show.

John Paul O. Bilonwas born in San Pedro, Laguna on January 13, 1995. He received the degree in Bachelor of Science in Electronics and Communications Engineering from the Polytechnic University of the Philippines Santa Rosa Campus, Laguna in 2016. He was a part of Continental Temic Electronics (Phils.) Inc., San Vincente, La Mesa, Calamba City, Laguna, Philippines as a team member of Test Engineering department for his On-The-Job training in 2014. He was the current President of Transformation Advocates through Purpose-driven and Noble Objectives Toward Community Holism (TAPNOTCH) and a member of Association of Electronics and Communication Engineering Students and Institute of Electronics Engineers of the Philippines- Laguna Chapter. He was also a former National Quizzer and representative of PUP-Santa Rosa on the 36th IECEP National Inter-Scholastic Quiz Show.

Mark Anthony M. Baris was born in Magdalena, Laguna on February 26, 1990. He received the degree in Bachelor of Science in Electronics and Communications Engineering from the Polytechnic University of the Philippines Santa Rosa Campus, Laguna in 2016. He was a part of Continental Temic Electronics (Phils.) Inc., San Vincente, La Mesa, Calamba City, Laguna, Philippinesas a team member of Test Engineering department for his On-The-Job training in 2014. He was a member of Institute of Electronics Engineers of the Philippines and Association of Electronics and Communication Engineering Students.

Roselito E. Tolentino is a registered Electronics Engineer and IECEP-Member. He is a graduate of B.S. Electronics and Communication Engineering at Adamson University in 2004 under the scholarship of DOST-SEI. He finished his Master of Science in Electronics Engineering Major in Control System at Mapua Institute of Technology under the scholarship of DOST-ERDT. He currently takes up Doctor of Philosophy in Electronics Engineering at the same Institute. He is currently working as a part time instructor at Polytechnic University of the Philippines Santa Rosa Campus and De La Salle University - Dasmarinas. His research interests are more on Robotics and Machine Vision.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication Pvt. Ltd.