Linear Motor Response to PID Stabilization

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Abstract

A method of reducing speed fluctuation in a moveable mirror actuator was explored. Due to the electromagnetic and frictional forces involved, traversing the mirror in scan mode can cause inconsistencies that hinder collection of reliable data and decrease potential resolution. Using a Stanford Research Systems PID controller, we tested the advantages and disadvantages of various potential components of a negative feedback loop meant to guide the motor to a stable, adjustable speed and keep it there for extended periods of time.

Methods & Approach

The first step was to test the motor with a standard low noise preamplifier. Using a Stanford Research Systems Model SR560 we tested the program (run in Visual Studio) that automatically controls the box and records the voltage output each second via a laptop connected to the amplifier. After the data was collected and saved in a text file, I wrote a program in ScLab to read in the data and extract the relevant points from the full set, which includes data from when the motor is moving back into position after a full scan.

After the desired points are acquired they are plotted so we can see at a glance what effects our optimization processes actually had. After acquiring profiles of the tuning arrangements that had a useable result (i.e. did not overload or fail to move), we moved on to the PID box, to see how it compared. Pictures of the motor and controller boxes we used can be seen on right.

Results

Examples from the results of the initial testing with the preamplifier can be found below. It turns out there is a narrow band of allowed gain and cutoff. Any gain higher than what is shown will result in the signal oscillating out of control. There are clear advantages though in making the gain as high as possible without pushing over the limit.

Comparative plots of varying gain and filter cutoff time constant. The vertical axes are the voltage and the horizontal is time counts. On the left, gains of 10, 20, and 50 (blue, red, green, respectively) were used. On the right, the time constant was modulated from 0.3, 0.1, and 0.03 Hz (blue, red, green, respectively).

Discussion and Conclusion

When using the PID controller, several issues emerged. First, the proportional gain polarity had been flipped, so rather than causing the feedback loop to track in onto the set-point, it was pushing it further away. This was sorted, but then we discovered that because a proportional gain higher than 1.0 would cause the motor to experience vibrational tremors, a dead zone in input voltage is created. The system ends up needing a certain amount to break free and start moving. Adding an integral term would give it the capability to move, but very slowly relative to the target speed. It took a long time to ramp up, and if the gain on this term was increased, it began to overshoot too much to recover. The derivative term seemed to have no significant impact, possibly because that term is based on the rate of change of the error function, which did not experience much movement, therefore preventing this term from contributing.

PID is a proven method of stabilizing things such as temperature controllers, but for this system is appears that too many mechanical issues interfere with this type of operation. There was also an added DC offset coming from the amplifier which could not be traced back to the controller or the motor, so could not be reduced. This had an effect on the minimum voltage we could apply. If the motor scanned faster (i.e. higher set-point) then the proportional gain would alone would be enough to get it moving, but at the speeds we were looking for it seems PID is not suitable for this application.

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Introduction and Background

Our goal was to test the potential application of a Proportional-Integral-Derivative (PID) controller to aid in reducing fluctuations from the targeted scanning speed of the mirror. This process works by the calculation of an error function, and then the application of a three-term gain function, seen below.

\[
\text{Output} = Pe + I \int \frac{dv}{dt} + D \frac{dv}{dt} + \text{Offset}
\]

Epsilon is the error function, defined as the set-point minus the current measured value, and the P, I, and D terms are the gains of each term of the function. Some systems only require proportional control, and some are more complicated and require two or even all three terms to get a steady response.

The motor we were testing is composed of a magnet held up on tracks from the targeted scanning speed of the mirror. This process works by traversing the mirror in scan mode can cause inconsistencies that hinder collection of reliable data and decrease potential resolution. Using a Stanford Research Systems PID controller, we tested the advantages and disadvantages of various potential components of a negative feedback loop meant to guide the motor to a stable, adjustable speed and keep it there for extended periods of time.

The motor we were testing is composed of a magnet held up on tracks. This magnet rests inside a solenoid that use low friction ball bearings. This magnet moves it induces a current in its coil and by measuring that we can tell how fast the whole thing is actually moving.