Unit 6
Computer Animation

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Unit 6 - Computer Animation

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DEFINITION

Computer Animation may be defined as a technique in which the illusion of a movement is created by displaying on a screen or recording on a device, individual states of a dynamic scene.

The main goal of computer animation is to synthesize the desired motion effect which is a mixing of natural phenomena, perception and imagination.

The animator designs the object's dynamic behavior with his mental representation of causality.

DEFINITION

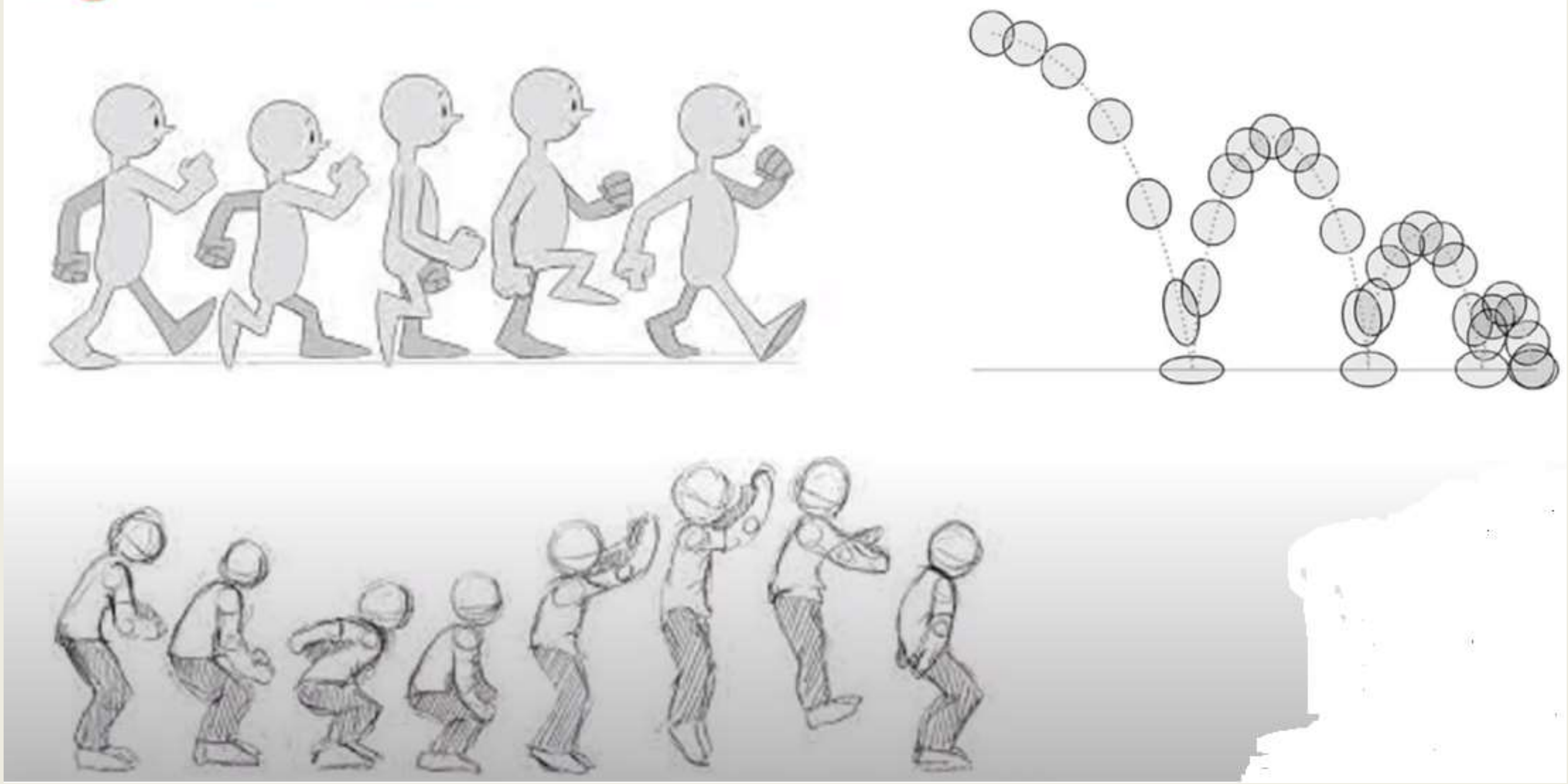
Animation means giving life to any object in computer graphics

The basic idea behind animation is to play back the recorded images at the rates fast enough to fool the human eye into interpreting them as continuous motion

Animation can be used in many areas like entertainment, computer aided-design, scientific visualization, training, education, e-commerce, and computer art.

DEFINITION

E.g. of Animation



Introduction

- Generate a sequence of images that, when played one after the other, make things move
  - One image is called ***a frame***
    - 24 frames per second for film, resolution approx 1600x1200
    - 30 frames per second for NTSC video, resolution less than 640x480
    - 60+ frames per second for "twitch" computer games, 640x480 or higher resolution
  - Interlacing: Display every second row for one frame, every other row for the next. Used in NTSC TV and older monitors

- Video

Introduction

- When evaluating an animation technique or application, the following things should be considered:
  - How fast can the images be generated?
  - How easy is it to control the appearance of the animation?
  - How much human expertise is required to generate the animation?
  - Can the animation be generated interactively?

Introduction

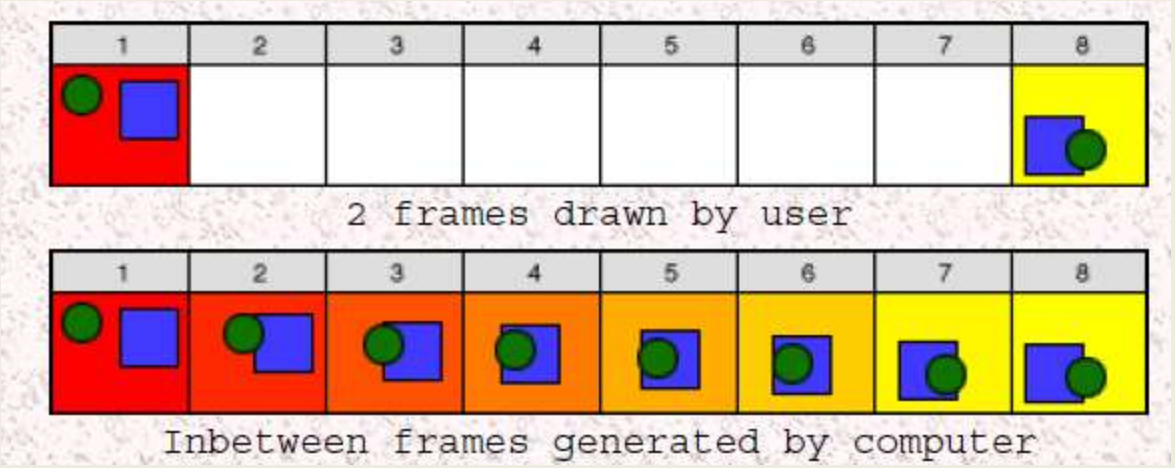
- **TYPES OF ANIMATIONS**
- **Frame by Frame (Key frame) Animation**
    - Each frame of the scene is separately generated and stored.
    - Later, the frames can be recorded on the film or they can be consecutively displayed in "real time play-back mode."
    - E.g.: Cartoon Film.
- **Real Time Animation**
    - The scene on the screen must change in real time based on the instruction provided by the player or user.
    - E.g.: Video Games.

Key frame animation

- Consists of automatic generation of the intermediate frames based on a set of key frames, supplied by an animator.
- **In-betweens** are obtained by shape interpolation.
- When someone creates a 3D animation on a computer, they usually don't specify the exact position of any given object on every single frame. They create **keyframes.**
- Keyframes are important frames during which an object changes its size, direction, shape or other properties

Key frame animation

- The computer then figures out all the in between frames and saves an extreme amount of time for the animator.
- Two frames are drawn by user In between frames generated by computer.

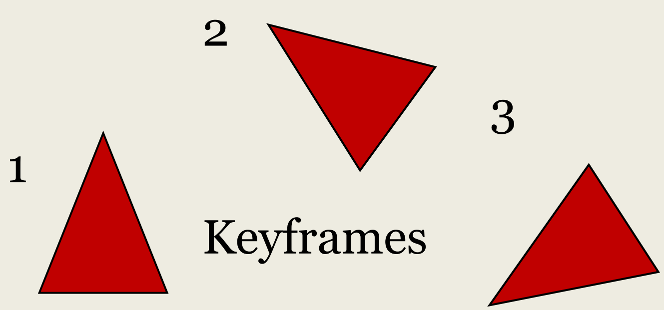


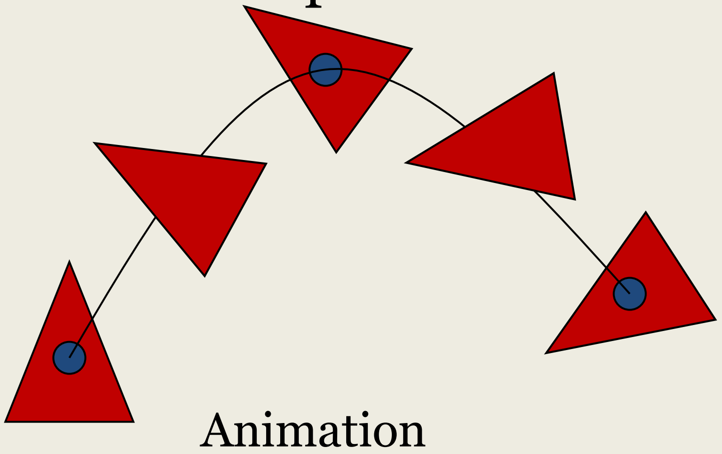
Key frame animation

- When two drawings do not have same number of vertices the motion can be distorted due to interpolation.
- Requires preprocessing to equalize the number of vertices of true drawings
- **Parametric key frame/key transformation animation:**
  - Interpolate parameters of the model instead of object itself
- In both key frame methods, a linear interpolation produces undesirable effects such as lack of smoothness, discontinuity in speed and distortion in rotations.

Key frame animation

- **Spline interpolation** methods are used.
- Splines are mathematically described as piecewise approximation of a cubic polynomial function
- Interpolating splines are smooth curves that interpolate their control points
- Perfect for keyframe animation
- Typically, time is directly associated with the parameter value and controlling speed.





Construction of an animation sequence

- An animation sequence is designed with the following steps:
  - Storyline layout
  - Object definitions
  - Key frame specifications
  - Twining(Generation of in between frames)

Construction of an animation sequence

- **Storyline layout:**
  - It is the outline of the action.
  - It defines the motion sequence as a set of basic events that are to take place .
  - Depending on the type of animation to be produced, the storyline could consist of a set of rough sketches or it could be a list of the basis ideas for the motion

Construction of an animation sequence

- **Storyline layout:**

Construction of an animation sequence

- **Object Definition:**
  - Each object participating in the action is given object definition
  - Objects can be defined in terms of basic shapes such as polygons, circles, arc, spheres etc.
  - In addition, the associated movements of each object are specified along with the shape.

Construction of an animation sequence

- **Keyframe specification:**
- Frame:
  - It is one of the many single photographic images in a motion picture. The individual frames are separated by frame lines.
  - Normally, 24 frames are needed for one second of film.

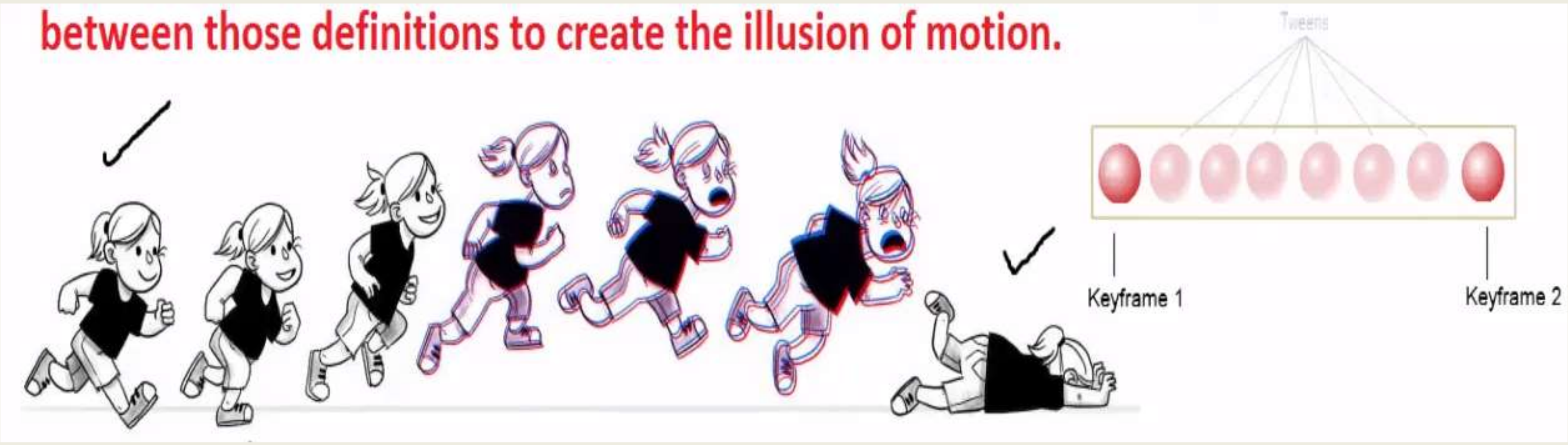
Construction of an animation sequence

- Key frame:
  - A key frame is a detailed drawing of a scene at a certain time in the animation sequence.
  - Within each key frame, each object is positioned according to time for that frame.
  - A key frame in animation and filmmaking is a drawing that defines the starting and ending points of any smooth transition.
  - A sequence of key frames defines which movement the spectator will see, but the position of the key frames on the film, defines the timing of the movement.
  - Because only 2 or 3 key frames can be present for a span of a second, the remaining frames are filled in with in-betweens

Construction of an animation sequence

- **Twinning(generating In-between):**
  - It is a process of generating intermediate frames between 2 images to give appearance that the 1st image evolves smoothly into the second image.
  - In – betweens are the drawing between the key frames which help to create the illusion of motion.
  - The number of in-between frames needed is determined by the media to be used to display the animation.
  - Film requires 24 frames per second and graphics terminals are refreshed at a rate of 30 to 60 frames per second. create the illusion of motion
  - Typically, time intervals for motion are set up so that there are from 3 to 5 in between frames for each pair of key frames.

Construction of an animation sequence



Twinning(generating In-between)

Motion Control Methods(MCMs)

- Computer animation may be defined as a technique in which the illusion of movement is created by displaying on a screen, or recording on a device a series of individual states of a dynamic scene.
- The key issue of Computer Animation is the way of defining motion, what is commonly known as Motion Control Methods (MCMs).
- MCMs may be classified based on the nature of the information, which is directly manipulated: geometric, physical, or behavioral
  - Methods based on Geometric and Kinematics information
  - Methods based on Physical information
  - Methods based on Behavioral information

Motion Control Methods(MCMs)

- **Methods based on Geometric and Kinematics information:**
  - Motion is locally controlled and defined in terms of coordinates, angles, velocities, or accelerations.
  - The simplest approach is **Performance Animation** which consists of magnetic or optical measurement and recording of direct actions of a real person for immediate or delayed playback.
  - The technique is especially used today in production environments for 3D character animation.
  - 3D Character Animation

Motion Control Methods(MCMs)

- **Methods based on Geometric and Kinematics information:**
  - **Key frame animation** is still another popular technique in which the animator explicitly specifies the kinematics by supplying keyframes values whose "in-between" frames are interpolated by the computer.
  - **Inverse kinematics** is a technique coming from **robotics, where the motion of links of a chain is** computed from the end link trajectory.
  - **Image Morphing is a warping-based technique** which interpolates the features between two images to obtain a natural in-between image.
  - https://youtu.be/o_l3NiAtoKo

Motion Control Methods(MCMs)

- **Methods based on Physical information (**dynamic-based**):**
  - In these methods, the animator provides physical data (*forces and torques)* and the motion is obtained by solving the dynamic equations.
  - **Motion is globally controlled.**
  - Two methods: **parameter adjustment and constraint-based methods**
  - **constraint-based methods:** where the animator states in terms of constraints the properties the model is supposed to have, without needing to adjust parameters.
  - For example, **Spacetime Constraints, for creating** character animation
  - Spacetime constraints are a new method for creating character animation. The animator specifies *what* the character has to do, for instance, "jump from here to there, clearing a hurdle in between;" *how* the motion should be performed, for instance "don't waste energy,"

Motion Control Methods(MCMs)

- **Methods based on Physical information (**dynamic-based)**:**
  - The forward dynamics problem consists of finding the trajectories of some point with regard to the forces and torques that cause the motion.
  - The inverse-dynamics problem determine the forces and torques required to produce a prescribed motion in a system.

Motion Control Methods(MCMs)

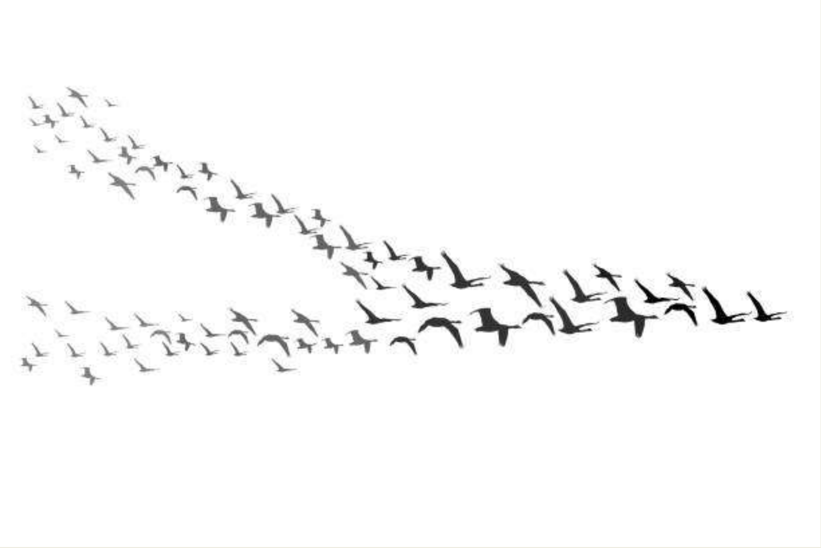
- **Methods based on Physical information (**dynamic-based)**:**
  - For realistic simulation there are a number of equivalent formulations which use various motion equations Lagrange equation
  - The Lagrangian L is defined as L = T – V, where T is the kinetic energy and V the potential energy of the system.
  - In physics-based animation, collision detection and response are also important
  - https://youtu.be/yQ2YZQhvc2c

Motion Control Methods(MCMs)

- **Methods based on Behavioral information** (Task-level Animation) **:**
  - Takes into account the relationship between each object and the other objects.
  - A behavioral motion control method consists of driving the behavior of autonomous creatures by providing high-level directives indicating a specific behavior without any other stimulus.
  - Task-level commands are transformed into low-level instructions such as a script for algorithmic animation or key values in a parametric keyframe approach. Typical examples of tasks for synthetic actors are**:**
    - walking from an arbitrary point A to another point B
    - pick up an object at location A and move it to location B
    - a distributed behavioral model to simulate flocks of birds and schools of fish a world inhabited by autonomous artificial fishes
    - A system based on a network of sensors and effectors.

Motion Control Methods(MCMs)

- **Methods based on Behavioral information** (Task-level Animation) **:**



flocks of birds

schools of fish

Motion Control Methods(MCMs)

- **Methods based on Behavioral information (Task-level Animation) :**
  - In order to implement perception, virtual creatures should be equipped with virtual sensors, used as a basis for implementing behavior such as visually directed locomotion or handling objects.
  - https://youtu.be/0eGAaqw7XDk

Procedural Animation

- A **procedural animation** is a type of computer animation, used to automatically generate animation in real-time to allow for a more diverse series of actions than could otherwise be created using predefined animations.
- To produce procedural animation, animators define a procedure or a set of operations to be performed.
- Procedural animation is used to simulate particle systems (smoke, fire, water), cloth and clothing, rigid body dynamics, and hair and fur dynamics, as well as character animation.
- In video games it is often used for simple things like turning a character's head when a player looks around (as in *Quake III Arena*)

Procedural Animation

- Technically, the procedural animation corresponds to the creation of a motion by a procedure, specifically describing the motion.
- Rules are established for a system, and an initial state is defined for objects in the system.
- Object locations or parameters for subsequent frames are computed by applying the forces or behaviors defined for the system to the conditions established in the previous frame.

Procedural Animation

- The procedural animation can be very useful for generating much life-like motion from relatively little input.
- Such an animation should be used when the motion can be described by an algorithm or a formula.

Example: a clock based on the pendulum law:

$$\alpha = A \sin(\omega t + \varnothing)$$

```
create CLOCK (...);
for FRAME:=1 to NB_FRAMES
TIME:=TIME+1/24;
ANGLE:=A*SIN (OMEGA*TIME+PHI);
MODIFY (CLOCK, ANGLE);
draw CLOCK;
record CLOCK
erase CLOCK
```

Procedural Animation

- The generation of a motion using a procedure is not really a method, but more a framework.
- There are so many possibilities of expressing a motion using a procedure or a law.
- The number of all possible algorithms is unlimited.
- But, since the look of future frame is entirely dependent on conditions from previous frames, procedural approaches can suffer from a lack of explicit control over the look of individual frames.

Procedural Animation

Two large categories of procedural animation are

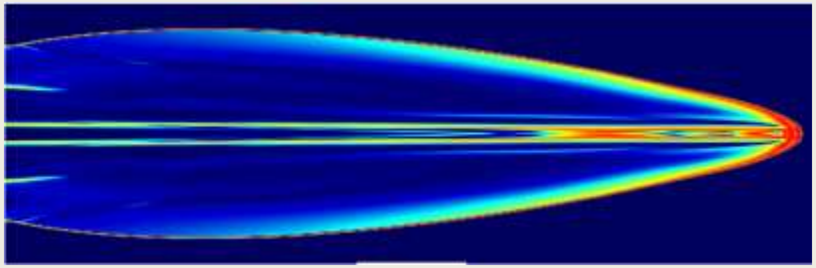
1. Physics-based modeling/animation
2. Alife (artificial life)

1. Physics-based modeling/animation

- It deals with things that are not alive.
- Physics-based modeling/animation refers to techniques that include various physical parameters, as well as geometrical information, into models.
- The behavior of the models is simulated using well-know natural physical laws.
- Physics-based modeling/animation can be considered as a sub-set of procedural animation and includes
  - particle systems,
  - flexible dynamics,
  - rigid body dynamics,
  - fluid dynamics, and
  - fur/hair dynamics

1. Physics-based modeling/animation

- **Particle systems** simulates behaviors of fuzzy objects, such as clouds, smokes, fire, and water.
- **Flexible dynamics** simulates behaviors of flexible objects, such as clothes. A model is built from triangles, with point masses at the triangles' vertices. Triangles are joined at edges with hinges; the hinges open and close in resistance to springs holding the two hinge halves together. Parameters are: point masses, positions, velocities, accelerations, spring constants, wind force, etc..



1. Physics-based modeling/animation

- **Rigid body dynamics** simulates dynamic interaction among rigid objects, such as rocks and metals, taking account various physical characteristics, such as elasticity, friction, and mass, to produce rolling, sliding, and collisions. Parameters for "classical" rigid body dynamics are masses, positions, orientations, forces, torques, linear and angular velocities, linear and angular momenta, rotational ineria tensors, et
- Rigid Body Animation.avi
- **Fluid dynamics** simulates flows, waves, and turbulence of water and other liquids.
- Fluid Dynamics animation.mkv
- **Fur & hair dynamics** generates realistic fur and hair and simulates behaviors of fur and hair. Often it is tied into a rendering method.

2. **Alife** (artificial life)

- **Alife** (artificial life) deals with things are virtually alive.

  - **Behavioral animation** simulates interactions of artificial lives. Examples: flocking, predator-prey, virtual human behaviors.

2. **Alife** (artificial life)

- **Artificial evolution** is the evolution of artificial life forms. The animator plays the role of God. As artificial life forms reproduce and change over time, the survival of the fittest is prescribed by the animator's definition of "fittest" (that is artificial 'natural' selection).

- **Branching object generation** generates plants, trees, and other objects with branching structures and simulate their behaviors. Without a procedural method, building a model of a branching object, such as a tree with a number of branches, requires a lot of time and effort. Branching object generation methods (L-systems & BOGAS) employ user defined rules to generate such objects.

KEY-FRAME ANIMATION V/S PROCEDURAL ANIMATION

- In order to produce a key-frame animation, the animator creates the behavior of a model manually by using an intuitive the "put that there" methodology.
- The animator has full and direct control over the positions, shapes and motions of models during the animation.
- On the other hand, to produce a procedural animation, an animator provides initial conditions and adjusts rather abstract physical parameters such as forces and torques, in order to control positions, shapes, and motions of models.
- The outcome of varying the parameter values is often unpredictable in the case of procedural animation and the animator has to run a simulation to see the result.

Morphing

- **Morphing** is a special effect in motion pictures and animations that changes (or morphs) one image into another through a seamless transition.
- Morphing is a phenomenon by which a picture smoothly transforms into another picture.
- Intermediate images that bridge the transition are calculated from the source and destination images using a mathematical function.
- Intermediate images can be calculated by two techniques: mesh and field morphing.

Morphing

- Morphing is a combination of two process:

a) Cross Dissolving

b) Warping

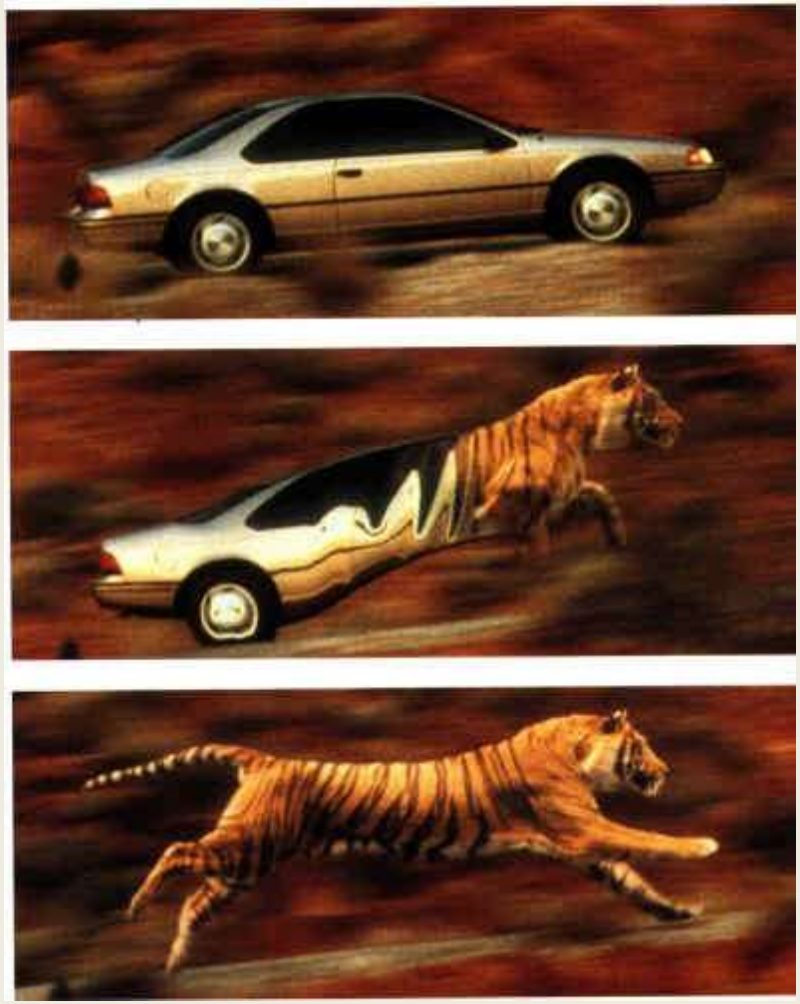
Morphing

- Cross Dissolving:
  - It changes the image color pixel by pixel
  - It produces intermediate images by averaging the pixel color row by row and column by column
  - A simple morph between two similar images and same dimension and resolution can be created by cross dissolving alone
  - Example cross dissolving can change a green circle into a blue square
  - However we need to change the shape of the circle to fit the shape of the square first before or while cross-dissolving

Morphing

- Warping
  - Warping changes the shape of the feature in an image by shifting its pixel around
  - Warping is used to change the shape of the image.
  - It changes the row and column values of an image pixel thus changing the actual shape of feature in an image
  - The process of morphing warping deforms the two images so that their features are in the same shape followed by the cross-dissolving between them, resulting in smooth transformation

Morphing from Car into Tiger



Intermediate images

- To make a transition smooth, each intermediate frame is seen as a combination of beginning and ending pictures.
- Early images in a sequence are much like first source image
- middle image is the average of first image distorted halfway towards second one and second one distorted halfway back towards first one.
- Last image is similar to second one
- Example: consider sequence of 10 frames
- First frame is 100% of start image blended with 0% of end image
- Second frame is 90% of start image blended with 10% of end image
- In general :

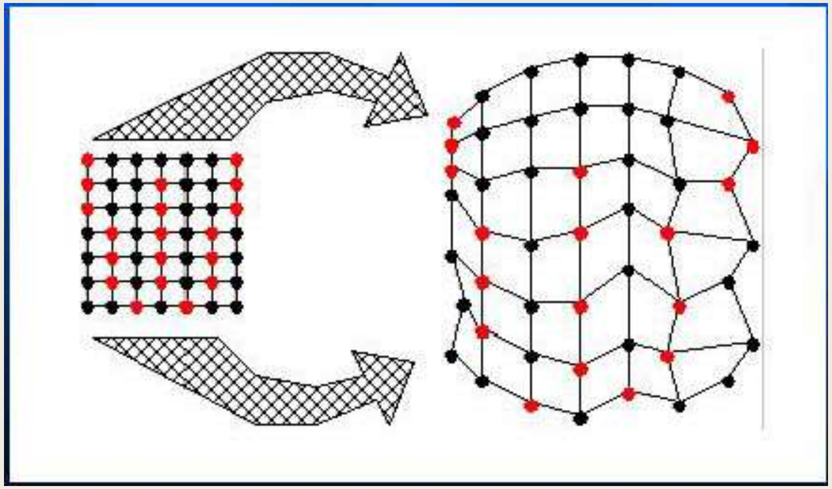
$$\text{Frame}_i = \left[\frac{\text{I}}{\text{No. frames}}\right] \%\ \text{Source}$$

blended with

$$\left[\frac{\text{No. frames} \quad \text{i}}{\text{No. frames}}\right] \%\ \text{Destination}$$

Warping techniques

- **Mesh Warping:**
  - Two-pass algorithm that relates features in source and destination images with control grids called meshes
  - The mesh-warping algorithm relates features with nonuniform mesh in the source and destination images, i.e., the images are broken up into small regions that are mapped onto each other for the morph
  - This causes features contained in a region of the source grid to morph into the features contained in the corresponding region of the destination grid.



Warping techniques

- Mesh Warping:
  - The algorithm accepts a source image, a destination image and two 2D arrays of coordinates.
  - The first array, S, specifies the coordinates of control points in the source image.
  - The second array, D, specifies their corresponding positions in the destination image.
  - Both S and D must have the same dimensions in order to establish a one-to-one correspondence.

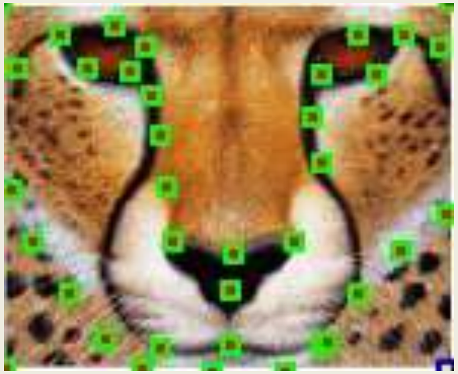
Source Image

Destination Image

Warping techniques

Source Image

Destination Image



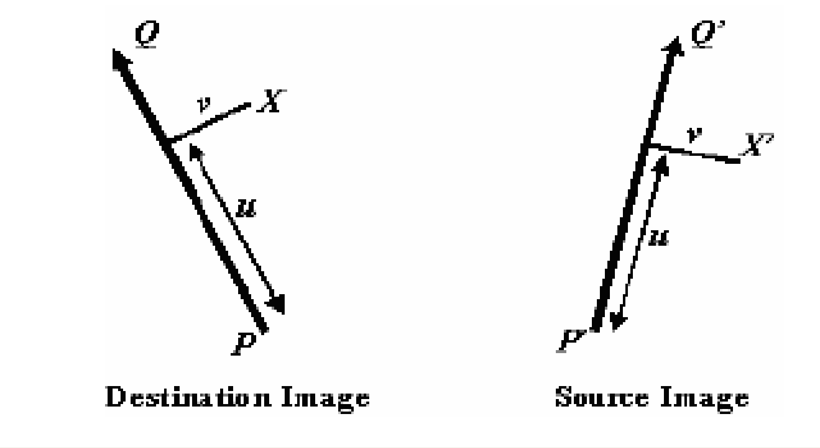
Images with Control Points

Warping techniques

- Mesh Warping:
  - Then two images are processed through 2-pass warping with 2 output intermediate images I1 and I2.
  - The first pass is responsible for resampling each row independently. It maps all initial image points coordinates (u, v) to their (x, v) coordinates in the intermediate image , thereby positioning each input point into its proper output column.
  - The second pass then resamples each column in intermediate image, mapping every (x, v) point to its final (x, y) position in I1/I2.
  - The 2D arrays in which the control points are stored to impose a topology to the mesh.

Warping techniques

- Feature-based image Warping:
  - Instead of using mesh and splines to specify feature, this method makes use of line segments to relate the features in the source image to the features in the destination image.
  - A pair of corresponding line segments defines a mapping from one image to other image

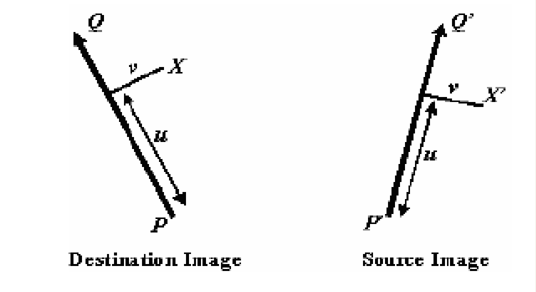


Warping techniques

- Feature-based image Warping:
  - Using reverse mapping a pair of corresponding lines in the sources and destination images defines a coordinate mapping from the destination image pixel coordinate X to the source image pixel coordinate X'.

$$u = \frac{(X-P)(Q-P)}{\|Q-P\|^2}$$

$$v = \frac{(X-P)\,Perpendicular(Q-P)}{\|Q-P\|}$$



  - Value of u goes from 0 to 1 as the pixel moves from P to Q and is less than 0 or Greater than 1 outside that range.
  - Finally the mapping of X to X' is given by

$$X' = P' + u(Q' - P') + v\frac{Perpendicular(Q-P)}{\|Q-P\|}$$

Warping techniques

- Feature-based image Warping:
  - For a single line pair the algorithm is given by

    For each pixel X in the destination image do

    Compute u and v in the destination image

    Compute the **X’ in the source image for that u and v**

    Set the destination image pixel **X to the value of the source image pixel X’**

    End

Warping techniques

- Feature-based image Warping:
  - The Displacement of a point in the source image is a weighted sum of the transformation due to each line pair with the weights depending on the distance and line length. For each line pair a position X' is calculated. Then a displacement D_i is calculates as:

$$D_i = X_i' - X$$

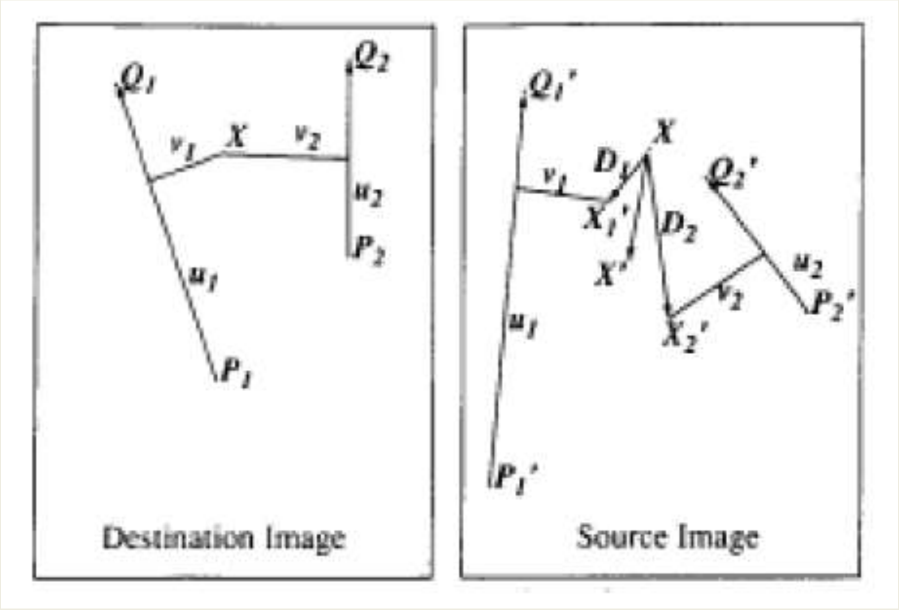
  - Finally a weighted average of these displacements is calculated. The weight assigned to each line should be strongest when the pixel fall exactly on the line and weaker when the pixels are further away from the line

$$Weight = \left(\frac{length^p}{(a + dist)} \right)^b$$

Where length is the length of the line, dist is the distance from pixel X to the line and a,b and p are constants that are varied chosen to control the warp.

Warping techniques

- Feature-based image Warping:
  - Multiple pairs of lines can specify more complex transformation
  - X' is the location to sample the source image for the pixel at X in the destination image. That location is a weighted average of the two pixel locations X'1 and X'2 computed with respect to the first and second line pair



FOR EACH PIXEL X IN THE DESTINATION IMAGE.

DSUM= (0, 0)

WEIGHT SUM=0

FOR EACH LINE

DIST=SHORTEST DISTANCE FROM X TO $P_I Q_I$

WEIGHT

DSUM+=D_I*WEIGHTS

X'=X+DSUM/WEIGHT

DESTINATION IMAGE(X) =SOURCE IMAGE (X')

END

End of Unit 6