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Models for Self-Balancing of Two Wheeled Vehicles: A Review

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Abstract: In this paper, we have studied the various models, techniques and principles of Self-balancing of two wheeled vehicles. Balancing a two-wheeledvehicle has always been a challenging task.The motion dynamics of a bicycle is very different from other vehicles. Unlike four wheeled or three wheeled vehicles, a bicycle lacks lateral stability when stationary, although bicycles are stable when in motion. Experiments and calculations conclude that a bicycle stays upright when it is steered to maintain its center of mass over its wheels. Either the rider steers to balance the bicycle or the bicycle itself balances above a definite velocity. Factors such as gyroscopic effect, centre of mass, mass distribution contribute in self-stability of bicycle. Numerous projects have been proposed keeping in mind the stability of two wheeled vehicles. Some projects use the concept of flywheels[1] while some use two heavy rotating disks for stability [2]. Most of the projects are based on the concept of inverted pendulum [3][4] and use PID controllers [5] to achieve self-stability. Gyroscopic sensors [4][6][7] are used in some projects which detect the angular tilt followed by a motor to achieve balance.

Keywords- *Self-balancing, lateral stability, velocity, gyroscopic effect, motion dynamics*

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1. INTRODUCTION

Bicycle is a very common form of workout, fun activity and transport medium used by billions of people around the world. It can also be used to improve strength, stamina and coordination. Bicycle can be used to train balance. Generally riding a bicycle seems to be a very simple task, but there are people for whom balancing becomes very difficult. The categories where balancing becomes difficult areold people, little children, injured people and people with physical disabilities.Technology which keeps the ease of riding a bicycle and helps in balancing could be a life savior for such groups of people. Balancing a bicycle is similar to balancing an inverted pendulum. An inverted pendulum has its center of mass above its axis. An inverted pendulum is unstable unlike a normal pendulum, and must be balanced to remain upright. In the case of a bicycle, the bicycle is a rigid structure which can rotate around its point of contact with the ground. A bicycle motion has variable motion dynamics. Bicycle tilt around a point of contact is the area where this research is centered.

Self-Balancing Bicycle can be future automated transport facility.There's a whole new science of how to balance bicycle. Well it turns out some bikes are actually quite good at balancing themselves.

2. EXISTING PROJECTS ON SELF-BALANCING OF TWO-WHEELED MODELS

Numerous projects have been done on self-balancing the two wheeled vehicles. We have studied the previous works based on different technologies and most of them have used gyroscope and PID control to achieve stability. In this section we briefly describe the working and principle of some of the previous projects on self-balancing.

3.1Autonomous AU Bicycle: Self-Balancing and Tracking Control[1]

An AU Bicycle Self-Balancing and tracking control is an autonomous bicycle robot developed at Assumption University. The project has beendivided into two parts. First is balancing control and second is tracking control. In this project a bicycle robot was developed whose balancing was achieved using flywheels.The direction of the flywheel is controlled which in turn controls the bicycle position. A navigation system was also implemented onto this robot. The project uses a compass to check the required direction and to check the steering position, an encoder is used. An encoder sensor is also added to detect the flywheel position and it controls the flywheel to be in horizontal position. Flywheel’s angle and the bicycle’s tilt angle is controlled using PD control.

3.2System Design of a two wheeler self-balanced vehicle[2]

The project discusses about the design of a two wheeler self-balancing car. The aim of this project is to balance a two wheeler against any impact and in zero velocity as well. Two heavy rotating disks are used around the frame to compensate the tilt of the vehicle and make it stable. The tilt angle of the chassis is measured by an android device using orientation sensor. The input is then sent to a bluetooth receiver which is connected to an arduino. The angle of tilt which is the input data is taken by an android application. The application then sends a control signal to the arduino accordingly. Using the inputs, tilt direction of the rotating disk is balanced by controlling the motor from the arduino. Two wheeler vehicles experience the greatest damage during an impact. The aim is to design a safe, inexpensive and fuel efficient vehicle.

3.3Development of a self-balanced Robot & its Controller[3]

The project is based on the principle of inverted pendulum configuration. A two wheeled robot was developed with similar configuration as a bicycle.The system itself is not stable on the vertical axis. Therefore, a gyrosensorsrequired to provide the angle position of the robot base and input into the microcontroller. The microcontroller provides a feedback signal through PWM control which in turn rotates the motor clockwise or anticlockwise for balancing the robot. Electro-mechanical mechanisms & control algorithms are the main focus required to enable the robot behave in real time.

3.4 Stabilizing controlof an autonomous bicycle[4]

A bicycle can be very closely related to an inverted pendulum. Inverted pendulum balancing is performed in a number of projects worldwide. To balancea rider-less bicycle, a stabilizing wheel is used and an IMU to ensure that the bicycle is always in the upright position and balanced. The tilt and angular velocity are measured along with the speed of the stabilizing wheel. The direction of movement of the stabilizing wheel compensates the tilt in the either direction.If the bicycle tilts towards left, the stabilizing wheel rotates in the clockwise direction and if the bicycle tilts to the right, the stabilizing wheel rotates anticlockwise.

The bike wheel uses a gyroscope. It uses common bicycle wheel, which reduces cost with a great amount. After installing this wheel the ground clearance is also reduced. The arrangement of the stabilizing wheel makes it a very odd structure to ride. The structure very efficiently balances the bicycle but makes it very difficult to ride. The size of the stabilizing wheel is a major drawback to this structure but can be reduced by replacing the material of the wheel used. Instead of using heavy steel wheel, a Tungsten, Osmium, or Lead disk can be used which can fit inside the frame. But still the design looks very odd and makes it very difficult to ride.

3.5 Dynamic Modeling and Control Design for a Self-Balancing Two-Wheel Chair[5]

Self-balancingtwo wheel chair is a very recent and innovative technology in the field of personal transportation modes. Like all other two wheeled models, self-balancing two wheel chair(SBC) also has unstable motion dynamics and requires technique to get stabilized. The model ensures steering and speed variation by the rider. Again the basis of this research is Inverted pendulum. Motor dynamics, wheel motion along with multi loop PID control is used to stabilize the SBC. The design of SBC is in the z-axis. The equations of rotating wheel and motor dynamics complements the equations of x-y direction.

3.6 Gyroscopic stabilization of a kid size bicycle[6]

Stabilizing kid size bicycle is again a project on self-balancing using gyroscope. This project uses a control moment gyroscope as an actuator for balancing. CMG is an altitude control device and is generally used in spacecraft altitude control systems. A spinning rotor and a motorized gimbal is present in the CMG. Motorized gimbals are used to tilt the rotors angular momentum. When the rotor tilts, the change in angular momentum produces a gyroscopic torque which balances the bicycle.

3.7 Design and Fabrication of Self Balancing Two Wheeler(Segway)[7]

The name of the technology that is described in this paper is Segway. It is based on gyroscopic lean detection. The basic structure of the model works in the z-direction and whenever the gyroscope detects that the rider is leaning forward, the speed of the wheels is adjusted accordingly and hence balance is achieved. The wheels of the device are attached to a motor which is connected to the control system of Segway. The gyroscopic sensors detect the motion of the rider and according alter the motor speeds to balance Segway.

3. COMPARISON OF THE EXISTING PROJECTS ON SELF-BALANCING

After going through different models on self balancing, we came to the following conclusion. All the existing projects use different and innovative approach to balance the model. Theproject which uses the idea of inverted pendulum has a model which is very much uncomfortable for a rider to ride the bicycle due to its complex design. Existing projects unfortunately increase the weight of the bicycle to as much as 35 kgs which is again a big shortcoming. Some projects have greater efficiency but they lack in the design. Projects on self- balancing can be compared on the basis of various parameters such as design, efficiency, weight and cost. Every model needs to be checked upon these parameters so

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as to develop the best. So far the existing techniques which have good efficiency unfortunately add a lot of weight to the model which is a disadvantage. And those who are at low cost are not that efficient. A model which does not alter the ease of riding a bicycle as well as does not increase the weight of the bicycle by a major factor and with high efficiency is not yet proposed.

4. PROPOSED IDEA

5.1Balancing by chain mechanism

To balance a bicycle, we need to do two things. First, we turn the handle in opposite direction of the tilt. Second, we shift the centre of mass according to the tilt. In our proposed model, the servo motors will be attached to a chain mechanism from one end and the other end will be attached to a sprocket which is in the same axis as of the axis of the handle. The movement of the sprocket turns the handle in the desired direction. PID controller is used for input data and output. The motors rotate in the desired direction resulting in the movement of the sprocket which further turns the handle of the bicycle in the desired direction. In short, if the bicycle is leaning towards left, the motor will move so as to turn the handle towards right and vice versa. The theory behind controlling this model is moving the handle of the model in the direction opposite to that the model is falling and hence keeping the center of gravity of the model vertically above the axis of the model wheels at all times. This way the model remains upright and does not topple over. The existing models have a numerous drawbacks which need to be overcome. Our model has a very good efficiency as compared to the previous models and not only this; it is light weight and low cost model. On the top of all of this the basic structure of a bicycle has been preserved in our model and the ease of riding a bicycle remains as it is.

5.2 Adjusting the center of mass using conveyor belt

The second part of our project is to adjust the center of mass according to the tilt. For this, we will use a conveyor belt to which weights will be attached. This assembly will be mounted on the rod below the bicycle seat so as to retain the position of center of mass. These weights will help in shifting the weight on either side. It is evident that the center of mass will shift to the left whenever the bicycle leans towards left and to the right if the bicycle is leaning towards right. The idea is to shift the weights on the conveyor belt in opposite direction of the tilt so as to keep the center of mass in the center.

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