Sensorized Self-Balancing Electric Vehicle

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***Abstract*- This Review Paper focuses on a battery powered Electric vehicle which self-balances with the help of sensors.It is designed for personal transportation but has its applications in security and military fields as well. A machine is designed with an electronic control system to make an inverted pendulum remain upright. Inverted pendulum is our system which will be used in a machine. By dynamically driving a motor which moves the axle along a track according to the motion of the vehicle, the vehicle will be prevented from falling from the upright position. As the system is unstable, control algorithm is developed and implemented digitally with the help of microprocessors (Arduino) and different sensors. With the increasing trend in global warming, this electric vehicle curbs the use of fuels and thus greenhouse gases. Cycles have limitations when being used indoors or for senior citizens for travelling uphill. Thus electric vehicles with minimum human mechanical efforts are being developed. Thus the objective of the project is to design &deliver zero pollution, compact, effortless, sensorized and a cost effective vehicle, without compromising on safety.**

Keywords*- *Electric vehicle, self-balances, personal transportation, inverted pendulum, zero pollution, self sensorized.

I. INTRODUCTION

As the price of petroleum products is increasing now-a-days, there is a need for cheaper and more efficient form of transport. In addition, saving energy in order to resolve the problem of fossil fuel depletion is becoming increasingly important. To overcome this problem, research on ecofriendly transportation has been increased. Manufacturers have a great need for competence in the field of hybrid or electrical vehicle technology as a step towards fulfilling these goals.

In 2001 Dean Kamen invented the Segway Personal Transporter with the intention to revolutionize city transportation. The Segway PT is a two-wheeled, sensorized, self-balancing, battery-powered electric vehicle. It works on the principle of inverted pendulum and employs the use of electromechanical components which can be used as a means of transportation for a single person. The two wheeled, vehicle is a non-linear multi-variable and naturally an unstable system. Controlling such a system is a hard task and thus it is the topic of research. It will move forward if the user tilts in forward direction and backward if the user tilts in backward direction.

In balancing the vehicles where pitch angle is of interest the accelerometer is used to measure the orientation of the vehicle with respect to gravity. To measure the angular rate of an object with respect to an inertial system, a gyroscopic sensor (gyro) is used.

A rider holds the steering handle while standing. The vehicle through an onboard-control system balances itself as well as responds to commands implied by the movement of the rider. For example, if the rider leans in the forward direction then the vehicle will accelerate in the forward direction and vice versa. By tilting the steering, we can take left and right turns. Accelerometer and gyro sensors are used to make tilt angle estimation. Today Segway is used widely because of its increased mobility, silent operation, smooth transition and portable nature. Segway provides a clean, fast and reliable alternative to traditional trucks, scooters and buses. Apart from this it is also eco-friendly.

The project is based on developing a similar personal commuter with similar methodology of operation but the original Segway is expensive for a college campus or even a mall for that case. Buying individual vehicles and giving them for rent or for personal use of the faculty or visitors is not feasible. Hence we have come up with a proposal to create a vehicle that is easily affordable, is equally safe and yet eco-friendly.

Fig.1

II. PROBLEM STATEMENT

The ever growing traffic expenses, the increase in the level of pollution, shortage of resources has made us to think of replacing the polluting vehicles with such which are environment friendly, economical and beneficial. This has led to the invention of Segway. Since its introduction, Segway has caused a good stir in the transportation community and general public. It has many applications such as for security purpose it can be used because of its silent operation, for commuting purpose, for large corporate parks it is easier to travel using a Segway in their campus. It reduces the impact of global warming by checking greenhouse gas output and fossil fuel consumption. If we are able to replace 10% of 900 million 3 mile car trips with the Segway PT there would be 6.2 million fewer gallons of gas consumed, 286 million fewer pounds of CO_2 emitted everyday.

III. PROPOSED SYSTEM

Figure2 shows the block diagram of self-balancing personal transporter. Control unit consists of a microcontroller. Micro controller process the data from the accelerometer and gyroscopic sensors. The motors used are controlled based on the data processed by the controller. The vehicle is to be built before it is controlled. The parts required to construct the vehicle are shown in fig1. It consists of components such as sensor modules, control module, motor drivers, motors and power supply modules, accelerometer & Gyroscope Sensor (MPU 6050): MPU stands for Motion Processing Unit.

Accelerometer and Gyroscope sensor: The MPU 6050 has 3 DOF accelerometers & 3 DOF Gyroscope Sensor. In the scooter the function of this sensor is to send the information about its current orientation to the Arduino. This information is in the form of yaw, pitch and roll angles. The sensor uses I2C Protocol for communication. It gets power from the 5V pin of Arduino.

Arduino Uno R3: Arduino Uno R3 is a microcontroller board based on the ATmega328P. Arduino gets power from the 5V pin of Motor Driver.

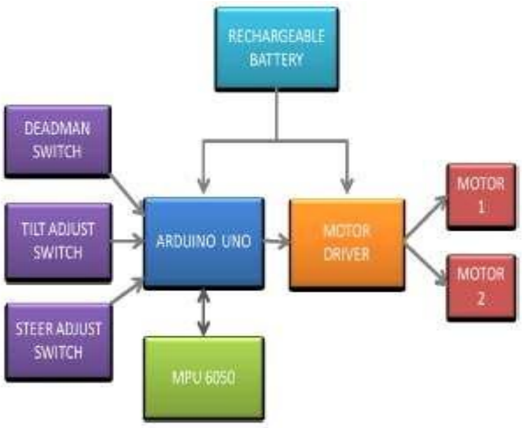

Fig.2 Block Diagram

Fig.3

Fig.4

The functions of the Arduino are as follows: – It has to receive the data sent from sensor. Arduino also receives data from Deadman's Switch, Tilt Adjust Switch and Steer Adjust Switch. It processes the data and depending on the conditions mentioned in the code, it provides necessary signals to Motor Driver.

Motor Driver: The Motor Driver/controller receives the signal sent by Arduino and generates current to drive the motors. Motor driver is required because Arduino doesn't have enough Voltage & current to drive the motors. The Driver operates on power from the batteries.

DC Motors: DC Motors are connected to the Motor driver. They rotate forwards/backwards to bring the Scooter back to balanced position. In order to achieve the better driving performance of the vehicle it is necessary to choose the motors that can handle system weight. For this purpose two high torque CIM DC motors are used which run with 12V DC supply.

Rechargeable Batteries: Rechargeable Sealed Lead Acid Batteries 'SLA' are used for easy maintenance and operation of Scooter. The Batteries can be easily charged through appropriate Charging Adapter.

Steer Adjust Switch: To control the direction of the scooter there is a Steer Switch. Pressing the switch in the left will cause the current through left wheel. So Right wheel moves faster and Scooter moves in left direction. Similar case is for turning right.

Dead man's Switch: This is a safety feature. As long as the dead man's switch is pressed the circuit is complete. But if the rider falls or loses control or any accident occurs, the contact with dead man's switch is lost and the circuit stops. Thus in case of any issues dead man's switch is helpful.

Tilt Adjust Switch: When Scooter is being tested and it is found that the platform/board tries to balance at a strange angle, you can use the tilt switch to change the reference.

IV. CONTROL STRATEGIES

The user interfaces will have control over the microcontroller and they feedback the vehicle status to the microcontroller. The controller reads the status information and controls the wheel movements accordingly. The system is powered through rechargeable battery. In this program structure, the readings from both the accelerometer and gyroscope sensors are sent to the controller. These are fused to get the exact tilt of the vehicle. To remove the high frequency distortion in the reading of the accelerometer it is passed through a low pass filter. The angular velocity obtained from gyroscope is integrated to obtain the angle and then passed through a high pass filter to remove the low frequency distortions. The result obtained from low pass and high pass filter are then summed to find the estimated angle. Controller receives commands from rider and controls the vehicle motion its direction. User can control the vehicle motion in 4 directions: Forward, Backward, Left and Right.

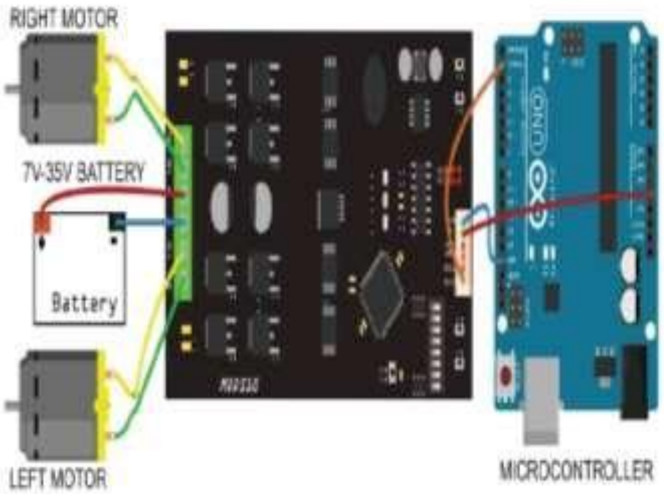

Fig.5.

In order to make the robot to move in these directions we should operate the motors as shown in table1.

TABLE I
DIRECTION OF MOTORS

Direction	Forward	Backward	Left	Right
Right Corner	Anti-clockwise	Clockwise	Clockwise	Anti-clockwise
Left Motor	Anti-clockwise	Clockwise	Anti-clockwise	Anti-clockwise

V. SWITCHES AND DISPLAYS

The user is able to control the behavior of self-balancing vehicle using a number of switches.These switches were incorporated into Self-balancing Electric Vehicle design to provide adequate safety for the rider. To complement the switches, visual feedback enables the user to easily determine which state EDGAR is in. Visual feedback of EDGAR is comprisedof three LEDs with the following functions:

- Green LED to indicate that power is on and EDGAR is ready to balance
- Blue LED to indicate that EDGAR is balancing
- Red LED to indicate low battery level

All three LEDs are connected to digital output pins on the microcontroller.

A resistor in series with each LED reduces the voltage from 5V to the LED's required 3.6V. The 'power on' and 'balancing' LEDs states are determined through the software on the microcontroller. The 'low battery level' LEDs state is determined using a voltage divider to interpret the 0-26V (completely flat to fully charged) battery level to the 0-5V range that the analog inputs of the microcontroller need. Using a voltage divider and the microcontroller is more desirable than a hard wired circuit as it allows adjustment of the low battery voltage threshold during testing.

These displays are mounted together on the upper side of the handlebar so that the rider can interpret the current status of EDGAR with nothing more than a glance. Arising from the aforementioned behavior, the following switches have been included in EDGAR's design:

- On/Off switch (doubling as a circuit breaker)
- Capacitive foot sensors to detect when a rider has a foot on the platform
- On/Charge switch (to ensure that EDGAR does not power up when the batteries are being charged)

1. on /off Switch

The on/off switch has been recessed into the rear of the fairing to prevent accidental power loss to EDGAR. This switch incorporates a 70A circuit breaker to ensure EDGAR is switched off in the event of an electrical fault. All power that EDGAR uses flows through this circuit breaker.

2. Capacitive Foot Sensors

Two capacitive proximity sensors are mounted in the platform that the riderstands on. They are located where the rider places their feet to detect when either or both feet are on the platform as discussed in Section 3. These sensors are normally high (12V) but switch to 0V when mass is placed above their front surfaces. These signals are reduced to 5V through voltage dividers before being fed into analog inputs on the microcontroller

3. On/Charge Switch

A second switch in addition to the on/off switch enables EDGAR to be placed in a 'charge' mode. When in 'charge' mode, a charging lead may be plugged into the back of EDGAR's fairing which allows the on-board batteries to be recharged. This switch drives a relay that severs power between the batteries and the rest of the power distribution board.

VI. CODING

The brain of the robot is an Arduino UNO which reads the accelerometer and gives commands to themotor controller which in turnpowers the motors. The Arduino takes 10 readings per second from the accelerometer and proportionally changes the motor speed and direction. The Arduino code has gone through many changes and tests, but you still may have to change some of the values to be compatible with your robot. To run the robot, hook up all the wires in the correct fashion and upload the code below to the Arduino. It should start working right there and then.

VII. CONCLUSION

This paper presents design and development of the self-balancing personal transporter which is capable of carrying single person to move from one place to another within the premises of large campus. It is fast and a cost effective way to commute short distances. The vehicle uses electricity to power both of its motors, hence there is zero pollution. The vehicle is capable of carrying a person easily and with an added luggage too if necessary for the commute for at least two hours. With an added battery pack, we can increase the duration to four or even8 hours. The vehicle is able to travel up to 30 kmph, which is more than enough speed for people to commute. It is also very safe as there is a foot switch acting as adead man's switch to avoid any accidental movement as well as provides eco-friendly environment tilting of the user The vehicle balances itself by moving the motors in clockwise or anti-clockwise direction base on the readings from sensors. Thus the proposed system can be much helpful in the large campuses like airports, universities etc. This system reduces the work of humans.

VIII. FUTURE ASPECTS

With the addition of an Android motherboard, the entire process becomes simple. An Android mother board comes inbuilt with agyroscope/accelerometer sensor, proximity sensor, GPS, digital compass, barometer etc. These inputs to the phone can also be forwarded through any of the output means, namely, Bluetooth, audio, video, Wi-Fi, Infrared ports etc. With these options and the Android operating system, the SUC now has incredible potential for third party and native applications.

We can also add a solar panel on it for battery charging. As it is a little tedious job to remove the battery for charging from time to time and to replace it. So to install a solar panel would be nice idea.

Again we can connect a flywheel to its gears to store energy in the form of kinetic energy which can again be used in the form of electrical energy by the Segway through the batteries.

A potentiometric steering arrangement similar to the original Segway can be added.

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