Lecture 13 : Experimentation IV (Contd.)

Hello all, we are back from the field experiments. Now, I am going to explain you, how we have done these field experiments, so that you can understand the logic of how the drone is moving forward, backward and it is doing circular motions in the field. So let's see. Consider this as a motor attached with a propeller. When this motor is spinning, the propeller is also spinning.

So basically there is a pressure difference generated here, which is getting in a force generation. So, this force, we can consider into two components. One is the downward force exerted by the air that is pushed down. So in reaction to that we are getting an upward lift force, here.

So this is one component according to Newton's third law. Another is due to the own spinning motion of the motor, this is getting exerted at the centre of the body as a torque. So, whatever this motor is rotating, it is creating an opposite reaction. Let's say this is rotating in clockwise direction. So this will generate a torque on the body, which will make the body to rotate in anticlockwise direction.

So we have two components, one is the torque component and another is the lift force component. So now how are we going to control and use this concept in our drone, we are going to see. As you have seen our drone is having four motors. I am going to number this according to its spinning direction. So, let's say this counter clockwise rotating motor is 1.

So opposite to that we have another counter clockwise rotating motor 2. This clockwise rotating motor is 3 and this clockwise rotating motor is 4. So why are we arranging specifically like this? What is the reason behind this configuration we are going to see. So as you can see a counter clockwise motor is generating a torque on the body in the clockwise direction. So to counteract this we have to have a clockwise rotating motor so that we will have a counter clockwise torque generated on the body.

So these two motors are compensating each other and these two motors are compensating each other. So that both on the lateral axis and the longitudinal axis we will have a balance of the torque. So now when all of these motors are spinning at the same rate means the RPM is same, the body will be stabilized. This is the concept between the drones. So now what is the concept between its altitude and altitude control.

When you are talking about a drone, we have two controls one is called as altitude control and the other is called as flight control. So what is altitude control? It is controlling on which height the drone is flying, that is called as the altitude of the drone, the flight altitude. So, that flight altitude will be denoted as z. So altitude is what we call as roll, pitch and yaw. So, pitching moment is shown as π and roll moment is θ and yaw moment is ϕ.

So this is how we define these things. Now, in a Cartesian coordinate system, if you define this the forward direction of the drone. It can be any drone like in our case it can be a cold cutter or it can be a fixed wing drone. In any drone, the forward direction of the drone is termed as x. And, the right side component of it is termed as y.

So vertical component mutually orthogonal axis is termed as z. So, this is how we define the axis of a drone. So now when you are having a rotation about its lateral axis that is called as pitching. When it is having a rotation along its forward axis or its longitudinal axis it is called as rolling. So when the total direction of the drone is going like in a car, how we are steering the car.

When the total direction of the drone is changing that we call as yaw motion. So these three components are called as attitudes of the drone. So, now to define any object in any robotic component in free space in the first experiment, we learnt that six components are back at. x, y, z and the rolling rate about x, rolling rate about y and rolling rate about z. This six degrees of freedom, we have learnt already in my experiment.

So, the same concept is there for drone also. So by controlling its attitude, its x and y positions are going to get changed. So, the resultant of this component is x and y. And, when all the speeds of the motors are same, we are going to control the z motion. Now, let us say all the RPMs 1, 2, 3, 4 motors are there.

I am going to equally increase the RPM of all motors. Then it will be lifting up. Let us say I am decreasing all the RPMs together at the same rate. Then the drone will be, it is actually moving down. So, this is how we control the z component.

So, how do we control the x and y positions of the drone? So let us say, we are having two counter clockwise motors and two clockwise motors. Let us say, I want to move the drone towards its left side. So let us say this is the forward direction and I want to move towards the left. So what I have to do is, I have to decrease the speed of these two motors and I have to increase the speed of these two motors. So, 1 and 3 will increase and 2 and 4 will decrease.

This is giving our left side motion. So, logically to get a right side motion, I will have to increase these two components. These 4 and 2, I have to increase and I have to decrease this. So that will give me my right side movement. So that will push my drone towards right.

How I am saying this drone is going to push this side? So, initially when the force is acting downwards, the reaction force is acting towards the up. So, this is the simple logic of action and reaction according to Newton's third law. But, let us say, when I am moving these components, I am varying the components of this side and this side. So, this is going to generate more lift force and the lift force on this side is less. So, what is going to happen?

The drone is going to tilt this side.

That we call as rolling. So, when rolling is happening, the components are getting splitted like this. So this is my reaction force and this is my action force. So this is what is lifting the drone. So, here if you split this into two components, we are having two components of the force here. So this is what is pushing the drone.

This force, this component, fx component of the lift force. So this is a vector form of this and what is this? This fx force is what is pushing the drone towards the side and this fy component is the drone, is the component, which is keeping the drone at a certain height. So, this is how the force component is getting resolved. So, similar way, we have left and right motion. So, how do we generate yaw motion? So now we had seen rolling motion similar way.

When this component, the forward two motors are decreased and rear two motors are increased. That way we will have forward pitch, 4 and 1 will be decreasing, 2 and 3 will be increasing. This is pitching forward. So in the counter clock, in the opposite side if you increase these two components and reduce these two components, we will have the backward motion. So, now we have attained all the motions of the quadcopter here.

Left motion, right motion, forward motion, backward motion, lifting up and pushing down. So, this is the total motion components of the quadcopter. So, now we had seen. So, similar way when you are changing only the forward and backward, you will be having pitching action. Similar way, we will be having, this is the pushing forward force and this will be our lifting force.

So, this is the concept. So, now how are we going to control x and y, we had understood. So individual x, individual y, you can control, individual z, you can control. So, now how are we going to get the yaw motion? So, this is critical. As I had said in the earlier section, this will generate a torque on the body. This circular motion, this RPM of this will generate a torque on the body.

So, now when all of these are equal RPM, all of the torques are balanced. It means, let's say this is positive torque, this is positive torque, negative torque, negative torque. Now, when you add, this is equal to 0. This is a balanced component. When I am changing these two, I am increasing these two motors' RPM and when I am decreasing these two motors RPM, that means this is slightly higher.

Clockwise torque is higher than, sorry clockwise torque is lesser than counter clockwise torque here. So, when you are adding, the net effective torque is not equal to 0. Since this is higher than this, we will have some of the counter clockwise torque. Something will be there. Let's call it something, some quantity is there.

So, this quantity of this torque will make the total body rotate in the counter clockwise direction. So, this is how we are getting the yaw motion. So, once this yaw motion is understood, now we have understood the total motion components of the quadcopter. So, as far as this is concerned, this is done. So, how do we do this physically? In a motor, we have two components, one is voltage, other is current.

When we keep the voltage constant and vary the current, that is called as current control method. When we keep the current constant and we vary the voltage, that is called as voltage control method. In drones, we usually follow the current control method, which is like, let's say in a motor, we have a term called as kV. kV is RPM per volt. So, this is one important concern and another is kT. kT is torque constant. When certain amount of torque is generated per unit of current, that is kT. And, another is kV is RPM per volt. So, this is what defines our force. Since RPM is indirect measurement of acceleration, force is mass into acceleration.

So, this is what is our force component. So, as I said, two components are important in this. One is torque component. So, this gives us the concept of torque. So, torque and force, we have now understood as a physical component of the motor. So, what we are going to do is by controlling this speed only.

Now, how the speed is controlled? By controlling the current to the motor. So, by controlling the current to the motor and RPM control, we are attaining all of this X, Y, Z motions in each axis and combine axis. So what is the importance of a circular path here? So, as per the concept I had explained here, you have individual X motion, individual Y motion and individual Z motion. And, individual yaw motion also we are attaining.

So, π, θ, ϕ, all are there. So when you want to move along a circular path, what is the component here? So we have to control both X-axis motion also, Y-axis motion also. This way our pitching motion and rolling motion are getting combined together. So, that is how we attain a circular trajectory and it is very critical, when these two components are coupled together, they become inseparable. So, this is how we had done the field experiment in reality. So, by controlling the RPM of the motor and the current going to the motor, we had generated all this altitude control and attitude control.

To do this in the background, how to control this current, we had employed a PID controller, basic PID controller and later on an adaptive controller was built on top of that. So this is about this. I hope you had understood the concept of drones, how they move forward, backward, right, left, up and down. So, thank you.