



National University of Singapore

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Assignment for EE5101/ME5401 Linear Systems

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Assignment for EE5101/ME5401 Linear System

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Abstract

This is abstract

Plant description Control and observer design method description Design details Simulation results Possible comparison Comments and discussion Modification and refinements

Keywords: Keywords1; Keywords2;...

Contents

1	Introduction	3
2	State feedback controller by pole placement	4
3	...	4
4	Conclusion	5

1 Introduction

Combining the high safety of car and low cost of motor, self-sustaining two-wheeled vehicle (Fig. 1) has drawn research interest in universities. Though most of study are still in experimental stage, different control methods have been tested on this motorcycle-like vehicle and some experimental results have been released online.

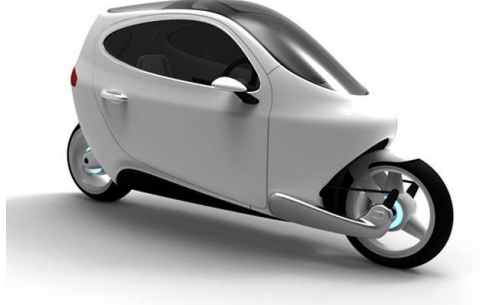


Figure 1: Two-wheeled self-balancing car

The two-wheeled vehicle is composed of a cart system, a steering system (front part) and a body (rear part). Driven by the DC servo motor, the cart and steering systems allow drivers to change cart position and handle angle. To simplify the modeling in this mini-project, the self-balance two-wheeled vehicle is assumed to be stationary and the mechanical structure is given in Fig. 2.

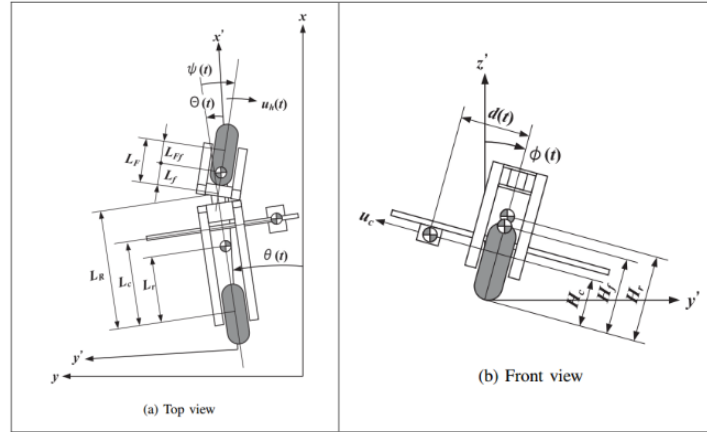


Figure 2: Simple two-wheeled vehicle model

Then, state space model is established

$$\begin{aligned} \dot{x} &= Ax + Bu \\ y &= Cx \end{aligned} \tag{1}$$

where the state is designed according to the cart position, handle angle, bike angle and their corresponding velocities respectively

$$x = \begin{bmatrix} d(t) & \phi(t) & \psi(t) & \dot{d}(t) & \dot{\phi}(t) & \dot{\psi}(t) \end{bmatrix}^T \tag{2}$$

and the relative matrices and input vectors are

$$A = \begin{bmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 6.5 & -10 & -\alpha & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & a_{56} \\ 5 & -3.6 & 0 & 0 & 0 & -\gamma \end{bmatrix}, B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ \beta & 11.2 \\ b_{51} & b_{52} \\ 40 & \delta \end{bmatrix} \quad (3)$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \end{bmatrix}, D = \begin{bmatrix} u_c(t) & u_h(t) \end{bmatrix}^T \quad (4)$$

The parameters in matrix A and B can be calculated as

$$\begin{aligned} a_{51} &= -\frac{M_c g}{den}, a_{52} = \frac{(M_f H_f + M_r H_r + M_c H_c)g}{den}, a_{53} = \frac{(M_r L_r L_F + M_c L_c L_F + M_f L_F L_R)g}{(L_R + L_F)den} \\ a_{54} &= -\frac{M_c H_c \alpha}{den}, a_{55} = -\frac{\mu_x}{den}, a_{56} = \frac{M_f H_f L_F \gamma}{den} \\ b_{51} &= \frac{M_c H_c \alpha}{den}, b_{52} = -\frac{M_f H_f L_F \delta}{den}, den = M_f H_f^2 + M_r H_r^2 + M_c H_c^2 + J_x \end{aligned} \quad (5)$$

The physical parameters appering in Eq. 4 and Eq. 5 are usually measured mannually by experiments and they are given in appendix.

After obtaining the linear system model and giving a step reference signal for each input channel, two basic response performance specifications are required to meet as follows

- The overshoot of system should below 10%.
- The 2% settling time should be less than 5 seconds.

The rest of the report is structured in the following manner: In section 2 a state feedback controller is designed using pole placement methods, followed by a discussion on effects of different pole choices. Section 3 concludes a Linear Quadratic Regulator controller design as well as the techique on choosing the weighting matrixes Q and R . Section 4 introduces a state observer based on the former LQR control system and its performance is evaluated by monitoring the state estimation error. Section 5 describes a decoupling controller for a 2-input-2-output system. Section 6 designs a controller enabling the output of plant to track the reference signal regardless of step disturbances in input channel. Section 7 tries the integral control method to maintain outputs at a constatatnt set point with zero steady-state error. Section 8 concludes the work.

2 State feedback controller by pole placement method

Size[1]

3 ...

...

4 Conclusion

Acknowledgments

References

- [1] M. E. Wilson, R. H. Trivedi, and S. K. Pandey, *Pediatric cataract surgery: techniques, complications, and management*. Lippincott Williams & Wilkins, 2005.