Introduction to Aircraft Control System

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Week – 01

Lecture – 02

In this lecture, we will be discussing in brief the open loop control system and closed loop control system and also we will be discussing how closed loop control system play an important role over open loop control system. Then we will move to this autopilot part, what are the different subsystems existing in the autopilot and how they are connected in a closed loop. We will discuss them briefly and then we will conclude the lecture. Let us go with some examples where the control system plays an important role. Let us consider we have an aircraft system and we want to maintain the desired speed of the aircraft is the output speed of the aircraft and here the pilot is here in this block for example, which is basically a controller we can say. The pilot is using the throttle which can provide the desired thrust to the aircraft control input we can say.

This is the aircraft system and we want to maintain a desired speed which is the response is going to the pilot desired speed. Or we can say desired output. Please note that this is the actual speed of the aircraft, but we want to maintain the desired output desired speed. Now, the pilot asked to accelerate the aircraft to a particular speed and we are assuming the pilot is flying the aircraft in a straight line.

So, we are assuming the pilot is flying the aircraft in a straight line. Here, flying in this fashion, the pilot does not have any idea about the actual speed because based on the input control the aircraft is getting some speed. So, does not know about the actual speed of the aircraft. If you look at this kind of system, this system may work perfectly or I should say this control system may work perfectly if the pilot knows the knowledge of the system.

What does it mean? The pilot knows here what output the system will produce when a known input is applied. So, it means the pilot knows the system perfectly only when we can get the desired speed of the aircraft. But if there are some uncertainties or disturbance come to the system, or some kind of unmodelled dynamics or uncertainty in the system, the desired speed cannot be maintained because here the pilot does not have any knowledge of the actual speed of the aircraft. So, in this case, we cannot achieve the desired speed of the aircraft if there is some disturbance or uncertainty coming to the system. But the pilot can achieve the desired speed if the pilot knows the exact model of the system.

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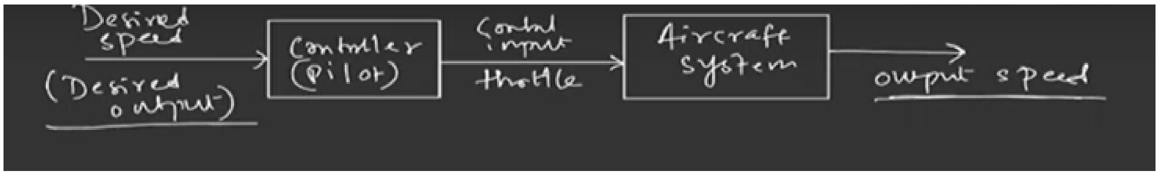

But due to this kind of input to the aircraft system, input means that uncertainty and disturbance, we can't achieve the desired speed. Again, if you have some wind to the system which is acting in the opposite direction to the flight motion, again, it will give some disturbance to the system. So, it means we can't get our objective. And this kind of system, I can say, this kind of control system where the pilot does not have full or associated knowledge of the system response, we can say is the open loop control system. So, based on whatever the response we are applying to the aircraft, we will get some output, but there is no means to correct that output.

There is no means, because there is no feedback in the system. And this kind of system we call an open loop control system. Now, the pilot decided to verify the actual speed of the aircraft. So, let's draw the figure again. So, we have a controller here, or pilot, which gives some control input to the plant.

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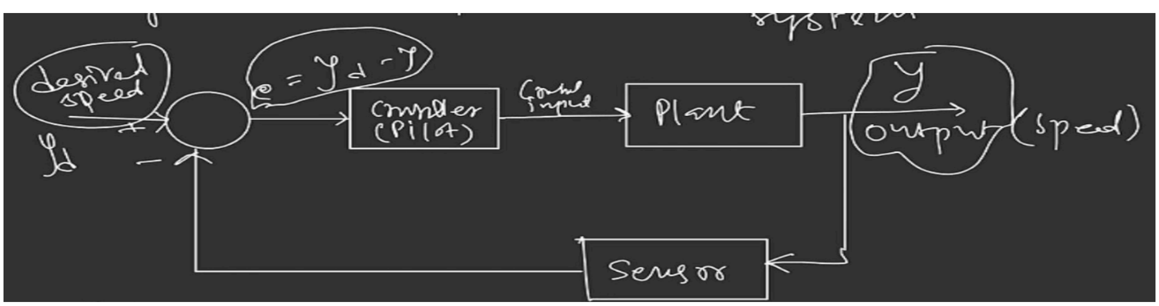

And we are getting the output speed. And if we have some kind of sensor, let's assume some sensor, and the sensor can get the actual output of the aircraft system. And if we have some summing point here, some kind of mechanism where we can, this is my desired speed. And this is the error.

And we can say this is the actual speed if you denote this is my y desired speed and this is y actual. So, the e will be $yd - y$. So, based on the error, the pilot can decide how far from the desired speed of the aircraft. And accordingly, the pilot can control the control input to the plant. And based on which we can modify the output response of the aircraft.

This is basically the low slope control system. So, now, here, the controller subsystem, because this is the complete system and here we have different subsystems like controller, plant, sensor system. So, a controller, also a system is the main design parameter in designing control system and determines how rapidly and with what maximum overshoot and undershoot the actual output, which is y in this case, will become equal to the desired speed, desired output. So, this is how the control system works. We can correct, we can modify the controller so that we can come up with our desired output.

Why does overshoot and undershoot? Because once the system goes to a desired response, it may go with some oscillations. After some time, we can come up with our desired value. We should note some points here. When the desired output yd is constant, the controller acts like a regulator. So, if you, or if the desired speed is constant and if you design the control algorithm for the system, the controller acts like a regulator and when the desired output is time varying the corresponding control system is called a tracking system.

So, this is how, in the closed loop control system, we design the regulator or tracking system. If the yd is constant to be tracked, it is the controller that acts like a regulator. If the yd is time varying function, then the design controller will be like a tracking system. So now, in control system, what are the different subsystems we are having and which can fulfill our mission objective? So, here control system means we are talking about the closed loop control system. In this course, since we'll be designing the autopilot, so most of the design algorithms are based on the closed loop control system.

So, generally it depends, it consists of three parts. One is navigation. So, navigation talks about where my vehicle is. So, it means navigation, basically we can say sensor, all these things come under the navigation system. So, navigation tells where the vehicle or what the actual speed, what are the conditions, output conditions, it measures those parameter navigation.

And second is guidance. Guidance tells where I want to be. So, guidance generally measures how far you are from the desired value. So, from this error function, we can comment how far the actual output of the aircraft is from the desired output. So, it generally measures the error, based on the error it calculates.

So, this is how the guidance works. And third is control. This is the most important part. So, control, how do I get there? So, control,based on the navigation guidance, how far you are from the actual value, then control will take the effective action so that you can achieve the mission. So, based on the error, the controller will provide the command to the plant and slowly we can come up with our desired value.

Now, let us look how the subsystems are connected in a closed loop. The navigation, guidance and control subsystems are connected in a closed loop fashion as following. First, we can start from the navigation part. This is the navigation which provides the estimated value to the guidance. So, this is my guidance loop and navigation provides the estimated values to the guidance and guidance generates the error.

And this error goes to the controller and the controller provides ideal torque and force command to the actuators. So, for example, if you are controlling the orientation of the aircraft, the actuator could be your aileron, rudder, elevator. So, the control algorithms give the commands to the actuator, commands mean what angle these control surfaces, aerodynamic control surfaces should be deflected so that we can get desired or applied force or torque to the aircraft system. And so, this is basically how actuators give the values to your 6 DOF model so that we can control the position and orientation of the body. And from the aircraft system, we are having the true values, true values means it can be x, y, z position of the aircraft or phi, theta, psi, the orientation angle of the aircraft.

So, these values are sensed by the onboard sensors. Some sensors are like an accelerometer or gyroscope or IMU. This is an onboard sensor, which senses these states and based on the sensing, sensed output, this output goes to the navigation platform or navigation subsystem. So, this we can say is the measurements. This measurement goes to the navigation.

So, this is how the closed loop control system works practically. Now, if you connect to our aircraft system, this is what we have discussed here. Suppose this is my summing block, where we input, there will be basically two inputs. This is the desired value. So, desired values can be your desired phi, theta, psi or a position of the aircraft.

And so, this is the error signal. Let me first draw the figure, then I'll explain. This is the controller and controller output goes to the servo system on the aircraft servo system.

And servo system generates the desired or the available torque or thrust, aileron, rudder elevator and these available values goes to the aircraft system.

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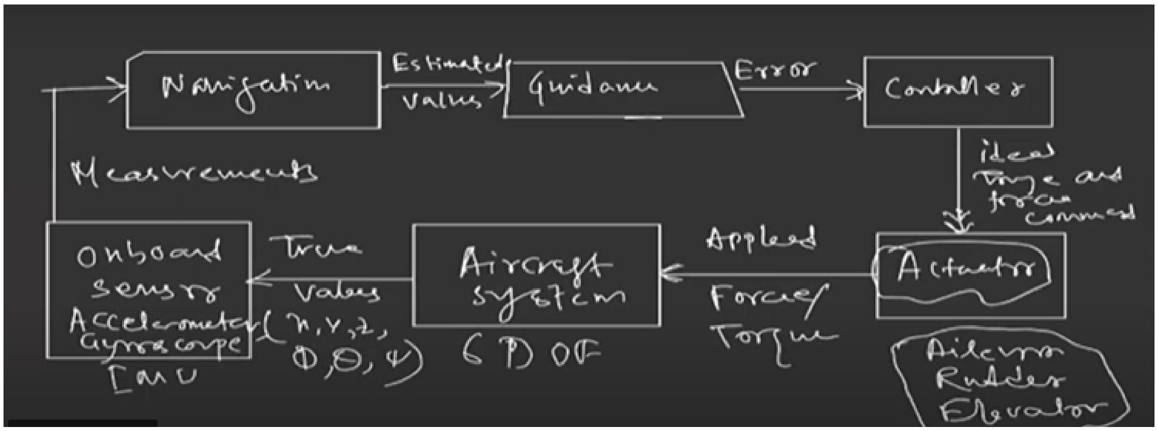

This is a 6 DOF model. If you are assuming the full aircraft equation, this is basically a 6 DOF model. And the actual output is sensed by onboard sensors, and the sense output goes to the navigation block. So, in navigation basically, we can come up with some filter techniques or some kind of other designs where we can find the estimated values. And these estimated values go to the summing point, negative, a negative loop. So, why is it negative? We'll be talking later, why not it's positive, all this thing will be covered.

And so, based on these estimated values, we can find the error and this error signal goes to the controller and the controller can take the effective actions based on the control system. We provide the ideal values to the servo system. Servo system basically can assume the motor, what deflection we should have for providing the desired torque or force to the aircraft system. So, this is how practically autopilot works. So, this is basically autopilot design. This can be for aircraft, for the rotational motion or translation motion or any other motions in the aircraft.

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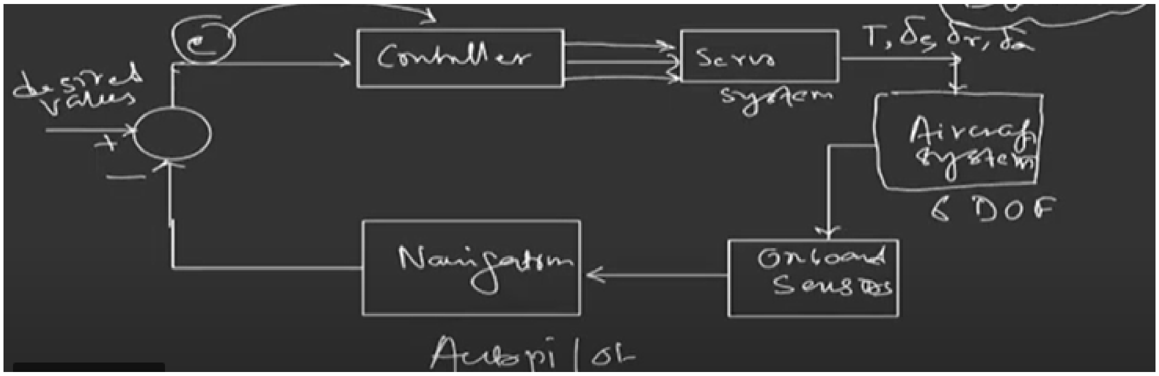

So, this is how we achieve our missions. Let's stop it here. We'll continue from the next lecture. We'll have some basics on our systems, how we will validate the system, whether it's linear or not, because most of those systems in this course will be considering linear system, because we'll be designing the linear controls for this aircraft. So, our systems should be converted into linear form and we can apply the linear controls.

So, this is how we'll be moving. Thank you very much. We'll be continuing from the next lecture.