Design And Development Of Self Balancing Bicycle Using Gyroscope

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Abstract - The goal of this project report is to study the design and development of a self-balancing bicycle with the goal of achieving static stability using advanced control systems and sensor integration. The major goal was to use self-balancing technologies to build a bicycle that can sustain its upright posture on its own without assistance from an outside source. The project included software development, electrical engineering, and mechanical design in an interdisciplinary manner. Among the essential parts were accelerometers and gyroscopes for real-time motion and orientation data, We used a strict approach throughout the entire project, beginning with the creation of a theoretical framework and a thorough assessment of the literature. Next, we carefully selected each component, taking into account factors like cost-effectiveness, correctness, and dependability. Assembling the mechanical components, integrating the electronic components, and creating the required software algorithms were all part of the implementation phase. The system's robustness and performance were confirmed through extensive testing and validation. The project's goals were met when the results showed that the self-balancing bicycle could successfully maintain equilibrium in a variety of situations. In addition to confirming that self-balancing systems in bicycles are feasible, this experiment offered insightful information about the difficulties and possible solutions for further advancement. The accomplishment of this project successfully establishes a solid basis for additional study and applications in robotics and personal transportation. Conclusively, the self-balancing bicycle project signifies a noteworthy progression in comprehending and utilizing self-balancing mechanics, underscoring the possibility of inventive approaches to augment mobility and stability throughout several fields.

Keywords - Interdisciplinary Approach, Self Balancing, Strong Foundation, Static Stability.

1.INTRODUCTION

Concern over the increasing number of traffic-related deaths and injuries is growing globally. The majority of two-wheeler riders die at the scene of traffic accidents, where they are involved. Two-wheeled Vehicles are a more popular form of transportation since they are affordable, practical, and efficient with time. Research indicates that the number of accidents has been rising over time, with the main factor contributing to this trend being the intrinsic instability of two-wheeled vehicles. In addition, the instability of the two wheels in both stable and dynamic settings make it challenging for individuals with disabilities to operate the vehicle.

People in India use two-wheeled vehicles with front and rear wheels for transportation. If the bike flips over sideways, there can be fewer accidents.

2. PROBLEM DEFINATION

Globally, there is growing worry over the escalating toll of traffic-related fatalities and injuries. Most two-wheeler riders die instantly in traffic crashes, if they are involved. Two-wheeled cars due to their affordability, timeliness, and practicality, are growing in popularity as means of transportation. Studies reveal that the number of accidents has been rising over time, with the fundamental instability of two-wheeled vehicles being the main contributor. Furthermore, it is challenging for those with disabilities to operate the vehicle due to two-wheeler instability in both stable and dynamic settings.

3.OBJECTIVES OF PROPOSED WORK

1. To identify bicycle instability in both static and dynamic conditions.
2. To keep the bike stable and prevent sideways falls.

4. METHODOLOGY OF PROPOSED WORK

1. The tilt and acceleration of a bicycle's motion are detected using gyro and accelerometer sensors.
2. Gyroscopic concept is used to stabilize the bicycle.

5. LITERATURE REVIEW

Sidharth R, V K Pranav, Nitheesh Kumar G, Pramod Sreedharan, and Gayathri G

This work explores the notion of stabilizing the bicycle through the application of gyroscopic precession theory. To verify that the chosen material is adequate and capable of supporting the expected loads, a statically-analysed bicycle frame is used. During Furthermore, a study is conducted on the bicycle's motion at different flywheel speeds. The result demonstrates that when the bicycle is stationary, the flywheel RPM grows along with the cycle's total topple time, and that when the bicycle is moving, an ideal flywheel speed is necessary. Because of the built-in model's limited flywheel capacity, higher RPM motors are required to create an upright bicycle. It can take a bicycle a long time to topple if high RPM motors aren't used.

Mehmet Ali Eroğlu, Mehmet Kürşat Yalçın
A self-balancing bicycle with support and rising up mechanisms is built in this study using a CMG with a single-axis gimbal. To ascertain the responses of the system, structural evaluations based on finite element modeling are conducted. The research reached the following conclusions: Rising flywheel spin and gimbal angular rate result in an increase in the gyroscopic moment. Gyroscopic moment demand increases with additional load. The bicycle's driving mechanism is ineffective during a gyroscopic moment regardless of which wheel is in front or back. There is no relationship between driving torque and gimbal torque.
It is necessary to select rough as the wheel-road contact type. To slip, fly, turn, and bounce, make other contacts. An active self-balancing requires the use of a control strategy.

Yadhu Krishnan, Ishaan Rahul Saxena
Using the gyroscopic effect, a two-wheeled bike that can balance itself was created. The prototype model could counter torque 0.28 N-cm for a maximum tilt of 30 degrees and self-balance at a maximum speed of 118 rpm along the vertices. The primary goal of the project was to minimize the amount of space taken up, the total weight of the assembly, and the distance to the Center of Gravity from the ground. This was accomplished in part by using a vertical momentum flywheel and layering the components to create a smaller two-wheeler model. After observing and analyzing the actual and theoretical torque and needed rotational speed values, it was concluded that the experimental value differed from the theoretical value by the least amount.

Akash C, Devapraseeth, Jills Babu, Mohammed Ryan, Mr. G Thilak
This project describes how to power a bicycle for long distance riding while utilizing all available energy sources as efficiently as feasible. The methods for including rider aid to promote safety and convenience of riding are also covered in this research. We've got established this idea with the intention of providing a dependable and reasonably priced means of transportation, particularly for the underprivileged. Two distinct technologies that have previously been used in conjunction have been skillfully merged to provide a novel and reasonably priced mode of transportation. Our concern for the causes and effects of environmental degradation led us to undertake this effort as well.

6. PRINCIPLE OF SELF BALANCING MECHANICS

In self-balancing mechanics, sensors and control systems are used to keep an object stable in an upright position—like a bicycle without the need for outside assistance. These are the main ideas that underpin self-balancing mechanics.
1. Fundamental Ideas:
Angular Momentum: A rotating object's rotational motion is quantified by its angular momentum. The rotational speed and moment of inertia of the item determine the magnitude of the angular momentum vector, which points along the axis of rotation.
Gyroscopic Effect: A gyroscope has a tendency to resist changes in its axis of rotation while it is rotating. Gyroscopic stability is the name given to this resistance. The gyroscope is more stable the quicker it rotates.
2. Feedback systems and sensors:
Accelerometers and Gyroscopes: The angular velocity is measured by these sensors.

7. HOW DOES SELF BALANCING MECHANISM WORKS ?

The concepts of angular momentum and gyroscopic effect underpin the operation of gyroscopic balance. The following explains how it functions:

1. Spinning Gyroscope: A gyroscope is made up of a rotor, which is a disk or wheel, placed such that it may rotate quickly around its axis. Rotating objects generate angular momentum.
2. Resistance to Tilt: The spinning gyroscope resists tilting and does not simply tilt in the direction of the applied force when an external force tries to tilt its axis. Instead, it undergoes a response known as precession as a result of the conservation of angular momentum. The gyroscope's axis moves perpendicular to the direction of the applied force due to precession.
3. Precession: The relationship between the rate of precession and the angular

8. CALCULATIONS FOR SYSTEM DESIGN

Parameters	Measurement	Unit
Mass of Bicycle	12	Kg
Mass of flywheel	3.5	Kg
Additional weight on Bicycle	15	Kg
Height of CG of Bicycle from Ground	0.5	Meter

Table -1: component specification

m = mass of the bicycle = 12 kg
m = mass of the flywheel = 3.5 kg
Additional weight on bicycle = 15 kg

For Tilt angle 15 degree,
Torque=Mghsin (Θ) = 30.5*9.81*0.5*sin(15)
(maximum tilt angle is considered 15 degrees)
Torque = 38.72 Nm

To counteract the deflection in the centre of mass of the body we need to equalize the centrifugal force produced by the flywheel to potential energy reduced by the deflection.
Angular velocity required to lift the bicycle upright
V^2 = u^2 + 2*g*h
As initial velocity is 0,
Therefore
u=0
V^2 = 2*9.81*0.5
Therefore,
V = 3.14 m/s
Wp = V/r= 3.13/0.5 = 6.26 rad/s
I = mr^2/2 = 3.5*0.1^2/2
I =0.0175 kg.m^2
T = I*w*Wp 38.72 = 0.0175*w*6.26
w = 353.44 rad/s
N= 353.44*60/2*3.14
N= 3377 rpm
Motor of rpm 3500 is required.

For Tilt angle 10 degree,
Torque=Mghsin (Θ) = 30.5*9.81*0.5*sin(10)
Torque= 25.97 Nm
To counteract the deflection in the centre of mass of the body we need to equalize the centrifugal force produced by the flywheel to potential energy reduced by the deflection.
Angular velocity required to lift the bicycle upright
V^2 = u^2 + 2*g*h
As initial velocity is 0, therefore
u=0
V^2 = 2*9.81*0.5
Therefore,
V = 3.14 m/s
Wp = V/r = 3.13/0.5 = 6.26 rad/s
I = mr^2/2 = 3.5*0.1^2/2
I =0.0175 kg.m^2
T = I*w*Wp 25.97 = 0.0175*w*6.26
w = 237.06 rad/s
N= 353.44*60/2*3.14
N= 2263 rpm
Motor of rpm 2300 is required.

For Tilt angle 5 degree,
Torque=Mghsin (Θ) = 30.5*9.81*0.5*sin(5)
Torque = 13.03 Nm
To counteract the deflection in the centre of mass of the body we need to equalize the centrifugal force produced by the flywheel to potential energy reduced by the deflection.
Angular velocity required to lift the bicycle upright
V^2 = u^2 + 2*g*h
As initial velocity is 0,
Therefore,
u=0 V^2 = 2*9.81*0.5
Therefore,
V = 3.14 m/s
Wp = V/r = 3.13/0.5 = 6.26 rad/s
I = mr^2/2 = 3.5*0.1^2/2
I =0.0175 kg.m^2
T = I*w*Wp 13.03 = 0.0175*w*6.26
w = 118.94 rad/s
N= 118.94*60/2*3.14
N= 1135 rpm
Motor of rpm 1200 is required.

For 0 degrees As sin(0) = 0,
at last we get required RPM=0,
But in order to reduce motor torque we assume,
N=500 rpm
For, tilt angle= 0 degree

Calculation for motor selection,
T= I* α
To find α,
α = W1-W2/T = 1400-500/5 = 180
Now,
T= 0.0175*180
T =3.15 Nm
So the motor of Torque=3.15 Nm and N=3500 rpm is selected.

Tilt Angle (Degree)	Motor speed (RPM)
0	500
5	1200
10	2300
15	3500

9.COMPONENTS OF SYSTEM

1.SmartElex 15S DC Motor Driver 15A (30A Peak):
• Supply Voltage: 6.8-30 VDC.
• Continuous Current: 15 Amp.
• Max Peak current: 30 Amp(For 10 Seconds).
• PWM Frequency: 20 KHz.
• One brushed DC motor Bidirectional control.

Figure-1: Motor Driver.

2.Spoinkky MPU-6050 Module 3 Axis Gyroscope
• Features three-axis gyroscope and three-axis accelerometer
• Communication modes: Standard iic communications protocol
• Chip built-in 16bit ad converter with16-bit data output
• Gyroscope range: 250 500 1000 2000°/s.

Figure-2: Gyrosensor.

3.Robodo SEN4 IR Infrared Obstacle Avoidance Sensor, E18-D80NK:
• Effective distance: Adjustable from 3-80cm
• Electrical characteristics u: 5vdc i: The 100ma
• Angle: More than 15 degree

Figure-3: IR Proximity sensor.

4.Display Unit:
• 16 x 2 Character LCD display module.

Figure-4: Display Unit.

5.Serial Module:
• IIC I2C Serial Interface Board Module.

Figure-5: Serial Module.

6.Battery:
• Capacity: 7.5 Amp
• Voltage: 12v

Figure-6: Battery.

7. DC Motor:
• Speed: 5000 RPM
• Voltage: 12V, HP: 60 Watts

Figure-7: DC Motor.

10. SYSTEM CODE

```
#include<Wire.h>
#include<LiquidCrystal_I2C.h>
#include<MPU6050.h>;    //Pin 9 is connected to OCR1A
MPU6050 mpu;
#define sensor 2
#define dir 8
#define pwmPin 9

Float Xvalue;
int rpm=0;
int i=0;
unsigned long millisBefore;
volatile int objects;
LiquidCrystal_i2Clcd (0x27, 16, 2)

Void setup ()
{
Serial begin (9600);
lcd begin ();
lcd backlight ();
lcd print("SELF-BALANCING");
lcd setCursor(0,1);
lcd print("TWO-WHEELER");
delay(2000);
lcd clear();
attachInterrupt(digitalPintoInterrupt(2), count, FALLING);
delay(1000);
pinMode(2, INPUT);

while(!mpu_begin(MPU6050_SCALE_2000DPS,
MPU6050_RANGE_2G))
{ Serial_println(" Could not find a valid MPU6050 sensor, check wiring!");
delay(500);
}
checkSettings();
pinMode(numPin, OUTPUT);
pinMode(dir, OUTPUT);
digitalWrite(dir, HIGH);
//Stop the timer
TCCR1A= 0;
```

```
TCCR1B= 0;
TCNT1= 0;

//Set Fast PWM mode with ICR1 as TOP
TCCR1A = (1<<WGM11);
TCCR1B|=(1<<WGM12)|(1<<WGM13);

//Set ICR1 to define the PWM frequency
// ICR1 = (16,000,000/(32,000*1))-1=499
ICR1= 499;

//Set the duty cycle to 50%(OCR1A=ICR1/2)
OCR1A= 249;

//Enable output compare match A mode
TCCR1A|= (1<<COM1A1);
}
void chechSettings();
{
Serial_println();

Serial_print(" * Sleep Mode:  ");
Serial_println(mpu_getSleepEnabled()?"Enabled": "Disabled");

Serial_print(" * Clock Source:  ");
Switch(mpu_getClockSource())
{
case MPU6050_CLOCK_KEEP_RESET. Serial_println("Stops the clock and keeps the timing generator in reset");break;
case MPU6050_CLOCK_EXTERNAL_19MHZ: Serial_println("PLL with external 19.2MHz reference");break;
case MPU6050_CLOCK_EXTERNAL_32KHZ : Serial_print;n("PLLwith external 32.768kHz reference"): break;
case MPU6050_CLOCK_PLL_ZGYRO: Serial_println("PLL with Z axis gyroscope reference"); break;
case MPU6050_CLOCK_PLL_YGYRO: Serial_println("pll with y axis gyroscope reference"); break;
case MPU6050_CLOCK_PLL_XGYRO: Serial_println("PLL with X axis gyroscope reference"); break;
case MPU6050_CLOCK_INTERNAL_8MHZ: Serial _println("Internal 8MHz oscillator "); break;
}

Serial_PRINT("* Accelerometer.");
Switch(mpu_getRange())
{
Case MPU6050_RANGE_16G: Serial_println("+/-16g"); break;
Case MPU6050_RANGR_8G: Serialprintln("+/-8 g"); break;
Case MPU6050_ RANGE_4G Serial_println("+/-4g"); break;
Case MPU6050_RANGE_2G Serial_println("+/-2g"); break;
}
}
Void loop()
{
Vector rawAccel = mpu_readRawAccel();
VectornormAccel=mpu_readNormalizeAccel();
If(millis()- millisBefore>1000)
{
Rpm=(objects/4.0)*60;
Objects=0;
millisBefore=millis();
}
Delay(100);
//Serial_print("Speed:");
//Serial_println(rpm);
Lcd_setCursor(0,0);
Lcd_print(rpm);
Lcd_print("  ");
Lcd_setCursor(0,1);
Lcd_print(normAccel_XAxis-0.1);

If((normalAccel_Xaxis-0.1)>=2 or (normalAccel_XAxis-0.1)<=-2)
{i=360;
}
Else if((normalAccel_XAxis-0.1)>=1.5 or (normalAccel_XAxis-0.1)<=-1.5)
{i=360;
}
Else if((normalAccel_XAxis-0.1)>=1 or (normalAccel_XAxis-0.1)<=-1)
{i=240;
}
Else if((normalAccel_XAxis-0.1)>=0.5 or (normalAccel_XAxis-0.1)<=-0.5)
{i=140;
}
Else if((normalAccel_XAxis-0.1)==0 )
{i=50;
}
OCR1A = I;
}
Void count()
{objects++;
}
```

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11.DESIGN AND ASSEMBLY OF MECHANICAL SYSTEM

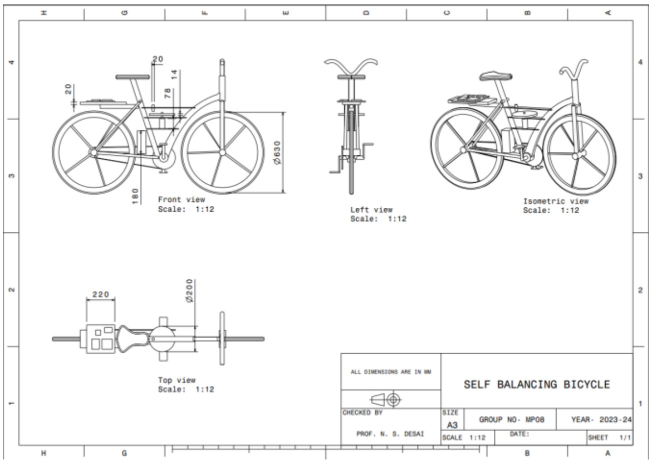

Figure-8: Design And Assembly.

Figure-09: Assembly Of Mechanical System-1

Figure-10: : Assembly Of Mechanical System-2

12 .DESIGN AND ASSEMBLY ELECTRONICS SYSTEM

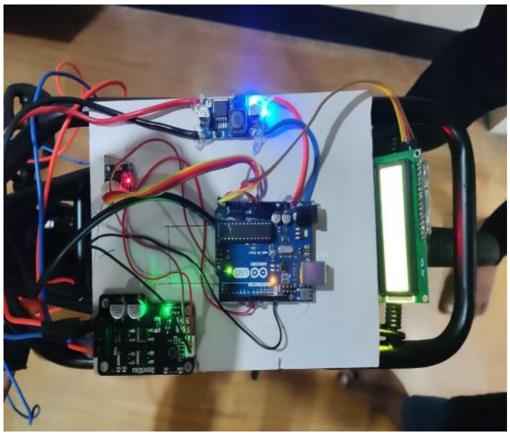

Figure-11: Assembly Of Electronics System

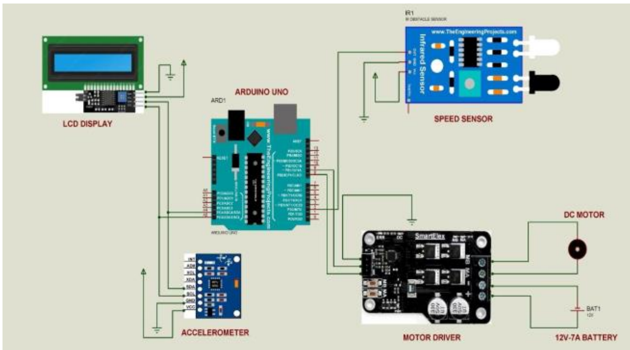

Figure-12: Circuit Of Electronic System

13.CONCLUSION AND FUTURE ENHANCEMENTS:

The self-balancing bicycle project has reached a major milestone with its completion. a turning point in the research and use of sophisticated control systems and sensor integration. By carefully planning, creating, and testing our product, we have effectively produced a prototype that effectively illustrates the fundamentals of self-balancing mechanics in an actual situation.

- Key Achievements:

Innovative Design: To achieve dynamic stability, we integrated essential parts including gyroscopes, accelerometers, microcontrollers, and motors into a sturdy mechanical and electronic framework. Advanced Control Systems: By continuously modifying the bicycle's orientation in response to real-time sensor data, the Proportional-Integral-Derivative (PID) control system has been shown to be effective in maintaining balance. Successful Integration of Sensors: Accurate and responsive data were obtained by the use of accelerometers and gyroscopes, enabling precise adjustments to offset imbalances.

Effective Prototyping and Testing: We were able to improve the self-balancing bicycle's overall performance and dependability by refining the system and addressing issues through our iterative approach to prototyping and testing.

- Project Outcomes:

Deepened Understanding: The project improved our comprehension of the intricate relationships between ssoftware algorithms, electrical control, and mechanical design that are present in self-balancing systems. Application in Practice: By effectively demonstrating theoretical ideas in a real-world setting, the development of a self-balancing bicycle helps to close the knowledge gap between academia and practical application.

- Basis for Future Work:

The knowledge acquired and the technologies created throughout this research provide a strong basis for subsequent developments. Potential research topics include boosting the system's resilience against different disruptions, investigating alternative sensor technologies, and optimizing the effectiveness of the control algorithms.

- Challenges and Lessons Learned:

Complexity of Integration: Combining software, electronics, and mechanical components presented many difficulties, highlighting the necessity of interdisciplinary cooperation and extensive testing.
Sensitivity to Disturbances: The necessity of adaptive control strategies was brought to light by ensuring the system's resilience to outside disturbances such uneven terrain and abrupt movements.
Iterative Improvement: The iterative character of the development process highlighted the importance of ongoing testing and improvement, enabling us to swiftly resolve problems and make small but significant system improvements.

- Future Directions:

Future work may concentrate on miniaturizing the components for a more compact design and enhancing the control algorithms for quicker reaction times.
Improved User Interface: By creating a user-friendly interface, usability and accessibility of the system parameters monitoring and altering might be increased. Product development and commercialization may be facilitated by investigating the self-balancing bicycle's commercial viability, including prospective market applications and user demographics.
To sum up, the self-balancing bicycle project has been a fruitful and educational undertaking. The practical application of a self-balancing mechanism not only shows that these systems are feasible, but it also creates new opportunities for robotics and personal transportation innovations. We are enthusiastic about the possible developments and uses that this foundational work may lead to in the future.

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