

# **CONTROLLABLE BIOMIMETIC BRISTLEBOT**

**A HOMEWORK SUBMITTED TO THE GRADUATE  
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## ABSTRACT

The main idea of this project is to produce a remote controlled bristlebot which can be able to move with a way of vibration in the controlled way. The future applications of this device will be to shrink it in to micro-size and add camera to be able to use the device as an in vivo imaging technique. In the prototype we build, by using ArduinoUNO, four vibration mototrs, a bluetooth module and a remote control program ,we are now able to move the system in a controllable manner. The connection of the system is made by cables. The negative sides of vibration motors connected in series and to the ground pin of Arduino UNO. On the other hand, positive sides of them are connected, directly, to the pins of Arduino UNO. For example, vibration motor one to pin one. And the bluetooth module is also connected to the Arduino Uno and powered by it. Then using the remote control the commands are send through the bluetooth module to the system to make it move in the direction of the command.

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## LIST OF COMPONENTS

### Arduino UNO:

We did launch the coding part to the Arduino UNO, and by this way we are able to determine the way of the system.



Figure 1.1

### Cables:

They are used to make a connection between the Arduino UNO and vibration motors. The negative sides of vibration motors are connected to the ground, from the motor through the board to the Arduino, and the positive sides of them are connected through the board to the pins of Arduino UNO.



Figure 1.2

**Brush:**

It is the moving part of the system.

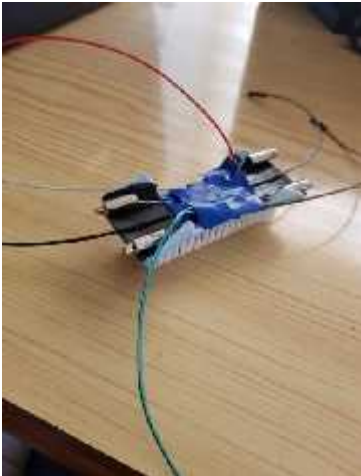


Figure 1.3

**Power Supply:**

It provides potential difference of 9V for the Arduino UNO in the system.



Figure 1.4

**Bluetooth Module:**

A HC-05 bluetooth module is used to provide data communication between the remote control and the bristlebot to be able to remote control the movements of the bristlebot.



Figure 1.5



Figure 1.6

#### 4\*Vibration Motors:

They are creating vibrational forces according the way they are programmed and this make the system (brush) move. Table 1.1 shows properties of vibration motors;

Size	14.5 mm x 6.7 mm
Weight	1.2 g
Suggested Working Voltage	1.7 - 3.6 V
Velocity (In 3 Volts)	14000 RPM
Current (In 3 Volts, when it is in space)	160 mA (180 mA max)
Introducing Current (In 3 Volts)	200 mA Max
Motor Resistance	$29 \pm 6$
Working Temperature	-10 ° C - +60 ° C
Storing Temperature	+70 ° C -30 ° C

Table 1.1



Figure 1.7

# CHAPTER 1

## INTRODUCTION

The bristle-bot is a form of robot that uses a force created by a vibration motors on brush. As the force is created by vibration motors it provides acceleration on system. Also, one of the important thing about the vibration motors is angle of them. When the optimum angle is provided by the system and vibration motors, acceleration of the system gives arise. Moreover, we reach the optimum angle by doing some mathematical expressions related with Kinematics of Particles and Kinetics of Particles. Four vibration motors, on the brush, are programmed by Arduino UNO. By this way, we are able to rotate them in both clockwise and anti-clockwise. Furthermore the vibration mototrs can be controlled wirelessly by a remote control to move in the desired direction. We used MIT APP INVENTER 2 to write a code for the remote control of thebristlebot. For now we are able to move the bristle bot forward, backwars, left and right. In addition to these, the power supply is used as a 9V supply. That 9V activates Arduino UNO and the Arduino UNO activates four vibration motors in the system, respectively, which provides the movement of the system. In further steps, our aim is to minimize the system in micro-size and capture photos inside of a human body.



## **CHAPTER 2**

### **PHYSICS BEHIND THE BRISTLEBOT**

The physics behind the motion of a bristlebot can be explained by the rules and the principles of kinematics of particles, e.g. velocity and acceleration, and kinetics of particles, Newton's second law of motion.

#### **2.1 Kinematics of Bristlebot**

Kinematics of particles is a discipline that works on the parameters like velocity, acceleration and time to explain the rectilinear motion of the particles.

The kinematics of bristlebot is based on the centrifugal force created by an eccentric mass that rotates around the shaft of a motor that creates a vibration force on the complete system that results in rectilinear motion of the bristlebot.

#### **2.2 Kinetics of Bristlebot**

Kinetics of particles is a discipline that works on the Newton's second law of motion to explain the rectilinear motion of particles.

Newton's second law of motion states that the acceleration of an object as produced by a net force is directly proportional to the net force, in the direction of the force, and inversely proportional to the mass of the object. Newton's second law can also state by the formula as

$$F_{\text{net}}=m.a$$

The Newton's second law can be used to calculate the resultant acceleration of the bristlebot that is caused by net force created by the vibration motor.

#### **2.3 Calculations**

##### **2.3.1 Known Parameters of the System**

Radius of motor ( $r_{\text{motor}}$ ) =  $3.35 \cdot 10^{-3}$  meters(m)

Mass of motor ( $m_{\text{motor}}$ ) =  $1.2 \cdot 10^{-3}$  kilograms(kg)

Speed of motor at 3v(N) = 14000 rates per minute(rpm)

Total mass of the system( $m_{\text{system}}$ )=  $106 \cdot 10^{-3}$  kilograms(kg)

## 2.3.2 Calculating Angular Velocity, Linear Velocity and Linear Acceleration

### 2.3.2.a Angular Velocity

“ $\omega$ ” is the symbol of the angular velocity of forced vibrations in radians.

$$[\text{rad.s}^{-1}] = (2\pi * N[\text{rpm}])/60$$

$$= (2\pi * 14000)/60$$

$$= 1466 \text{ rad.s}^{-1}$$

### 2.3.2.b Linear Velocity as the Coefficient of Angular Velocity

“ $v$ ” is the symbol of the linear velocity

$$V[\text{m.s}^{-1}] = r_{\text{motor}} * \omega$$

$$V = (3.35 * 10^{-3}) * (1466)$$

$$V = 4.91 \text{ m.s}^{-1}$$

### 2.3.2.c Linear Acceleration

The program that runs the motors of the bristlebot supplies energy to the motors for three seconds for each set of instruction. Thus, we are going to calculate our acceleration( $a$ ) for the first, second and the third seconds, time( $t$ )=1,2,3 sec. Using the formula:

$$V = u + at$$

Where the  $v$  is final velocity,  $u$  is initial velocity,  $a$  is acceleration and  $t$  is time.

i) For  $t=1$  sec.

$$V = u + at$$

$$4.91 = 0 + a(1)$$

$$a = 4.91 \text{ m.s}^{-2}$$

ii) For  $t=2$  sec.

$$V = u + at$$

$$4.91 = 4.91 + a(2)$$

$a=0 \text{ m.s}^{-2}$  this means that the bristlebot reached to its maximum speed in the first second and it will continue to move with a constant velocity for the 2<sup>nd</sup> and 3<sup>rd</sup> seconds.

iii) For  $t=3$  sec.

$$V=u+at$$

$$4.91=4.91*a(3)$$

$a=0 \text{ m.s}^{-2}$  this result could be used as the proof of the result and comment on the  $t=2$  seconds part.

### 2.3.2.d Calculating the Most Efficient Mount Angle

In this section Microsoft Excel is used to calculate the most efficient connection angle of the vibration motor to the bristlebot to obtain maximum net force created on the system by each vibration motor. Since we are going to mount the vibration motor with an angle to the brush we took the x-plane, where the rectilinear motion of the bristlebot takes place, as the  $\sin$  to calculate the net force in that direction.

θ,(degree)	F(Newton)
0	0
10	0,001023
20	0,002015
30	0,002946
40	0,003787
50	0,004514
60	0,005103
70	0,005537
80	0,005802
90	0,005892
100	0,005802
110	0,005537
120	0,005103
130	0,004514
140	0,003787
150	0,002946
160	0,002015
170	0,001023
180	0

Table 2

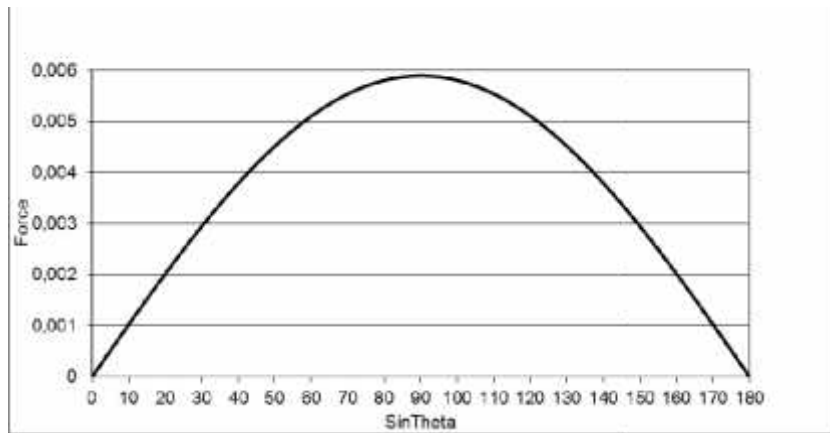


Figure 2.1

### 2.3.3 Net Force of Vibration Motors and Acceleration of the System

In this section Newton's second law of motion ( $F_{\text{net}}=m.a$ ) is used to calculate the resultant net force of each vibration motor and the total net force of the system when power is on.

#### 2.3.3.a Net Force of Each Vibration Motor

$$F_{\text{net}}=m_{\text{motor}}*a_{\text{motor}}$$

$$F_{\text{net}}=(1.2*10^{-3})*(4.91)$$

$$F_{\text{net}}=5.892*10^{-3} \text{ Newton}$$

#### 2.3.3.b Acceleration of Complete System

The program that runs the bristlebot gives power to two different vibration motors on each set of instruction. Thus, we will multiply the net force created by a vibration motor, that we calculated in section 2.3.3.a, by two to find the resultant Acceleration of complete system for each set of instruction.

$$F_{\text{net system}}=m_{\text{system}}*a_{\text{system}}$$

$$2*5.892*10^{-3} = (106*10^{-3})*a_{\text{system}}$$

$$a_{\text{system}}=0.111 \text{ m.s}^{-2}$$

# CHAPTER 3 APPLICATION

## 3.1 Design

We used four vibration motors for this bristlebot. First two motors were at the front side of the brush which are side to side to each other and the other two are at the back of the brush which is at the opposite side of the first two. We place the vibration motors like this because when we want to make the bristlebot go in a straight way, the side forces of the vibration motors will cancel each other and it will go directly straight.

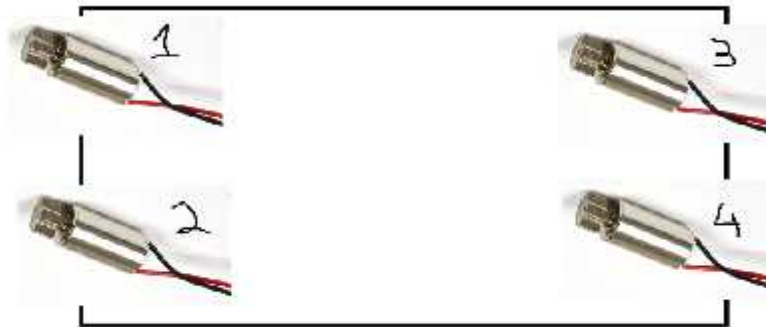


Figure 3.1

## 3.2 Connections

First motor (m1)(Top Left) negative side (Black Wire) is connected to the pin 1 of the Arduino UNO and the positive side (White Wire) of it is connected to the ground. Second motor (m2)(Top Right) which places at the right side of the first motor. Its positive side is connected to pin 2 of the Arduino UNO and the positive side of it is connected to the ground. We connected first and second motors differently because we want them to rotate in different directions to make the bristlebot go forward. For Third Motor (bottom left) it is connected same like the Second motor expect in this time we connected positive side to pin 3. The reason why we connected the third motor same with second motor is to rotating the bristlebot in clockwise by rotating both of the second and third vibration motor in same direction. The last vibration motor which is the fourth motor (m4) is connected like first motor. Except the fourth motor's negative side is connected to pin number 4 and positive side is connected to the ground. Then we connect Bluetooth module (HC-05) according to its ports (RX, TX, 5V, GND) we connected RX to TX, TX to RX, GND will connect to arduino's ground and 5V will connect to arduino's 5V.

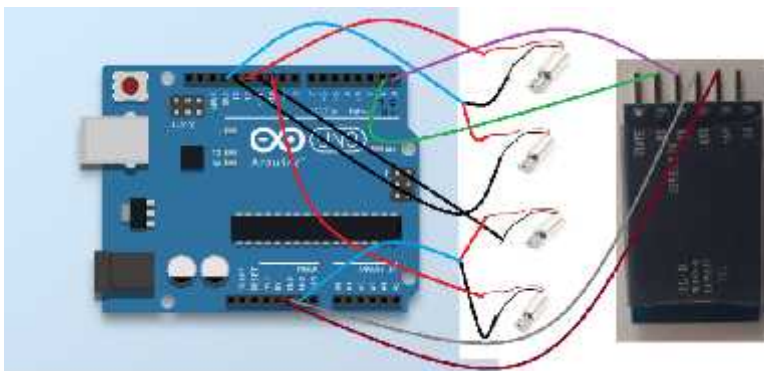


Figure 3.2

## 3.3 Programming

### 3.3.1 Arduino Coding

```
#include <SoftwareSerial.h>
SoftwareSerialBTserial(0,1);
int m1=10;
int m2=11;
int m3=12;
int m4=13;
const long baudRate = 38400;
char c=' ';
void setup() {
  Serial.begin(9600);
  pinMode(m1, OUTPUT);
  pinMode(m2, OUTPUT);
  pinMode(m3, OUTPUT);
  pinMode(m4, OUTPUT);
  BTserial.begin(baudRate);
}
void loop() {
  if (Serial.available())
  {
    c = BTserial.read();
    Serial.write(c);
  }

  if( c == 'F'){
    digitalWrite(m1,HIGH);
    digitalWrite(m2,HIGH);
    digitalWrite(m3,LOW);
    digitalWrite(m4,LOW);
  }

  else if( c == 'B'){
    digitalWrite(m1,LOW);
    digitalWrite(m2,LOW);
    digitalWrite(m3,HIGH);
    digitalWrite(m4,HIGH);
  }

  else if( c == 'L'){
    digitalWrite(m1,HIGH);
    digitalWrite(m2,LOW);
    digitalWrite(m3,LOW);
    digitalWrite(m4,HIGH);
  }

  else if( c == 'R'){
    digitalWrite(m1,LOW);
    digitalWrite(m2,HIGH);
```

```
digitalWrite(m3,HIGH);
digitalWrite(m4,LOW);
}
```

```
else if( c == 'S'){
digitalWrite(m1,LOW);
digitalWrite(m2,LOW);
digitalWrite(m3,LOW);
digitalWrite(m4,LOW);
}
```

```
else if( c == 'D'){
digitalWrite(m1,LOW);
digitalWrite(m2,LOW);
digitalWrite(m3,LOW);
digitalWrite(m4,LOW);
}
}
```

### **3.3.2 Remote Control Coding**

```
when ListPicker1.BeforePicking
do set ListPicker1.Elements to Bluetooth1.AddressesAndNames
```

```
when ListPicker1.AfterPicking
do if call BluetoothClient1.Connect
address ListPicker1.Selection
then set ListPicker1.Elements to BluetoothClient1.AddressesAndNames
when Button1.Click
do call BluetoothClient1.SendText
text "F"
when Button2.Click
do call BluetoothClient1.SendText
text "L"
when Button3.Click
do call BluetoothClient1.SendText
text "S"
when Button4.Click
do call BluetoothClient1.SendText
text "R"
when Button5.Click
do call BluetoothClient1.SendText
text "B"
```

## **CHAPTER 4**

### **CONCLUSION**

During our graduation project time, we have made a bristlebot with four vibration motors. Our aim was to prove that the 4 vibration motors can actually control the bristlebot according to the user command sent wirelessly. While we were doing this project, we have had some struggles during preparation of this project, such as finding some important electrical parts like vibration motors and Bluetooth module. Also, it was very hard to balance the mass of the bristlebot. During our research, we tried different types of motors but none of them were useful as the eccentric rotating mass vibration motors. Because that the force which is created by the rotation wasn't applying to the right place that we desired. We also had a problem related with the cables, we couldn't find the exact cables we were looking for. Nevertheless, we achieved our goal which was building and controlling the bristlebot. This research is important because hopefully we can apply this project in medicine by minimizing the size of our bristlebot to use it in imaging or we can use it to detect dangerous things that can harm a person. For example, we can use it in endoscopy, to image the patient's stomach to find the problems that can harm the patient. By achieving our aim, we might make some imaging techniques easier and it can be more effective than others. This bristlebot can be a solution for harmful effects of some of imaging techniques.

For the future, our plan is to minimize this bristlebot into micro size and produce this device with biocompatible materials to be able to inject into patient's body safely for researches.



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