EECE 460
CONTROL SYSTEM DESIGN PROJECT
Control of optical storage drive

Due April 10, 2013

CD-drives, DVD-drives and Blu-ray drives rely on control technology. These optical storage drives read information from a disk using optical read-out. The information is stored on the disk surface through a sequence of reflective and non-reflective pits in a track. An optical unit picks up the reflected light to recover the information. The position of the lens needs to be controlled accurately to be able to read the information on the disk [1].

The radial position of the lens is controlled to follow the track and the distance from the disk is controlled to provide focus. The radial distance in a DVD player is controlled using two actuators, one with a large range of motion that positions the optical unit and a second one that controls the position of the lens within the unit [1]. In this project, we will focus on the control of the radial position of the lens within the unit[1].

Control Specifications

The amount of data that can be stored on a disk depends on the width of the tracks. This track width is 740 nm for a DVD. To preserve read-out and continuous playing, the tracking error needs to remain within half the track width, ie. 370 nm. In optical storage drives, the difference between the disk position $r(t)$ and the lens position $p(t)$ is measured, resulting in the control setup shown in Figure 1.

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[1] System description, model and disturbance models based on [1].

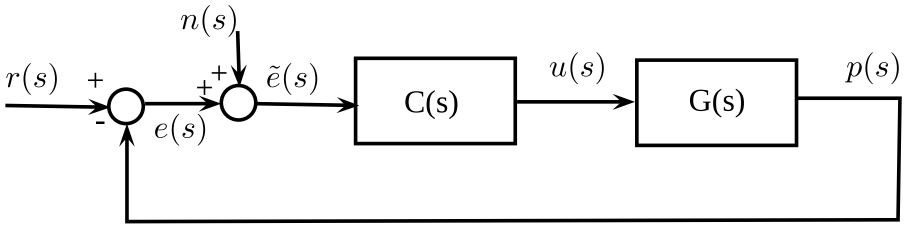

Figure 1: Control setup for the radial position of the lens. $r(s)$ represents the track position, $p(s)$ corresponds to the lens position. To preserve read-out, the error $e(s)$ needs to remain within half the track width. The measured variable is $\tilde{e}(s)$, the error affected by measurement noise $n(s)$.

- The model of the system is given by:

$$G(s) = \frac{1}{(ms^2 + bs + k)}, \tag{1}$$

  where the lens dynamics are represented by a second order damped mass-spring system. $m = 7\text{x}10^{-4}$ kg, $b = 2\text{x}10^{-2}$ Ns/m, $k = 32.2$ N/m [1]. The actuator dynamics are much faster than the dynamics of the mass-spring system and are approximated by 1.

- The control signal $u(t)$ is limited between -2V and +2V.

The following disturbances affect the system:

1. Low frequency disturbances due to movement and shock impact to the dvd player. This movement will move the disk and thereby the position of the track $r(s)$. Assume that disturbances $\tilde{r}(t)$ of up to 3μm affect the disk position $r(s)$ up to 200 Hz ($200 \cdot 2\pi$ rad/s). The controller will need to compensate for these movements and follow the track with an error smaller than half the track width to preserve read-out (ie. the gain from $r(t)$ to $e(t)$ needs to be $\leqslant 0.370/3 = 0.1233 < -18dB$ at 200 Hz).

   Note that due to these disturbances, the track position $r(t)$ is affected by two signals;

$$r(t) = r_t(t) + \tilde{r}(t),$$

   where $r_t(t)$ is the track reference defined by the user and $\tilde{r}(t)$ is the disturbance. The track reference $r_t(t)$ is known. The disturbances $\tilde{r}(t)$ are not measured and although they appear in the track position $r(t)$, they cannot be filtered outside the loop.

2. High frequency measurement noise due to disk defects like scratches or fingerprints $n(s)$ affect the measured error. Assume that measurement noise equivalent to 100 nm affects the system at frequencies > 3000 Hz. To achieve continuous read-out noise amplification needs to be limited to $\leqslant 370/100 = 3.7 < 11$ dB for > 3000 Hz.

Design Project

A Design a controller $C(s)$ for the radial position of the lens in the DVD optical drive described by $G(s)$ that:

- achieves zero tracking error in steady state
- provides continuous read-out given the disturbances described in 1) and 2)

- follows step changes in the track reference position $r_t(t)$ with < 5 % overshoot.

Show the response of the controlled system for a step change in the reference signal $r_t(t)$ of 1mm. To evaluate whether your design meets the specifications to guarantee continuous read-out for disturbances described in 1) and 2), you can generate disturbance signals that meet 1) and 2) by filtering a unity step signal $r_s(t)$ and $n_s(t)$:

$$\begin{aligned}\tilde{r}(t) =& \frac{3.5}{s^2 + 75.4s + 1.58 \cdot 10^4} r_s(t), \\ n(t) =& \frac{3.18 \cdot 10^{-12} s}{3.18 \cdot 10^{-5} s + 1} n_s(t).\end{aligned}$$

B Eccentricities of the disk and tracks lead to sinusoidal disturbances that can largely exceed 3μm. The frequency of the disturbances due to eccentricities depends on the rotation speed of the disk. Assume that the disk rotates at 15 Hz ($15 \cdot 2\pi$ rad/s). Design a controller that achieves the design objectives in A) and achieves zero steady state error also in the presence of eccentricities.

Show the obtained response to a sinusoidal track position due to disk eccentricity

$$\tilde{r}(t) = 10^{-3} \sin(15 \cdot 2\pi t).$$

Evaluate whether your design meets the specifications to guarantee continuous read-out for the same disturbance signals generated in A.

Report

You can do this project alone or in groups of two. Report how the controller was designed and evaluated. Send your report as a pdf and attach the matlab files that generate your results (provide one master file that reproduces the results).

References

[1] N. van de Wouw, H. A. Pastink, M. F. Heertjes, A. V. Pavlov, and H. Nijmeijer, "Performance of convergence-based variable-gain control of optical storage drives," *Automatica*, vol. 44, no. 1, pp. 15–27, Jan. 2008.