Introduction to Computer Graphics
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Lecture - 33
Computer Animation

We have been talking about various issues in computer graphics primarily modeling and rendering. So, today we are going to start another aspect which is also very important in computer graphics known as animation.

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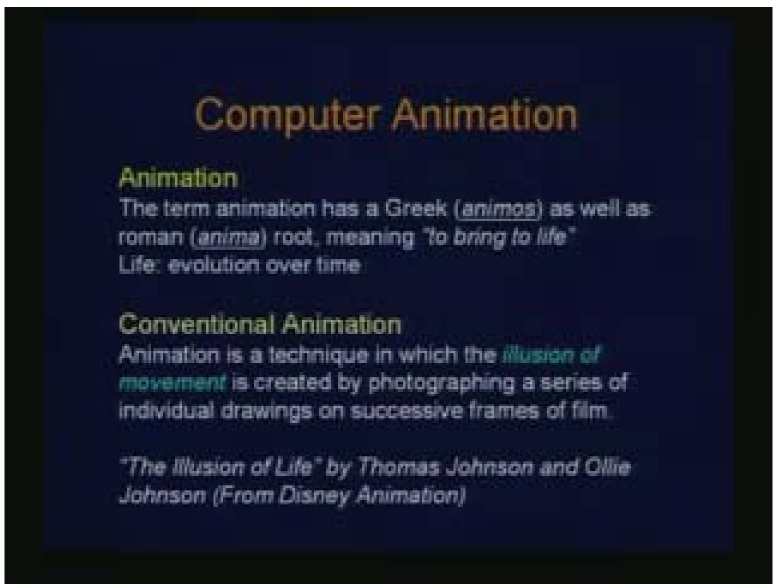

Much of what we do through computer animation in fact has been inspired from conventional animation. If you just look at the term animation it has the origin from a Greek word animos and Roman anima which basically means to bring to life. So there is a sense of evolution over time, things are changing over time and that is what we capture through animation. Conventional animation has been evolving for a long time and the primary concern there of animation techniques has been to create this illusion of movement.

What we are trying to do is basically have the aspect of movement which could be just an illusion without simulating the motion in its physical sense. So what it may involve is basically a series of photographs as frames and then run through those frames over time. That is the idea behind what happens in conventional animation. This aspect of illusion of life has been used by various commercial set up even in Disney animations for their productions.

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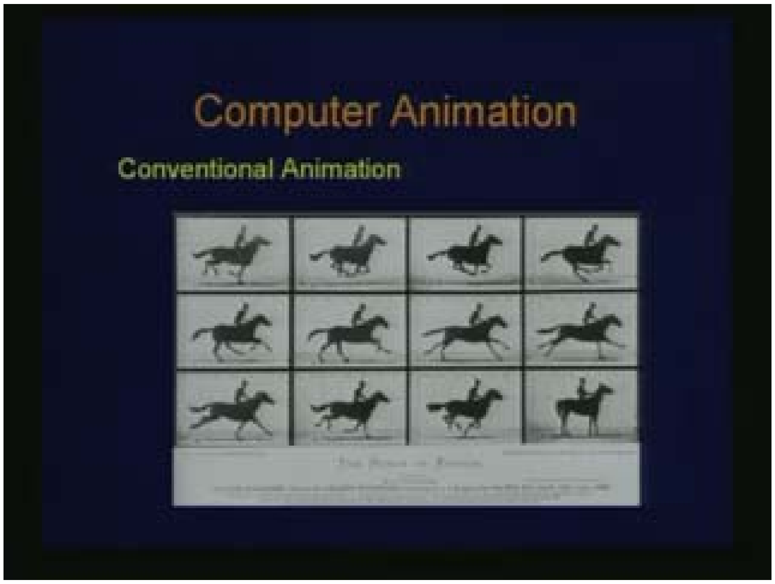

For instance, if you look at this illusion of movement if you look at the example here each of these images are in some sense a still photograph with different poses or different variations and if I run through all these frames over time so if I just time stamp them so this is first frame, this is the second frame, this is the next frame and so on so what I would obtain is a sense of motion and that is an illusion of movement although each frame is actually a snapshot it is a static frame. This is what happens in conventional animation and that has been the practice since its beginning. Let us also look at how we use computer in conventional animation.

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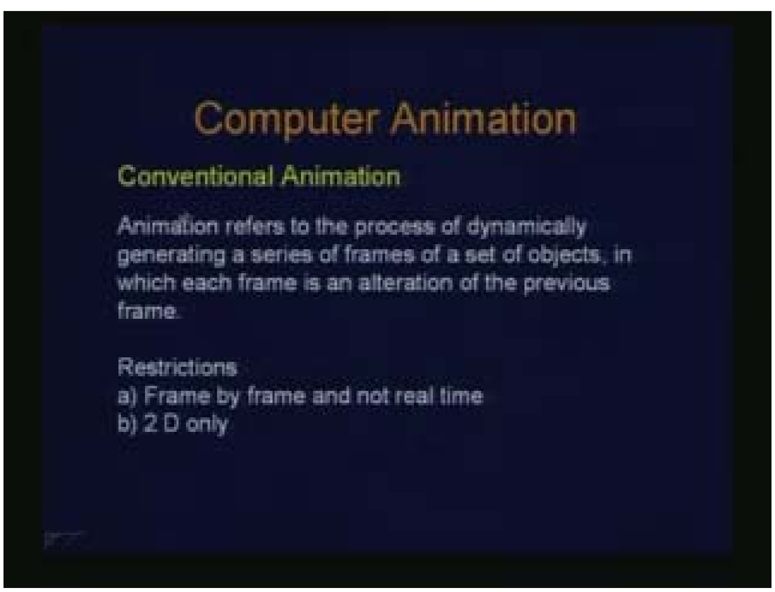

Therefore, animation refers to the process of dynamically generating a series of frames of a set of objects or reasons in a scene where each frame is an alteration of the previous frame. Now if you look at the kind of restrictions it may impose is that, one we are talking about a construction of a frame which is a snapshot. So the notion of real time animation is not there because you are generating a frame and then you collect the series of frames and run overtime. And the other thing is that it remains a two dimension.

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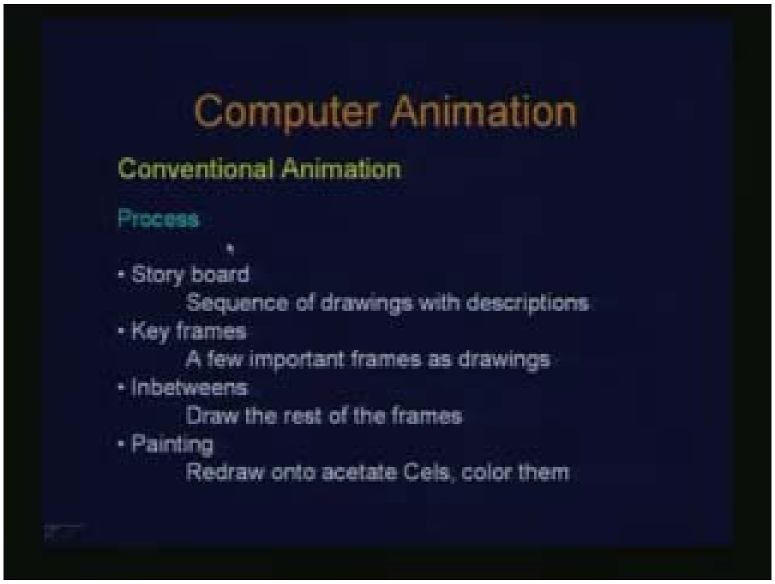

If you look at the process which is generally implied in the conventional animation we have a notion of what we call as a story board. So the animator who is generating the sequence of animation basically creates these drawings which are in a sense capturing what contents are there in the frame and how these contents are to be laid in that particular frame. So what you are trying to do is you give a pictorial depiction of the frame with the description you want to associate and that is what we mean by story board. Even today this is an important step when we generate animation films. Then we have a notion of what we call as key frames. While we are generating these frames it is perhaps not desirable that you do this for each frame.

Therefore, you have a notion that there are certain key frames in the sequence which requires proper description which requires proper content definition and then may be the other frames would be computed using the in between of these key frames. So that is the notion of key frames. So you choose the important frames. Now inbetweening basically means that how do you get the frames which are between these key frames which you have defined. That in a way requires a technique like interpolation. You have defined these key frames and then you may imply an interpolation to be able to compute the in betweens. Now once you have done then there is a process of painting the entire set of frames which you have generated so you are doing a sort of a redraw on a film which could be using acetate cells. So you basically fill where we produce the final animation.

One of the aspects which are very popular in the conventional animation is called as stretch and squash.

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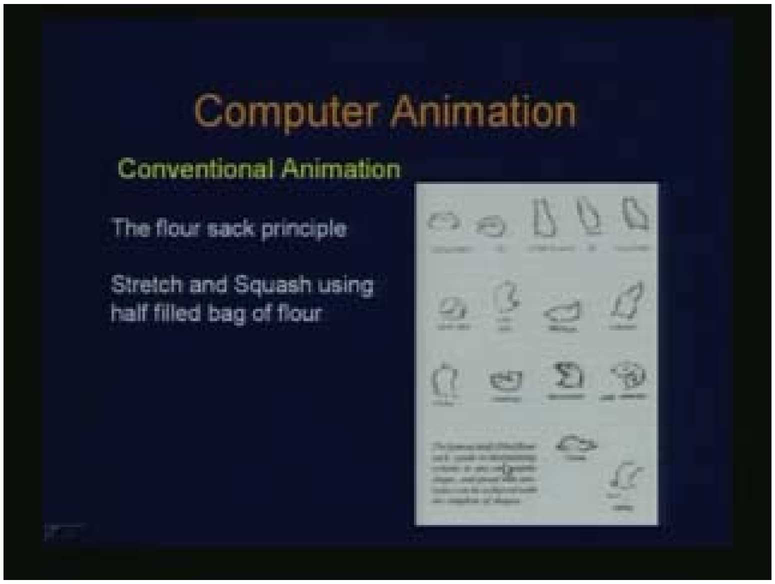

It is a very simple idea. Imagine there is a sack with partial flour in it. Then what you are trying to do is squash and twist and deform that sack to be able to generate various effects as illustrated here. This is completely squashed, this is stretched and this is twisted. So all this is showing is that you can actually generate various forms and shapes using the technique of squash and stretch. This even inspires for a technique which you might use when you are using computer animation. So this is one technique and one of the aspects which we observe in conventional animation particularly in 2-D cartoon animation is the stretch and squash because what we are trying to do is have some caricature. The caricature in fact does exaggeration. You want to exaggerate so that what you are trying to impress upon is believable. So the technique of stretch and squash and others are basically for having an exaggeration like this.

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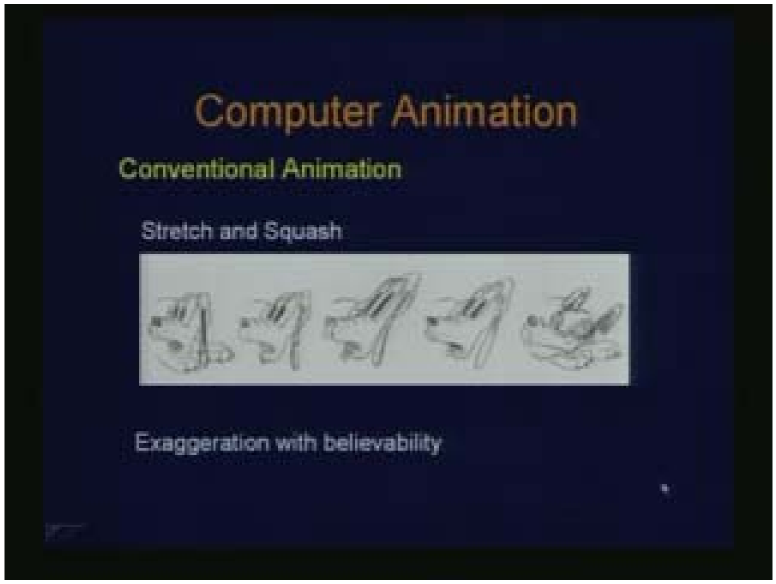

You can straight away observe that this is some sort of a stretching of this and this is some sort of a squashing. So, various expressions in animations can be generated using just the principle of stretch and squash. The next thing we will look into is how to address in computer animation. The conventional animation is primarily image by image animation it generates every frame.

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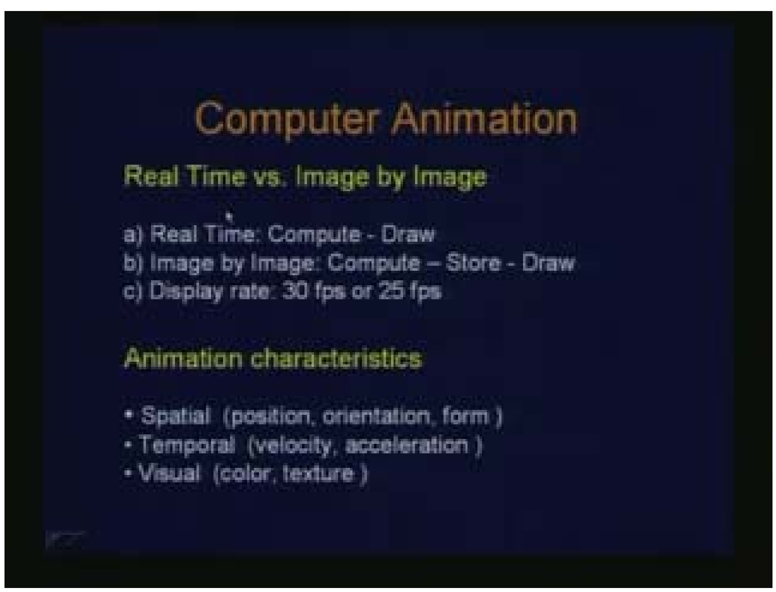

When we are doing image by image animation there is a notion of you compute a frame when you are using computer animation, you store that frame and then you draw the frame when you need it. So this is the three step process which is involved in image by image animation. Whereas if I want to do a real time animation, the real time animation is basically a process that implies to compute the frame and draw it. So there is no notion of storing it, they compute it and draw it.

Now one needs to look at the rate of display which you will require to use. So typically when I am generating an animation depending on what display standards I have I require thirty frames per second or twenty five frames per second. This is just to enable our visual perception. It does not perceive the discrepancies in the frames or jerks in the frames, the transitions in the frames. We just see a seamless sequence of frames. Now if you look at some sort of a characteristic of animation one can see there are three primary characteristics which may contribute towards animation.

For instance, I may have spatial characteristics which are basically saying that there are things like position, orientation, shape, form which is going to change known as spatial characteristics in animation. Similarly, you also have temporal characteristics. So there could be notion of velocity, there could be notion of acceleration etc. It is just not that things change but things change differently with time. Similarly, there could also be visual characteristics which contribute. So there could be a change in color over time, there could be a change in texture and so on. So, one can see that these are the three major characteristics which contributes to animation. Let us look at the techniques which could be used for animation and what has been used overtime historically in computer animation.

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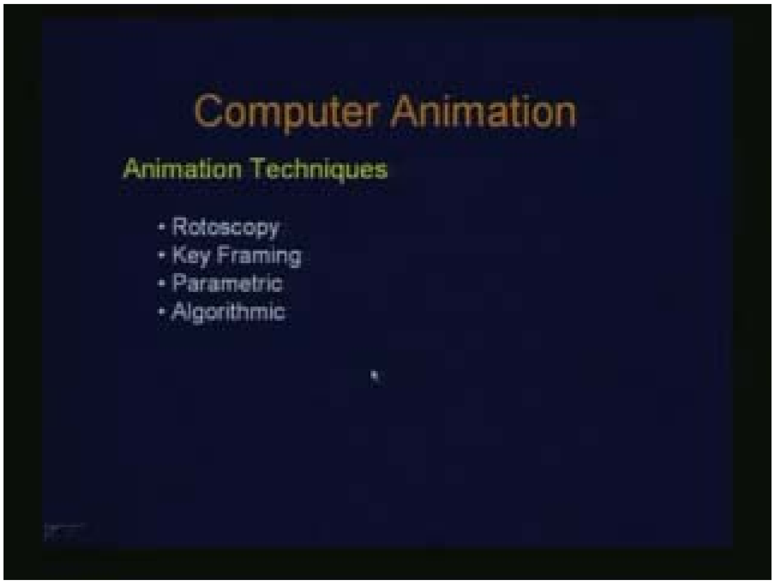

Animation techniques: There are various methods available. We will look at these methods in four categories. One is rotoscopy, then key framing, then we have parametric animation and then algorithmic animation. This basically covers a spectrum of various animations techniques which we may have for animation.

What do we mean by rotoscopy?
Rotoscopy basically implies that you are trying to record or register data for each frame. So when I say data that means it may imply everything, it involves the geometric description of the scene, it involves the illumination characteristics of the scene and so on so everything is recorded. Recorded could also mean I generate that, I register that from some means I acquire them. What we are looking at is an approach which is extremely data intensive. And if you look at this technique could be useful in particular when I am trying to capture a complex motion which I may not be able to generate by any other technique.

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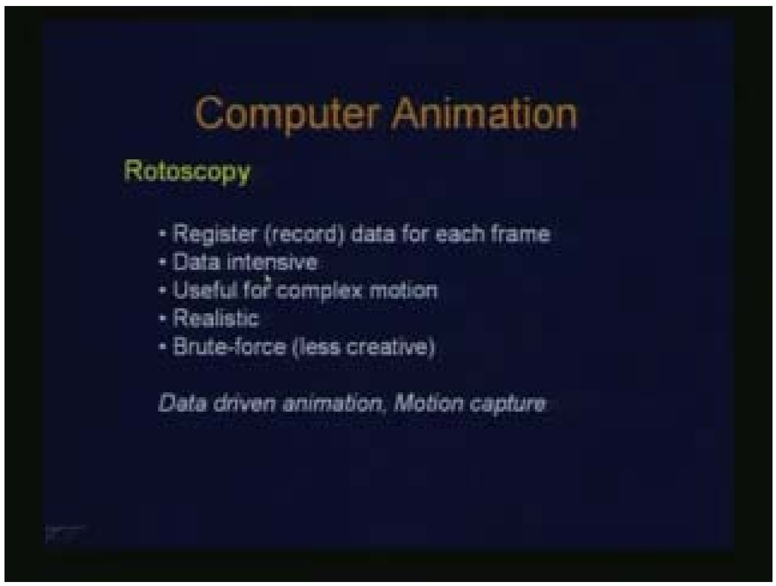

Also, when I am doing so, it is realistic because I am capturing every frame. But if you look at it as animation creativity it is actually less creative since it is just a brute force. The only emphasis is that you capture the data which is required for each frame. So we observe that this is in a sense a data driven animation and lots of data which need to be handled. And many techniques today that you might have seen through motion capture could fall in this category. This is one of the earliest techniques where every frame was registered or recorded.

But now-a-days because of the complexity we want to include in the animation this has again become popular also because we have the acquisition methods. So there are lots of motion capturing ways and methods which we can use these days through sensors of various kinds which can give us the required data. And also they are technically challenging because what you need there is the brute force data which is coming perhaps may be at a much larger speed. So the amount of data you get could be noised and what you need may be just a small set of that data. So you need to filter that data according to your application. This has again become a sort of a trendy method of animation today.

Key framing: The notion of key frame is very similar to what was seen in conventional animation.

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We have this selected key frames which are specified and then we use some interpolation to compute the intermediate frames and this approach is again though simple is very popular and still in use. Most of the animation software has key frames. Now one of the limitations which we may observe later is that it actually can cause inconsistency in the result or can give you incorrect results.

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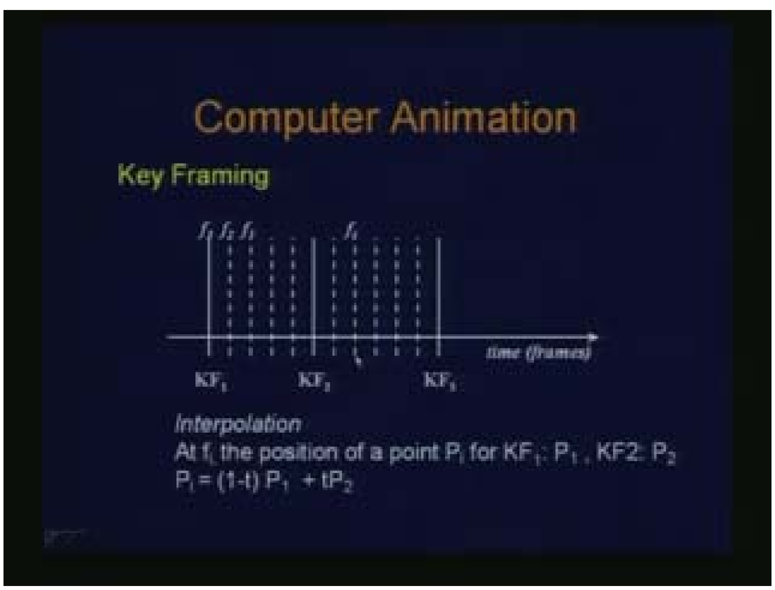

Therefore what we mean by this is, if we just see the formulation of key framing again then if I have a time axis here which is nothing but in terms of the frames I have I specify these key frames as KF_1 KF_2 and KF_3 and I compute the frames f_1 f_2 f_3 and so on which are in between these key frames. So any frame f_i which is the intermediate frame may be reflecting the position of a point or an object then all we are saying is that this Pi which is the position of a point or the object for the intermediate frame is a linear interpolation of the position at P_1 and the position at P_2. Therefore, linear interpolation is one way of doing the interpolation of key frames. There are some consequences as follows if I use linear interpolation.

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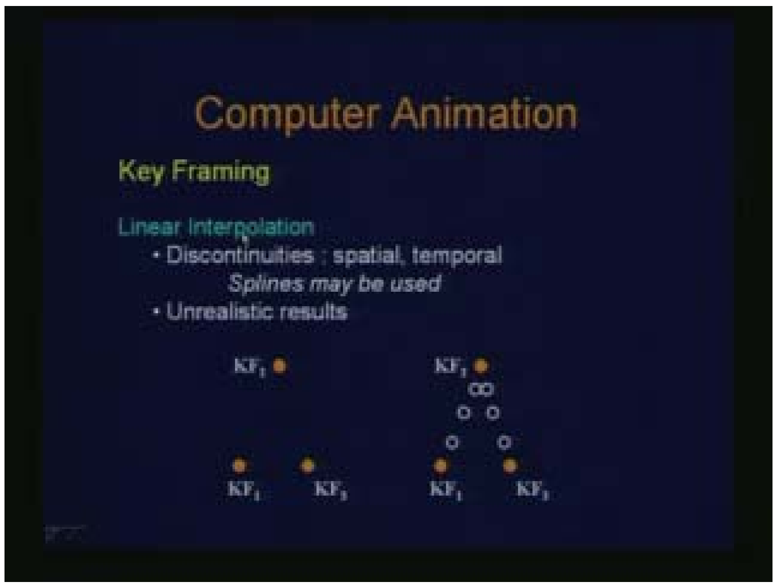

If I have linear interpolation one may have discontinuities. Discontinuity could be a spatial discontinuity or it could be temporal discontinuity. So, in order to address the issue of discontinuity you may use splines. Splines are basically ways of interpolating which are higher order interpolations which can give you higher order continuity.

Now if you look at examples here there could be some unrealistic results which we may obtain. So there is an example where I define key frames at KF_1 KF_2 and KF_3 so it is something which is trying to simulate that some object or a ball is thrown up and it falls.Now if that is the situation I am trying to animate and if I use linear interpolation then this is going to give me a result like this.

Here these white circles are showing the intermediate positions. What we observe is that this is not capturing the notion that when I throw a ball it goes with certain acceleration or velocity and it reaches this point, it sort of slows down when it reaches the highest point and then again an acceleration starts. So nothing of that sort gets captured here. So when I see the resulting motion which I will get using this interpolation it may not be realistic.

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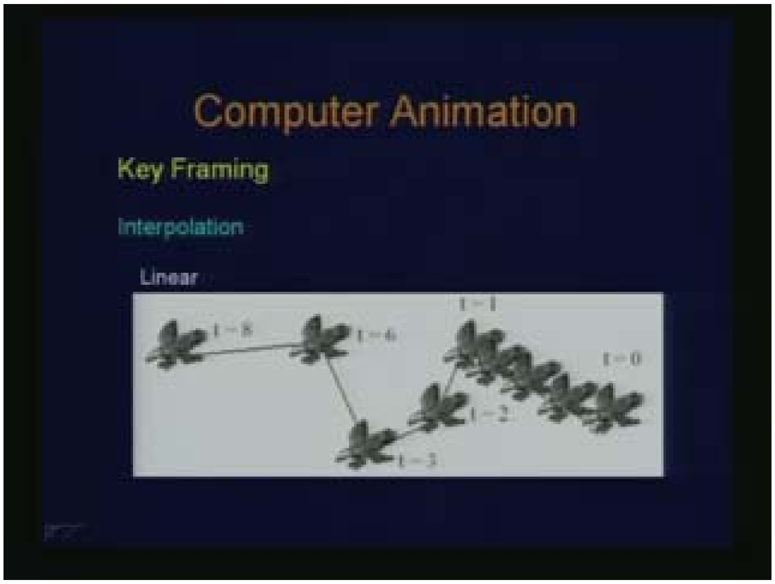

Now if there is an example of linear interpolation here, here the interpolation I have from one frame to another frame, so these are sort of frames which are specified over time and all I have is a trajectory which is computed using linear interpolation where this object moves. Now there also if I use linear interpolation it causes discontinuity. So wherever a joint is I will see a discontinuity in the path and that would give me some jerky motion. This could be corrected if I had used a spline curve. If I had used cubic interpolation then I would see a smooth transition over this path.

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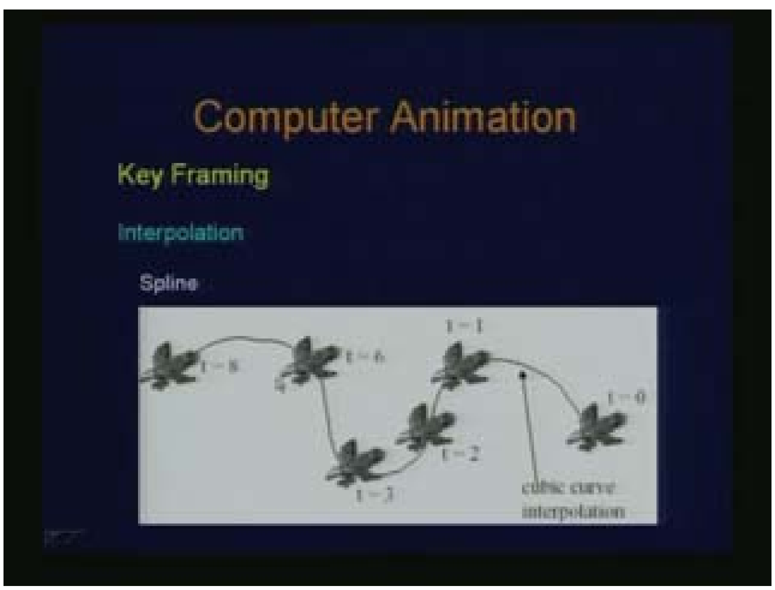

So the path is continuous and this may be more realistic and would not have these jerks or discontinuities. Now again as we are looking at the issues of interpolation one can incorporate, I have used interpolation but what I also want is to capture the notion that there is a slow start in the beginning and then there is a slow stop which we call it slow in slow out.

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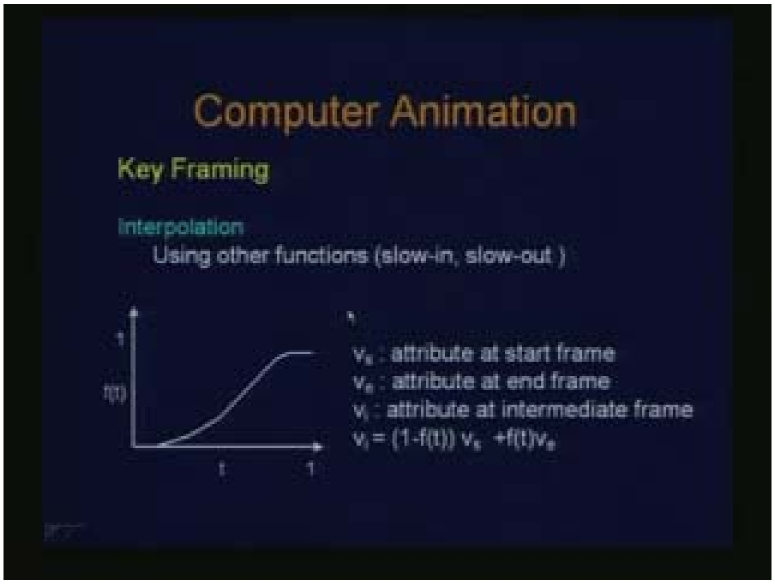

So what is happening is if I use some function of this form which is a function of a parameter t which I am going to use for interpolation would give me the impression of slow in slow out. Therefore, I can use a function for my interpolation rather than just using a linear interpolation. So here this interpolation is basically on an attribute which could be a position which could be anything which is represented through V_s and V_e is the attribute of the end frame and I do the interpolation using this 1 minus ft V_s(ft) instead of just using t.

Now any other function if I want to use could be incorporated through ft so this was just to have slow in slow out. But if you want to have some other kind of variation then you can use that function. Some of these problems which we have looked at which arise from interpolation and in particular linear interpolation we can resolve either using splines or these functions for interpolation. There is another issue here when we are talking about interpolation and particularly referring to the interpolation of shapes.

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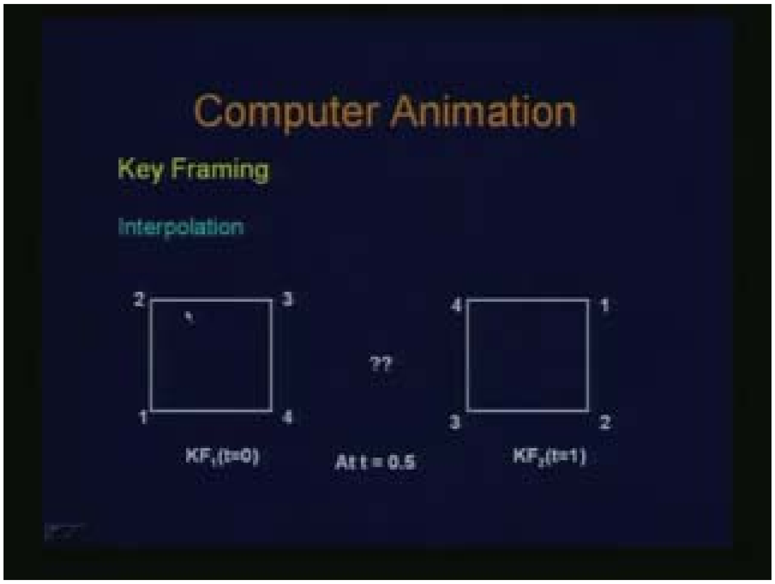

Now I have an object for which I have a key frame one and t is equal to 0 so this object is nothing but a square with vertices at 1 2 3 4. And this is my other key frame at t is equal to 1 KF_2 which is again the point one two three four this square. In a sense now this square has transformed to this square. Now if I apply a simple interpolation technique which I use for key frame and try to compute what happens to the shape at t is equal to 0.5?

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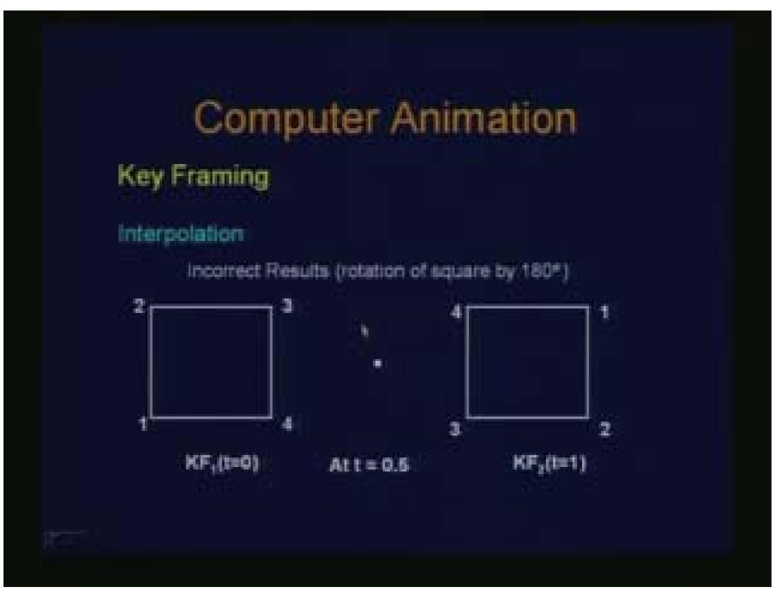

A dot will come so the whole shape is distorted so that is what happens. This is what the result is. Now if you compute all the transitions going from key frame KF_1 to key frame KF_2 it will pass through this which would look strange.

And one can actually observe these issues or these problems at different situations. In fact if somebody observes it is actually a rotation then perhaps a different method is required to be able to generate an intermediate frame here again and perhaps using only interpolation but not employing or not using interpolation on the shape or the set of points. These things have to be kept in mind when you do key framing. This is what this we mean by inconsistencies which can arise using key frame animation. So an alternative is which is actually inspired from what we have observed is to use parametric animation. What do we mean by parametric animation? If we look many times at many situations the animation is caused by a set of parameters.

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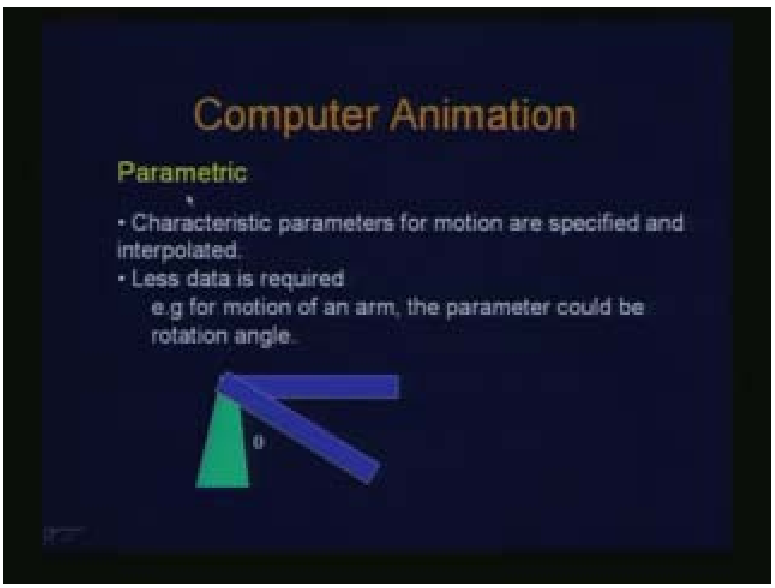

The shape change or form change is a consequence in change of some parameters. So instead of doing the shape interpolation you may use interpolation of that parameter. So your definition of animation is in terms of that parameter. A very obvious example is shown here. For instance, what you are doing is you are doing some kind of a motion of an arm or a robot arm, you have a robot which rotates from here to here. When this happens the entire motion can be parameterized by an angle of rotation.

Now I can generate animation using interpolation of this parameter. So the benefit is that it obviously requires less data because I am defining the animation in terms of this, I do not need to look at the entire shape. I have a shape somewhere and the entire animation that is done is defined in terms of this parameter which I apply onto this shape. So it is some sort of a transformation which I derive from this parameter and apply it to shape of the object. That is what we mean by parametric animation. This is particularly relevant to the example of the motion of articulated structures. There is another category of animation which we refer to as algorithmic. Many times we observe certain laws of Physics or motion to be the driving force for animation.

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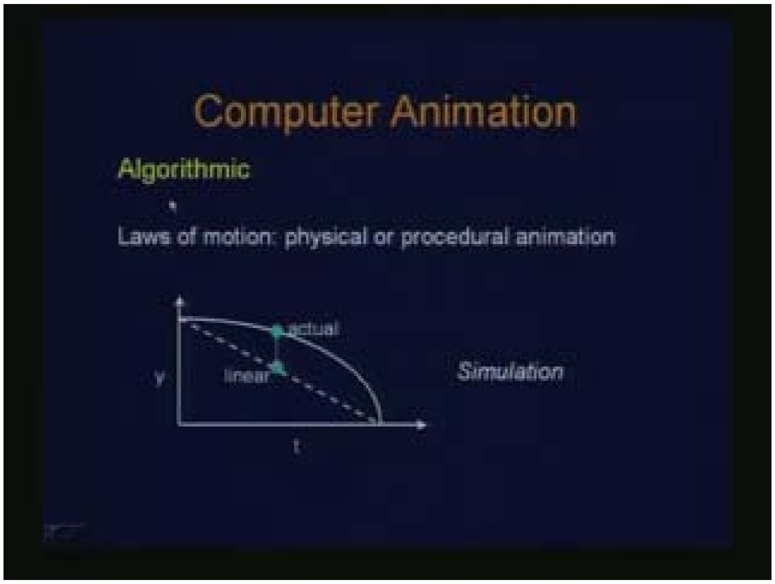

In fact what we are trying to do in animation is to simulate those situations for which we know the law of Physics, the law of motion. Then it is perhaps better to do or use that law of motion for creating an animation. So a very simple example is shown here. You have a motion of projectile you throw some kind of an object from a height and it hits the ground. That is the kind of thing you want to simulate.

Now if you use a simple interpolation then obviously you may get something like this a dotted line which is shown here which is by linear interpolation which is completely wrong knowing that it is a projectile motion whereas if I had used the law of motion a simple equation to generate this motion then I would have got this. So again this is not a real simulated trajectory which I am showing here but it is some curve which I have drawn using a power point tool. But this is just to indicate that I could compute or do the simulation of this entire projectile motion with the known equation of motion. So I can embed the law of Physics or law of motion which is there in the process which I am trying to simulate. This gives you the spectrum of technique which could possibly be used in computer animation. Here is an example which will illustrate you some of the techniques which are used even in the commercial studios. This is an example by Monster Inc. by Pixar and Pixar is an animation company.

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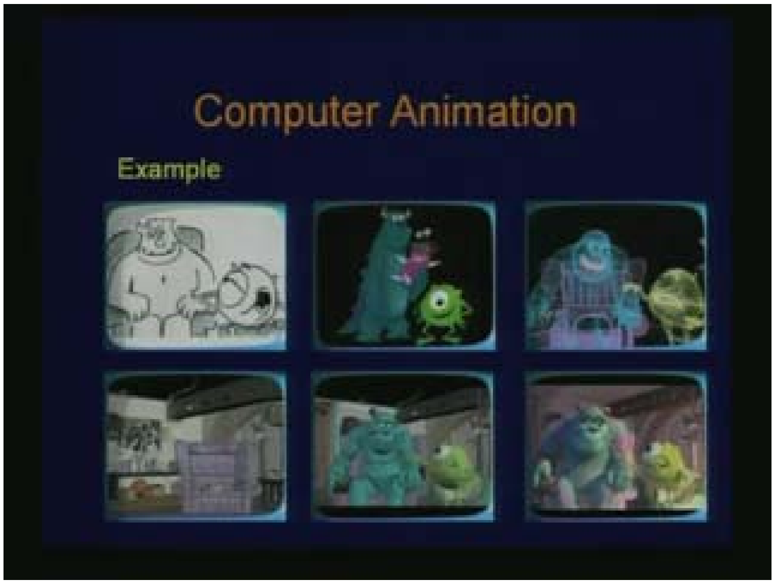

This is a Pixar project with Disney. They have produced this. Here what you see is that this in a sense gives you various stages which may be required for animation. Here for instance the first thing which you need to have is a sketch which could be drawn by the animator which gets used in the story board. So you try to give an expressive depiction of what is there in the frame or in that key frame. Now this does not correspond to this frame though but then the idea is that you try to do some color coding to reflect the different colors you may be using for these characters. And in case if you are just using 2-D animation then you assign the various colors which you would be using for portions here.

Now if you have the 3-D animation then you try to build the corresponding 3-D models or you already have 3-D models and you pose these 3-D models according to your sketch. So, 3-D model basically here, for instance, is shown through the mesh models wireframes. So this is a character called Sally and this is Mike. Then this is what your rest of the scene is, the staging of the entire action. So this is the scene building where you put whatever is required and then do the necessary modeling here.

Then you have your illumination. So this was wireframe with the color scheme you might have defined. Now this is a shaded model where you see the shaded objects on to the same. And then you may also have further realism through addition like fur or any other aspect you want to attach. All it is showing is that once you have done these 2-D displays of these sketches which capture your story board then you create the necessary environment in 3-D and do the animation in 3-D.

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There is also some other task related to this. You have created the visuals then you have to overlay the audio on it where you do the production. So there are set of frames which you have created and then you have to overlay the sound on it. Since it could be a longer sequence, a typical computer generated film may have thousands of frames. Therefore you may need to have necessary infrastructure to be able to compute those frames and store them because typically these animation sequences are not real time but they are more in the sense of frame by frame philosophy.

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