3D Display Methods in Computer Graphics

Introduction

Three-dimensional (3D) display methods are techniques used in computer graphics to represent objects with **depth, height, and width**, giving a realistic perception of the real world. Since display devices are two-dimensional, special methods are used to create the illusion of depth using **human visual perception**, **stereoscopy**, and **optical principles**.

Classification of 3D Display Methods

3D display methods can be broadly classified into:

1. **Stereoscopic Display Methods**
2. **Autostereoscopic Display Methods**
3. **Volumetric Display Methods**
4. **Holographic Display Methods**
5. **Depth Cueing Techniques**

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1. Stereoscopic Display Methods

Stereoscopic displays create the illusion of depth by presenting **two slightly different images** to each eye, similar to human binocular vision.

Working Principle

- Left-eye and right-eye images are generated with slight horizontal displacement.
- Each eye sees only its corresponding image.
- The brain fuses both images to perceive depth.

Types of Stereoscopic Displays

(a) Anaglyph Method

- Uses **red and cyan (or blue-green)** colored images.
- Viewer wears glasses with colored lenses.
- Simple and low-cost method.

Advantages

- Inexpensive
- Easy to implement

Disadvantages

- Color distortion
- Eye strain

(b) Polarized Glasses Method

- Two images projected with different polarization angles.
- Glasses filter images using polarized lenses.

Advantages

- Better color reproduction
- Reduced eye strain

Disadvantages

- Requires special screens and glasses

(c) Active Shutter Glasses

- Uses LCD shutter glasses synchronized with display.
- Images for left and right eye shown alternately.

Advantages

- High-quality 3D effect
- Full color images

Disadvantages

- Expensive
- Requires synchronization hardware

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2. Autostereoscopic Display Methods

Autostereoscopic displays provide a 3D effect **without the need for glasses**.

Techniques Used

(a) Parallax Barrier

- A barrier with vertical slits placed in front of the screen.
- Directs different pixels to each eye.

(b) Lenticular Lens

- Uses cylindrical lenses placed over the screen.
- Directs different images to different viewing angles.

Advantages

- No glasses required
- User-friendly

Disadvantages

- Limited viewing angles
- Reduced resolution

Applications

- 3D televisions
- Mobile phone displays
- Advertising displays

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3. Volumetric Display Methods

Volumetric displays create images by generating **light points (voxels)** in a physical 3D space.

Working Principle

- Images are formed within a volume rather than on a flat surface.
- Viewer can see different sides of the object naturally.

Types

- Swept-volume displays
- Static volumetric displays

Advantages

- True 3D representation
- 360-degree viewing

Disadvantages

- Complex and expensive
- Limited color and resolution

Applications

- Medical imaging
- Scientific visualization
- Air traffic control

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4. Holographic Display Methods

Holography records and reconstructs **light wave interference patterns** to display a complete 3D image.

Working Principle

- Uses laser light to record interference between reference and object beams.
- When illuminated, the hologram reconstructs the 3D image.

Advantages

- Highly realistic 3D images
- Full depth cues available

Disadvantages

- Requires laser sources
- High computational and hardware cost

Applications

- Security systems
- Medical visualization
- Advanced research and entertainment

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5. Depth Cueing Techniques (Pseudo-3D Methods)

These techniques enhance depth perception without true 3D display hardware.

Common Depth Cues

- **Perspective projection**
- **Shading and lighting**
- **Occlusion**
- **Texture gradients**
- **Motion parallax**
- **Depth fogging**

Advantages

- Easy to implement
- No special hardware required

Disadvantages

- Not true 3D
- Limited realism compared to stereoscopic methods

Comparison Summary

Method	Glasses Required	True 3D	Cost	Applications
Stereoscopic	Yes	Partial	Medium	Movies, VR
Autostereoscopic	No	Partial	High	3D TVs
Volumetric	No	Yes	Very High	Medical, Scientific
Holographic	No	Yes	Very High	Research, Security
Depth Cueing	No	No	Low	Games, CAD

Conclusion

3D display methods play a vital role in computer graphics by enhancing realism and user interaction. Each method has its own advantages and limitations, and the choice depends on **application requirements**, **cost**, and **level of realism needed**. With advancements in graphics hardware and display technologies, 3D display systems continue to evolve and find applications in entertainment, medicine, education, and virtual reality.

Projection and Its Types in Computer Graphics

Introduction

In computer graphics, **projection** is the process of transforming a **three-dimensional (3D) object** onto a **two-dimensional (2D) display surface** such as a computer screen or paper. Since display devices are 2D, projection techniques are used to represent 3D objects accurately by preserving certain geometric properties like **shape, size, and depth**.

Need for Projection

- To display 3D objects on 2D screens
- To visualize engineering and architectural designs
- To represent depth and spatial relationships
- To simplify rendering and visualization

Classification of Projection

Projections are broadly classified into:

1. **Parallel Projection**
2. **Perspective Projection**

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1. Parallel Projection

In **parallel projection**, the **projectors (projection lines)** are parallel to each other. The center of projection is assumed to be at infinity.

Characteristics

- Object size remains unchanged regardless of distance
- No perspective distortion
- Useful for engineering drawings

Types of Parallel Projection

(a) Orthographic Projection

- Projectors are perpendicular to the projection plane.
- Most commonly used projection in engineering.

Views:

- Front view
- Top view
- Side view

Advantages

- True shape and size preserved
- Easy to measure dimensions

Applications

- CAD systems
- Mechanical drawings

(b) Axonometric Projection

In axonometric projection, the object is rotated about one or more axes before projection.

Types of Axonometric Projection

i) Isometric Projection

- Angles between the projected axes are equal (120°).
- All three axes are equally foreshortened.

Advantages

- Easy to construct
- Widely used in technical drawings

ii) Dimetric Projection

- Two axes have equal foreshortening.
- Third axis has a different scale.

iii) Trimetric Projection

- All three axes have different foreshortening.

(c) Oblique Projection

- Projectors are at an angle (not perpendicular) to the projection plane.
- One face of the object is shown in true shape.

Types of Oblique Projection

i) Cavalier Projection

- Receding axis is drawn at full scale.
- Angle usually 45°.

ii) Cabinet Projection

- Receding axis is drawn at half scale.
- Produces a more realistic view.

Applications

- Furniture design
- Technical illustrations

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2. Perspective Projection

In **perspective projection**, projectors converge at a **finite center of projection**. It mimics human vision.

Characteristics

- Distant objects appear smaller
- Provides realistic depth perception
- Size varies with distance

Types of Perspective Projection

(a) One-Point Perspective Projection

- One vanishing point
- One face of the object is parallel to the projection plane

(b) Two-Point Perspective Projection

- Two vanishing points
- Object edges are not parallel to the projection plane

(c) Three-Point Perspective Projection

- Three vanishing points
- Used for tall buildings or deep scenes

Advantages

- Highly realistic representation

Disadvantages

- Measurements are not accurate
- Complex to construct

Comparison Between Parallel and Perspective Projection

Feature	Parallel Projection	Perspective Projection
Projectors	Parallel	Converging
Realism	Low	High
Size Accuracy	Preserved	Not preserved
Depth Effect	Weak	Strong
Applications	Engineering	Games, Movies

Conclusion

Projection techniques are fundamental in computer graphics for converting 3D objects into 2D representations. **Parallel projections** are preferred for technical accuracy, while **perspective**

projections are used for realistic visualization. Understanding the types of projections helps in choosing the appropriate method for different graphics applications.

Below is a **detailed, exam-oriented answer** suitable for a **17-marks question** in **Computer Graphics**, with definitions, equations, properties, algorithms, comparison, and applications.

Bézier and B-Spline Curves in Computer Graphics

Introduction

In computer graphics, **curves** are used to model smooth shapes in CAD/CAM, animation, font design, and surface modeling. Among the most important parametric curves are **Bézier curves** and **B-spline curves**. These curves are defined using **control points** and **blending functions**, allowing designers to create smooth and flexible shapes.

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1. Bézier Curves

Definition

A **Bézier curve** is a **parametric curve** defined by a set of **control points**, where the curve is generated using **Bernstein basis polynomials**.

Mathematical Representation

For **n + 1 control points** $P_0, P_1, \ldots, P_n$, the Bézier curve is given by:

$$B(t) = \sum_{i=0}^{n} P_i \, B_{i,n}(t), \quad 0 \le t \le 1$$

where

$$B_{i,n}(t) = \binom{n}{i} (1-t)^{n-i} t^i$$

are **Bernstein basis polynomials**.

Types of Bézier Curves

- **Linear Bézier curve** (2 control points)
- **Quadratic Bézier curve** (3 control points)
- **Cubic Bézier curve** (4 control points – most common)

Properties of Bézier Curves

1. Curve passes through the **first and last control points**
2. Entire curve lies within the **convex hull** of control points
3. Curve is **tangent** to the line joining first two and last two control points
4. Affine invariance (translation, rotation, scaling)
5. Global control – moving one control point affects the entire curve

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de Casteljau Algorithm

The **de Casteljau algorithm** is a recursive method to compute Bézier curves using **linear interpolation**.

Steps:

1. Start with control points
2. Interpolate points for parameter (t)

3. Repeat until a single point is obtained on the curve

Advantages

- Numerically stable
- Easy to implement

Advantages of Bézier Curves

- Simple and intuitive
- Easy to design and edit
- Widely supported in graphics systems

Disadvantages of Bézier Curves

- Lack of local control
- Complex shapes require high-degree polynomials

Applications

- Font design (TrueType fonts)
- Vector graphics (SVG, PostScript)
- Animation paths

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2. B-Spline Curves

Definition

A **B-spline (Basis Spline) curve** is a generalization of Bézier curves that provides **local control** and is defined by **control points**, **degree**, and a **knot vector**.

Mathematical Representation

A B-Spline curve of degree p is defined as:

$$C(t) = \sum_{i=0}^{n} P_i \, N_{i,p}(t)$$

where

- P_i → control points
- $N_{i,p}(t)$ → B-Spline basis functions
- Knot vector: $U = \{u_0, u_1, ..., u_m\}$

B-Spline Basis Functions (Cox–de Boor Formula)

$$N_{i,0}(t) = \begin{cases} 1 & u_i \le t < u_{i+1} \\ 0 & \text{otherwise} \end{cases}$$

$$N_{i,p}(t) = \frac{t - u_i}{u_{i+p} - u_i} N_{i,p-1}(t) + \frac{u_{i+p+1} - t}{u_{i+p+1} - u_{i+1}} N_{i+1,p-1}(t)$$

Properties of B-Spline Curves

1. **Local control** – moving a control point affects only part of the curve
2. Curve lies within the convex hull of control points
3. Degree of curve is independent of number of control points
4. Can be **open**, **closed**, **uniform**, or **non-uniform**
5. Continuity can be controlled ((C^0, C^1, C^2) continuity)

Types of B-Splines

- **Uniform B-splines**
- **Non-uniform B-splines**
- **Open B-splines**
- **Closed B-splines**

Advantages of B-Spline Curves

- Better shape control
- Lower-degree polynomials for complex curves
- High smoothness and continuity

Disadvantages of B-Spline Curves

- More complex mathematics
- Requires knot vector management

Applications

- CAD/CAM systems
- Automotive and aircraft design
- Surface modeling (NURBS)

Comparison Between Bézier and B-Spline Curves

Feature	Bézier Curve	B-Spline Curve
Control	Global	Local
Degree	Depends on control points	Independent
Complexity	Simple	More complex
Flexibility	Limited	High
Applications	Fonts, vector graphics	CAD, surface modeling

Conclusion

Bézier and B-spline curves are fundamental tools in computer graphics for modeling smooth and flexible shapes. **Bézier curves** are simple and intuitive but lack local control, whereas **B-splines** provide greater flexibility, smoothness, and control, making them ideal for advanced modeling applications. Understanding both curves is essential for effective geometric design in computer graphics.
