Unit 5

Computer Animation

&

Image Manipulation and Storage

Computer animation

- 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 device individual states of a dynamic scene.
- Any computer animation sequence may be defined as a set of objects.
- It is characterized by state variables evolving over time or it is a time sequence of changes in a scene.
- Animation is production of consecutive images which when displayed together convey a feeling of motion.
- In addition to changing object position with translations or rotations, a computer generated animation could display time variations in object size, color, texture etc.
- Computer animations can also be generated by changing camera parameters such as position, orientation and focal length.

PRINCIPLES OF ANIMATION

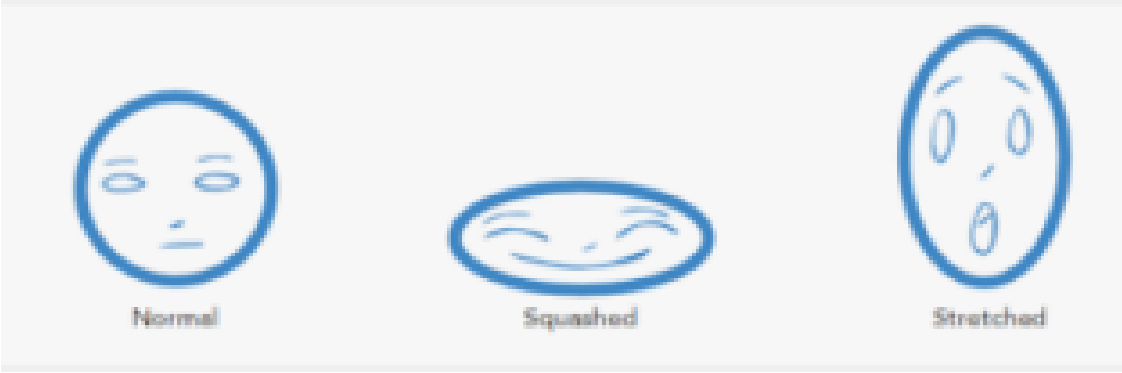
12 Principles of Animation

01. Squash and Stretch
02. Anticipation
03. Staging
04. Straight ahead action and pose to pose
05. Follow through and overlapping action
06. Slow in and slow out
07. Arc
08. Secondary action
09. Timing
10. Exaggeration
11. Solid drawing
12. Appeal

@Animaders.com

SQUASH AND STRETCH

- The most important principle is "squash and stretch".
- The purpose of this is to give a sense of weight and flexibility to drawn objects.
- When an object moves, its movement indicates the rigidity of the object. Many real world objects have little flexibility, such as furniture, however most organic objects have some level of flexibility in their shape.
- It can be applied to simple objects, example like a bouncing ball, construction like the musculature of a human face etc.
- A figure stretched or squashed to an exaggerated degree can have a comical effect.



- In realistic animation, the most important aspect of this principle is the fact that an object's volume does not change when squashed or stretched.
- When a person smiles, the shape of the face is determined by the movement of muscles underneath a layer of skin. During a smile, though the head seems to increase in size, with the widening of the mouth and jaw, it does not. The object is simply displacing its matter into the stretched shape. The most important rule to squash and stretch is that no matter how squashed or stretched out an object gets, its volume remains constant.
- If the length of a ball is stretched vertically, its width (in three dimensions and also its depth) needs to contract correspondingly horizontally.

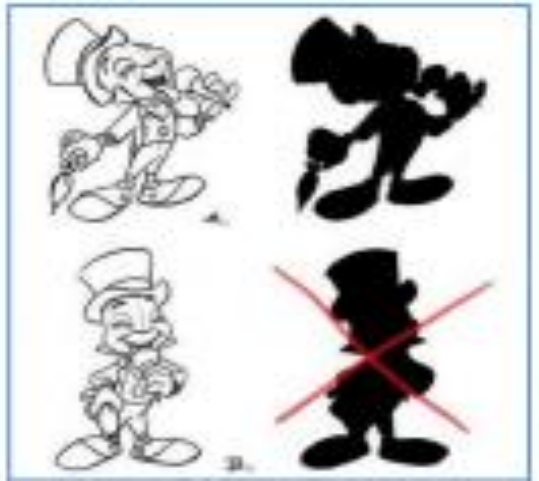
ANTICIPATION

- Anticipation is used to prepare the audience for an action.
- It makes the action appear more realistic.
- A dancer jumping off the floor has to bend the knees first, a golfer making a swing has to swing the club back first are example of it.
- By contrast, the anticipation pose can also be omitted in cases where it might be expected. The resulting sense of anticlimax will produce a feeling of surprise in the viewer, and can often add comedy to a scene.

STAGING

- Its purpose is to direct the audience's attention.
- This makes it clear that what is of greatest importance in a scene.
- Johnston and Thomas defined it as "the presentation of any idea so that it is completely and unmistakably clear", whether that idea is an action, a personality, an expression or a mood.
- This can be done by various means such as the placement of a character in the frame, the use of light and shadow or the angle and position of the camera.
- The essence of this principle is keeping focus on what is relevant.

- Here are 3 tips on staging :
- 1. Halves and thirds One easy technique keeps the characters of interest in the a half or third of the camera frame. If you divide a frame of the shot in half or thirds and place the character in those sections, you control the attention of the audience while communicating the importance of that character.
- 2. Lines of focus By using sets, other characters, and camera angles, one can create lines of focus that can draw the attention of the audience where you intend it to be.
- 3. Consistent Screen Direction Screen direction is the direction that a character appears to be moving or speaking. Having a consistent screen direction is important to convey information to your audience clearly.

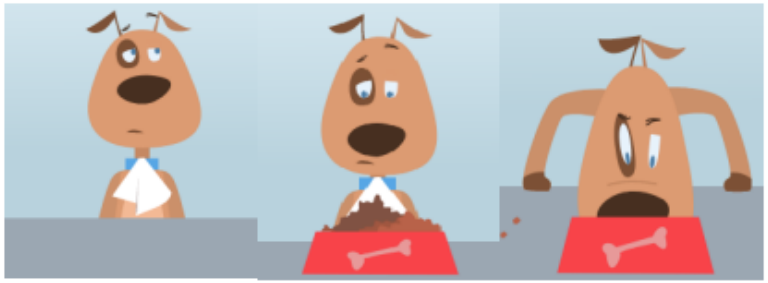


STRAIGHT AHEAD ACTION AND POSE TO POSE

- These are two different approaches to the actual drawing process.
- "Straight ahead action" scenes are animated frame by frame from beginning to end.
- Straight ahead action creates a more fluid, dynamic illusion of movement.
- It is better for producing realistic action sequences.
- It is hard to maintain proportions and to create exact, convincing poses along the way.
- "Pose to pose" involves starting with drawing a few key frames and then filling in the intervals later.
- "Pose to pose" works better for dramatic or emotional scenes.
- Here composition and relation to the surroundings are of greater importance

FOLLOW THROUGH AND OVERLAPPING ACTION

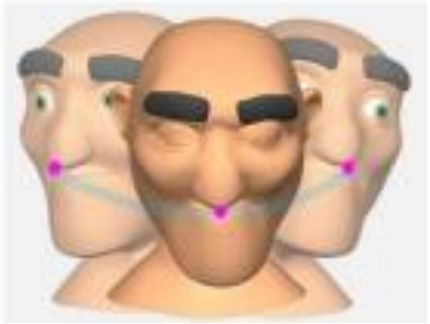
- Follow through and overlapping action is a general heading for two closely related techniques.
- It helps to render movement more realistically.
- "Follow through" means that loosely tied parts of a body should continue moving after the character has stopped.
- Also the parts should keep moving beyond the point where the character stopped only to be subsequently "pulled back towards the center of mass or exhibiting various degrees of oscillation damping.
- "Overlapping action" is the tendency for parts of the body to move at different rates example an arm will move on different timing of the head and so on.
- A third related technique is "drag" where a character starts to move and parts of him take a few frames to catch up.
- These parts can be inanimate objects like clothing or the antenna on a car or parts of the body, such as arms or hair.

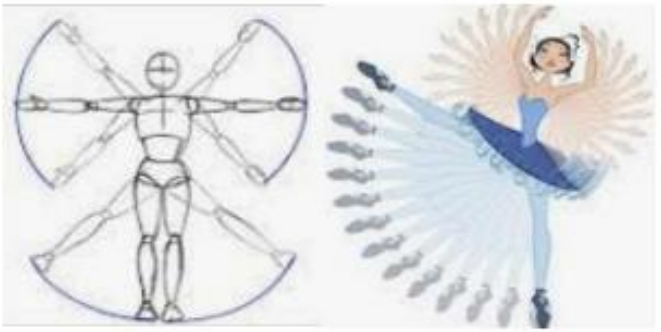


EASE IN AND EASE OUT

- The movement of the human body and most other objects needs time to accelerate and slow down.
- For this reason, animation looks more realistic.
- It has more drawings near the beginning and end of an action, emphasizing the extreme poses and fewer in the middle.
- This principle goes for characters moving between two extreme poses for example sitting down and standing up but also for inanimate moving objects like the bouncing ball.

ARC





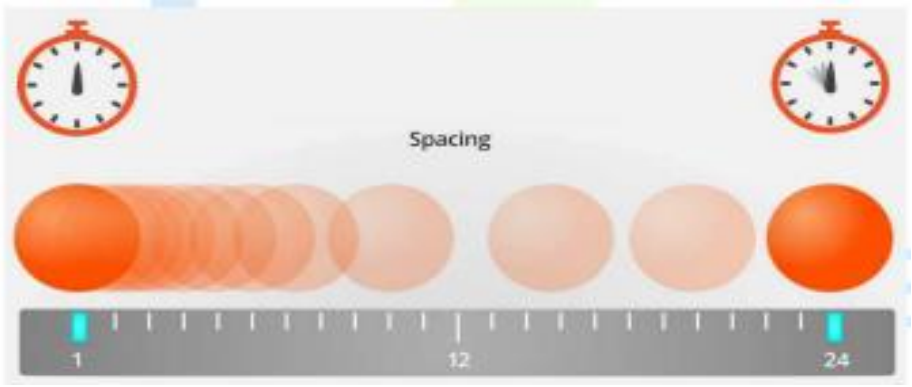
- Most natural action tends to follow an arched trajectory and animation should adhere to this principle by following implied "arcs" for greater realism.
- This technique can be applied to a moving limb by rotating a joint or a thrown object moving along a parabolic trajectory.
- As an object's speed or momentum increases, arcs tend to flatten out in moving ahead and broaden in turns.
- An object in motion that moves out of its natural arc for no apparent reason will appear erratic rather than fluid.
- For example, when animating a pointing finger, the animator should be certain that in all drawings in between the two extreme poses the fingertip follows a logical arc from one extreme to the next.

SECONDARY ACTION

- Adding secondary actions to the main action gives a scene more life.
- It can help to support the main action.
- A person walking can simultaneously swing their arms or keep them in their pockets, speak or whistle or express emotions through facial expressions.
- The important thing about secondary actions is that they emphasize rather than take attention away from the main action.
- For example during a dramatic movement, facial expressions will often go unnoticed.
- In these cases it is better to include them at the beginning and the end of the movement rather than during.

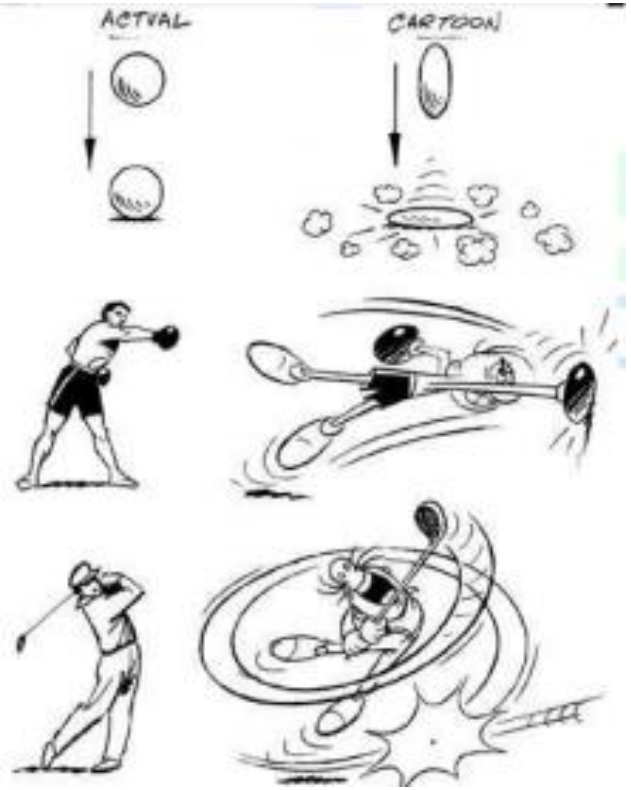
TIMING

- Timing refers to the number of drawings or frames for a given action.
- It translates to the speed of the action on film.
- Correct timing makes objects appear to obey the laws of physics.
- Example an object's weight determines how it reacts to an impetus like a push.
- Timing is critical for establishing a character's mood, emotion and reaction.
- It can also be a device to communicate aspects of a character's personality.



EXAGGERATION

- Exaggeration is an effect especially useful for animation.
- It enhances animated motions that strive for a perfect imitation of reality can look static and dull.
- The level of exaggeration depends on whether one seeks realism or a particular style like a caricature or the style of a specific artist.
- The classical definition of exaggeration employed by Disney was to remain true to reality just presenting it in a wilder and in more extreme form.
- If a scene contains several elements, there should be a balance in how those elements are exaggerated in relation to each other.
- This is to avoid confusing or overawing the viewer.



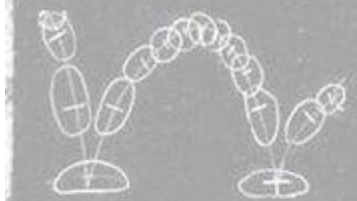
SOLID DRAWING

- The principle of solid drawing means taking into account forms in three-dimensional space or giving them volume and weight.
- The animator needs to be a skilled artist.
- He has to understand the basics of three-dimensional shapes, anatomy, weight, balance, light and shadow etc.

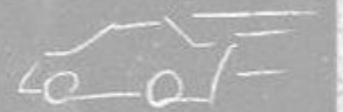
APPEAL

- Appeal in a cartoon character corresponds to what would be called charisma in an actor.
- A character that is appealing is not necessarily sympathetic,
- Villains or monsters can also be appealing.
- The important thing is that the viewer feels the character is real and interesting.
- There is way for making a character connect better with the audience.
- Example a complicated or hard to read face will lack appeal.
- It may more accurately be described as 'captivation' in the composition of the pose or the character design.

Squash and Stretch



Timinig and Motion



Anticipation

Staging

Follow Through and Overlapping Action

Straight Ahead and Pose-to-Pose Action

Slow In and Out

Arcs

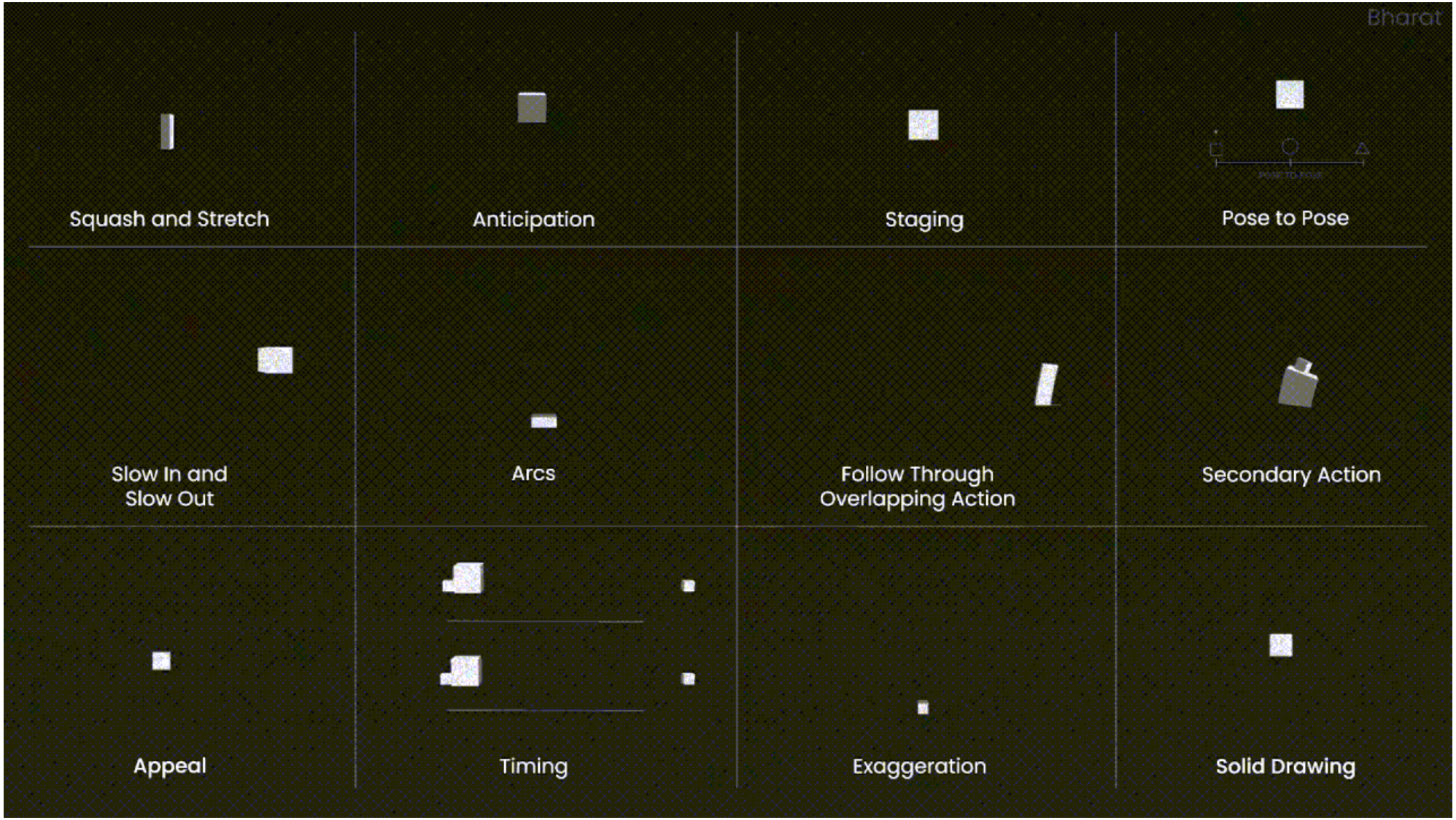
Exaggeration

Secondary Action

Solid drawing

Appeal

Bharat


Squash and Stretch
Anticipation
Staging
Pose to Pose
Slow In and Slow Out
Arcs
Follow Through Overlapping Action
Secondary Action
Appeal
Timing
Exaggeration
Solid Drawing

KEY-FRAME ANIMATION

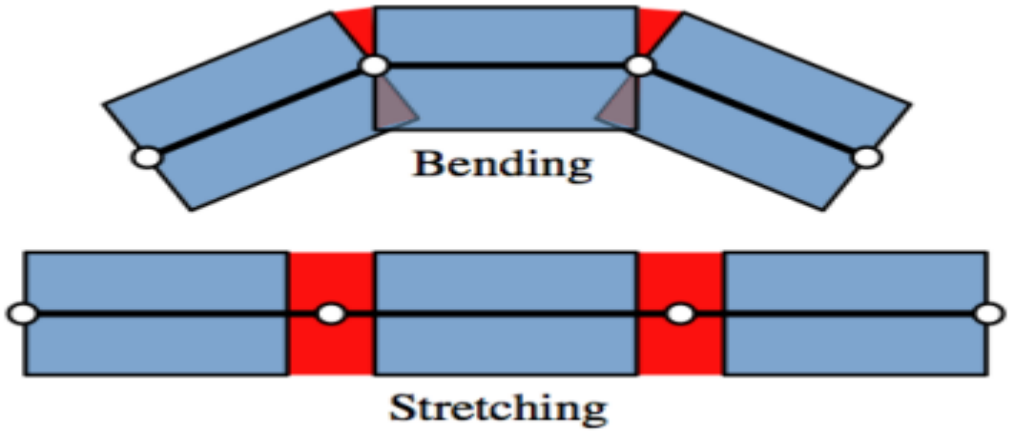
- A key frame animation consists of an automatic generation of the intermediate frames based on a set of key frames that is supplied by an animator.
- A key frame in animation and filmmaking is a drawing that defines the starting and ending points of any smooth transition.
- In order to produce a key-frame 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.
- There are two fundamental approaches to a key-frame:

  1. In-betweens are obtained by shape interpolation. This method makes it possible to transform a geometrical form into another during an animation. There is a serious problem for an image based key frame as the motion can be distorted due to the interpolation. The problem becomes complicated when the two drawings do not have the same number of vertices. In such case it is initially necessary to carry out a preprocessing step to equalize the number of vertices of the two drawings.

  2. A way of producing better images is to interpolate parameters of the model instead of the object itself. The parameters are normally spatial parameters, physical parameters and visualization parameters that decide the model's behavior.

DEFORMATION

- It’s an important aspect of geometry processing used in CAD and movie industry.
- In this shape manipulation is driven by a variation optimization.
- It guarantees high quality deformations by minimizing physically inspired energies subject to user controlled constraints.
- Physically-plausible deformations are achieved by a constrained minimization of stretching (center) or bending (right) energies.



CHARACTER ANIMATION

- This type of animation defines specialized area of animation in which animated character are brought to life.
- Character animators are often known as “actors with pencil”.
- Character animator captures the performance data with varies input technology using camera, keyboard, microphone, mouse or touch devices etc.
- They capture facial expression.
- This make animation looks real.
- Character animator tries to put life in their character work for creating the illusion of emotion, personality and thoughts.
- Example of this are animated feature films, gaming industry,

PHYSICS BASED ANIMATION

- Physics based animation is study of simulation of physically plausible behaviors at collaborative rate.
- This animation is constraint by strict time as it is imposed by interactive animation.
- It is inspired by need to include physically motivated behaviors in complex movie, video games etc.
- In these animation an animator provides physical data and the motion is obtained by solving the dynamics equations.
- It focuses on numerical stability and visual appeal over the physical accuracy.
- Here motion is globally controlled.
- We can distinguish methods based on parameter like adjustment and constraint-based methods.
- Here the animator states are in terms of constraints and the properties the model is supposed to have without needing to adjust parameters.

PROCEDURAL TECHNIQUES

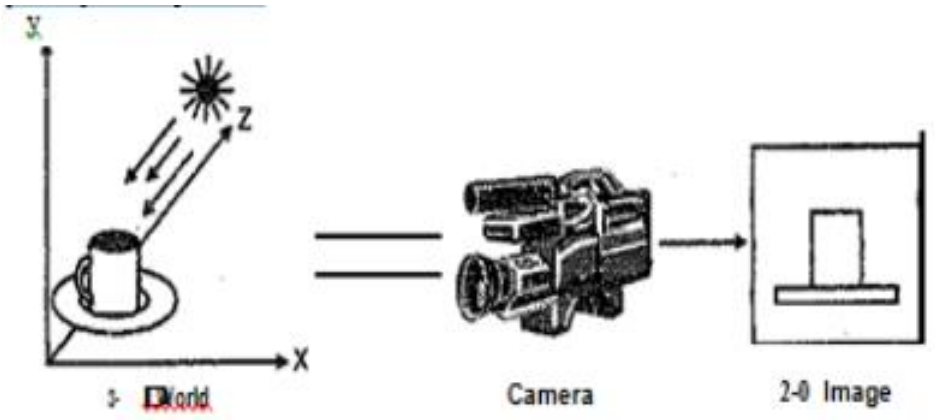
- A procedural technique helps a type of computer animation which is used to automatically generate animation in real time.
- It allow for a more diverse series of actions than could also be created using predefined animations.
- The procedural technique is used to simulate particle system like smoke, fire, water, etc., cloth and clothing, rigid-body dynamics, hair and fur dynamics and character animation.
- In computer and video games it is often used for simple things like turning a character's head when a player looks around.
- The procedural techniques correspond to the creation of a motion by a procedure by describing the motion.
- Rules are established for a system and an initial state is defined for objects in the system.

- The procedural technique 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.
- 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.
- Procedural approaches can suffer from a lack of explicit control over the look of individual frames.

IMAGE

- An image can be defined as a 2-dimensional representation of 3- dimensional world.
- The world around us is 3-dimensional
- Images obtained through a camera are 2-dimensional.
- Hence image can be defined as a two-dimensional function, f(x, y) where x and y are spatial coordinates and the amplitude of f at any pair of coordinates (x, y) is called the intensity or grey level of the image at that point.
- When x, y and the intensity values of f are all finite discrete quantities we say the image is a digital image.
- A digital image is composed of a finite number of elements, each of which has a particular location and value.
- These elements are called image elements, picture elements, pels or pixels.
- Pixel is the term used most widely to denote the elements of a digital image.
- As we discuss earlier vision is the most advanced of our senses, therefore images play the single most important role in human perception system.

- In 2-dimension image we lose one dimension.
- Depth information is lost in this moving process from 3-dimension object to 2-dimension image .
- Photographs on identity card, all family pictures etc. are example of 2- dimensional image.

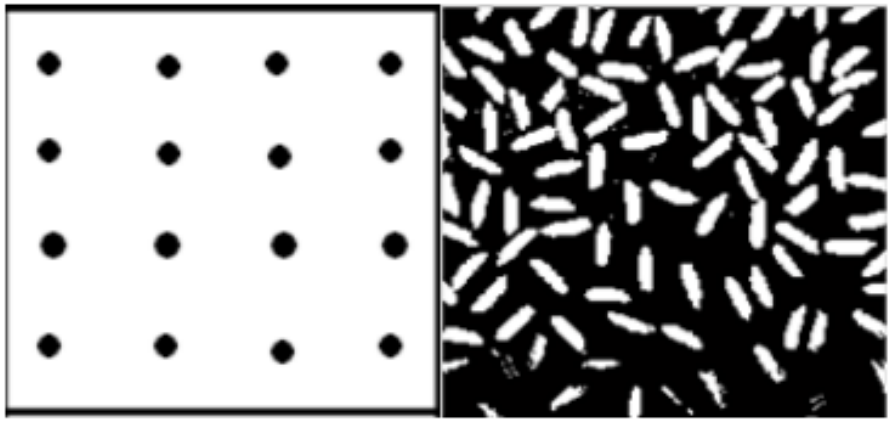


Types of Image

- It was stated earlier images are 2-dimensinal functions. Images can be classified as follows:
  (1) Monochrome Image
  (2) Grey Scale Image
  (3) Colour Image

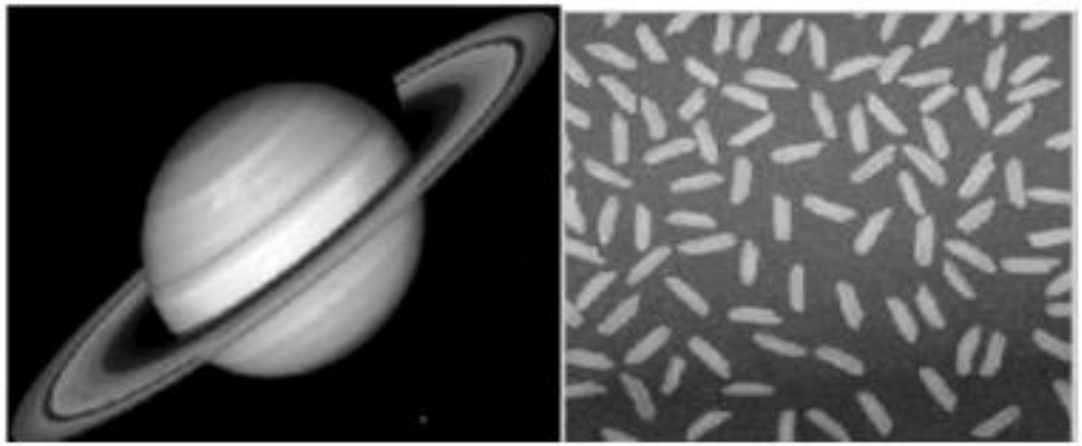
(1) Monochrome Image:

- In this type of image, each pixel is stored as a single bit 0 or 1.
- These images are also called as bit mapped image or binary image.
- Here 0 represent black and 1 represent white.
- It is also called as black and white image.



(2) Grey Scale Image:

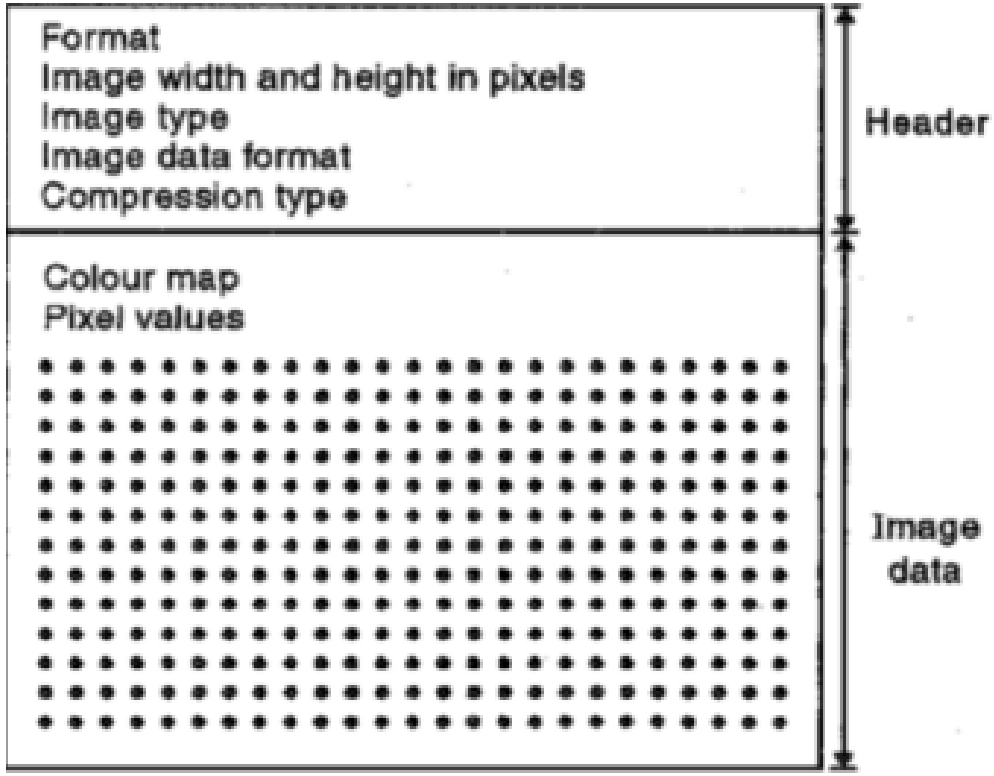
- In this type of image, each pixel is usually stored as 8-bits (1 byte).
- Because of this each pixel can have value ranging from 0 to 255.
- Here 0 represent black and 255 represent white.
- In this image we have black, white and various shades of grey present in image.



(3) Colour Image:

- In this type of image, each pixel is usually stored as 24-bits.
- Variety of colors can be generated by mixing the three primary colors Red, Green and Blue in appropriate proportions.
- In color images, each pixel is composed of RGB values and each of colors requires 8-bits for its representation.
- Hence each pixel is represented by 24-bits[R (8 bits), G (8 bits),B(8 bits)].
- Color images can be easily converted to grey scale image using the equation, $X = 0.30R+0.59G+0.13B$
- Easier formula to achieve same result as follows, $X = R + G + B / 3$

- The image file shows organization of information encoded that consists of two parts: 1. Header 2. Image data.



- Header: The header file gives us the information about the kind of image.
- Format: The header file identifies the format as binary code or ASCII string.
- Width and Height: The width and height of the image are given in number of pixels.
- Common image types: binary images, 8-bit greyscale images, 8-bit color and 24-bit color images.
- Image data format: It specifies the order in which pixel values are stored in the image data section. Order used is left to right and top to bottom.
- Image data format also specifies if the RGB values in the image are interlaced or not interlaced.

- Example of interlaced: R G B R G B R G B

  1 pixel 2 pixel 3 pixel
- Example of not interlaced: R R R…. G G G…. B B B….
- By interlaced we mean that the RGB values of each pixel stay together consecutively followed by the three colour components for the next pixel.
- If the RGB values are not interlaced, the values of one primary colour for all pixels appear first, then the values of the next primary colour followed by the values of the third primary colour.
- Compression type: It shows image data is compressed

DIGITAL IMAGE FILE FORMATS

- A file format is a structure which defines how information is stored in the file and how that information is displayed on the monitor.
- There are numerous image file formats which are available.
- Some of the image formats that can be used on either Macintosh or PC platforms are:
  1. BMP (Bit Mapped Graphic Image)
  2. JPEG (Joint Photographic Expert Group)
  3. TIFF (Tagged Image File Formal)
  4. EPS (Encapsulated Post Script)
  5. GIF (Graphic Interchange Format)
  6. PICT (Macintosh Supported)
  7. PNG (Portable Network Graphics)

- BMP:
  - Images developed by Microsoft can save both monochromes as well as color images.
  - All the wallpaper on computer is example of BMP images.
  - It is normally not compressed.
  - Lossless compression can be specified in it.
  - When we work in paint Brush, we can save our work as BMP image.
  - The quality of BMP files is very good but they occupy a lot of memory space.
- JPEG:
  - Joint Photographic Expert Group is the name of committee that developed this JPEG image format which is used in compression algorithms.
  - JPEG images are compressed images which occupy very little space.
  - It is based on the Discrete Cosine Transform-DCT.
  - JPEG images use lossy compression algorithms which result in some loss of original data.
  - The quality of JPEG images is not as good as BMP images.

- TIFF:
  - Most well-known formats were developed in 1986.
  - A TIFF format is also a data compression technique for monochrome as well as colour images.
  - Images seen on the Internet sites are normally TIFF/GIF images simply because they occupy less space.
- EPS:
  - It is file format of the post script page description language and is device independent.
  - This means that images can readily be transferred from one application to another.
  - However EPS image scan only be printed in script compatible printers.

- GIF:
  - Uses a form of Huffman coding.
  - Used in Internet images
  - Limited color palette with RGB values, in the range of 0 to 255.
  - CMYK (Cyan, Magenta, Yellow, and Key (black)) colors are not possible in GIF.
- PICT:
  - It is a general purpose format supported by Macintosh and used for storing bit-mapped images.
- PNG:
  - It is lossless image format.
  - To improve and replace the GIF format, PNG image format was designed.

IMAGE COMPRESSION

- In comparison to text files, images take up a huge amount of disk space.
- The term data compression refers to the process of reducing the amount of data required to represent a given quantity of information.
- Various amounts of data may be used to represent same amount of information.
- This is known as data redundancy.
- Data redundancy is central issue in digital image compression.
- Basically there are three basic redundancies:

  1. Coding redundancy. Coding redundancy normally is present in any natural binary encoding of the gray levels in an image. It can be eliminated by coding the gray levels.
  2. Interpixel redundancy. It is due to correlations between the image pixels.
  3.Pyschovisual redundancy. It occurs when the information is visually not essential.

- Data compression is achieved when one or more of these redundancies are eliminated.
- In image compression based on methodologies, there are two types of compression as follows:
  - Lossy compression: Part of original data is discarded permanently to reduce file size. After decompression original data cannot be retrieved back.
  - Lossless compression: Original data is not changed permanently during compression. After decompression original data can be retrieved back.

Factor	*Lossless Compression*	*Lossy Compression*
Definition	The compression algorithm allows the original data to be entirely reconstructed from the compressed data.	An encoding method that uses a rough approximation to represent content. The method reduces data size for storage, handling and transmitting content.
Uses	Text or programme, images and sound	Images, audio and video
Advantages	High output quality Low data loss	High compression ratio
Disadvantages	Low compression ratio	High data loss Low output quality Complex algorithm

IMAGE COMPRESSION STANDARD-JPEG

- JPEG stands for Joint Photographic Expert Group.
- Image compression is known to most users of computers in the form of image file extensions such as the jpg file extension.
- JPEG images are compressed images which occupy very little space.
- It is based on the Discrete Cosine Transform (DCT).
- JPEG images use lossy compression algorithms.
- This compression is used to reduce the size of file without damaging its quality.

- JPEG Compression Process:
  - First, we convert the R, G, B color format to Y, Cb and Cr format.
  - In YCbCr, Y is luma (brightness), Cb is blue minus luma (B-Y) and Cr is red minus luma (R-Y). The luma channel, typically denoted Y , approximates the monochrome picture content. The two chroma channels, Cb and Cr, are color difference channels.
  - Some colors are more sensitive to human eye, thus are high-frequency color and some of chromium compounds like Cb and Cr are less sensitive thus can be ignored.
  - Then we reduce the size of pixels by down sampling process.
  - We divide our image into 8*8 pixels and perform forward DCT (Direct Cosine Transformation).
  - Then we perform quantization using quantum tables.
  - Finally we compress our data using various lossless compression methods such as run-length encoding, Huffman encoding etc.

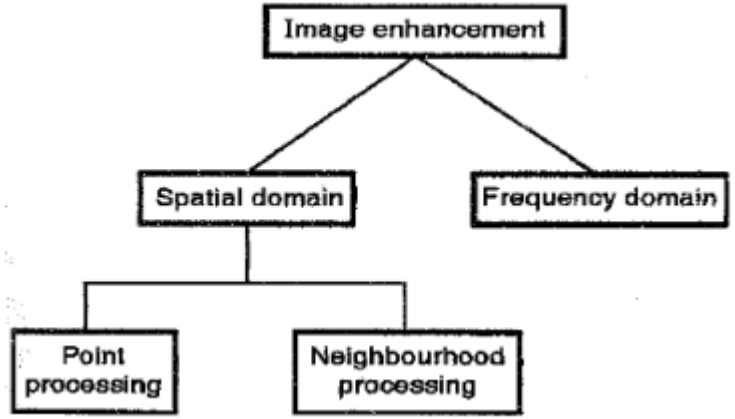
IMAGE PROCESSING

- Image Processing is a subject which basically studies the images and manipulation of images by computer.
- It involves processing the images that are obtained by camera.
- With the beginning of computers, image processing grew rapidly as a subject.
- It was stated earlier that human eye-brain mechanism represents ultimate imaging system. Now let us understand this with a scenario. What happens when we look at an object? Let us take a simple example: when we see an explosion, we immediately identify it as something danger.
- Two things have happened here:
    1. The scene has been captured by the eye.
    2. The brain processed the scene and gave out a warning signal. This is known as Image Processing.
- In above example the scene is captured by the eye and it sends the signal to the brain.
- Brains processed this signal and some meaningful information is generated.
- When working with computer, images captured from camera are fed into the system where algorithm is written to process these images.

- Hence in image processing system, camera replaces the human eye and computer replaces brain which does the processing.
- The field of digital image processing refers to processing digital images by means of a digital computer.
- Therefore we start processing the images the day we are born and continue till we die.
- Hence image processing is integral part of us.
- An another important trait that is common to all human being is to store the information, analyze it, discuss it with others and try to make it better.

DIGITAL IMAGE ENHANCEMENT

- Image enhancement is the next step after image acquisition in fundamental image processing.
- There are many improvisation methods to manipulate an images and the result is more suitable than the original image.
- Here image is enhanced.
- The desired result can vary from person to person.
- In image enhancement no extra information is added to the original image.
- It simply improves the subjective quality of an image by working with the existing data of an image.
- Image enhancement can be carried in two domains:
  1. Spatial domain
  2. Frequency domain



1. Spatial Domain:

- Spatial domain means working in the given space.
- It implies working with the pixels values of an image.
- Assume f(x, y) is original image. Here f is grey value and (x, y) are image coordinate.
- For 1 byte image f values range from 0-255, where 0 represent black, 255 represent white and all intermediate values represent shades of grey.
- The modified image can be expressed as, g (x, y) = T [f(x, y)] Where g (x, y) is modified image. f (x, y) is original image. T is the transformation applied on original image.
- Spatial domain enhancement can be carried out in two ways: Point processing and Neighborhood processing.

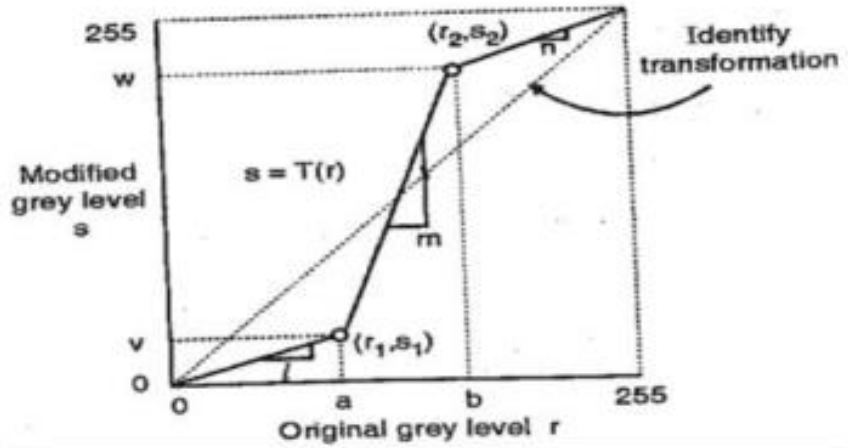
2. Frequency domain

- Frequency domain means working with the frequencies value of an image.
- Frequency domain techniques are the study of working in the Fourier domain.
- Example: 1D-Fourier transforms, 2D-Fourier transform, 1D-DFT and 2D-DFT etc

CONTRAST STRETCHING

- We obtain low contrast images because many reasons such as poor illumination, lack of dynamic range in the imaging sensor or wrong setting of a lens aperture during image acquisition.
- Contrast stretching expands the range of intensity levels in an image.
- This means that contrast stretching increases dark portion to darker and bright portion to brighter.
- Contrast stretching is also used to increase the dynamic range of the modified image.

- In figure dotted line indicate identity transformation and solid line indicate contrast stretching transformation.
- Here the dark grey levels are made darker by assigning slope value less than one and bright grey levels are made brighter by assigning slope value greater than one.
- The equation of the contrast stretching algorithm is given as: g (x, y)= l.f (x, y) for 0 <= r < a or g(x, y) = m.(r – a) + v for a <= r < b or g(x, y) = n.(r – b) + w for b <= r < L-1 where g (x, y) is modified image. f (x, y) is original image. l, m, n are slopes.
- It is clear from figure that l and n slope values are less than one while m slope is greater than one.

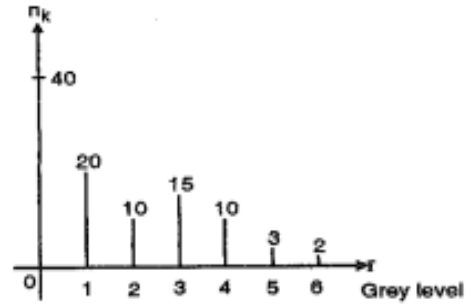


HISTOGRAM

- Histogram of images provides a global description of the appearance of an image.
- The information obtained from histograms is enormous.
- Histogram of an image represents the relative frequency of occurrence of the various grey levels in an image.
- Histogram of an image can be plotted in two ways.
- In the first method, the x-axis has the grey levels and the y-axis has the number of pixels in each grey level.
- In the second method, the x-axis represents the grey levels, while the yaxis represents the probability of the occurrence of that grey level.

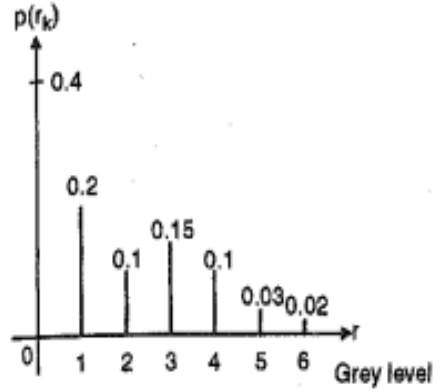
- In method 2, P (rk) = nk / n rk
- k th grey level nk
- Number of pixel in the k th grey level n
- Total number of pixel in an image

Grey level	Number of pixels (n_k)
0	40
1	20
2	10
3	15
4	10
5	3
6	2



Method 1

Grey level	Number of pixels (n_k)	$p(r_k) = \frac{n_k}{n}$
0	40	0.4
1	20	0.2
2	10	0.1
3	15	0.15
4	10	0.1
5	3	0.03
6	2	0.02
	n = 100	

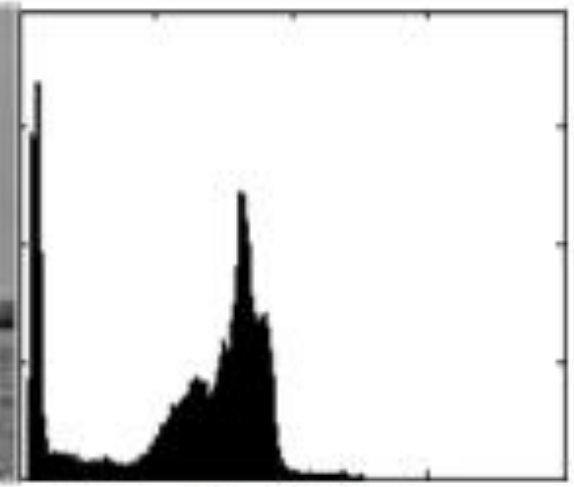


Method 2

HISTOGRAM EQUILIZATION

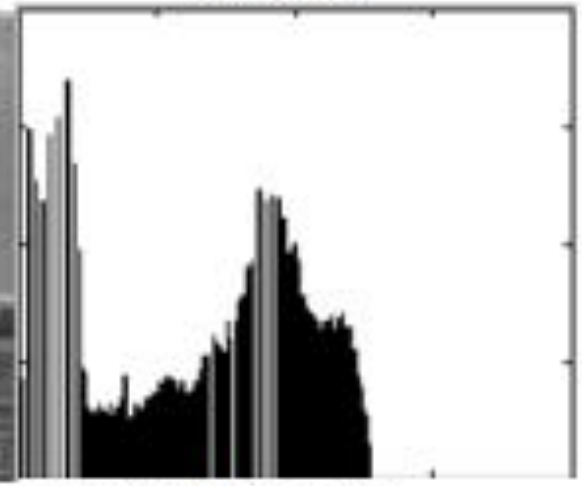
- There are many applications where we need flat histogram.
- **Histogram equalization gives us flat histogram.**
- **A perfect image is one which has equal number of pixels in all its grey level, which is achieved by ideal histogram equalization.**
- This technique carries the transformations that transform bad histogram to a flat histogram.
- It also increases the dynamic range of a given image along with equal distribution of pixels in its grey levels.
- The transformation we are looking for must satisfy the following two conditions:
  - 1. T(r) must be single valued and monotonically increasing in the interval 0 <= r <= 1.
  - 2. 0 <= T(r) <= 1 for 0 <= r <= 1 i.e. 0 <= s <= 1 for 0 <= r <= 1 . Here range of r is [0, 1].This is called normalized range.

Original Image



Histogram

Equalized Image



Equalized Histogram

FILTERING

- As we studied in image enhancement topic, neighborhood processing is one of the important technique in spatial domain.
- In neighborhood processing we consider pixel as well its immediate neighbors to enhance the image.
- Fig.13.5.4.2 shown is called filter, mask, window or a template.
- Mask can be 3 x 3, 5 x 5, 7 x 7 and so on.

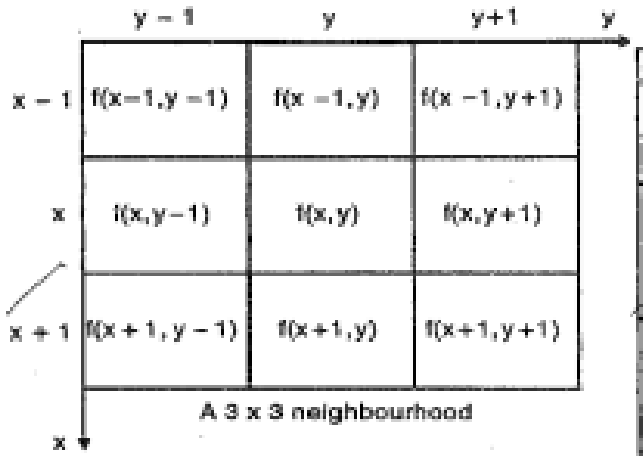


Fig. 13.5.4.1

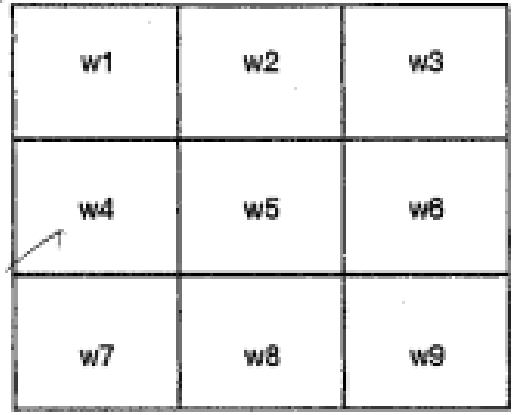


Fig. 13.5.4.2

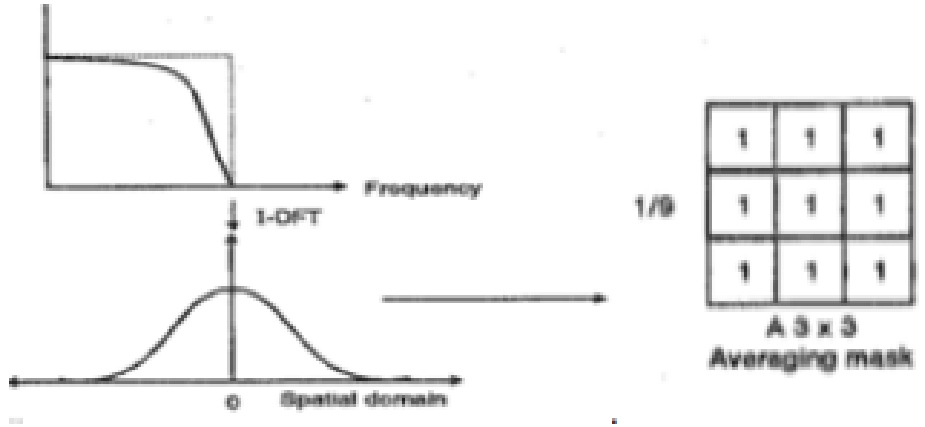
- To process image we place mask on image, multiply each component of mask with corresponding value of image, add them up and place the calculated value at center.
- Consider f(x, y) is the original image and g(x, y) is modified image then,
- g(x,y)=w1*f(x-1,y-1)+w2*f(x-1,y)+w3*f(x-1,y+1)+w4*f(x,y-1) +w5*f(x, y)+w6*f(x,y+1)+w7*f(x+1,y-1)+w8*f(x+1,y) +w9*f(x+1,y+1)
- Once g(x, y) is calculated we shift the mask by one step towards the right to the next pixel.
- One of the important operations of neighborhood processing is image filtering.
- In filtering we remove the noise from the image.
- In most images, the background is considered to be low frequency regions and edges are considered to be high frequency region

SMOOTHING

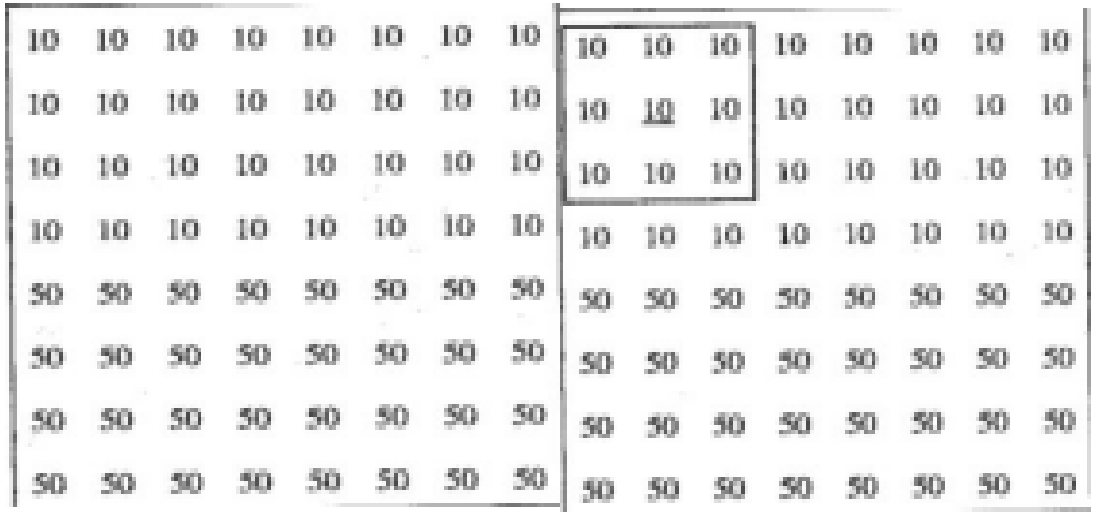
- Smoothing is also called as low pass filtering.
- Smoothing implies removing or blurring the edges.
- Smoothing is used to remove noise present in the image.
- Noise is normally high frequency component and low pass filtering removes these high frequency components.
- Here we are going to study smoothing in two ways: Low Pass Averaging Filter and Median Filter.

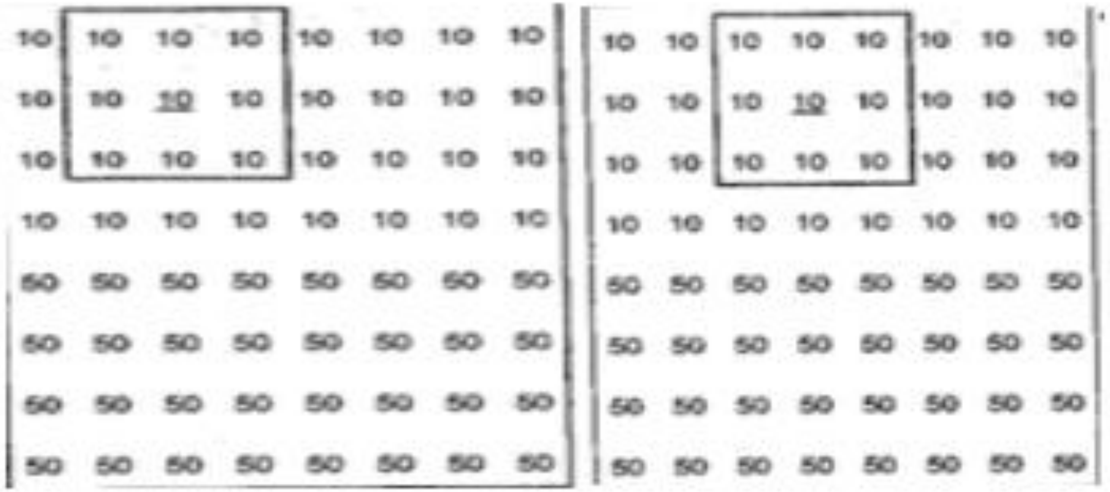
LOW PASS AVERAGE FILTER

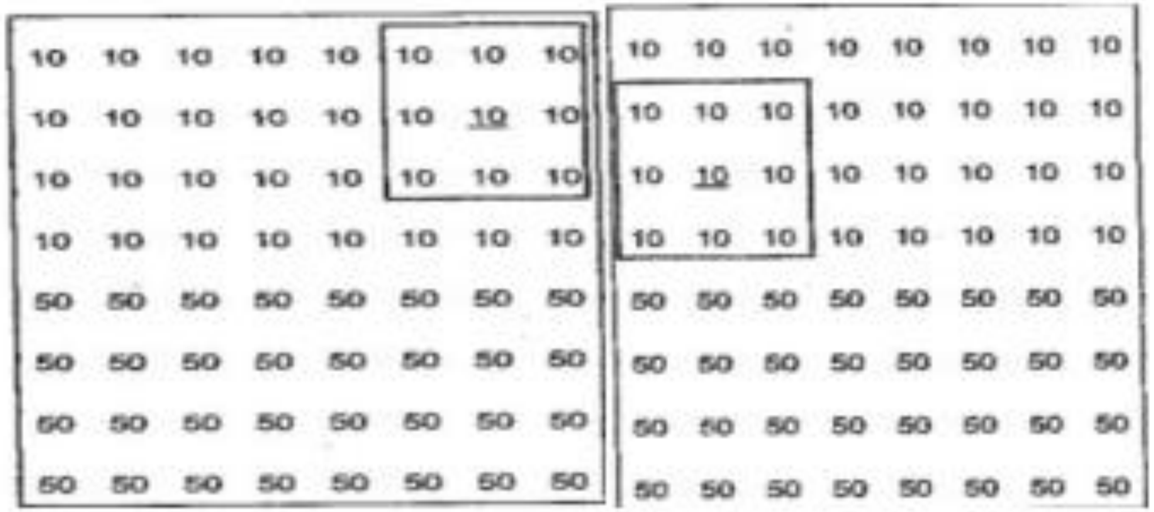
- When an electrical variation obeys a Gaussian distribution, such as in the case of thermal motion cited above, it is called Gaussian noise, or RANDOM NOISE.
- This filter is used to eliminate Gaussian noise from the image.
- Frequency response of low pass averaging filter along with spatial response is shown in figure.
- We generate the mask which gives us low pass filtering operation.
- The coefficient use in mask should be positive in case of low pass averaging filter.
- Let us take the 3 x 3 average masks shown below on the pseudo image given below to understand working of low pass averaging filter.

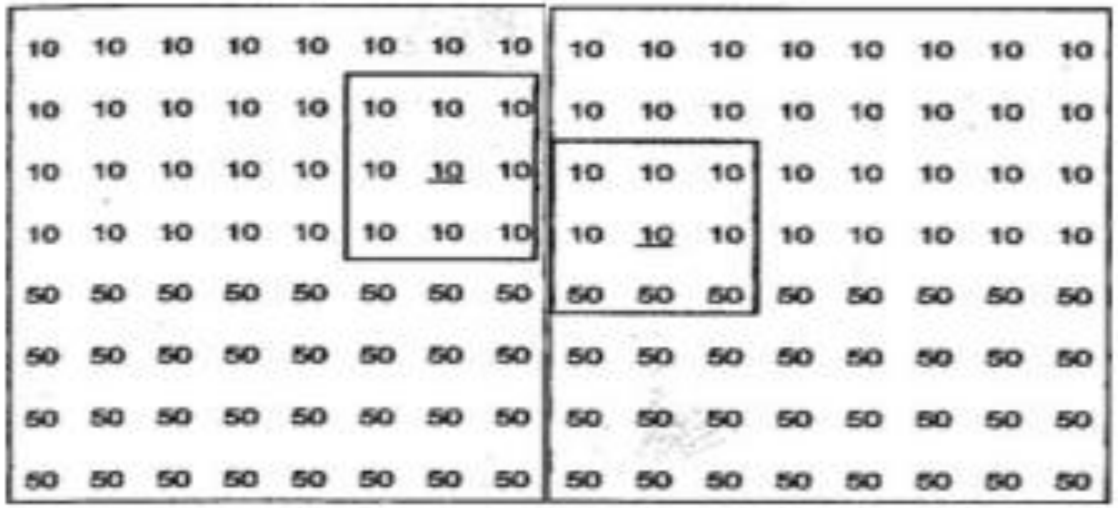


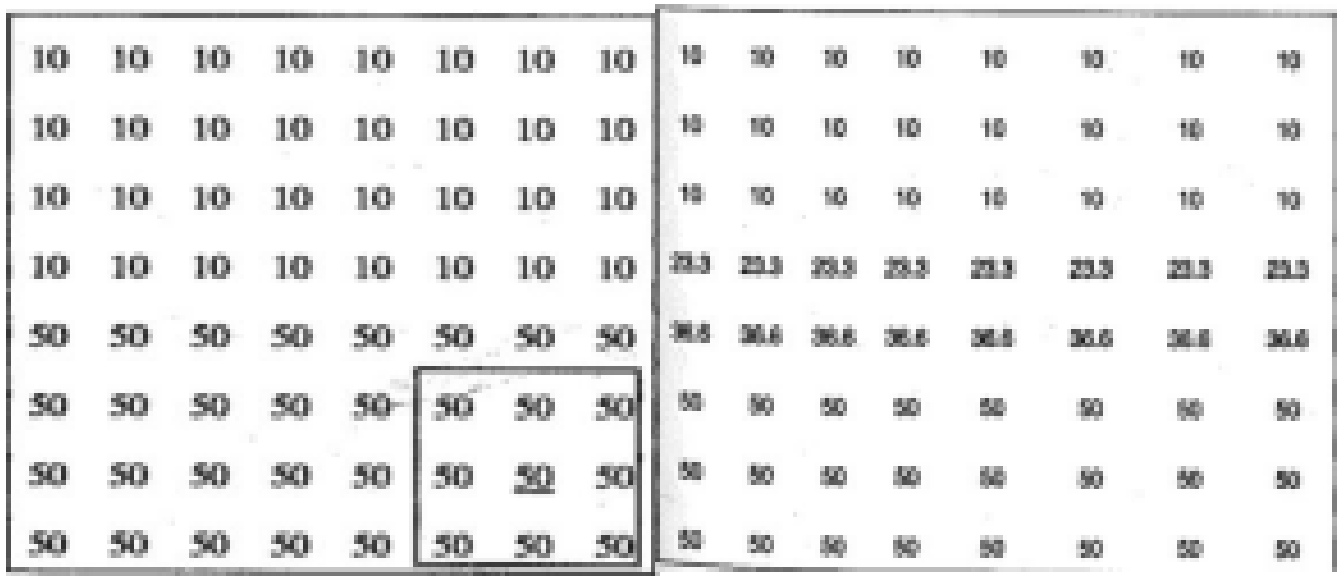
- Consider the size of image is 8 x 8.
- It is clear that 8 x 8 image have single edge between 10 and 50.
- Place the 3 x 3 average masks on this image.
- Start from top left hand corner.
- Multiply each component of image with the corresponding value of mask.
- As all values of image inside mask are 10, we get average as 10 and center pixel remains 10.
- Therefore according to equation of neighborhood processing,
- g(x, y)=1*10+1*10+1*10+1*10+1*10+1*10+1*10+1*10+1*10/9
- =10+10+10+10+10+10+10+10+10/9 =90/9 =10
- Next shift the mask toward right till we reach end of line, perform same step of calculation as explain above and then move it downwards.
- Some of calculation of mask position is shown below


10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50


10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50


10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50


10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10 10 10 10 10 10 10 10 10
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50 50 50 50 50 50 50 50 50


10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10
10 10 10 10 10 10 10 10
50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50
50 50 50 50 50 50 50 50

- Once we get final result you can observe that the low frequency region has remained unchanged. Hence we can conclude that sharp edge has become blur.
- The sharp edge between 10 and 50 has become blurred.
- We can see from grey level 10 it changes to 23.3(after rounding off its 23), from 23 it changes to 36.6(after rounding off its 36) and finally from 36 it changes to 50.

LOW PASS MEDIAN FILTER

- We have seen low pass averaging filter blurs the edges by eliminating the noise.
- Bigger the averaging mask more is blurring.
- Also there are chances image can contain salt and pepper noise.
- Salt and pepper noise refers to a wide variety of processes that result in the same basic image degradation: only a few pixels are noisy, but they are very noisy. The effect is similar to sprinkling white and black dots – salt and pepper – on the image.
- If we work with low pass averaging filter to remove the same it will blur noise but at same time it will also ruin the edges.
- Therefore we need to work with non-linear filter.
- Such non-linear filter is called as Median filter.
- Low pass median filter removes the salt and pepper noise from the image.
- They are also called as order statistic filters because their response is based on ranking of the pixels contained within the mask.
- Consider using the mask similar to averaging filter except that the mask will contain no values.

- The step to perform median filtering is as follows:
  1. Assume 3 x 3 empty mask.
  2. Place the empty mask at top left hand corner of given pseudo image.
  3. Arrange all nine pixels inside mask in ascending or descending order.
  4. Choose the median value from these nine pixels and place at center.
  5. Move the mask in similar fashion as done in averaging filter.
- Consider the 8 x 8 pseudo image with salt and pepper noise given below.
- We need to remove noise without disturbing the edges.
- Place the empty mask at top left hand corner.
- Arrange the nine pixels of image inside mask either in ascending or descending order as given below. 10 10 10 10 10 10 10 10 250
- The median is value placed at fifth position. Therefore this value is placed at the center.
- Continue this procedure until all salt and pepper noise get replaced by median value.

- Hence we get the final result as salt and pepper noise got eliminated without distortion of edges.