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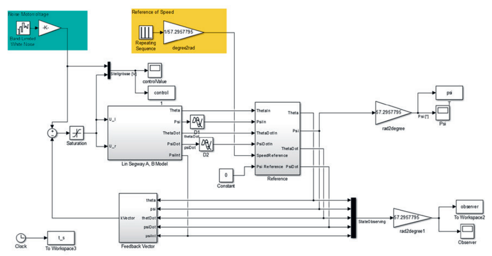
Subject Area	Embedded Systems

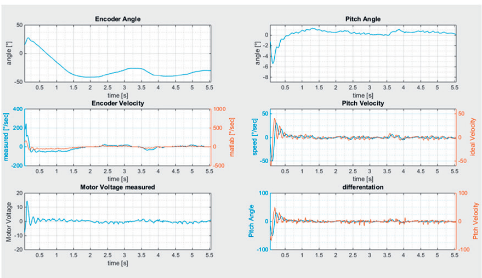
Mini-Segway Extension

Design of a state space controller and its implementation on an ARM Cortex M4

Completed Segway platform with the pendulum



Simulink model of the state space controller



Measured control values of the actual physical system

Introduction: The IMES (Institute of Microelectronics and Embedded Systems) requires a demonstration object in the field of control theory. The Mini-Segway represents a challenging application in control design. Various semester studies have already developed components of the Segway platform used, thus most hardware already exists. The aim of this bachelor thesis is to complete the Segway platform. This includes to design and implement a controller in order to achieve safe and proper operation of the Segway application. Important functional characteristics of the Segway are its reliable upright standing position and its ability to balance out any turbulence. Another requirement is the ability to drive in two coordinate directions, namely forward/backward driving and turning. To conclude the task formulation, with the option to steer the Segway with the HSR Lego-Segway application over a Bluetooth interface all functional goals are described.

Proceeding: First, a product specification sheet was created. With a detailed product plan and fixed milestones the ground was laid for verifiable work progress. After detailed research in control theory, the control design was chosen. The approach of a state space representation of the progress seemed ideally suited. This was followed by modelling and simulating the system with Matlab's Simulink. A software concept was defined and the controller implemented. By testing the model on the real platform and continuously adapting parameters to measured data, the model was aligned to the physical system. In addition to the Segway controller, a reference calculation based on user and distance-sensor inputs was also designed.

Solution: As a result, a fully working Segway which achieves all functionalities specified was developed. The Segway achieves upright stability by a controller based on the state space approach. Internal states are fed back and thus even the position of the Segway can be controlled. A trick was used to steer the Segway and thus the position reference is integrated into the state vector along with a given speed vector. Furthermore, with the usage of a wireless Bluetooth module, the Segway can be steered wirelessly with the HSR Lego application. To secure its operability, the output values are monitored and trigger a shutdown in a case of failure. With distance sensors the speed reference is levelled according to obstacles near the platform.