

Introduction to Computer Graphics

Introduction to Computer Graphics

Key concepts, terminology, and foundational techniques

1. What Is Computer Graphics?

Aspect	Description
Definition	The creation, manipulation, and representation of visual data using computers.
Goal	Transform data into images that can be displayed on screens, printed, or used in virtual environments.
Main Domains	1. 2D Graphics – UI design, vector illustration, raster imaging. 2. 3D Graphics – Modeling, animation, rendering, virtual reality.
Typical Applications	Video games, movies, scientific visualization, CAD, UI/UX design, AR/VR, medical imaging, simulation.

2. Core Pipeline Overview

- Modeling** – Build geometric representation (meshes, curves, surfaces).
- Scene Setup** – Position objects, define cameras, lights, and environment parameters.
- Transformation** – Apply linear algebra (translation, rotation, scaling) to move objects into view space.
- Projection** – Convert 3D coordinates to 2D screen coordinates (orthographic or perspective).
- Rasterization** – Turn geometric primitives into fragments/pixels.
- Shading** – Compute color for each fragment (lighting, textures, material properties).
- Post-Processing** – Effects such as anti-aliasing, bloom, depth of field.
- Display** – Send final pixel buffer to the monitor or output device.

Visualization

! [Simplified graphics pipeline diagram] (imagine a flowchart from Modeling → Display)

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3. Mathematical Foundations

Topic	Why It Matters	Typical Use
Vectors & Points	Represent positions, directions, and colors.	Vertex coordinates, normals, light vectors.
Matrices	Encode linear transformations (rotate, scale, translate).	Model, view, and projection matrices.
Homogeneous Coordinates	Allow translation to be expressed as matrix multiplication.	4×4 transformation matrices.
Dot & Cross Products	Compute angles, projections, and normals.	Lighting calculations, backface culling.
Interpolation	Smoothly vary values across primitives.	Gouraud shading, texture mapping.
Linear Interpolation (LERP)	Blend between two values.	Animation blending, morph targets.
Barycentric Coordinates	Express a point inside a triangle as a weighted sum of vertices.	Texture mapping, rasterization.

4. 2D Graphics Basics

Concept	Description	Common APIs
Raster Images	Grid of pixels; each pixel stores color (RGB, RGBA).	HTML5 Canvas, GDI+, Pillow (Python).
Vector Graphics	Geometry defined by mathematical equations (lines, curves).	SVG, PDF, OpenVG.
Color Models	RGB, CMYK, HSV, HSL, YUV.	Color manipulation, blending.
Alpha Blending	Combine foreground/background using transparency.	Porter-Duff compositing.
Transformations	2D translation, rotation, scaling, shear.	CSS transforms, Canvas <code>setTransform</code> .
Clipping	Restrict drawing to a defined region (viewport).	Scissor test, CSS <code>clip-path</code> .

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5. 3D Graphics Fundamentals

5.1 Geometry Representation

Representation Typical Data Pros / Cons