1

Introduction to virtual reality

An interactive world, a moving body, a perceptual experience

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COURSE NOTES

VR connects a person’s perception and actions with a simulated environment through technical interfaces. Understanding that loop clarifies what distinguishes VR from an image, a film or an augmented view of the physical world.

The eight-course roadmap

Understand the field → explain perception → design systems → evaluate experience

1

Introduction to virtual reality

Concepts · systems

2

History of virtual reality

Origins · milestones

3

Applications of virtual reality

Uses · research

4

Perception and theoretical foundations

Perception · models

5

Building a VR system

Tracking · rendering

6

3D interaction

Select · manipulate

7

3D navigation

Travel · orient

8

Human factors in virtual reality

Experience · comfort

COURSE NOTES

The eight courses connect complementary questions: what VR is, how it developed, what it is used for, how perception works, how systems are built, how people interact, how they navigate, and how the experience affects them. Design choices can therefore be examined from several viewpoints. A navigation technique, for example, depends on tracking and visual feedback as well as spatial understanding and comfort.

Outline of the introduction course

Definitions

1.1

Action and perception

1.2

Quiz: VR, AR or neither?

1.3

COURSE NOTES

The introduction establishes VR and AR definitions, then explains the perception–action loop. It ends with a quiz that applies these criteria to examples and boundary cases. Technical components are developed in course 5 and practical work.

The sequence connects the following topics: Definitions ; Action and perception ; System overview.

The course ends with cases to discuss: panorama, 360° video, head-up display, visual effects and tracked experiences. Technical components are developed in course 5.

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Part 1 of 3

1.1 Definitions

COURSE NOTES

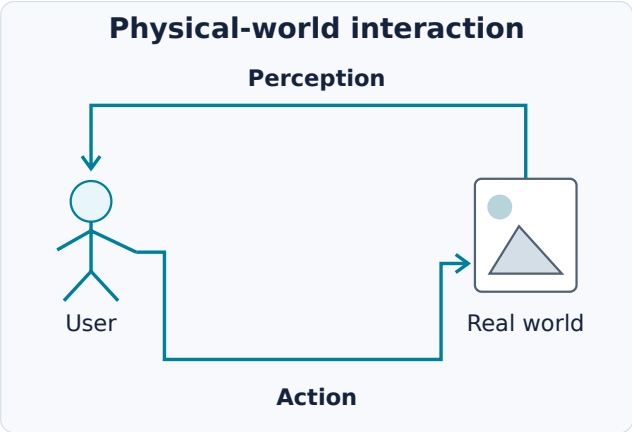
In the physical-world situation on the left, perception and action directly relate the person to the environment. The user perceives the world through sensory information and acts on it through movement. Their actions change the world or their position within it, which changes what they perceive. This is the perception–action loop.

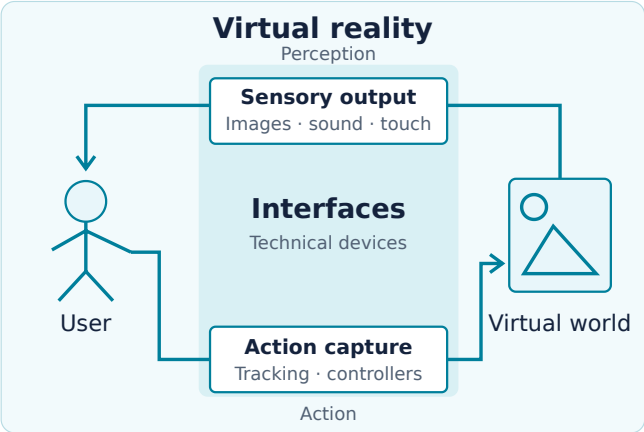
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1.1 Definitions

Virtual reality





> Replace the real world with a virtual world through perception and action interfaces.

COURSE NOTES

In the physical-world situation on the left, perception and action directly relate the person to the environment. The user perceives the world through sensory information and acts on it through movement. Their actions change the world or their position within it, which changes what they perceive. This is the perception–action loop.

The VR situation on the right preserves this loop while placing technical interfaces between the user and a virtual world. Sensory interfaces generate the stimuli through which the user perceives that world: images, sounds and, when available, haptic feedback. The perception arrow therefore runs from the virtual world, through the sensory interfaces, to the user.

In the opposite direction, tracking systems, controllers or other input devices capture the user’s actions and translate them into actions in the virtual world. The simulation updates the environment and produces the next sensory feedback. The action arrow therefore runs from the user, through action-capture interfaces, to the virtual world.

The defining idea is the mediated perception–action loop: a virtual world takes the place of the physical world in the interaction, with interfaces providing the sensory information and the means to act. An artificial environment alone does not explain this relationship. The environment can represent a real place, make an otherwise invisible phenomenon perceptible, or create an imaginary world; the interfaces maintain the coupling in real time.

Augmented reality

Keep the physical world

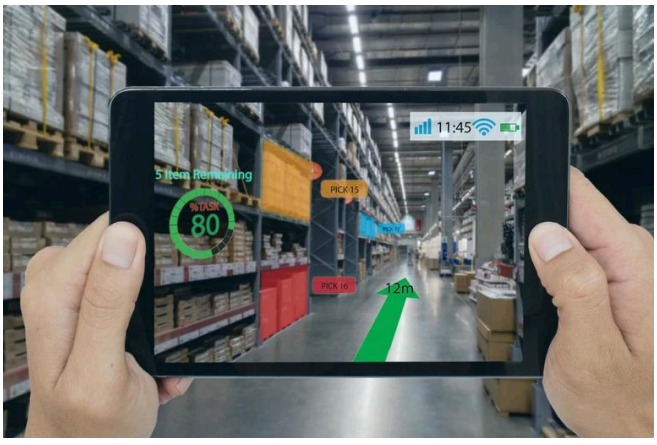
Objects, surfaces and physical constraints

Keep its spatial structure

Positions, distances and reference points

Add virtual elements

Objects and information situated in the scene



Information overlaid on the physical environment



Virtual content in a real setting

> Keep the physical world as the setting of the experience; add virtual elements within it.

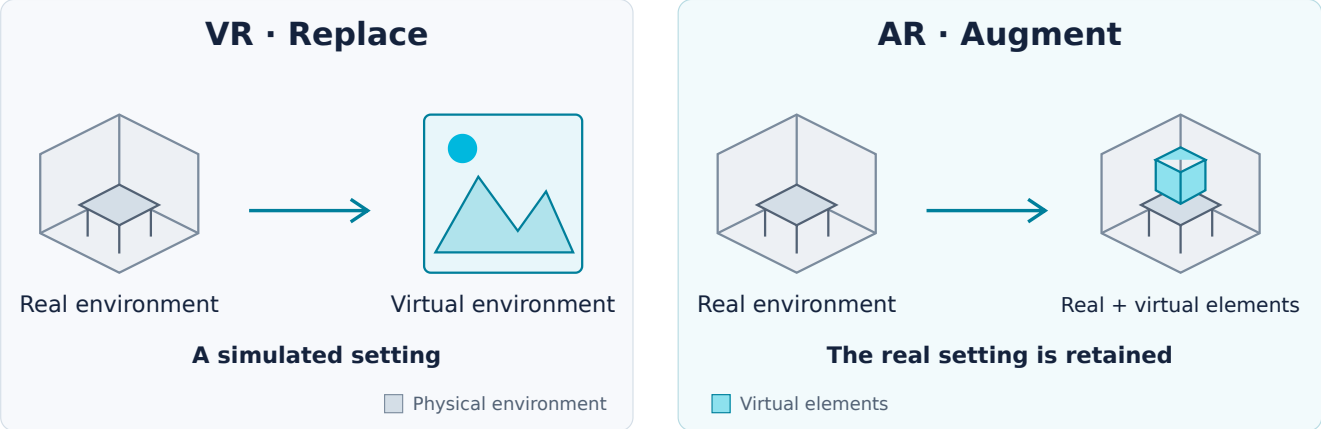
COURSE NOTES

The starting point of augmented reality is the real environment. Its objects, surfaces, material properties and physical constraints remain part of the experience. The user continues to inhabit and act in that environment.

AR preserves the environment's spatial organisation: the positions of objects, distances, surfaces and reference points remain meaningful. Virtual elements are added in relation to that setting, for example an object on a real table, guidance attached to a machine, or information associated with a place. Spatial alignment helps the added content remain coherent with the real scene.

The design objective is to enrich the real environment while retaining its physicality and spatiality. Optical see-through, video see-through, handheld screens and projection are different ways of pursuing this objective. The experience's relationship with the real environment is the key point of this definition.

VR and AR: two design goals



> Different goals; devices and perception–action mechanisms can be shared.

COURSE NOTES

The distinction concerns the objectives of the experience. In VR, the goal is to substitute a virtual environment for the real environment in the user's perception–action loop. In AR, the goal is to retain the real environment and enrich it with virtual elements.

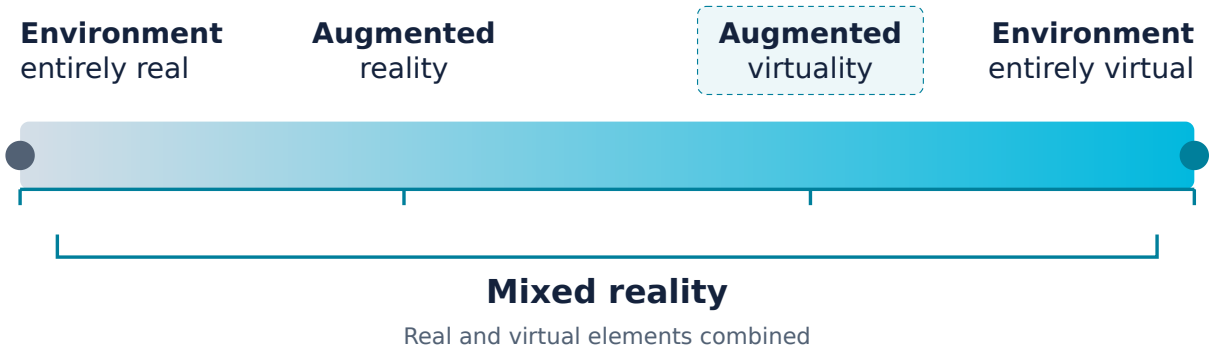
Both diagrams begin with the same situation: a physical room with a table. On the left, the room is replaced by a simulated setting. On the right, the room and table remain, with a virtual object added in their spatial frame. Grey represents the physical environment; cyan represents virtual elements.

These objectives do not map to a simple hardware division. Tracking, displays, rendering and interaction techniques can be shared, and a device can support different experiences. A passthrough headset, for example, can retain a view of the real scene and add virtual objects, while also supporting a virtual experience that replaces the visible surroundings.

The two approaches also share the perception–action framework: the user perceives and acts, and the system responds in real time. The distinction emphasised here concerns the role assigned to the real environment and the intended experience. The following continuum describes how real and virtual elements can be combined.

The historical continuum

Milgram and Kishino · 1994



> The view can be virtual: what remains real in the experience?

COURSE NOTES

Milgram and Kishino introduced this framework in 1994 for visual displays. One endpoint is an entirely real environment; the other is an entirely virtual environment. The combinations between them constitute mixed reality.

Augmented reality adds virtual elements to a mainly real setting. Augmented virtuality introduces real elements into a mainly virtual setting. In this historical framing, the two pure endpoints sit outside mixed reality. The graphic describes types of combination, rather than a measured percentage.

Real content inside a virtual world

Augmented virtuality · two examples

Spatial · a webcam inside the VR room



A participant’s camera feed appears inside the virtual room alongside avatars.

Spatial · screenshot published by WIRED · 2020 ↗

Quest 2 · Space Sense (Guardian)



Outlines of real objects and people are revealed within the play area, over the VR environment.

▶ In-headset demonstration · Skarredghost · 2021 (2:33) ↗

> The setting is virtual; visual information from the real world is brought into it.

COURSE NOTES

The collaborative version of Spatial shown in 2020 allowed participants without a headset to share a webcam inside a virtual room. In this screenshot supplied by Spatial and published by WIRED, the “Bri Scully’s Webcam” panel is a real camera feed. Other people appear as avatars: distinguish the video panel from the textured avatar faces.

The second capture comes from Antony Vitillo’s (Skarredghost) hands-on test of Space Sense on Quest 2 in November 2021. The linked video starts at 2:33, at the beginning of the in-headset demonstration. Space Sense overlays camera-derived outlines of real objects and people onto the VR view. This is more than the virtual Guardian boundary grid, and is not a full camera view of the real world.

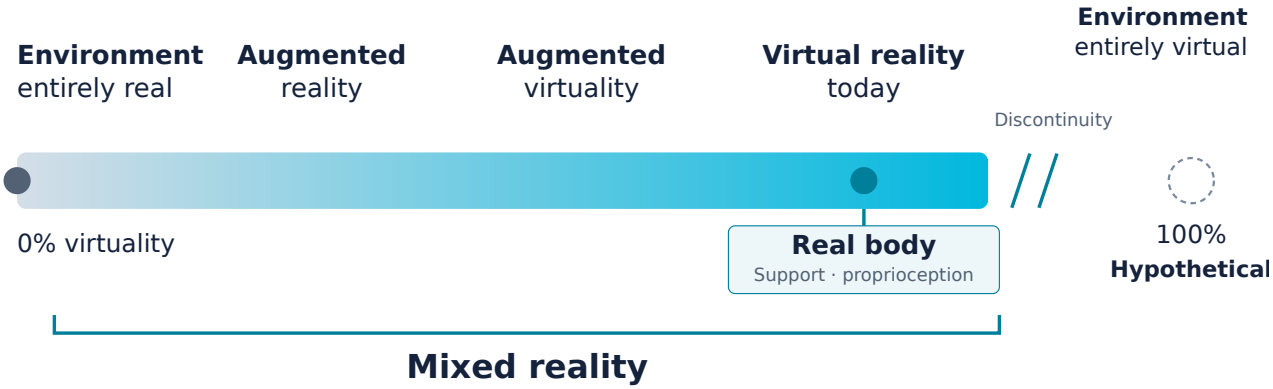
Space Sense was introduced as an experimental Roomscale Guardian feature on Quest 2 with v34 in 2021. This capture documents that historical behaviour rather than its current availability on all headsets.

This slide is a vertical detail beneath the continuum: use the down arrow to visit it, and the up arrow to go back.

1.1 Definitions

The continuum revisited

Body, support, movement limits · Skarbez, Smith and Whitton, 2021



> The real body keeps conventional virtual reality within mixed reality.

COURSE NOTES

Now consider the user's experience across the senses. Even when the visible environment is virtual, the user acts with a real body: support from the floor, body position and balance can still provide real sensory information.

The proposed revision therefore places conventional virtual reality within mixed reality. A purely real experience is outside the mixture. An entirely virtual experience would require all sensory input, including bodily sensations, to be simulated; it is shown as a hypothetical endpoint separated by a discontinuity.

The 0% and 100% labels mark conceptual limits, not a standard numerical measure of virtuality. This is the authors' theoretical proposal; terminology remains variable.

1.1 Definitions

Interaction paradigms

Graphical interfaces

How do we act on screen objects?

Ubiquitous computing

How do we coordinate distributed systems?

Immersive interfaces

How do we act in a simulated world?

Augmented interfaces

How do we link additions to the real scene?



COURSE NOTES

Rekimoto and Nagao compare how the person, computer and physical world relate. A conventional graphical interface separates digital objects from their physical context. Ubiquitous systems distribute computation through that context. VR and AR alter the interface between person and environment in different ways. These approaches can coexist in a single application.

Rekimoto, J., & Nagao, K. (1995). The World through the Computer: Computer Augmented Interaction with Real World Environments. In Proceedings of the 8th Annual ACM Symposium on User Interface and Software Technology (UIST ’95), pp. 29–36. ACM. https://doi.org/10.1145/215585.215639

Google Glass archive

Observe: does information follow the head or remain linked to the scene?



Google Glass archive

Watch the video ↗

> Information in the field of view is not necessarily attached to the world.

COURSE NOTES

Google Glass illustrates information displayed alongside the physical environment. The distinction to examine is how digital information is positioned in relation to the scene and the user's activity. A wearable display is not necessarily a system that registers virtual objects precisely to physical surfaces. This historical example helps separate access to information from spatial augmentation.

HoloLens archive

Observe: which movement reveals how objects are anchored in the room?



HoloLens archive

Watch the video ↗

> Look for the spatial link; a promotional video does not describe the full field of view.

COURSE NOTES

HoloLens illustrates optical see-through augmentation: the physical scene remains visible through the optics while virtual imagery is added. The design question is how the virtual content is positioned and updated relative to surfaces and the moving observer. Alignment, visibility and the correspondence between gesture and response determine whether the added content can serve the intended activity.

ARKit demonstration

Observe: does the object stay in place as the tablet moves?



ARKit demonstration

Watch the video ↗

> The shared problem: maintain correspondence between real and virtual.

COURSE NOTES

ARKit illustrates augmentation through a handheld camera view. The system estimates how the device moves and how virtual content relates to the filmed scene. The screen combines the camera image and rendered objects, while the surrounding physical space remains directly visible around the device. Maintaining registration as the camera moves is central to the illusion of an object located in the room.

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Part 2 of 3

1.2
Action and perception

COURSE NOTES

Moving the head changes the visible scene. Reaching changes the position of a virtual hand. Grasping can change an object’s state. The system must detect an action, update the simulation and return coherent sensory information. A long delay or an inconsistent mapping changes the experience even if the images are visually impressive.

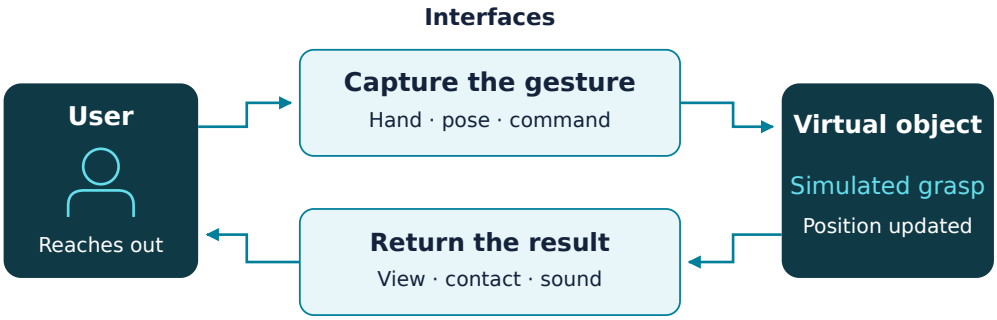
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1.2 Action and perception

One gesture, one loop: grasping an object

What is measured? What changes? What feedback is produced?



> Action: person → world. Sensory feedback: world → person.

COURSE NOTES

Moving the head changes the visible scene. Reaching changes the position of a virtual hand. Grasping can change an object’s state. The system must detect an action, update the simulation and return coherent sensory information. A long delay or an inconsistent mapping changes the experience even if the images are visually impressive.

Shared example: a person reaches towards an object. The system measures the hand and a grasp command; the application attaches the object to the hand and updates its position; rendering returns the new state. In this diagram, action flows left to right along the top and feedback right to left along the bottom.

Headsets and projection rooms

Choose for the task: individual viewing, sharing, collaboration

Headset

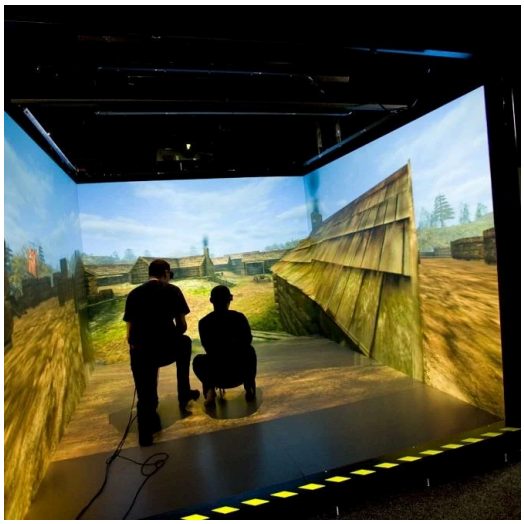
Individual view; share through an external screen

Projection room

Side-by-side observation; tracking determines perspective



Head-mounted display



Immersive projection room

> Comfort, collaboration and infrastructure: the activity guides the choice.

COURSE NOTES

A headset and a projection room can both support immersive experiences. Their constraints differ in field of view, optical properties, mobility, visibility of the physical body and collaboration. Tracked projection must generate an image appropriate to the observer’s position. Device selection follows the task, rather than a single hierarchy of immersion.

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Part 3 of 3

1.3

VR, AR or neither?

COURSE NOTES

The quiz closes the introduction by reusing the definition criteria. For each case, ask for a classification and, above all, a justification before revealing the answer on the next advance. Answers are also visible in the handout. Scenarios specify capabilities: hardware names or image appearance alone are insufficient.

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Online slide ↗

1.3 Quiz: VR, AR or neither?

Street View

VR, AR or neither?



Interactive panorama

360° photos can be explored, without tracking body movements.

COURSE NOTES

360° photos can be explored, without tracking body movements.

AirPano · Maldives

VR, AR or neither?



Maldives, Piece of Heaven — AirPano VR (2026)

Watch the video ↗

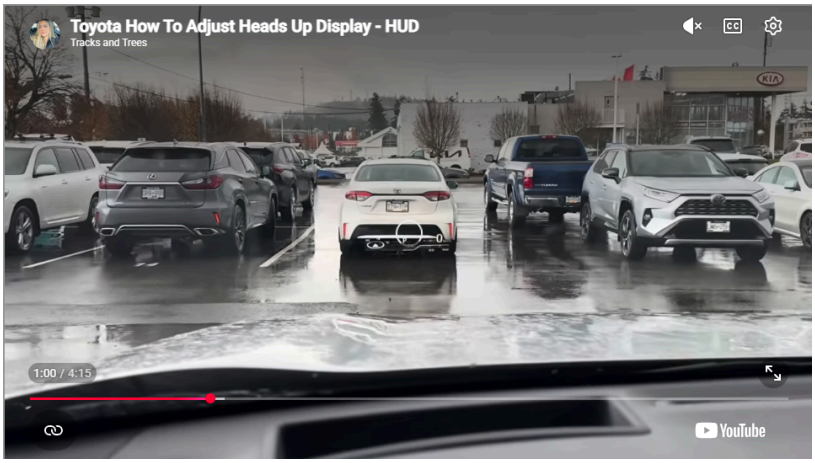
> **Immersive video, limited interaction**
>
> We choose where to look; the flight remains prerecorded.

COURSE NOTES

We choose where to look; the flight remains prerecorded.

Behind the wheel of a Toyota

VR, AR or neither?



Toyota How To Adjust Heads Up Display — Tracks and Trees (2024)

Watch the video ↗

> **Head-up display, not spatial AR**
>
> Information stays within a display area; it is not anchored to objects on the road.

COURSE NOTES

Information stays within a display area; it is not anchored to objects on the road.

The clip shows a conventional HUD from the driver’s seat. Toyota’s manual describes driving information projected on the windshield.

Benedict Cumberbatch · Smaug

VR, AR or neither?



Conversations With Smaug — Warner Bros. UK & Ireland (2014)

Watch the video ↗

> ## Visual effects
>
> The performance helps create the dragon; the film does not respond to the viewer.

COURSE NOTES

The performance helps create the dragon; the film does not respond to the viewer.

Performance capture and the animators' work produce the film character. This case concerns the audience's film experience.

F1 · 4DX cinema

VR, AR or neither?



F1: The Movie — 4DX Trailer Reaction, Cineworld (2025)

Watch the video ↗

> **Multisensory cinema**
>
> The effects follow the film, not the viewer’s actions.

COURSE NOTES

The effects follow the film, not the viewer’s actions.

Hello, Dot

VR, AR or neither?



> **AR**
>
> The virtual companion occupies the real living room and responds to gestures.

COURSE NOTES

The virtual companion occupies the real living room and responds to gestures.

Snapchat · face filter

VR, AR or neither?



Pin to Face Mesh — Snap, Lens Studio 5.x

Watch the video ↗

> **AR**
>
> The virtual effect follows the face in real time.

COURSE NOTES

The virtual effect follows the face in real time.

Ghost Town

VR, AR or neither?



Ghost Town — Meta Quest, launch trailer (2025)

Watch the video ↗

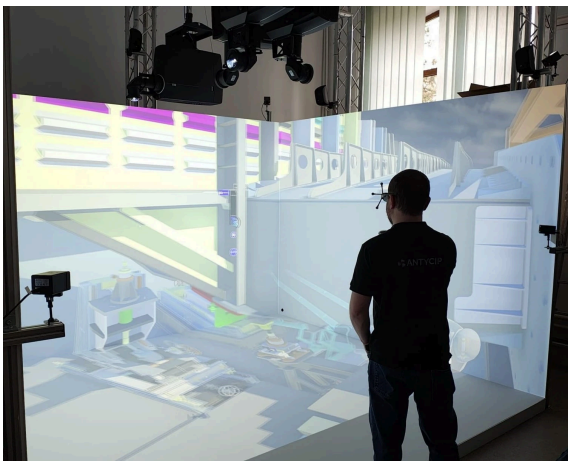
> **VR**
>
> Movements and gestures allow interaction with the simulated world.

COURSE NOTES

Movements and gestures allow interaction with the simulated world.

CAVE · University of Bacău

VR, AR or neither?



> **Room-scale VR**
>
> A simulated environment can surround the user without a headset.

COURSE NOTES

A simulated environment can surround the user without a headset.

Takeaways

VR

Act and perceive within a simulated world

AR

Enrich reality with virtual content registered in real time

> A headset and rich sensations alone are not enough.

COURSE NOTES

A headset and rich sensations alone are not enough.