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Self-Balancing Hover Integrating the Concept of Regenerative Braking and Gyroscopic Action

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Abstract- **There is an increasing need for an intelligent electrical transport system to combine ease of transportation with maximum efficiency. The self-balancing hover board model aims on providing a vehicle which balances itself and transports the load to different locations within a small area. Regenerative action is implemented to reuse the energy lost in braking. This can be done by using the concept of regenerative braking. A certain amount of kinetic energy is wasted as frictional and heat energy when brakes are applied, which can be used for other purposes within the vehicle like headlights, infotainment, etc. The main aim of this project was to develop a vehicle that stores the energy which is otherwise lost during braking. Electric Motor, when used as a generator is used to convert kinetic energy into electrical energy.**

Keywords- DC motors, Arduino microcontroller, gyroscope, accelerometer, regenerative action, self-balancing

I. INTRODUCTION

Over the few years, automatic robots have seen a boom in application in industrial settings, hospitals and as personal aids also.

The self-balancing hover board, concept of two-wheel inverted pendulum has gained momentum in research over the last few years. Inherently it is unstable and would roll over the wheel's rotation axis without any external control and eventually fall. The hover returns to a correct stable position if motor driving it moves in the correct direction. An electromechanical system developed helps the platform balance on a pair of wheels and remain in the vertical up-right position, without falling off.

A PID controller is commonly used to control the balance of the robot. Gyroscopes can deliver a major contribution towards stabilization of two wheeler vehicles. A gyro sensor provides the PID controller with the angular position of the base (or platform) of the robot with respect to the vertical axis. The PID controller drives the motor in two directions either clockwise or anticlockwise depending on the position of the platform with respect to the vertical axis, or the way in which the robot is falling.

To determine this change the angles provided by the gyro sensors are used. Pulse width modulation (PWM) is used as a control signal here as the motor is of low capacity.

A gyro chip is needed to provide the PID controller with the angular position of the base of the self-balancing hover with respect to its stable vertical axis. An algorithm for the self-balancing of the hover is programmed in the Arduino which implements the PID controller. The PID controller is used to drive the motor forward/ backward or clockwise/anti-clockwise [1]. Pulse width modulation (PWM) is used as the control signal. The hover has to move smoothly upon any type of surface using only the two motors.

II. PRINCIPLE OF REGENERATIVE BRAKING

Electric vehicles are a great alternative to traditional internal combustion engine vehicles. When brakes are applied in a vehicle, the kinetic energy is converted to heat energy due to friction. This heat energy cannot be captured and thus useful energy is wasted. Regenerative braking is used as a way of recouping energy during braking. It is the process of feeding energy from the motor drive into the battery during the braking process.

During braking the vehicles inertia allows to drive the motor as a generator. The battery is observed as a load during this period, thus providing with a braking force. Use of regenerative braking has many advantages such as increased driving range of up to 15%, higher efficiency, lesser maintenance along with a reduce in energy to propel the vehicle forward. For the system to be cost effective, parameters like initial cost, size and weight of the system need to be considered.

The battery or energy storage unit should also be compact, durable and capable of converting energy efficiently. Fig.1 A machine can work as a generator or motor depending on the input provided. If the input provided is mechanical and output obtained is electrical we term it as a generator. For an electrical input and mechanical output the machine is called a motor. In the prototype we implement a double H bridge circuit to drive the DC motor as a generator or a motor as required.

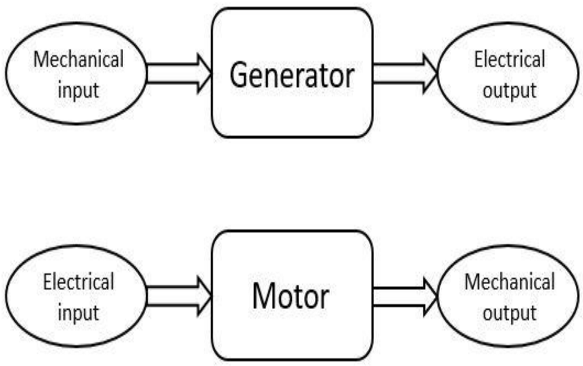

Figure 1. A machine can behave as a generator or motor depending on the input supplied and output obtained.

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III. GYROSCOPE

A gyroscope is a device used for measuring angle or maintaining orientation, based on the principle of preserving angular momentum [4]. It works on the principle of conversation of angular momentum. It consists of a spinning disk supported on an axis that is free to move on its own. Fig.2 when a force is applied to this spinning disk, a torque perpendicular to the spin axis makes the disk rotate about a third axis called the axis of precession. The axis of precession is perpendicular to the plane containing the spin axis and torque applied. As long as the disk is rotating the gyroscope will try to maintain its orientation.

Advantages of Gyro sensor -

1. MEMS version of gyroscopes are extremely small, lightweight and inexpensive. They make a much smaller stabilized system with great stability.
2. Gyroscope sensor resolution depends largely on spin rate of the rotor. Moreover it is much higher than other force or tilt sensors.
3. Gyroscope compass indicates true north as opposed to magnetic north unlike magnetic compass. Hence they are preferred sensor for high precision navigation systems.
4. It is fast in operation and measures relative orientation on all 3 axes.

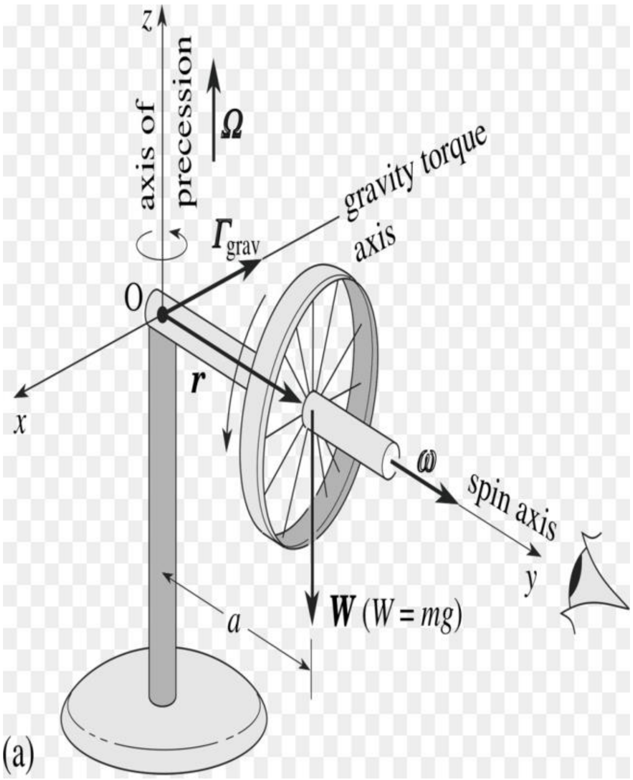

Figure 2. Vector diagram to understand the working of gyroscope [5].

IV. FLOWCHART OF THE MODEL DESIGNED

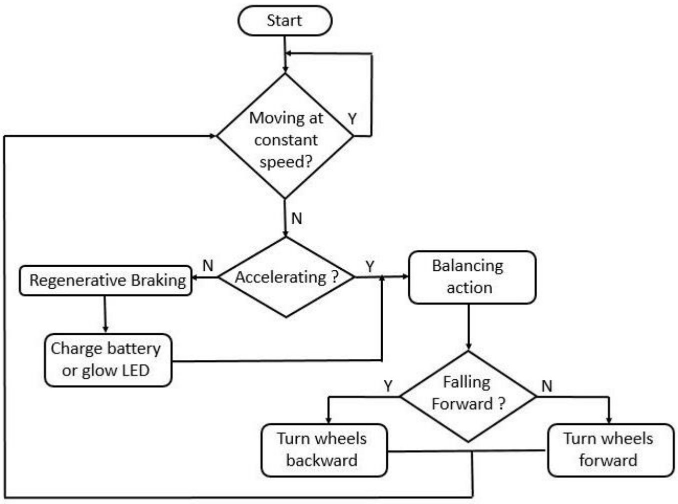

Figure 3. Flowchart for the working of the prototype/model

There are three ways in which the hover could move- it could accelerate, decelerate, or move at a constant speed.

If it travels at a constant speed, continue the motion. If not, check if the hover board is accelerating or decelerating.

In case of acceleration, the concept of regeneration does not come into picture as there is no braking action. Motors are fed by the battery through the capacitor.

In case of deceleration, brakes are applied and the supply from the source is cut off. Hence the motor supplies to the load due to the back emf present, behaving as a generator. The energy obtained is stored in the battery or may be used for other purposes. In the model here, the energy stored in the capacitor is discharged and the power obtained is seen as the LED glows. In case of higher rating components, we could use this regenerated energy in auxiliary systems.

In both the cases, hover board must be balanced. Analyzing the hover position during imbalance, it is clear that it could fall either forward or backward.

If the hover board is falling forward, we rotate the wheels backward to stay in the equilibrium position. Similarly, if the vehicle falls backward, we rotate the wheels forward.

V. MECHANICAL MODEL DESIGNED AND IMPLEMENTED

The mechanical model designed consists of a base with a pair of DC motors. Motors are chosen to be of smaller rpm value (geared motors) to ensure high more torque, which helps handle higher load and smooth control of speed.

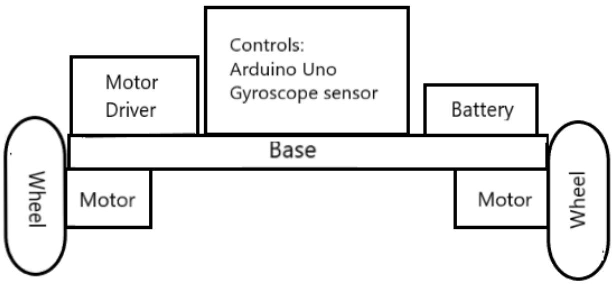

Figure 4. Mechanical model design of the prototype

Motor driver controls the direction of rotation of the motors according to the action to be performed- motoring or braking. The gyroscopic sensors were used to balance the hover if it falls beyond a predefined angle. The controls for both these components are given using Arduino Uno. Batteries of suitable voltage is used to supply input power to the controls and motors.

Charging and discharging of a capacitor (which causes the LED to glow) takes place during motoring and regenerative braking action respectively. When implemented on a real life-size vehicle, the energy obtained can be used for headlights, infotainment, or other secondary functions.

VI. RESULTS OBTAINED

Figure 5. Final prototype/model of the hover board

TABLE I. FINAL DESIGN VALUES OF PROTOTYPE OF HOVER BOARD

PARAMETERS	VALUE
Dimensions (cm x cm x cm)	26.5 x 11 x 13
Weight (kg)	1.24
Running time (min)	35
Voltage Regenerated (V)	3

VII. APPLICATIONS

- Manufacturing industries for transportation of heavy materials from one workstation to another.
- Space exploration; for image capturing on uneven terrains of planets.
- ‘Helping vehicle’ for the elderly; it can be used by the elderly for balancing and transporting simple items.
- Balancing instrument trays during surgeries in hospitals.
- In mines and locations where humans are at risk, it can be used to carry materials, helping reduce human labor.

VIII. CONCLUSION

The vehicle balances itself under various conditions like forced tilt of the vehicle. The regenerative braking system helps in utilization of part of the energy that would have otherwise been lost during braking. Theoretically, up to 30% of the energy delivered can be recovered for a larger system. However, with this prototype demonstration being of a smaller scale, the energy recovered is almost 12%.

Regenerative braking systems requires further research to develop a system that captures energy more efficiently. All vehicles in motion can benefit from these systems if the energy can be recaptured and reused. Future technologies will include new motors which will be more efficient as generators and electric systems that have lesser energy losses.

A few limitations encountered during the project were related to size and balancing of hover, the amount of energy obtained due to regenerative process being too small due to low rpm motors used. Higher rpm motors would not allow smooth balance of hover board and hence we needed to optimally draw a line and use the geared motors. The flywheel concept to balance a two-wheeler is popular but inefficient for our project since the flywheel is heavy and continuously rotating, dissipating more energy than what would be obtained from regenerative action. Further research can be done in this domain to come up with various solutions.

IX. REFERENCES

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