DESIGN & DEVELOPMENT OF SEGWAY

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Abstract -*In this paper describes design and construct a fully functional two wheeled balancing vehicle which can be used as a means of transportation for a single person. It should be driven by natural movements; forward and backwards motion should be achieved by leaning forwards and backwards. Turning should be achieved by tilting the handlebar sideways. 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 detects the motion of rider, so that he can accelerate, brake or steer the vehicle. This Segway is absolutely eco-friendly mode of transport which causes zero pollution.*

Keywords: gyroscopic, inverted pendulum, Segway, RMP

1. INTRODUCTION

The Segway was introduced in the year 2001 by Dean Kamen.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. 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. This paper describes the design and Construct of Segway using gyroscopic sensors, Arduino-UnoR3 development board and battery powered electric motors. The design which we have come with will cost the Segway around 30,000 as compared to original Segway which costs around 3 lakhs plus tax, thus making the product cost effective. The Segway is a two-wheeled, self-balancing, battery-powered electric vehicle. 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 [2]. The main purpose was to design and construct a fully functional two wheeled balancing vehicle which can be used as a means of transportation for a single person. It should be driven by natural movements; forward and backwards motion should be achieved by leaning forwards and backwards. Turning should be achieved by tilting the handlebar sideways. To provide untethered operation the vehicles' energy source was designed to be a battery. One of the goals was to implement easy recharging of this battery.

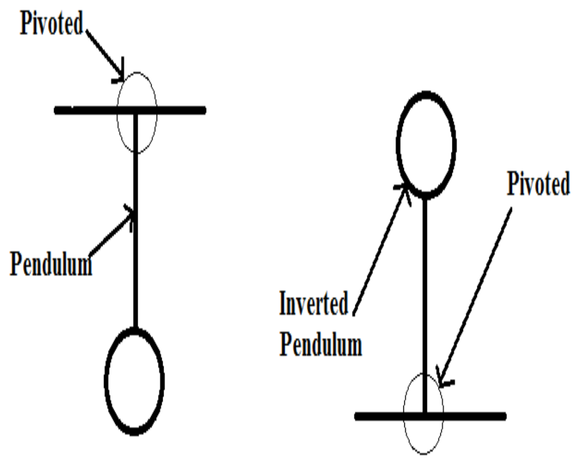


Fig -1: Normal and inverted pendulum

2. DESIGN GOALS

1. Speed should be controlled by the rider leaning forwards and backwards.
2. Turning should be controlled by tilting the handlebar.
3. Transport persons weighing up to 80 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.
7. Segway should use as Robotic Mobility Platform.

3. BLOCK DIAGRAM OF SEGWAY

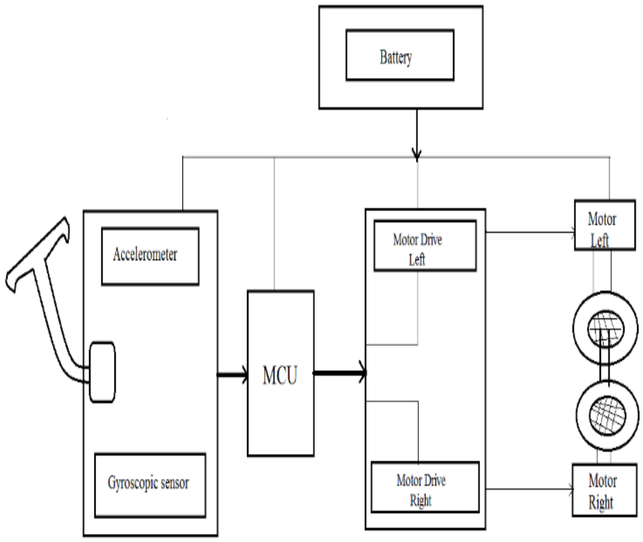


Fig -2: Block Diagram

4. MECHANICAL STRUCTURE

Mechanical Structure of segway is like an inverted pendulum. It stands on two wheels which place right and left sides. Figure- 3 demonstrates the system. Top part of the body is created by holders where push buttons are mounted for steering. Driver stands on the bottom part whose shape looks like a box. All hardware is placed in the bottom part. Also, a lifting mechanism is placed in front of segway. Chassis is made of sheet metal and aluminum. Aluminum is used in the frame of bottom part, and sides are covered by sheet metal plate. Total height of body is approximately 1.3 m from ground[3].

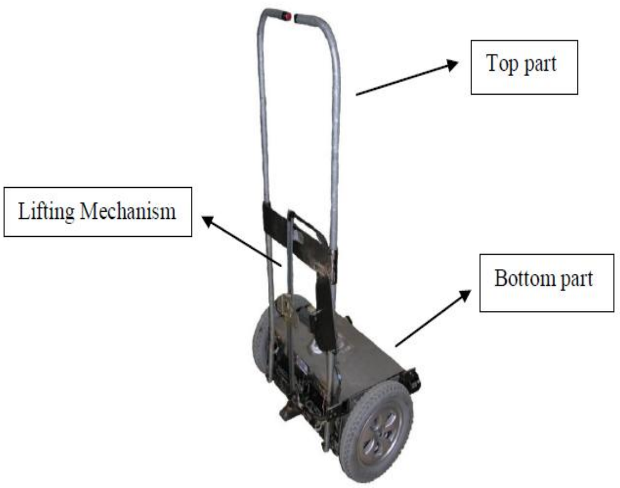


Fig -3:Mechanical structure

The self-balancing Principle of the Segway is as shown in the Fig- 4(a).

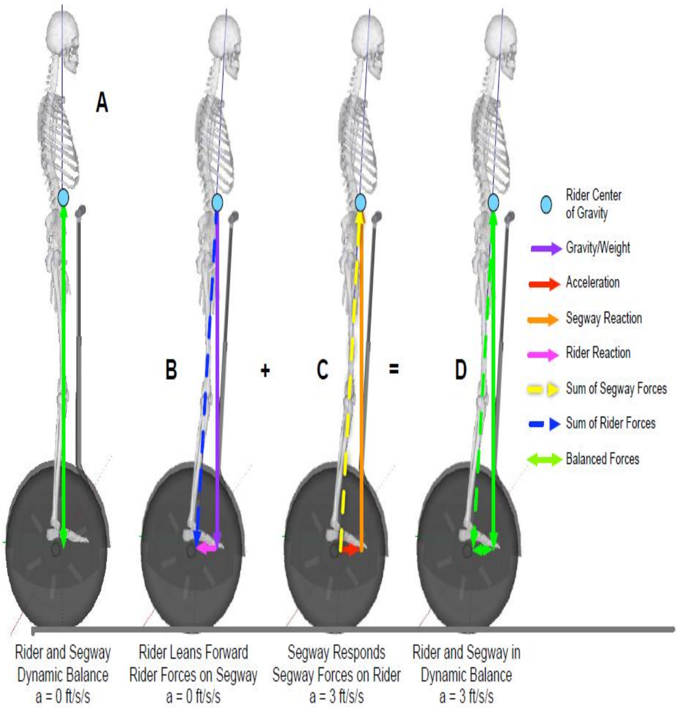


Fig - 4(a): The Forces Acting on a Segway Rider

The balancing action of segway is as explained below fig-4(b). in this fig-4(a)on the left show that the rider standing, with gravity and the Segway reaction force in balance. In diagram B the rider has leaned forward to start moving. The purple arrow is gravity/weight .The magenta arrow is the reaction force of rider against the Segway. The dashed blue line is the vector sum of the two. If the Segway doesn't respond rider will fall forward as the Segway is pushed backward. Diagram C shows the response of the Segway as it sense the tilt of the Segway platform as rider leaned forward. The computers order the motors to power the wheels and accelerate the Segway. The force of acceleration is the red arrow, and the reaction force of the Segway to rider is the orange arrow. The dashed yellow line is the vector sum of the two forces. Diagram D shows that the sum of the forces in diagrams B and C are in balance. The vector sums run through each other and the rider, so there are no unbalanced forces or torque. The on board computers adjust the power to the wheels to keep the forces balanced through the rider. This how the Segway balances itself out. Fig.4(b) shows balancing of Segway at different conditions that are accelerating, cruising (constant velocity) and decelerating [1].

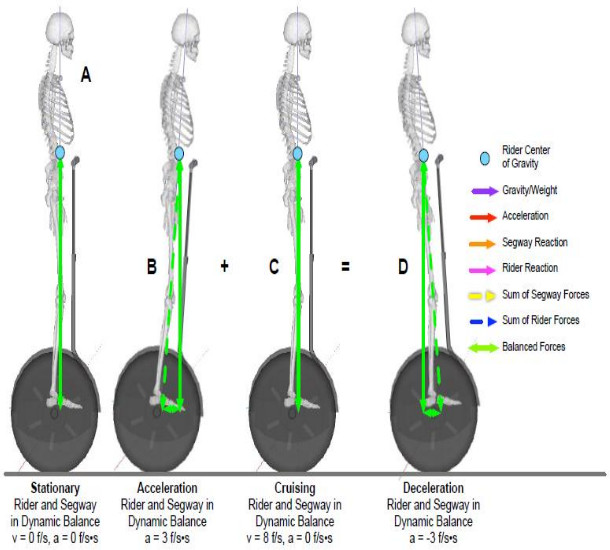


Fig- 4(b): Segway Balances the Forces on the Rider in All Phases of Riding

5. METHOD

1. Preliminary modelling and investigation of the dynamical system.
2. Mechanical and electrical design.
3. Software design.
4. Selection of main components.
5. Testing and verification.

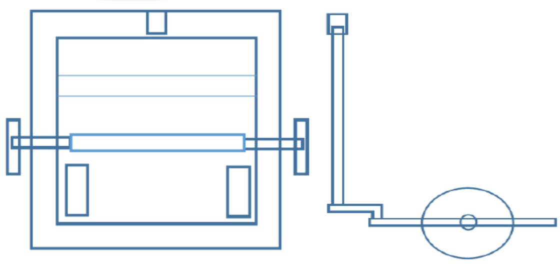
6. DESIGN CONSIDERATION

6.1 Torque Calculations

Maximum weight of rider = 80 kg
Chassis weight including batteries = 40 kg
Therefore, Total weight=120 kg (approx.)
Coefficient of friction between road and tyre = 0.3
Torque required = Friction Force * Radius Of Wheel
T = 120*0.3*25cm
T = 9 kgf-m (Approx.)
As two motor are used. Therefore torque required by each motor = 4.5 kgf –m(Approx.)

6.2 2D Representation of Segway Chassis[2]

Top view Side view



6.3 Component[2]:

1. Arduino board

The Arduino Uno is a microcontroller board based on the AT mega 328 . It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller.

2. GY521 module

The triple-axis MEMS gyroscope in the MPU-60X0 includes a wide range of features: Digital-output X , Y and Z Axis angular rate sensors (gyroscopes) with a user-programmable full scale range of ±250, ±500,±1000, and ±2000°/sec. this angular rate sensor performs the task for the Segway.

3. Motor Driver

The Saber tooth 2X25 is one of the most versatile, efficient and easy to use dual motor drivers on the market. It is suitable for high powered robots - up to 100lbs in combat or 300lbs for general purpose robotics. Out of the box, the Saber tooth can supply two DC brushed motors with up to 25A each. Peak currents of 50A per channel are achievable for a few seconds.

4. DC Motor

Motor is fixed with the chassis through screwed bolts and it is the main source of power to drive the vehicle. There are two motors, each for one wheel. The motors are driven by two 12 V batteries arranged in series. The maximum torque provided by the motor is 18kgf-m Approx.

5. Power Supply

The power supply for the Segway is two 12v dc motors connected in series to give 24V dc to source16.5A current require to drive the motor.

6.4 Subsystem Design & Implementation:

1.Handlebar

- The handlebar is attached to the chassis and serves as support for the rider.
- Adjustable height to provide a stable support for riders of heights between 1.6-1.9 m[4].

2.gearbox

- The gearbox consists of metal gears with a ratio of 14:1.
- It is used to increase the RPM of the Motor[4].

3. Chassis

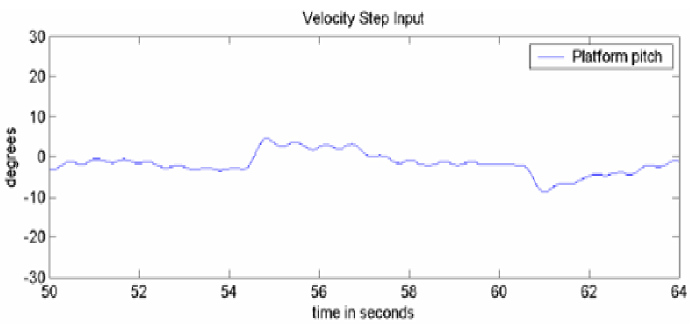
The chassis was designed to provide the rider with a safe and robust standing platform and to protect the electrical system and components .Bent alumina sheet metal was used to design a chassis in the shape of a box. The top plate of the box is easy to detach and the space inside is big enough to allow easy servicing of components [4].

7. SEGWAY AS ROBOT MOBILITY PLATFORM (RMP)

The overall objective of the Segway RMP development project was to quickly create a minimally modified machine. Segway LLC leveraged the design of the Segway HT to the highest possible degree, which created a robust design in a three-month period. The primary modifications involved changes to firmware and creation of an electrical interface to the RMP. The existing HT design offered the possibility of creating a reliable and robust system quickly, but it also constrained the product performance in several respects[5].

8. EXPERIMENT ANALYSIS

The dynamics of the Segway RMP are non-minimum phase in position and velocity. That is, the wheels must first move backward before the RMP can accelerate forward. This is dictated by the dynamics of the inverted pendulum. An example of this behavior is show in Fig. 4. As the figure shows, there is a time lag between the time the step command occurs and the RMP reaches the commanded velocity. It is also worth noting the pitch angle of the platform during the acceleration phase. Just like sprinters in a 100 yard dash, the machine leans forward initially and then straightens up when it reaches constant velocity. In the example, a pitch of 5 degrees is observed during the initial portion of the acceleration. Greater accelerations require more pitch. Rapid acceleration and deceleration can lead to platform pitches as great as 40-50 degrees (along with a commensurate reduction in normal force!). In some applications, the tilting of the platform may be useful for increasing the effective range of a sensor. In other cases, it may introduce additional processing and sensing requirements to orient the sensor data properly [5].



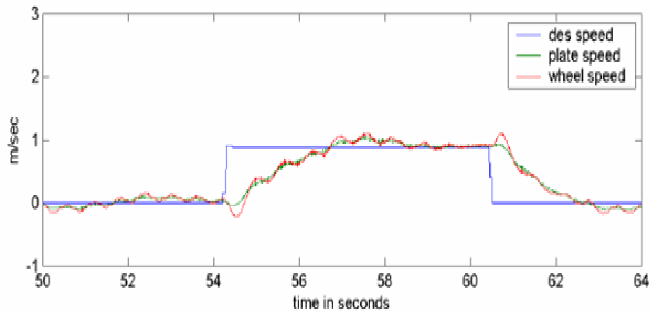


Fig -5: Dynamics of the Segway RMP during acceleration and deceleration.

9. CONCLUSION

We have studied a two-wheeled self balancing electric transporter which can operate in manned and unmanned mode. It was constructed as a term project in Mechatronics in Automotive Engineering course in 2009. As part of this thesis, physical system is improved. A load carrier mechanism is mounted in front of the system. This is the first step to transform into an Segway RMP. Also, electrical construction is rearranged and components are placed more appropriately. Sensor set is improved by integrating an encoder on the shaft of the motor. We will be Programming the arduino board as per the logical flow given above so that at the last we can see that segway can be manufactured at a very low cost.

REFERENCES

[1]. Brian G.R. Hughes, "The Unique Physics of the Segway PT Balanced at All Times", May 30,2009.
[2]. Sadhana Pai, "Design Of Segway Personal Transporter",2015.
[3]. Ayca Gocmen ,"Design Of Two Wheeled Electric Vehicle" ,July 2011.
[4]. Jonas Karlsson, "Design, construction and verification of a self-balancing vehicle",2012
[5]. John Morrell ,"Segway Robotic Mobility Platform", October 2004.
[6]. Rongfang (Rachel) Liu,"SegwayTM Human Transporter (HT): Potential Opportunities and Challenges for Transportation Systems", November, 2002.

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