Self-balancing Two-wheel Electric Vehicle (STEVE)

Abdelkareem M. Muhtaseb, Mohsen H. Shawar
Supervisor: Karim Tahboub
Mechanical Engineering Department
College of Engineering and Technology
Palestine Polytechnic University

Introduction

STEVE is an applied research project to design, analyze, and construct an electric vehicle with two parallel wheels similar to Segway. A rider holds the steering while standing. The vehicle through an onboard-control system will self balance itself as well as respond 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. This vehicle can also turn to the right and to the left as commanded by the rider. Overall, this vehicle can move quickly over a long distance with only one battery charge.

Working Principle

Is similar to stabilizing an inverted pendulum on a cart by accelerating the cart in the direction of the falling pendulum. This results in a stabilizing counter torque to the gravity. The value of the applied torque is calculated in a feedback loop that relies on the estimate of STEVE tilt through the fusion of an accelerometer with a gyrometer using Kalman filter. The feedback loop and tilt estimation are realized by embedded microcontrollers. Figure1 shows the implementation of STEVE.

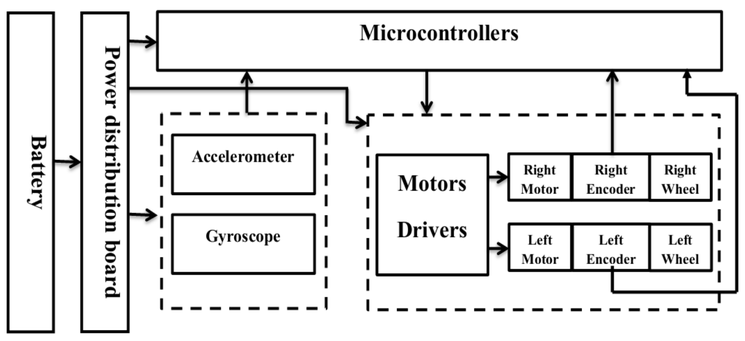

Figure 1: STEVE Implementation

STEVE main control board

An electrical board that can achieve multitasks is designed and built for this vehicle. This board is consisting of many regions as shown the figure 2. Every region has a specific task that can achieve.

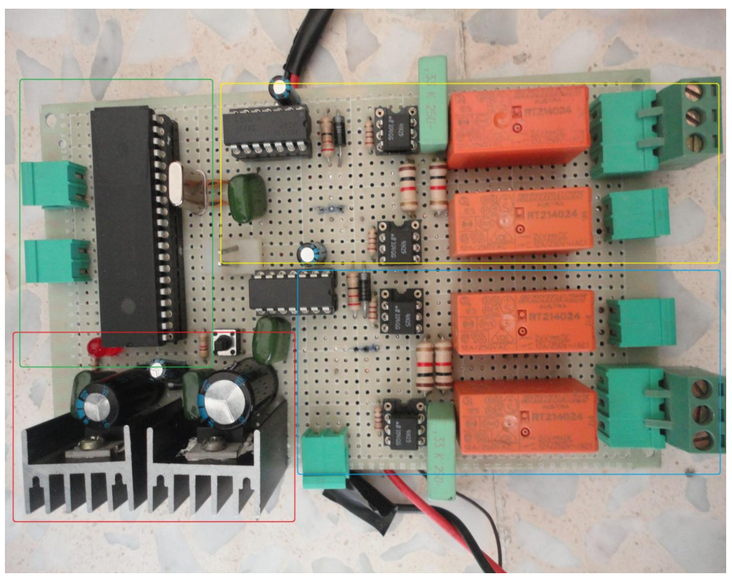

Figure 2: STEVE main control board.

Conceptual design

Figure 3: STEVE main control board.

Control Architecture

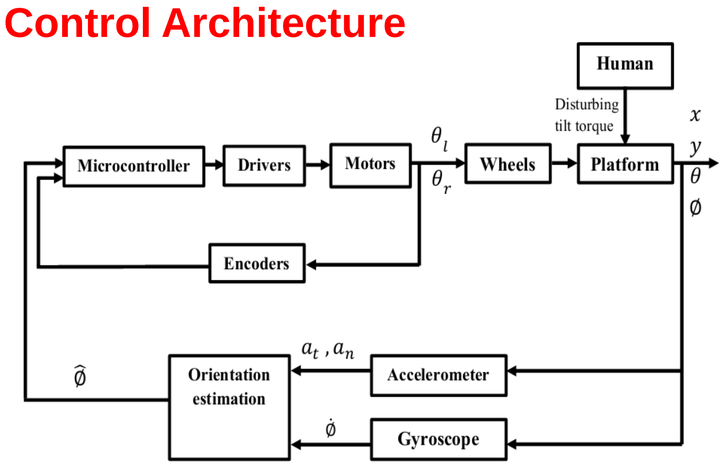

Figure 4: STEVE main control board.

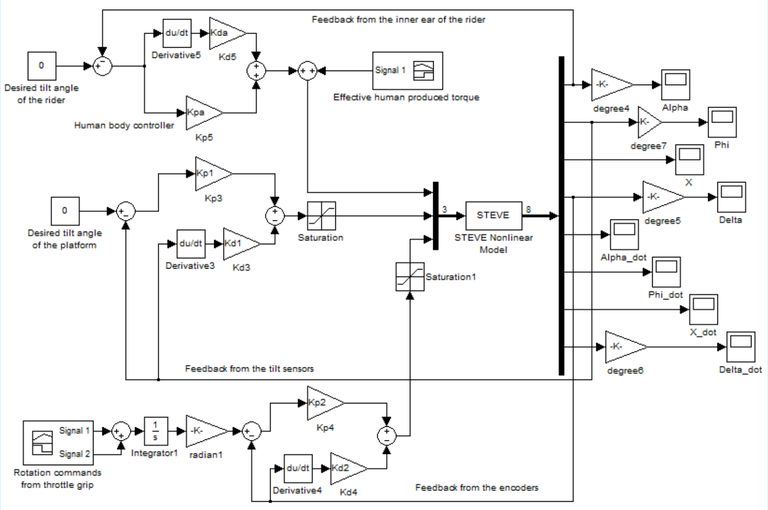

Figure 5: The simulation of nonlinear model of STEVE on horizontal flat road with rotation.

Control System

STEVE represents an unstable system, because of that a controller is needed for it to make the system stable and usable. There are many options for control laws that can be implemented here, but for a simple and quick solution a PD controller is designed. Tilt angle is set to zero to make the vehicle accelerates forward for forward tilt and to make it accelerate backward for backward tilt. So the controller (tilt=0) is the mechanism for stabilizing and at the same time to command speed. This controller also used to test the simulation results of the mathematical models. In addition, it is used to study the response of the system in order to make a deep understanding for it.

Simulation Results

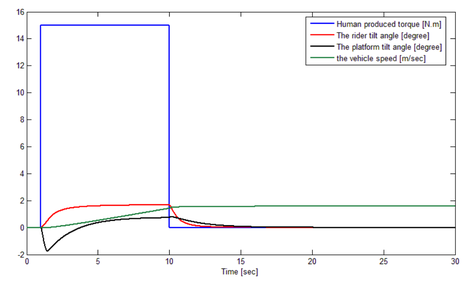

Figure 6: The response of the system for the acceleration commands.

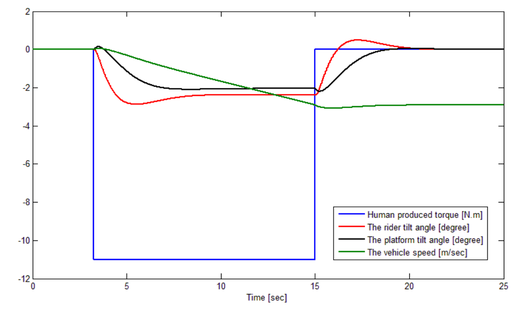

Figure 7: PD controller results using estimated tilt angle of the nonlinear model.

Experimental Results

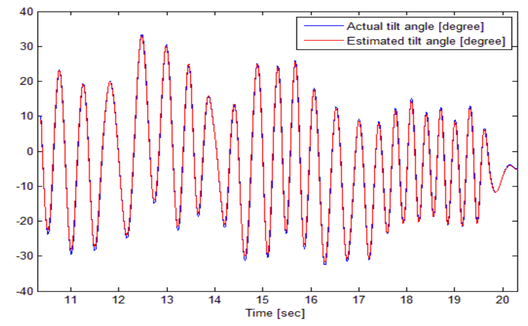

Figure 8: Sensor calibration and Kalman filter response.

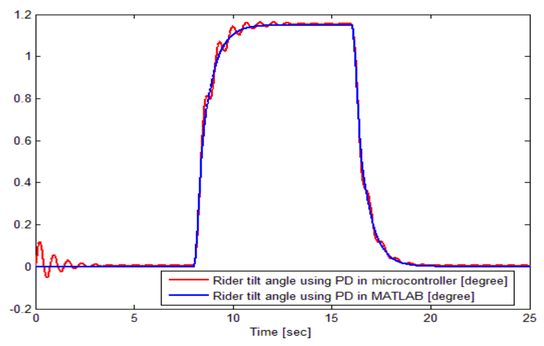

Figure 9: Hardware in the loop results.