Self Balancing Personal Transporter

B.Thaseen Kousar
Electronics and Communication dept.
G.Pulla Reddy Engineering College (Autonomous)
Kurnool, Andhra Pradesh, India

G. Ramesh
Electronics and Communication dept.
G.Pulla Reddy Engineering College (Autonomous)
Kurnool, Andhra Pradesh, India

***Abstract*— In developing countries, the increasing rate of urbanization and prevalence of motor vehicles is the principal cause of energy over-consumption, greenhouse gas emissions, and environmental deterioration. As a new type of transportation device, personal transporter may offer several potential benefits to solve current transportation-related problems. Balancing the personal transporter is a hard task. In this paper we design and develop a personal transporter with self balancing mechanism. This transporter works on the principle of inverted pendulum. It includes the designing of PID controller to combine the results from the sensors, designing motor speed controller and implementation of the self balancing mechanism. The battery is used to provide supply to the transporter.**

***Index terms*— Self balancing mechanism, inverted pendulum, PID controller, motor speed controller.**

I. Introduction

As the price of petroleum products increasing now-a-days, there is a need for cheaper and more efficient form of transport. Even large industries and manufacturing companies that spread over large areas restrict the usage of means of transport by their employees within their premises to avoid the risk of contamination due to emissions[1]-[3]. In addition, saving energy in order to resolve the problem of fossil fuel depletion is becoming increasingly important. To meet those needs, research on eco-friendly transportation has been increased [3]. Manufacturers have a great need for competence in the field of hybrid vehicle technology or even fully electrical vehicle technology as a step towards fulfilling these goals [9].

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 [3]. The two-wheeled, self-balancing vehicle is a non-linear multivariable and naturally an unstable system. Controlling such a system is a hard task and thus it is the topic of research [4]-[7] It will move forward if the user tilts in forward direction and backward if the user tilts in backward direction.[8]

This paper presents a vehicle in which all components (mechanical, electrical and control) have been designed from ground up, produced, coupled together and tested. This vehicle can be viewed as ecological, battery operated and very easy to be used as system [10]-[11].

A rider holds the steering 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 forward, 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 [14].

The balancing of the vehicle can be done using inverted pendulum principle [15]. An inverted pendulum is a pendulum which has its center of mass above its pivot point. It is often implemented with the pivot point mounted on a cart that can move horizontally and may be called a cart and pole whereas a normal pendulum is stable when hanging downwards, an inverted pendulum is inherently unstable, and must be actively balanced in order to remain upright [12],[13]. this can be done either by applying a torque at the pivot point, by moving the pivot point 3 horizontally as part of a feedback system, changing the rate of rotation of a mass mounted on the pendulum on an axis parallel to the pivot axis and thereby generating a net torque on the pendulum, or by oscillating the pivot point vertically [9]-[11]. As an example, we can consider a stick to be balanced by placing it vertically on the hand. If the stick tends to fall forward then we move our hand in the forward direction and vice-versa so that the stick does not fall down. In this paper the same principle is applied to balance the two wheeled vehicle [17].

In balancing the vehicles where pitch angle is of interest the accelerometer can be 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 [15]. The output from these sensors is processed in to the controller. The information from both the sensors is combined and filtered. The PID control algorithm is used to produce the relevant pwm signal. Based on these outputs, the controller balances the vehicle [16].

This personal transporter has two wheels. Two high torque dc motor are connected to the wheels. These motors are used to handle the human weights. Based on user instruction the controller drives the motors through Victor888 motor

ISSN: 2278 – 7798

speed controller. We use concept of PWM to vary the speed of the motor.

The direction of the rotation of motors is controlled by the motor controller. In this paper we propose victor motor controllers so that the precise control and meet braking requirements. The victor is first calibrated by giving 1ms-2ms PWM signal and then it is connected to the motors.

Power supply plays a vital role in any embedded system. Batteries are used to provide power to the system. The battery status information is processed into the controller, which displays this information on LCD to intimate the rider.

In this paper, we design and develop a two wheeled self balancing personal transporter. The readings from the sensors are combined and are given to the controller. The controller continuously processes the data and gives the relevant motor power required to drive the wheels in the required direction.

II. Block Diagram Of Proposed System

Figure 1 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 in the vehicle are controlled based on the data processed by the controller.

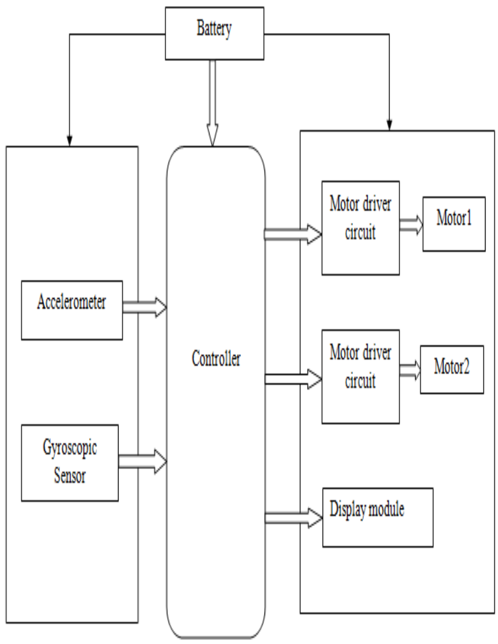

Fig.1.Block diagram of self balancing personal transporter

The vehicle is to be built before it is controlled. The parts required to construct the vehicle are shown in fig1. It consists of sensor modules, control module, motor drivers, motors and power supply modules.

The 12V battery is used to provide supply to the whole circuit. The recargeable battery is useful so that it can be charged and used to drive for certain distance.

In the proposed system the sensors used are accelerometer and gyroscope sensors. The Atmega16 microcontroller is used as a control unit. The accelerometer to be used is adxl335 by analog devices available as a breakout board. It is selected because of its sensitivity. The values of gyroscope sensor adxrs620 are combined with the accelerometer values to know the exact tilt of the vehicle by the rider.

The system cannot provide efficient and reliable information to ensure the balance of the body by using the accelerometer or the gyroscope only, so the sensor fusion is usually used to combine the data from several sensors. There is no such thing as a perfect measurement device, each type of sensor has its strong and weak points. The accelerometer measures inertial force, which can be caused by gravity or by the acceleration of the vehicle. The accelerometer is very sensitive to vibration and mechanical noise, even when it is still or in a relatively stable state. The gyro sensor outputs a quick response to changes in angles, but it suffers from integration errors due to zero drift. So the simple complementary filter is used to filter noise by combining these two kinds of sensors to obtain the data on the inclination angle. The idea behind sensor fusion is that characteristics of one type of sensor are used to overcome the limitations of another. The complementary filter is useful in noisy measurements. The controller processes the data and gives the relevant output signal to the motor driver so that the wheels are rotated in required direction.

III. Control Srategies

The user interfaces will have control over the microcontroller and feedbacks 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.

This is a two-wheeled vehicle in which the two wheels are driven through motors which are attached to the motor drivers. The vehicle is controlled with four different motions: Forward, Backward, Left and Right. To make the robot to move in these directions we should operate the motors as shown in table 1.

TABLE I

DIRECTION OF MOTORS

Direction / Motor	Forward	Backward	Left	Right
Right Motor	Anti Clockwise	Clockwise	Clockwise	Anti Clockwise
Left Motor	Anti Clockwise	Clockwise	Anti Clockwise	Clockwise

ISSN: 2278 – 7798

In order to achieve the better driving performance of the vehicle we should 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.

The motor speed controller victor888 is used to change the direction of motors forward or backward. The victor is first calibrated by following the instructions provided in the manual. The PWM signal varying in the range of 1-2ms is generated first using the controller and then given to the victor. The signal is varied between the ranges using joystick so that the maximum and minimum ranges are detected by the victor. PWM signals with varying time periods give different speeds.

TABLE II

PWM SIGNALS OF DIFFERENT TIME PERIODS TO GET VARIABLE DIRECTIONS

Direction / PWM Signal	Backward	Neutral	Forward
Time Period	1.0ms	1.5ms	2.0ms

The PWM signals with different time periods are given to motor speed controller based on the user commands. The possible different speeds are also considered in between the neural and forward/backward directions. The experimental results of the PWM signals that are given motor speed controller in order to achieve different directions are shown in figure 2.

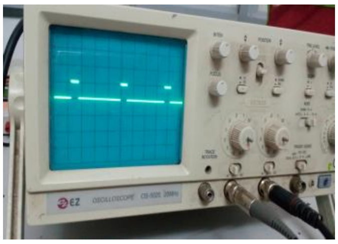

Fig (a): PWM for reverse condition

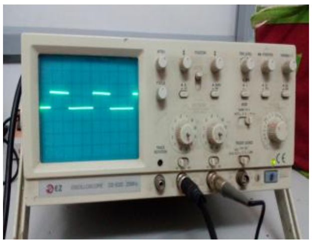

Fig (b): PWM for Neutral condition

Fig (c): PWM for forward condition

Fig.2: PWM signal different diretions

IV. Control Algorithm

All the inputs and outputs of the system are controlled by the on-board microcontrollers in the system. The software running in the controller is embedded C. Embedded C is a set of language extensions for the C programming language. Extra functions and libraries that are related to the specific controller have been added to the original C language.

Figure 3 shows the control program structure of the self balancing personal transporter. 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.

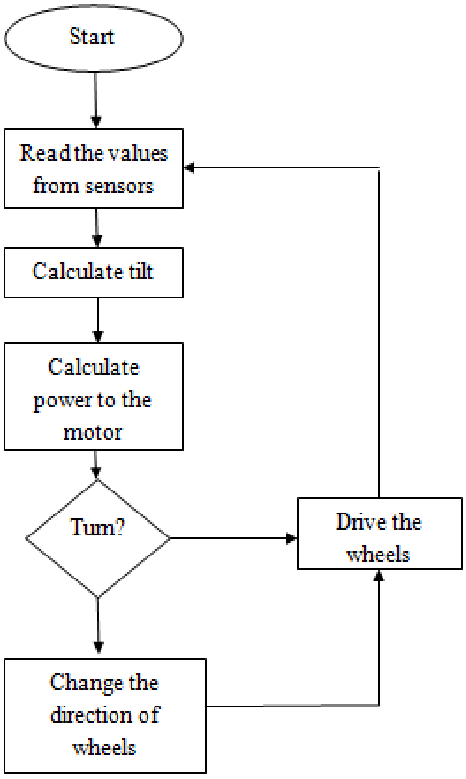

Fig.3.Control Program Structure

V. Conclusion

This paper presents design and the 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. The vehicle balances itself by moving the motors in clockwise or anti-clockwise direction

ISSN: 2278 – 7798

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 as well as provides eco friendly environment.

References

[1] Ching-Chih Tsai, Hsu-Chih Huang and Shui-Chun Lin, "AdaptiveNeural Network Control of a Self-Balancing Two-Wheeled Scooter," *IEEE transactions on industrial electronics,* vol. 57, no. 4, april 2010

[2] Pierpaolo De Filippi, Mara Tanelli, Matteo Corno, Sergio M. Savaresi, and Mario D. Santucci. "Electronic Stability Control for Powered Two-Wheelers*", IEEE transactions on control systems technology*, vol. 22, no. 1, january 2014

[3] Karthik, Ashraf, Asif Mustafa Baig And Akshay Rao, "Self Balancing Personal Transpoter" *4th Student Conference on Research and Development*, pp. 180-183, June.2006.

[4] Junfeng Wu, Yuxin Liang and Zhe Wang, "A Robust Control Method of Two-Wheeled Self-Balancing Robot," 2011, *the 6th International Forum on Strategic Technology*.

[5] Wang Lujun and xu yang, "Design of Motor driver for a two wheeled self balancing vehicle", *2010 international conference on opto electronics and image processing*.

[6] Hiroki Igarashi, Toshihisa Saito, Takaya Kinjyo and Fumitoshi Matsuno, " Development of an autonomous inverted pendulum mobile robot for outdoor environment", *SICE Annual Conference* 2008 August 20-22, 2008, The University Electro-Communications, Japan

[7] Plamen Petrov and Michel Parent, "Dynamic Modeling and Adaptive Motion Control of a Two-Wheeled Self-Balancing Vehicle for Personal Transport", *2010 13th International IEEE Annual Conference on Intelligent Transportation Systems,* Madeira Island, Portugal, September 19-22, 2010

[8] Muhammad Harris Khan, Mehak Chaudhry, Taimoor Tariq, Qurat-ul-Ain Fatima and Umer Izhar, "Fabrication and Modelling of Segway", *Proceedings of 2014 IEEE International Conference on Mechatronics and Automation,* August 3 - 6, Tianjin, China

[9] Miseon Han, KyungHwan Kim, DoYoun Kim and Jaesung Lee, "Implementation of Unicycle Segway Using Unscented Kalman Filter in LQR control", *2013 10th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI),* October 31-November 2, 2013 / Ramada Plaza Jeju Hotel, Jeju, Korea

[10] Osama Jamil, Mohsin Jamil, Yasar Ayaz, Khubab Ahmad, "Modeling, Control of a Two-Wheeled Self-Balancing Robot", *2014 International Conference on Robotics and Emerging Allied Technologies in Engineering (iCREATE),* Islamabad, Pakistan, April 22-24, 2014

[11] Pawel Bethke,Rafal Dlugosz and Tomasz Talaska, " Project and realization of a two wheels balancing vehicle", *20th International Conference "Mixed Design of Integrated Circuits and Systems"*, June 20-22, 2013, Gdynia, Poland.

[12] M. A. Johnson, and M. H. Moradi, "PID Control: New Identification and Design Methods". Springer, 2005.

[13] Abdalkarim M. Mohtasib 1, and Mohsen H. Shawar, "Self-balancing Two-wheel Electric Vehicle (STEVE)", *Proceedings of the 9th International Symposium on Mechatronics and its Applications (ISMA13),* Amman, Jordan, April 9-11, 2013

[14] Yufeng Zhuang, Zeyan Hu and Yi Yao, "Two-Wheeled Self-balancing Robot Dynamic Model and Controller Design*", Proceeding of the 11th World Congress on Intelligent Control and Automation*, Shenyang, China, June 29 - July 4 2014

[15] H. Ha et al., "A robust control of mobile inverted pendulum using single accelerometer," Pusan National University, Korea, *The Fifteenth International Symposium on Artificial Life and Robotics*, Feb, 2010.

[16] H. Lee, S. Jung (2011), "Balancing and navigation control of a mobile inverted pendulum robot using sensor fusion of low cost sensors," Mechatronics, Elsevier Ltd, Nov 2011

[17] Segway Inc. (2011). "How the Segway PT Works". New Hampshire, USA. [Online] Available: http://www.segway.com/individual/ learn-how-works.php

ISSN: 2278 – 7798