Segway – The Human Transporter

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Abstract

The Segway Human Transporter is one of several low-speed transportation devices (e.g., bikes, scooters, wheelchairs) that, under certain circumstances, travel on sidewalks, roadways, and other shared-use paths. The objective of this research was to examine the primary operating characteristics of the Segway. In this thesis, we designed and constructed mechanically based system for a two wheel balancing Segway robot. In this paper we present a Segway based on gyro sensor, accelerometer along with a microcontroller and use of mechanical and electrical hardware's. The dynamics of the vehicle is similar to the classical control problem of an inverted pendulum, which means that it is unstable and prone to tip over. This is prevented by electronics sensing the pitch angle and its time derivative, controlling the motors to keep the vehicle balancing. This kind of vehicle is interesting since it contains a lot of technology relevant to an eco-friendly and energy efficient transportation industry. This thesis describes the development of a similar vehicle from scratch, incorporating every phase from literature study to planning, design, vehicle construction and verification. The main objective was to build a vehicle capable of transporting a person weighing up to 70-80 kg and capable of travelling to some km distance with varying speed. The rider controls are supposed to be natural movements; leaning forwards or backwards in combination with tilting the handlebar sideways should be the only rider input required to ride the vehicle. This thesis also takes into consideration the material used with minimum possible cost. The design of Segway Human Transporter is such that it covers less space and comfort to the user.
Keywords: Segway, accelerometer, gyro sensor, Arduino uno, IMU MPU6050, Motor driver

I. INTRODUCTION

The Segway personal transporter (PT) is a two-wheeled, self-balancing, battery-powered electric vehicle invented by Dean Kamen. Computers and motors in the base of the device keep the Segway PT upright when powered on with balancing enabled. A user commands the Segway to go forward by shifting their weight forward on the platform and backward by shifting their weight backward. The Segway detects, as it balances, the change in its centre of mass, and first establishes and then maintains a corresponding speed, forward or backward. Gyroscopic sensors and fluid-based levelling sensors detect the weight shift. To turn, the user presses the handlebar to the left or the right.

II. REVIEW OF LITERATURE

A. The Physics behind Segway:

[1]The Segway is a uniquely sophisticated machine that uses on-board computers working with multiple sensors and redundant physical systems to sense the motions of the rider, and to react to those motions. The "Stand up Scooter" requires the rider to learn how the machine will respond to the throttle and brake, while physically holding on to the machine to counter the unbalanced forces of acceleration and deceleration. Diagram A (Fig.:1), on the left shows person standing, with gravity and the Segway reaction force inbalance. In diagram B Person has leaned forward to start moving. The purple arrow is gravity/weight. The magenta arrow is the reaction force of person against the Segway. The dashed blue line is the vector sum of the two. If the Segway doesn't respond person will fall forward as the Segway is pushed backward. Diagram C shows the response of the Segway as it senses the tilt of the Segway platform as person leans 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 person is the orange arrow. The dashed yellow line is the vector sum of the two. 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 is what makes the Segway unique. [1]Fig 2 shows how the Segway keeps the rider in balance during all phases of a ride: stationary, accelerating, cruising at 6 mph, and decelerating. This continuous balancing of forces is what makes riding the Segway possible. There are no unbalanced forces to topple the rider off the Segway, which is why many people with diseases or injuries which result in muscular weakness, such as Muscular Dystrophy or Multiple Sclerosis, can safely ride a Segway. They do not have to compensate for unbalanced forces with their own strength - the Segway does it for them. [1]On a Segway you initiate moving forward by leaning forward. The Segway senses your leaning and accelerates forward, balancing the forces, and you are underway. This is the process shown in Fig 4 above. The beauty of this is that the Segway is controlled by same set of reflexes and reactions that control basic human locomotion. Even if you can't walk due to physical limitations, you retain these reflexes and reactions. [2]The Segway personal transporter, shown in Figure 2, is a device that transports one person at relatively low speeds. The low-speed (limited to approximately 20 kmph) operation combined with its electric propulsion system makes the Segway a candidate for providing short-distance transportation on city streets, sidewalks, and inside buildings. When a Segway is in use, the device is driven by two wheels that are placed side-by-side, rather than the standard in-line configuration of a bicycle or a motorcycle. When the operator leans forward, the wheels turn in unison in the same direction to provide forward motion. In order to stop, the wheels must accelerate forward to get out in front of the system's centre of mass and then apply a deceleration torque to slow the system down without causing the operator to fall forward off the device. These operating principles are reversed to allow the system to move backward. [2]In order to turn, the wheels rotate at unequal speeds causing the system to travel in an arc. If the system is not translating forward or backward, then the wheels can rotate in opposite directions to turn the machine in place. However, it is not possible for the human operator to balance the device, as they can with a human-powered inverted pendulum such as a unicycle. The sensors in the device must constantly be measuring the state of the machine and feeding this information to the computer controller. The controller then uses this feedback signal to adjust the wheel speed so that the forward/backward (pitch) falling motion is maintained within an acceptable envelope so that device and rider do not fall over. Note that under many operating conditions, the system is mechanically stable in the side-to-side (roll) direction. Therefore, the computer does not attempt to control the roll motion. Assuming wheel-ground rolling stiction, the system is also stable in the yaw direction. However, the computer must change the yaw rate in order to turn the machine in 10 response to the operator input. It also limits the turning rate to a maximum value.[3]A Segway is often used to transport a user across mid-range distances in urban environments. It has more degrees of freedom than car/bike and is faster than pedestrian. However a navigation system designed for it has not been researched. The existing navigation systems are adapted for car drivers or pedestrians. Using such systems on the Segway can increase the driver's cognitive workload and generate safety risks. [3]Paper presents a Segway Augmented Reality, Tactile navigation system which visualizes the route through an augmented reality interface displayed by a mobile phone. The turning instructions are presented to the driver via vibro-tactile actuators attached to the handlebar. Multiple vibro-tactile patterns provide navigation instructions. Results show the augmented reality, interface reduces user's subjective workload significantly. The vibro-tactile patterns can be perceived correctly and greatly improve the driving performance. [4]Paper concerns the adaptation of a Segway electric scooter for mobile robot navigation work and its instrumentation in preparation for these experiments, potentially aimed at security applications where its speed and dexterity are of distinct value.[4]Paper has shown how to convert a Segway scooter into a mobile robot in a simple but effective manner and has detailed its instrumentation towards developing it as a security robot working within the context of a video surveillance system.[5]Paper presents an obstacle avoidance system for the Segway Robotic Mobility Platform (RMP). The system consists of four main modules: terrain mapping, terrain traversability analysis, path planning, and motion control. The main sensor in our system is a forward/downward-looking 2-D Sick laser rangefinder. The terrain mapping module registers real-time laser range data into a grid-type elevation map. The traversal property of the elevation map is then analysed by the traversability analysis module, which transforms the elevation map into a traversability map. The paper introduces a new concept called "traversability field histogram," which is used to transform the traversability map into a one-dimensional polar histogram. Finally, the path planning module determines the steering and velocity commands and sends them to the motion control module.

III. DIAGRAMS

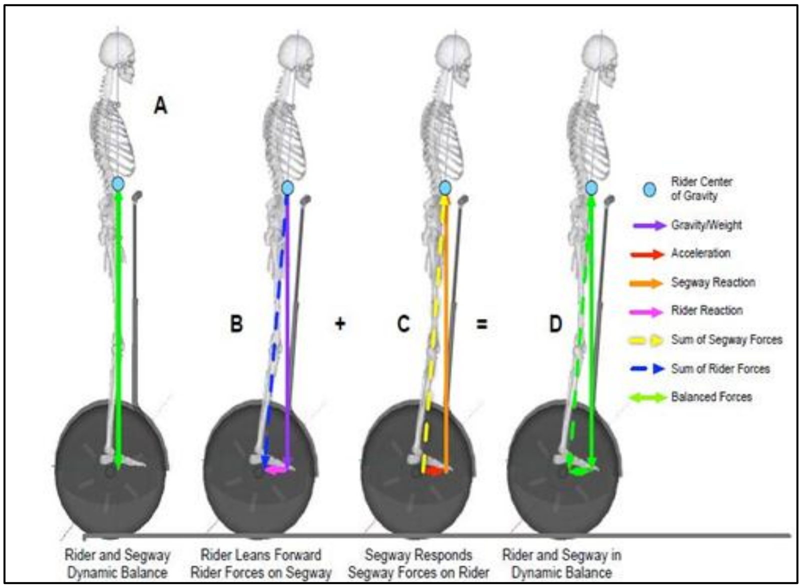

Fig. 1: Forces acting on segway rider

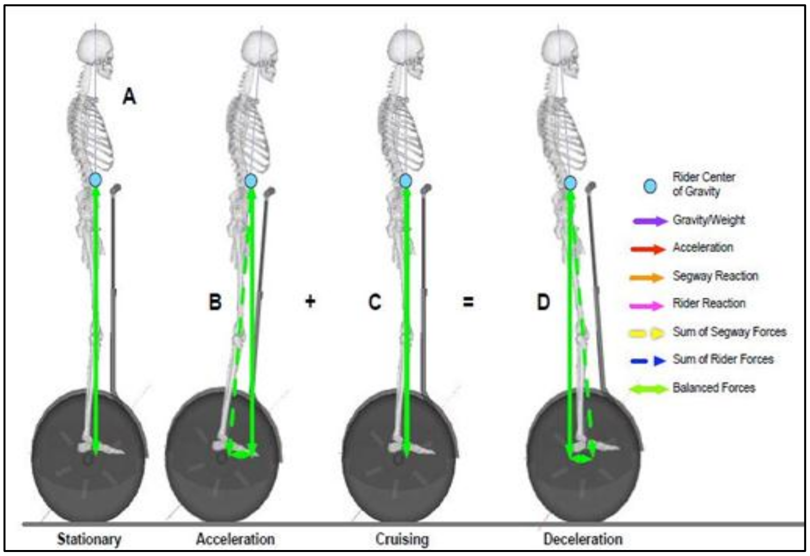

Fig. 2: Segway Balances the Forces on the Rider in all Phases of Riding

IV. ELECTRONIC CONNECTIONS

Segway is going to be controlled by a main microcontroller which is going to be Arduino Uno with an IMU MPU 6050 which has 6-axis Gyroscope and accelerometer inbuilt in it, a motor driver and a rotary potentiometer. Two 24V DC motor with a capacity of 250W each are going to be controlled a motor driver. This motor driver will manage the current of about 15 to 19 Amps. Outputs from motor driver will go into 5V of Arduino Uno and other at pin number 13. Other output will be connected to a dead man switch which when pressed will break the circuit and both the motors will be switched off. Now for the IMU MPU6050 its GND (ground) will be connected to GND of Arduino Uno and VCC of IMU(Inertia measurement unit) to the 5V of microcontroller then SCL(serial clock) of IMU chip to analog input of A5 pin of microcontroller while SDA(serial data) pin of IMU chip to the A4 analog pin of Arduino Uno and lastly the INT (Interrupt) pin of IMU chip to the digital pin number 2 of Arduino Uno. Two sealed lead acid batteries of 7ampere hour shall be connected in series and they will provide sufficient power to the machine. Rotary potentiometer will be connected to the main steering column and it will calculate the angular displacement of the steering and accordingly will send analogue signal to the controller. Thus the tilting of steering will cause motion in that particular direction.

V. WORKING

As we power on the segway the gyro and accelerometer sensors will evaluate some random angle and values which we have to ignore and focus on the stable position of the segway without any load on it. As we get a stable position we will lock the position by pressing a button and thus that will be our reference co-ordinate. As the rider tries to move forward/backward there will be pitching in segway which will be sensed by accelerometer and gyro sensors. As the tilting of steering is done at particular angle and weight is displaced to the direction at which the users wants to move, sensors will sense this & they will transmit signal to microcontroller and from controller to the motor. Thus the balancing as well as motion in that particular direction will be achieved. When the vehicle leans forward, the motors spin both the wheels forward to keep from tilting over. When the vehicle leans backward, the motors spin both wheels backward. When the rider operates the steering control to turn left or right, the motors spin one wheel faster than the other, or spin the wheels in opposite directions, so that the vehicle rotates.

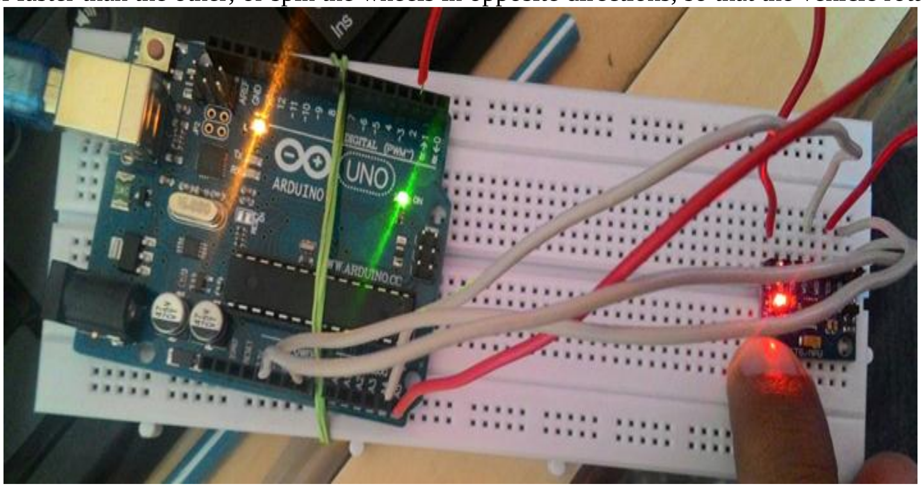

Fig. 3: MPU6050 tested successfully with Arduino uno

VI. CONCLUSION

Experiments were performed to study the dynamic behaviour of the Segway human Transporter. Under small disturbances, the Segway-Human system has a very predictable behaviour. In such cases, pitch angle and speed responses showed almost linearly under-damped responses. However, when stronger forces were involved, the human dynamics started to play a role. In such cases, the responses were difficult to predict due to the movements performed by the rider, showing the importance of their role in controlling the vehicle. Yaw turning dynamics were also studied and a map between the turning command and a resulting yaw rate was obtained from the experimental results. The experimental results were used to set the simulation parameters for three different cases. First, the parameters of a two-wheeled inverted pendulum were adjusted to simulate the impulse response of an unloaded Segway. Then, a rigid-body model of a human was added to the model and its parameters adjusted until the simulation response matched the experimental impulse response of a loaded Segway to a manually applied force on the rider. Finally, the model parameters were set to match the response of the Segway and human rider to a known force. The dynamic model was used to simulate different environmental conditions. Simulations of sudden turning motions showed the importance of the human rider for the stability in the roll direction. Without the person compensating for the centrifugal effect, the Segway model could not turn at very high speeds or high yaw rates without losing wheel-ground contact. When travelling on inclined surfaces, the pitch angle stability and speed are affected. It was found that the ability to climb up or go down a hill is highly affected by the pitch angle. Higher pitch angles helped the vehicle climb up, and negative pitch angles helped to avoid instability when going down a slope. Slick surfaces also affected how well the vehicle could balance. Low friction surfaces limit the capability of the motors to accelerate the vehicle. When a high pitch angle is present and the traction provided by the ground is low, the vehicle is more likely to lose balance. If only one of the wheels loses traction with the ground, unstable yaw dynamics can be observed, and the effect was aggravated when high pitch angles were present. Simulations of inclined surfaces and slipping in both wheels also showed that contact between the rider and the vehicle can be lost under many combinations of pitch angular accelerations and linear accelerations. Because the forces between the rider and the vehicle are compressive contact forces, when abrupt changes in net accelerations occur at high pitch angles, there is no force available to hold the rider and the vehicle together.

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