İSTANBUL SABAHATTİN ZAİM ÜNİVERSİTESİ
MÜHENDİSLİK VE DOĞA BİLİMLERİ FAKÜLTESİ

ELEKTRİK-ELEKTRONİK MÜHENDİSLİĞİ BÖLÜMÜ

BİTİRME ÇALIŞMASI

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İstanbul Sabahattin Zaim Üniversitesi

3 DOF KARTEZYEN ROBOT SİSTEMİ KONTROL YAZILIMI TASARIMI VE UYGULAMASI

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ÖZET

Kartezyen robotlar 3 eksenleri lineer olarak kontrol edilen ve birbirlerine dik açılarla yerleştirilmiş endüstriyel robotlardır. Kayan üç eklemi sayesinde uzaysal ortamda erişim sağlar. Tekrar gerektiren taşıma, paketleme, istifleme gibi işlemlerde oldukça işlevsel cihazlardır.

Projemize ilk olarak daha önce yapılan tasarımları inceleyerek başladık, birkaç farklı tasarım üzerinde yoğunlaştık ve danışman hocamız Gökhan Erdemir ile yaptığımız görüşmeler sonucu robotun son şekline karar verdik. Daha sonra tasarımı FUSİON 360 programını kullanarak bilgisayar ortamında oluşturduk.

Gerekli malzemeleri, Vidalı mil, mil, mil tutucu, rulman, kaplin, yataklı rulman , limitler ve kabloları internet alışverişi ile temin ettik ayrıca kendimiz gerekli özel tasarladığımız metal parçaları kestirdik.

Parçaları birleştirip Kartezyen robotun iskeletini tamamladıktan sonra 3 adet servo motor ile sistemin hareketini sağladık , motor sürücü kartları ve arduino üzerinden gerekli yazılımları tamamladık.

İÇİNDEKİLER

MALZEME LİSTESİ

1. 12 ADET 3D YAZICI MİL TUTUCU

2. 6 ADET KROM KAPLI MİL

3. 3 ADET TRAPEZ VİDALI MİL

4. 3 ADET KAPLİN

5.12 ADET LİNEER RULMAN

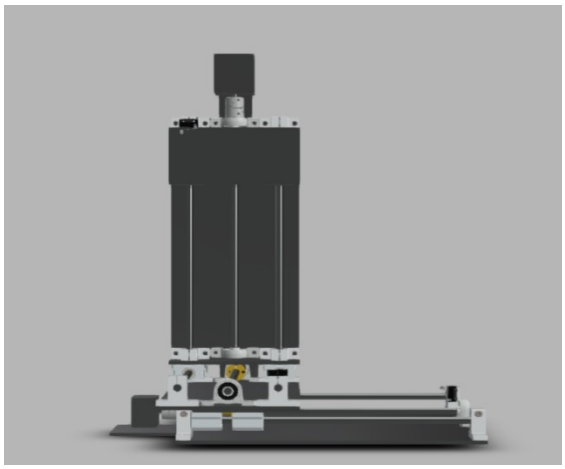
6 .6 ADET YATAKLI RULMAN

FUSİON 360 TASARIM

1.TASARIM

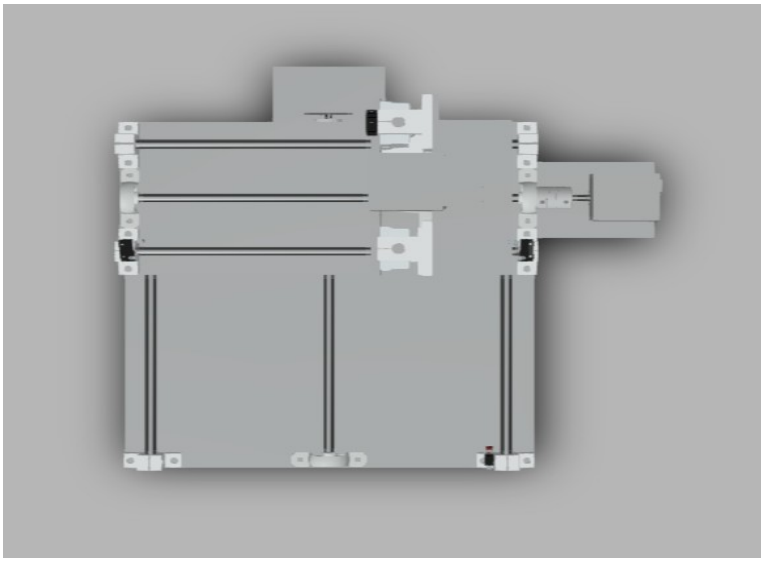
ÖNDEN GÖRÜNÜM

Şekil 1.1



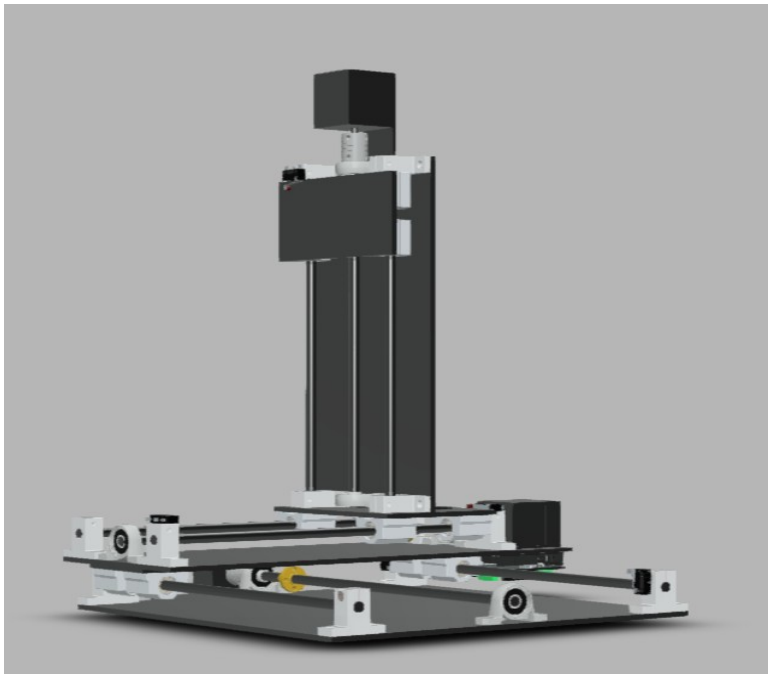
ÜSTTEN GÖRÜNÜM

ŞEKİL 1.2



ÇAPRAZ GÖRÜNÜM

ŞEKİL 1.3



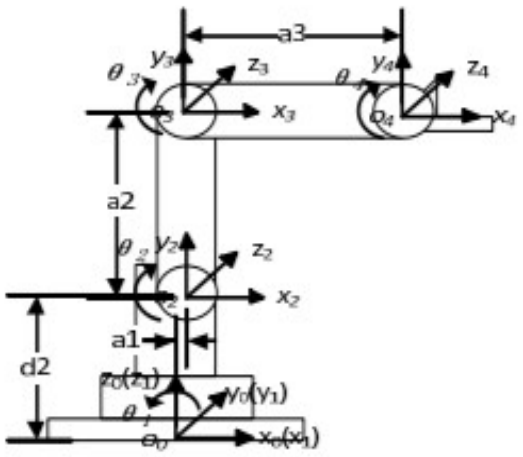
MATEMATİKSEL DENKLEMLER

2. 3 DOF ROBOTİC MANİPULATOR KİNEMATİC ANALİZİ

2.1 İleri kinematik hesabı

Aşağıda 3 DOF robot manipülatörün parametreleri cebirsel ifadeler ile belirtilmiştir.

Şekil 2.1 – 3 DOF manipülatör koordinat sistemi



No.	θ_i	a_{i-1}	a_{i-1}	d_i
1	θ_1	0	0	0
2	θ_2	-90°	a_1	d_2
3	θ_3	0	a_2	0
4	θ_4	0	a_3	0

θi z ekseni etrafındaki dönüş açısıdır

a-1, x-1 ekseni etrafındaki bükülme açısıdır

a-1, eksenler arası mesafedir (x i-1 ile x i arası)

d, eksenler arası mesafedir. (z i-1 ile z i arası

Bitişik eklemler arasındaki dönüşüm matrisleri parametreleri değiştirilerek elde edilebilir.

$$ {}^{0}_{1}\mathbf{T} = \begin{bmatrix} \cos\theta_1 & -\sin\theta_1 & 0 & 0 \\ \sin\theta_1 & \cos\theta_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (1) $$

$$ {}^{1}_{2}\mathbf{T} = \begin{bmatrix} \cos\theta_2 & -\sin\theta_2 & 0 & a_1 \\ 0 & 0 & -1 & 0 \\ \sin\theta_2 & \cos\theta_2 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (2) $$

$$ {}^{2}_{3}\mathbf{T} = \begin{bmatrix} \cos\theta_3 & -\sin\theta_3 & 0 & a_2 \\ \sin\theta_3 & \cos\theta_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (3) $$

$$ {}^{3}_{4}\mathbf{T} = \begin{bmatrix} \cos\theta_4 & -\sin\theta_4 & 0 & a_3 \\ \sin\theta_4 & \cos\theta_4 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad (4) $$

Bu nedenle, taban arasındaki dönüşüm matrisi ve uç aktüatör aşağıdaki gibidir.

$$ {}^{0}_{4}\mathbf{T} = {}^{0}_{1}\mathbf{T}\,{}^{1}_{2}\mathbf{T}\,{}^{2}_{3}\mathbf{T}\,{}^{3}_{4}\mathbf{T} $$

$$ {}^{4}_{0}\boldsymbol{T} = \begin{bmatrix} \boldsymbol{n}_x & \boldsymbol{o}_x & \boldsymbol{a}_x & \boldsymbol{p}_x \\ \boldsymbol{n}_y & \boldsymbol{o}_y & \boldsymbol{a}_y & \boldsymbol{p}_y \\ \boldsymbol{n}_z & \boldsymbol{o}_z & \boldsymbol{a}_z & \boldsymbol{p}_z \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$n_x = (c_1c_2c_3 - c_1s_2s_3)c_4 - (c_1c_2s_3 + c_1s_2c_3)s_4$$

$$n_y = (s_1c_2c_3 - s_1s_2s_3)c_4 - (s_1c_2s_3 + s_1s_2c_3)s_4$$

$$n_z = (s_2c_3 + c_2s_3)c_4 - (s_2s_3 - c_2c_3)s_4$$

$$o_x = -(c_1c_2c_3 - c_1s_2s_3)s_4 - (c_1c_2s_3 + c_1s_2c_3)c_4$$

$$o_y = -(s_1c_2c_3 - s_1s_2s_3)s_4 - (s_1c_2s_3 + s_1s_2c_3)c_4$$

$$o_z = -(s_2c_3 + c_2s_3)s_4 - (s_2s_3 - c_2c_3)c_4$$

$$a_x = s_1$$

$$a_y = -c_1$$

$$a_z = 0$$

$$p_x = (c_1c_2c_3 - c_1s_2s_3)a_3 + a_2c_1c_2 + a_1c_1$$

$$p_y = (s_1c_2c_3 - s_1s_2s_3)a_3 + a_2s_1c_2 + a_1s_1$$

$$p_z = (s_2c_3 + c_2s_3)a_3 + a_2s_2 + d_2$$

where

$s_1 = \sin\theta_1$, $s_2 = \sin\theta_2$, $s_3 = \sin\theta_3$, $s_4 = \sin\theta_4$,

$c_1 = \cos\theta_1$, $c_2 = \cos\theta_2$, $c_3 = \cos\theta_3$, $c_4 = \cos\theta_4$.

2.2 Ters kinematik hesabı

$$ {}^0_1\mathbf{T}^1(\theta_1){}^0_4\mathbf{T} = {}^4_1\mathbf{T} = {}^1_2\mathbf{T}{}^2_3\mathbf{T}{}^3_4\mathbf{T} = \begin{bmatrix} \cos\theta_1 & \sin\theta_1 & 0 & 0 \\ -\sin\theta_1 & \cos\theta_1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} n_x & o_x & a_x & p_x \\ n_y & o_y & a_y & p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

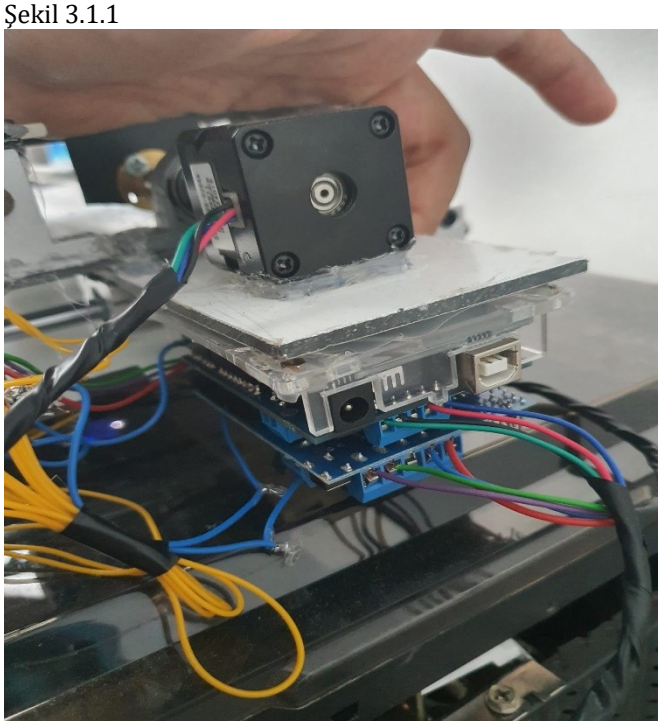
$$ = \begin{bmatrix} \cos\theta_1 n_x + \sin\theta_1 n_y & \cos\theta_1 o_x + \sin\theta_1 o_y & \cos\theta_1 a_x + \sin\theta_1 a_y & \cos\theta_1 p_x + \sin\theta_1 p_y \\ -\sin\theta_1 n_x + \cos\theta_1 n_y & -\sin\theta_1 o_x + \cos\theta_1 o_y & -\sin\theta_1 a_x + \cos\theta_1 a_y & -\sin\theta_1 p_x + \cos\theta_1 p_y \\ n_z & o_z & a_z & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

3.1 ELEKTRONİK DEVRE TASARIMI

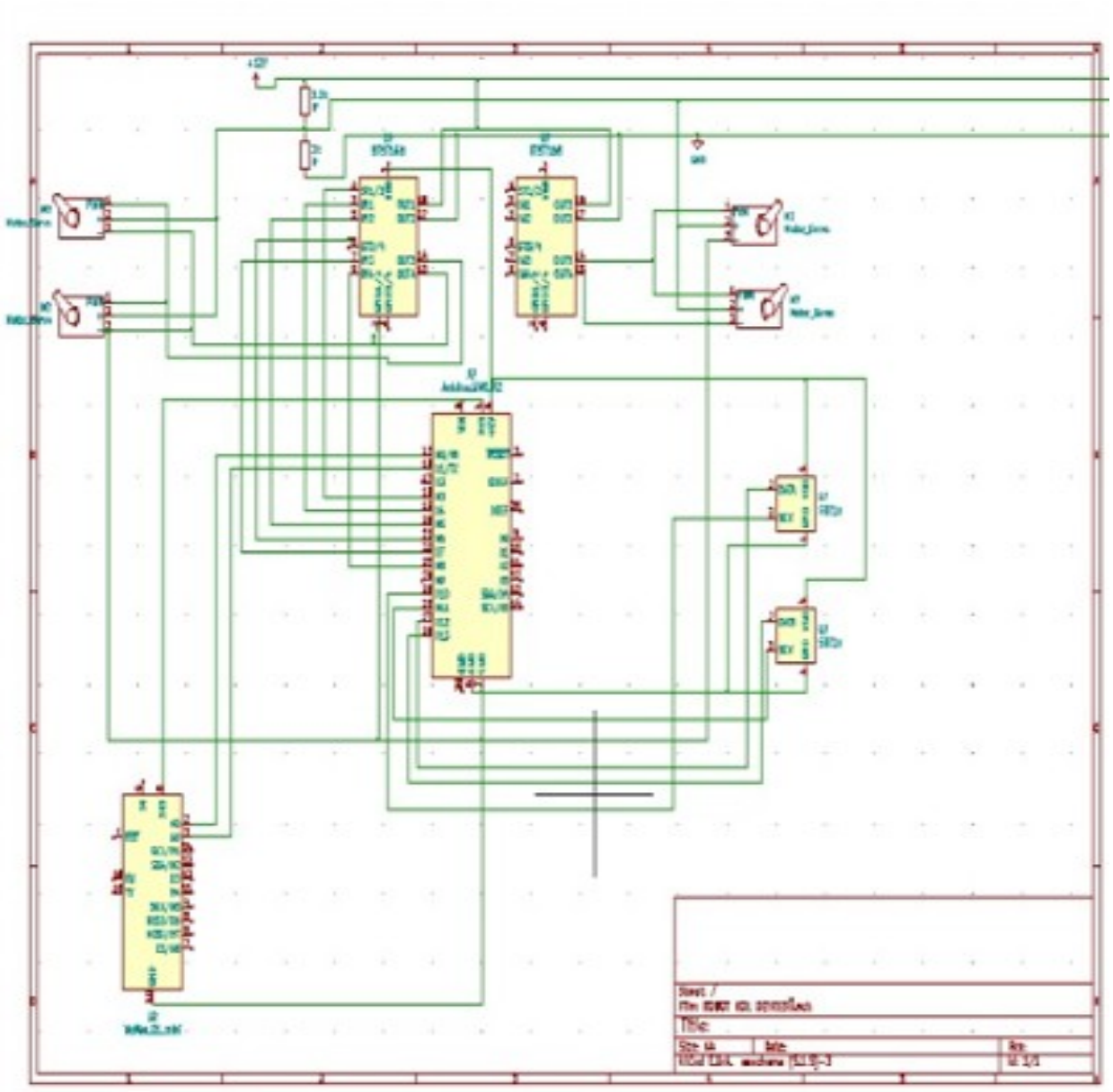
3.1.1 TASARIMDA KULLANILAN DEVRE ELEMANLARI

Ardunio Uno
Motor shield v1
Motor shield v2
sy35st26-0284a Step motor
sy42sth47-1206b Step motor
sy35st28-0504a Step motor
Kablolar
Limiterlar

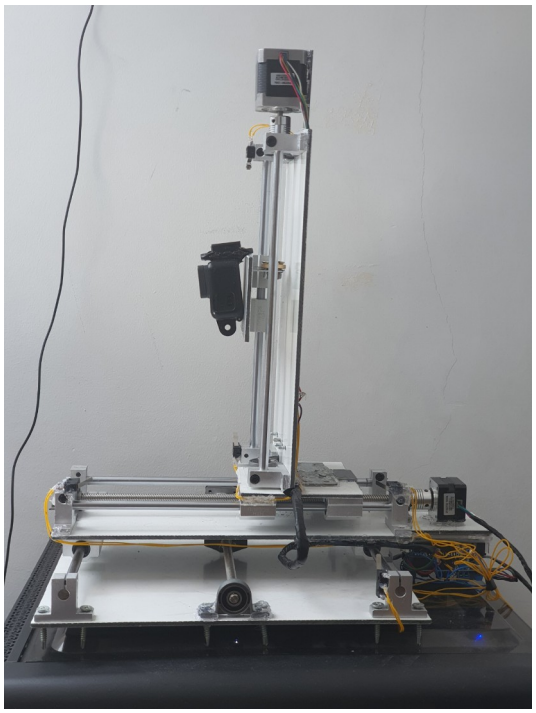
Şekil 3.1.1

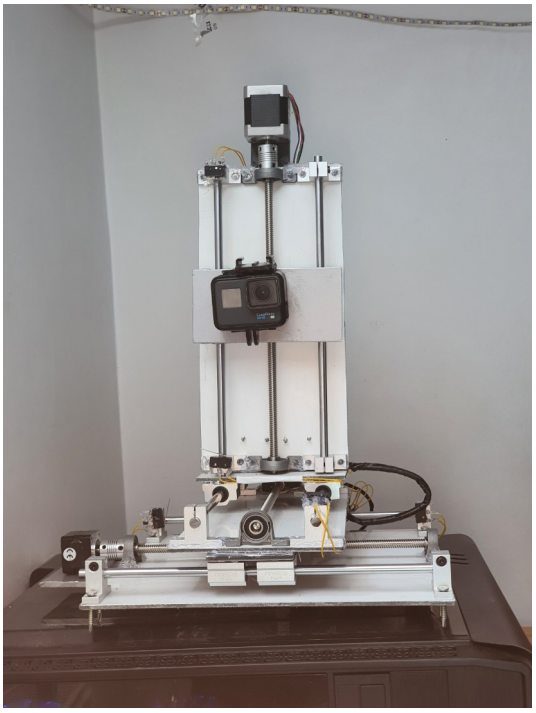


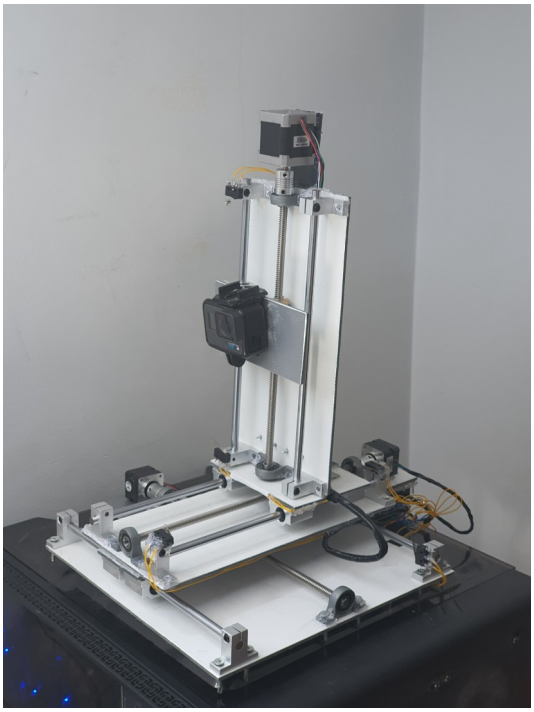
3.1.2 ELEKTRONİK DEVRE ŞEMASI

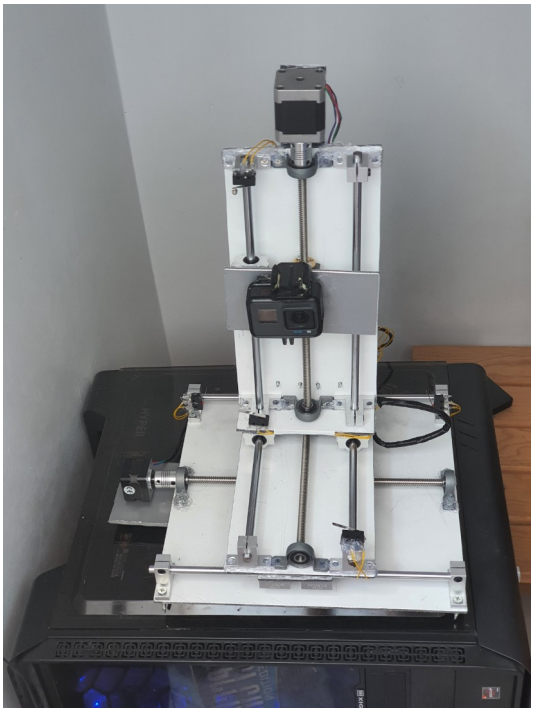


PROJEDEN RESİMLER









KAYNAKÇA

[1] maker.pro/arduino/tutorial/how-to-make-arduino-and-processing-ide-communicate

[2] processing.org/reference/libraries/

[3] forum.processing.org/two/discussion/20226/how-to-read-serial-string-from-arduino-as-int-on-processing

[4] learn.adafruit.com/adafruit-motor-shield-v2-for-arduino

[5] learn.adafruit.com/adafruit-motor-shield/using-stepper-motors

[6] cdn-learn.adafruit.com/downloads/pdf/adafruit-motor-shield.pdf

EKLER

ARDUINO CODES

```
#include <AFMotor.h>
#include <Wire.h>
#include <Adafruit_MotorShield.h>
String readString;
int btnx1 = 0;
Adafruit_MotorShield AFMS = Adafruit_MotorShield();
AF_Stepper motorx(220, 1);
Adafruit_StepperMotor *myMotory = AFMS.getStepper(200, 1);
Adafruit_StepperMotor *myMotorz = AFMS.getStepper(200, 2);
  int dly = 20;
  int x = 0;
  int y = 0;
  int z = 0;
  int times = 1;
  int i=0;
  int gecicix =0;
  int geciciy =0;
  int geciciz =0;
  int cikartx = 0;
  int cikarty = 0;
  int cikartz = 0;
  int k = 1;
  int delayhizi = 1;
void setup() {
  Serial.begin(9600);           // set up Serial library at 9600 bps
  Serial.println("Stepper test!");
  pinMode(btnx1, INPUT);    // button as input
  digitalWrite(btnx1, HIGH); // turns on pull-up resistor after input
 AFMS.begin();
motorx.setSpeed(120);
myMotory->setSpeed(255);
myMotorz->setSpeed(255);
}
void loop() {
  if (Serial.available()){
for (int bekletum = 1; bekletum > 0 ; bekletum=bekletum) {
  Serial.println("tumbekliyor"); //
    int sec = Serial.read();
    if (sec == 'k'){
      x=0;
      gecicix=9999;
      cikartx=9999;
      y=0;
      geciciy=9999;
      cikarty=9999;
      z=0;
      geciciz=9999;
      cikartz=9999;
    }
    if (sec == 'x'){
      for (int bekle = 1; bekle >0 ; bekle==bekle){//////////////
        while (Serial.available()) {
        char c = Serial.read();;  //gets one byte from serial buffer
        readString += c; //makes the String readString
        delay(50);  //slow looping to allow buffer to fill with next character
         }
         if (readString.length() >0) {
         x = readString.toInt();  //convert readString into a number
         //Serial.println(x); //so you can see the integer
         readString="";
         }
```

```
      Serial.print(" serial read x = ");
      Serial.println(x);
      delay(dly);
      int secc = Serial.read();
      if (secc == 'c'){//////////////
       //x=x*25;
       bekle=-1;
       }
      }
    }
    else if (sec == 'y'){
     for (int bekle = 1; bekle >0 ; bekle==bekle){//////////////
       while (Serial.available()) {
       char c = Serial.read( );  //gets one byte from serial buffer
       readString += c; //makes the String readString
       delay(50);  //slow looping to allow buffer to fill with next character
        }
        if (readString.length() >0) {
        y = readString.toInt();  //convert readString into a number
        //Serial.println(x); //so you can see the integer
        readString="";
        }
      Serial.print(" serial read y = ");
      Serial.println(y);
      delay(dly);
      if (Serial.read() == 'c'){//////////////
       //y=y*25;
       bekle=-1;
       }
      }
    }
    else if (sec == 'z'){
     for (int bekle = 1; bekle >0 ; bekle==bekle){//////////////
       while (Serial.available()) {
       char c = Serial.read( );  //gets one byte from serial buffer
       readString += c; //makes the String readString
       delay(50);  //slow looping to allow buffer to fill with next character
        }
        if (readString.length() >0) {
        z = readString.toInt();  //convert readString into a number
        //Serial.println(x); //so you can see the integer
        readString="";
        }
      Serial.print(" serial read z = ");
      Serial.println(z);
      delay(dly);
      if (Serial.read() == 'c'){//////////////
       //z=z*25;
       bekle=-1;
       }
      }
    }
if (sec == 'v'){//////////////
       bekletum=-1;
       }
       delay(dly);
}//bekletum
  }
  Serial.print(" x = ");
  Serial.print(x);
  Serial.print(" y = ");
  Serial.print(y);
  Serial.print(" z = ");
  Serial.print(z);
  Serial.println();


  k=1;
  cikartx = gecicix;
  if (x > gecicix){////////////////////////////xxxxxxxxxxxx
    for (i=0 ; i<(x-cikartx)*times ; i++ ){
      Serial.println("calısması lazım");
      motorx.step(25, FORWARD, DOUBLE);
      delay(delayhizi);
```

```
          while(digitalRead(btnx1) == LOW){
          motorx.step(25, BACKWARD, DOUBLE);
          Serial.println("Emergency");
          i=(x-cikartx)*times;
          delay(10);}
     if (k = 1){
     gecicix = x;
     k = 0;
     }
   }
   }
k=1;
if (x+1 < gecicix){
    for (i=0 ; i<(cikartx-x)*times ; i++ ){
  Serial.println("calısması lazım");
  motorx.step(25, BACKWARD, DOUBLE);
  delay(delayhizi);
          while(digitalRead(btnx1) == LOW){
          motorx.step(25, FORWARD, DOUBLE);
          Serial.println("Emergency");
          i=(cikartx-x)*times;
          delay(10);}
  if (k = 1){
    gecicix = x;
    k = 0;
    }
  }
}
k=1;
cikarty = geciciy;
  if (y > geciciy){//////////////////////////yyyyyyyyyyyy
  for (i=0 ; i<(y-cikarty)*times ; i++ ){
    Serial.println("calısması lazım");
    myMotory->step(25, FORWARD, DOUBLE);
    delay(delayhizi);
          while(digitalRead(btnx1) == LOW){
          myMotory->step(25, BACKWARD, DOUBLE);
          Serial.println("Emergency");
          i=(y-cikarty)*times;
          delay(10);}
    if (k = 1){
     geciciy = y;
     k = 0;
     }
  }

}
k=1;
if (y+1 < geciciy){
       for (i=0 ; i<(cikarty-y)*times ; i++ ){
  Serial.println("calısması lazım");
  myMotory->step(25, BACKWARD, DOUBLE);
  delay(delayhizi);
          while(digitalRead(btnx1) == LOW){
          myMotory->step(25, FORWARD, DOUBLE);
          Serial.println("Emergency");
          i=(cikarty-y)*times;
          delay(10);}
  if (k = 1){
    geciciy = y;
    k = 0;
    }
  }
}
k=1;
cikartz = geciciz;
if (z > geciciz){//////////////////////////zzzzzzzzzzzzzzz
  for (i=0 ; i<(z-cikartz)*times ; i++ ){
    Serial.println("calısması lazım");
    myMotorz->step(25, FORWARD, DOUBLE);
    delay(delayhizi);
          while(digitalRead(btnx1) == LOW){
          myMotorz->step(25, BACKWARD, DOUBLE);
```

```
            Serial.println("Emergency");
            i=(z-cikartz)*times;
            delay(10);}
      if (k = 1){
       geciciz = z;
       k = 0;
      }
    }
  }
  k=1;
  if (z+1 < geciciz){
    for (i=0 ; i<(cikartz-z)*times ; i++ ){
     Serial.println("calısması lazım");
     myMotorz->step(25, BACKWARD, DOUBLE);
     delay(delayhizi);
            while(digitalRead(btnx1) == LOW){
            myMotorz->step(25, FORWARD, DOUBLE);
            Serial.println("Emergency");
            i=(cikartz-z)*times;
            delay(10);}
    if (k = 1){
      geciciz = z;
      k = 0;
      }
    }
  }
 motorx.release();
 myMotory->release();
 myMotorz->release();
  delay(dly);
}
```

PROCESSING CODES

```
 import processing.serial.*;
import controlP5.*;
Serial port;
ControlP5 cp5;
String textValue = "";
String xdeger, ydeger, zdeger;
int delay = 200;
void setup() {


  port = new Serial(this, "COM3", 9600);
  size(400,400);
  PFont font = createFont("arial",20);
  cp5 = new ControlP5(this);
  cp5.addTextfield("x")
     .setPosition(20,100)
     .setSize(40,40)
     .setFont(font)
     .setFocus(true)
     .setColor(color(255,0,0))
     .setAutoClear(false)
     ;
  cp5.addTextfield("y")
     .setPosition(70,100)
     .setSize(40,40)
     .setFont(createFont("arial",20))
     .setAutoClear(false)
     ;
  cp5.addTextfield("z")
     .setPosition(120,100)
     .setSize(40,40)
     .setFont(font)
     .setFocus(true)
     .setColor(color(255,0,0))
     .setAutoClear(false)
     ;
  cp5.addBang("gonder")
     .setPosition(170,100)
     .setSize(40,40)
```

```
    .getCaptionLabel().align(ControlP5.CENTER, ControlP5.CENTER)
    ;
  cp5.addBang("Calibration")
    .setPosition(170,200)
    .setSize(60,40)
    .getCaptionLabel().align(ControlP5.CENTER, ControlP5.CENTER)
    ;
  textFont(font);
}
void draw() {
  background(0);
  fill(255);
  text("1 = 1 milimetre", 30,60);
  text(textValue, 30,30);
}
public void gonder() {
  xdeger = cp5.get(Textfield.class,"x").getText();
  port.write('x');
  delay(delay);
  port.write(0);
  port.write(xdeger);
  println(xdeger);
  delay(delay);
  port.write('c');


  ydeger = cp5.get(Textfield.class,"y").getText();
  port.write('y');
  delay(delay);
  port.write(0);
  port.write(ydeger);
  println(ydeger);
  delay(delay);
  port.write('c');


  zdeger = cp5.get(Textfield.class,"z").getText();
  port.write('z');
  delay(delay);
  port.write(0);
  port.write(zdeger);
  println(zdeger);
  delay(delay);
  port.write('c');


  delay(delay);
  port.write('v');


  println("gonderildi");
  //cp5.get(Textfield.class,"x").clear(); //gonderlidiye basınca yazıyı siliyor
  //cp5.get(Textfield.class,"y").clear();
  //cp5.get(Textfield.class,"z").clear();
}
public void Calibration() {
  port.write('k');
  delay(delay);
  port.write('v');
  }
void controlEvent(ControlEvent theEvent) {
  if(theEvent.isAssignableFrom(Textfield.class)) {
    println("controlEvent: accessing a string from controller '"
          +theEvent.getName()+"': "
          +theEvent.getStringValue()
          );
   port.write(theEvent.getStringValue());
   int aci = int(theEvent.getStringValue());
   println("aci = "+aci); ////////////////////////////////////////////////////////////


  }
}
public void aci(String theText) {
  // automatically receives results from controller input
  println("a textfield event for controller 'aci' : "+theText);
```

}