Trajectory Control of a Two-Wheeled Robot

by

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1 Problem Statement

The two-wheeled robot is an inverted pendulum that can also move about in a two dimensional plane. The robot contains sensors which provide feedback for balancing and trajectory tracking. The two-wheeled robot will need to be modeled and a control system designed. The control program will be downloaded into a hardware two-wheeled robot.

2 Justification for and Significance of the Study

The two-wheeled robot has some challenges that are not seen in the inverted pendulum problem. In the inverted pendulum problem found in the book by Vaccaro [1], the pendulum is mounted to a cart. The cart is directly coupled to the drive motor, while the pendulum moves freely on a mounted encoder. The two-wheeled robot has the inverted pendulum directly coupled to the drive motor. Also, the inverted pendulum rotates on a single shaft. The two-wheeled robot does not rotate on one shaft, but uses two shafts, one for each wheel. This problem was examined by Yamamoto [2] by controlling the average of the two wheels. Yamamoto was successful in creating a closed loop control for balancing, however, his controller did not provide closed loop control for trajectory tracking. Rather than control the average of the wheels (a single control input), the proposed control system will send independent, coordinated, signals to each motor (two control inputs). The design of this system will require the tools of multivariable control theory. Tests with the hardware robot will demonstrate the applicability of multivariable control theory to a real-world system, and what, if any, modifications have to be made for the theoretical results to be implemented in hardware.

The ability to accurately track a trajectory will be the main focus of this thesis. Trajectory control has been studied in three-wheeled robots by Nilulescu [3] and Yuan [4]. The methods used by both Nilulescu and Yuan will be examined for the use in a two-wheeled robot.

The controller will also require attention to nonlinear dynamics. Along with the balancing and trajectory tracking, friction compensation may need to be added to increase the dynamic response of the robot control. Nonlinear dynamics other than friction can be seen in the state space equation shown in reference [5], which was compensated for by using a Proportional Integral Sliding Mode Control PMSMC.

The proposed controller will utilize a digital tracking system for balancing and trajectory tracking. The previously mentioned references will be used along with controls textbooks references [6], [7] and [8] to design the controller.

3 Methodology or Procedures

The research for this master's thesis will require a scientific approach. The dynamics of the system need to be carefully scrutinized, utilizing research from the above references, and the micro controller architecture which can introduce delays [9]. A plant model exists [2], however a simpler or more complex model may be needed. The model will need to be extended to include the effects of computational time delay in the hardware system. Also, an attempt will be made to obtain a system model directly from measurements of the hardware system. This thesis will include details of reference trajectory generations, including acceleration profiles that are achievable by the hardware system.

Once the model is completed, a controller will be outlined and designed. A stability analysis will be performed on the controller to ensure the design is robust. Simulations will be used to observe the response of the system. Once the controller is determined to be stable and simulations show confidence, it will be loaded onto hardware. The robot will connect with Matlab Simulink using an interface designed by Villanova University [10]. Finally, collected data from the hardware and simulations will be compared.

4 Resources Required

The resources required to perform the research has been acquired by the University of Rhode Island (URI) College of Engineering. Simulations will require the use of Matlab Simulink for which URI has available student licenses. The hardware uses LEGOs and LEGO Mindstorm which URI has already purchased for use in the Controls Laboratory.

LIST OF REFERENCES

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