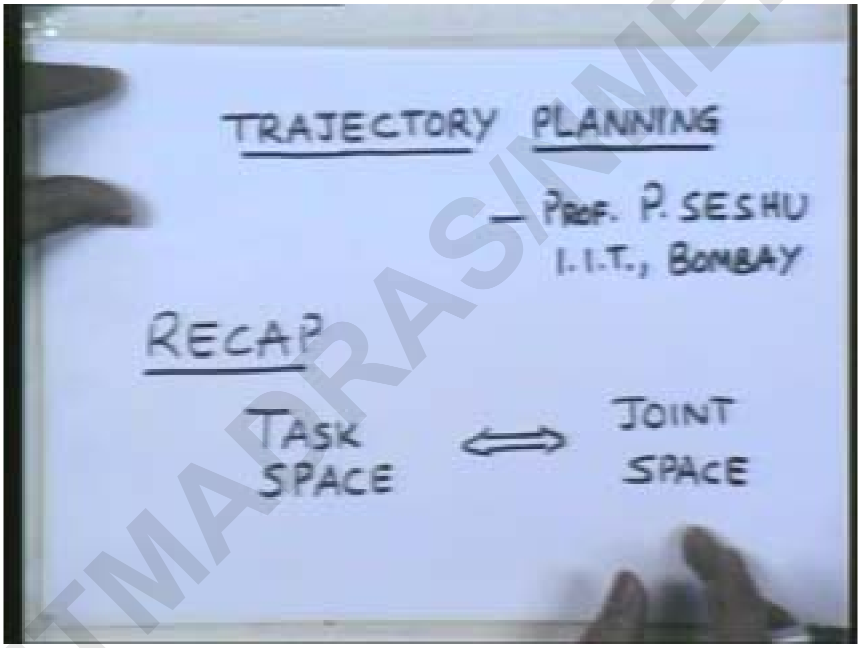
ROBOTICS
Prof. P. Seshu
Mechanical Engineering
IIT Bombay
Lecture No-13
Trajectory Planning

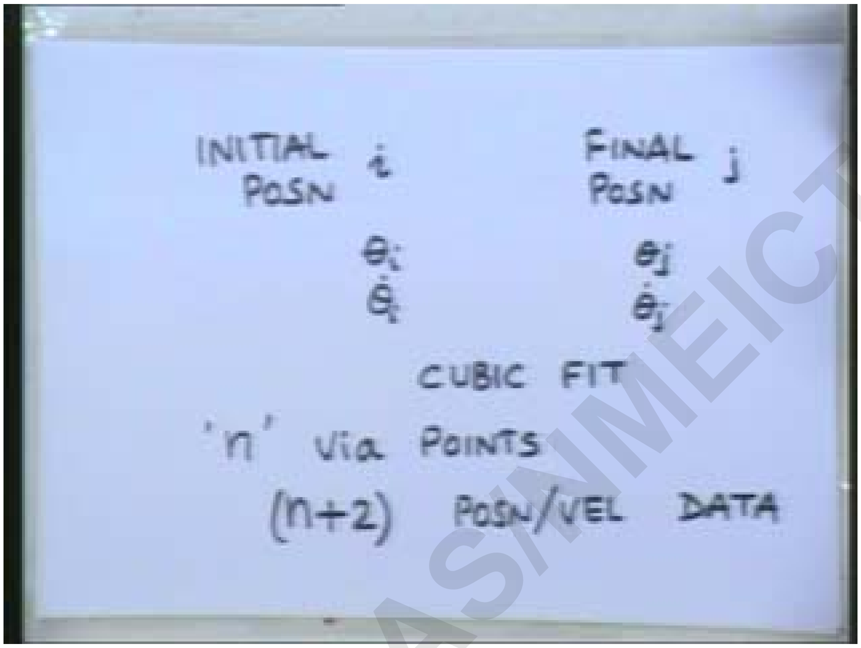
We were discussing in the previous lecture the concept of trajectory planning because any robotics designed to execute a certain specific task that will entail that the end effector moved through certain specified motions through specific points with some velocities and desired acceleration [???]. So we start a discussion of how we will plan the motion of individual joints such that we will be able to actually get the desired motion and the end effector. So we call this a trajectory planning and when you look at the trajectory planning we have also, just to recapitulate what we discussed earlier, (refer slide time 03:25)



we talked about the way in which the task specification naturally happens in the joint, in the world coordinate frame, and the lower level control of the motion of the robot manipulated actually takes place in the joint coordination, because you have the actuators at the individual joints, we have the sensors at individual joints, and so the controlled motion could more conveniently be achieved in the joint space.

We were mentioning the previous class about how the task space or cartesian space is related to the joint space,
ok? So we discussed it through an example of the planar 2R manipulator and showed how the, what are the intricacies of matching these two on one on together and then showed that these are related and so we could go ahead doing the manipulation of the trajectory planning etcetera in the joint discussion.

So this is what we were doing in the previous class.
When we look at the joint space trajectory planning we looked at the particular way in which we would like do that in the sense of for a specified initial position, i, to a final position, j, or some other position, j, with specified velocities and position at these points, so theta i theta i dot theta j theta j dot being given we showed how a cubic curve fit can be achieved in the joint space, ok? (refer slide time 04:51)



So this is the stage where we were but the problem we identified at the end of the previous discussion was that if we have to follow this type of strategy to be implemented in a real manipulator, then if you have between the initial and final positions if we have say n via points, then the user needs to give n plus 2 because for the initial position 1 and the final position the second n plus 2 sets of data on position, velocity, data. The [???] that we raised with respect to this aspect, that is he has to give a large set of data, that is one aspect. The other aspect is that he has to give us what is known us kinematically consistent data. What do you mean by kinematically consistent data?

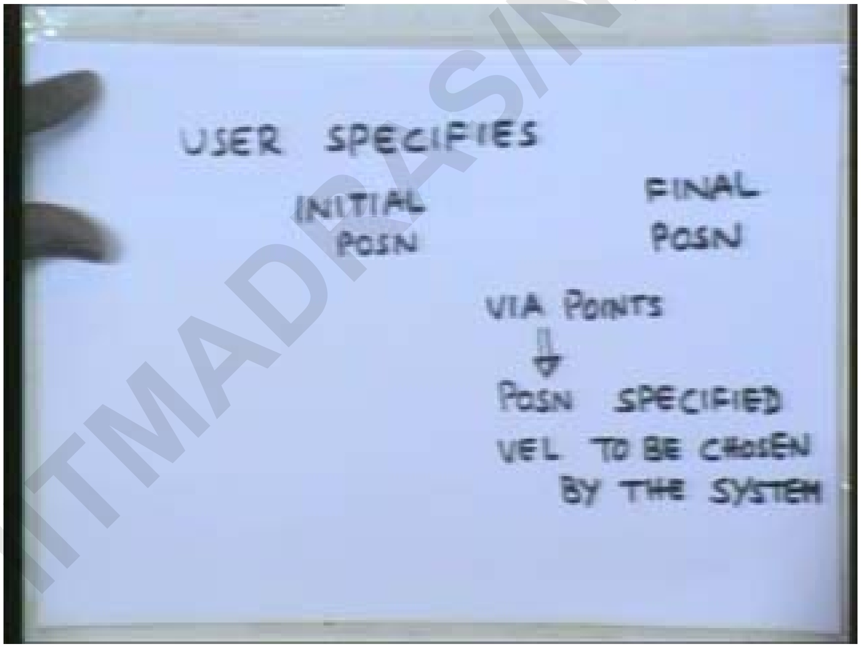
We have, for example, we were talking about the task space to joint space manipulation, ok? Or mapping the task space to the joint space. Now if the user specifies certain positions and certain velocities for the end effector in the task space in the world coordinates, it is perhaps possible when it specifies this for n plus 2 points and two positions in the world coordinates the end effectors velocity that will decides may not be achievable to any final velocities of the individual joints, what are known as we have similar position to that and so we can not probably achieve certain desired velocities for the end effector.

So, when we say that it has to be kinematically consistent data what we really mean is that it should be such that for finite joint motions we will be able to exceed the required end effector velocities at the desired positions.

So this is something that we need to keep in mind. So the user has to keep track of these aspects and give final appropriate data, ok? So in terms of user interface we mentioned that therefore this is not probably the mostly desirable way of doing it because users [???] have to give a [???] set of data and complex set of functions with respect to time and so on and so forth, and effort [???] [???]worry about the kinematic consistency of the data or otherwise.

So what rather would be convenient for the user is to specify that user would love to specify, simply, user simply specifies that you go through an initial position and when I say position you may specify the initial position and the velocity of that position and so on and so forth, and the final position, ok? Because these are the things that are of importantce to him, but in between, at the via points, we may only specify the positions of these via points, ok? And he may allow the system to choose appropriate velocity, ok?

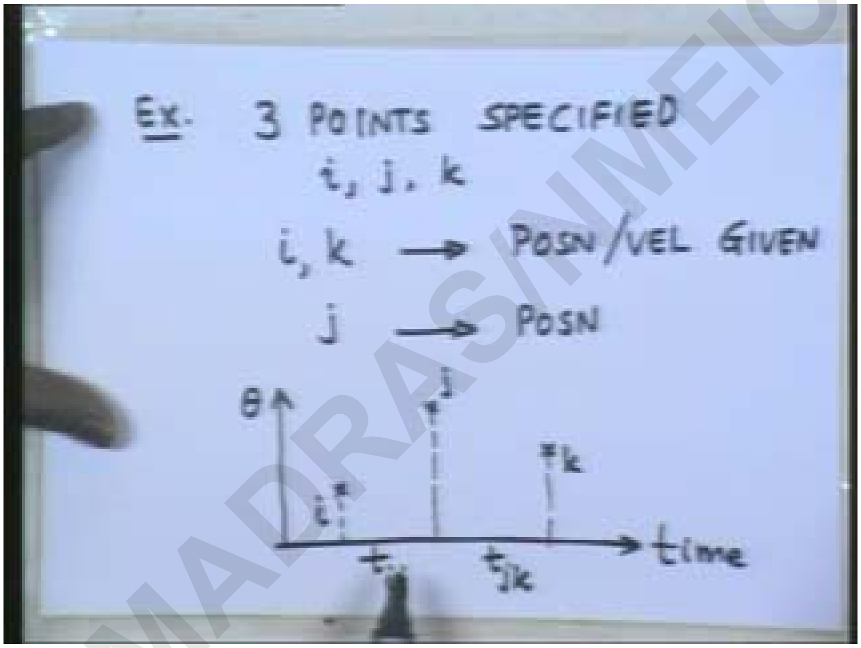
So positions specified at these points, position specified, velocity to be chosen by the system, ok? So this choice eliminates any requirement of kinematic consistency from the point of view of the user. (refer slide time 07:43).



We need to simply specifies the initial position and the final position and a set of via points and system will choose appropriate attainable velocities may be based on the smoothness of the motion through this via points. The system will choose that appropriately and then plan the entire trajectory. So let's look at some aspects of how we will do this type of a motion.

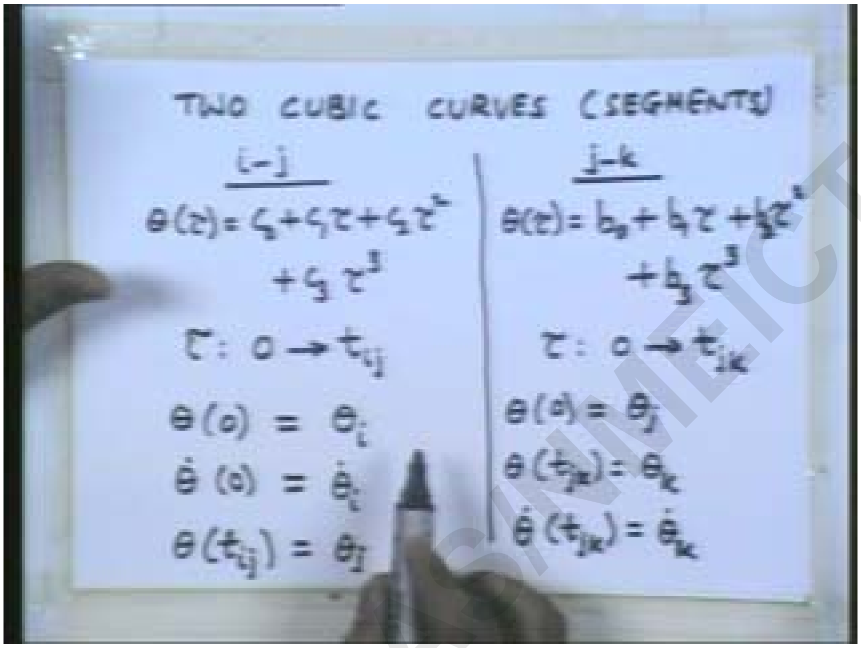
So let's look at for the example a typical case of three points specified, three positions, or three points specified. I am calling them i j k. These need not be the initial and final position. They are just three general points and what are trying to say is that i and k to be representative at i and k position and velocities specified, ok? But at j which is the via point or intermediate point, it specifies only the position. How do we fit a trajectory? Through these type of problems, ok?

So, what it means is that to have the time we have the theta we have one position here, another position here, and a third position here. This could be i, this is j, this is k, ok?
So we need to find the smooth trajectory through this points, ok?
So let's look at how we will do that. One easy way to visualize extending the idea of a cubic segment that we just now talked about is to say that one cubic polynomial between i and j and another cubic polynomial between j and k, ok?
So let us say that the durations of the motion are also specified. Let this be t i j, and let this be t j k. So, t i j refers to the time taken moving from i to j and t j k refers to the time taken moving from j to k. (refer the slide time (10:08).



And at i and k position velocity being given, and at j only the position is given velocity is being left for the system closed. So let's look at how we will solve this type of a problem. So, between i j, [???] first of all we have been talking about two cubic curves of segments, ok? Two cubic segments to be fit between i and k, so i j is one segment and j k is another segment. So what I am going to do is to say the theta of τ τ is c not c 1ττ c 2ττ squared plus c 3 ττ cube, and here theta of ττ is again say some b not, plus b 1 ττ plus b 2 ττ squared plus b 3 ττ cube, where τ is the local timeframe, like we introduced in the previous lecture, τ here τwill vary from 0 to t i j, here τ will vary again from 0 to t j k, where that is the local timeframe with reference to the specific cubic segment of motion, ok?
So now, the constraints are that theta of 0 for this segment should be the initial position are the theta i, we have also said that the velocity is specified here, so theta dot of 0 at the beginning of the motion in the i j segment is the prescribed value of the velocity at

the position i so theta i dot and the position at j is specified, therefore, at t ij the profile should be such that at the time t ij when τ is equal to t ij theta should be theta j, ok? Similarly, on this segment, jk, theta of 0 when τ is 0 that means you are referring to the position j now, because the time axis is the local time axis moving from 0 to the time period for that segment, so the theta of 0 should be theta j then theta of t jk is theta k and theta dot of t jk is the given velocity at the point k. (refer slide time 13:43).



So let's look at now that two cubic curves between ij and jk and each cubic curve has four coefficients c not c 1 c 3 b not b 1 b 3, so totally we need to determine eight coefficients for the cubic curves.

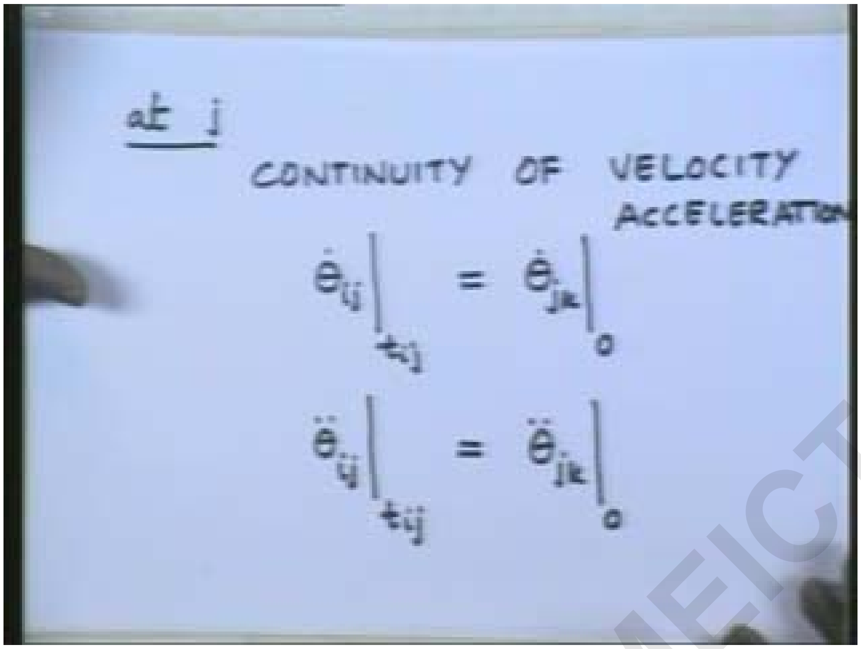
So among the eight coefficients to be determined, we need to get eight conditions, sorry equations, to be followed for those eight unknown coefficients and therefore what we are writing down here is only six. We need to generate two more, and thus two more equations are generating based on the fact that at position j velocity has not been prescribed any value, we want a smooth motion, ok?

So I would say that the velocity and acceleration at the position j be continuous, ok? So these two conditions I will use to generate the necessary two equations at the position j.

So at j, we want continuity of velocity and acceleration and that gives us the two equations that we are looking for.

Now what is the continuity of velocity and acceleration? Whether the theta dot i j I would say, that is coming from the ij segment at t ij should be equal to theta dot jk at 0.

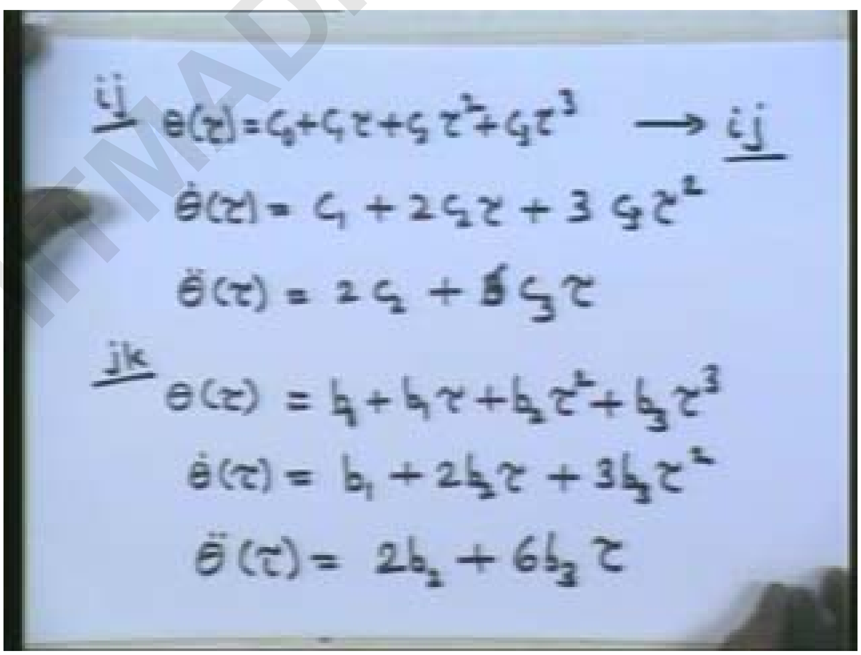
Similarly, theta double dot ij segment at time t ij should be equal to theta double dot jk when you evaluate it at τ is equal to 0. These are the two conditions that we want. (refer slide time 15:08).



Ok, let's look at how these would turn out to be. So what this means is that in terms of theta of τ be c not plus c 1 τ plus c 2 τ squared plus c 3 τ cube in the i j segment, therefore, theta dot of τ is c 1 plus 2 c 2 τ plus 3 c 3 τ squared and theta double dot of τ is 2 c 2 plus 3 c 3 6 c 3 τ. Ok? This is for the i j segment.

Now, similarly for the j k segment theta of τ j k and this is i j, ok?

Theta of τ is b not plus b 1 τ plus b 2 τ squared plus b 3 τ cube and so theta dot of τ is b 1 plus 2 b 2 τ plus 3 b 3 τ squared, or theta double dot of τ is 2 b 2 plus 6 b 3 τ. (refer slide stile time 16:41).



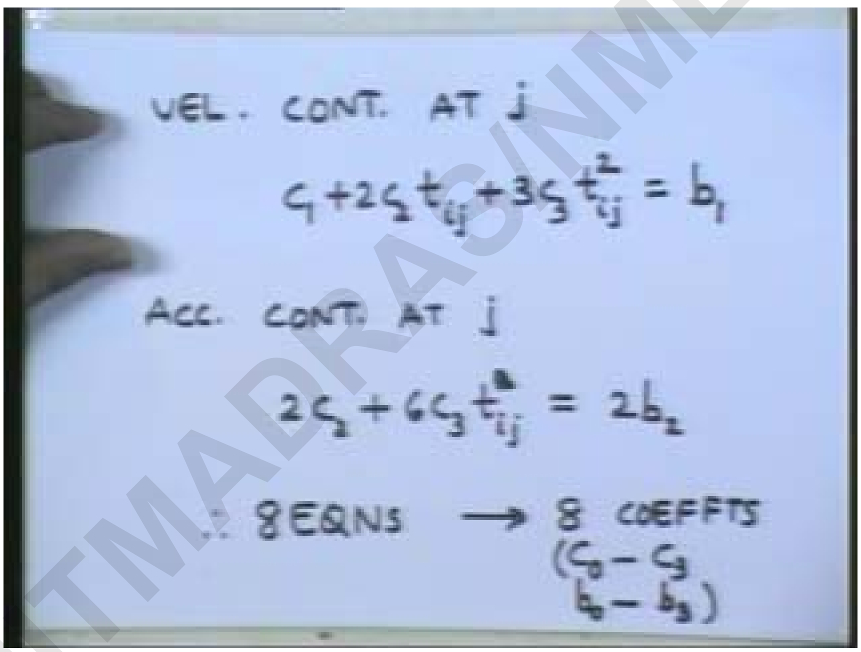
So we now have the relations for the velocity and acceleration we will just stipulate to the necessary smoothness constraints that is the velocity and acceleration be continuous at the position j.

So let's see how those relations between the coefficients turn out to be. So theta dot of velocity continuity at j that would be that theta dot be same

so therefore we are talking in terms of c 1 plus 2 c 2 t i j plus 3 c 3 t ij squared this is the velocity coming from the ij segment that should be equal to the velocity coming as calculated from the j k segment that is simply b 1 where τ is 0 for the segment.

Acceleration continuity at j will mean that you have 2 c 2 plus 6 c 3 t ij squared is equal to 2 b 2 t ij t ij, ok? 2 c 2 plus 6 c 3 t ij squared is t ij is 2 b 2 because τ is 0 and τ is equal to t ij here, ok? So we have additional two equations as we can see here and therefore we have the next three equations to solve for all the eight coefficients two cubic segments so each cubic segment has four coefficients to be determined, so we have eight equations.

So, therefore, eight equations for eight coefficients c not to c 3 and b not to b 3, ok? (refer slide time 18:48).



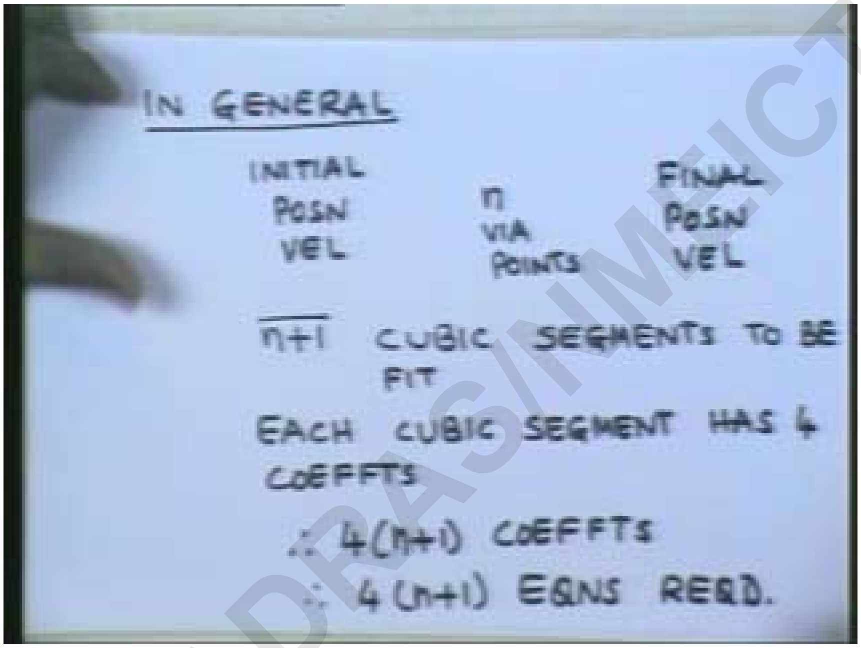
So we would see that therefore the user has specified this stage only the initial position velocity final position velocity but at all the intermediate via points we are only required the points to the position in which the end effector should move, and the system has chosen appropriate velocity such that the velocity and acceleration are smooth at the interface point, a via point, j, ok?

So we are able to give a curve fit[???] essentially using again cubic polynomial segments, ok? between t ij 0 to t ij in the ij segment and jk segment for two cubic polynomial in this case. These

generals, if we have n number of points then how would we use this type of a strategy? So if we have an initial position in general this type of a strategy, how do we carry out? in general we have initial position initial position velocity as specified, final position velocity as specified, and in between we have specified n via points.

So we talk in terms of therefore totally one plus n plus one n plus two points and so we are talking in terms of n plus one cubic segments cubic [???]. So n plus one cubic segments to be fit and each cubic segment will require four coefficients and so we are talking about each cubic segment needs four coefficients, has four coefficients, and therefore, four into n plus one coefficient to be determined. The moment you have four into n plus one coefficients to be determined. We also require four into n plus one equations to get the corresponding coefficients we need to.

Four into n plus one equations are required. (refer slide time 21:15)



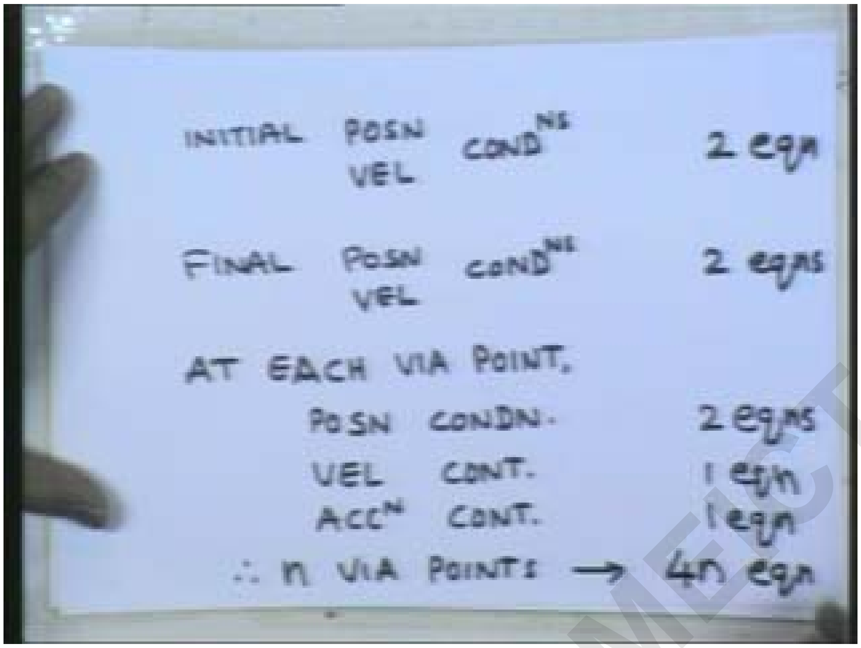
Now, how do we get these four into n plus one equations? It is essentially same as what we discussed with the example of three general points, ok? expanded to any number of n number of intermediates via points.

So at the initial position and velocity constraint velocity conditions we will have two equations, right? Initial positions and initial velocity. Similarly, the final position and final position velocity conditions will give you two more equations, ok?

Now at each intermediate position at each via points we have position condition. Position condition is that whether you come from the left segment or from right segment the position has to be the prescribed position,

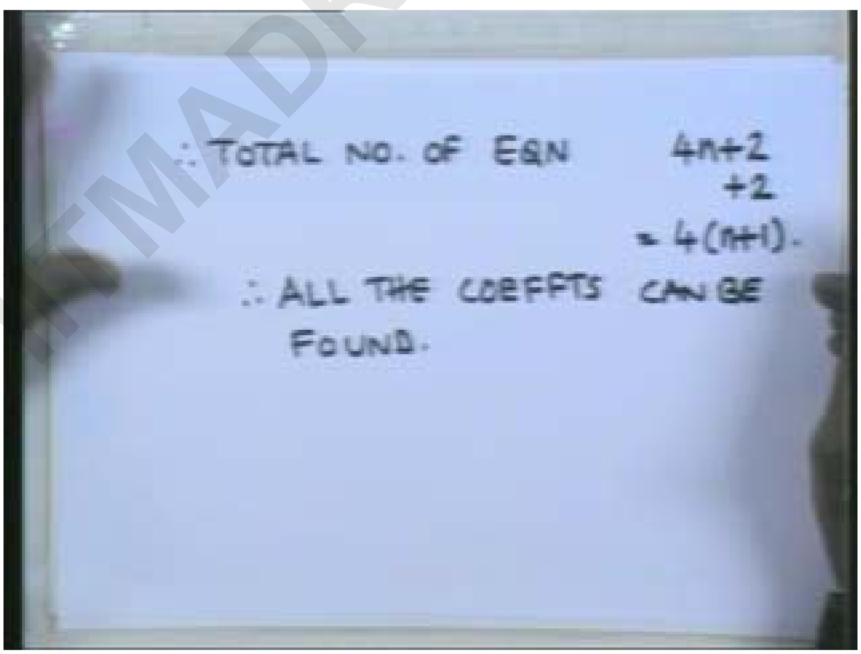
so you have actually three equations, ok? And then velocity continuity and acceleration continuity,

we have therefore two more equations. This is one equation and this is another equation, ok? So you keep on writing these equations so you would see that if there are n points therefore n via points will give you two plus one plus one four n equations. (refer slide time 23:43).



Ok, and you have here two equations for the initial positions and two equations for the final positions, so total number of equations will be four n plus four, ok? That is what you will require.

So total number of equations will be four n plus two plus two is four into n plus one. These are the number of equations required so therefore all the coefficients can be determined. All the coefficients can be found, (refer slide time 24:32)



and we will be able to, given any strategy any set of initial and final positions velocities and a set of any number of via points before the user having to tell you what is the velocity based on the simple curve fit[???] that the smoothness of the motion the [???] velocity and acceleration be continuous at all the intermediate via points you will be able to fit entire trajectory from the initial position to the final position making use of the cubic curves, ok?

So if you look at what we have discussed, this is for one particular um joint motion, so if we have multiple joints then you have to do this type of thing for each and individual joints motion, ok? So that combined motion of all the joints will give you the required and effector motion, ok? So keep that point in mind.

When we are talking about an individual joints motions being planned we need to do this type of trajectory planning and generation for all the individual joints,
and so, the number of coefficients that we are talking about here will be increasing based on the number of joints in the actual robotechnology manipulator, ok? So keep this perspective in mind.

Now if we look at, you know, this particular discussion that we have had so far, we have used the cubic polynomials.

Now why only cubic polynomials for the curve fitting? It would very simply be a lowest degree polynomial that allows you to ensure velocity and acceleration continuity, ok?

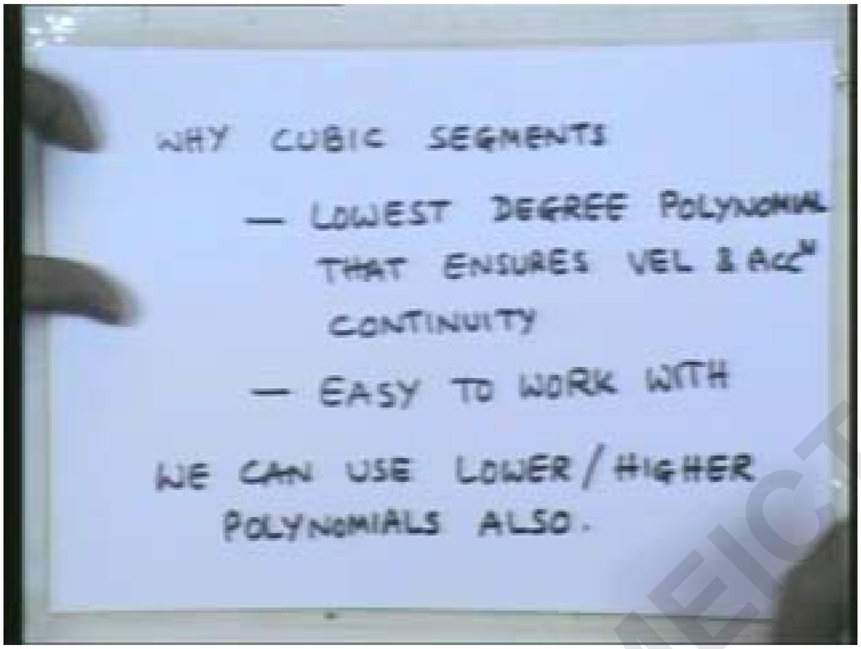
So that is the advantage. Why cubic? If you ask the question, why did we emphasize cubic curves, these, ok,

why cubic segment, a simple answer is that it is an easy, the lowest degree polynomial, and hence, easiest to work with lowest degree polynomial, ok? That ensures velocity and acceleration because these are quantities of importance to us as engineers, velocities and acceleration are very important for parameters of motion, so velocities and acceleration continuity is guaranteed, Ok? Now therefore, it is, since it is lowest degree polynomial is obviously easy to work with.

We have seen how we can determine all the coefficients in a very systematic manner generating all the equations that are required to obtain all the coefficients we will be able to fit any such cubic [???].

Now is it that we cannot use a higher order polynomial? No, it is not really like that. You [???] the higher order polynomial [???] ok?

So we can use, in fact, we can use even lower or higher order polynomial. So I will discuss both these aspects so that we don't, you know, [???] only on the cubic curve fit. So, we can use even lower or higher polynomials. (refer slide time (28:19).



So we will see how for example, ok, I should use a higher degree polynomial, ok? When we are talking in terms of a higher degree polynomial, how did we come with the idea of using a cubic polynomial? If we recall, when we looked at the problem of fitting a trajectory to an individual joint motion,

I talked about moving from a position i to a position j where I said at the position i and at position j we have prescribed position as well as velocity information which we need to satisfy. So, therefore, for the joint we talked about four conditions to be satisfied and therefore any polynomial that requires four coefficients we would be able to fit.

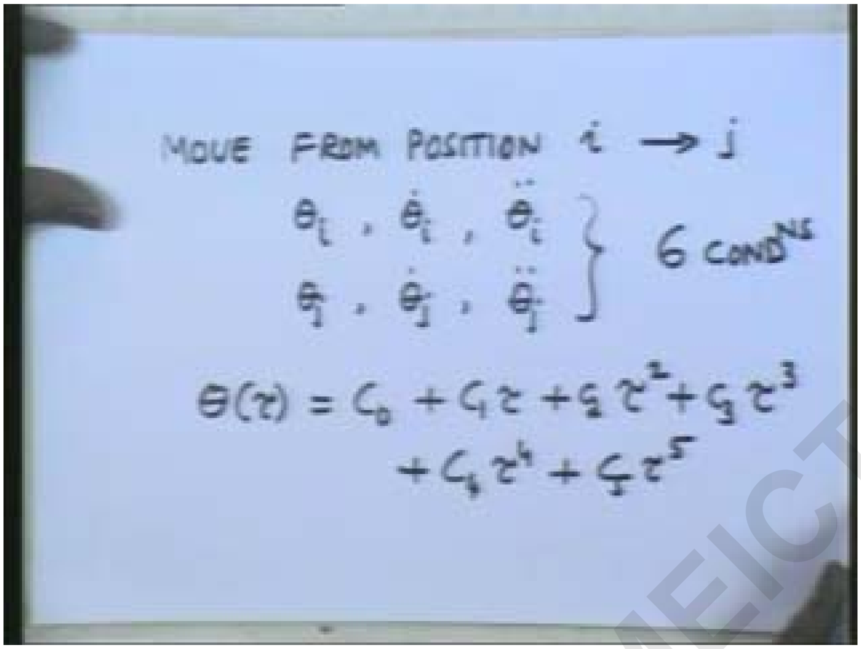
So we talked about a cubic curve fit that is how we got the idea of using a cubic curve, ok?

So we were introduced to the idea of using a cubic curve fit from the point of view of having to satisfy the position and velocity constraints at the position i and at position j, so we are talking about this. If we were to use a higher degree polynomial so naturally we will have to use higher degree polynomials if we have more constraints to be satisfied.

Supposing I am going to talk about moving from from position i to j such that we have theta i theta i dot and theta i double dot. Similarly, theta j theta j dot and theta j double dot that [???] specified [???], ok?

Let's have the hypothetical space to present the argument in front of you. If you have described positions velocities and accelerations at both the position i and both the position j then you have six conditions. When you have six conditions you can actually generate equations for determining six coefficients. When you say six coefficients we are talking about theta of τ therefore can be c not plus c one τ plus c two τ squared plus c3 τ cube plus c four τ four plus c five τ for five, ok?

So we can use actually a higher degree polynomial which may have additional constraints specified in terms of the acceleration also at the points i and j, ok? (refer slide time (31:07)



So this is one case wherein you could use actually a higher degree polynomial, but accelerations specification will require again as we mentioned the idea of the user interface, the user has to give you more data, more requirements, more specifications.

So it is not necessary that we use a higher degree polynomial only when there are acceleration specification, even otherwise also we may actually use the higher degree polynomial. So, I will now highlight for you one such case where we would like to use a higher degree polynomial in terms of trajectory planning for an individual joint.

Suppose you look at the application of a pick-and-place, ok? So if you look at the example this is an example of a pick-and-place kind of application,

then we are talking about a surface on which a certain object is placed, ok? We have certain object placed on the surface, ok? And you have, from somewhere, the gripper, or the end effector is approaching this, ok?

When you look at that type of, this is the gripper, or end effector approaching the object on a surface, this is support surface. When it is being picked up you wouldn't like the gripper to press into the support surface. That is the nature of motion, approach motion, should be such that it doesn't press into the support surface or it doesn't really crash into the support surface.

So you now want to control the process of picking up the object by specifying actually a certain point slightly away from the initial positions on a normal to the surface, ok?

So if a surface is here and the object is on the surface, I am trying to capture this object, grasp this object. I might actually specify a surface slight away from this on a normal to the surface, so that my takeoff from the surface is appropriately controlled, ok? (33.53)

so i might actually specify from the initial position a slightly separated position on a normal to the outward normal to the surface.

Similarly, at the other end when I am actually placing the object on the another supporting surface I would specify a position slightly away from the final position, so if I am trying to place the object on a surface, support surface, then I can place it, I can specify a position slightly away from the final position, on outward normal to the surface, such that I [???] down into that position, and then gradually place the object onto the final support surface.

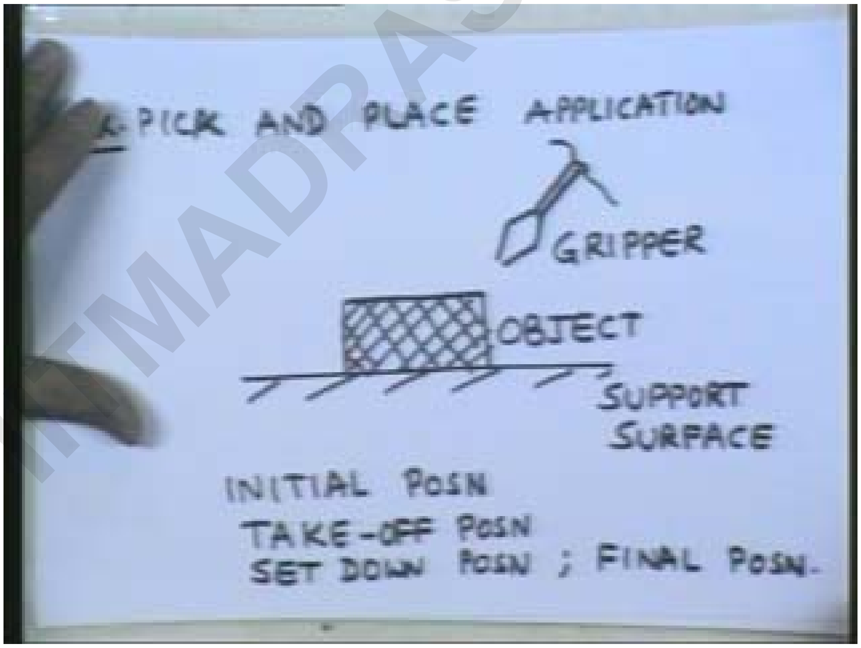
So we might actually specify the motion required, ok, in terms of the end effectors motion that there is an initial position, there is the position slightly separated from the initial position which is on a normal to the surface, and then there is a final position, but just before the final position you place yourself appropriately so that you will gradually settle into the final position.

So this can be converted through the kinematics of the manipulator into a requirement on the joint space motion, ok?

That we have discussed in the previous class through an example of a 2R manipulator, how the kinematic relationship can be written down and then you can obtain the joint's motion required.

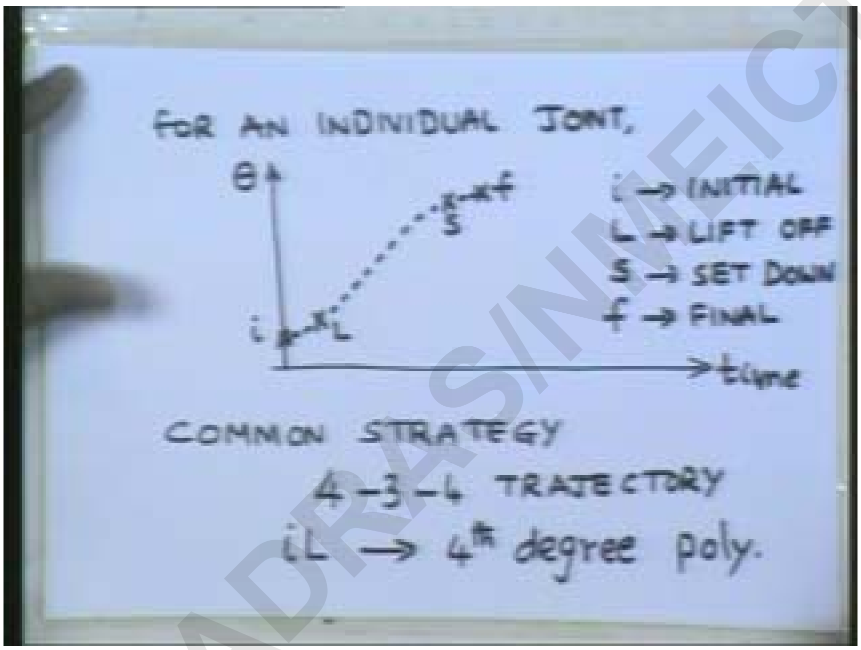
So therefore, if we look at this type of situation where you are talking about a pick-and-place application, where you would specify initial position and then, say, takeoff position, let as say,

so that it is slightly, you know, separated from the initial position with a[???] a normal to the surface, and you can control the takeoff approach, velocities, and points. Similarly, you will have a final position, but before that, you will have a [???] where you are going to place it, let me say that it is a set-down position, and finally, we are talking about the final position, ok? So that the supporting surface [???] the interaction environment is in a desirable manner. (refer slide time 36:19).

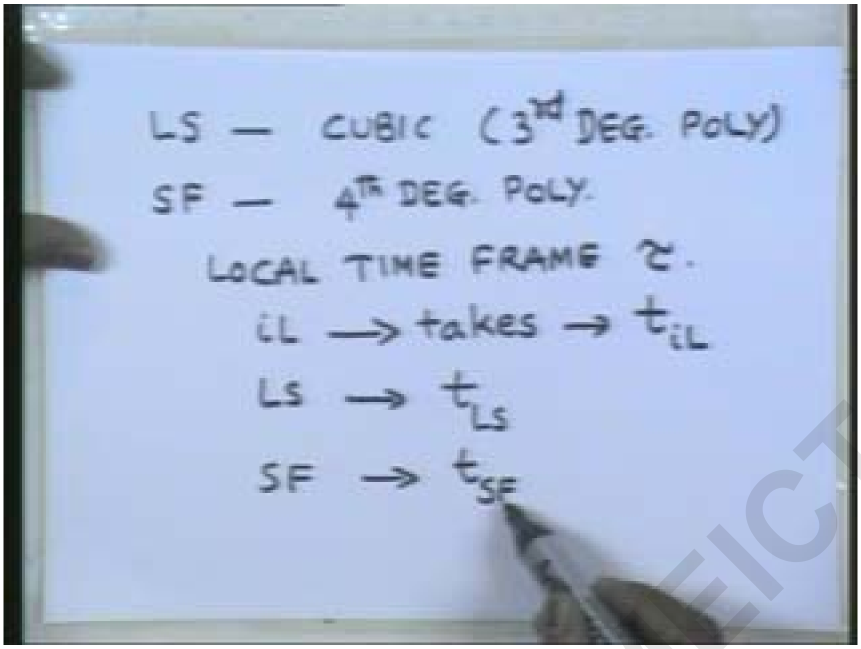


So, if we do that, then for an individual joint, this might actually mean that we have [???]. So, you have an initial position, let's say, i, and a position slightly separated from this, let's say, here, and a final position that you want to go, here, and the position slightly before this.

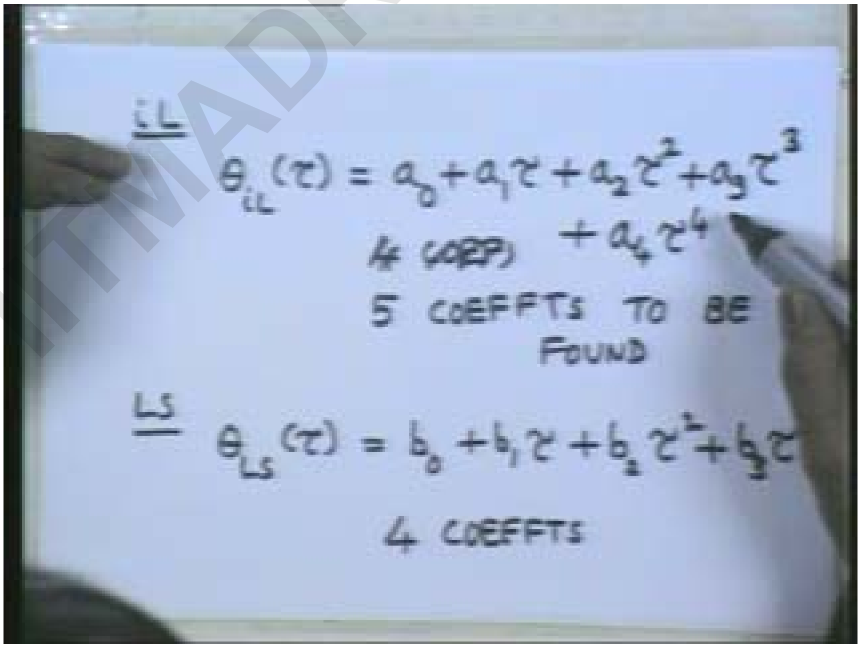
So you may want to actually pick a smooth curve through this. So you have these positions, I, f, liftoff or takeoff position, ok? And then the set-down position, ok?
So, i is initial, l is reference to liftoff, or takeoff, I am not using this letter t here, because t could be confused with time, so we could call this as a liftoff position, and s is the set-down, and f is the final position, ok? So these are the four points.
So such a type of trajectory planning, a method that is commonly done, is to follow what is known us a four-three-four trajectory. What we mean by four-three-four, as you would have guessed, it [???] to the degree of the polynomial curve fit[???38:32] that was used, ok?
Four means that you have actually i l, you use as a fourth degree polynomial, ok? (refer slide time (38:49).



And you use between l and s, the liftoff position and [???] up to the set-down position, we use the cubic, that is, third degree polynomial, and final set-down to the final position, we use again a fourth degree polynomial. This is another common strategy that is employed in trajectory planning for joint space motion, ok?
So, how do we get to the corresponding equations? Say for example, if you again define local time frames, you define local time frame τ let us say that i to l takes t i l time, then l to s should take you, the duration is also specified, which is say, t l s, and s to f should take you a duration that is specified t s f [???].
So, in each place, for local time frame τ will go from 0 to t i l, 0 to t l s, 0 to t s f,
so we are talking in terms of a fourth degree polynomial to be fit in this segment, a cubic polynomial to be fit in this segment, and a fourth degree polynomial to be fit in the final segment. (refer slide time 40:29).

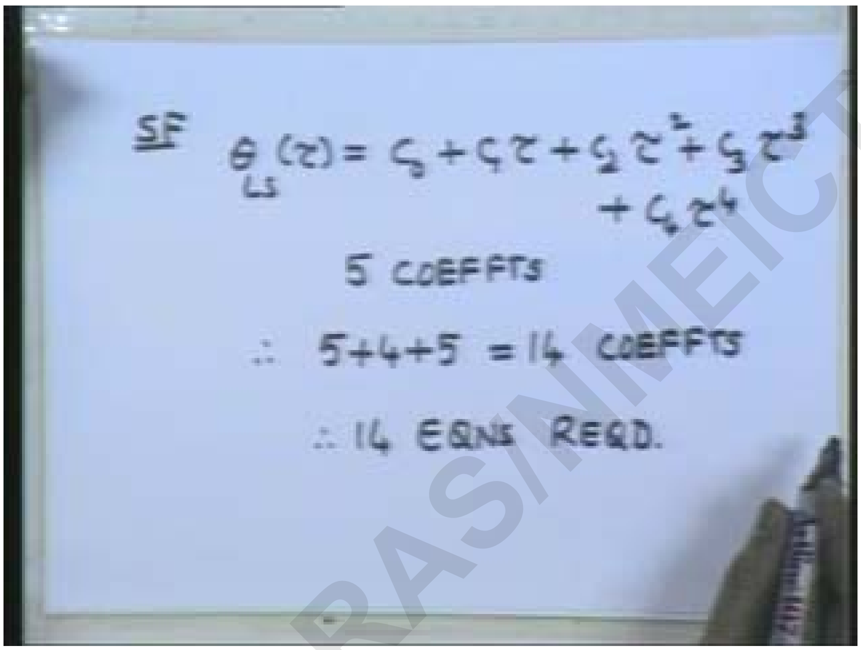


So we are talking in terms of three specific segments being used, ok? So, from i to l, we can say that theta i l of τ is an a not, because it is a fourth degree polynomial, a 1 τ plus a 2 τ squared plus a 3 τ cube, ok?
Now, so therefore, fourth degree polynomial will have a 4 τ four, so five coefficients to be found to be able to generate this strategy. l to s is cubic for theta l s of τ is b not b 1 τ plus b 2 τ squared plus b 3 τ cube, so four coefficients to be found, ok? (refer slide time (41:39).



Ok so we are using a fourth degree polynomial for five coefficients here from between i and l and we are using cubic polynomial between l and s therefore four coefficients and similarly again from s to f we are using a fourth degree polynomial theta l s of τ is c not plus c 1 τ plus c 2 τ squared plus c 3 τ cube plus c 4 τ power 4.

So we are talking in terms of again five coefficients here to be determined. Therefore, in all, 5 plus 4 plus 5, that is fourteen coefficients to be determined. So I need to generate fourteen equations based on the different type of constraints that I need to satisfy, then I will be able to actually do this kind of a curve fit and planned trajectory appropriately. So fourteen conditions required, ok? Now, where do I get these fourteen coefficients, conditions, from? (refer slide time43:03).

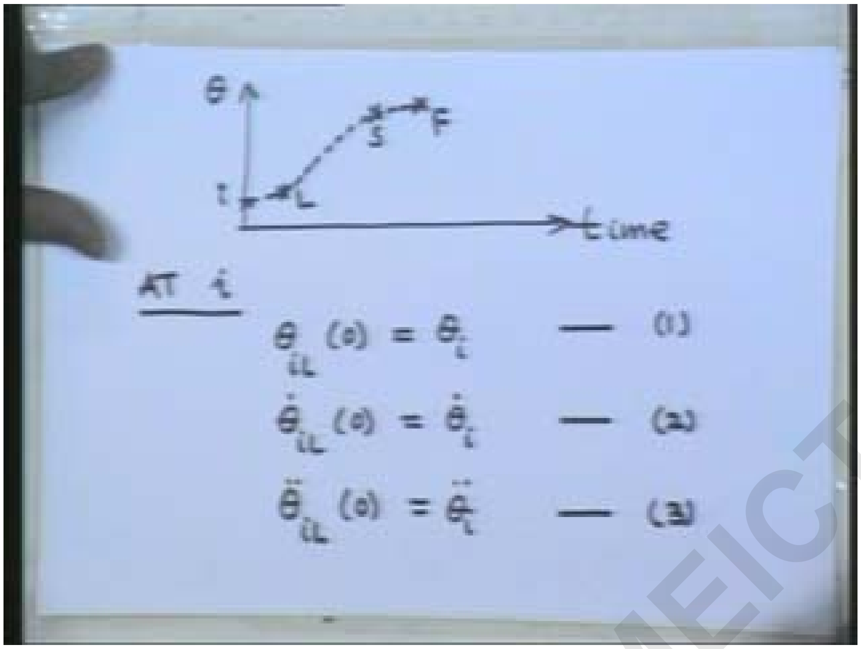


Ok, so you look at the motion that you are [???], so there is an initial position i, there is a final position, there is set-down position, there is a takeoff, or liftoff, position, and corresponding time durations.

So, we need to generate fourteen equations for fitting a four-three-four polynomial cubic, so that we will get a smooth motion from the initial to a final position with the objective of actually the pick-and-place operation of interacting with the environment, and the support surface is satisfied.

So we are talking about the initial position at i. You can have the initial position specified, a position where theta i l of 0 is theta i theta dot i l of 0 is theta i dot.

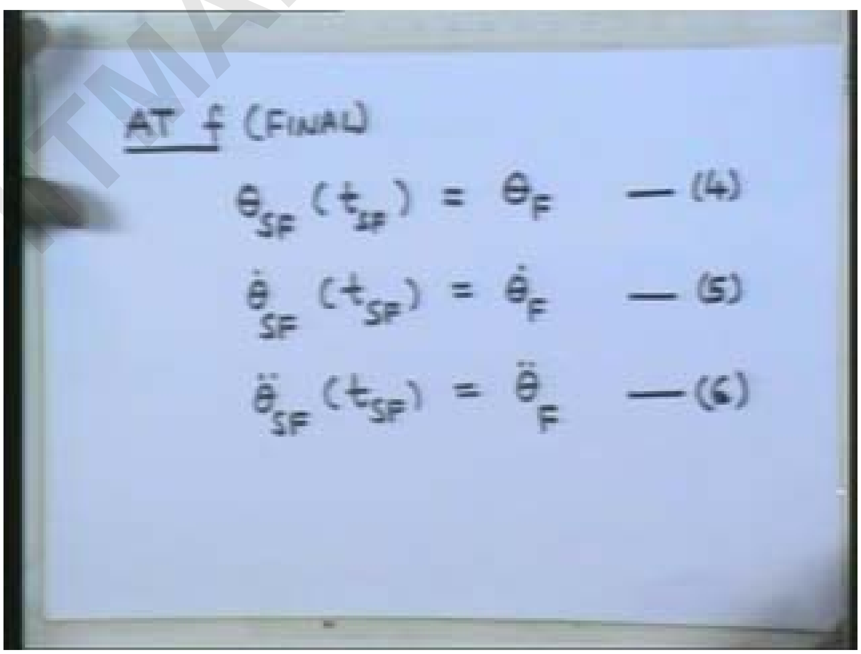
These are prescribed position velocity conditions so similarly theta double dot of i l the polynomial that we are (fourth degree polynomial that we are fitting) at time τ is equal to 0 at the initial position i, should be theta i double dot that it [???] prescribed, ok? So we have, let us say, one, three conditions, ok? (refer slide time44:50).



Ok. Let's look at the final position again on a similar line. At the final position, f, we have theta s f of a t s f, should be equal to theta f that is prescribed, and it should have [???] velocity, theta dot final theta double dot, that is, accelerations are also prescribed, and therefore, we can have this, ok?

For this I will number them as four, five, six, ok? So this is the prescribed position velocity and acceleration at the final position. This velocity and acceleration could be actually 0 depending on the application, particular application, that we are talking about, ok,

but in general, any prescribed velocity and acceleration can be specified. So we now have six equations. We need to generate eight more equations based on the intermediate positions l and s, ok? (refer slide time45:55).



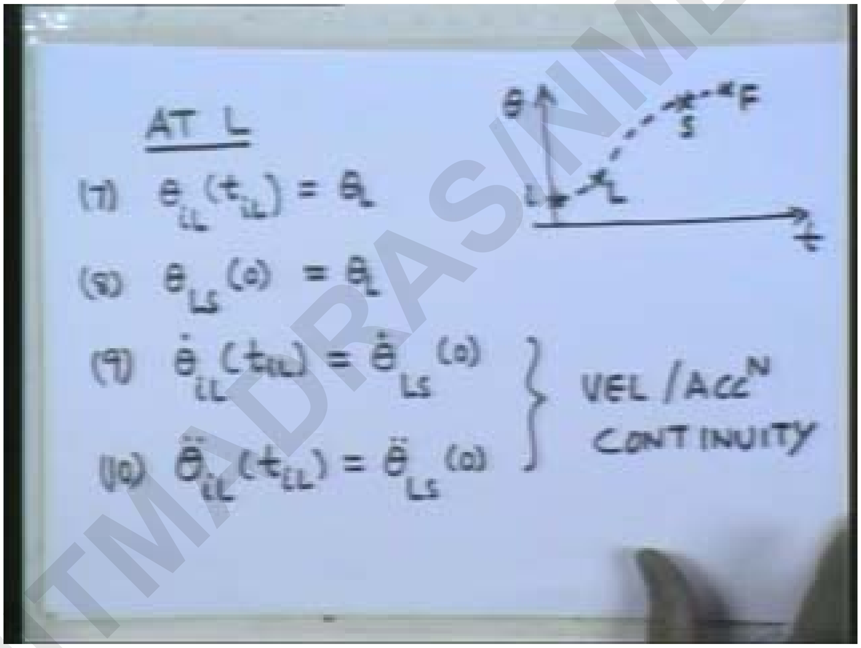
So at l, this is for your benefit, let's look at the time graph again. We are talking about the liftoff position here, the set-down position here, and then the final position there, ok?

At l, you have theta i l, ok, that is for this segment, f tij til [???] theta l that is specified. You have the time directly specified, and the position is specified where it is slightly away from the initial position and along the normal to the support surface, ok?

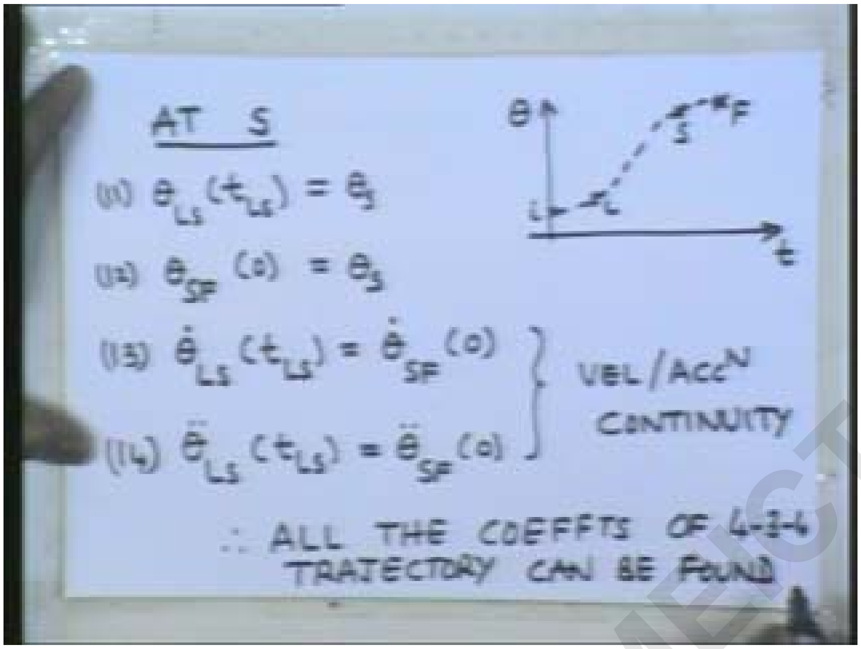
Theta ls at 0 could be theta l and we can talk of theta dot and that is velocitie and acceleration should be continuous at the position.

So theta dot of il at til would be equal to theta dot of ls at 0. This is velocities and continuity, and theta double dot il at til is theta double dot ls at 0. These are equations 7, 8, 9, and 10. These two being velocity and acceleration continuity [???], ok?

And these give the prescribed position of the liftoff points conditions, ok? So we have four conditions at the point l, so we have ten equations, so far, if we get we write four more equations at the position s then we will have the necessary equations to solve for all the coefficients. (refer slide time (48:25).



So at s again f s l i, so at s theta of theta ls of tls should be the position that we have described theta sf at time t is equal to zero because we are talking about a local time frame from f to s again, where time is equal to 0 for this cubic segment here or a [???] segment here at time t is equal to 0, your position should be what has been described. Similarly, the velocity and acceleration continuity conditions, and theta double dot, this is again velocity and acceleration continuity. We have 11, 12, 13, 14, so all the equations can be solved, therefore, all the coefficients of four-three-four trajectory can be found. (refer slide time (50:35).



So we are talking in terms of a commonly employed strategy of the higher degree polynomial along with the cubic polynomial, so four-three-four can be all the coefficients can be found out in this manner.

So if we look at the process of trajectory planning in the joint space the way we have discussed it, we will see that conceptually it is actually fairly straightforward simple way of satisfying the prescribed conditions, and depending on the nature of constraints positions alone, or positions velocities, or positions velocities and accelerations, or continuity on the velocity and accelerations at certain intermediate positions, so that we will have smooth motions, we will be able to choose the polynomial type that we would be able to fit for the individual segments, and correspondingly, you can determine the number of coefficients in the polynomial, ok?

So the trajectory planning in principle is a process of curve fitting to satisfy the prescribed conditions on position, velocity, and acceleration if need be, ok, and the smoothness of constraints and [???] in velocities and accelerations.

So this is another commonly employed strategy, four-three-four strategy. There are other strategy if you would find commonly employed, that the basic concept remains the same so we need not really discuss each and every strategy because once you understand the basic philosophy of trajectory planning in the joint space through one set of curve fit, you will able to extend it to other types of, you know, trajectory planning strategy.

So instead of having, say, a four-three-four for the same kind of motion you can have actually, say, a three-five-three. That means, it will have a cubic fit between i and l, and then a fifth degree polynomial between l and s and then a final cubic segment to takeoff [???] towards the approach position.

So, it is possible that you can have different types of strategies, and all of them revolve around essentially satisfying your simple motion constraints and positions, velocities, and accelerations. Ultimately, you want to move from one position to another position with sufficient smoothness of motion. That is essentially what we need to keep in mind.

So far, we should remember, I mean, recapitulate the point that we mentioned in one of the previous lecture is that
you have not talked about how much acceleration can actually be obtained at the joint. Is there any limit on that?
So such constraints have not been taken into account. I am clearly doing a kinematic or geometry of motion kind of an analysis and trying to fit the polynomial curve fit to satisfy the constraints,
but we have not talked about whether or not a particular acceleration can actually be achieved with a particular joint actuator sitting there in real time in real world, because each actuator has certain finite capabilities.
Similarly, we have not looked at the aspects of other dynamic issues like, for example, we talk in terms of complaints at the joints, ir complaints in the knees and so and so forth. So, manipulated dynamics could also [???]
So these aspects [???] with trajectory planning further, we wouldn't able to discuss those, but what we will try to discuss is a couple of other issues related to how we could use very simple strategies similar to this cubical and higher degree polynomials, but as you would notice, such cubical and higher degree polynomials, that more the number of terms in the polynomial curve fit we use, so many equations have to be generated, so many equations have to be solved, and so, for a multijoint robotic manipulator, it could become quite a task. So, we would rather have, is there any possibility of simpler strategy for trajectory planning?
So, we would rather ask such questions and try to address whether I can [???] even simpler, rather than trying to make it more complicated, even simplest strategies for trajectory planning. So we will discuss that, see what are the other issues related to trajectory planning in the next class.