Visulization

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Chapter-IV

Visulization => Visulization in computer graphics is the use of imagery to convey information and makes it easier to understand.

Tools & Techniques in visulization -:

(i) 3D modeling S/w (ii) Animation S/w (iii) Rendering S/w (iv) virtual Reality technology (v) Graphics programming language

Appl^n of visulization =>

(i) Business
(ii) Marketing
(iii) Education
(iv) Data Science
(v) Health Care Industries
(vi) Food delivery apps

Visulization in computer graphics is the process and transform data into visual representation of data or infor^n using computer S/w & H/w.

In computer graphics, there are various visulization method that can be used to create diff^n types of visual representations.

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The goal of visulization is to communicate complex infor^n in a simple and intutive way.

Visulization methods-

1) **Line drawing-** This is a simple technique that involve drawing lines to represent the edge & contour of an object. Line drawing can be used to create simple 2D images or complex 3D models.

2) **Wireframe models-** A wireframe model is a 3D model that represents the surface of an object using a mesh of lines and points.
Used in-
(i) architectural
(ii) Engineering design

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3) **Lighting** ⇒ Lighting is the process of adding light source to a scene to create shadows, highlight & other lighting effects. This technique is used to create realistic lighting in 3D scene.

4) **Ray tracing** ⇒ It is a rendering techniques that simulates the behaviour of light in a 3D scene. This technique can create highly realistic images with accurate shadows, reflection & refraction.

5) **Animation** ⇒ It is the process of creating a sequence of images that simulate motion.
Used in - create animated movie, vedio game & other interactive media

Visulization in 1D, 2D, 3D Scalar fields
=>

Scalar field => A scalar field assign a single numerical value (a scalar) to each point in a space, which can be 1D, 2D or 3D.

1D Scalar visulization => 1D scalar field visuliza-tion represent a single variable along a single axis.

OR

In a 1D scalar field, the space is a line and each point on the line has a scalar value associated with it.

Ex Histogram

fig.: 1d

2D Scalar field ⇒ A 2D scalar field is a function that assigns a single numerical value to each point in a 2D dimensional space.

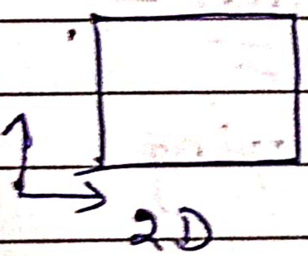
$$f: D \to R^2 \qquad (x, y)$$

D is a domain, subset of R^2.

This value can be visualized using techniques like-

Techniques for 2D Scalar field

(i) Color mapping
(ii) contour plot
(iii) Bar chart
(iv) Pie chart
(v) Line Graphs
(vi) Scatter plot
(vii) Isoline



3D Scalar field ⇒ A 3D scalar field represent a function that assigns a single value to each point in a 3D space.

$$f: D \to R^3 \qquad (x, y, z)$$

Visualization Technique for 3D scalar fields:

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(I) Iso surface
(II) Color mapping
(III) Volume rendering
(IV) 3D Graphs
(V) 3D models

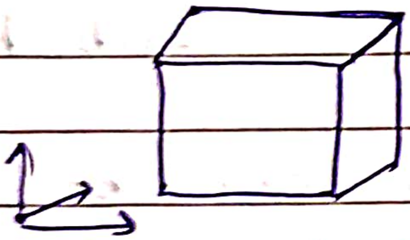

fig:- 3D

Isolines :- It is common visulization technique especially for mapping data across a 2D space.

→ They used lines to connect point of equal value like temperature or Elevation, weather maps or Topographic maps (contour line).

Ex of using Isolines:-

(i) Weather maps :- Common use of Isoline to show temperature distribution

(ii) Topographic Maps :- Contour line

(isolines representing elevation) are used to show the shape of the land.

Iso Surfaces ⇒

→ 3D surface where all points share the same scalar value within a dataset

→ Represent various data types like temperature, pressure etc

→ It is a powerful tool for visulizing & analyzing 3D scalar field.

Appl^n

1) Medical Imaging → Extracting anatomical structures like organs or bones from 3D scans. (CT scan; MRI)

2) Scientific Data ⇒ Representing various data field in chemistry; geophysics

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3) CFD (Computational fluid dynamics

⇒ Visulizing flow pattern , shock waves in fluid dynamics simulation. (liquid and gas).

It help to understand the distribution & structure of volumetric data.

Color Mapping :- Color mapping in visulization is the process of assigning colors to data values to convey information effectively.

Color mapping in 2D and 3D visulization involves assign colors to data values to enhance understanding and reveal patterns.

It can be done using various color modes like RGB , HSV , CMYK.

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Benefits:-

(i) Enhanced visulization
(ii) Increased inforⁿ Density (shapes & forms)

2D color mapping Examples:-

1) Contour Maps
2) Scatter plots with color.

3D color mapping Examples:-

1) Medical Imaging:- To highlight specific region or structures in medical scans

2) 3D models with data:- Color 3D models to represent data like temp distribution, pressure or density.

3) Scientific simulation:- Visualize results of simulations like fluid flow with color coded representation

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Direct volume Data Rendering:-

Volume data → Volume data refers to 3D data that represent values sampled in a volumetric space, typically in the form of a grid of voxels (volume elements). Unlike 2 dimensional images, volume data captures infor^n through out an entire volume, allowing for the visulization of internal structures & details

Direct volume Rendering → Direct volume Rendering is a technique used to visualize 3 dimensional volume data without first extracting surfaces or features.

DVR directly maps data value to visual properties such as color and opacity ( ) allowing for the depiction of internal structures within a volume

Voxel => [A voxel is a cubic cell, which has a single value covers the entire cubic region.]

This approach provides a comprehensive view of the data, enabling the visulization of complex features and relationship.

Rendering => It refers to the entire process that produce color values for pixels, given a 3D representation of the scene.

Used in field -:

1) Medical Imaging => organs, tumors, blood vessels

2) Scientific visulization to gain insights from volumetric data.

Techniques in DVDR -:

1) Transfer funct^n => A transfer funct^n is crucial for mapping raw scalar data to visual attributes like color & opacity.

This funct^n essentially defines how data values are visualized, playing a key role in highlighting or suppressing ( ) different features within the volume.

By assigning colors & varying degree of transparency to specific data ranges, transfer funct? help in interpreting complex data structure.

2) Ray Casting :- Ray casting is a rendering technique in computer graphics where virtual light rays are traced from a viewer's perspective to determine the colors and shading of objects in a 3D scene.

OR

Ray casting is a rendering technique that projects a 3D view of a 2D environment by tracing line (rays) from the camera's perspective.

The core idea is to find the closest object that each ray intersect, create the illusion of depth.

1) Rays :- Imagine a camera emitting a series of lines (rays) into the scene.

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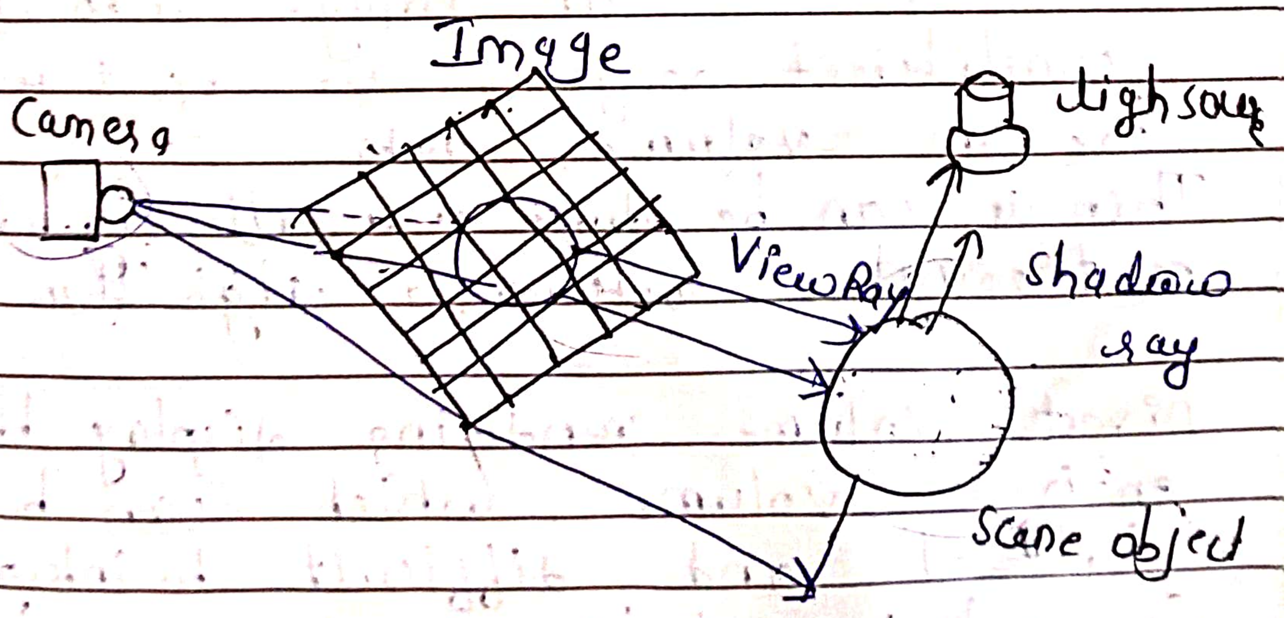
2) Intersection ⇒ Each ray is traced until it hits an object or the edge of the map.

3) Distance calculation → The distance b/w the camera and the point of intersection determines the depth of the object

4) Rendering ⇒ The information about the closest intersecting ~~poi~~ object (distance, texture etc), is used to draw a vertical strip on the screen, building up the 3D image



Opacity ⇒ Degree to which an object or element can block light, influencing its transparency or visiblity. It contd how much of the underlying background or objects can be seen through a layer

Opaque object ⇒ 100% opacity

Transparent object ⇒ 0% opacity

Segmentation ⇒ segmentation subdivide an image into its constituent region or object within the 3D volume data.
This is can be done manually by a user or through automated algorithm.

Direct volume rendering displays the entire volume, which can be cluttered and difficult to interpret. Segmentation help isolate areas of interest, making them more easily visible and analyzable

CT scan ⇒ bones ~~not~~ visible
MRI ⇒ ~~[illegible]~~ soft tissue visible

Once segmented, regions can be rendered with specific colors, opacities or other visual attributes, allowing for easier interpretation and analysis of complex 3D structures

Segmentation can be used to remove uninteresting parts of the volume (e.g. bones in a CT scan) or to isolate specific structure (e.g. tumors in a medical scan).

Ray tracing ⇒ Ray tracing works:

(i) starting point ⇒ A virtual camera is positioned within the 3D scene

(ii) Tracing light rays ⇒ The camera send send out rays of light into the scene

(iii) Interactions ⇒ As these ray travel they interact with object in the scene, potentially being reflected, refracted or absorbed

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4) Calculating pixel colors => Based on the interaction, the color of the each pixel on the screen is calculated, resulting in a realistic image

Visulization of vector and flow data =>

Vector field & flow data visulization techniques aim to represent the direction & magnitude of vectors at each point in a space, often using techniques likes

1) streamlines :- It provide the overall flow direction & structure of a particle.

2) Glyphs :- Glyphs like arrows or hedgehogs are used to represent the vectors at each point with varying length, thickness, or color to identicate magnitude

→ direction

3) **Hedgehog plots** :- Also known as line glyphs visulize the direction & magnitude of vectors using lines or arrows.

4) **Vector arrows** :- Simple arrows plotted at regular intervals can provide a basic representation of the vector field.

Appl^n

1) **Medical Imaging** :- Representing blood flow, diffusion of molecules

2) **Meterology** :- Visulizing atmospheric pressure gradients & wind direct^n

High Dimensional data ⇒ High dimensional data visulization refers to the techniques and strategies used to represent and explore datasets with a large no. of features or variables.

Goal → The goal is to reveal hidden patterns, relationship and insight within complex dataset

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Importance ⇒ High dimensional data visulization is crucial for making better decisions, communi-cating finding & gaining a deeper understanding of data.

⇒ Traditional visulization methods (like scatter plots, histograms) struggle to efficiently represent data with more than a few dimensions.

Techniques for High-dimensional data visulization ⇒

1) Dimensional reduction ⇒ It reduces the no. of dimensions while preserving the data's essential structure allowing for easier visulization

Techniques
i) PCA
ii) t-SNE (distributed Stochastic Neighbour Embedding).

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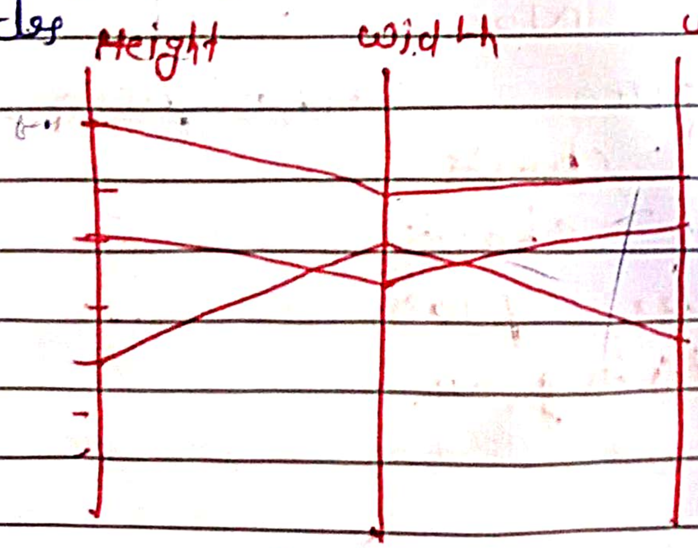
PCA → PCA is a dimensionally reduction technique that transform high dimensional data into lower dimensional space while preserving as much of the original variance as possible.

2) Parallel co-ordinates → A parallel coordinates plot is graphical method where each observation or data point is depicted as a line traversing a series of ∥ axes, corresponding to a specific variable or dimension.

→ ∥ coordinates plots are ideal for comparing many variable together & seeing the relationship b/w them.

for ex → If you had to compare an array of product with the same attributes



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Non-spatial data ⇒ Non-spatial data visulization involves using graphical methods to represent data that is not inherently linked to a geographic location.

Non-spatial data, also known as attribute or characteristic data, is independent of spatial coordinates and focuses on "what" rather than "where".

Ex: Non-spatial data includes lists of reference values characteristics of spatial features such as population of a town, its names or types of transporation which are not dependent on their geographic location.

Common Non-Spatial Data Visulization Techniques:-

1) Bar charts
2) Point Charts
3) Scatter plots
4) Histogram.

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Multivariate ⇒ Multivariate data refers to data where multiple variable / features are measured or observed for each individual or observation.

Ex You might be analyzing the relationship b/w income, education level for a group of people.

Tree Graph Structure ⇒ Tree graph are hierarchial data structure where nodes represents data points & edges represent relationship b/w them. They are useful for visualizing:

(i) **Hierarchial relationship** :- for example visulizing an organizational chart where employees are grouped into departments & then further into teams.

Ex Brain neurons can be represented as a tree, with the cell body as the root & dendrites as branches

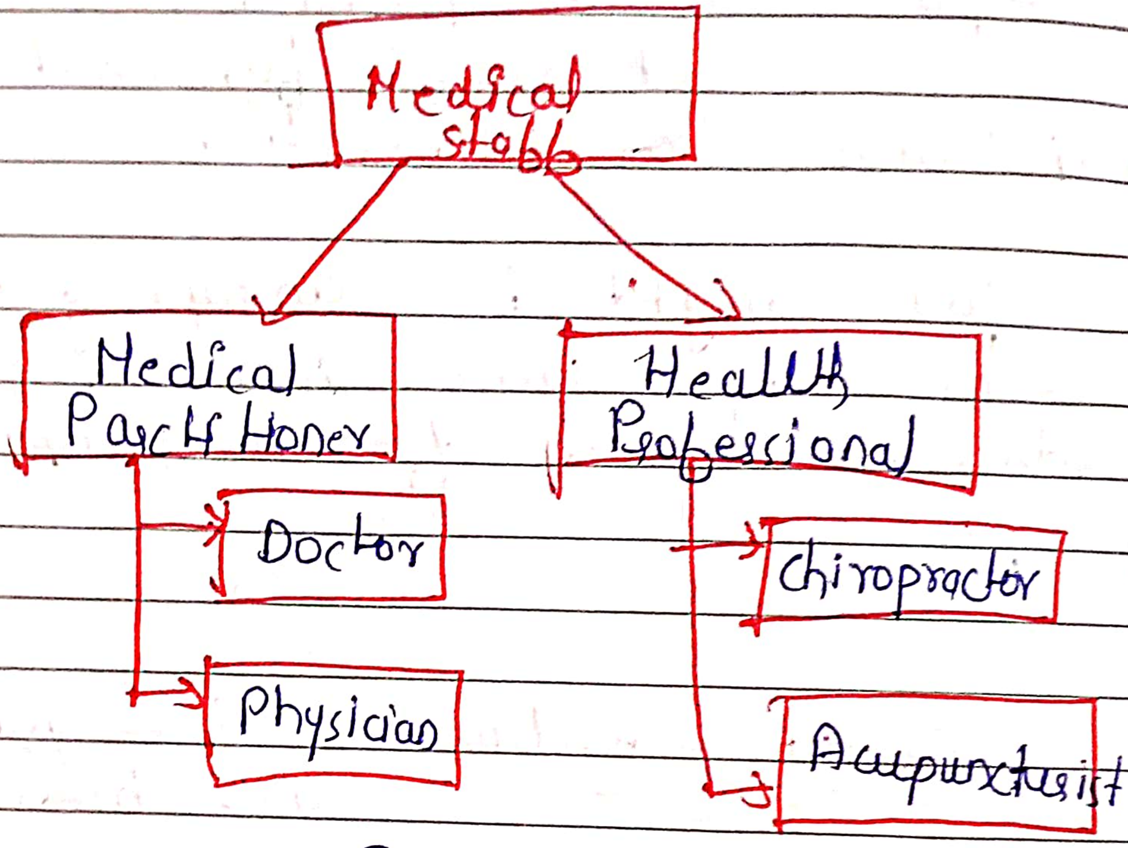

Fig: Tree structured Graph.

Animation Techniques:-

Traditional Animation / Cel Animation =>

Each frame is drawn by hand typically on cels (clear sheets) placed over painted backgrounds.

→ It is very time consuming

GIS ⇒

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Ex Snow white & Little Mermaid are examples of traditional animation.

Keyframe Animation ⇒ Animators define key positions or poses at specific points in time & the s/w interploates the in-b/w frames.

By this animators have control over the timing & motion of the animation, allowing for precise & smooth transition

Works

1) Define keyframes ⇒ Animators set keyframes at specific points in time, defining the starting & ending positions or properties of an object or character.
2) Interpolation ⇒ The animation s/w fills in the gaps b/w the keyframes, creating the in-b/w frames that smoothly transition the object from one keyframe to the next.
3) Control ⇒ keyframes allow animators to control the movement & behaviour of

objects at specific points in time.

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Text Perceptual and Cognitive foundation
=>

Text Perceptual => Text perception in visulization refers to how effectively visual elements like text labels, title, annotation within a visulization convey infor? and influence how the users interprets the data.

key aspects in Text Perception =>

1) Legibility => Text should be easy to read, considering factors like:
→ font choice
→ size
→ spacing

2) Clarity => Text should be concise & avoid complex language to ensure easy understanding

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3) Context => Text should provide the necessary context for visulization, helping viewer interpret the data & understand its significance

4) Positioning
5) Colors

Cognitive in visulization => Cognitive visulization is refers to the study of how humans perceive and interpret visual infor" to understand data

Ex
1) Data storytelling
2) Charts & Graphs
3) Maps
4) User Interface design