RBE 502 Project Adaptive Control Report

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This report will follow the structure as below:

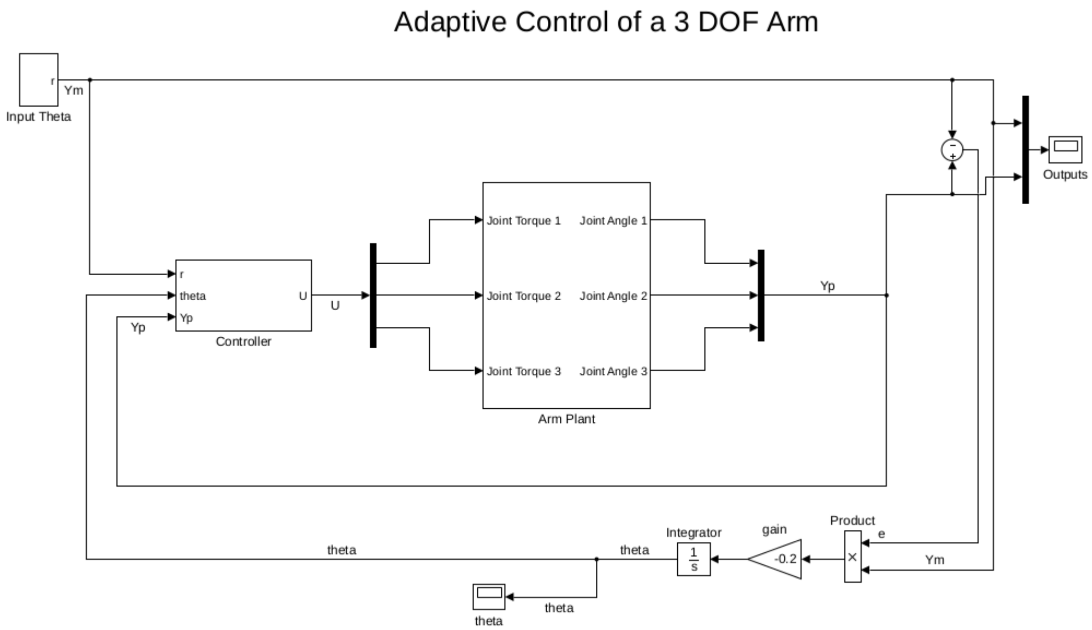
1. adaptive control definition
2. simulink design
3. reference mode
4. sub-control system
5. dynamic feedback
6. adaptive mechanism
7. learning rate
8. results

1. Adaptive Control Definition

Adaptive control is the control method used by a controller which must adapt to a controlled system with parameters which vary, or are initially uncertain.(Wiki)

For example, a motor may changes it's stiffness value during the runtime or a plane's gas tank may reduce the plane's whole weight during a flight. As we see, in those cases the plant's system parameters are changing along with time and that is when we want to use a adaptive control to compensate this.

2. Simulink Design



In this project, we have designed a simulink model that will use the adaptive control to control a 3 DOF arm model. The system has following parts:

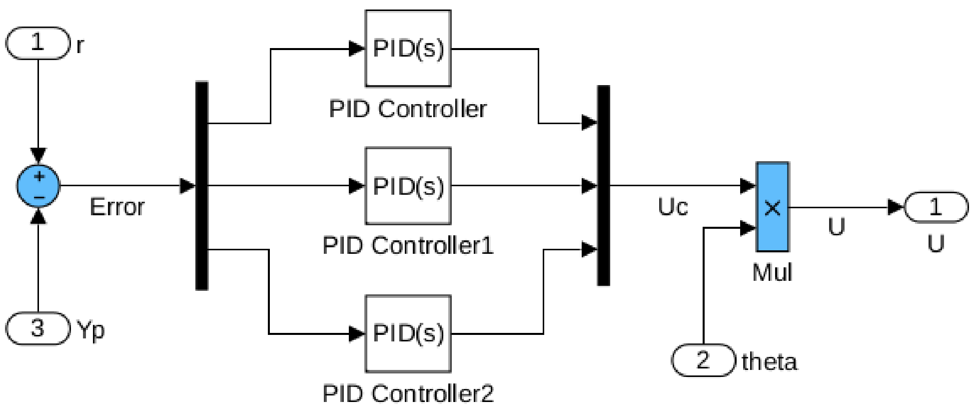
- An input model
- A Sub-Controller model
- A Reference model
- A Plant model
- A adaptive adjustment model
- Several outputs

3. Reference Model

The reference model is how you want your system behavior like, it should a transfer function along with time. In my understanding, this will be seen as the desired value of your system output and then you compare it with the actual value from dynamics to calculate the error.

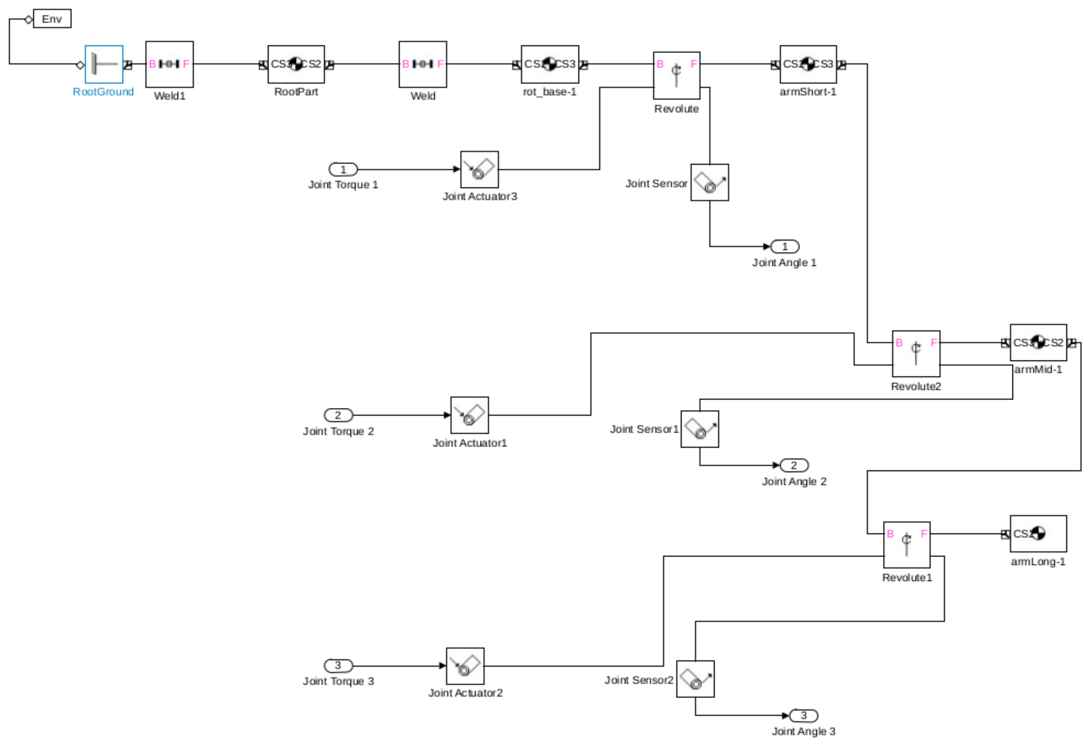
In this simple case, we have a very raw reference model that the output is just the same as the input.

4. Sub-control System

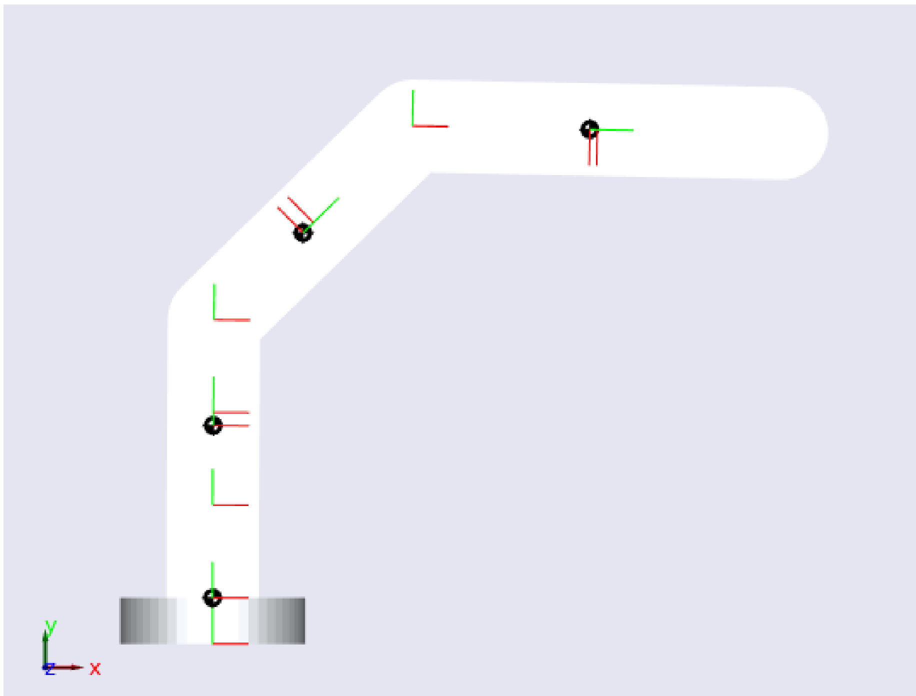


We have three PID control as the sub-control system to control our three joints. We are using the **direct adaptive control** so the adjustment value coming from the adaptive controller will directly affect the PID control's output. Which is shown in the picture above as the <2> theta.

5. Dynamic Feedback



We use Simmechanics to generate dynamics feedback, this is a online feedback. We design our physical model in solidworks and setup all the material properties and then import them into Simmechanics. As for that, we can get the simulated value from it.



This is the simulated arm model

6. Adaptive Mechanism

We can conclude that

$$M(q)\ddot{q} + C(q,\dot{q})\dot{q} + F\dot{q} + g(q) = u$$

under the control law

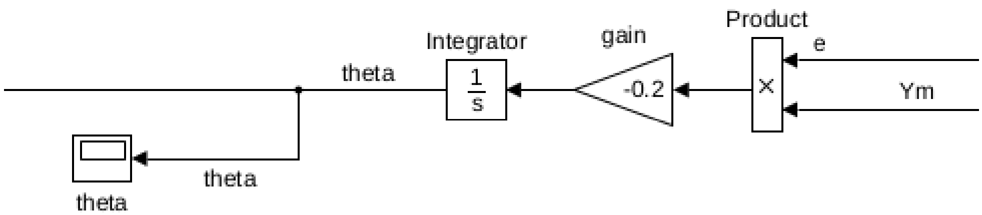
$$u = Y(q,\dot{q},\dot{q}_r,\ddot{q}_r)\hat{\theta} + K_D(\dot{\tilde{q}} + \Lambda\tilde{q})$$

and the parameter adaptive law

$$\dot{\hat{\theta}} = K_\theta^{-1} Y^T(q,\dot{q},\dot{q}_r,\ddot{q}_r)\left[\dot{\tilde{q}} + \Lambda\tilde{q}\right]$$

asymptotically converge to $\sigma = 0$ and $\tilde{q} = 0$.

As from the note reference, the adaptive results is given by Y * theta_hat, so we collect the theta_hat, which is the error, by Y_pant - Y_m. Since this is a theta speed, we integrate it to be a theta angle and pass it to the sub-controller.

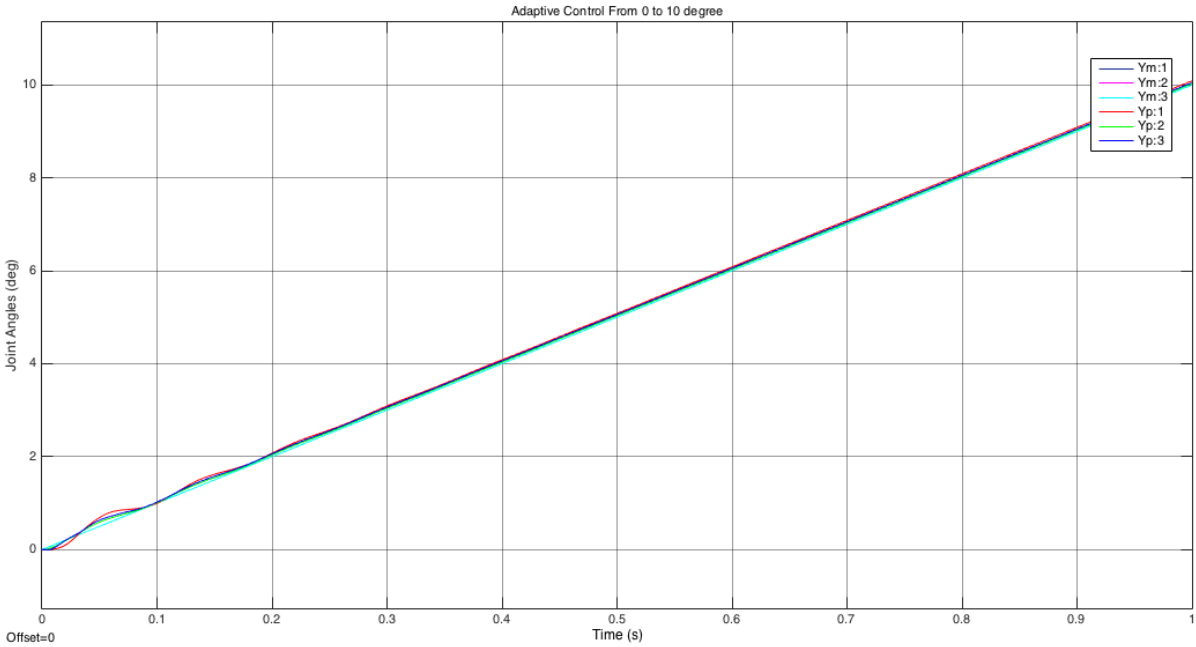


(The adaptive model)

7. Learning Rate

In the adaptive model, we have put a gain value as the learning rate. This will give a weight info to the system that how fast should the adaptive mechanism react to the error.

8. Results



(Ym is the desired value and Yp is the actual output value)

We run the system with a ramp source(slope = 10) to test. As shown in the figure, the actual values are following the desired values. We tune the PID parameters and get a reduced overshot range as well as make it converge at the end. Meanwhile, we also change the learning rate to 0.5, 0.1, 0.01; however the results are not having big difference.