Designing the Self –Balancing Platform (Segway)

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***Abstract*— There is increase transportation of goods and public transportation. The adverse effects are known and well documented. Discussions about various views of the best solutions for these problems are taking place around the world. One of these visions involves the use of advanced technology based on the public transit as the basis for all sustainable solutions. In this search for different methods, MPTDs could help promote a modal transfer away from the automobile for short-distance trips. Electric scooters and Segways are two, user friendly, "in" modes of transportation that facilitate effortless travel and could provide suitable transportation in metro cities. Our aim is to make a design and fabrication of Segway personal transporter. The Segway is based on the principle of inverted pendulum that will keep an angle of Zero degrees with vertical at all times. The Segway is an intelligent vehicle which uses gyroscopic sensors to detect the motion of rider, so that he can accelerate, brake or steer the vehicle. This Segway is absolutely ecofriendly mode of transport which causes zero pollution.**

***Index Terms*—Segway, inverted pendulum, gyroscopic sensors.**

I. INTRODUCTION

It is a two-wheeled, self-balancing, battery powered electronic vehicle that maintains its own balance and that of its passenger. It is equipped with a stationary T-shaped control shaft fitted into a platform mounted on two parallel wheels. Segways are driven standing up and handle according to human body dynamics: lean forward to move forward, stand straight up to stop, and lean backward to reverse. The device has no brakes or accelerator, but has a handgrip for making turns. It is the only vehicle able to turn in place, just like a person, because its wheels have the ability to turn in opposite directions. For two-wheeled self-balancing robots, stability is vital as they cannot remain upright (balanced) without effort. As previously mentioned, their design concepts are mostly derived from classical robotics research called the inverted pendulum. An inverted pendulum, like its name suggests, is a pendulum that has its mass above its pivot point and not below like traditional pendulums. A self-balancing robot, such as a Segway, is an extended version of an inverted pendulum[3].

One of the most important tasks of autonomous systems of any kind is to be able to acquire knowledge about its environment. This can be done through the use of sensors (Ronald Siegwart et.al 2004). The use of sensors in robotics provides the robots with external physical information which help these systems to govern themselves accordingly. It uses two types of sensors where an accelerometer is an electromechanical device that measures inertial acceleration forces whereas gyroscope is a device used to measure the rate of rotation (angular velocity) of a body. Using microcontroller, the Segway continually analyses its performance. Five gyroscopes and two sensors work together to determine the Segway's position in relation to its centre of gravity. The onboard computers analyse their measurements and compensate in real time for surface irregularities in order to control the device's movement and ensure the rider's stability. The Segway has a maximum range of 25 km in optimal use conditions (no wind, flat terrain and constant speed) or 17 km in normal use conditions[1].

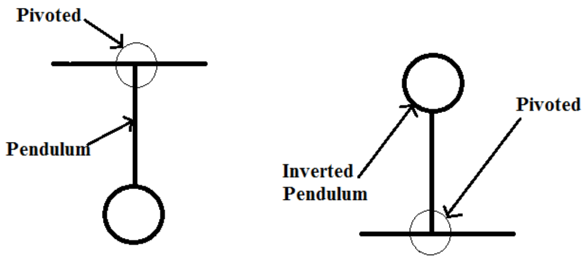

Fig1.Normal and Inverted Pendulum

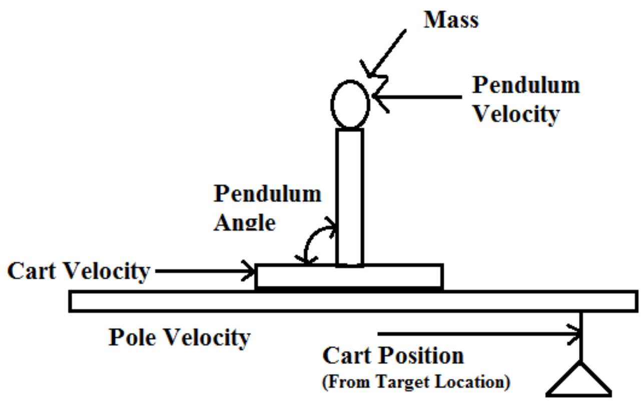

Fig2.Inverted Pendulum Experiment Set up

II. LITERATURE REVIEW

The United States began regulating Segways in 2002, just after the product began to be marketed and a year after a media campaign promoting the Segway HT and its inventor Dean Kamen. At the time this report was written, 40 states and the District of Columbia13 had introduced regulations governing the use of Segway HTs on sidewalks, bicycle paths and some roads. The laws vary from state to state, but most define the Segway as an "electronic self balancing personal vehicle". Few states also resolute to redefine the phenomenon pedestrian to include "a person using a Segway."14 In fact, the first step toward approval of Segway HTs on sidewalks was adoption of national legislation in June 2002 that legalized their use on sidewalks under federal jurisdiction. This legislation defined the Segway HT as a new vehicle class an two wheel self balanced personal artifice separating it from other motorized vehicles such as scooters. However, Senate Bill 2024, which defines the Segway as an electric transportation device with a stabilized platform between two parallel wheels, gives states and local authorities the power to pass legislation governing the use of Segways at the regional and local level. It approves the use of Segways on sidewalks under federal authority and on private property[2].

According to the Bill's wording, the device "employs advances in technology and effectiveness to fully and safely integrate the user with personal transportation;"…"enables individuals to travel farther and carry more without use of traditional vehicles," and "promotes gains in utility; minimizes environmental impacts; and facilitates better use of public roadways." This two wheeled balanced aritfice is promoted as a viable transport alternative to other mainstream option.Additionally this robot has features suited to adventure, commuting, law enforcement and transportation in general[4].

Two-wheeled, self balancing systems are studied in many different concepts. They can be considered as robotic platform or as electric vehicle/transporter. Researchers focus on various issues besides the main problem stability.

Segway Human Transporter (HT), which is invented by Dean Kamen, is known as the first two-wheeled, self-balancing system in the literature. Flexibility, safety and performance are important due to being commercial product. Segway HT is demonstrated in fig. Also, Segway brings out two wheeled self balancing robotic platform which is called Robotics Mobility Platform (RMP)[5].

Fig.3 Segway

Two-wheeled self-balancing systems are mainly classified into two groups as robotic platforms and transporters according to their structure. Robotic platforms are generally constructed as small sized . Fig is that kind of robot. Some of them are driven by an operator while rests are driven autonomously. Operator controlled robots are moved by remote control . This can be achieved by receiving command from a personal computer (PC) via a bluetooth module or a radio receiver. Fully autonomous robots may also have intelligence . These robots generally have camera in order to detect the environment and path planning[6].

As a transporter system, it is driven semi-autonomously by the driver on it. The driver determines the speed and direction of movement of the vehicle by leaning forward and backward. Most of the transporters are combined of standing base and handlebar which make the driver feel comfortable . Also, steering mechanism is generally mounted on the handlebar. However, the vehicle in only consists of a standing base. Steering is provided by shifting center of gravity (COG) of driver. The study discusses the system both as a transporter and as a robotic platform which carries goods.Some studies which are inspired by Segway emphasize creating lightweight and low- cost systems.Their low-costs make them affordable and lightweight make them portable in anywhere.

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Fig. 4 nBot by David Anderson(Andeson 2007)

Such two wheeled systems have a wide range of application area. It is clear that the transporter system is used for transportation. On the other hand, robotic system is used for telepresence applications by integrating camera as in . Also, soccer player is made up in . Some robotic systems are designed to carry load . They are used for educational purposes in some studies. Robotic systems generally turn into hybrid systems by combining with necessary components according to the application. Two wheeled robot with arms and waist is designed as a human assistant robot in . The hybrid system in is the robot combined with a manipulator. Two wheeled platform is also used for actuator of a humanoid robot . Moreover, a system which is designed as both ground and aerial robot is studied in [7].

Besides the two-wheeled system, similar studies about one-wheeled (unicycle) self balancing system and balancing on ball systems exist in the literature. As a mechatronic system, it is interested by the academicians. Its stability problemand the interaction among controller algorithm, hardware and software make it popular to study on[8].

Designing controller is the crucial part of the system. The main problem stability is satisfied by the controller. Although this system is highly non-linear, linear controllers are generally applied to the system after linearization because of its low- cost and less complexity. However, non-linear controllers are also attempted in . Most of the studies focus on auto-balancing control. Besides auto-balancing control, controllers are used for tracking control in some studies . Tracking the reference input is achieved here. Many kinds of linear control algorithms are studied on this system. One of the most common controllers is PID type algorithm . This algorithm is easily implemented on the system. Moreover, PD controller is preferred . The reason of not using Integral parameter "I" is stated in as its demand of large amount of processing power. Other common controller algorithm is LQR which depends on state feedback controller approach. It is designed and implemented . State feedback controller makes the system robust. Observer is used in order to estimate the states[9] .

The essential aim is to stabilize pitch angle in the system. Thus, necessary data must be taken from sensors. The main sensors of the system are accelerometer and gyroscopes which measure the angle and angular rate of the body, respectively. Most of the studies, use both of these sensors together. However, accelerometer gives noisy data and gyroscope causes drift. Thus, these two sensors are combined with a complementary filter in order to get more accurate data in . Kalman filter is used for sensor fusion during combination of gyroscope and inclinometer . Also, advanced sensor units as inertial measurement units comprising both gyroscope and accelerometer are used . These units give filtered data. The studies which only use accelerometer or gyroscope also exist. Gyroscope is used alone while accelerometer is used . There are also different sensors to measure tilt angle instead of accelerometer in the literature. Inclinometer detects the pitch angle. Also, tilt angle is obtained from infrared range sensors .

All processing are carried out by the embedded controller hardware. Microcontrollers are generally preferred in literature because of affordability . Microcontrollers manufactured by Microchip and Atmel are used in many researches. Digital Signal Processing (DSP) board is used for real time applications . Besides DSP, field programmable gate arrays (FPGA) is used as the controller hardware of the systems[10].

PROBLEM STATEMENT

Industries working in the field of transportation are required to put more work into building environmentally friendly vehicles than ever. Air pollution, a sustained increase in the average temperature of the earth and the need for efficient, green energy powered vehicles that can also be utilized in the project of '"Smart City" concept.

OBJECTIVES

[1] To design and construct a fully functional two wheeled balancing vehicle which can be used as a means of transportation for a single person.

[2] Design a small footprint electronic vehicle which will promote more environmentally friendly and energy efficient transportation method in metropolitan areas.

DESIGN GOALS

[1] Speed should be controlled by the rider leaning forwards and backwards.

[2] Turning should be controlled by tilting the handlebar.

[3] Balance and transport persons weighing up to 100 kg.

[4] Be strong enough to handle minor bumps and going up and down curbs at low speed.

[5] Propel the vehicle safely at the maximum speed of 20 km/h.

[6] Provide enough torque to balance a 100 kg rider in inclines of 20 degrees.

III.PROPOSED SYSTEM

Block Diagram of Segway

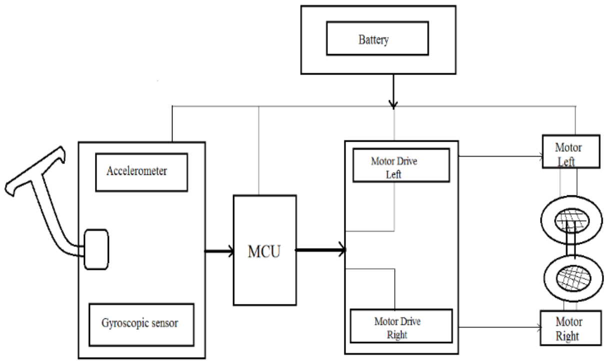

Fig.5 Block Diagram

System initially takes the inertial inputs from the IMU (Inertial Measurement Unit) which comprises of the two sensors i.e.Accelerometer a device capable of sensing acceleration. A modern accelerometer often includes a spring loaded structure whose deflection in response to external forces can be capacitively sensed and converted to an electrical signal. And a gyroscopic sensor (gyro) is used to measure the angular rate of an object with respect to an inertial system.

Knowing the properties of these two sensors, smart filtering can be used to fuse the outputs and attain a better estimation of the angle. According to these physical input parameters the controller sets the PID action for the platform to be balanced. So the desired responses are applied to the motor controllers and hence to the motors so as to run. The total balancing action is depends on the principle of traditional inverted pendulum.

The Arduino Mega 2560 is a arduino based microcontroller board based on the ATmega microcontroller 2560. It contains 16 analog inputs, 4 UARTs (hardware serial ports), 54 digital input/output pins (of which 14 can be used as PWM outputs), a 16 MHz crystal oscillator, a power jack, an ICSP header, a USB connection, as well as a reset button. It contains all on chip peripherals to support the microcontroller. By connecting it simply to a computer with a USB cable or with an AC-to-DC adapter or battery (for power purpose), to get started. Most shields designed for the Arduino Duemilanove or Diecimila is compatible with arduino mega 2560.

The accelerometer and gyroscope within the IMU are mounted such that coordinate axes of their sensor are not aligned with self-balancing bot. This is the real fact that the twosensors in the IMU are mounted in two different orientations according to its orientation of the axis neede..

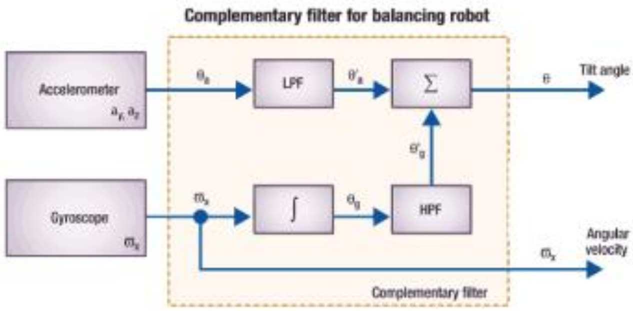

Fig.6 Complementry filter for balancing robot

ALGORITHM

[1] Start

[2] Acquire the physical parameters using the Inertial Movement Unit.

[3] Use Complementary Fusion Technique to detect the corresponding change.

[4] If the robot is leaning, drive the wheels in the direction of the lean.

[5] If you lean more, go faster.

[6] If you lean quickly, go faster.

[7] Turns out to be a control systems problem:

a. Input variable is platform angle.

b. Output variable is motor speed.

[8] By controlling the output variable, attempt to keep the input variable zero.

[9] When lean zero with respect to the original vertical positions, stop driving the wheels.

[10] Stop

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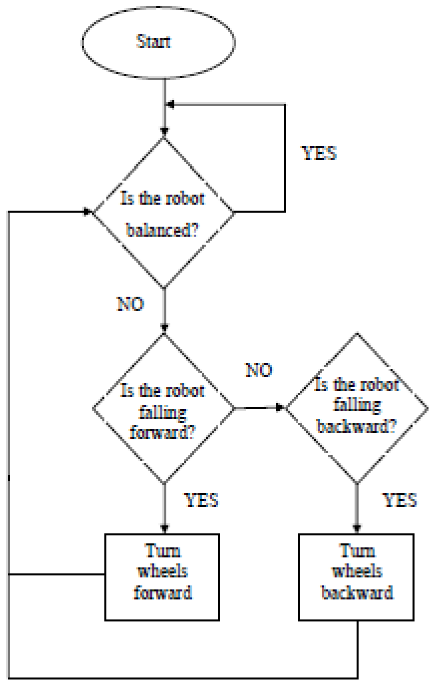

Fig.7 Segway Flow Chart

HARDWARE REQUIREMENTS

[1] Two wheels to drive the platform.

[2] Two motors to drive the wheels

[3] Motor controller unit

[4] Platform to stand on, Gaffer tape and movement controlling shaft.

[5] Batteries to power everything

[6] Sensors to detect leaning. (Gyroscopic and Acceleromerer sensor)

[7] Electronics to drive the motors. (Microcontroller–Arduino capable of reaching clock speeds of 16MHz.)

[8] Software to drive the electronics.

RESULT

A complementary filter is a frequency domain filter. At the beginning of this journal it was mentioned that the accelerometer cannot follow tilts at fast motion and that the gyroscope respond better to fast motions. Therefore, this means that for motion that is greater or faster than 0.09 second time period the gyroscope's integrated tilt angle θ_g is weighted more. Furthermore, the accelerometer noise is filtered out because the values of the accelerometer at this speed are trusted less for the same reason mentioned above.

When the motion is slower than the 0.09 second time period, the accelerometer tilt measurement θ_a has more weight than the θ_g of gyroscope. So in this case the accelerometer measurements are trusted more than that of the gyroscope, which tends to reduce the gyroscope bias drift impact from the vertical point.

This technique was chosen over Kalman filter technique because it is not mathematics extensive and simple to implement when programming the microcontroller. It is just a line of code and can be expanded to fuse multiple axis sensors like the one used for this project.

APPLICATIONS

[1] Police patrols

[2] Assistance for maintenance services (reading of water or electricity meters)

[3] Mail transport and delivery

[4] Natural gas pipeline inspections

[5] Rentals in recreational and tourism areas

[6] Guided tours for tourists and local residents

[7] A solution for people with reduced mobility (trials by an amputee)

IV.ACKNOWLEDGEMENT

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V.CONCLUSION

In the course of this project we have design the personal transporter with the more efficient use of energy and providing the alternatives to form an eco-friendly artifice by using the relevant concepts like complementary fusion, PID action, MPPT algorithm. This project was implemented with an idea to find an effective solution to transportation problem. The main objective is to achieve space utilization and minimize the fuel consumption especially for commuting over shortest distance. By list survey, the basic concept of cogwheel is studied.

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