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# Review on Methods of Self-Balancing of Two Inline Wheels

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***Abstract:** Self-balancing of two inline wheels has been a problem for many years for researchers and engineers. Many attempts have been successfully made to achieve self-balancing in two-wheelers by using the gyroscope. This paper illustrates on different techniques of gyroscopic stabilization in a two inline wheels system & some of the recent modern technology to achieve self-balancing in two-wheelers. The factors which affect balancing are mass distribution, the center of mass of the system, steering of the vehicle towards left or right, acceleration & most importantly gyroscopic effect. Most of the projects are based on balancing by using reaction wheel or flywheel which uses sensors along with PID controller, some other sensors such as Control Moment Gyro (CMG) are also being developed & used for analysis. Some projects include the concept of gyro wheel which use precession to avoid misbalancing. We have also studied various models of self-balancing where researchers did not use gyroscopic effect. Hondas Riding assists bike incorporating advanced robotics is an example of such system.*

***Keywords:** Proportional Integral Derivative Controller; Control Moment Gyro; Kalman Filter; Gyrowheel; Gyroscopic Effect.*

## I. INTRODUCTION

Two wheeler vehicles are one of the most growing transportation and traveling system in the modern world. However balancing of two-wheelers has been the problem as it regards to drivers safety and its stability under different variable conditions such as acceleration, the angle of tilt of vehicle, road conditions, the path of curvature. This problem of balancing is solved by using gyroscopic effect. The gyroscopic effect occurs in a spinning wheel or disc in which the axis of rotation is free to assume any orientation by itself. When rotating, the orientation of this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum. Because of this, gyroscopes are used for measuring or maintaining orientation. The reactive couple to which disc is subjected when the axis of spin rotates about the axis of precession is known as a gyroscopic couple. The reactive gyroscopic couple helps to balance the vehicle against the external disturbing couple. This phenomenon is used in airplanes, naval ships for steering, pitching & rolling

Self-balancing can be one of the future technologies developed for the transportation system. Self-balancing is broadly classified into two types, active balancing, and passive balancing, active balancing is incorporated in the system by use of extra supporting wheels or counterweights to have a center of mass of lying on these weights. While passive balancing is achieved by using a gyroscope to produce a reactive gyroscopic couple.

 

## II. AUTOMATIC BALANCING BICYCLE BY USING REACTION WHEEL OR FLYWHEEL

The Automatic Balancing bicycle will employ a control system to keep itself from falling over while in motion, and to be propelled by a motor. This system is designed to build a two that inline-wheel bicycle prototype capable of balancing itself using reaction wheel. This robotic bicycle is able to drive and also come to a complete stop without losing its balance. In order to maintain balancing, the robot reads sensor input to detect tilt angle and correctly reacts to maintain a steady vertical position. Sensor data is fed into a control system which outputs a balancing torque to a motor spinning the reaction wheel. The requirements include that the bicycle should be capable of accelerating, driving in a straight line and stopping without falling. Gyroscope & accelerometer are employed in this system to read bike's tilt angle and its motion dynamics. They are fed through a complementary filter to reduce noise and a proportional integral derivative (PID) controller is used to achieve modulated control.

The flywheel design has several advantages. This design is very stable; the bicycle can balance even in a stationary position. The mathematical model of this system is not complex. As a result of the relative math simplicity and the ease of starting and stopping, the controller would be relatively straightforward to implement. This design would also allow the bicycle to travel in a relatively straight line with only small deviations.

One of the main disadvantages of this design is that it does not likely permit easy steering, especially for higher speeds, considering that the PID gains will be optimized for straight-line travel. Also, the frame would have to be altered, causing the design to look less similar to a bicycle than others.

## III. GYROSCOPIC STABILIZATION BY USING CONTROL MOMENT GYRO (CMG)

Control Moment Gyro (CMG) consists of a spinning rotor with large, constant angular momentum, but whose angular momentum vector direction can be changed with respect to bicycle by rotating the spinning rotor. The balancing is achieved by using CMG, a PID controller for feedback and an IMU sensor to detect roll angle. The spinning rotor is mounted on a gimbal, and applying torque to the gimbal results in a precessional, gyroscopic reaction torque orthogonal to both the rotor spin and gimbal axes. The CMG is a torque amplification device because small gimbal torque input produces large control torque on the bicycle.

An IMU sensor would detect the roll angle. This roll data is feed to an onboard controller which in turn will command to the CMG's gimbal motor to rotate such that a gyroscopic precession torque is produced to balance the bicycle to an upright position. The system uses a single gimbal CMG and generated only one axis torque.

The advantage of such system is that it is capable of producing a large amount of torque and has no ground reaction forces. The disadvantage is that such system consumes more energy and is heavier.

## IV. ERROR REDUCTION BY USING POSE ALGORITHM ESTIMATION OF BICYCLE

The automatic self-balancing bicycle uses accelerometer and gyro sensor to control its flywheel direction and speed. They are integrated together with complimentary Kalman filter for feedback control. In this new method by which the error of two self-balancing robot sensors can be reduced and it avoids the use of traditional Kalman filter which cannot meet real-time modulation. A correction algorithm can come out real-time robot posture in the right way according to the characteristics of navigation sensor error from the iteration of nonlinear least-squares error model based on the method Dynamic Regulator. By computer simulation, an error through the gyro and accelerometer can be corrected. Kalman filter fused the data of gyroscope and accelerometer adaptation and errors of the sensors pose estimation can be corrected. The mathematical derivation of Dynamic Regulator shows that this method of reducing posture estimation error is feasible and effective, and can achieve better accurate estimates inexpensively.

Dynamic Filter estimates the state of the process and measurement noise and feedback. The feedback control provides an efficient recursive solution to solve the minimum mean square by the feedback correction of optimal estimation of nonlinear optimal estimation of the final state vector. The main idea of inertial sensor data fusion is the use of gyroscopes and accelerometers different error characteristic information collected in order to correct their mistakes. Optimal estimation of the two robot pose is obtained by the Dynamic Regulator and gyro bias calibration, automatic tracking deviation.

## V. SELF-BALANCING BY USING GYROWHEEL

Gyrowheel essentially has a gyroscope inside. Gyroscopes are spinning wheels that exhibit a special property called precession. When a force is put at the top of a spinning wheel (such as a rider falling on a bicycle), rather than falling, the gyroscope simply turns, or processes, in the direction of the fall. This occurs on normal bike wheels when the bike is traveling at higher speeds. Hence, it is easier to ride after gaining momentum. Gyrowheel takes advantage of this property even when the bike is moving slowly. The disk inside gyrowheel spins independently of the bike wheel. Thus, even when a rider is moving very slowly on the bicycle, the precession of gyrowheel is still felt. If the rider begins to fall, gyrowheel precesses under the rider's weight, restabilizing the bike.

Essentially all gyros are just a device in which something has some rotational movement, and which generates a measurable signal when an external torque is applied to it.

There are a few different kinds:

### *A. Traditional Gyros*

It is a wheel that is driven by a motor. Its gyroscopic forces that help bicycles and motorbikes stay up (or lean into corners). If a gyroscope is mounted inside three sets of gimbals it can be set up so that it always points in the same direction no matter how the thing it's attached to moves. It acts like a gyrocompass, which is still used on things like ships. They're very accurate but big, bulky and slow to initialize.

### *B. Strapdown Gyros*

Strapdown gyros don't need gimbals, they're used in sets of three mounted in the x, y, and z directions and move with the thing they're attached to. The main kind is ring laser gyros, which is used in modern aircraft and spacecraft. They shoot two lasers in opposite directions around a ring in such a way that they set up a standing wave when they interfere. If something makes the gyro spin it will ever so slightly change the wavelength of the lasers and that shows up as a change in the standing wave.

Ring laser gyros have the advantage of not using gimbals, so they don't suffer from gimbal lock, they're faster to set up, lighter and more compact. They aren't as accurate as spinning gyros though and aren't north-seeking, so they can only tell the amount of movement, which is not quite the same as knowing exactly which way you're facing. In practice, that means the system needs to get an accurate fix from something like GPS every so often to zero the errors.

## VI. RECENT TRENDS IN SELF-BALANCING

### *A. Self-Balancing without Gyroscopic Effect*

A riderless bicycle can automatically steer itself so as to recover from falls. The common view is that this self-steering is caused by gyroscopic precession of the front wheel, or by the wheel contact trailing like a caster behind the steering axis. Using linearized stability calculations, a bicycle with extra counter-rotating wheels which cancels the wheel spin angular momentum and with its front-wheel ground-contact forward of the steering axis (making the trailing distance negative) it is self-balanced. When laterally disturbed from rolling straight this bicycle automatically recovers to upright travel. The results show that various design variables, like the front mass location and the steer axis tilt, contribute to stability in complex interacting ways.

### *B. Honda Riding Assist Bike*

Honda Riding Assist basically uses technology that allows the motorcycle to balance itself in slow speeds without the use of gyroscopes. This is achieved essentially by raking out the motorcycle's front forks and then moving the front wheel back and forth - just like cyclists do to balance themselves at extremely slow speeds.

The most self-balancing technology uses gyroscopes, but that adds a lot of weight, which could limit a motorcycle's ability to maneuver. Instead, the Honda Riding Assist motorcycle leverages the company's Robotics technology. When engaged, the system increases the fork angle of the front suspension lengthening the bike's wheelbase and, disconnecting the front forks from the handlebars. The system then uses minute steering inputs to keep the bike perfectly balanced, without the use of heavy gyroscopes or other mass-shifting devices.

## CONCLUSION

Of all the above methods explained above, gyroscopic stabilization seems to be cost effective & easy to implement on two-wheelers. But, the addition of gyroscope increases the weight of system & it does not permit easy steering. Similarly, gyroscope and accelerometer require the more refined integrated system to achieve proper control. On another side, balancing without using gyroscope seems to have more design stability & it also permits to easy steering and controls, thus in near future, this such system can prove to be more effective than balancing by using gyroscopic effect.

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