Virtual Reality

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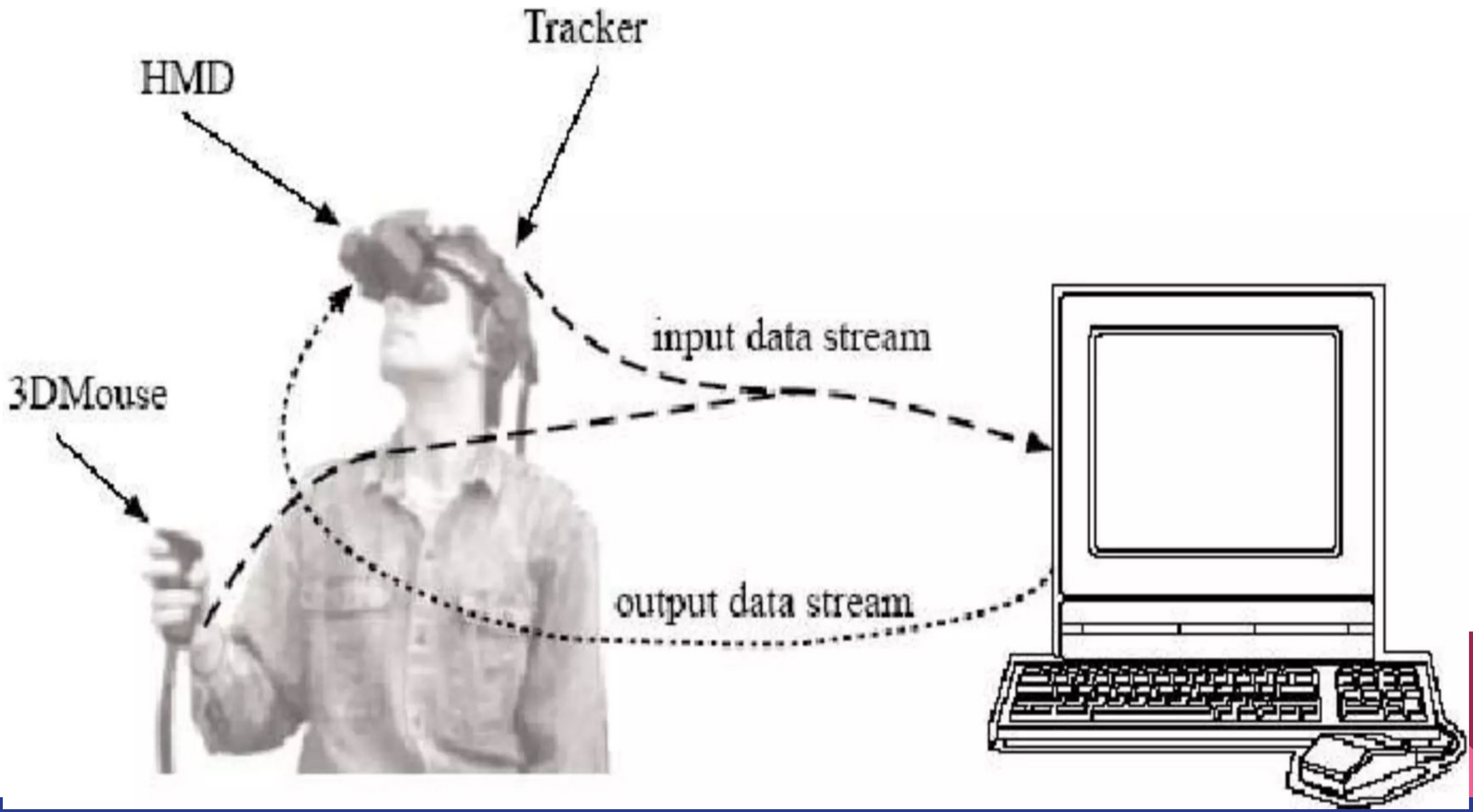
Virtual Reality

Virtual Reality (VR) is a technology that creates an immersive, computer-generated environment that users can interact with using special devices like VR headsets, gloves, and controllers.

VR aims to simulate real or imaginary worlds, making users feel as if they are physically present in a digital environment.



Tracker
HMD
input data stream
3DMouse
output data stream

Types of Virtual Reality (VR)

1. **Non-immersive:**

- Non-immersive VR is a computer-generated environment that users interact with through a standard screen, such as a desktop, laptop, or mobile device.
- It does not provide a fully immersive experience but allows for some level of interaction.

Examples:

1. **Google Earth VR** (desktop mode) (allows virtual travel using a computer).

2. **AutoCAD & 3D Modeling** Software (used for architectural design).

3. **Flight Simulator Games** that do not require a VR headset.

2. Fully Immersive VR:

- Fully immersive VR provides a complete virtual environment where users feel like they are inside the digital world.
- This type of VR requires specialized hardware such as VR headsets, motion tracking sensors, and haptic feedback devices.

Examples:

1. **VR Gaming** (e.g., Beat Saber, Half-Life: Alyx).
2. **Training Simulations** (e.g., military, medical, astronaut training).
3. **Virtual Tourism & Exploration** (e.g., Google Earth VR).
4. **VR Meetings & Collaboration** (e.g., Meta Horizon Workrooms).

2. Semi-Immersive

- Semi-immersive VR provides a more engaging experience than non-immersive VR but does not fully replace the real-world environment.
- It uses large screens or projection systems to create a more realistic experience.


Examples:

1. **Flight Simulators** (used for pilot training with large multi-screen setups).

2. **Driving Simulators** (used in automotive training).

3. **Medical Training Simulations** (surgery training in medical schools).

Key Components of VR

Input devices allow users to interact with the virtual environment by providing commands, gestures, or movement data.

A **VR engine** is the core software that renders the virtual environment, processes user input, and manages interactions.

Output devices generate feedback for the user to enhance immersion.

Display devices present the virtual environment visually to the user.

Types of VR Input Devices

Input Device	Description	Example
Motion Controllers	Handheld devices that track movement and gestures.	Oculus Touch, HTC Vive Controllers
Hand Tracking Sensors	Detects hand movements without controllers.	Oculus Quest Hand Tracking, Leap Motion
VR Gloves	Provides finger and grip tracking with haptic feedback.	Manus VR Gloves, HaptX Gloves
Eye Tracking Sensors	Tracks user's gaze to improve interaction and performance.	Tobii Eye Tracking in HTC Vive Pro Eye
Treadmills & Walkers	Allows users to walk in any direction for realistic movement.	Virtuix Omni, Cyberith Virtualizer
Brain-Computer Interface (BCI)	Uses brain signals to control actions in VR.	Neurable BCI headset

Popular VR Engines

VR Engine	Description	Example
Unity	A flexible game engine with VR support for various platforms.	Used in games like Beat Saber
Unreal Engine	High-quality graphics and physics for VR simulations.	Used in VR training and architectural visualization
CryEngine	Realistic rendering for immersive VR environments.	Used in VR military training
Amazon Lumberyard	A cloud-based engine for multiplayer VR experiences.	Supports AWS integration for cloud VR
Godot Engine	Open-source VR engine with built-in support.	Used in indie VR projects
OpenXR	A standard API for VR development across different hardware.	Compatible with Oculus, HTC Vive, Windows MR

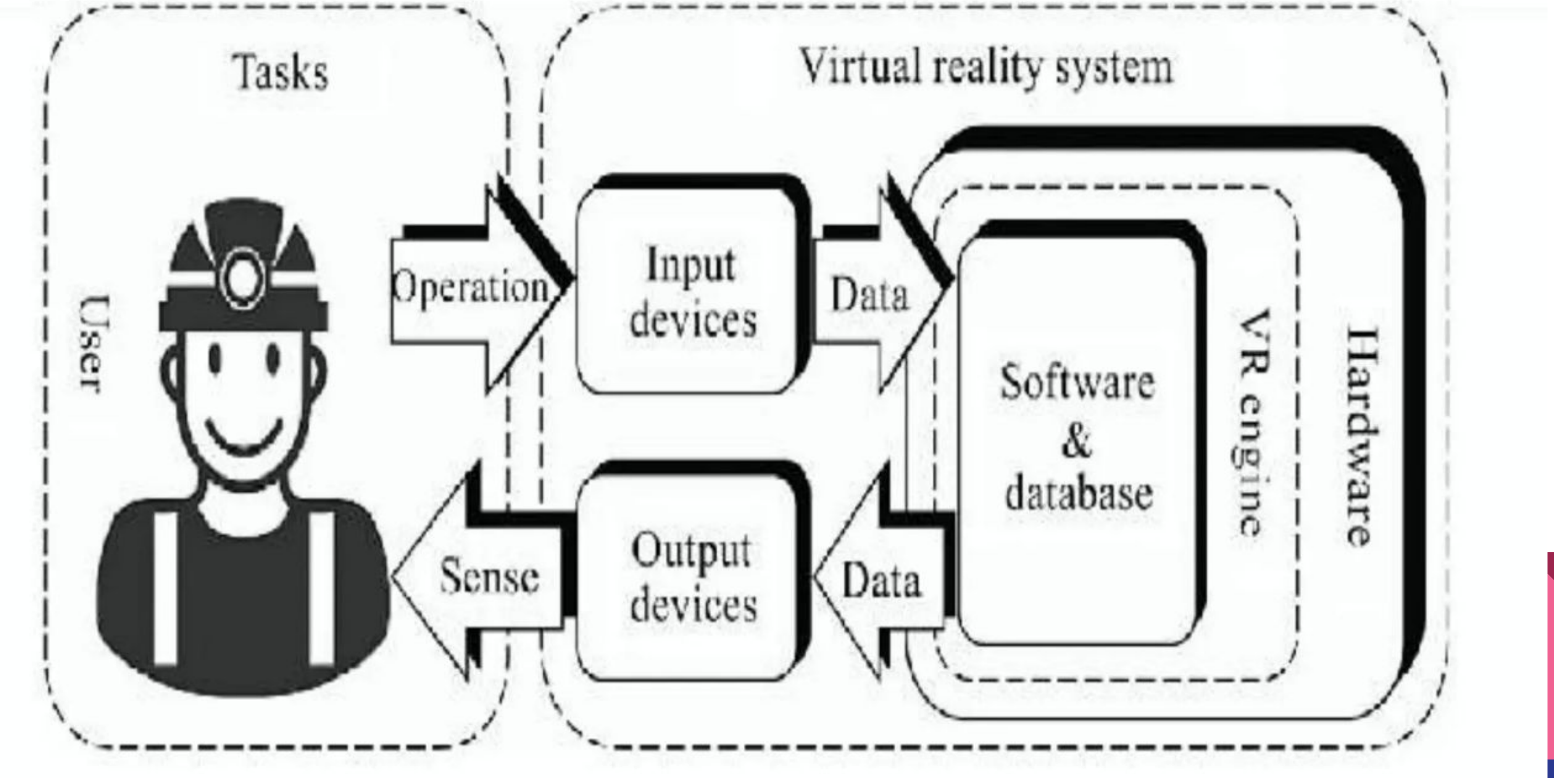
Types of VR Output Devices

Output Device	Description	Example
Haptic Feedback Devices	Provide tactile feedback to simulate touch.	Haptic gloves, bodysuits (Teslasuit)
Spatial Audio Systems	3D sound positioning for realistic audio experience.	Oculus Spatial Audio, Dolby Atmos
Force Feedback Controllers	Provides resistance and vibration based on virtual interactions.	VR racing wheels, flight sticks
Motion Platforms	Simulates movement like tilting, shaking, or acceleration.	VR simulator chairs, 4D motion platforms

Types of VR Display Devices

Display Device	Description	Example
Head-Mounted Display (HMD)	Worn on the head to display VR content with motion tracking.	Oculus Quest, HTC Vive, PlayStation VR
Projection-Based VR	Uses room-scale projection to create immersive environments.	CAVE (Cave Automatic Virtual Environment)
Augmented VR Displays	Mixed reality glasses that blend VR with the real world.	Microsoft HoloLens, Magic Leap
360° Dome Displays	Surrounds the user with a VR scene in a physical dome.	Used in VR theme parks and simulations

VR component system architecture



Advantage of VR

1. **Immersive Experience:** Creates realistic and engaging environments.

2. **Safe Training**: Useful for medical, military, and aviation training without real-world risks.

3. **Improved Learning**: Enhances education through interactive simulations.

4. **Entertainment & Gaming**: Offers new levels of engagement in video games and movies.

5. **Remote Collaboration**: Enables virtual meetings and social interactions.

Disadvantage of VR

1. **Expensive:** High-end VR hardware and software are costly.
2. **Health Issues:** Can cause motion sickness, dizziness, and eye strain.
3. **Isolation:** Excessive use may reduce real-world social interactions.
4. **Technical Limitations:** Requires powerful hardware and stable tracking.
5. **Limited Content:** VR content development is still growing.

Application of VR

1. **Gaming & Entertainment:** Immersive video games, movies, and virtual concerts.
2. **Education & Training:** Medical training, flight simulators, and virtual classrooms.
3. **Healthcare:** Pain management, mental health therapy, and rehabilitation.
4. **Military & Defense:** Combat training, simulation exercises.
5. **Architecture & Real Estate:** Virtual walkthroughs of buildings.
6. **Tourism & Cultural Heritage:** Virtual museum tours and historical reconstructions.
7. **Retail & E-Commerce:** Virtual shopping experiences.
8. **Sports & Fitness:** Training simulations and VR fitness apps.

3D positional tracking

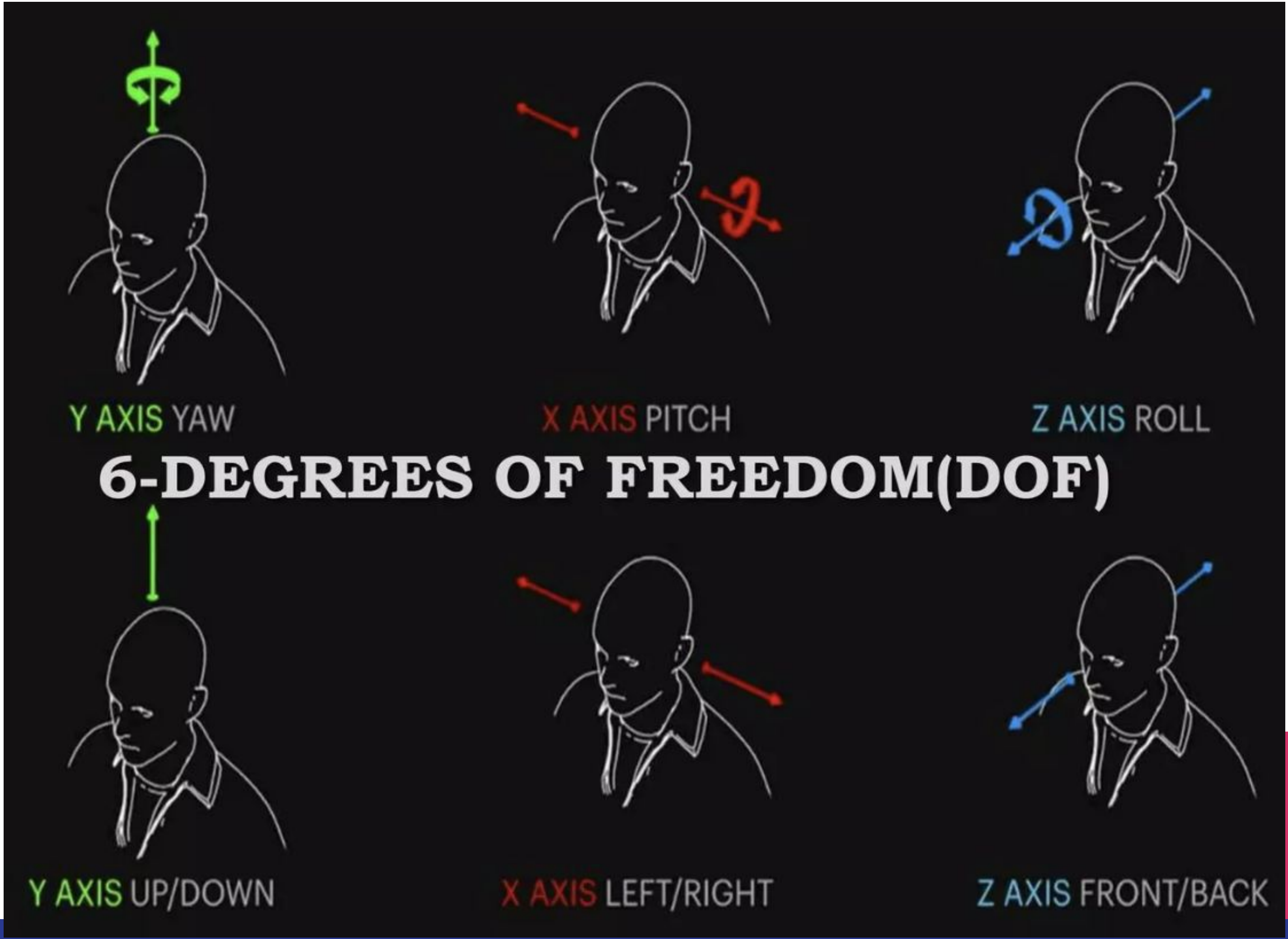
3D positional tracking is a technology that tracks a user's movement in three-dimensional space, allowing for realistic and immersive interactions in Virtual Reality (VR).

It helps determine a user's position (X, Y, Z) and orientation (yaw, pitch, roll) in real time.

3D positional tracking systems use sensors, cameras, or other tracking methods to capture the user's head, hands, and body movements. This data is then processed to update the virtual environment accordingly.

Tracking Parameters

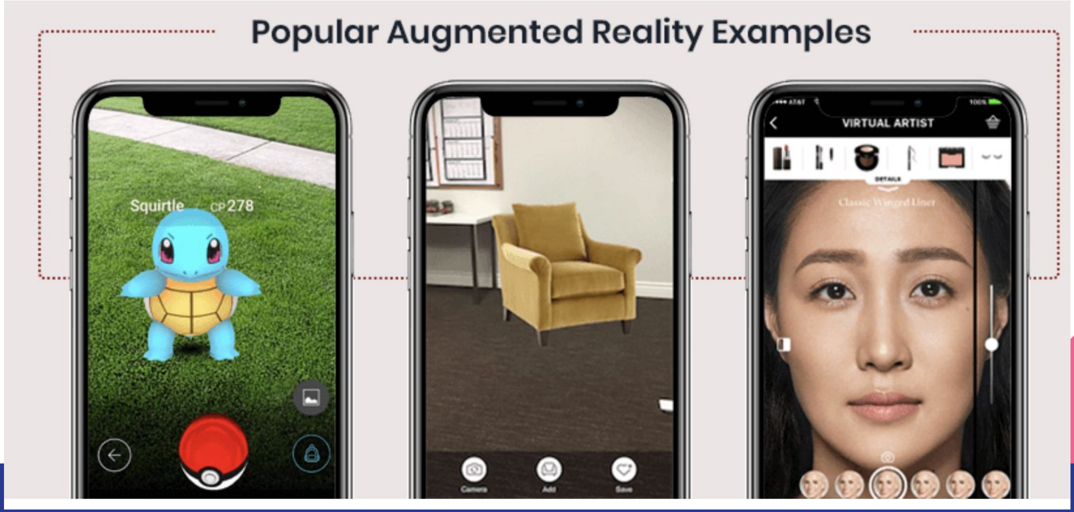
1. **Position** (X, Y, Z): Where the user is located in 3D space.
2. **Rotation** (Yaw, Pitch, Roll): The direction the user is facing.
3. **Velocity & Acceleration**: How fast and smoothly the user moves.


Y AXIS YAW
X AXIS PITCH
Z AXIS ROLL
6-DEGREES OF FREEDOM(DOF)
Y AXIS UP/DOWN
X AXIS LEFT/RIGHT
Z AXIS FRONT/BACK

Augmented Reality

Augmented Reality (AR) is a technology that overlays digital content (such as images, sounds, or 3D objects) onto the real world in real time.

Unlike Virtual Reality (VR), which creates a completely virtual environment, AR enhances the real world by adding interactive digital elements.



AR vs VR

Feature	Augmented Reality (AR)	Virtual Reality (VR)
Definition	Enhances the real world with digital elements	Creates a fully immersive digital environment
Device	Smartphones, AR glasses (e.g., Microsoft HoloLens)	VR headsets (e.g., Oculus, HTC Vive)
Interaction	Users interact with real and virtual objects simultaneously	Users interact only with the virtual world
Examples	Pokémon GO, IKEA Place app, Google Lens	Beat Saber, VRChat, Flight Simulators

Navigation in VR

Navigation in a VR system refers to the user's ability to move around and explore the virtual environment.

It plays a crucial role in providing an immersive and interactive experience.

The way users navigate in VR depends on the functionality provided by the system.

Types:

- Steering (Direction & Velocity Control)
- Target-Based Navigation
- Route Planning

1. Steering (Direction & Velocity Control)

Users navigate by controlling direction and speed, which can be done through:

- **Hand-Directed Navigation** – Moving hands to guide movement.
- **Gaze-Directed Navigation** – Looking at a point to move towards it.
- **Physical Devices** – Using hardware like:
  - Steering wheels (for driving simulations).
  - Flight sticks (for flight simulations).

2. Target-Based Navigation

This method allows users to move to specific locations by:

- **Pointing at an Object** – Users can select an object or location, and the system moves them there automatically.
- **List of Coordinates** – Predefined locations that users can choose from.

3. Route Planning

Placing Markers in the Virtual World – Users can define a path by placing virtual markers, and the system guides them accordingly.

Manipulation Interface in VR

Manipulation in VR refers to how users interact with objects and interfaces inside the virtual world.

The Manipulation Interface in Virtual Reality (VR) allows users to interact with and modify objects in a 3D space.

Based on the image, when a data probe (or an interactive object) is moved, several key operations must occur to ensure a realistic and responsive interaction.

Manipulation Interface

1. Collision Detection : The system detects when a user picks up, moves, or interacts with an object. Prevents objects from overlapping or passing through each other unnaturally.

2. Data Access : When an object (such as a data probe) is moved, the system retrieves the relevant data for that location. In scientific or simulation applications, this could involve vector fields, temperature maps, or flow data.

3. Visualization Computation: Adjusts the geometry and structure of the object based on its new position. In cases like streamline visualization, the system updates the displayed flow paths.

4. Graphical Rendering : The system re-renders the environment from the user's viewpoint. Ensures that the scene remains immersive and realistic, adapting to the new position of the manipulated object.