Control of a Segway

Student

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Introduction: A Segway is a self-balancing vehicle with two independent wheels and various sensors to keep itself upright. It can be driven/controlled by tilting the frame of the Segway in the desired direction. Using control theory, the angle and position of the frame are to be regulated. Additionally, a PlayStation controller should be used to either manually attempt to balance the Segway or to drive it while the controller stabilizes it. This representation of a Segway will be used to showcase control applications in the Control Theory lecture or as an advertisement for the Electrical and Computer Engineering Bachelor program.

Approach: A physical system model was designed to create the controller. The Segway was modelled as a two-wheeled inverted pendulum. The model was heavily based on the example found in the Control Engineering Lecture, which was based on Yamamoto Yorihisa's documentation. The motion equations of the system were derived using the Lagrangian method. Moreover, the generalized forces in the system were expressed using DC motor equations. The complete system was then represented in State Space form. A state space regulator with integral action was then calculated using the Linear-Quadratic Regulator (LQR) algorithm. Iteratively, multiple controllers were simulated in MATLAB until a satisfactory step response was achieved. With MATLAB code generation, the regulator was implemented on the Nucleo-G474RE microcontroller. Different types of sensors were used to measure all required states. An Arduino Micro was used to read the controller values the Nucleo board, then requests the data and uses it accordingly.

Conclusion: As a result, a controller, which runs at 100 Hz, was created and implemented on the microcontroller, which manages to balance the Segway. The regulator has a step response rise time of 0.267 seconds for the pitch angle and 2.76 seconds for the yaw angle. A PlayStation 2 controller can then be used to choose one of the different modes. A battery powers the Segway, and all the components are either in the frame or on top of it.
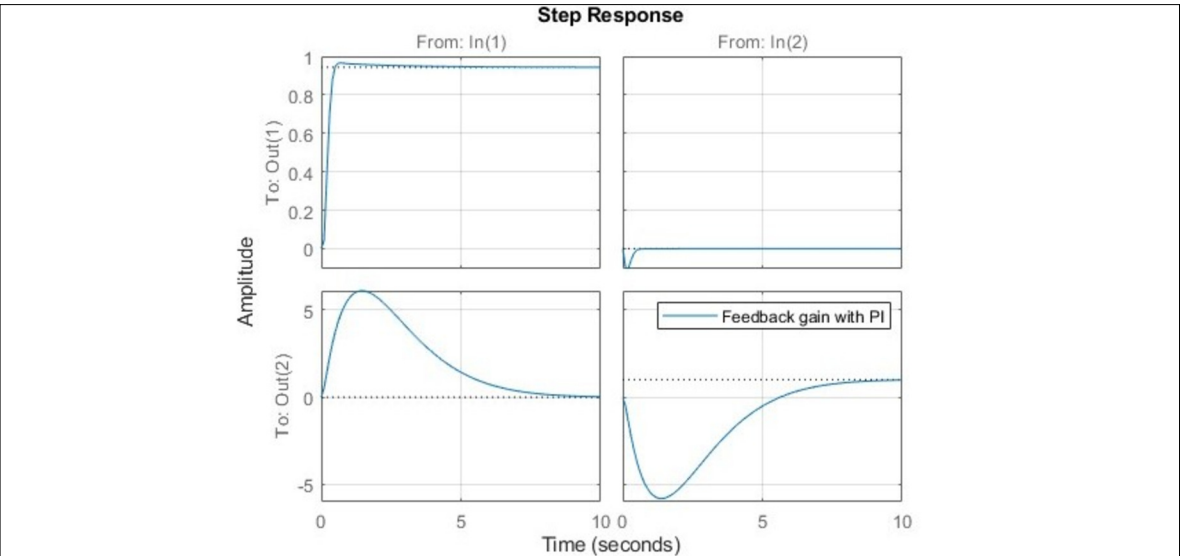
P1. Picture of Segway during testing phase
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P3. Simulation of the controller with a starting pitch angle of -1 degrees. Plot of the pitch angle of the Segway
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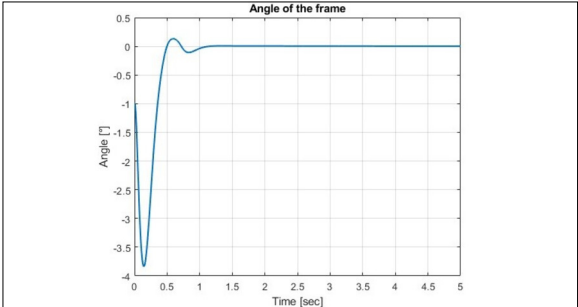
P2. Step response of the regulator. Input 1 is the control variable for the pitch angle and Input 2 for the yaw angle.
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Subject Area
Regelungstechnik / Control Theory