# ERI 1

- Prof. Dr. Kalpana Shankhwar
- This course aims to introduce extended reality (XR/AR, VR, MR) and its applications in Industry 4.0. It covers various topics that are integral parts of XR technology, for example, haptic technology, 3D modeling, tracking, metaverse and digital twin. The main focus of this course is to enable students to develop their own Android/iOS augmented reality (AR) applications. In addition, the students will also get familiar with using Microsoft HoloLens2 AR headset.

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# Lecture 1: Introduction

## Instructor Information

- **Instructor:** Dr. Kalpana Shankhwar
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- **Office Hours:** Monday 1:30–3:30 pm
- **Class Timings:** Monday and Thursday 11:00–12:30 pm
- **Google Classroom:** https://classroom.google.com/c/NzkxMzY2MDQyNDgw?cjc=egnlvkyb
- **Class Code:** egnlvkyb

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## About the Instructor

- PhD in Mechanical Engineering (National Taiwan University)
- M.Tech in Mechanical Engineering (IIT Guwahati)
- B.E. in Mechanical Engineering (SGSITS Indore)
- Industry experience as Engineer at MAN Trucks India Pvt. Ltd.
- Assistant Professor at KIIT University, Bhubaneswar and currently at IIIT Delhi since July 2023.

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## Lab Focus: Emerging Technology Integrated Design & Manufacturing (ETIDM) Lab

- Research on **Emerging Technologies** like:
  - Extended Reality (XR): Includes Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR)
  - Artificial Intelligence (AI)
  - Digital Twin
  - Internet of Things (IoT)
  - Haptic Technology
- Smart systems for **Industry 4.0** and **Education 4.0** contexts.
- Interdisciplinary applications: education, healthcare, manufacturing, teleoperation, safety guidance.

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## Grading Policy

| Evaluation Type | Contribution to Final Grade |
| --- | --- |
| Class Exercise (participation) | 10% |
| Assignments (4 total) | 30% |
| Final Project (individual or group) | 20% |
| Midterm Exam | 15% |

| Evaluation Type | Contribution to Final Grade |
| --- | --- |
| End Term Exam | 25% |

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## Extended Reality (XR)

- XR is an umbrella term for technologies that blend the physical and virtual worlds.
- Key components include VR, AR, and MR.

#### Virtual Reality (VR)

- Completely artificial environment experienced via computer-generated sensory stimuli (sight, sound).
- Provides *immersive experience* enabling navigation and interaction in 3D spaces.
- Users' actions influence the environment dynamically.

#### Augmented Reality (AR)

- Enhances reality by overlaying digital information onto the physical world.
- Usually accessed via smartphone cameras or smart glasses.
- Virtual objects appear integrated into the real-world scene.

#### Mixed Reality (MR)

- Combines AR and VR by allowing interaction between physical and virtual objects in real time.
- Virtual and real objects coexist and can be manipulated interactively.

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## History of Virtual Reality

- **1838:** Charles Wheatstone demonstrated depth perception using stereoscopic photos viewed through a stereoscope, creating a 3D illusion by presenting slightly different images to each eye.
- **1929:** Edward Link created the first commercial flight simulator ("Link Trainer")—an electromechanical device mimicking turbulence and aircraft motion.
- **1950s:** Morton Heilig developed the Sensorama, an arcade-style multi-sensory theatre.
- **1960:** Heilig invented the Telesphere Mask, the first head-mounted display (HMD) with stereoscopic 3D and stereo sound but without motion tracking.
- **1961:** Philco engineers created the Headsight, the first motion-tracking HMD linked to remote camera viewing—used mainly for military applications.
- **1968:** Ivan Sutherland and Bob Sproull developed the Sword of Damocles, the first computer-connected VR HMD, which was bulky and suspended from the ceiling.
- **1987:** Jaron Lanier coined the term "virtual reality" and developed early VR devices including data gloves and HMDs.
- **1997:** VR was used for PTSD treatment for war veterans by Georgia Tech and Emory University.
- **2007 onward:** Mass adoption begins, with Google Street View (360-degree imagery), Oculus Rift Kickstarter in 2012, and later commercial VR products (HTC Vive, Oculus Quest, Microsoft HoloLens).

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## Industry 4.0 and XR in Industry

- **Industry 4.0:** The current industrial revolution characterized by digital integration of manufacturing processes with intelligent automation, IoT, AI, and smart machines for efficient and flexible production.
- In Industry 4.0, smart devices, sensors, and machines are interconnected for autonomous communication and minimal human intervention.
- XR technologies play a key role in:
    - Smart training and tutorials
    - Real-time visualization of manufacturing processes
    - Remote operation and teleoperation of machinery
    - Assembly and maintenance tasks
    - Human-robot collaboration
    - Health and safety training
    - Architecture and design simulation

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## XR Applications in Industry

- Assembly and maintenance process assistance
- Teleoperation of robotic systems
- Welding and manual milling training simulators
- Visualization of finite element analysis data
- Medical and surgical training with haptics
- Skill evaluation and performance tracking
- Architecture and customized design visualization
- Safety and emergency response training
- Interactive gaming and educational tools

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## Important XR Devices and Tools Timeline (Recent)

| Year | Device/Technology | Description |
|---|---|---|
| 2007 | Google Street View | Street-level immersive 360-degree imagery |
| 2010 | Oculus VR prototype | Development of modern VR headset prototype |
| 2012 | Oculus Rift Kickstarter | Crowdfunded launch of a consumer VR headset |
| 2014 | Google Cardboard, Samsung Gear VR | Affordable mobile VR platforms powered by smartphones |
| 2016 | HTC Vive | PC-tethered VR with room-scale tracking |
| 2019 | Oculus Quest | Standalone wireless VR headset |
| Present | Vision Pro, HoloLens 2, Meta Quest 3 | Advanced AR/VR/MR devices blending digital and real worlds |

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## Summary: Industrial Revolutions

| Wave | Period | Core Technology | Industrial Impact |
|---|---|---|---|
| 1st | 1750–1850 | Mechanization, water & steam power | Mass production replaces manual labor |
| 2nd | 1870–1914 | Assembly line, electricity, oil & gas | Increased production volume & communication tech |
| 3rd | 1970–2010 | Computing, automation, telecommunications | Digitization of factories, programmable automation |
| 4th | 2011–present | Cyber-physical systems, IoT, AI, XR | Smart factories, automation with minimal human input |

### Additional Notes on XR Technologies

- XR not only enhances immersion but also offers **interactive experiences** that improve learning effectiveness and operational safety.
- Haptic devices integrated with XR provide **tactile feedback**, crucial for applications like surgical training or remote machinery operation.
- Gesture-based interfaces and real-time 3D reconstruction improve the naturalness of human-machine interaction.
- GenAI (Generative AI) visualization combined with XR creates highly customized and dynamic virtual environments for architecture and design.

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## Lecture 2: Introduction to Extended Reality Hardware and Software

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### Overview

Extended Reality (XR) encompasses technologies that merge the real and virtual worlds to create immersive experiences. XR includes **Virtual Reality (VR)**, **Augmented Reality (AR)**, and **Mixed Reality (MR)**. These technologies play a crucial role in Industry 4.0 by enhancing manufacturing, training, design, and maintenance processes.

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### Course & Instructor Details

- Instructor: Dr. Kalpana Shankhwar, Assistant Professor, IIIT Delhi
- Class Timings: Monday & Thursday 11:00-12:30 pm
- Office Hours: Monday 1:30-3:30 pm
- Contact: kalpana@iiitd.ac.in
- Grading Structure:
  - Class Exercises: 10%
  - Assignments: 30%
  - Final Project: 20%
  - Mid Term Exam: 15%
  - End Term Exam: 25%

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## Weekly Topics and Focus Areas

| Week | Topic | Activities |
| --- | --- | --- |
| 1 | Historical overview, trends, and future applications of XR technologies | Introduction; types of game engines |
| 2 | 3D creation, design and modeling theory for XR | Engineering drawing, computer graphics basics |
| 3 | Basics of 3D modeling software and interface | 3D modeling of objects |
| 4 | Game engine tools for XR, importing 3D models | In-class exercise |
| 5 | User interface elements in game engines | Assignment/In-class exercise |
| 6 | Tracking for AR, types of tracking methods | Vuforia Engine introduction |
| 7 | Building Android/iOS AR apps | Assignment/In-class exercise |
| 8 | Particle systems and 3D modeling in them | |
| 9 | Haptic technology and visuo-haptic XR | Assignment/In-class exercise |

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## Key Concepts in XR

#### Types of XR

- **Extended Reality (XR):** Umbrella term for VR, AR, and MR technologies.
- **Virtual Reality (VR):** Fully immersive digital environments.
- **Augmented Reality (AR):** Overlaying virtual elements on the real world.
- **Mixed Reality (MR):** Blending real and virtual worlds interactively.

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## Haptic Technology

Haptics add the *sense of touch* to XR to make experiences more immersive.

#### Types of Haptic Feedback

- **Kinesthetic:** Senses force and motion involving muscles and joints. Simulates size and density of objects through physical sensations.
- **Tactile:** Relates to skin sensations such as vibration, surface texture, temperature, and pressure.

#### Devices and Application

- Kinesthetic devices use motors or actuators to simulate forces.
- Tactile devices use vibrations or temperature changes on the skin.

Examples of haptic feedback implementation include VR controllers that provide force feedback or mobile phone vibrations.

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## XR Development Platforms

- **Unity Engine:** Most accessible, supports 2D and 3D apps using C#. Extensive online resources available.
- **Unreal Engine:** Known for powerful rendering, performs well with fewer computing resources, uses C++.
- **Vuforia Studio:** Platform focused on AR development.

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## XR Hardware

### Device Types

- **Mobile devices, tablets, laptops:** Common platforms for lightweight XR applications.
- **Head Mounted Displays (HMDs):** Key XR hardware with varying specificity for AR or VR.

### Examples

- AR HMDs: Microsoft HoloLens 2, Google Glass, Epson.
- VR HMDs: Oculus Quest, HTC Vive, Valve Index.

### Advantages of AR devices

- Immersive experiences
- Connection with the real world
- Hands-free operations

### Disadvantages of AR devices

- Small field of view
- User discomfort for long use
- Limited battery life
- Higher cost

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## Tracking in XR

Tracking is essential to synchronize physical and virtual environments by detecting position and orientation of objects in real-time.

### Tracking Types

- **Head Tracking:** Tracks the position/orientation of the HMD.
- **Hand Tracking:** Tracks hand movements and gestures.
- **Eye Tracking:** Detects gaze direction for interaction and foveated rendering.
- **Full Body Tracking:** Tracks the entire body’s movements.
- **Object Tracking:** Detects and tracks other physical objects.

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## Degrees of Freedom (DoF) in Tracking

Degrees of Freedom define the types of movements a device can track.

**3DoF (Three Degrees of Freedom)**

- Tracks rotational movements only:
  - **Roll:** Tilting head side to side.
  - **Pitch:** Nodding head up/down.
  - **Yaw:** Turning head left/right.
- Does **not** track translational movement (walking, sidestepping).

**6DoF (Six Degrees of Freedom)**

- Tracks rotational and translational movements:
  - Rotation: Roll, Pitch, Yaw.
  - Translation: Moving forward/backward (surge), left/right (strafe), up/down (elevate).
- Enables full 3D movement and immersive interaction in virtual spaces.

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## Emerging Technologies Related to XR & Industry 4.0

- Robotics
- Artificial Intelligence (AI)
- Drones
- Internet of Things (IoT)
- Large Language Models (LLM)
- Generative AI
- Haptics
- Brain Computer Interface (BCI)
- Autonomous vehicles (Self-driving cars)

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# Lecture 3: Introduction to 3D Creation

*Dr. Kalpana Shankhwar, IIIT Delhi*

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## Introduction

- A picture is worth a thousand words.
- Use of drawing language to convey ideas.
- Engineering drawing is a “standardized” drawing language.
- Important for product development:
  - Product specification
  - Product drawing
- Engineering drawing is an effective communication language between engineers.
- Geometric theorems are essential in engineering drawing.

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## What is 3D modeling?

- Constructing drawings on a computer screen using specialized software and hardware is called Computer Aided Drafting (CAD) or 3D modeling.
- CAD drawings are clearer and more precise than manual drawings.
- It creates interactive designs representing real-life objects.
- Allows quick creation and analysis of physical properties of parts and iterative updating of models.
- Widely used for internal and client presentations.
- Can be time and cost-efficient.

**Visual Representation**

- 3D modeling is visually represented in 2D using 3D rendering or visualization techniques.

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### 3D Modeling Methods

- **Polygonal Modeling**: Represents points in 3D connected by line segments forming polygon meshes.
- **Curve Modeling**:
  - Uses curves to generate surface geometry.
  - Curves can be parametric (based on geometric/functional relationships) or freeform.
  - Curves influenced by mathematical equations and designer's control points.
- **Digital Sculpting**:
  - Newer method.
  - User interacts with the model like sculpting virtual clay.
  - Enables pushing, pulling, pinching, or twisting of the digital clay.

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### Importance of Computer Graphics

- CAD systems rely on Interactive Computer Graphics (ICG).
- Converts user commands into graphical representations.
- Supports creating, modifying, storing, and exploring drawings.
- Also essential in Computer-Aided Manufacturing (CAM) where graphics data is converted to machining data for CNC machines.
- Computer graphics hardware and software are primary constituents.
- 3D modeling software is designed to be interactive, intuitive, and user-friendly.
- Software interface has two main parts:
  - Graphics window: visual feedback of object design.
  - Command window: for entering commands.

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### Advantages of CAD

- **Accuracy:** Higher accuracy than manual drawing.
- **Speed:** Faster drawing creation; features like copy, mirror, array, automatic hatching, text, and dimensioning.
- **Easy Editing:** Drawings can be edited easily; components can be reused.
- **Standard Libraries:** Standard parts like gears, valves included.
- **Scaling:** Objects can be scaled up or down automatically.
- **Better Visualization**

- **Freedom from manual instruments**
- **Space Effectiveness**

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## Applications of 3D/CAD Modeling

- **Viewing:** Easily create and visualize 3D components and generate multiple views including sectional.
- **Mechanism:** Model components to simulate real kinematic assembly.
- **Finite Element Method (FEM):** Numerical method for solving physical problems using differential equations.
- **Manufacturing:**
  - Computer-aided manufacturing via CNC machines,
  - Robotic applications,
  - Automated measuring and inspection.
- **3D Printing:** Physical object creation via layer-wise material addition controlled by computer.
- **Entertainment:** Character creation in films and TV using 3D sculpting.
- **Automation:** Programming CAD for automatic component generation with variable parameters.
- **Fashion:** Virtual clothes design and dynamic visualization.
- **Medicine:** Design prosthetics and parts for organ repair.

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## Dimensioning

- Shows exact size (length, width, height, diameter) on drawings.
- Uses numerical values with lines, symbols, and notes.
- Most common measurement unit: millimeters (mm).
- Symbols for special features like diameter (Ø), radius (R), square (SQ), cylinder (CYL), etc.
- Dimension elements: dimension line, extension lines, arrowheads, leader, notes.
- Uses standard rules:
  - Align system,
  - Do not mix dimensioning system styles,
  - Follow preferred dimensioning styles for clarity.

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## Scales in Drawing

- Objects drawn to scale: enlarged or reduced proportionally.
- Scale represented by Representative Fraction (RF) or Scale Factor.
- RF = (Length on drawing) / (Actual length)
- Example: A 1.5 m long steel bar shown as 15 cm line on drawing gives RF = 1/10.

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Thank you!

# Lecture 4: Structure of 3D Modeling

*Dr. Kalpana Shankhwar, IIIT Delhi*

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## Theory of Projection

- Projection in engineering drawing means creating an image or view of an object.
- Engineers use various projection techniques to construct views of objects.

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## Projection System

- Light rays from a bulb striking an object create a shadow (image) on a screen.
- The image is larger due to divergent light rays.
- The observer replaces the light source; lines of sight form the view.
- The screen is called the Plane of Projection (POP).
- Lines of sight are called projection lines or projectors.
- Three basic elements: object, observer, and POP.

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## Classification of Projection Methods

- **Multi-view projection**
- **Orthographic projection**
- **Axonometric projection**
- **Parallel projection**
- **Oblique projection**
- **Convergent projection**
- **Perspective projection**

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## Parallel Projection

- Projectors are parallel.
- **Orthographic projection:** Projectors are perpendicular to the POP.
  - **Multiview projection:** Two or more views on different POPs showing two dimensions per view.

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## Axonometric Projection

- One view showing all three dimensions.
- Object oriented so three perpendicular edges are inclined to POP.
- Types:
  - **Isometric:** All three edges equally inclined to POP.
  - **Dimetric:** Two edges equally inclined.
  - **Trimetric:** All three edges different inclinations.

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## Oblique Projection

- Projectors are parallel but inclined at 30°, 45°, or 60° to POP.
- One face is parallel to POP called principal face.
- Types:
  - **Cavalier Projection**
  - **Cabinet Projection**

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## Convergent Projection

- Projectors converge to a station point (observer's eye).
- Parallel edges appear to converge at vanishing points.
- Object appears smaller with distance.
- Most common is perspective projection.

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## Perspective Projection

- Linear perspective: Size relates proportionally to distance.
- One, two, or three vanishing points used for different views.
- Aerial perspective considers atmospheric effects: contrast and color fade with distance to create depth illusion.

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## Perspective Viewing Types

- **Three-point perspective:** Three vanishing points on three principal directions.
- **Two-point perspective:** Two vanishing points, one direction parallel to POP.
- **One-point perspective:** One vanishing point, two directions parallel to POP.

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## Principal Planes

- POP where views are projected.
- In multiview, different POPs needed for different views.
- Three mutually perpendicular planes called principal/reference planes (RP):
  - Horizontal Plane (HP): parallel to ground.
  - Vertical Plane (VP): perpendicular to ground and HP.
  - Profile Plane (PP): perpendicular to HP and VP.
- Reference planes are imaginary and transparent.

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## Structure of 3D Modeling

- 3D models consist of entities and features like datum, solids, surfaces, etc.
- Operations on these features are accessed through CAD software commands via menus and icons.

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## Unit Settings in CAD

- CAD has predefined unit sets; users must select units before modeling.
- Unit systems include:
  - SI (International System)
  - MKS (meter-kilogram-second)
  - IPS (inch-pound-second)
  - FPS (foot-pound-second)
  - CGS (centimeter-gram-second)
- SI base units: meter, kilogram, ampere, kelvin, mole, candela.

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## Sketch Entities, Objects, and Classification

- CAD models include sketches, solids, annotations, datums, parameters.
- Sketches generate solids or surface models.
- Annotations display dimensions and process info.
- Objects facilitate drawing generation, analysis, manufacturing planning.

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## Datum Entities

- Have no physical mass but assist in model creation and analysis.
- Include planes, axes, and points.
- Planes are required to create sketches on flat surfaces.

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## Plane

- Imaginary/real flat surface where a straight line lies.
- Used as sketch planes or reference for measurement.
- Default CAD planes: Front, Top, Right.

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## Axis

- Imaginary infinite straight lines used as sketch/reference geometry or rotational axes.

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## Point

- Created in sketches or 3D space.
- Used for creating geometry or aiding measurement.

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## Sketch Entities in CAD

- Basic geometry tools include:
    - Point
    - Line
    - Arc or Circle
    - Rectangle
    - Parallelogram
    - Polygon
    - Ellipse
    - Spline

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## 3D Curves

- Curves whose points do not lie on a single plane.
- Created by equations, special CAD tools, or tracing mechanisms.

- Used for creating objects or defining paths.

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### Surfaces

- Imagined as the "skin" of solids.
- Used in shaping objects like vehicle bodies, airplane wings.
- Mathematical representation allowing multi-angle viewing.

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### Solids

- Created via primitives or by extruding sections along paths.
- Used to visualize shape, analyze models, and produce drawings.

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### Regional Operations (Boolean Operations)

- Used to manipulate regions to create complex shapes.
- Types:
  - Union (addition)
  - Difference (subtraction)
  - Intersection
- Volumes after operations follow certain volume formulas involving overlaps.

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### Wireframes

- Show basic structure with lines and transparency.
- Wireframes represent object boundaries with points and connections, not solid.

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### Common 3D Modeling Software

- AutoCAD
- Pro-E (Pro/Engineer)
- Catia
- SolidWorks
- Blender
- Maya
- SketchUp
- 3DS Max
- Zbrush
- ArchiCAD
- Fusion 360

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### File Types in CAD

- Contain 3D/2D models including geometry, manufacturing, and material data.

- **Native formats:** Software-specific files (*.CATPart for CATIA).
- **Neutral formats:** Interoperable formats like STL, FBX, 3DS, OBJ, STEP.
  - STL: Popular in 3D printing, rapid prototyping.
  - FBX: Used in film/video games; geometry plus texture and color.
  - 3DS: Used in engineering, architecture.
  - OBJ: Polygonal models for 3D printing.
  - STEP: Widely accepted cross-industry format for interoperability.

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### Low Poly and High Poly Models

- Polygon count affects smoothness, accuracy, and file size.
- **High Poly Models:**
  - Photorealistic and detailed.
  - Complex geometry with many polygons.
  - Suitable for close inspection but costly to render.
- **Low Poly Models:**
  - Faster processing and smaller files.
  - Suitable for real-time manipulation (games, VR/AR).
  - Lower cost but less visual detail.
  - Ideal for applications prioritizing speed and interactivity.

## Lecture 5: Structure of 3D Modeling

- [ERI Lecture 5](ERI/ERI, Lecture 5.pptx_compressed.pdf)
- Study .pdf too

### Introduction to 3D Modeling in Computer Graphics

**Problem Statement:** Real objects (e.g., a teapot) exhibit curved surfaces, hidden lines, complex shading, perspective distortions, textures, and varied materials (pottery, ceramic, copper, etc.). Achieving realism requires solving these challenges via research in computer graphics.

### Physical vs. Synthetic Images

- **Physical Images:** Captured by cameras or digitizers; objects exist in the real world.
- **Synthetic Images:** Generated entirely in software by defining 2D/3D primitives (points, lines, polygons) and applying rasterization, shading, and lighting models.

### Core Entities: Object and Viewer

- **Object:** Defined in 3D space with geometric primitives independent of any viewer.
- **Viewer:** Human, camera, or digitizer that “sees” the object and defines the image formation process.

### Imaging Models

- **Ray Tracing:** Simulates light-ray interactions—reflection, refraction, absorption—with scene objects to produce highly realistic images.
- **Basic Ray–Object Interactions:**

- Ray enters camera directly.
- Ray reflects off a mirror.
- Ray refracts through a transparent sphere.
- Ray misses all objects (“goes to infinity”).

## Multiview Orthographic Projection

- **Definition:** Projectors are parallel and perpendicular to the projection plane (POP). Multiple views are drawn on planes at right angles.
- **Principal Planes:**
    - VP (Vertical Plane) → Front View
    - HP (Horizontal Plane) → Top View
    - PP (Profile Plane) → Side View
- **First-Angle vs. Third-Angle Projection:**
    - *First-Angle:* Object lies between observer and plane; FV above XY, TV below.
    - *Third-Angle:* Plane lies between observer and object; FV below XY, TV above.

## Principal Orthographic Views

1. **Front View (FV):** Observer looks at the front face; drawn on VP.
2. **Top View (TV):** Observer looks from above; drawn on HP.
3. **Side Views (SV):**
    - Left-Hand Side View (LHSV) or Right-Hand Side View (RHSV) on PP.
4. **Bottom View (BV):** Observer looks from below.
5. **Rear View (RV):** Observer looks from the back.

## Rules for Projection of Faces and Edges

1. Face ⊥ viewing direction → True shape and size visible.
2. Face ∥ viewing direction → Edge (line view).
3. Face inclined → Foreshortened view (true shape not visible).
4. Edge ⊥ viewing direction → True length visible.
5. Edge ∥ viewing direction → Point view.
6. Edge inclined → Foreshortened length between projected endpoints.

## Hidden Features and Sectional Views

- **Hidden Features:** Internal/external geometry not visible in a given view; shown with dashed lines.
- **Limitations:** Excessive dashed lines clutter drawings.
- **Sectional Views:** Cut planes (vertical, horizontal, profile, auxiliary) slice the object to reveal internal features.
    - **Vertical Section:** Plane perpendicular to HP cutting front/back.
    - **Horizontal Section:** Plane parallel to HP cutting top/bottom.
    - **Profile Section:** Plane parallel to PP cutting side features.
    - **Auxiliary Section:** Any nonprincipal plane used to reveal inclined faces.
- **Hatching:** Sectioned surfaces are filled with 45° hatch lines to denote cut material.

## Example Exercise & Solution

- [ERI Lecture 5](ERI/ERI, Lecture 5.pptx_compressed.pdf)
- Provided an exercise with a composite object having vertical, horizontal, and profile cut planes.
- Sectional front, top, and side views illustrate internal geometry, dimensions, and relationships.

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**Key Takeaway:** Understanding projection methods, viewing rules, and sectional techniques is essential for accurately representing an object’s three-dimensional depth and internal features in engineering and design documentation.