UNIT 1 COMPUTER ANIMATION

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1.0 INTRODUCTION

The word Animation is derived from 'animate' which literally means 'to give life to', 'Animating' a thing means to impart movement to something which can't move on its own.

In order to animate something, the animator should be able to specify, either directly or indirectly, how the 'thing' is to move through time and space. We have already discussed various transformations in Block 2 Unit 1 using which you can impart motion, size alteration, rotation, etc, to a given graphic object. Before dealing with complexities of animation, let us have a look at some basic concepts of Animation in section 1.2. In section 1.3, we will discuss different kinds of animations.

In our childhood, we all have seen the flip book of cricketers which came free along with some soft drink, where several pictures of the same person in different batting or bowling actions are intact sequentially on separate pages, such that when we flip the pages of the book the picture appears to be in motion, this was a flipbook (several papers of the same size with an individual drawing on each paper so the viewer could flip through them). It is a simple application of the basic principle of Physics called Persistence of Vision. This low tech animation was quite popular in the 1800s when the Persistence of vision (which is 1/16 th of a second) was discovered. This discovery led to some more interesting low tech animation devices like, the zoetrope, wheel of life, etc. Later, depending on many basic mathematics and physics principles, several researches were conducted which allowed us to generate 2D/3D animations.

1.1 OBJECTIVES

After going through this unit, you should be able to:

- describe the basic properties of animation;
- classify the animation and its types;
- discuss how to impart acceleration in animation, and
- give examples of different animation tools and applications.

1.2 BASICS OF ANIMATION

Traditional and historical methods for production of animation

In units 1 and 2 of block 2 we have studied the transformations involved in computer graphics but you might not have noticed there that all transformations are related to space and not to time. Here, lies the basic difference between Animation and graphics. The difference is that animation adds to graphics, the dimension of time, which vastly increases the amount of information to be transmitted, so some methods are used to handle this vast information and these methods are known as animation methods the *Figure 1* gives a broad description of methods of animation.

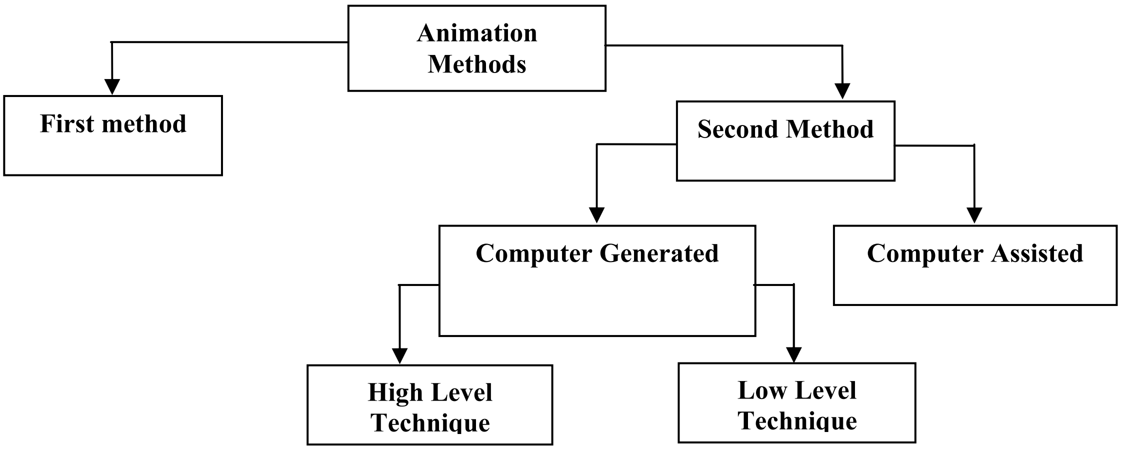

Figure 1: Methods of animation

First method: Here, artist creates a succession of cartoon frames, which are then combined into a film.

Second method: Here, the physical models are positioned to the image to be recorded. On completion the model moves to the next image for recording and this process is continued. Thus, the historical approach of animation has classified computer animation into two main categories:

a) *Computer-assisted animation* usually refers to 2D systems that computerise the traditional animation process. Here, the technique used is interpolation between key shapes which is the only algorithmic use of the computer in the production of this type of animation equation, curve morphing (key frames, interpolation, velocity control), image morphing.

b) C*omputer generated animation* is the animation presented via film or video, which is again based on the concept of persistence of vision because the eye-brain assembles a sequence of images and interprets them as a continuous movement and if the rate of change of pictures is quite fast then it induce the sensation of continuous motion.

This motion specification for computer-generated animation is further divided into 2 categories:

Low level techniques (motion specific)

Techniques used to fully control the motion of any graphic object in any animation scene, such techniques are also referred as motion specific techniques because we can specify the motion of any graphic object in scene, techniques like interpolation, approximation etc., are used in motion specification of any graphic object. *Low level* *techniques* are used when animator usually has a fairly specific idea of the exact motion that he or she wants.

High level techniques (motion generalized)

Techniques used to describe general motion behavior of any graphic object, *these techniques are* algorithms or models used to generate a motion using a set of rules or constraints. The animator sets up the rules of the model, or chooses an appropriate algorithm, and selects initial values or boundary values. The system is then set into motion and the motion of the objects is controlled by the algorithm or model, this approaches often rely on fairly sophisticated computation such as vector algebra and numerical techniques and others.

Isn't it surprising that *the Computer animation has been around as long as computer graphics* which is used to create realistic elements which are intermixed with the live action to produce animation. The traditional way of animation is building basis of the computer generated animation systems and are widely used now a days by different companies like, Disney, MGM, Warner Bros, etc, to produce realistic 3D animation using various animation tools. As various tools are available for different uses. Thus, the basic problem is to select or design animation tools which are expressive enough for the animator to specify what s/he wants to specify while at the same time are powerful or automatic enough that the animator doesn't have to specify the details that s/he is not interested in. Obviously, there is no single tool that is going to be right for every animator, for every animation, or even for every scene in a single animation. The appropriateness of a particular animation tool depends on the effect desired by the animator. An artistic piece of animation will probably require different tools for an animation intended to simulate reality. Some examples of the latest animation tools available in the market are Softimage (Microsoft), Alias/Wavefront (SGI), 3D studia MAX (Autodesk), Lightwave 3D (Newtek), Prism 3D Animation Software (Side Effects Software), HOUDINI (Side Effects Software), Apple's Toolkit for game developers, Digimation, etc.

After having some breifings about the overall topic of animation, now let us go to its details. Firstly we define/describe computer animation which is a time-based phenomenon that covers any change of appearance or any visual effect with respect to the time domain, which includes motion, i.e., positional change(translation/rotation), time-varying changes in shape, colour (palette), transparency and even changes of the rendering technique.

1.2.1 Definition

A time based phenomenon for imparting visual changes in any scene according to any time sequence, the visual changes could be incorporated through translation of object, scaling of object, or change in colour, transparency, surface texture etc.

Note: It is to be noted that computer animation can also be generated by changing camera parameters such as its position, orientation, focal length etc. plus changes in the light effects and other parameters associated with illumination and rendering can produce computer animation too.

1.2.2 Traditional Animation Techniques

Before the advent of computer animation, all animation was done by hand, which involves an enormous amount of work. You can have an idea of work by considering that each second of animation film contains 24 frames (film) then, one can imagine the amount of work in creating even the shortest of animated films. Before, creating any animation the first step is to design the concerned storyboard which is the first sight of what a cartoon or a piece of animation is going to look like. It appears as a series of strip comics, with individual drawings of story lines, scenes, characters, their emotions and other major part of movie. Now, let us discuss a couple of different techniques, which were developed for creating animation by hand.

Key Frames

After a storyboard has been laid out, the senior artists go and draw the major frames of the animation. These major frames are frames in which a lot of change takes place. They are the key points of the animation. Later, a bunch of junior artists draw in the frames in between. This way, the workload is distributed and controlled by the key frames. By doing work this way, the time in which an animation can be produced is cut dramatically, depending on the number of people working on the project. Work can be done simultaneously by many people, thus cutting down the time needed to get a final product out.

Cel Animation

By creating an animation using this method, each character is drawn on a separate piece of transparent paper. A background is also drawn on a separate piece of opaque paper. Then, when it comes to shooting the animation, the different characters are overlaid on top of the background in each frame. This method also saves time in that the artists do not have to draw in entire frames, but rather just the parts that need to change such as individual characters, even separate parts of a character's body are placed on separate pieces of transparent paper. For further understanding, let us have an example. Say you want to show that an aeroplane is flying. You can draw an aeroplane on a transparent sheet and on another opaque sheet you can have clouds. Now, with the opaque sheet as background you can move the transparent sheet over it, which gives the feeling of flying aeroplane.

These traditional techniques were extended to the era of computer animation techniques and hence different animation systems are evolved. We cannot say which technique is better because different techniques are used in different situations. In fact all these animation techniques are great, but they are most useful when all of them are used together. Cel animation by itself would not help out much if it wasn't for key frames and being able to distribute the workload across many people.

Now, let us also discuss the computer animation methods, which are in wide use, two of the typical computer animation methods are ‘frame’ animation and sprite animation.

Frame animation non- interactive animation rectangular shape (Cartoon movies)

This is an “internal” animation method, i.e., it is animation inside a rectangular frame. It is similar to cartoon movies: a sequence of frames that follow each other at a fast rate, fast enough to convey fluent motion. It is typically pre-compiled and non-interactive. The frame is typically rectangular and non-transparent. Frame animation with transparency information is also referred to as “**cel”** animation. In traditional animation, a cel is a sheet of transparent acetate on which a single object (or character) is drawn.

Sprite animation interactive, may be non rectangular (Computer games)

In its simplest form it is a 2D graphic object that moves across the display. Sprites often can have transparent areas. Sprites are not restricted to rectangular shapes. Sprite animation lends itself well to be interactive. The position of each sprite is controlled by the user or by an application program (or by both). It is called “external” animation.We refer to animated objects (sprites or movies) as “animobs”. In games and in many multimedia applications, the animations should adapt themselves to the environment, the program status or the user activity. That is, animation should be *interactive*. To make the animations more event driven, one can embed a script, a small executable program, in every animob. Every time an animob touches another animob or when an animob gets clicked, the script is activated. The script then decides how to react to the event (if at all). The script file itself is written by the animator or by a programmer.

☞ Check Your Progress 1

1) What do you mean by animation, what are different ways to produce it?

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2) What do you mean by computer generated and computer assisted animations?

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3) Differentiate between
   a) Key frame and Cel animation b) Low level and high-level animation techniques.

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4) Which animation technique is better, Keyframe or Cel animation?

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1.2.3 Sequencing of Animation Design

Till now we have discussed a lot about the traditional and current trends of computer generated animation but now it, is time to practically discuss the necessary sequencing of animation steps which works behind the scenes of any animation.

This sequencing is a standard approach for animated cartoons and can be applied to other animation applications as well. General Steps of designing the animation sequence are as follows:

1) **Layout of Storyboard:** Storyboard layout is the action outline used to define the motion sequence as a set of basic events that are to take place. It is the type of animation to be produced which decides the storyboard layout. Thus, the storyboard consists of a set of rough sketches or a list of basic ideas for the motion.

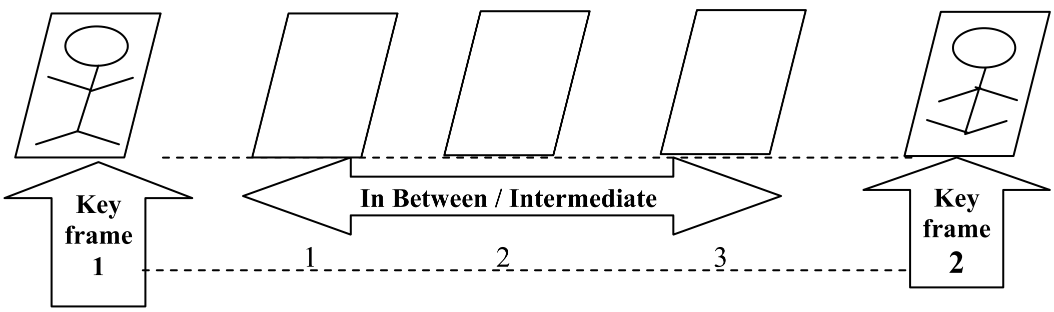
2) **Definition of Object:** The object definition is given for each participant object in action. The objects can be defined in terms of basic shapes, associated movements or movement along with shapes.

3) **Specification of Key Frame:** It is the detailed drawing of the scene at a certain time in the animation sequence. Within each key frame, each object is positioned according to time for that frame. Some key frames are chosen at the extreme positions in the action; others are spaced so that the time interval between key frames is not too great. More key frames are specified for intricate motion than for simple, slowly varying motions.

4) **In-between frames Generation:** In-between frames are the intermediate frames between the key frames. The number of in between frames is dependent on the media to be used to display the animation. In general, film requires 24 frames per second, and graphic terminals are refreshed at the rate of 30 to 60 frames per second. Typically the time interval for the motion are set up so that there are 3 to 5 in-betweens for each pair of key frames. Depending upon the speed specified for the motion, some key frames can be duplicated.

Note: There are many applications that do not follow this sequence like, real time computer animations produced by vehicle driving or flight simulators, for instance, display motion sequence in response to setting on vehicle or aircraft controls, plus the visualization applications are generated by the solution of numerical models. And for frame-by-frame animation each frame of the scene is separately generated and stored. Later the frames can be recorded on film or they can be consecutively displayed in "real time playback" mode.

In order to explain the overall process of animation mathematically consider the *Figure 2*. In order to have smooth continuity in motion of objects, a number of in-between frames are sandwiched between two key frames Now, there is a relation between different parameters, i.e., key frame, in-between frame, time, number of frames required per second which is



Formula:
Required Key frames for a film= $\dfrac{\{[\text{Time(in seconds)}]*[\text{frames required per second(in general =24)}]\}}{\{\text{no. of in between frames}\}}$

Figure 2

Example 1: How many key frames does a one-minute animation film sequence with no duplications require ?

Solution: One minute = 60 seconds
No. of frames required per second=24
No. of frames required in entire film=24*60=1440

That is we would need 1440 frames for a one-minute animation film.

Example 2: How many key frames does a one-minute animation film sequence with no duplications require if there are five in betweens for each pair of key frames ?

Solution: One minute = 60 seconds
No. of frames required per second = 24
No. of in-between frames = 5
No. of frames required in entire film=(24*60)/5=288

That is we would need 288 key frames for a one-minute animation film if the number of in-between frames is 5.

☞ Check Your Progress 2

1) How many frames does a 30-second animation film sequence with no duplication require? What will be the answer if duplication is there?

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2) How many frames does the same film as in E1 require if it has three in-between frames?

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3) Why does an animation film require 24 animation frames per second? Can this number be less than 24? If yes, then up to what extent this number can decrease and what will be the effect of animation on the reduction of this number?

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4) What are the steps to create an animation?

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1.2.4 Types of Animation Systems

We have discussed above that the sequencing of animation is useful in developing any animation. This sequencing is more or less the ‘same in all animation systems’. Before proceeding to the types of animation in the next section, let us study the types of Animation Systems.

So let us discuss a few animation systems, which are generally used:

Key Frame Systems

This technique is for low-level motion control. Actually these systems include languages which are designed simply to generate the in-betweens from the user-specified key frames.

Usually, each object in the scene is defined as a set of rigid bodies connected at the joints and with a limited number of degrees of freedom. Key frame systems were developed by classical animators such as Walt Disney. An expert animator would design (choreograph) an animation by drawing certain intermediate frames, called Key frames. Then other animators would draw the in-between frames.

The sequence of steps to produce a full animation would be as follows:

1) Develop a script or story for the animation.
2) Lay out a storyboard, that is a sequence of informal drawings that shows the form, structure, and story of the animation.
3) Record a soundtrack.
4) Produce a detailed layout of the action.
5) Correlate the layout with the soundtrack.
6) Create the "key frames" of the animation. The key frames are those where the entities to be animated are in positions such that intermediate positions can be easily inferred.
7) Fill in the intermediate frames (called “in-betweening” or “tweening”).
8) Make a trial “film” called a “pencil test”.
9) Transfer the pencil test frames to sheets of acetate film, called “cels”. These may have multiple planes, e.g., a static background with an animated foreground.
10) The cels are then assembled into a sequence and filmed.

With computers, the animator would specify the key frames and the computer would draw the in-between frames (“tweening”). Many different parameters can be interpolated but care must be taken in such interpolations if the motion is to look “real”. For example, in the rotation of a line, the angle should be interpolated rather than the 2D position of the line endpoint. The simplest type of interpolation is linear, i.e., the computer interpolates points along a straight line. A better method is to use cubic splines for interpolation (which we have studied in Block 3). Here, the animator can interactively construct the spline and then view the animation.

Note: From the above discussion, it is clear that in key frame systems the in-between frames can be generated from the specification of two or more key frames, and among them we can set the motion path of the object under consideration by describing its kinematics description as a set of spline curves. For complex scenes we can separate the frames into individual components or objects called cels (Celluloid transparencies). In these complex scenes, we can interpolate the position of individual objects between any two times. And in this interval the complex objects in the scene may suffer from various transformations like the shape or size of object may change over time, etc., or the entire object may change to some other object. These transformations in a key frame system lead to Morphing, Zooming, Partial motion, **Panning** (i.e., shifting of background/foreground to give the illusion that the camera seems to follow the moving object, so that the background/ foreground seems to be in motion), etc.

MORPHING: Transformation of object shapes from one form to another is called **morphing** (short form of metamorphism). Morphing methods can be applied to any motion or transition involving a change in shape. To understand this, consider the *Figure 3*.

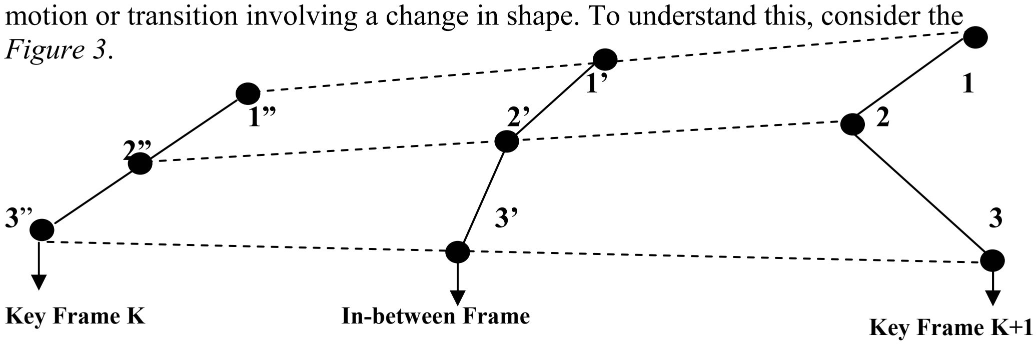

Figure 3

The *Figure 3* shows the linear interpolation for transformation of two connected line segments in key frame K on to a line segment in key frame K+1. Here, the number of vertices in both frames are the same, so simply position changes.

But if the situation is *vice versa*, i.e., say key frame K is a Line and key frame K+1 is a pair of lines, we need to have linear interpolation for transforming a line segment in key frame K into two connected line segments in key frame K+1. As transformation is from one line to two lines and since frame K+1 has extra vertex we add a vertex between 1 and 3 in frame K, to have balance between number of vertices and edges in two frames

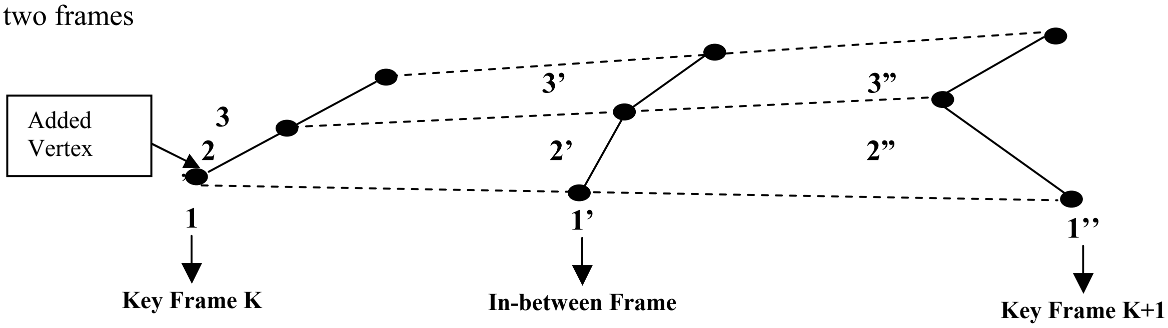

Figure 4

Scripting Systems are the earliest type of motion control systems. Scripting systems allow object specifications and animation sequence to be defined with a user input script., and from this script, a variety of various objects and motions can be constructed. So, to write the script the animator uses any of the scripting languages. Thus, the user must learn this language and the system. Some scripting systems are PAWN (An embedded scripting language formerly called Small) with syntax similar to C, ASAS (Actor Script Animation Language), which has a syntax similar to LISP. ASAS introduced the concept of an actor, i.e., a complex object which has its own animation rules. For example, in animating a bicycle, the wheels will rotate in their own coordinate system and the animator doesn't have to worry about this detail. Actors can communicate with other actors by sending messages and so can synchronize their movements. This is similar to the behavior of objects in object-oriented languages.

Parameterised Systems these are the systems that allow objects motion characteristics to be specified as part of the object definitions. The adjustable parameters control such objects characteristics as degree of freedom, motion limitations, and allowable shape changes.

☞ **Check Your Progress 3**

1) After being exposed to different concepts of computer graphics and animation through and Block 2 (which inform uses concepts of CS-60) and the introduction of this Unit, can you answer one simple question. "*when do we need to use computer graphics in computer animation ?"*

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2) What do you think which type of animation system will be suitable to generate cartoon films and which one will be suitable to generate computer games?

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3) What are animobs, in which system of animation they are used?

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4) What do we mean by Morphing and Panning? What is their significance in animation?

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1.3 TYPES OF ANIMATIONS

Procedural Animation: This type of animation is used to generate real time animation, which allows a more diverse series of actions to happen. These actions be created using some could otherwise predefined animation procedures are used to define movement over time. There might be procedures that use the laws of physics (Physical i.e., modeling based) or animator-generated methods. Some example of procedural animation is collision which is an activity that is the result of some other action (this is called a "secondary action"), for example throwing a ball which hits another object and causes the second object to move; simulating particle systems (smokes water etc.) hair and for dynamics. In computer video games it is often used for simple things like players head rotation to look around, etc.

Representational Animation: This technique allows an object to change its shape during the animation. There are three sub-categories to this. The first is the animation of articulated objects, i.e., complex objects composed of connected rigid segments. The second is soft object animation used for deforming and animating the deformation of objects, e.g., skin over a body or facial muscles. The third is morphing which is the changing of one shape into another quite different shape. This can be done in two or three dimensions.

Stochastic animation: This uses stochastic processes (A stochastic process can be considered as a random function). This randomness could be in time or space variable of function, the randomness in time leads to stochastic animation to control groups of objects, such as in particle systems. Examples are fireworks, fire, waterfalls, etc., or speech audio signal, medical data ECG, BP, etc, or Random walk.

Behavioural animation: Used to control the motion of many objects automatically. Objects or "actors" are given rules about how they react to their environment. The primary difference is in the objects being animated, instead of simply procedurally controlling the position of tiny objects. This type of animation is generally used to animate flocks, school, herds and crowds. Examples are schools of fish or flocks of birds where each individual behaves according to a set of rules defined by the animator.

So as to generate these types of animations, we need to have familiarisation with some general functions which every animation software is suppose to have. In general animation functions include a graphic editor, a key frame generator, an in-between generator, and standard graphic routines. The graphic editor allows us to design and modify object shapes using splines surfaces, Constructive Solid Geometry (CSG) methods and other representational schemes.

In the development of an animation sequence some steps are well suited for computer solutions, these include object manipulations, rendering, camera motions and the generation of in-betweens. Animation packages such as wave front provide special functions for designing the animation and processing individual objects.

Some general functions available in animation packages are:

- Object Function to store and manage the object database, where the object shapes and associated parameters are stored and updated in the database.

- Object Function for motion generation and object rendering. Motions can be generated according to specified constraints using 2D and 3D transformations. Standard functions can then be applied to identify visible surfaces and apply the rendering algorithms.

- Object function to simulate camera movements, standard motions like, zooming, panning, tilting etc. Finally the specification for the key frames, the in-between frames can be automatically generated.

1.4 SIMULATING ACCELERATIONS

In Block 2, we have seen the dominance and role of mathematics in computer graphics and here, we will undertake the involvement of mathematics to simulate motion. As the motion may be uniform with acceleration to be zero, positive or negative or non-uniform, the combination of such motions in an animation contributes to realism. To impart motion to a graphic object, curve fittings are often used for specifying the animation paths between key frames. Given the vertex positions at the key frame, we can fit the positions with linear or non-linear paths, which determines the trajectories for the in-between and to simulate accelerations, we can adjust the time spacing for the in-betweens.

Let us discuss different ways of simulating motion:
- Zero Acceleration (Constant Speed)
- Non-Zero Accelerations
    - Positive accelerations
    - Negative accelerations or Decelerations
    - Combination of accelerations

1) **Zero Acceleration (Constant Speed)**: Here, the time spacing for the in-betweens (i.e., in-between frames) is at equal interval; i.e., if, we want N in-betweens for key frames at time Ta and Tb, then, the time interval between key frames is divided into N+1 sub-intervals leading to in-between spacing of Δ T given by the expression in *Figure 5*.

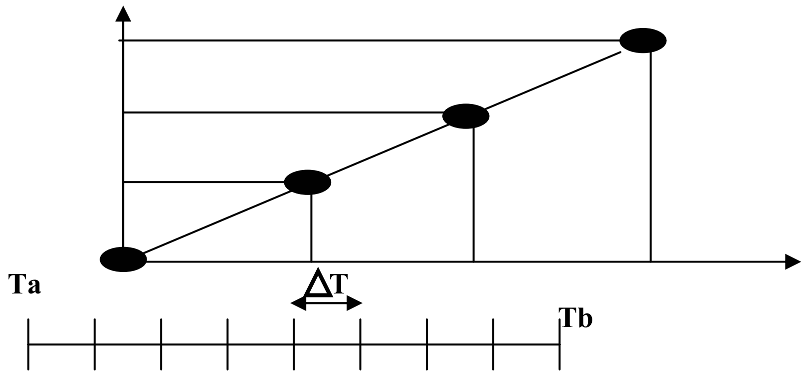

Figure 5

Thus, the time of any J th in-between can be found by

$$\boxed{Tj = Ta + J^{*}\,\Delta\,T} \qquad J = 1, 2, 3, \ldots\ldots, N$$

Note: A linear curve leads to zero acceleration animation.

2) **Non-Zero Accelerations**: This technique of simulating the motion is quite useful introducing the realistic displays of speed changes, specially at the starting and completion of motion sequence. To model the start-up and slow-down portions of an animation path, we use splines or trigonometric functions (note: trigonometric functions are more commonly used in animation packages, whereas parabolic and cubic functions are used in acceleration modeling).

- **Positive Accelerations:** In order to incorporate increasing speed in an animation the time spacing between the frames should increase, so that greater change in the position occur, as the object moves faster. In general, the trigonometric function used to have increased interval size the function is (1-Cos Θ) ,0<Θ<Π/2 .

  For n in-betweens, the time for the J th in-between would be calculated as

$$\boxed{\Delta T_J = Ta + \Delta T[1 - Cos(J\,\Pi/2(N+1))] \qquad J = 1,2,3,\ldots\ldots.., N}$$

△T=time difference between two key frames =Tb-Ta

Figure 6

Figure 6 represents a positive acceleration case because the space (i.e., time space) between frames continuously increases leading to the increase in accelerations i.e., changes in object position in two frames is fast. Let us, study the trigonometric function used to achieve positive acceleration, i.e., Y=(1-Cos Θ) ,0<Θ<Π/2

$$\text{At}\,\Theta = 0; \quad Y = (1 - \text{Cos}0) = 1 - 1 = 0$$
$$\text{At}\;\Theta = \Pi/2; \quad Y = \;(1 - \text{Cos}\,\Pi/2) = 1 - 0 = 1$$

Now look at *Figure 7* for proper understanding of concept.

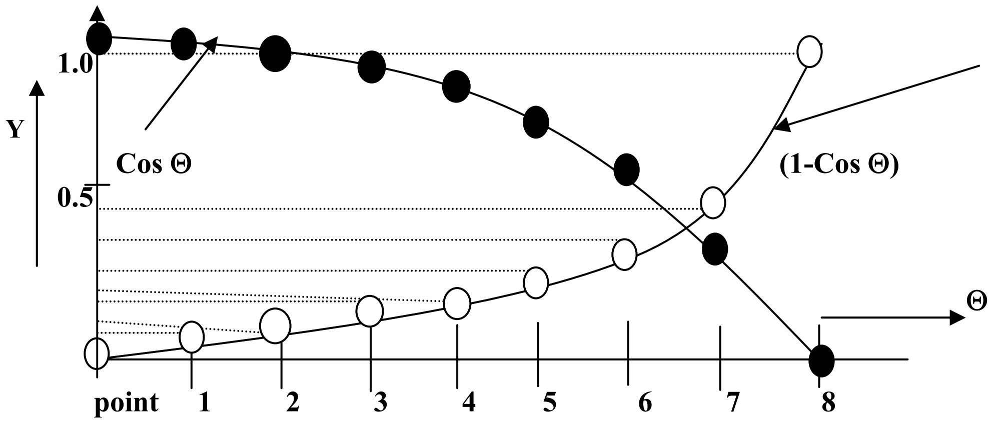

Figure 7

Note: Having projections of points on curve, over Y axis, we will receive a pattern similar to *Figure 6*, which is required to produce positive acceleration.

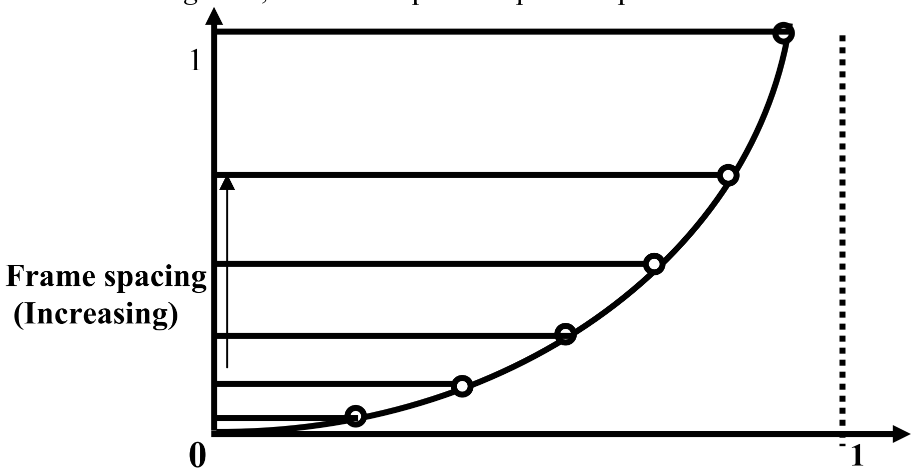

Figure 7(a)

Increases in gap along y-axis depict that spacing between key frames increases, which leads to accelerated motion.

As our aim here is to have acceleration in the motion so we create N-in between frames, between two key frames (which leads to N+1 sections) and divide Θ axis in to N fragments, for each fragment, we find Y=(1-CosΘ). Substituting different values of Θ we get different Y as shown in *Figure 7 and 7(a)*, the space between frames is continuously increasing, imparting an accelerated motion.

Length of each subinterval ($\triangle\Theta$) = (Θ_1-Θ_2)/no. of subintervals

$$= (\Pi/2 - 0)/N + 1 = \Pi/2(N+1)$$

Hence, change in ($\triangle\Theta$) produces change of 1- Cos (Π / 2(N+1))

- **Negative Accelerations:** In order to incorporate decreasing speed in an animation the time spacing between the frames should decrease, so that there exist lesser change in the position as the object moves. In general, the trigonometric function used to have increased interval size the function is Sin Θ ,0<Θ<Π/2.

  For n in-betweens, the time for the J th in between would be calculated as:

$$T_J = Ta + \Delta T[Sin(J\,\Pi/2(N+1))] \qquad J = 1,2,3,......N$$

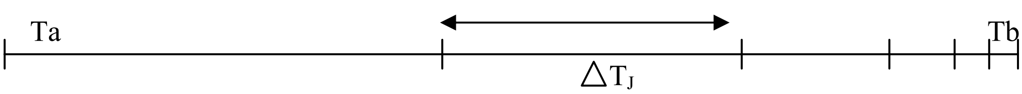

Figure 8

As in the *Figure*, the spacing between frames is decreasing so the situation changes from fast motion to slow motion, i.e., decreasing acceleration or deceleration. Let us, study the trigonometric function used to achieve this negative acceleration, i.e.,

$Y=\text{Sin}\Theta$ in the interval $0<\Theta<\Pi/2$

$\text{At}\,\Theta = 0 \quad ; \quad Y = \text{Sin}(\Theta = 0) = 0$
$\text{At}\,\Theta = \Pi/2 \quad ; \quad Y = \text{Sin}(\Theta = \Pi/2) = 1$

Now, dividing the Θ range in to N+1 parts and plotting the graph Y Vs Θ we will get a sine curve as shown below:

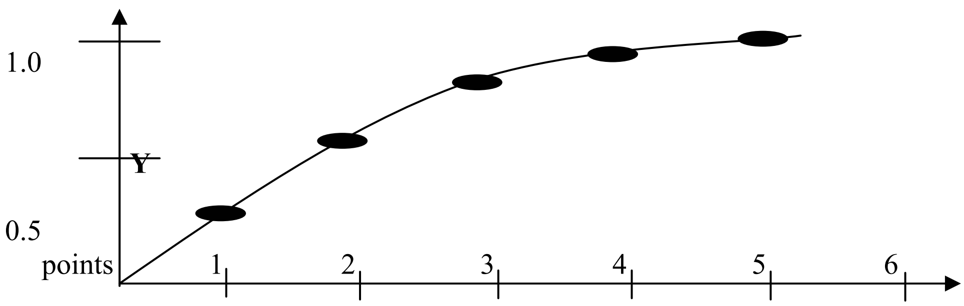

Figure 9

Note: Having projections of points on curve, over Y axis we will receive a pattern similar to *Figure 8*, which is required to produce negative acceleration.

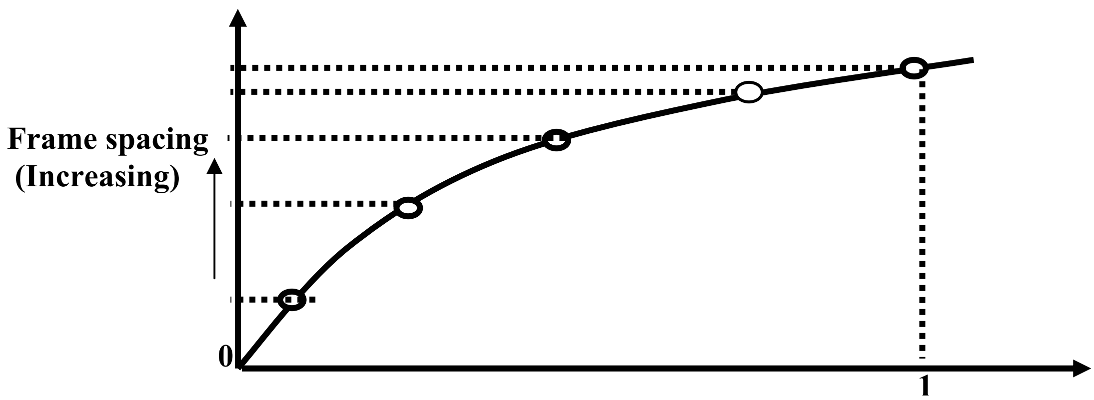

Figure 9(a)

Having projections on y-axis we find, as we, move from y = 0 to y = 1 the distance or spacing between frames continuously decreases leading to negative acceleration or slow motion.

The range $0<\Theta<\Pi/2$ is divided into N+1 parts so length of each fragment will be
$\Delta\Theta) = (\Pi/2 - 0)/N + 1 = \Pi/2(N+1)$

Each $\Delta\Theta$ change produces change of $\Delta Y = \text{Sin}(\Pi/2(N+1))$
For Jth segment $\Delta Y = \text{Sin}(J * \Pi/2(N+1))$

Therefore, out of N in between frames the time for the Jth in-between frame is
$T_J = Ta + \Delta T[\text{Sin}(J\,\Pi/2(N+1))]$

Where ΔT=Gap between two key frames=Tb-Ta

- **Combination of Positive and Negative accelerations:** In reality, it is not that a body once accelerated or decelerated will remain so, but the motion may contain both speed-ups and slow-downs. We can model a combination of accelerating – decelerating motion by first increasing the in-between spacing and then decreasing the same. The trigonometric function used to accomplish these time changes is

  $Y = (1 - \text{Cos}\Theta)/2 \quad ; \quad 0 < \Theta < \Pi/2$

  The time for the Jth in-between is calculated as

$$T_J = Ta + \Delta T\{[1 - (Cos(J\,\Pi/(N+1))]/2\} \qquad J = 1,2,3,........N$$

Δ T=time difference between two key frames =Tb-Ta

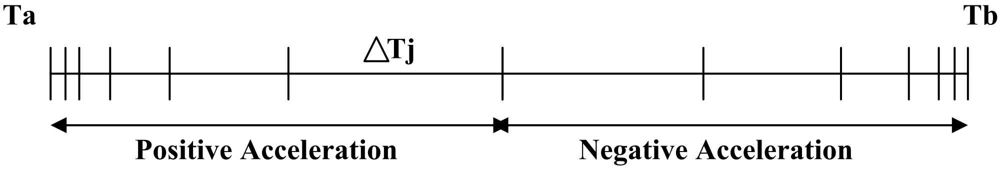

Figure 9

In the shown *Figure 9*, the time interval for the moving object first increases, then the time interval decreases, leading to the simulation of motion that first accelerates and then decelerates.

Note: Processing the in-betweens is simplified by initially modeling "skeleton" (wire frame) objects. This allows interactive adjustment of motion sequences. After the animation sequence is completely defined, the objects can be fully rendered.

☞ Check Your Progress 4

1) What type of acceleration will be simulated if:
   a) Distance between frames is constant
   b) Distance between frames continuously increases
   c) Distance between frames continuously decreases

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

2) What type of animation does a straight line function (y=mx+c) produce and why?

   ……………………………………………………………………………………

   ……………………………………………………………………………………

   ……………………………………………………………………………………

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   ……………………………………………………………………………………

3) Why the animation seems to be accelerating if the spacing between frames keeps on increasing?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

Also discuss the case when it is decelerating the spacing between frames keep on decreasing.

1.5 COMPUTER ANIMATION TOOLS

To create different types of animation discussed above, we, need to have special software and hardware too. Now, the basic constraint is about the choice of proper hardware and software out of the many available in the market.

Thus, the basic problem is to select or design animation tools, which are expressive enough for the animator to specify what s/he wants to specify which, at the same time, are powerful or automatic enough so that the animator doesn't have to specify the details that s/he is not interested in. Obviously, there is no single tool that is going to be right for every animator, or for every animation or even for every scene in a single animation. The appropriateness of a particular animation tool depends on the effect desired by the animator. An artistic piece of animation will probably require different tools (both software and hardware) to simulate reality. Along with software we need to have some special hardware to work with the concerned software.

Here is a short list of some 3D animation software:

Softimage (Microsoft)
Alias/Wavefront (SGI)
3D studia MAX (Autodesk)
Lightwave 3D (Newtek)
Prism 3D Animation Software (Side Effects Software)
HOUDINI (Side Effects Software)
Apple's Toolkit for game developers
Digimation etc.

The categories of both hardware and software required to work on animation are now to be discussed. Computer animation can be done on a variety of computers. Simple cell animation requires nothing more than a computer system capable of simple graphics with proper animation software. Unfortunately, most of the computer animation that you see on television and in other areas is done on extremely sophisticated workstations. So as to cover both hardware and software required for animation, the tools are seggregated into two sections, software and hardware.

In the hardware section, all the different computer platforms on which computer animation is done are explained. The software is explained in the software section. Only the most popular and most well known software are explained, since, a huge number of software are available in the market, so it would be practically impossible to name all computer animation programs because there are so many of them.

1.5.1 Hardware

Hardware comes in many shapes, sizes, and capabilities. Some hardware is specialised to do only certain tasks. Other kinds of hardware do a variety of things. The following are the most common hardware used in the field of computer animation.

SGI (Silicon Graphics Inc.): The SGI platform is one of the most widely used hardware platforms in professional or broadcast quality computer animation productions. Some of the salient features of SGI computers are that, of the different types available in the market. SGI computers are extremely fast, produce excellent results, and operate using the widespread UNIX operating system. SGIs are produced by Silicon Graphics, ranging from the general purpose Indy®, to the high power Indigo2 Extreme® used to produce animations, the Onyx®, which is especially suited to do complex calculations. Almost all major production studios use SGIs state of the art software like Wavefront, Alias, and SoftImage which run on SGIs.

PCs (Personal Computers really): PCs are really versatile machines, which have been around for years. PCs are the favourite of many computer users, because of their combination of flexibility and power, PC's have proven to be very useful for small companies and other businesses as platforms to do computer animation. Some applications such as 3DStudio and Animator Studio are used on PCs to make animations. PCs are relatively cheap and provide pretty good quality of animation. Recently though, PCs have been getting a lot of attention from different production houses because of their relatively small price and the quality of the finished products.

Amiga: Originally owned by Commodore, Amiga computers have held a position in the computer animation industry for a number of years. It is widely used in introduced effects and amination for movies/TV shows etc. There are two software packages that Amiga¹s are basically known for: Video Toaster and LightWave 3D. The Amiga is based on Commodore, but it has been greatly customised to be a graphics machine.

Macintosh: Macs were originally designed to be graphic and desktop publishing machines. Macs did not become that widely known until recently, when newer, faster models came out. Many people consider Macs slow and inefficient, but that is not necessarily true. Right now with the advent of the Power Macintosh, the Mac is a pretty useful tool for small-scale companies wishing to do nice looking applications. Many companies are producing computer graphics and animation software for Macintosh. Some of these are Adobe with products such as Photoshop and Premiere and Strata with Strata Studio Pro. There are also a few applications that were ported to the Macintosh from the SGIs such as Elastic Reality and Alias Sketch (a lower end version of Alias). Lately, a lot of production studios have started using Macs because of their graphical abilities for smaller scale projects.

1.5.2 Software

You might have the best hardware in the world, but without a good software package, your hardware can do nothing. There are literally hundreds of computer animations and graphics software packages out there, however, only a few are considered industry favourites. Some of the most popular software packages used by companies, schools, and individuals all around the globe are:

1) **Adobe flash:** Formerly, it was known as Macromedia flash and prior to this, it was Futuresplash. It is in fact an IDE that refers to both Adobe flash player and the multimedia authoring program which are used to create applications like, websites, games, movies, etc. It has features to support both vector and raster graphics, the scripting language used with it is k.a Action script. So, Adobe flash is an IDE (integrated development environment). Flash players is important component of Adobe flash because, it is the virtual machine which is used to run or parse the flash files (traditionally flash files are called flash movies that have software extension). Now-a-days the flash technology is used very frequently to create interactive websites, Animation, Advertisements, etc.

2) **3Dstudio:** 3DStudio is a 3D computer graphics programme. 3DStudio runs on PCs. It is relatively easy to use. Many schools and small time production studios

use 3DStudio to satisfy their needs. 3DStudio is created by AutoDesk. 3DStudio consists of a 2D modeler, in which shapes can be drawn, a 3D Lofter, in which 2D shapes can be extruded, twisted, or solidified to created 3D objects. Then, there is a 3D modelet, in which a scene is created. Finally, there is an animator in which key frames are assigned to create an animation and a material editor, in which a great variety of textures can be created. Overall, this is a great program.

3) **3DStudio Max:** The successor to 3DStudio 3.0, 3DStudio Max runs under WindowsNT. It is entirely object oriented, featuring new improvements such as, volumetric lighting, space warps, and an all new redesigned interface.

LightWave3D

LightWave 3D is another high end PC 3D computer graphics software package. Originally developed for the Amiga platform, LightWave 3D is now also available on the PC. LightWave 3D is used in quite a few television productions such as, Babylon 5 and SeaQuest.

Adobe Photoshop

Although Adobe Photoshop is not a computer animation application, it is one of the top of the line graphics programs. It is created by Adobe. Photoshop runs both on Macs and PC Windows, and even on SGIs. It can be used to touch up digitized images or to create graphics from scratch.

Adobe Premiere

Adobe Premier, just like the name says, is created by Adobe. It is a tool used to composite digitized video, stills, and apply a veriety of transitions and special effects. Adobe Premiere runs, both on Macintoshes and PCs Windows.

AliasIWavefront

Alias is one of the topmost computer animation packages out there. Alias was produced by the company that used to be Alias, but now it joined with Wavefront and is known as Alias. It runs on SGI's. Alias is well known for its great modeler which is capable of modeling some of the most complicated objects. Also, this software package is very flexible, allowing for programmers to create software that will run hand in hand with Alias.

Animator Studio

Animator Studio is a cell animation program from AutoDesk. Its predecessor was Animator Pro for PC DOS. Animator Studio runs under Windows. It has a multitude of features that minimize the animation creation time.

Elastic Reality

Elastic Reality is one of the top of the line morphing programs. Elastic Reality runs on Macs and SGIs. One of the great features of Elastic Reality as opposed to other programs is that, it uses splines as opposed to points to define the morphing area. Elastic Reality allows us to morph video as well as still images.

SoftImage

One of the most popular computer animation software packages. SoftImage is used in many top production studios around the country and around the world.

Strata Studio Pro

Strata Studio Pro is probably the most known 3D graphics application on the Mac. It is created by Strata Inc. Strata Studio Pro is mainly a still graphic rendering application, but it does have animation capabilities. Graphics for some games such as Myst were created in Strata Studio Pro.

1.6 APPLICATIONS FOR COMPUTER ANIMATION

Now-a-days, animation influences almost every aspect of life right from entertainment to education to security and many more areas. Here are some domains in which animation has, played a great role and many more applications and domains are about to come. Some applications in different domains are:

Entertainment: Games, Advertising, Film, Television, Video, Multimedia, are some of the entertainment fields in which computer animation has wide contribution, the topic is self explanatory as you all are exposed to the usage of animation in these fields from your day to day life programs on televisions, computers, etc.

Film: Computer animation has become regular and popular in special effects. Movies such as "*Jurassic Park*", "*Terminator 2: Judgment Day*", and "*The Abyss*" have brought computer animation to a new level in their films. Scale models are a fast and cost effective method of creating large alien scenes. But animation has done just as well in animating fire, smoke, humans, explosions, and heads made out of water.

A major part in integrating live film and the computer animation is to make absolutely sure that the scale and perspective of the animations are right. The scale is important to making the animation believable. The animators go through a great deal of work to make sure this is right. Usually computer animation is only used when the scene needed would be impossible or very difficult to create without it.

Television: Computer Animation plays a great role in television. Most of the titles on the television programs, news casts, and commercials, are done with computer animation. In the past, when computers were not a part of the process, animations were done with live video, cel animation, scale models, and character generators. Now, with the advent of computers, special programs could be used (i.e., computer painting, 3-D animation, motion control, and digital compositing programs).

Computer animation has simplified the making of television program titles, because of the versatility of computer generated animations, almost anything is possible. An animator can have a totally computer generated animation or have an animation with live video integrates, or even live video with animation integrated. Computer animation has advantaged the media also desires. With computer animation, professional animators can use pre-made templates to create animations for broadcasting within minutes of receiving the news.

Video: Everyone heard of animated cartoons. There is a new era of cartoons emerging on television. Computer animated cartoons can be produced much faster than cell animated ones. This is because, the animator does not have to draw every single frame, but only has to create a keyframe using, which the computer generates the in-between frames.

Sometimes computer animation looks more realistic. Sometimes, it is even possible to create computer animations that look realistic so that a person might not be able to tell, if it is real or not by simply looking at it, but this requires, enormous team effort.

Education: Now-a-days, studies of subjects like, Art, Physics, Chemistry, Maths, Biology, Medicine, Engineering, Technology, etc., are quite simple and interactive through the concept of E-Learning, where the electronic data like, educational CD's, websites, T.V. programs are contributing a lot. To make studies quite simple, animation plays an important role in fields that excessively need use animation for better understanding, are:

Physics: Say some students want to study the concept of rocket propulsion and its related aspects like, velocity, payload etc. Then, by using animation, we can easily describe the forces applicable at any instant, causing respective changes in different parameters of rocket. Without animation the teaching of concepts may not be that simplified because understanding from books doesn't include motion and understanding from video can't describe the applied forces and respective directions.

Mathematics: Probability, permutation, combination, etc., are some of the areas which can be well explained with the help of animation, which helps in enhancing the learning of the student.

***Chemistry**:* Computer animation is a very useful tool in chemistry. Many things in chemistry are too small to see, handle, or do experiments on, like, atoms and molecules for example, computer animation is the perfect tool for them. Chemistry teachers can create realistic models of molecules from the data they have and look at the way these molecules will interact with each other. They can get a full 3D picture of their experiments and look at it from different angles. Computer animation also allows them to do things that would be extremely hard to do in real life. For example, it is visible to construct models of molecules *on a computer.* People are always looking for new ways to educate their children. If, they are having fun, they learn better. Computer animation can be used to make very exciting and fun videos into which education can easily be incorporated. It is much more interesting to learn maths for example, when the letters are nice and colorful and flying around your TV screen instead of solving problems on plain black and white paper. Other subjects such as science, English, foreign languages, music, and art can also be tought by using computer animation.

***Engineering**:* CAD has always been an imperative tool in industry. For instance in automobile design, CAD could be used to model a car. But with the advent of computer animation, that model could now be changed into a full 3-D rendering. With this advantage, automobile makers could animate their moving parts and test them to make sure these parts don't interfere with anything else. This power helps car makers a lot by ensuring that the model of car will have no defects.

Art: Just like conventional animation, computer animation is also a form of art. A multitude of effects can be created on a computer than on a piece of paper. An artist can control a magnitude of things in a computer animation with a few clicks of a mouse than he can do in the conventional animation methods. A light source can be moved very easily, changing the way an entire scene looks. Textures can be changed just as easily, without redoing the whole animation. Computer graphics are not very likely to replace conventional methods anywhere in the future. There are still many things that cannot be done on the computer that an artist can do with a paintbrush and a palette. Computer graphics is simply just another form of art.

Advertising: One of the most popular uses for computer animation is in television advertising. Some of the models that the commercials would call for would be extremely difficult to animate in the past (i.e., Saxophones, boxes of detergent, bathrooms, kitchens, etc.) The modeled objects would then be animated, and incorporated with live video.

Archeology: With the advent of the computer, the archeologist has acquired a new tool, computer animation. A model of an object can be made relatively quickly and without any wear and tear to the artifact itself using a 3D digitizer. All the scenery is modeled and put together into a single scene. Now, the archeologist has a complete model of the site in the computer. Many things can be done to this model. The exact position of artifacts is stored in the computer and can be visualized without visiting the excavation site again.

Architecture: One of the reasons for the development of virtual reality (which is actually a form of computer animation) was that it was going to be very useful to architects. Now, that has proved to be true. A person can hire an architect half way across the world over the Internet or other network. The architect can design a house, and create a walkthrough animation of the house. This will show the customer what the house will actually look like before anyone lays a hand on a hammer to build it.

Computer animation can also be helpful to architects so that they can see any flaws in their designs. This has proved to be very cost and time saving because no one has to build anything. This is one field, in which computer animation has proved to be extremely useful.

Military: In order to enter the military, one has to go through a lot of training. Depending on whether you want to be in the army, navy, or the marines, you might be working with equipment worth hundreds of thousands or even millions of dollars. The military wants to be sure you know, how to use this equipment before they actually let you use it. Training in simulators instead of on the battleground is proving to be a much cheaper and safer approach. Let us take the air force, for example, one has to learn how to fly a fighter jet.

Using computer animations in flight simulation is a very useful tool. Using animation a programmer can replicate real time flying. By creating a camera showing the view through the cockpit window, a pilot could fly through either virtual worlds or real animated places with all the natural disasters, and difficulties that could happen, if flying a real plane.

In this virtual world, the pilot would witness the usual distractions that a real pilot would, for instance, transport buses drive along the runway, and other planes take off and land. The programmer can put any type of weather condition or scenario into the animation.

Forensics: Accidents happen every minute. Very often, there are no witnesses except for the individuals involved in the accident or, worse yet, there are no surviving witnesses. Accident reconstruction is a field in which computer animation has been very useful. People arguing for it say that it offers, the ability for the court to witness the accident from more than just a bystander’s perspective. Once, the reconstruction has been done, the camera can be placed anyway in a scene. The accident may be seen from either driver's perpective, or even birds eye view.

New animation systems allow detectives to recreate terrains and surroundings and actually calculate different things such as angles of bullet shots or levels of visisbility. This is extremely useful since very often, the site of an accident may have changed a lot since the time of the mishap.

Computer animation can also be used to simulate the landscape in which an operation will be going on. A satellite altitude picture can be converted into a 3D model using software and then animated with trees and under different weather.

Medicine: It is very hard for a doctor to get inside a living human body and to see what is happening. Computer animation once again comes in very useful. Every single organ in the body has already been modeled in a computer. A doctor, for example, can fly through these models and explore the area of the body s/he is going to be operating on in order to get a better picture of the operation and possibly increase the success rate.

Another very important use of computer animation in medicine is to look at living tissue or organ of a patient and to explore it, and to see what if anything is wrong with it, without even making a single incision. Data can be gathered from a living specimen painlessly by means of various sensing equipment. For example, an MRI (Magnetic Resonance Imaging) scan takes pictures of across-sections of a part of a body (brain for example) every half a centimeter. Then, the data is transmitted to a computer, where a model is constructed and animated. A doctor can get a very clear picture of undisturbed tissue the way it looks in a body. This is very helpful in detecting abnormalities in very fragile parts of the body such as the brain.

With recent advances in the computer industry, people have developed faster and better computer hardware. Systems are underway which allow doctors to conduct operations with only a couple of small incisions through which instruments can be inserted. The use of virtual reality has allowed doctors to train on virtual patients using this procedure without once opening up a cadaver.

***Multimedia**:* Multimedia is the use of various media to present a certain subject. This presentation itself is a multimedia presentation in the sense, it brings together graphics and text. Multimedia presentations can include text, graphics, sounds, movies, animations, charts, and graphs. Using computer animation in multimedia presentations is growing extremely popular since, they make a presentation look more professional and more pleasing to the eye. Computer animation is also very useful in demonstrating how different processes work.

***Simulation**:* There are many things, places, and events people cannot witness in first person. There are many reasons for this. Some may happen too quickly, some may be too small, others may be too far away. Although people cannot see these things, data about them may be gathered using various types of sensing equipment. From this data models and simulations are made. Using computer animation for these simulations has proven very effective. If, enough data has been gathered and compiled correctly, a computer animation may yield much more information than, a physical model. One reason for this is that a computer animation can be easily modified and simply rendered (Rendering is the process a computer uses to create an image from a data file. Most 3D graphics programs are not capable of drawing the whole scene on the run with all the colours, textures, lights, and shading. Instead, the user handles a mesh which is a rough representation of an object. When the user is satisfied with the mesh, s/he then renders the image) to show changes. It is, not that easy however, to do this with a physical model. Another reason for using computer animation to simulate events as opposed to models is that variables can be programmed into a computer and then, very easily changed with a stroke of a button.

Space Exploration: As of now, the farthest point away from earth that the human was on is the moon, but we continually want to learn more. A trip by a human to another planet would take way too long. This is why we, have sent satellites, telescopes, and other spacecraft into space. All of these spacecraft continually send data back to earth. Now, all we have to worry about is presenting that data so it makes sense. This is where computer animation comes in. It can show an incredible amount of data visually, in the way that humans perceive it the best.

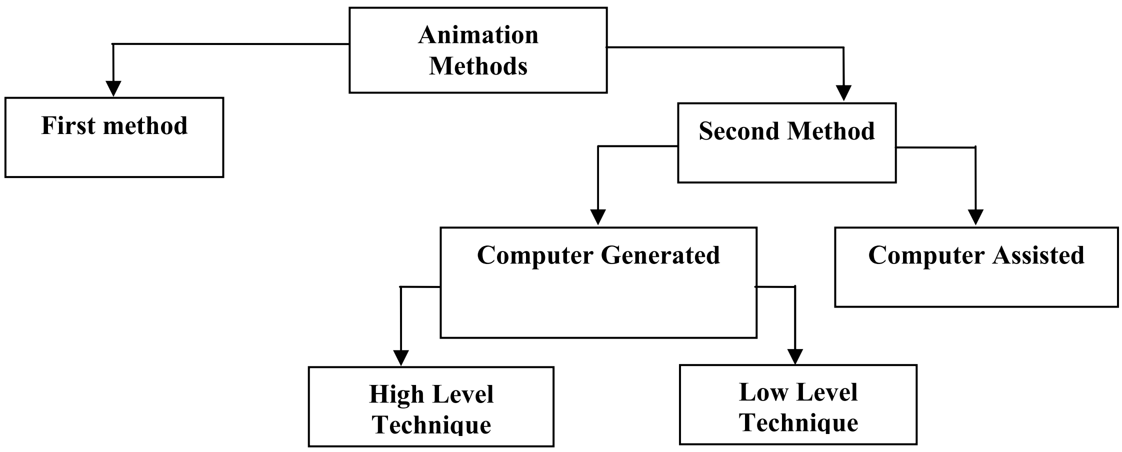
Much of the data sent from spacecraft can be input into a computer which will in turn generate an awesome looking animation so that one may actually navigate, explore, and see the distant worlds as if, we, were actually there.

Computer animation can also be used to **design** satellites and other spacecraft more effitiently. Another possible use of computer animation is to plan the routes of future ships to make sure there is nothing wrong with the path and so that a ship can gather the most data possible.

Note: The usage of computer animation is not restricted to only these fields, it is a creative process and has enormous applications in a wide range of fields.

1.7 SUMMARY

- **Traditional and historical methods for production of animation**



- **Definition:** Computer animation is a time based phenomenon of imparting visual changes in a scene according to any time sequence , the visual changes could be incorporated through positional changes , in object size , color , transparency , or surface texture etc.

- **Traditional Animation techniques :**
  1) Key Frames **2) Cel Animation**

Formula:
Required Key frames for a film
$$= \frac{\{[\text{Time(in seconds)}]*[\text{frames required per second(in gen.eral =24)}]\}}{\{\text{no. of in between frames}\}}$$

- **Types of Animation Systems : Keyframe, scripting, parameterized**

- **Morphing:** Transformation of object shapes from one form to another is called **morphing** (short form of metamorphism)-morphing methods can be applied to any motion or transition involving a change in shape.

- **Panning:** (i.e., shifting of background/foreground to give the illusion that the camera seems to follow the moving object, so that the background/ foreground seems to be in motion), etc.

- **Types of Animation :**

  Procedural Animation **Representational Animation**
  Stochastic Animation **Behavioural Animation**

- **Different ways of simulating motion:-**
  Zero Acceleration (Constant Speed) **Non-Zero Accelerations**
  Positive accelerations **Negative accelerations**

Combination of accelerations

- **Animation Tools:**

  Hardware tools: PCs ,Macintosh, Amiga
  Software tools

  Softimage (Microsoft) ; Alias/ Wavefront (SGI)
  3D studia MAX (Autodesk) ; Lightwave 3D (Newtek)
  Prism 3D Animation Software (Side Effects Software)
  HOUDINI (Side Effects Software)
  Apple's Toolkit for game developers ; Digimation etc.

- **Application of animation:** There are a variety of uses for computer animation. They can range from fun to practical and educational ones. Military, medicine, education, entertainment, etc., are some domains in which animation has played a great role and many more applications and domains are about to be opened up.

1.8 SOLUTIONS/ANSWERS

Check Your Progress 1

1) *Computer animation is a time based phenomenon of imparting visual changes to a scene according to any time sequence. The visual changes could be incorporated through positional changes, in object size, colour, transparency , or surface texture, etc.*

   Production of animation is done by two methods:

   First method is by artists creating a succession of cartoon frames, which are then combined into a film.

   Second method is by using physical models which are positioned to the image, where the image is recorded; then the model is moved to the next image for its recording, and this process is continued.

2) Two main categories of computer animation:

   a) *Computer-assisted animation which* usually refers to two dimensional systems that computerize the traditional animation process. Interpolation between key shapes is typically the only algorithmic use of the computer in the production of this type of animation.

   b) *computer generated animation*. is the animation presented via film or video. This is possible because the eye-brain assembles a sequence of images and interprets them as a continuous movement. Persistence of motion is created by presenting a sequence of still images at a fast enough rate to induce the sensation of continuous motion. Motion specification for computer-generated animation is divided into two categories: *Low level techniques* (techniques that aid the animator in precisely specifying motion) and *High level techniques* (techniques used to describe general motion behaviour).

3)

Low level techniques	High level techniques
Low level techniques provide aid to the animator in precisely specifying the motion. It involves techniques such as shape interpolation, algorithms which help the animator fill in the details of the motion. Here the animator usually has a fairly specific idea of the exact motion that he or she wants.	High level techniques used to describe general motion behavior. These techniques are algorithms or models used to generate a motion using a set of rules or constraints. The animator sets up the rules of the model, or chooses an appropriate algorithm, and selects initial values or boundary values. The system is then set into motion and the motion of the objects is controlled by the algorithm or model. This approach often relies on fairly sophisticated computation such as vector algebra and numerical techniques and others.
Cel Animation	**Key Frames**
When creating an animation using this method, each character is drawn on a separate piece of transparent paper. A background is also drawn on a separate piece of opaque paper. Then, when it comes to shooting the animation, the different characters are overlaid on top of the background in each frame. This method also saves time in that the artists do not have to draw in entire frames, but rather just the parts that need to change such as individual characters. Even separate parts of a character's body are placed on separate pieces of transparent paper	After a storyboard has been laid out, the senior artists go and draw the major frames of the animation. These major frames are frames in which a lot of change takes place. They are the key points of the animation. Later, a bunch of junior artists draw in the frames in between. This way, the workload is distributed and controlled by the key frames. By doing work this way, the time in which an animation can be produced is cut dramatically, depending on the number of people working on the project. Work can be done simultaneously by many people, thus cutting down on the time needed to get the final product out.

4) We cannot say which technique is better because different techniques are used in different situations. In fact, all these animation techniques are great, but they are most useful when they are all used together. Cel animation by itself would not help out much if it wasn’t for key frames and being able to distribute the workload across many people.

Check Your Progress 2

1) Film duration= 30 seconds
   No. of frames required per second=24
   No. of frames required in entire film=24 * 30=720
   That is, we would need 720 frames for 30-second animation film;
   If the duplication of frames is allowed then the number of frames will be halved

2) Film duration = 30 seconds
   No. of frames required per second = 24
   No. of in-between frames = 3
   No. of frames required in entire film=(24 * 30)/3=240
   That is, we would need 240 frames for a half-minute animation film if number of in- between frames is 3.

3) Animation is an application based on the principle of persistence of vision that is $(1/16)^{th}$ of a second , so if we have approximately 24 frames change per second then our eye will not be able to identify the discontinuities in the animation scene .

If the number of frames decreases to less than 24 frames per second then possibility of detecting the discontinuities in the scene increases and our animation will not be effective

4) The sequence of steps to produce a full animation would be as follows:
   a) Develop a script or story for the animation.
   b) Lay out a storyboard, that is a sequence of informal drawings that shows the form, structure, and story of the animation.
   c) Record a soundtrack.
   d) Produce a detailed layout of the action.
   e) Correlate the layout with the soundtrack.
   f) Create the "key frames" of the animation. The key frames are those where the entities to be animated are in positions such that intermediate positions can be easily inferred.
   g) Fill in the intermediate frames (called "in-betweening" or "tweening").
   h) Make a trial "film" called a "pencil test".
   i) Transfer the pencil test frames to sheets of acetate film, called "cels". These may have multiple planes, e.g., a static background with an animated foreground.
   j) The cels are then assembled into a sequence and filmed

Check Your Progress 3

1) Whenever we require to have some realistic display in many applications of computer animation like, accurate representation of the shapes of sea waves, thunderstorm or other natural phenomenon, which can be described with some numerical model, the accurate representation of the realistic display of scene measures the reliability of the model. Computer Graphics are used to create realistic elements which are intermixed with live action to produce animation. But in many fields realism is not the goal, like physical quantities are often displayed with pseudo colours or abstract shapes that change over time.

2) Frame animations is an "internal" animation method, i.e., it is an animation inside a rectangular frame where a sequence of frames follow each other at a fast rate, fast enough to convey fluent motion. And it is best suited for cartoon movies. Sprite animation is an interactive – external animation where the animated object interaction script is written by the programmer, every time an animob touches another animob or when an animob gets clicked, the script is activated and decides what is to be done. These features are usefull in the gaming systems.

3) Animated objects (sprites or movies) are refered as "animobs", which are used in the gaming applications designed using sprite animation. That is these are programmable animated objects , which can respond to the interactive environment according to the scripts written by the programmers.

4) Morphing is short form of metamorphism which means transformation of object shapes from one form to another. Morphing methods can be applied to any motion or transition involving a change in shape. Panning means shifting of background/foreground to give the illusion of camera in motion following a moving object, so that the background/ foreground seems to be in motion. Both techniques are widely used in animation application.

Check Your Progress 4

1) a) If the distance between frames is constant then the motion will neither be accelerated nor decelerated. In fact the uniform motion will be simulated in the animation.

b) If the Distance between frames continuously increases, then accelerated motion will be simulated in the animation.
c) If the distance between frames continuously decreases, then decelerated motion will be simulated in the animation.

2) Uniform motion will be simulated by the straight line. As straight line leads to a constant distance between frames, the motion will neither be accelerated nor decelerated. In fact the uniform motion will be simulated in the animation.

3) By definition computer animation is a time-based phenomenon of imparting visual changes in a scene according to any time sequence. The visual changes could be incorporated through positional changes, in object size, color, transparency, or surface texture, etc. So, if the spacing between frames is more, then it means that less frames appear in the same duration (in-between frames are less). Thus there are fast positional changes in the images drawn on the frames, imparting to fast motion simulation in the animation. For the same reason, the decreasing spacing between frames contributes to simulate deceleration.