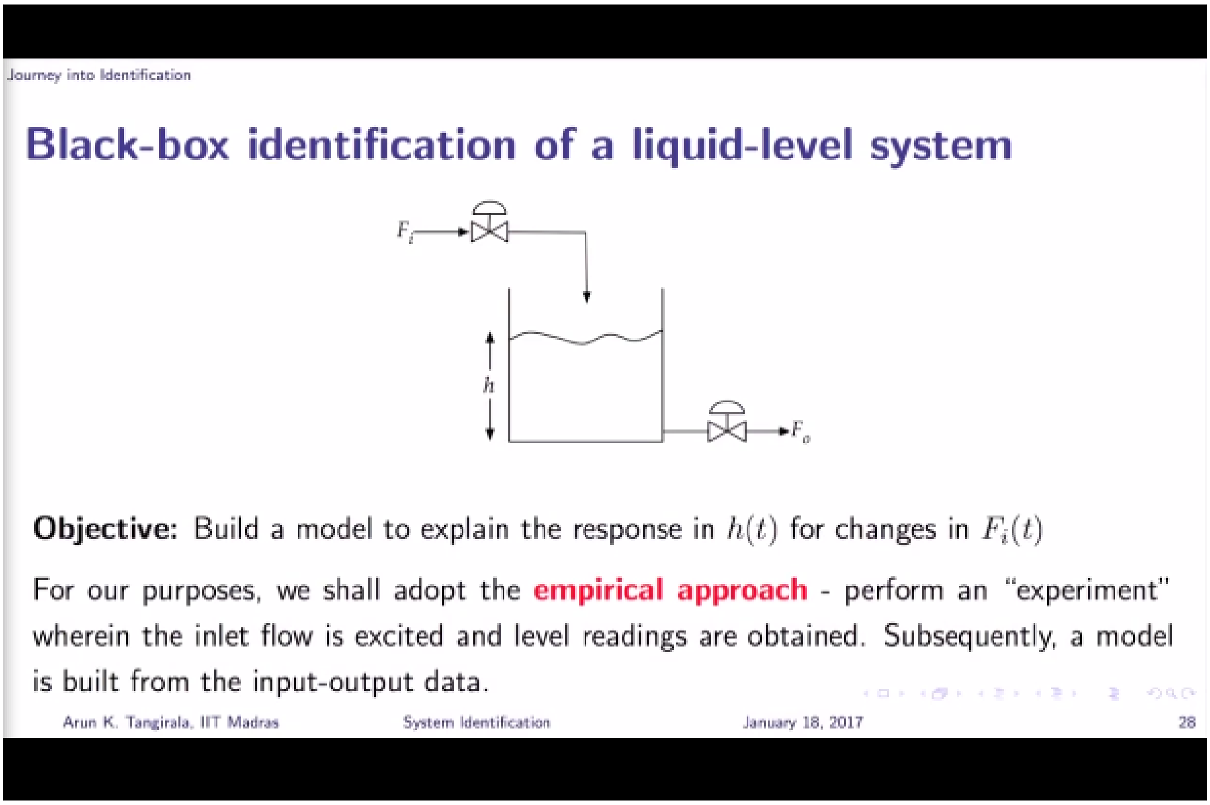
CH5230: System Identification

Journey into Identification

(Case Studies) 8

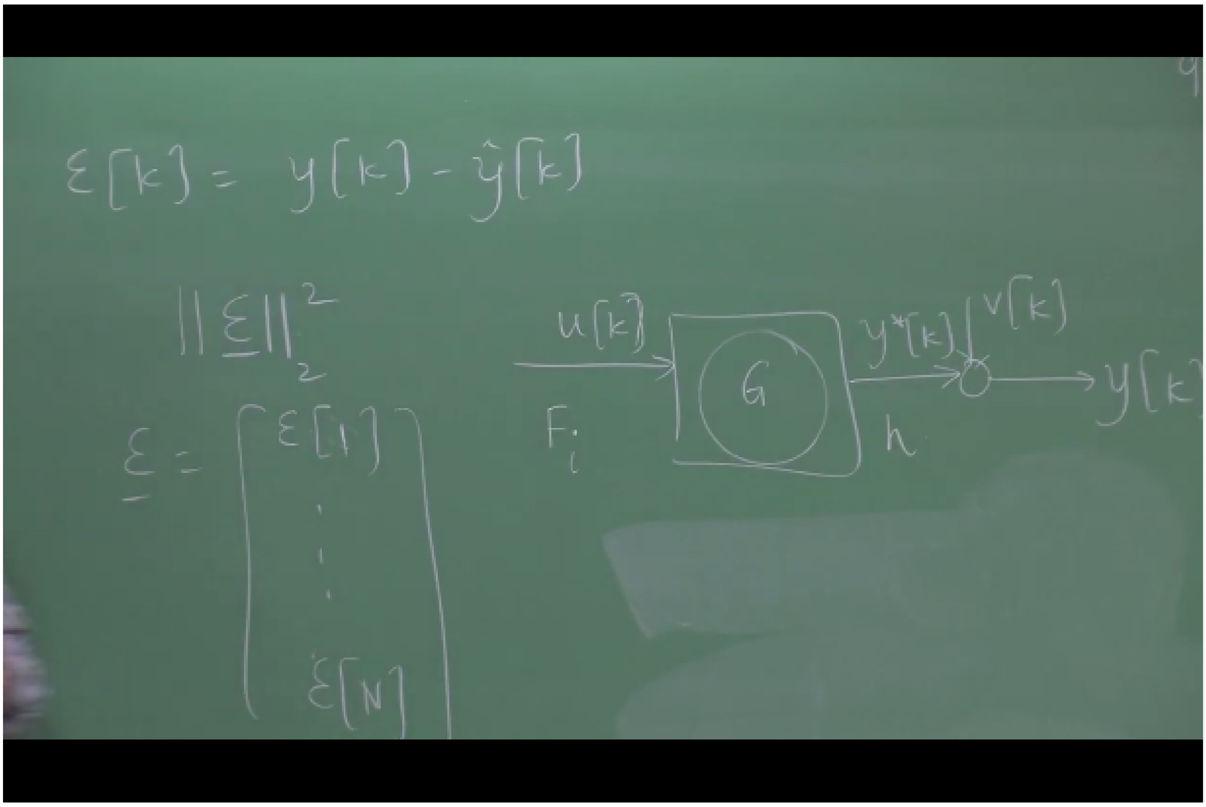
Until now, at least in the last example we have looked at static systems. Now we move to the more realistic situation, where I have a dynamic process. As I said it's a very simple process. It's a liquid level case study. The purpose of this case study is to demonstrate a typical system identification procedure. In fact you should keep referring to these examples whenever you are in doubt in future, whenever you are given data and your fitting models fall back on this case studies and see what procedure has been adopted. Of course, we will go through a few more examples later on but this will serve as good guiding examples for you.

(Refer Slide Time: 00:57)



The system is very simple, it's a liquid level system. There is a flow, in flow and then there is an outflow. There a certain amount of buffer in the tank. And the goal is to develop a model that explains the transient behavior of the liquid level. Whenever changes occurred in the inlet flow. In other words I want a dynamic model. That relates the inlet flow, rest of the things hold good. So here, the input is F I and the output is h. And I want a dynamic model between Fi and h.

(Refer Slide Time: 01:32)



Of course you know I can easily later mass balance equation and make certain assumptions and come up with an ODE, right. What kind of an ODE would you get. I mean what kind of meaning. Is it a non-linear, linear, first order, second order.Linear first order.Seriously? Depends on. Correct. Right.The way you develop the ODE is right the mass balance which will involve inlet and outlet flow rate, assuming incompressible flow. And then you use a constitutive relation between the outlet flow and the pressure and the head of the liquid level. If you assume a linear relation you'll end up with linear ODE. First order linear ODE. Typically we assume a square root relationship, therefore you will end up with that nonlinear first order ODE, that's in continuous time.

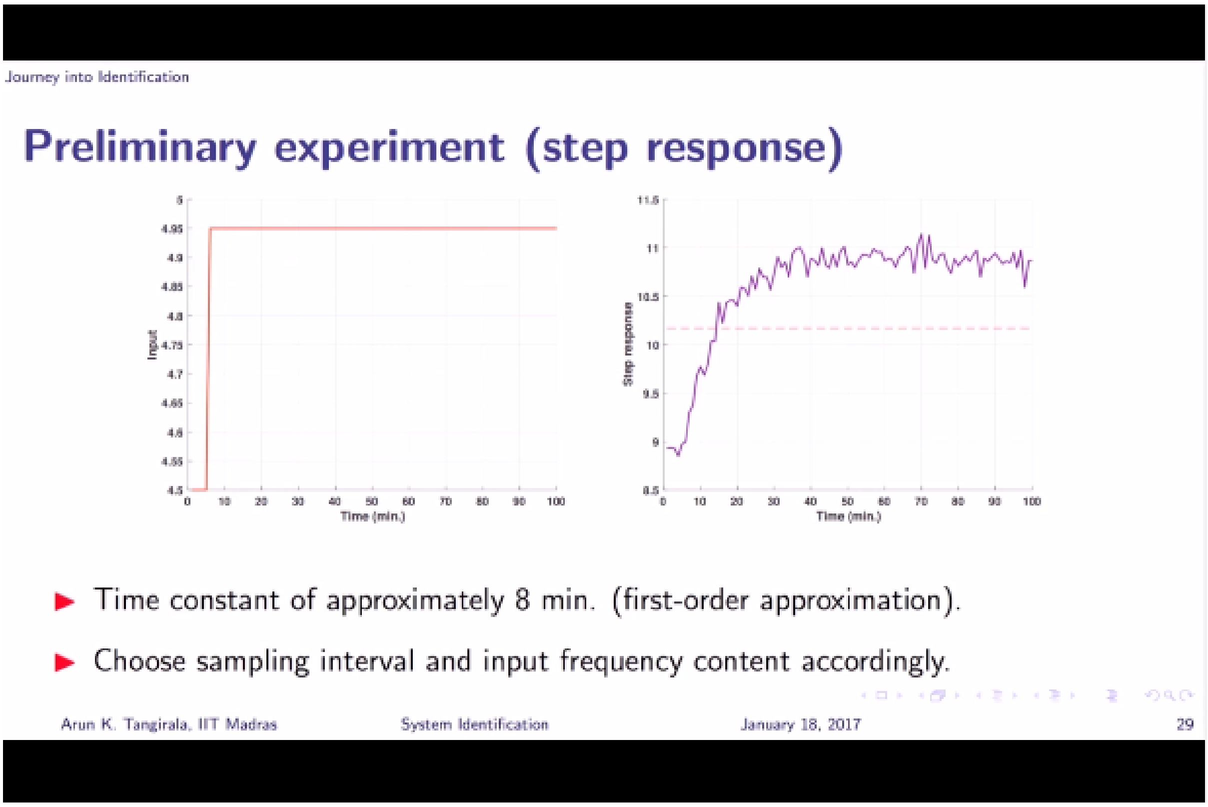
Here we'll take a different route. We'll take an empirical approach. This is quite different from what you have learnt in many of the courses. And see if I'm able to actually come up with a model that is as accurate or nearly as accurate as a first principles one. Right.So this is the empirical approach. I'm going to perform an experiment where I'm going to excite the floor and then measure the level, changes in the level. Many departments have this kind of setup. These are standard setups. So the big question now is what kind of changes should I introduce in the flow. That is question number 1. Right. This is the first challenge that you will face, question that you have to answer in system identification. If you have to perform the experiment.If somebody else has done, the experiment for you, good and bad. Why I say, good and bad? Good because you don't have to break your head down figure answering these questions. What changes have to be done. What should be the sampling interval and so on. What is bad about it. Maybe the person didn't do a good job of the experiment and you are tied down. That is equality now of the model is entirely dependent on the quality of the data that somebody else has generated. But because you are going to be an expert in system identification, given an opportunity you would perform the experiment in an excellent manner. So what kind of changes should I introduce in the flow. What do you think?Sinusoidal, step type, impulse, arbitrary changes. Step type. Okay.Let's do a step type. There you go. I performed the step test for you. You asked for it. It has been done.

It's good to perform a step test but it is not good to end with the step test hence I am done. It's a preliminary test that typically one conducts in a system identification exercise or a model empirical model development. For those of you have taken control courses you must have learned that normally in feedback control, we use lower order approximations of the model that are typically developed from step responses. This is how it is practiced in industry as well. Well, largely but not entirely. So let's say you have performed a step test and you have generated thestep response. Before you perform this step test the other question that you have to answer. Let's see how many sub questions are involved. How much of a change in step that you have to give. Do you start the experiment from empty vessel from an empty tank or do you have to bring it to a steady state and then introduce a step test. What do you think?

Steady state.

Yeah. So bring it to steady state because typically what we are interested in is a model that explains deviations from steady state. The process of starting up any process being a liquid level system, or a distillation column or Bajaj scooter, whatever it is, its different, right. We know what is a Bajaj wayof starting a faultyscooter. I mean, I'm not saying Bajaj has recommended it but it has acquired that name, I cannot help it. We ignore all the startup issues, we have assumed that the process at steady state. Now I am going to introduce a change. How much change? So, I've brought the process to a steady state and I've introduce some change but what was the basis of how much change I should introduce? So on the left you have the input, I mean, the floor essentially. And on the right you have the response.

(Refer Slide Time: 06:25)

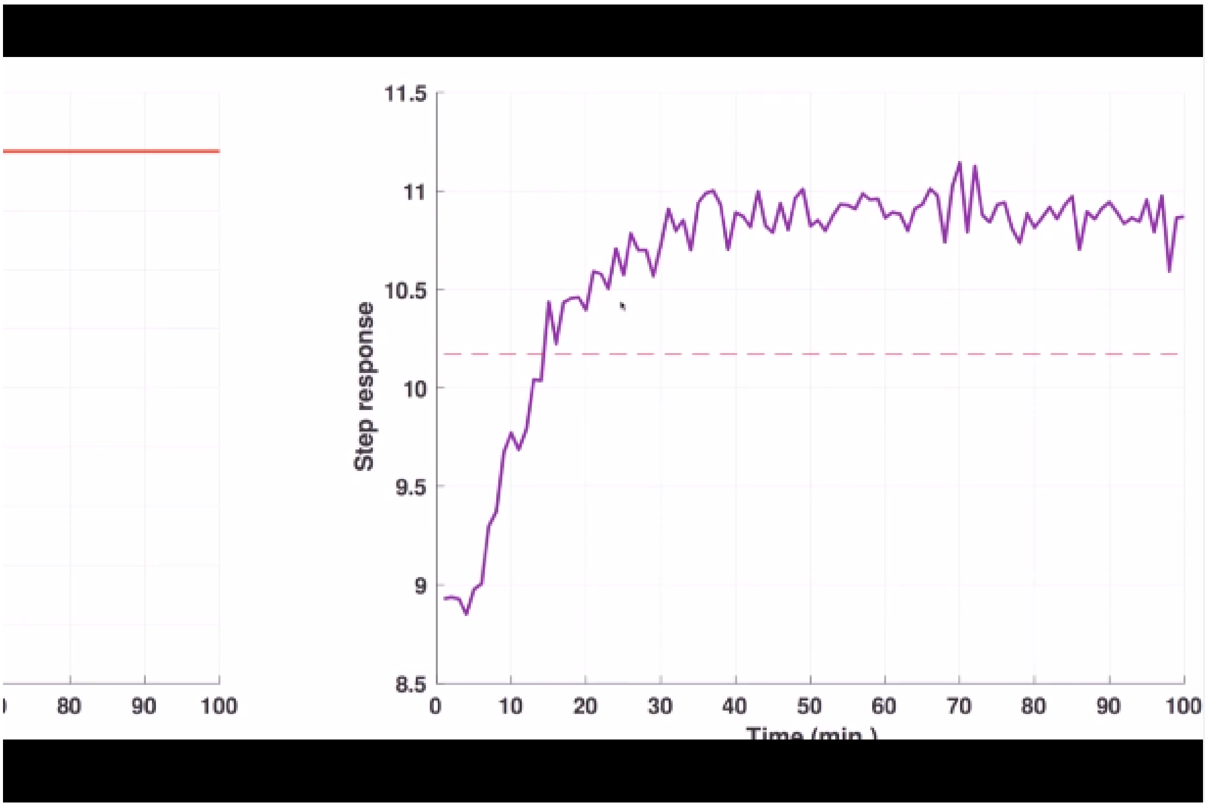


So look at the steady state here, right. Again I will zoom in for you. So the steady state is 4.5, and I have gone up to 4.95, So how much of a change, 25%. Now I have to send you back to probably 8th standard or--

Ten percent, correct. Right. Why did they choose to excite, you know, introduce a change of 10%. Why not 7.647%.Why not 5%, why not 2%, why not 25% as somebody demanded. What do you think? So, you know, jokes apart actually it is very important to answer this question.See, we are going to be build a linear model. We have to now, keep that in mind.When I'm going to build a linear model for a process that is generally non-linear. Here, this is also a non-linear but it is not as non-linear as a PH process for example or any other non-linear process that you may encounter. We say these processes are mildly nonlinear, nevertheless we are going to build not linear models but linear approximations and these linear approximations will work well for small changes around an operating point. Right.It's like imagine there is a non-linear curve and we are going to fit a straight line. A straight line will do a good job for small changes right, for locally be linear. Now, how much local? Now don't get remember this item song and so on. How much local is just that depends on the non-linearity. Right. What your linear model is going to be a pakka local. There's no doubt about it. But you see, the point is the amount of, that is a neighborhood in which your linear model will do good job. Entirely depends on the nature of not-linearity. So sometimes even a linear model may fail to do a good job for 3% or 4%changes around operating point. One has to figure that out actually. So there is an intermediate test that you have to conduct to figure out what is the percentage excitation you should introduce, change you should introduce. I have just chosen 10%. But in practice what should be done is you introduce 2%. Again one has to worry about signal to noise ratio. If you introduce too small to change your step response may have so much noise that the effect of input may not be felt.So there are so many things now I have to start worrying about even in a simple step test. So what one does is to figure out how far I can actually go and fit a linear model is to try a staircase like signal. You change by 2% or 5%. Bring it down by 2% and then again raise it by 3%. The reason for doing that is you are not only seeing whether the gains are remaining the same. That is output a scaling up, proportion to the change but also seeing whether the direction of change matters. Ifthe direction of change matters, it's a sign of non-linearity. That means if I change upwards by 5%, let me bring them back to steady state and then go down by 5%, the gain should be the same. The decrease in level should be proportional. If there is a huge difference between the gains that you have obtained. How do you figure out the gain from the step response? Just let the process come to steady state. Look at the difference in the output to the difference in the input. If that ratio is differing from the same magnitude of change but the direction is different then it's a sign of non-linearity. That means you have to back off maybe 5% is exciting the process non-linearity significantly. So even in a simple step test, one has to answer quite a few questions. Here, I have bypassed a few questions and just excited by 10% and also the other thing that I have to worry about is sampling interval. But at this stage you can choose a fairly fast sampling interval, sampling rate. And that is what kind of I have done and I've generated a step response, we will stop after this slide. And now I have the step response here. What does this step response giveme. Why should I perform this step test in system identification. Of course, it will give me some preliminary model but two important things to remember, a step test or a step input does not have sufficient excitation, predominantly the step has a zero frequency because only the change that you see contains high frequencies, that sudden change at the beginning. But otherwise barring that, what you have is actually low frequency or zero frequency, constant DC 1.

So this step is not considered a persistently exciting signal unfortunately. Okay. That means it doesn't have significant power at all frequencies. And particularly not great for maintaining good signal to noise ratio and so on. Nevertheless it's a good thing because if you give you some rough idea of the time constant and the gain whether it's positive gain whether system is unstable. Maybe you did know it was unstable and so on. Whether there is an inverse response and so on. So here you can read off roughly the time constant assuming a first order behavior, right. And I have drawn the dash line here showing 63.2% of the change between two steady states. And also notice that I have introduced here the step at the 6th instant at 6 minutes. So after 6 minutes you should see how long it has taken to reach 63.2%. And that comes out to be roughly 8 minutes.

(Refer Slide Time: 06:25)



You can read this plot carefully at leisure when you're done with all your WhatsApp messages and so on. Look at this figure. Spend some time. And then you'll figure out that 8 minutes roughly is a good time quantity. Why is this time constraint useful? Think about it. We are not going to discuss any further.Why is this time constant such a useful piece of information for,in system identification experiments or in any empirical approach.

What value does it hold?You think about it and you come back and tomorrow we'll discuss. Okay.Then we'll go through this case study in detail. Hopefully we'll be able to finish.