**Black Box Control**

Let’s assume we have a dynamical system:

And an unknown closed loop controller:

Example: , in this case and

The closed-loop system holds:

With the property:

We want to control the torque of the dynamical system

With *almost-known* , with known, but unknown. Note that . We can consider this a problem similar to the Black-Box Control problem:

With and being the output torque we want to control. Note that we have also access to the state variables .

We can take advantage on the fact that the control signal appears explicitly in the output . In fact that arise 2 control ideas:

1. Find the inverse function: At least in a given domain. In fact, if is not injective respect to we can still chose one of the multiples values of the inverse, considering some continuities issues. If is not surjective, doesn’t reach some particular values of torque, simply it will not be possible to get those values, we must delimit the domain for the inverse.

If we can find a with and . We can simply send as control signal and “instantaneously” get when the restrictions hold (Note that is the desired torque).

Finding the function or the inverse will use an empirical method. Some approaches are regression or machine learning, in any case, we need to get data and fill a big part of the operational space to get some good results, or at least, the interesting part (a subset of it).

1. Use integral control: In fact, main problem with find the inverse is the amount of data it will require. It grows exponentially with the order of the system, so another possible solution can be use simple integral control. Let’s define:

Defining as a virtual state variable, and as the new virtual control variable with:

Let’s suppose now:

And suppose we know the sign of .

If we apply:

With diagonal positive definite matrix, we have:

Finally let’s suppose that in the operational space and

For each if we pick a with :

In particular we have:

So the error will always be moving with as minimum speed. Knowing that . We can use the following Lyapunov function:

Given that is non-smooth when , we will have chattering at this point. The higher is the higher is chattering, but this is reduced when the integration step is increased.

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1. Use integral control and an estimate of the inverse function: Now let’s give robustness to the system, we’ll mix the estimate of the function and integral control. In particular, the advantage here is that possibly we need a lower value of the integral term, and chattering will be drastically reduced. Let’s define again:

Defining as a virtual state variable, and as the new virtual control variable with:

Let’s note that , taking time derivative we have:

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In particular, if and

\* will be a tensor