TECHNOCRATS ROBOTICS

VACATION TASKS

SET-5

Auto-Leveling for MPU-6050

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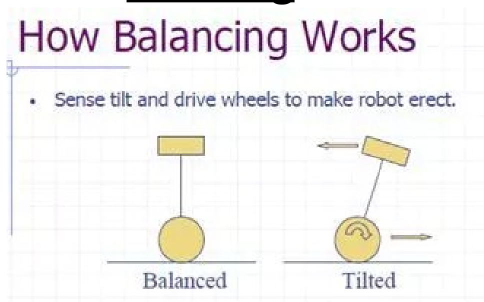
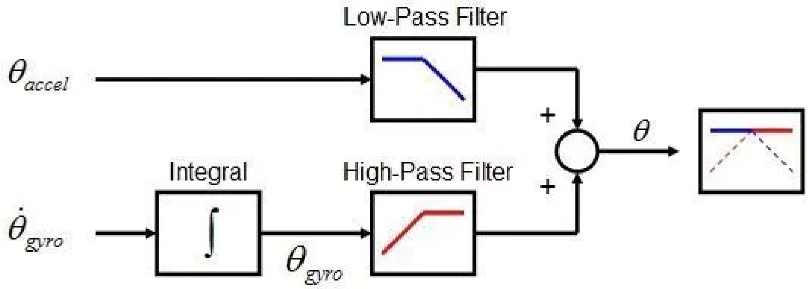
Working





The physics for this robot is simple: the robot stands in two points lined with the wheel, and it tends to fall vertically. The movement of the wheel in the direction of the falling raises the robot to recover the vertical position.

A Segway-type vehicle is a classic inverted pendulum control problem that is solvable in two degrees of freedom for the simplest models. The vehicle attempts to correct for an induced lean angle by moving forward or backward, and the goal is to return itself to vertical. Or at least not fall over.

For that objective we have two things to do; on one hand we have to measure the angle of inclination (Roll) of the vehicle, and on the other hand we have to control the motors for going forward or backward to make that angle 0, maintaining a vertical position.

Measure the Angle

For measuring the angle, we have two sensors.

The accelerometer and gyroscope both have its advantages and disadvantages. The accelerometer can measure the force of the gravity, and with that information we can obtain the angle of the robot. The problem of the accelerometer is that it can also measure the other forces on the vehicle, so it has lot of error and noise.

The gyroscope measures the angular velocity, so if we integrate this measure we can obtain the angle the robot is moved. The problem of this measure is that it is not perfect and the integration has a deviation. That means that for short term the measure is good, but for a long duration the angle will deviate much from the real angle.

Sensor Fusion

Those problems can be resolved by the combination of both sensors, that's called sensor fusion, and there are a lot of methods to combine it. Here's two of them: Kalman filter, and complementary filter.

1) The Kalman filter is an algorithm extended in robotics, and offers a good result with low computational cost. There is a library for Arduino that implements this method.

2) The Complementary filter is a combination of two or more filters that combines the information from different sources and gets the best value you want. It can be implement in only one line of code.

The complementary filter gives us a "best of both worlds" kind of deal. On the short term, we use the data from the gyroscope, because it is very precise and not susceptible to external forces. On the long term, we use the data from the accelerometer, as it does not drift. In it's most simple form, the filter looks as follows:

$$angle = 0.98 * (angle + gyrData * dt) + 0.02 * (accData)$$

The gyroscope data is integrated every timestep with the current angle value. After this it is combined with the low-pass data from the accelerometer (already processed with atan2). The constants (0.98 and 0.02) have to add up to 1 but can of course be changed to tune the filter properly.

Code

```
#include <Wire.h>
#include "Kalman.h" // Source: https://github.com/TKJElectronics/KalmanFilter
#define RESTRICT_PITCH
Kalman kalmanX;
Kalman kalmanY;
double accX, accY, accZ;
double gyroX, gyroY, gyroZ;
int16_t tempRaw;

double gyroXangle, gyroYangle; // Gyroscope angle
double compAngleX, compAngleY; // Complementary filter angle
double kalAngleX, kalAngleY; // Angle after Kalman filter
double corrected_x, corrected_y; // Corrected with offset

uint32_t timer;
uint8_t i2cData[14]; // Buffer for I2C data

char a;
double m = 0.7;
```

```
double m1 = -0.7;
int d = 0;
int c = 0;
char p;
int in1_motor_left = 8;
int in2_motor_left = 7;
int in3_motor_right = 3;
int in4_motor_right = 4;
int pwm_on = 5; // ms ON
int pwm_off = 5; // ms OFF
//-----------------------------------------------------------------------------
void setup() {
  // Define outputs
  pinMode(in1_motor_left, OUTPUT);
  pinMode(in2_motor_left, OUTPUT);
  pinMode(in3_motor_right, OUTPUT);
  pinMode(in4_motor_right, OUTPUT);
  // Start serial console
  Serial.begin(115200);
  //BT.begin(9600);
  delay(50);
  // Initiate the Wire library and join the I2C bus as a master or slave
  Wire.begin();

  TWBR = ((F_CPU / 400000L) - 16) / 2; // Set I2C frequency to 400kHz

  i2cData[0] = 7; // Set the sample rate to 1000Hz - 8kHz/(7+1) = 1000Hz
  i2cData[1] = 0x00; // Disable FSYNC and set 260 Hz Acc filtering, 256 Hz Gyro filtering, 8
KHz sampling
  i2cData[2] = 0x00; // Set Gyro Full Scale Range to 250deg/s
  i2cData[3] = 0x00; // Set Accelerometer Full Scale Range to 2g

  while (i2cWrite(0x19, i2cData, 4, false)); // Write to all four registers at once
  while (i2cWrite(0x6B, 0x01, true)); // PLL with X axis gyroscope reference and disable sleep
mode

  while (i2cRead(0x75, i2cData, 1));
  if (i2cData[0] != 0x68) { // Read "WHO_AM_I" register
    Serial.print(F("Error reading sensor"));
    while (1);
  }
  delay(100); // Wait for sensor to stabilize

/**
* Set kalman and gyro starting angle
*
*/
  while (i2cRead(0x3B, i2cData, 6));
  accX = (i2cData[0] << 8) | i2cData[1];
```

```
  accY = (i2cData[2] << 8) | i2cData[3];
  accZ = (i2cData[4] << 8) | i2cData[5];

  // atan2 outputs the value of - to  (radians) - see http://en.wikipedia.org/wiki/Atan2
  // It is then converted from radians to degrees
  #ifdef RESTRICT_PITCH
    double roll  = atan2(accY, accZ) * RAD_TO_DEG;
    double pitch = atan(-accX / sqrt(accY * accY + accZ * accZ)) * RAD_TO_DEG;
  #else
    double roll  = atan(accY / sqrt(accX * accX + accZ * accZ)) * RAD_TO_DEG;
    double pitch = atan2(-accX, accZ) * RAD_TO_DEG;
  #endif

  kalmanX.setAngle(roll);
  kalmanY.setAngle(pitch);
  gyroXangle = roll;
  gyroYangle = pitch;
  compAngleX = roll;
  compAngleY = pitch;
  timer = micros();
}

//-----------------------------------------------------------------------------
void loop() {
    while (i2cRead(0x3B, i2cData, 14));
    accX = ((i2cData[0] << 8) | i2cData[1]);
    accY = ((i2cData[2] << 8) | i2cData[3]);
    accZ = ((i2cData[4] << 8) | i2cData[5]);
    tempRaw = (i2cData[6] << 8) | i2cData[7];
    gyroX = (i2cData[8] << 8) | i2cData[9];
    gyroY = (i2cData[10] << 8) | i2cData[11];
    gyroZ = (i2cData[12] << 8) | i2cData[13];
    // Calculate delta time
    double dt = (double)(micros() - timer) / 1000000;
    timer = micros();


  #ifdef RESTRICT_PITCH
    double roll  = atan2(accY, accZ) * RAD_TO_DEG;
    double pitch = atan(-accX / sqrt(accY * accY + accZ * accZ)) * RAD_TO_DEG;
  #else
    double roll  = atan(accY / sqrt(accX * accX + accZ * accZ)) * RAD_TO_DEG;
    double pitch = atan2(-accX, accZ) * RAD_TO_DEG;
  #endif

  double gyroXrate = gyroX / 131.0; // Convert to deg/s
  double gyroYrate = gyroY / 131.0; // Convert to deg/s

  #ifdef RESTRICT_PITCH
```

```
   // This fixes the transition problem when the accelerometer angle jumps between -180 and
180 degrees
   if ((roll < -90 && kalAngleX > 90) || (roll > 90 && kalAngleX < -90)) {
     kalmanX.setAngle(roll);
     compAngleX = roll;
     kalAngleX = roll;
     gyroXangle = roll;
   } else
     kalAngleX = kalmanX.getAngle(roll, gyroXrate, dt); // Calculate the angle using a Kalman
filter

   if (abs(kalAngleX) > 90)
     gyroYrate = -gyroYrate; // Invert rate, so it fits the restriced accelerometer reading
   kalAngleY = kalmanY.getAngle(pitch, gyroYrate, dt);
 #else
   // This fixes the transition problem when the accelerometer angle jumps between -180 and
180 degrees
   if ((pitch < -90 && kalAngleY > 90) || (pitch > 90 && kalAngleY < -90)) {
     kalmanY.setAngle(pitch);
     compAngleY = pitch;
     kalAngleY = pitch;
     gyroYangle = pitch;
   } else
     kalAngleY = kalmanY.getAngle(pitch, gyroYrate, dt); // Calculate the angle using a Kalman
filter

   if (abs(kalAngleY) > 90)
     gyroXrate = -gyroXrate; // Invert rate, so it fits the restriced accelerometer reading
   kalAngleX = kalmanX.getAngle(roll, gyroXrate, dt); // Calculate the angle using a Kalman
filter
 #endif

   gyroXangle += gyroXrate * dt; // Calculate gyro angle without any filter
   gyroYangle += gyroYrate * dt;
   compAngleX = 0.93 * (compAngleX + gyroXrate * dt) + 0.07 * roll; // Calculate the angle
using a Complimentary filter
   compAngleY = 0.93 * (compAngleY + gyroYrate * dt) + 0.07 * pitch;

   // Reset the gyro angle when it has drifted too much
   if (gyroXangle < -180 || gyroXangle > 180)
     gyroXangle = kalAngleX;
   if (gyroYangle < -180 || gyroYangle > 180)
     gyroYangle = kalAngleY;
   delay(2);
   Serial.println();
   // Corrected angles with offset
   corrected_x=kalAngleX-171,746;
   corrected_y=kalAngleY-81,80;
 corrected_y = corrected_y+84;
```

```
  Serial.print(corrected_y);
  pwm_adjust(corrected_y);
  if(corrected_y>=m && corrected_y<20){
   if(c>6){
    m-=0.2;
    m1-=-0.2;
    c=0;
    }
    backward();
   }
   else if(corrected_y>=-20 && corrected_y<=m1){
    Serial.print("  ");
    if(d>6){
    m+=0.2;
    m1+=0.2;
    d=0;
    }
    forward();
  }else{
    stop();
    m=0.7;
    m1=-0.7;
    pwm_on = 0;
    pwm_off = 0;
  }

}

void forward(){
  d++;
  //Serial.print(d);
  digitalWrite(in3_motor_right, LOW);
  digitalWrite(in4_motor_right, HIGH);
  digitalWrite(in1_motor_left, HIGH);
  digitalWrite(in2_motor_left, LOW);
  delay(pwm_on);

  digitalWrite(in3_motor_right, LOW);
  digitalWrite(in4_motor_right, LOW);
  digitalWrite(in1_motor_left, LOW);
  digitalWrite(in2_motor_left, LOW);
  delay(pwm_off);
}

void backward(){
  c++;
  digitalWrite(in3_motor_right, HIGH);
  digitalWrite(in4_motor_right,LOW);
  digitalWrite(in1_motor_left, LOW);
```

```
  digitalWrite(in2_motor_left, HIGH);
  delay(pwm_on);

  digitalWrite(in3_motor_right, LOW);
  digitalWrite(in4_motor_right, LOW);
  digitalWrite(in1_motor_left, LOW);
  digitalWrite(in2_motor_left, LOW);
  delay(pwm_off);
}

void stop(){
  digitalWrite(in1_motor_left, LOW);
  digitalWrite(in2_motor_left, LOW);
  digitalWrite(in3_motor_right, LOW);
  digitalWrite(in4_motor_right, LOW);
  delay(pwm_on);

  digitalWrite(in1_motor_left, LOW);
  digitalWrite(in2_motor_left, LOW);
  digitalWrite(in3_motor_right, LOW);
  digitalWrite(in4_motor_right, LOW);
  delay(pwm_off);
}
void pwm_adjust(int value_y){

  if(value_y >=-1 && value_y <=1 ){

    int k = (value_y*value_y);
    Serial.print(k);
    pwm_on = 5; // ms ON
    pwm_off = 3; // ms OFF
  }
 else if((value_y>=-3 && value_y<-1)||(value_y>1 && value_y<=3) ){
    pwm_on = 50;
    pwm_off = 5;
  }
  else if(value_y >5 || value_y <=-5 ){
    Serial.print("**");
    pwm_on = 120; // ms ON
    pwm_off = 3; // ms OFF
  }
  else
    stop();

  }
```