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Review Paper

Segway with Human Control and Wireless Control

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Abstract

Segway is device which will respond on the variation of angle provided by accelerometer and gyroscope with its reference and counter it. After studying several papers it is concluded that existing system is very complex in design so in this paper this will be reduce by combination of sensors and controllers this all are so adjusted that it looks like a simple device and can be understand easily. This segway consist of accelerometer, gyroscope, tilt sensor and motor driver, ADC and micro controller 2051.assembly is made by wooden cart board. This is simple inverted pendulum based robot which will carry the things in bad surface area for transportation purposes (wireless control). In this paper here it tries to reduce the cost of overall system because now a day's their cost of a segway is very high so with this project it can be reduced with simpler design configuration. Because if simpler the design means we are removing some redundant and less used part. Now available segway has lots of complexicity in design in this project it will be reduced.

Keywords: Two wheeled inverted pendulum (TWIP), System on programmable chip (SoPC), Human transport (HT), Personal transport (PT).

Introduction

This paper involves in designing a control system using electronic system to make an inverted pendulum remain upright. Inverted pendulum is a concept which will be used in a machine that is known as "Segway". Pendulum is nothing but a steering which is connected with its base and this will fall in either forward or backward. After studying several papers here proposed control system is simpler, this will have two types of control one is manual and other is wireless control for that here IR trans-reciever will be used and this is controlled by dynamically driving a motor which moves the axle along a track according to the motion of the segway, the segway will be prevented from falling from the upright position. System is initialy unstable, the segway will not remain upright without external forces, for this control it requires DC motors which will actuate on command of controller and sensors output[1].

In the suggested paper, a control algorithm will be developed and implemented digitally using a microcontroller, motors and sensors, and a working demonstration will be built. Ultimately, this project will show the effectiveness of a digital control system to stabilize a machine quickly, and it will be used for transportation purposes. A segway model can be shown as in Figure-3.

Methodology

This paper introduces the construction and design of human transport and personal transport with wireless control for which a control system is required which will maintain 0 degree with the vertical axis. The balancing robot system is built in order to do filter experimentation and to test out their performance. This design is divided in three steps Mechanical design, Electronic design, construction and implementation and algorithm for the control[2].

Mechanical structure consists of fiber plate, motor clamp and aluminum pipe. The electronic construction consists of IR, analog accelerometer and gyroscope used as sensors, ADC, AT89C51 controller IC etc. Segway is combination of several gears, motors, ADC, motor driver ic, batteries and several sensors these all so adjusted to perform a task as in Figure-4. In this initially sensor senses the tilt angle of the steering about its reference vertical axis. This tilt angle is fed to the microcontroller[1]. Where it is programmed to compare the tilt voltage and the reference voltage (set point).according to the output of controller motor will respond and it will perform actual task as flow of work shown by the flow chart in Figure-5.

Motion Equation: The motion equations for inverted pendulum are dependent on weight of cart, length of pipe and change of inertia.

Stationary Pivot Point: A pipe that is steering of robot is fixed at one end with base which is moving without any friction or other resistance to movement. Aluminium rod is considered massless and moment is 2 dimensional.

$$\ddot{\theta} - \frac{g}{l}\sin\theta = 0$$

Where: pendulums angular acceleration $=\ddot{\theta}$, gravity at surface of earth $=g$, length of the aluminium rod$=l$, and angular displacement measured from the reference position $=\theta$.

Angular acceleration becomes:
$\ddot{\theta} - \frac{g}{l}\sin\theta$

Thus, the pendulum will move away from the vertical reference equilibrium value in the either direction initially, length and acceleration is inversely proportional. More the length of rod slowly the pendulum falls[3].

Derivation using Torque and Moment of Inertia: $\boldsymbol{m}$ is a point mass which is affixed to the free end of rod which is mass less, of length $\mathbf{l}$, The net torque of system =(moment of inertia)x (angular acceleration):
$\boldsymbol{\tau_{net} = I\ddot{\theta}}$

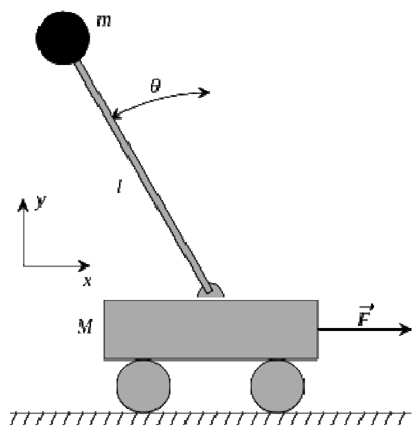

Figure-1
A free body diagram for the inverted pendulum on a cart (own)

Net torque due to gravity: $\tau_{net} = mgl\sin\theta$

Where: θ is angular displacement of rod from its the equilibrium position.

The resulting equation is:
$I\ddot{\theta} = mgl\sin\theta$

Moment of inertial of a point mass:
$I = mR^2$

Since the length of rod, l is the radius of pendulum system becomes:
$I = ml^2$
$ml^2\ddot{\theta} = mgl\sin\theta$

Mass and l^2 is divided from each side:
$\ddot{\theta} = \frac{g}{l}\sin\theta$

Inverted Pendulum on the Cart: A cart pendulum consists of a mass $\boldsymbol{m}$ at the top, length of pipe is $\boldsymbol{l}$ as shown in the image. The cart will move only inlocomotion[4].

Essentials of Stabilization: Stabilizing the inverted pendulum can be understand in three simple steps. i. If the tilt angle is positive with its reference then base will move forward else backward. ii. The position of cart is $\boldsymbol{x}$ which is moving as the reference angle is given in between piot pipe at the horizontal and vertical axis and its acceleration. iii. A normal pendulum is to a moving pivot point such as a load lifted by a crane, has a peaked response at the pendulum. The angular frequency of $\boldsymbol{\omega_p} = \sqrt{g/l}$ .Is calculated by gyroscope[4]. To prevent swinging, the frequency spectrum of the pivot motion should be suppressed near $\boldsymbol{\omega_p}$. The Inverted Pendulum device requires the same suppression to achieve stability of the system.

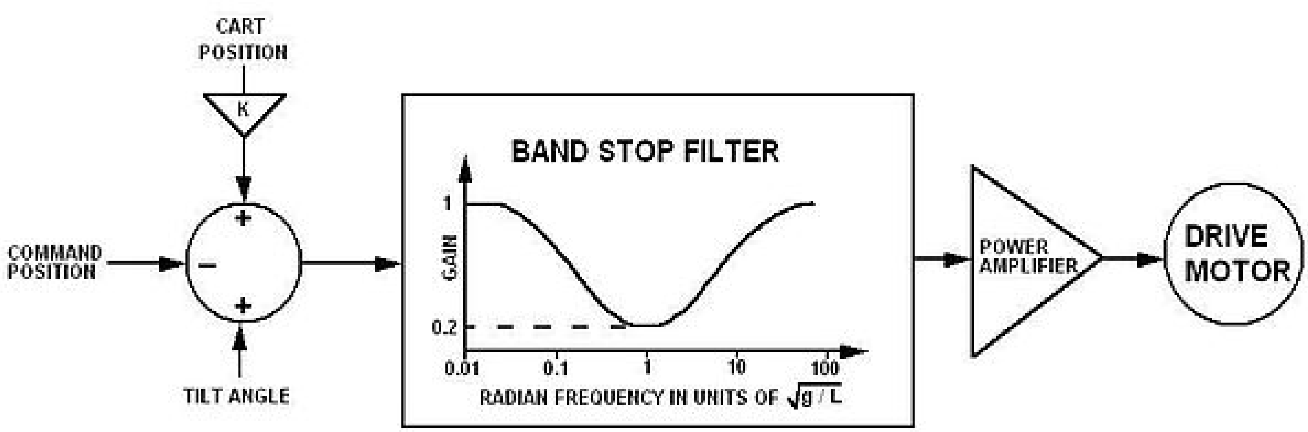

Figure-2
The simple stabilizing control system used on the cart with things on the Segway (own)

A sudden command to move forward will generate an initial motion of cart to the backward followed by a move forward to rebalance the IP. At the time of moving forward or backward getting stability is a feature that makes the mathematical analysis an interesting and challenging problem.

Equation of Motion: We will derive the equation. Where: $\theta(t)$ =tilt of pendulum from its reference place and$l$ =the length of pipe with respect to the vertical direction and the gravity is acting force and $F =$ an external force in the X-direction. $x(t)$ = the position of the cart. By using Lagrange's equations$L = T - V$ thus system becomes

$$L = \frac{1}{2}Mv_1^2 + \frac{1}{2}mv_2^2 - mgl\cos\theta$$

where cart velocity is $v_1$and velocity of the point mass m is v_2. v_1 and $v_2$can be expressed in terms of x and θ.
First derivative of the position (velocity);

$$v_1^2 = \dot{x}^2$$

$$v_2^2 = (\frac{d}{dt}(x - l\sin\theta))^2 + (\frac{d}{dt}(l\cos\theta))^2$$

After Simplification v_2 becomes:

$$v_2^2 = \dot{x}^2 - 2l\dot{x}\dot{\theta}\cos\theta + l^2\dot{\theta}^2$$

The Lagrangian equation is now written as:

$$L = \frac{1}{2}(M + m)\dot{x}^2 - ml\dot{x}\dot{\theta}\cos\theta + \frac{1}{2}ml^2\dot{\theta}^2 - mgl\cos\theta$$

and the motion equations are:

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{x}} - \frac{\partial L}{\partial x} = F$$

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{\theta}} - \frac{\partial L}{\partial \theta} = 0$$

substituting L in these equation and simplify

$$(M + m)\ddot{x} - ml\ddot{\theta}\cos\theta + ml\theta^2\sin\theta = F$$
$$l\ddot{\theta} - g\sin\theta = \ddot{x}\cos\theta$$

These nonlinear equations will be linearized around $\theta \approx 0$,when goal of system to keep the pendulum upright is achieved[5].

Discussion and Expected Result

After studying several papers it was concluded that those system is having lots of complexicity in design. This idea has taken from Shane Colton's research paper where simplicity and low cost has helped inspiring a new wave of self-balancing projects in this work[4], which is SoPC model in this paper have chosen some sensors individually firstly try with only tilt sensor but got some problem with this.

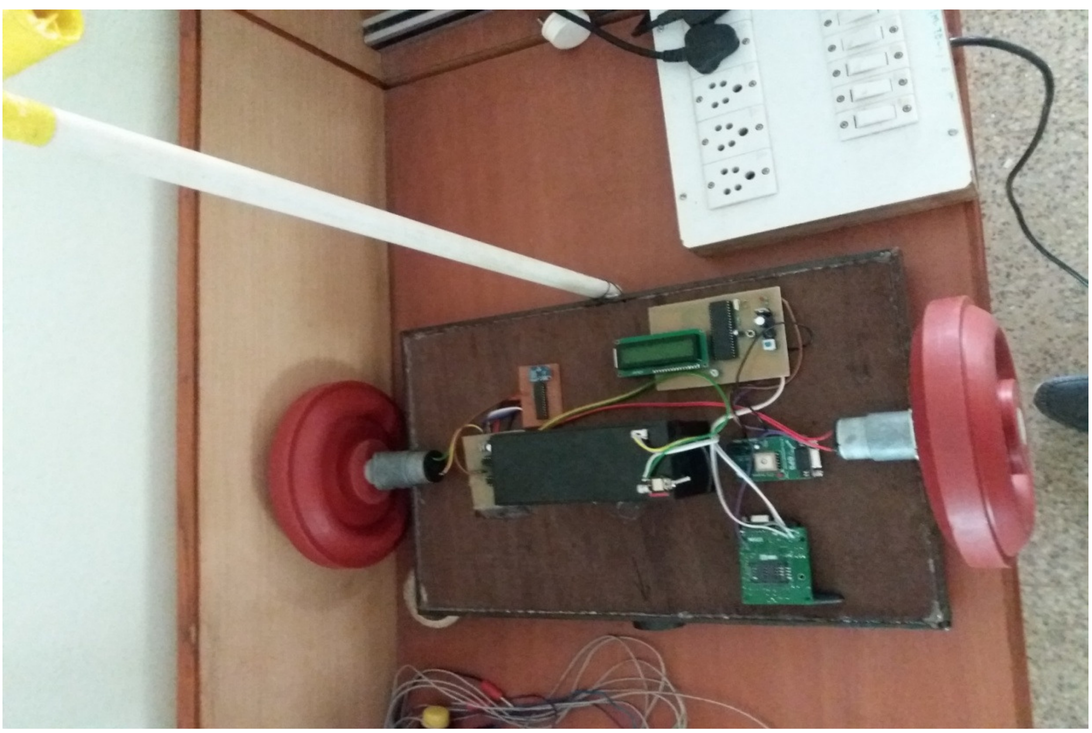

Figure-3
Segway for Personal Transport (own figure)

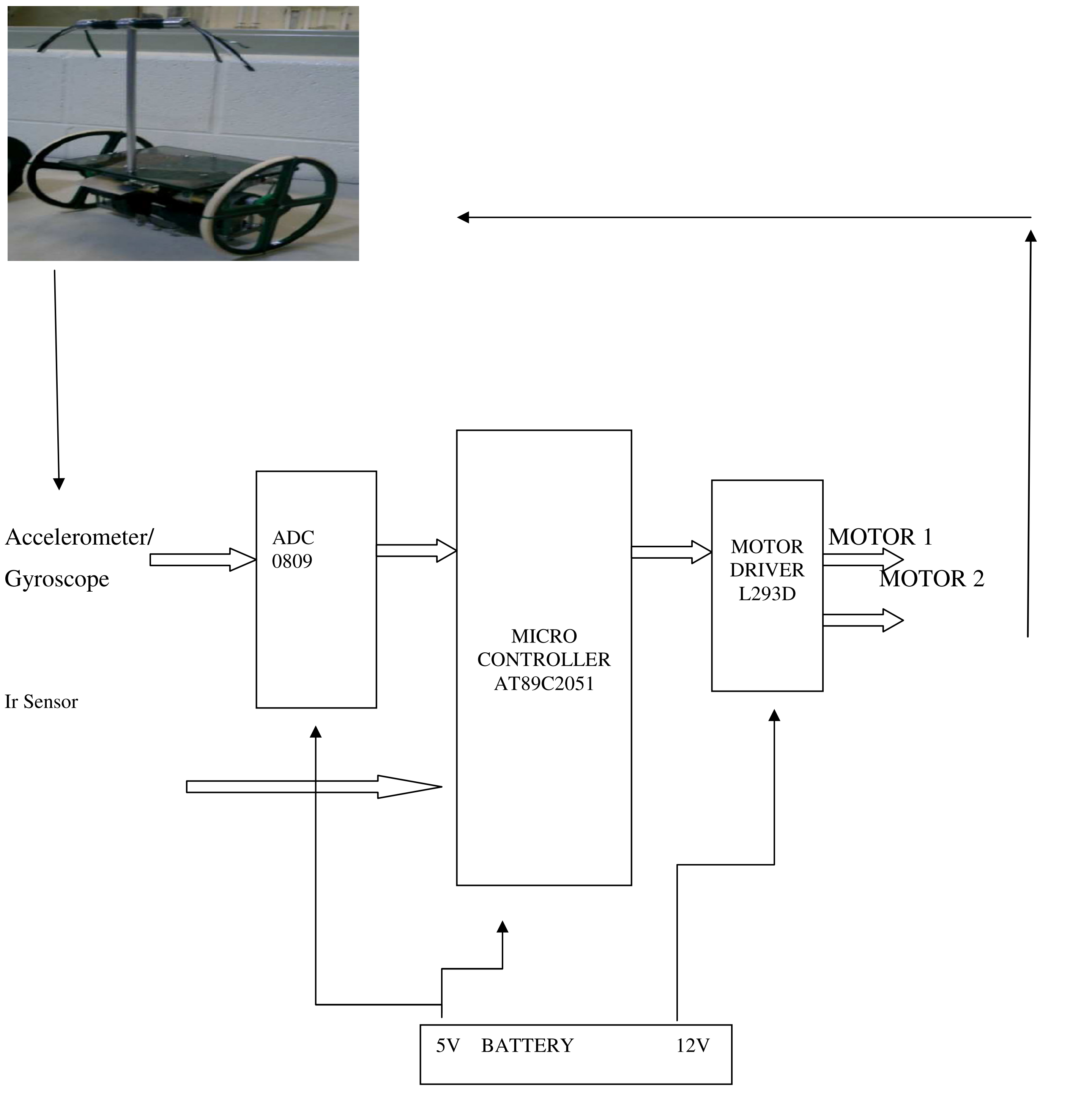

Figure-4
Basic block diagram for Segway(own figure)

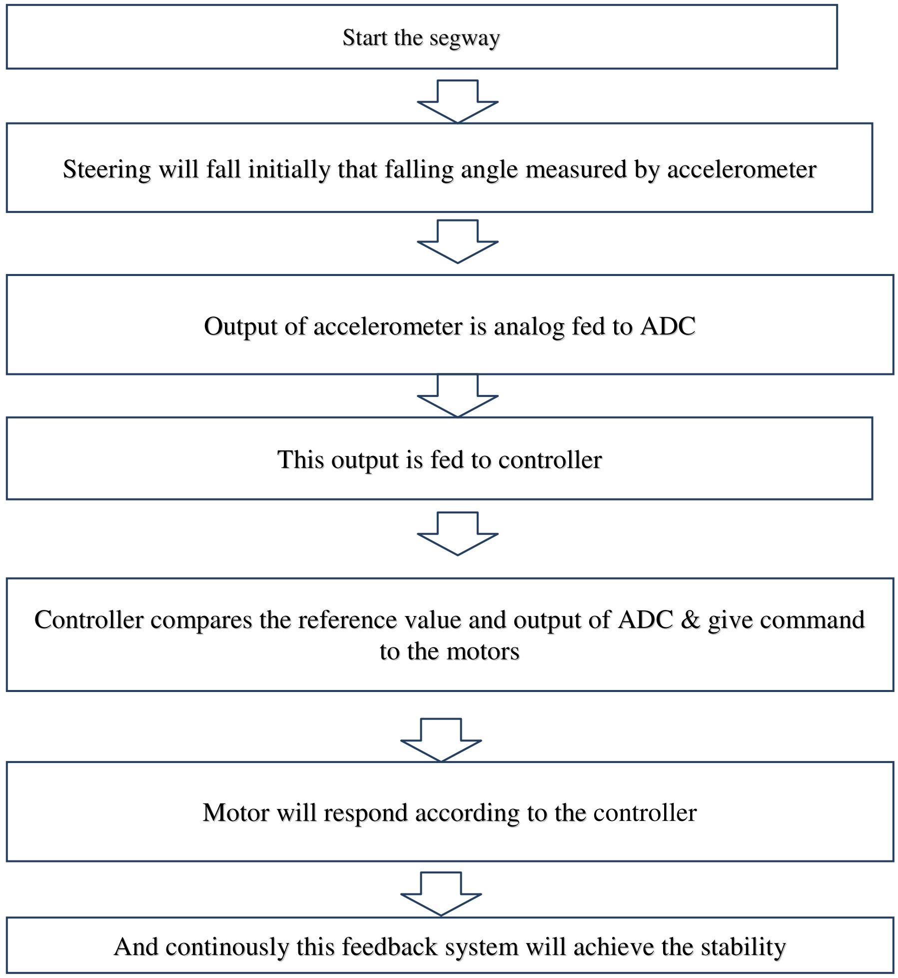

Figure-5
Flow chart for segway operation

Conclusion

Once this model is prepared we will have low cost TWIP model which will allow industrial transportation HT and PT in cheaper way with multi operation in one system.

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