Computer Graphics
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Lecture No. 2
Historical Evolution, Issues and Challenges

Hello and welcome to lecture number 2 in the course Computer Graphics. So, before we start, let us recap what we have learned in the previous lecture.

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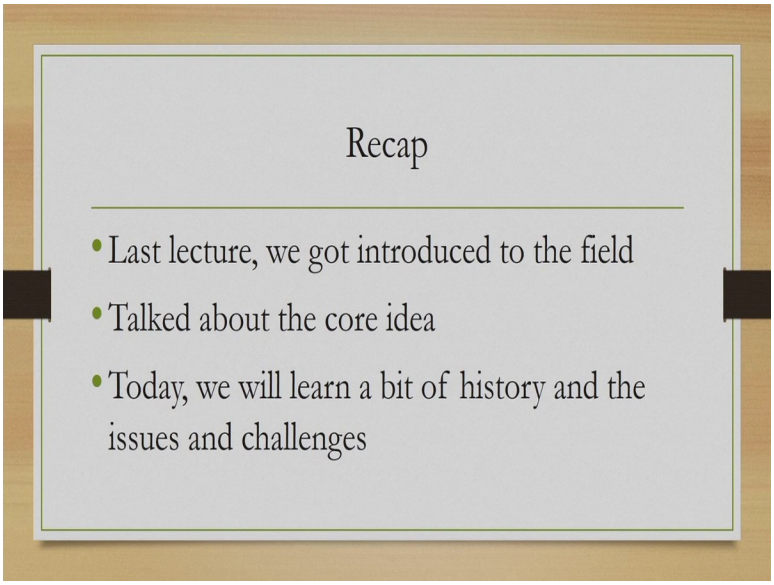

In the last lecture if you may recall, we got introduced to the field and talked about the basic idea. That means, what is computer graphics, what it deals with. Now today, what we are going to do is, we will discuss the historical evolution of the field. And also we will discuss the issues and challenges that are faced by researchers in this area.

Historical evolution knowledge is always beneficial for the broader understanding of the subject. So, we will go into a bit details of the evolution followed by discussion on the issues and challenges.

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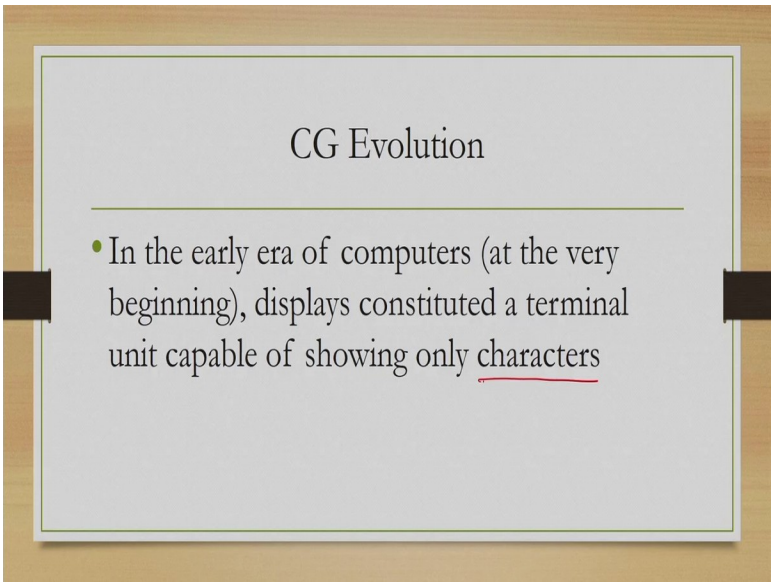

In the early days when computer just started appearing, that means in the 1940s, 50s of the last century, displays constituted a terminal, a terminal unit capable of showing only characters. So, in earlier days we had displays that used to show only characters, there was no facility or no way to show anything other than characters.

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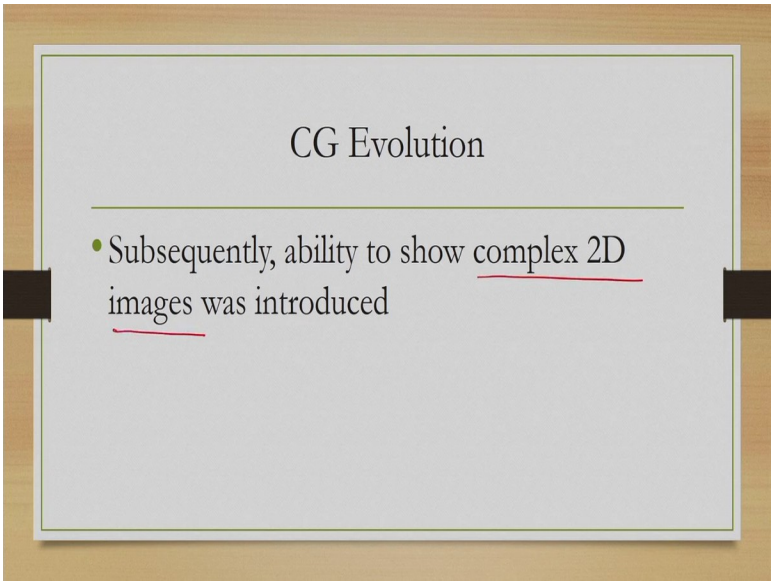

Subsequently, the ability to show complex 2D images was introduced, that is the later developments. Now, with the advent of technology other things changed.

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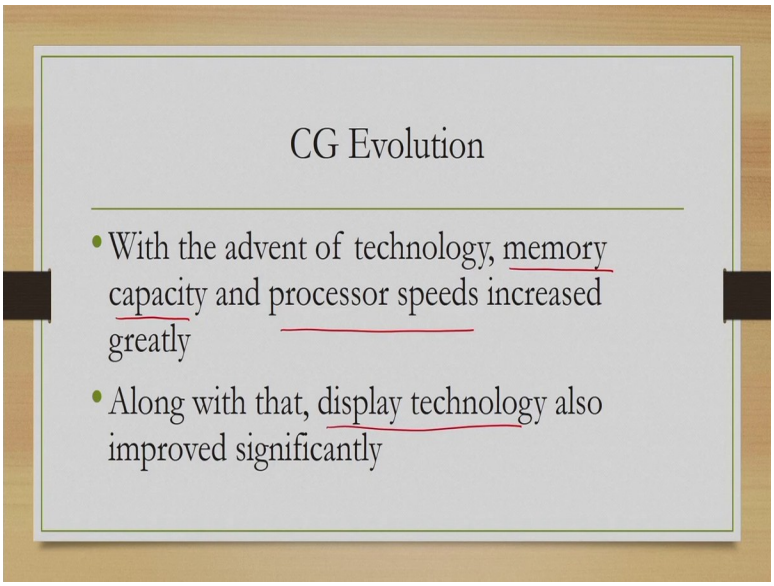

We have now higher memory, capacity and increased processor speeds. Along with those changes, the display technology also improved significantly, so we had 3 broad developments, memory capacity enhancement, processor speed increase, as well as improvement in display technology.

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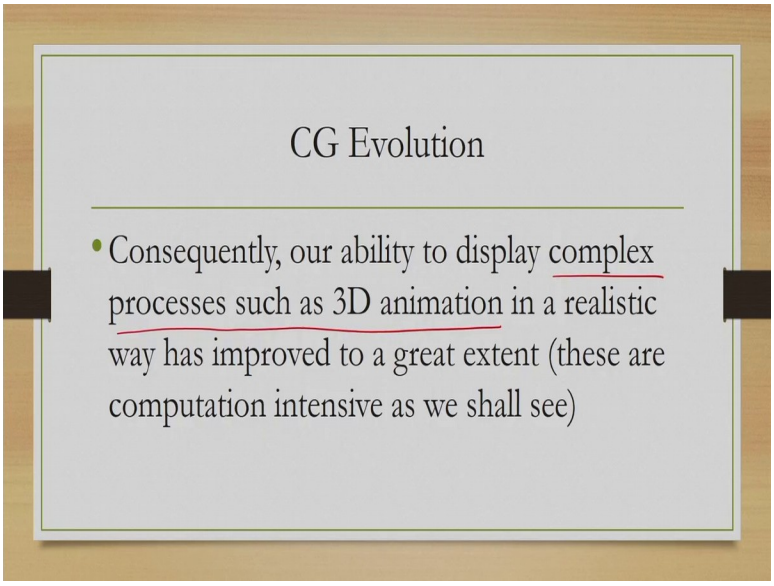

Now, all 3 contributed together to display or to make it possible to display complex 3D animations which are computationally intensive and which assumes that we are capable

of performing the computations in real time. How computers computationally intensive these processes are, we will see in the subsequent lecture. In fact, that is the core content of this course.

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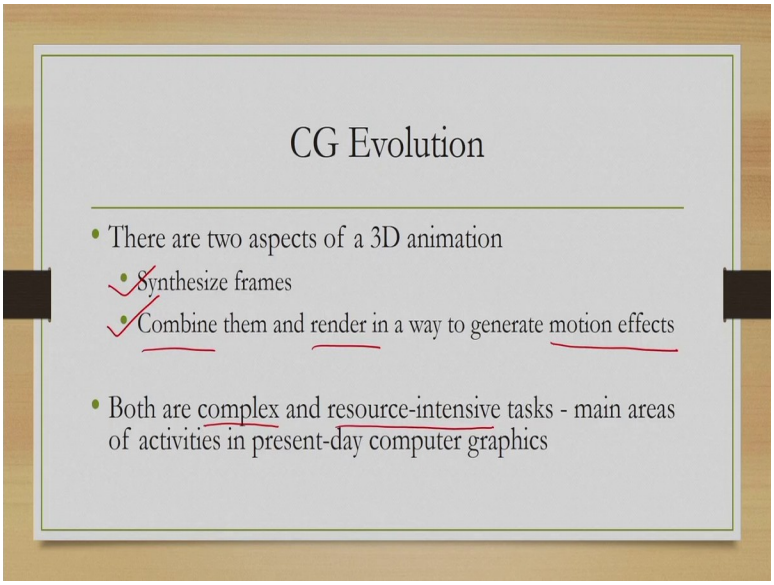

Now, if we look closer to the 3D animation, then we will see that there are 2 aspects, one is synthesize of frames and the second one is combining the frames together and render them in a way such that it generates a perception of motion or generates the motion effects. Now, synthesis of frame as well as combining them and rendering them on the screen to generate motion are complex processes and they are also resource intensive. They require lots of hardware resources.

So, these are the main focus areas of present day computer graphics activities, how to make the computer these processes workable in the modern day computing environment.

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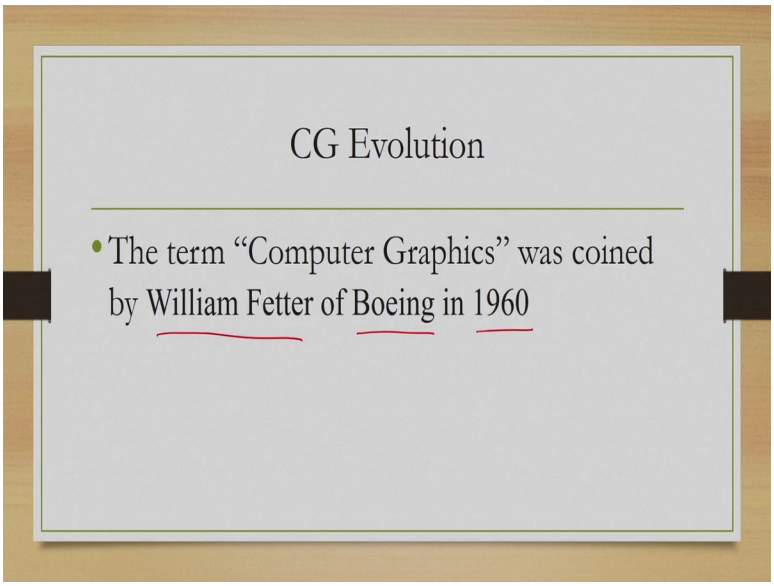

Now, we are repeatedly talking about the term computer graphics but it has an origin. So, the term was first coined by William Fetter of the Boeing Corporation in 1960. That is 60 years ago.

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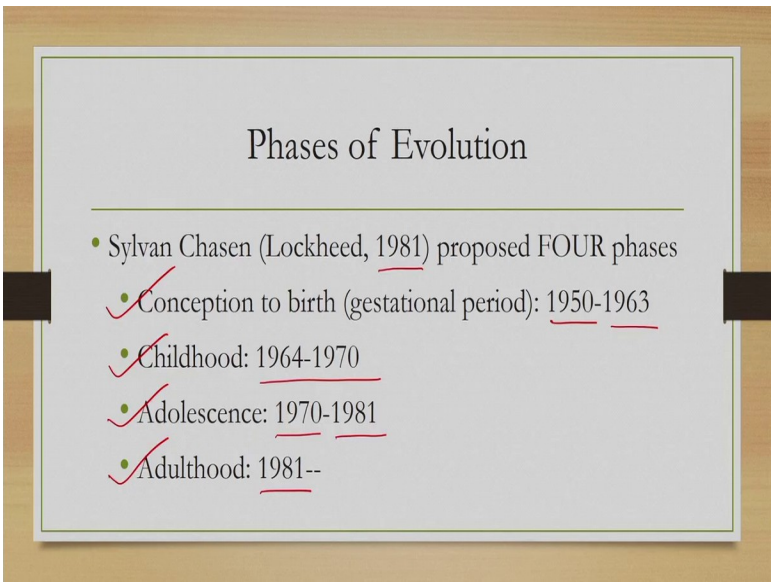

Subsequently, Sylvan Chasen of Lockheed Corporation in 1981 proposed 4 phases of the evolution of the field. What are those phases? The phase was concepts to birth which is typically considered to be between 1950 and 1963. This is also known as the gestational

period. The second phase is the childhood phase of short duration 64 to 70 in the last century, then we have adolescence, this is again somewhat significant phase and span between 1970s to early phase of 1980s and then we have the adulthood which is still continuing starting from the early 1980s.

So, these are the 4 phases that was proposed by Sylvan Chasen in 1981, gestational period, childhood, adolescence period and adulthood. Now, let us have a quick look at the major developments that took place in each of these phases.

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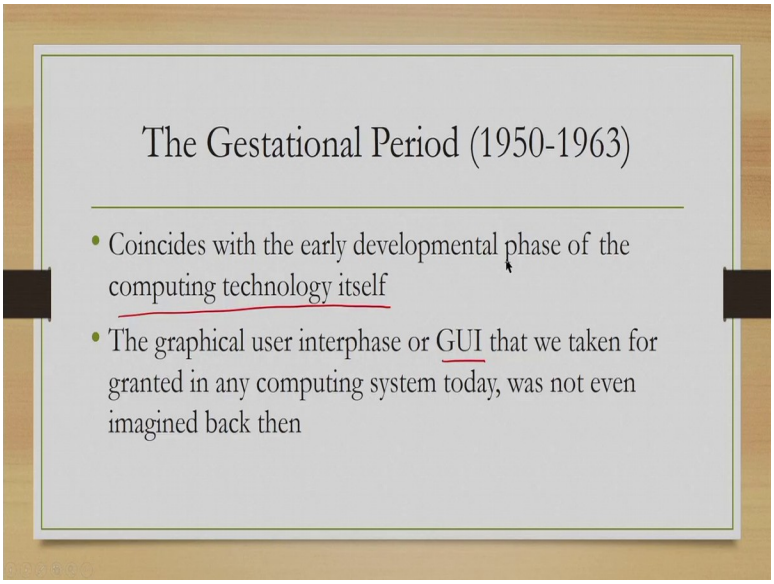

Let us start with the first phase that is the gestational period between 1950 and 1963 at the early stages of computers. Now, if you are aware of the evolution of computers in the early phases, then you know that, that phase the gestational period also coincides with the early developmental phases of the computing technology itself. So, that was the phase when technology evolved.

And nowadays, we take for granted the availability of interfaces that are popularly known as graphical user interfaces. So, we get to see it on all of our computer screens mostly, if we are using desktop, laptops or even smartphones. But in that phase, in the gestational period, the GUI concept was not there. In fact, nobody was even aware of the possibility of such an interface, it could not be imagined even.

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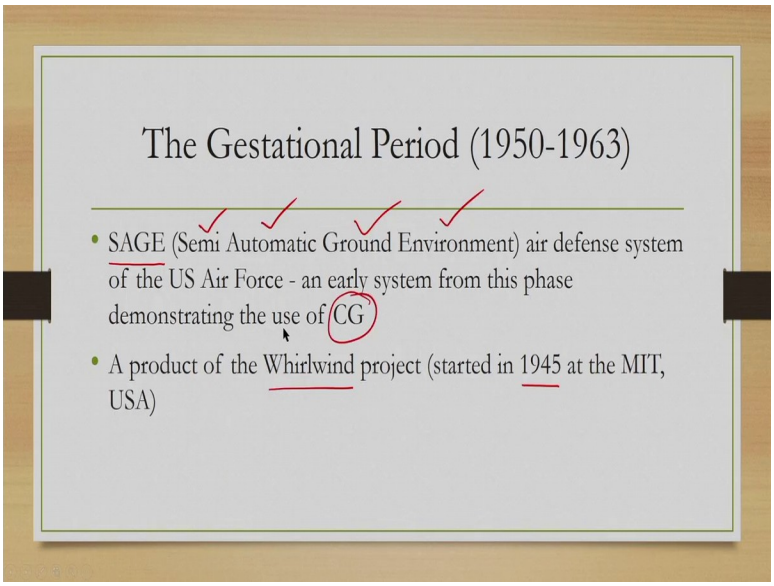

Now in that phase, there was one system developed which was called SAGE, which stands for Semi automatic, Semi Automatic Ground Environment. Now, it is developed by or for the benefit of the US Air Force, which is part of a bigger project called the Whirlwind project which was started in 1945. Now, the SAGE system is an early example from this phase of gestational period demonstrating the use of computer graphics.

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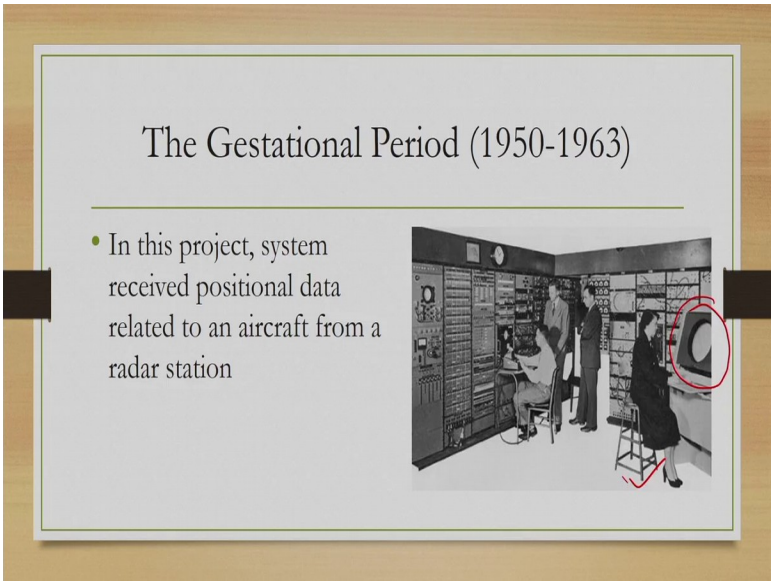

What this system does or what this system did, now the basic idea of the project was to get the positional information of an aircraft from rudder stations that is typically the job radar network. Now there is an operator who like this operator here, who was sitting in front of a screen, as you can see, but not the traditional screens that we are accustomed with but early version of a screen.

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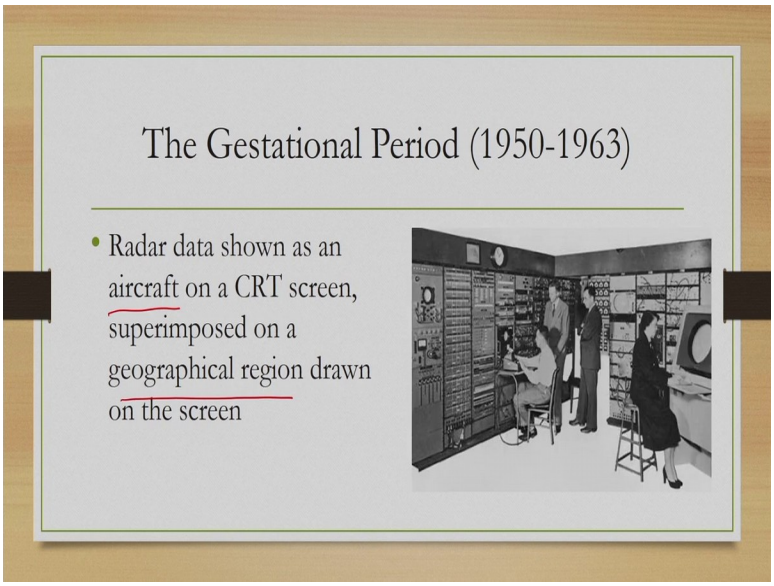

And on this screen aircrafts are shown and on the aircraft other data, the data received from the radar was superimposed. So, essentially what we have is that on the screen, a geographical region is shown and on that region the aircraft information is shown.

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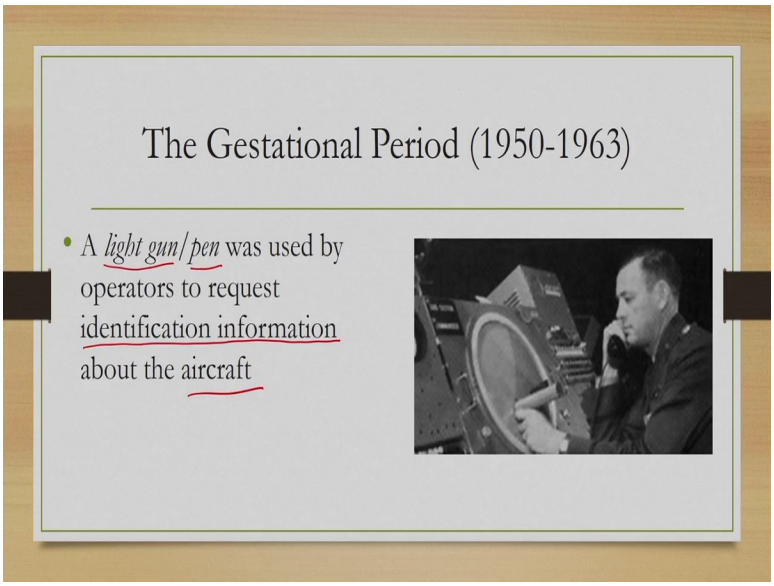

There was more one more aspect of the system. So, it was actually in a sense interactive system, so the operator can actually interact with the system with the use of an input device called a light gun or pen, light pen. Now, if there is an aircraft shown on the screen, the operator can point the pen to that aircraft to get the identification information of the aircraft.

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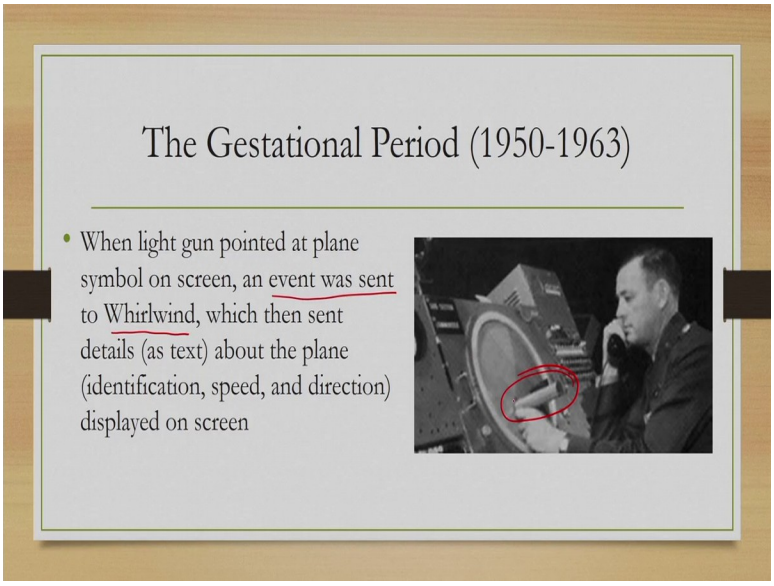

So, when the gun was pointed at the plane symbol on the screen an event was sent to the Whirlwind system which in turn sent the details as text about the plane or about the identification information of the plane which was then displayed on the screen of the operator. Something like this. As you can see this is a light gun or light pen, operator is pointing the pen on the screen where an aircraft symbol is shown and once the pointing is done, then the system sends message to the overall system, Whirlwind system which had all the information, which is sent back to the interface to be seen by the operator.

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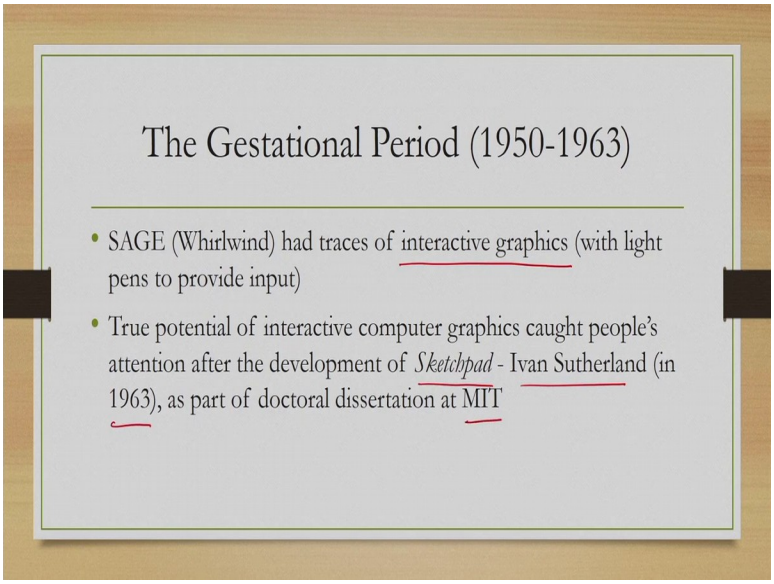

So as I said, the system SAGE which is part of the Whirlwind system had traces of interactive graphics, where the interaction was done with the light gun or the light pens, but it was still not fully interactive the way we understand interaction in the modern context. True potential of the interactive computer graphics came into picture after the development of another system called Sketchpad by Ivan Sutherland way back in 1963. So, this Sketchpad system was a part of doctoral theses of Ivan Sutherland at MIT. And this system actually demonstrated the idea as well as the potential of an interactive graphics system.

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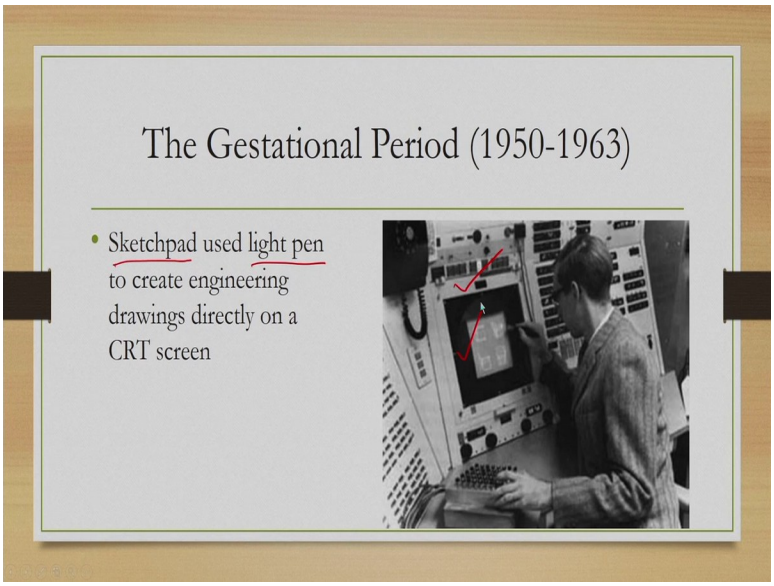

Like the SAGE system in Sketchpad also, the interaction was done through light pen and it was mean to develop engineering drawings directly on a CRT screen. So, here the operator need not be a passive input provider instead active input can be given in the form of creating drawings itself on the screen. An example is shown in this figure as you can see, this is the screen and on the screen the operator is holding light pen to create a drawing here.

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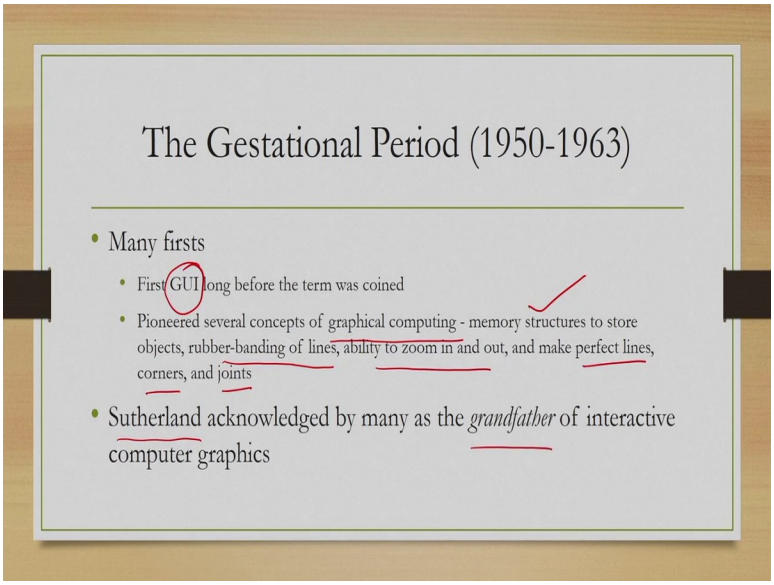

Now this Sketchpad system actually contains many firsts. It is widely considered to be the first GUI, although the term GUI was still not popular at that time, it is also credited with pioneering several concepts of graphical computing namely how to represent data in memory, how to deal with flexible lines, ability to zoom in and out, draw perfectly straight lines, corners, joints.

These are things that nowadays we take for granted but these were very, very difficult at the time and sketchpad actually managed to demonstrate that these are possible. Accordingly, Sutherland is widely acknowledged by many as the grandfather of interactive computer graphics.

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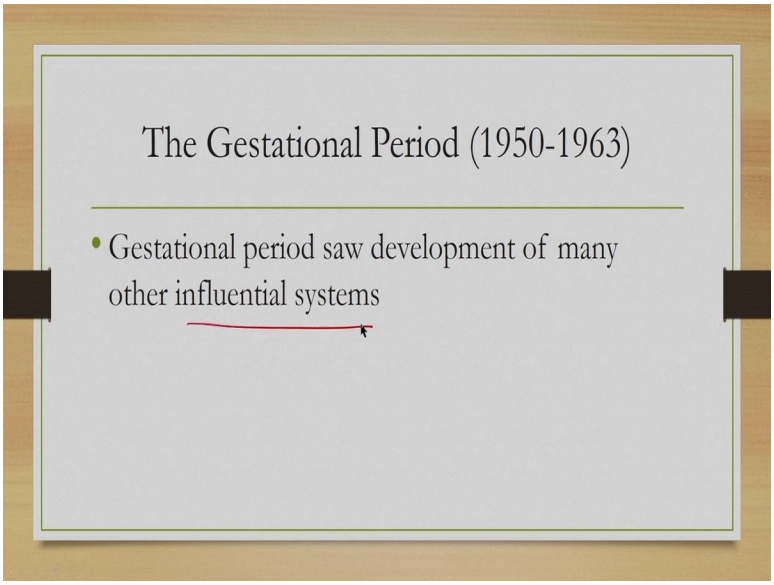

Now along with SAGE and Sketchpad, this period, gestational period also saw development of many other influential systems.

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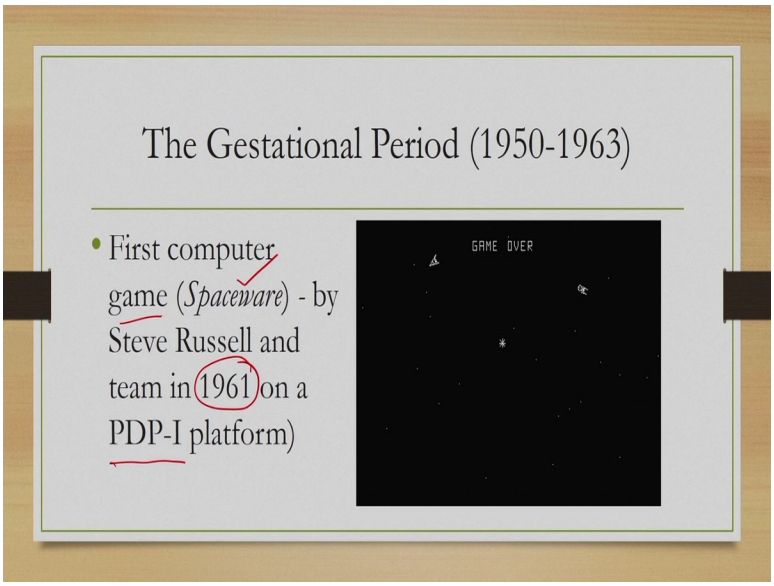

During this phase first computer game called Spaceware was developed in 1961 on a PDP-1 platform which is an early computing platform.

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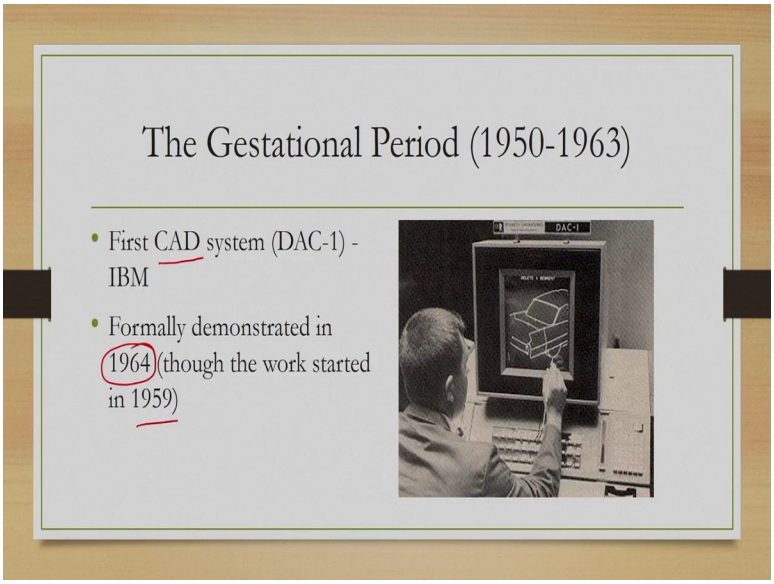

IBM also developed the first CAD or Computer Aided Design system, recollect our previous lecture these systems are meant for helping engineers create mechanical drawings and test various thing without actually requiring to build the system. And in the

gestational period, IBM came up with this first CAD system in 1964 although the work started in 1959.

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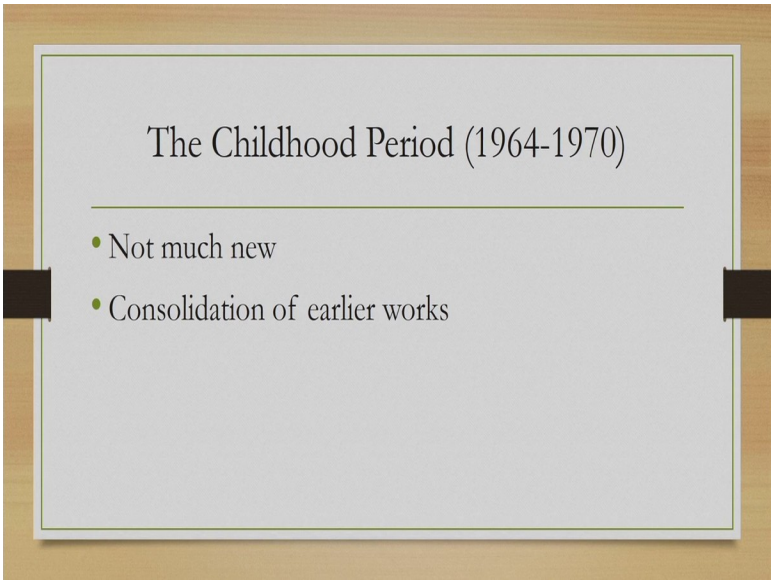

Now, the gestational period was followed by the childhood period, which is reasonably short duration period only of 6, 7 years. Now, in this period now much significantly new things happen only whatever was developed earlier in the gestational period, further development took place along those lines and consolidation took place of the earlier ideas.

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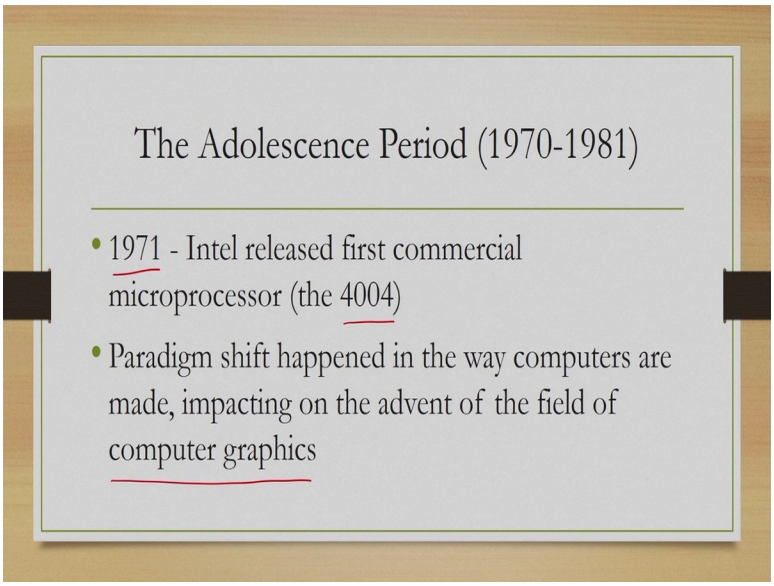

Then came the adolescent period, mostly confined to the 1970s and early phase of 1980s. Now, in this phase again, many new things happen, in 1971 Intel released the first commercial microprocessor called the 4004. Now, as we all know, with the coming of this microprocessor, a paradigm shift took placed in the way computers were designed and that in turn impacted the computer graphics field in a significant way by making computations less costly and affordable.

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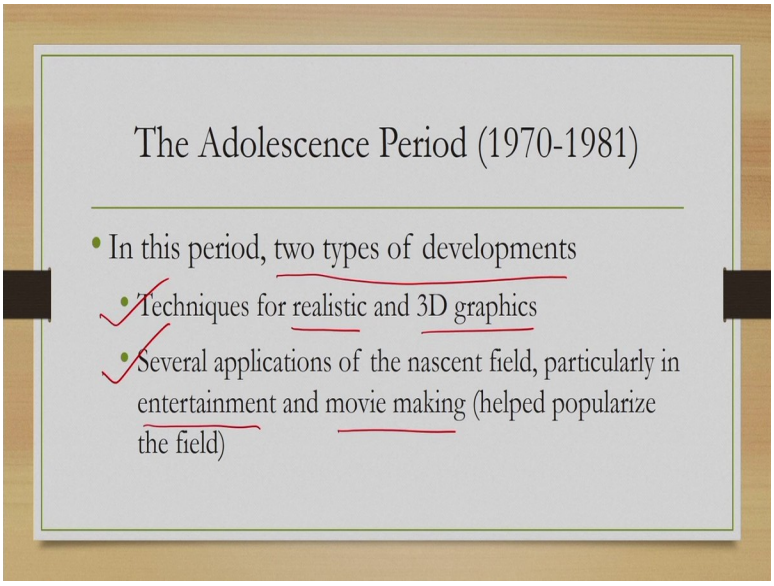

As a result, in this period several interesting things happened, primarily two types of developments took place, one is techniques for realistic 3D graphics and several applications were developed during this phase particularly in the entertainment and movie making fields. As a result of those applications, people started noticing the potential of the field and invested more and more time and money so, both the development were significant in the context of overall evolution of the field.

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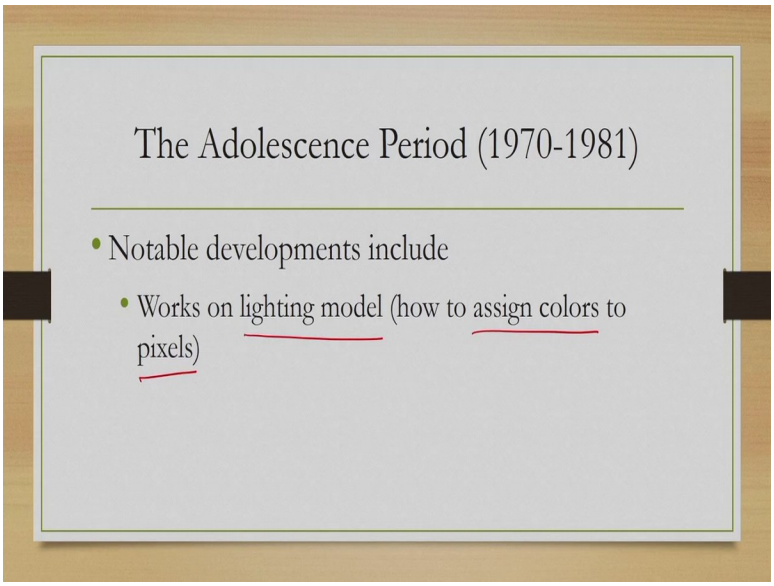

Now, what were the works that were done for realistic and 3D image generation? One important development was the working on the lighting models. Now, these models we will learn later. What these models were meant to do, were to assign colors to pixels and this coloring of pixels or smallest graphical units on a screen is very important to give us a perception of realistic images as we all know. And we shall see in details in later lectures.

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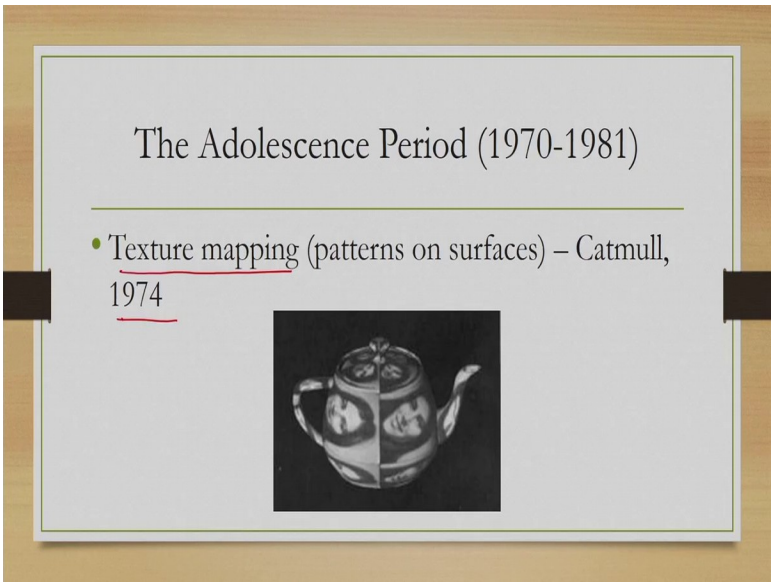

Apart from that, another thing took place that is development of texture mapping techniques, now texture is basically patterns that we get to see on the surfaces. So, if we can impose textures on our artificially created object surfaces, then definitely that will lead us to a more realistic image representation and that development took place in this adolescence period.

So, the first work was done by Catmull in 1974. First notable work, as you can see, that on this object some textures are shown, because of that, we are able to make out that it is a 3D object and it is having certain characteristics. So, without texture, it will look dull and non realistic.

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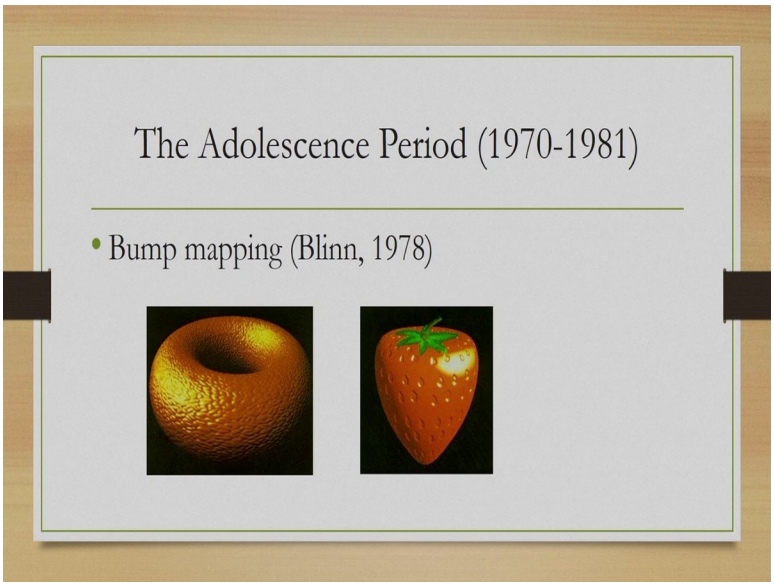

An advanced form of texture mapping was done through Bump mapping by Blinn in 1978. Like the example shown here, on the object surfaces, we can see that that special type of textures were incorporated, inserted to make it look more real, natural. These are called bumps, Bump mapping.

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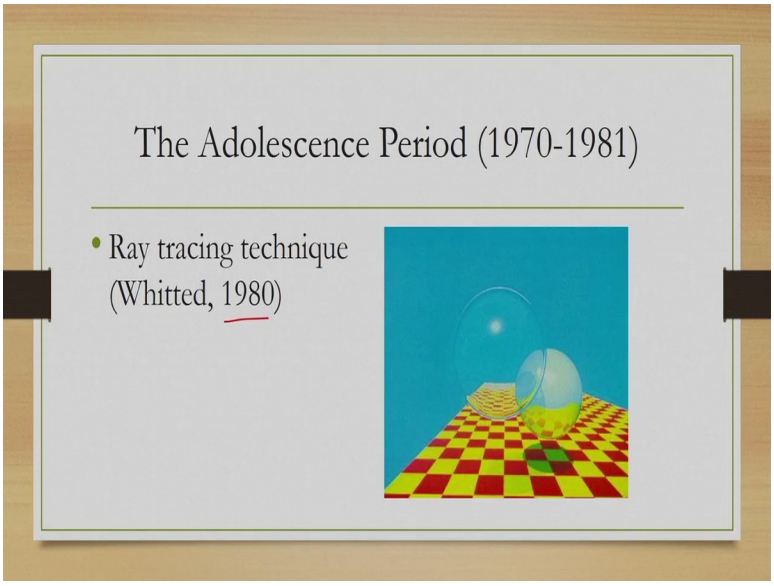

Also another development took place which is an advanced technique of creating 3D images that is called Ray Tracing and first notable development took place in 1980s in

the adolescence period, using this technique, we can develop realistic 3D images on a 2D screen, in a more better way than using the other techniques. Now, these are techniques that were developed to improve the quality of the synthesized images, to make them more realistic, more natural.

So, to recap, broadly 4 approaches were develop in this phase. First one is lighting modern, basic work on the lighting model followed by texture model and bump modeling, bump mappings and finally Ray tracing methods. Apart from that, as I mentioned earlier, another strand of development that took place during this phase was development of several applications of computer graphics, whatever was the state of the art at that time based on that several applications were developed. Particularly in entertainment and movie making.

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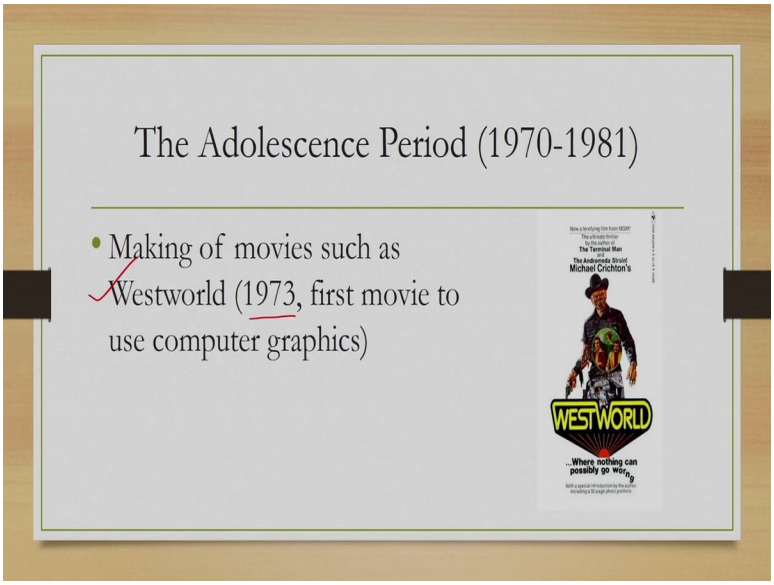

So, in 1973 the first movie came out named Westworld, which was the first movie to use computer graphics.

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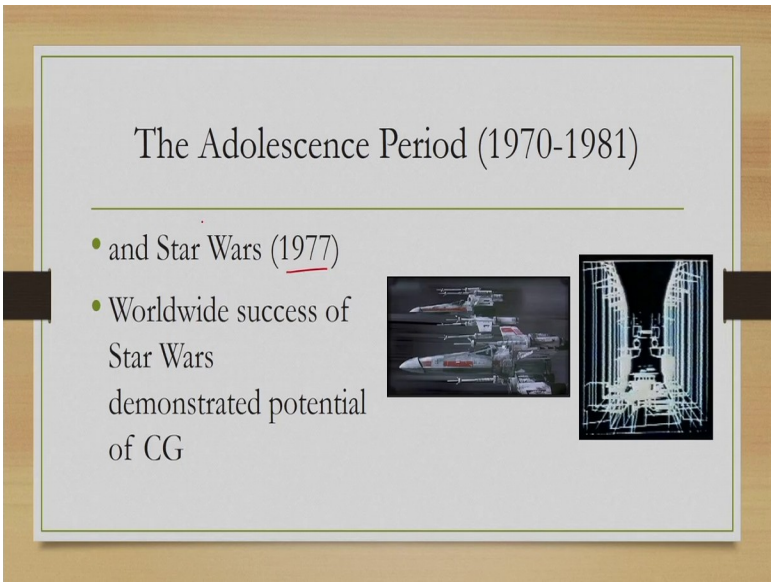

This was followed in 1977 by the movie Star Wars, I think most of you, if not all, may be aware of this movie. So, the first movie came out in 1977 and it became hugely popular throughout the world and as a result, people learned about the potential of computer graphics in a more compelling way.

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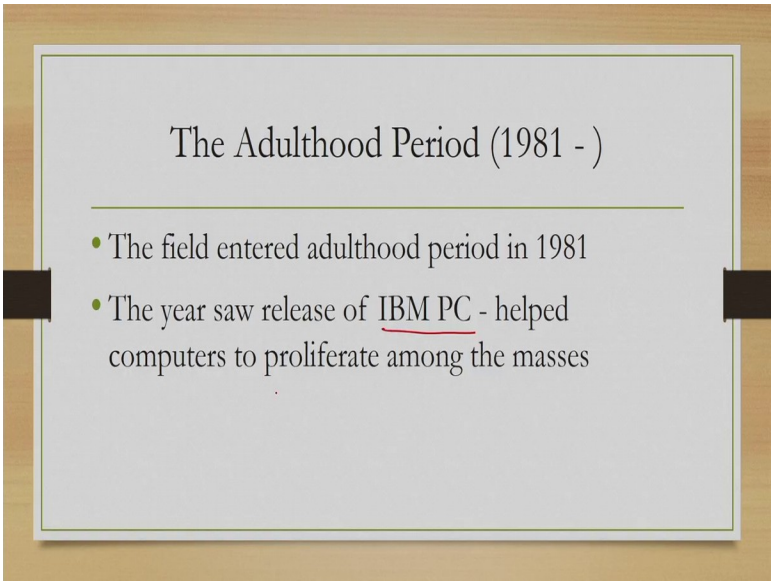

The adolescence period was followed by the adulthood period, starting from the early phase of 1980s. Now, in this period, the field entered the adulthood with the release of

IBM PC in 1981. Now as we all know, after the advent of the PC or personal computers, computers became a mass product, earlier it used to be confined to only a few people who were well educated in an advanced stage of studies and primarily does research or development works using this but after the advent of PC proliferated and become a mass product. And since it had become a mass product, focus now shifted to the development of applications that were appealing to the masses.

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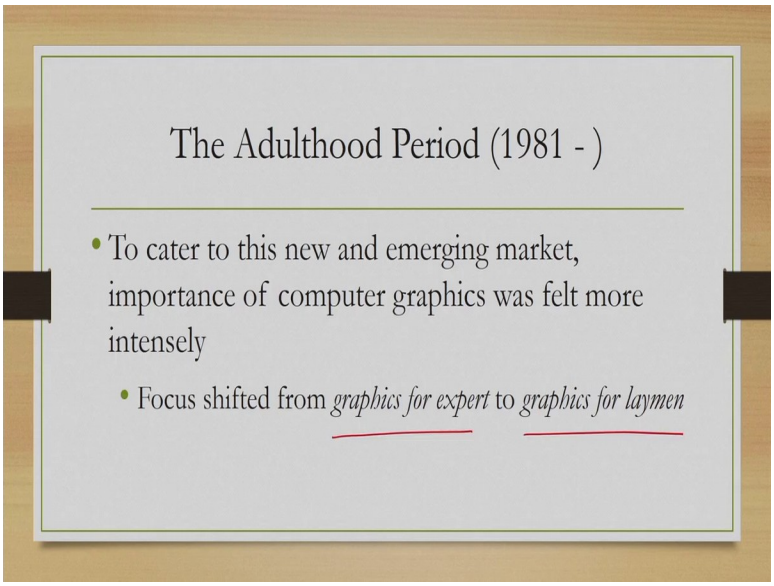

And using computer graphics lots of such applications were developed and focus shifted from graphics for expert to graphics for laymen.

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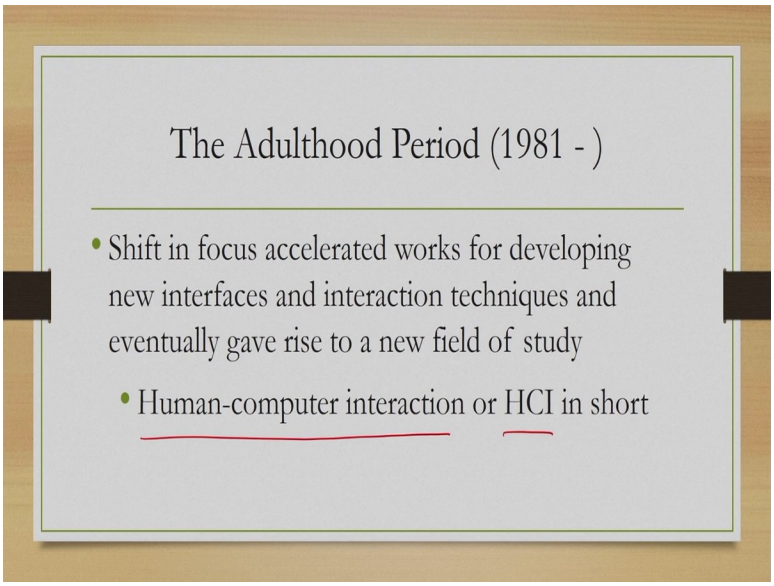

And as a result, we got to see several developments including the development of GUIs and the associated concepts. In fact, so many developments took place that it gave rise to a new field of study, which is called human-computer interaction or HCI in short.

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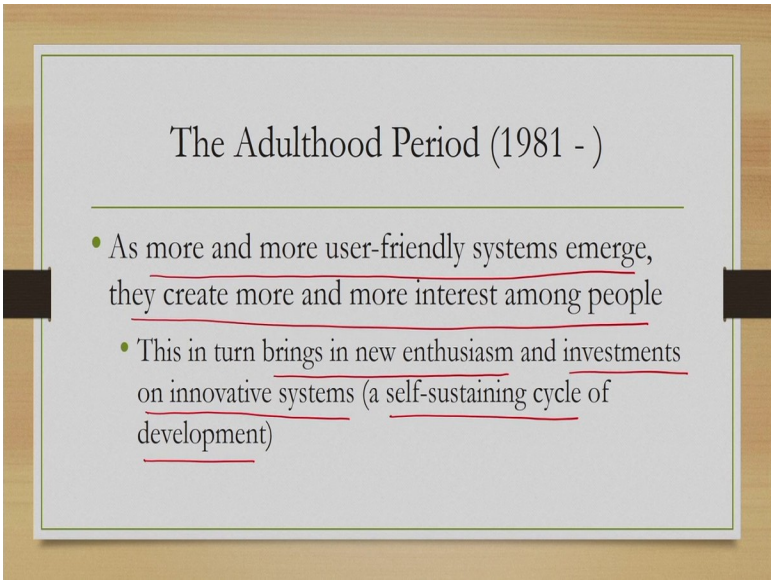

One thing happened during this phase, a self sustaining cycle of development emerged, what is that? As more and more user friendly systems emerge, they create more and more interest among people, in turn that brings in new enthusiasm and investments on

innovative systems. So, it is a self sustaining cycle of development, more and more applications are there that is appealing to more and more people and the people in turn want more and more so, more and more investment came and it continued and it is still continuing.

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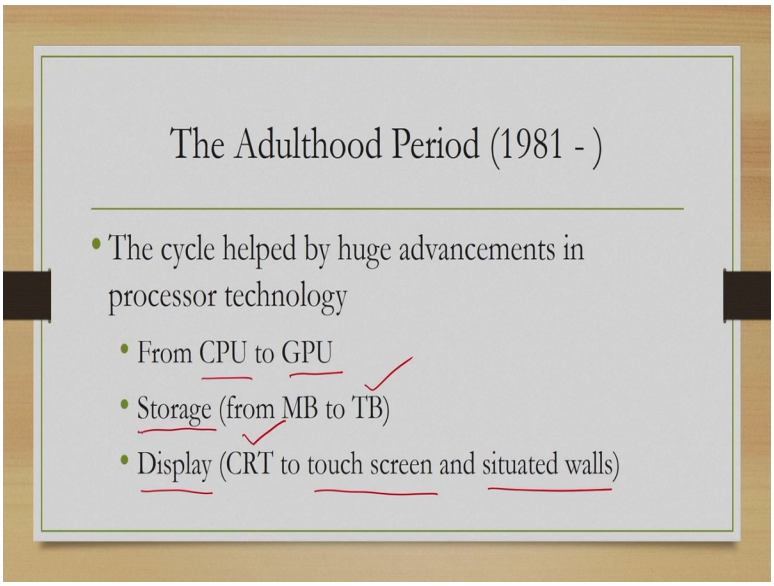

And as a result of this self sustaining cycle of development, other associated developments took place. So, from CPU, we migrated to GPU or graphics processing, dedicated hardware for graphics, storage capacity improved significantly to be able to store and process large amount of data required for 3D realistic graphics. So, now we are talking in terms of terabytes, petabytes, instead of kilobytes or megabytes that used to be the case earlier.

Similarly, display technology have seen huge improvement from the earliest cathode ray tubes to modern day touchscreens or situated walls or even better things. So, all this took place because of this self sustaining cycle of development.

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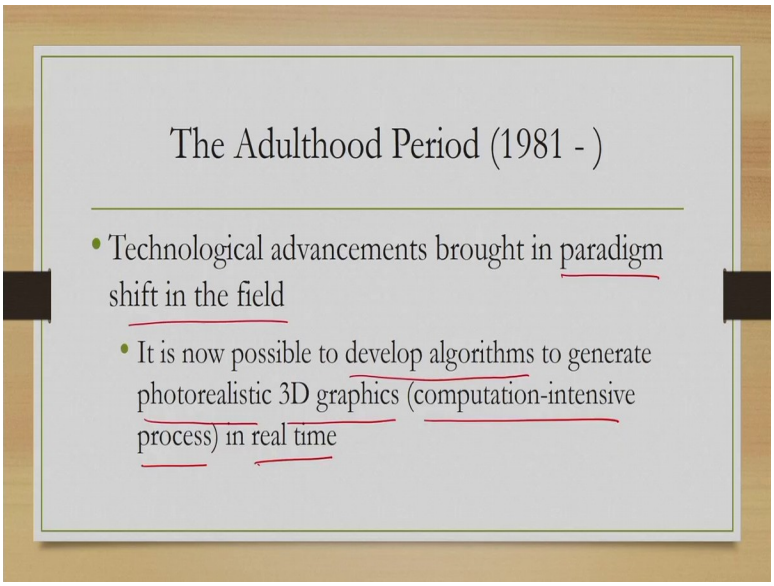

So, we can say that these technological developments brought in a paradigm shift in the field and we are now in a position with the help of new technology to develop algorithms to generate photorealistic 3D graphics in real time. So, all these things are important and this will form the core subject matter of our discussion in subsequent lectures. Now, note that all these are computation intensive process and because of the advancement in technologies, such computation intensive process has become manageable, possible to implement in real time.

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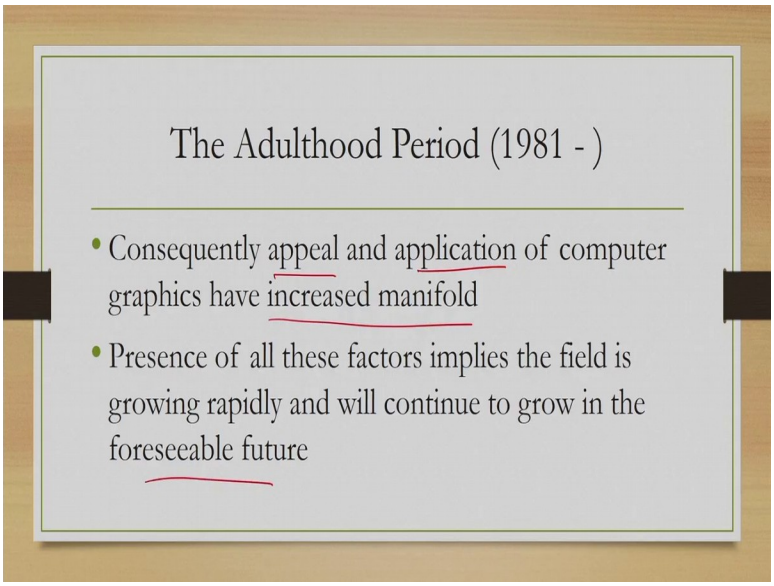

And since we are able to do those things now then the appeal and application of computer graphics have increased manifold and they presence of all these factors implies that the field is growing and will continue to grow in the foreseeable future. So, that is in brief the evolution of the field, 4 phases starting with the gestational period to the adulthood and the major developments we briefly discussed.

Now, let us shift our focus to another important aspect of the field that is what are the issues and challenges that confront workers in this field?

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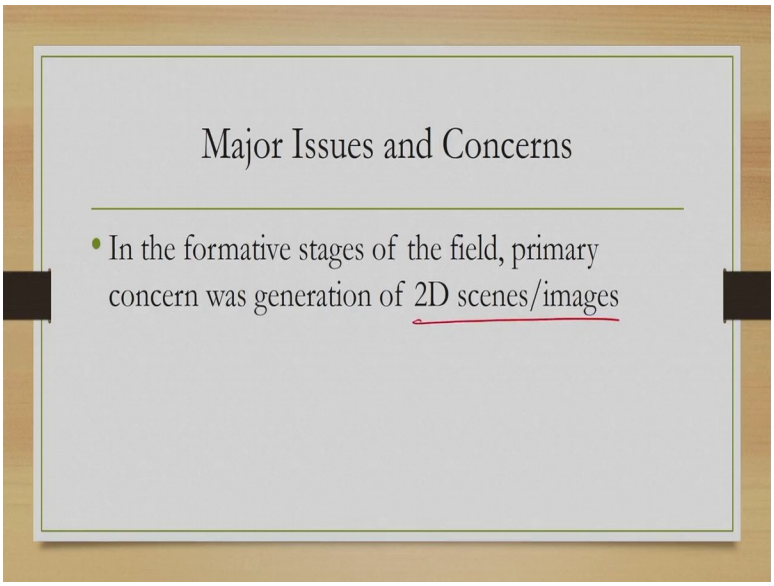

Now, in the formative stages of the field, primary concern was as we all know, generation of 2D images or 2D scenes.

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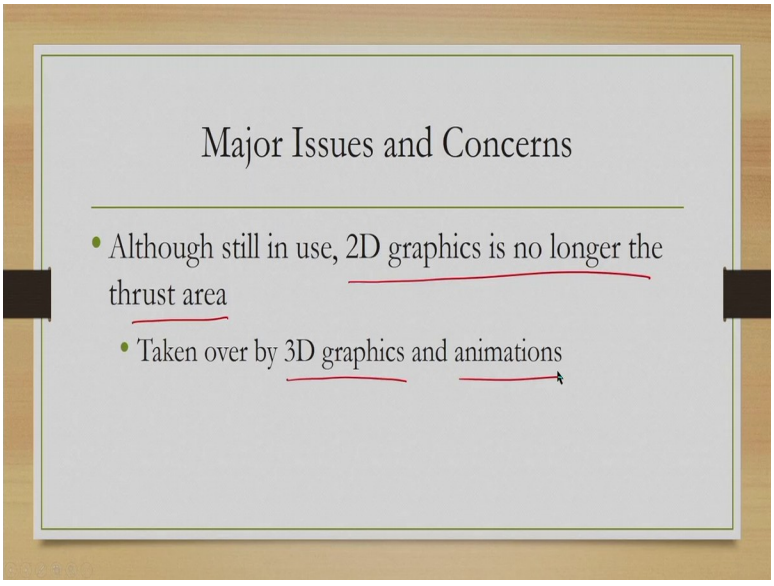

But again as we have already discussed that subsequently changed and 2D graphics is no longer the thrust area and we are mostly focused on, nowadays we are mostly focused on the generation of 3D graphics and animation.

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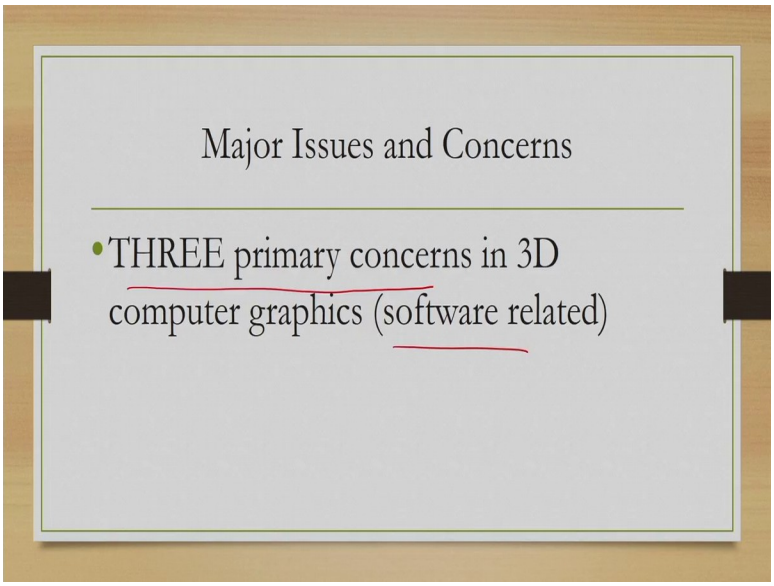

In the context of 3D graphics and animation, there are 3 primary concerns related to software, software development for the system.

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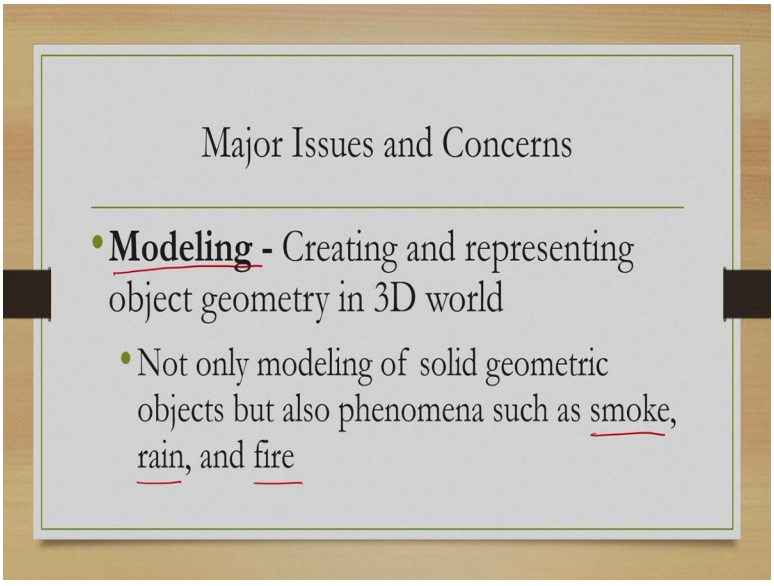

One is modeling which essentially means creating and representing object geometry in 3d world and here we have to keep in mind that we are not only talking about solid geometric objects, but also some phenomena such as bellowing of smoke, rain, fire, some

natural events phenomena so, how to model both objects as well as phenomena, that is one concern.

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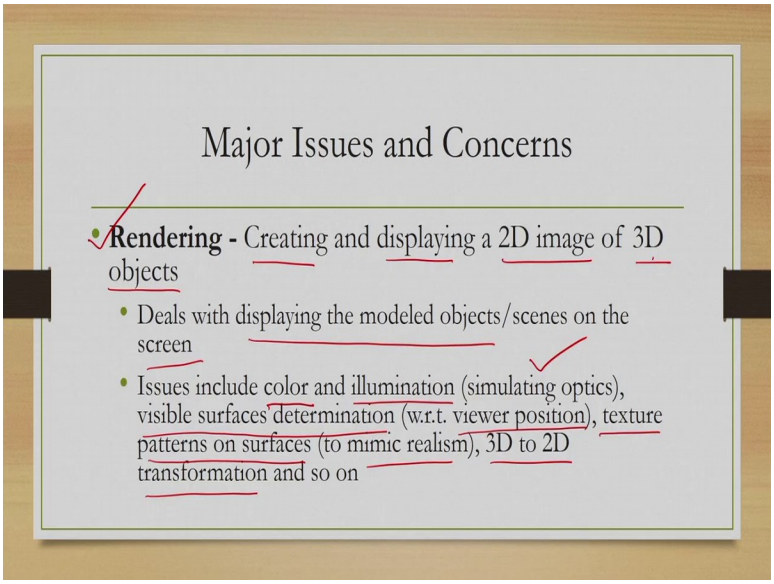

Second concern is rendering, essentially creating and displaying 2D image of the 3D objects, why 2D image? Because our screen is 2D so we have to convert the 3D objects into a 2D form. So, then this rendering deals with issues related to displaying the modeled objects on the screen and there are some other related issues involved namely color, coloring of the pixels on the screen, color and illumination which involves simulating the optical process.

Then, visible surface determinism with respect to the viewer position, textured patterns on the surfaces or texture synthesis to mimic realism, 3D to 2D transformation and so on. So, these are the issues that are there in rendering.

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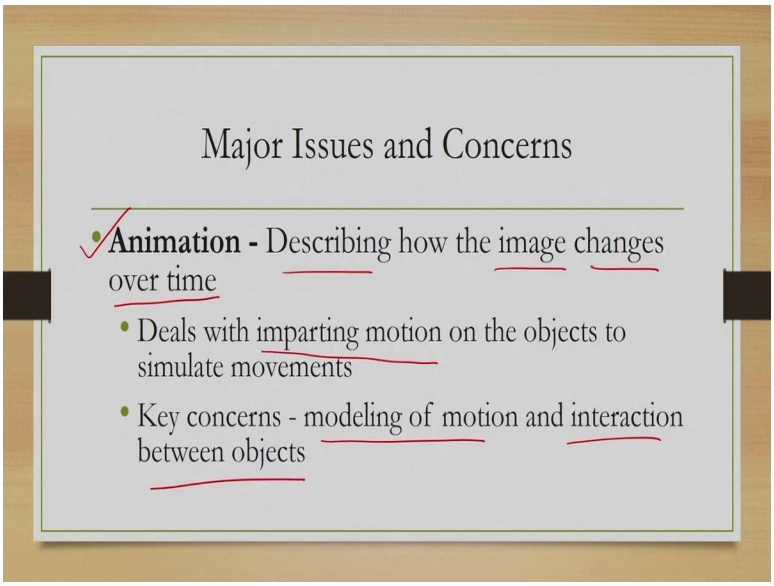

Then the third issue, third major issue related to graphic software is animation, describing how the image changes over time so, what it deals with? It deals with imparting motion on the objects to simulate movement, so, give us a perception of movement. Then the key concerns here are modeling of motion and interaction between objects during motion. So, the 3 major issues related to software are modeling of objects, rendering of objects and creating of animation. Now, there are some hardware related issues as well.

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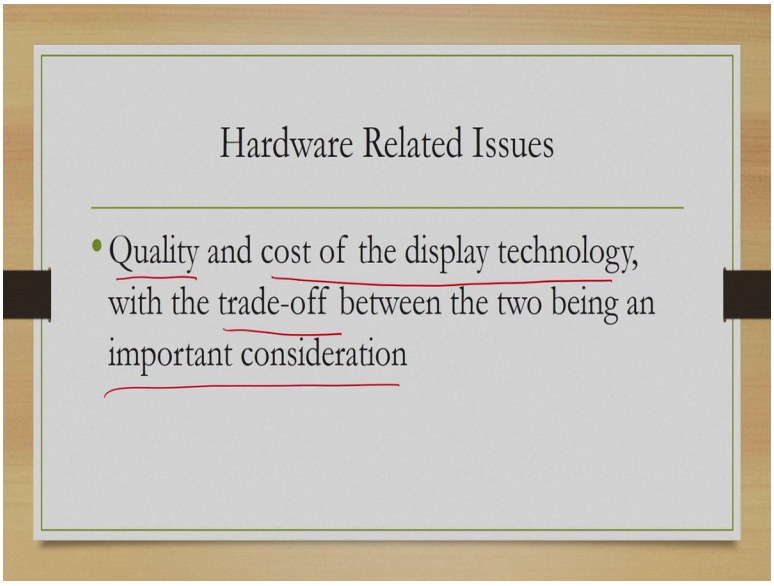

Why those are important, because quality and cost of the display technology is of important concern, because there is always a tradeoff between the two, quality of the hardware as well as the cost, so we cannot get high quality in low cost and vice versa. And while building a graphics system application, we need to keep in mind this tradeoff.

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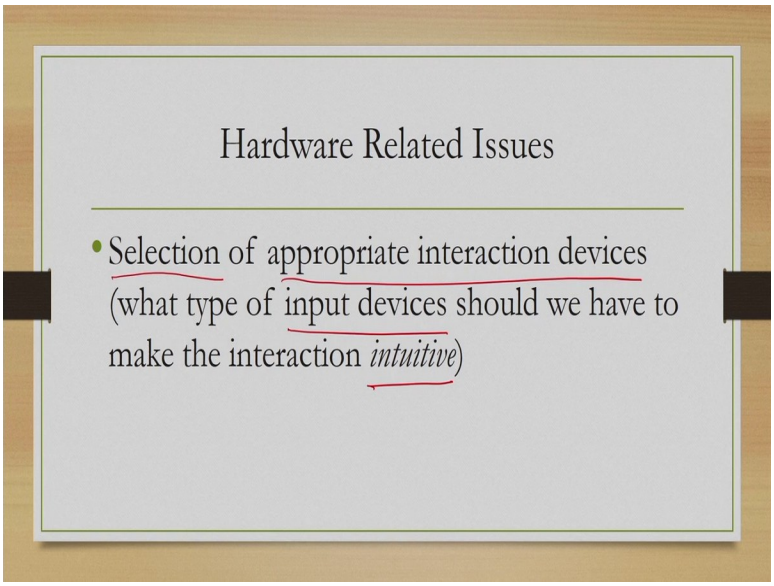

Along with that, we need to keep in mind selection of appropriate interaction device because nowadays we are talking of interactive computer graphics. So, the interaction component is important and it is important to choose an appropriate mode of interaction or input device such that the interaction appears intuitive to the user. The user should not be forced to learn complex patterns or complex operations, it should be as natural as possible.

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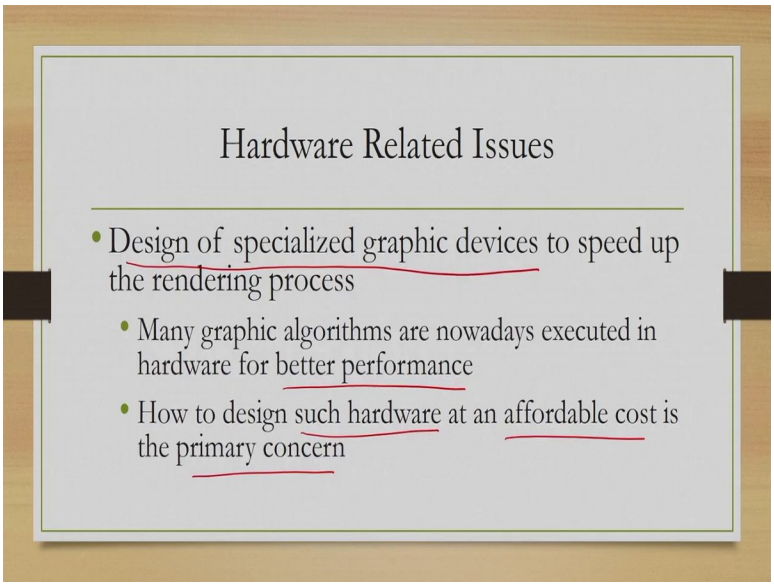

Finally, design of specialized graphic devices to speed up the rendering process is also of utmost importance. Because graphics algorithms are computation intensive and if we can have dedicated hardware to perform those computations, then we can expect better performance. Now, the issue is how to design such hardware at an affordable cost and that is of primary concern related to hardware platforms for computer graphics.

So, from the point of view hardware, we have this quality of the hardware as well as cost tradeoff to keep in mind also, we have to keep in mind the type of input device we are using as well as the dedicated graphic systems that we can afford.

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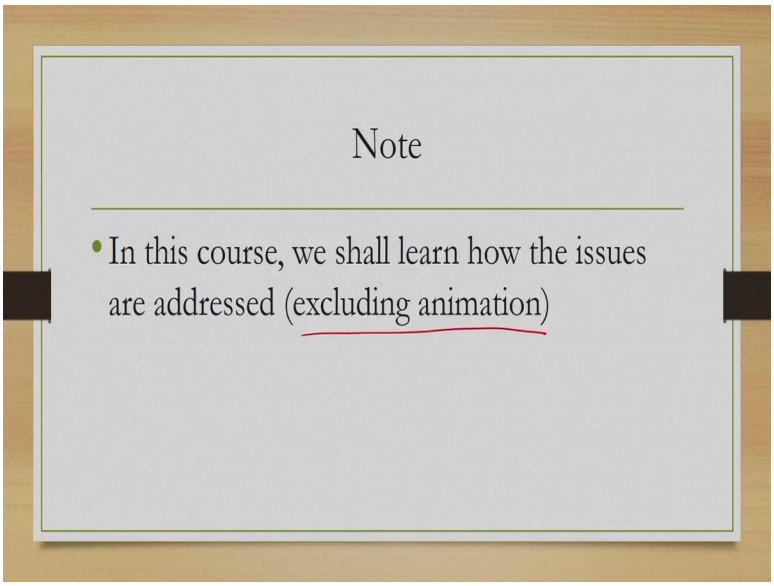

Now, one thing we should note here is that in this course, we shall learn how the issues are addressed, but we will not discuss issues related to animation, we will restrict our discussion to modeling and rendering of 2D images on the screen.

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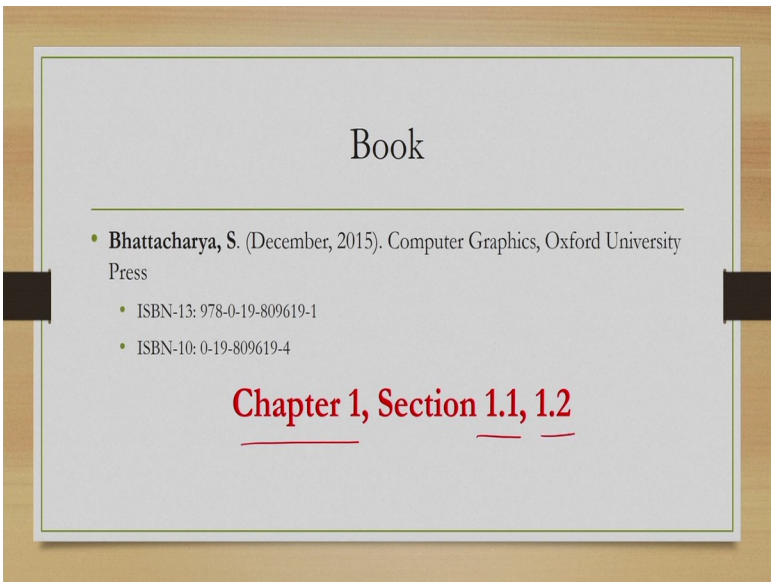

So, whatever we have discussed so far can be found in chapter 1 of the book that we are following. You are advised to go through section 1.1 and section 1.2 for getting more

details on the topics that we have covered today. So, that is all for today, we will meet again in the next lecture, thank you and good bye.