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Model Reference Adaptive Control of Satellite Orientation GUI:

Background and Analysis

This GUI is a visualization of the motion about one axis of a communications satellite oriented through an adaptive controller. This GUI also explores the addition of Gaussian dither to the input signal to enhance the rate of convergence of the adaptive controller.

An adaptive controller can be of great utility as it can provide a controller that optimizes itself over time to the existing system, even with limited information on the parameters of the system. Limitations on this information can be due to an initial lack of information, or an imprecisely measured change in parameters due to damage or other unexpected changes. In this case, the controller has limited information of , the moment of inertia of the satellite.

**System Dynamics**

The motion of the satellite is such that:

where : satellite attitude angle

: control input

: moment of inertia about mass center (uncertain value)

We are aiming to control the system such that it behaves as a second order critically damped system decaying towards our reference input. That is, the system should follow the model reference:

with reference dynamics, .

**Controller Background**

The adaptive controller in this GUI is an adaptive PD controller given by:

If the system parameters were fully known, the desired choice of P and D would be:

to match the reference model. However, with limited information, we choose the initial values based on an estimate of J, .

The controller parameters are functions of time:



with and being the desired values of P and D.

**Controller Design**

Defining the state variables:

, the difference between the actual output and the reference model output





Now the state equations can be written:



The controller is designed for global Lyapunov stability, using the Lyapunov function:



where  are positive constants chosen such that the Lyapunov stability criterion ( is satisfied.

Taking the derivative of V(**x)**, we find:

Substituting values of the state variable time derivatives for this system and simplifying

For to be less than or equal to zero for all values of the state variables, the first, third, and fourth terms must be 0. The second term is negative definite.

Thus, the following must hold:

From this, we find:

and are equivalent to and respectively. These can be solved from the latter two equations, giving us our adaptive controller:

*where  are arbitrary positive constants*

**Dither Background**

Dither is a noise injected into a signal for various purposes. In adaptive controllers, it can be used to introduce artificial perturbations into the system that will allow the adaptive controller to tune itself faster. By adding artificial perturbations, the system gains enhanced opportunities to compare its behaviors to those it desires, and adjust accordingly.

**Results**

A standard procedure on a satellite might be to adjust the orientation to another fixed position. This is equivalent to a single step input. Running this input through our adaptive controller as shown in Figure 1, the controller’s values of P and D are seen to change towards their final values.

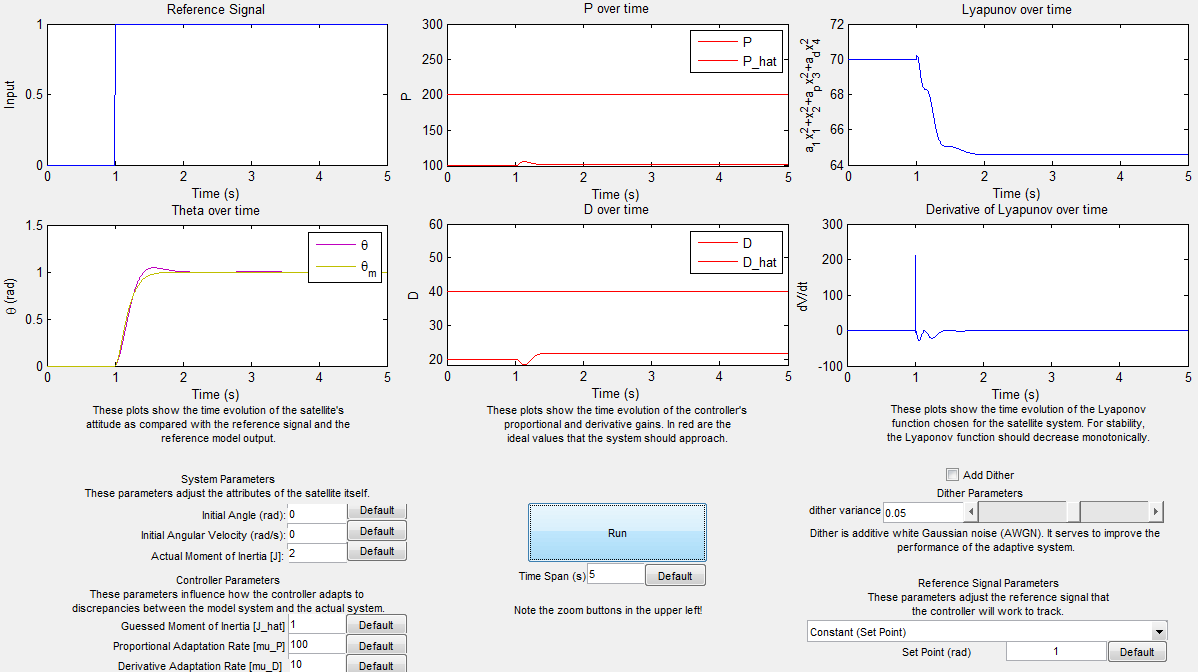
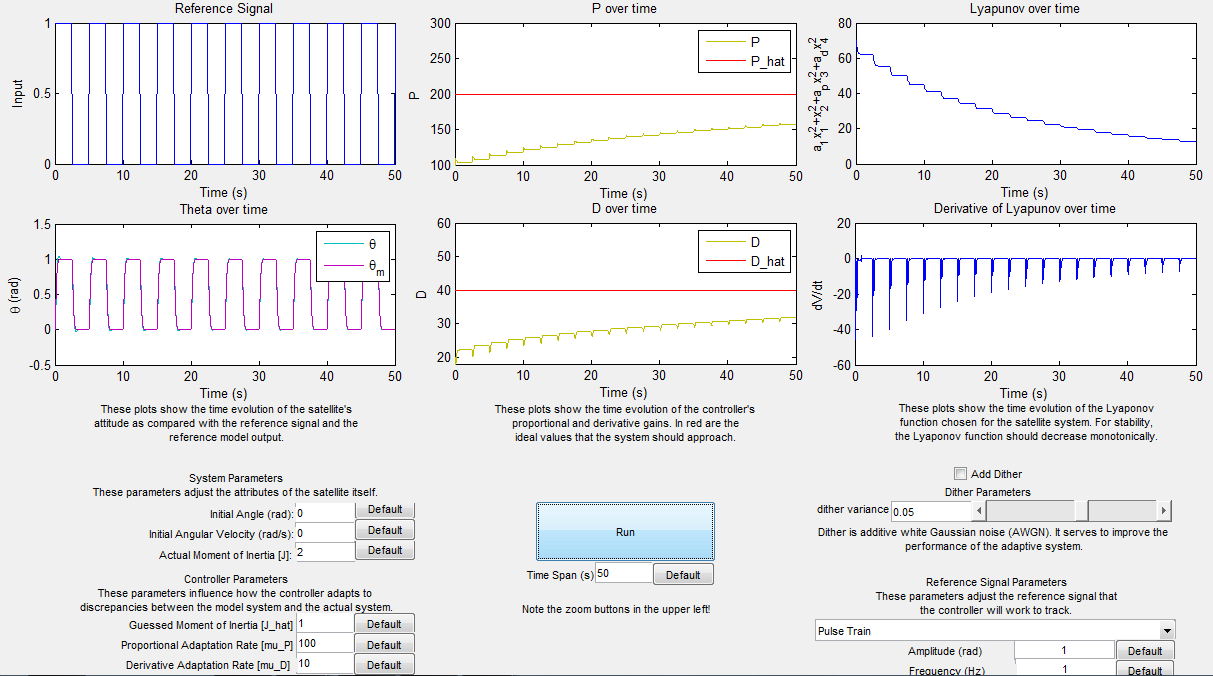


Figure 1: Step input (no dither) with adaptive controller



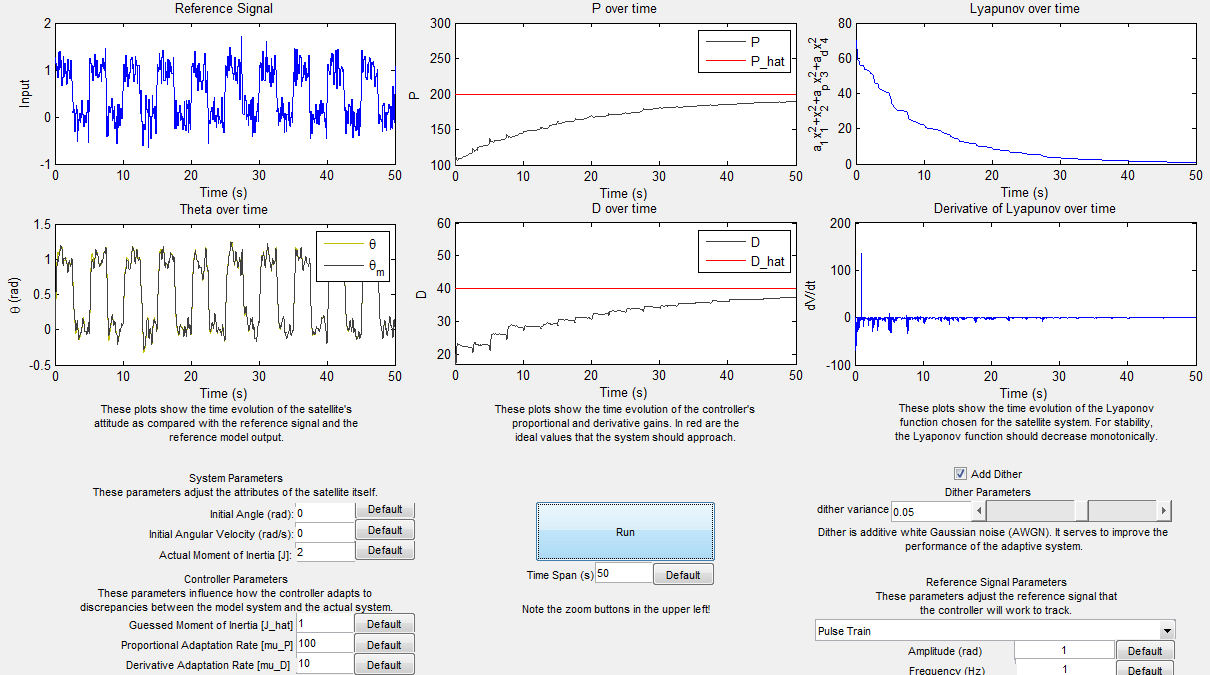


Figure 2(Top): Pulse train (no dither) with adaptive controller.

Figure 3 (Bottom): Same pulse train with 5% variance dither added to reference signal.

