

The XRSI Definitions of Extended Reality (XR)

XR Safety Initiative Standard Publication XR-001



XR Safety Initiative

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XR Data Classification Framework Public Working Group

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Abstract

The **Extended Reality – Data Classification Framework – Public Working Group (XR-DCF-PWG)** at the XR Safety Initiative (XRSI) develops and promotes a fundamental understanding of the properties and classification of data in XR environments by providing technical leadership in the XR domain. XR-DCF-PWG develops tests, test methods, reference data, proof of concept implementations, and technical analysis to advance the development and productive use of immersive technology.

XR-DCF-PWG's responsibilities include the development of technical, physical, administrative, and management standards and guidelines for the risk-based security and privacy of sensitive information in XR environments. This Special Publication XR-series reports on XR-DCF-PWG's research, guidance, and outreach efforts in XR Safety and its collaborative activities with industry, government, and academic organizations. This specific report is an enumeration of terms for the purposes of consistency in communication.

Certain commercial entities, equipment, or materials may be identified in this document in order to describe an experimental procedure or concept adequately. Such identification is not intended to imply recommendation or endorsement by the XR Safety Initiative, nor is it intended to imply that the entities, materials, or equipment are the best available for the purpose.

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SECTION 1

Introduction

The XR Safety Initiative (XRSI) developed this document as part of its mission to help build safe virtual environments.

XRSI is responsible for developing standards and guidelines, including minimum requirements. However, such standards and guidelines may not apply universally to all XR systems and applications.

These guidelines have been prepared for use by XR stakeholders. They may be used by governments, non-governmental organizations, and academics on a voluntary basis. They are not subject to copyright, although attribution is desired.

Purpose and Scope

1.2

Extended Reality (XR) is an evolving paradigm. The XRSI definitions characterize important aspects of XR and are intended to serve as a means for a broad comparison of XR technologies and environments. This document also provides a baseline on what Extended Reality (XR) is and how to best use it. The definitions and taxonomies defined in this document are not intended to prescribe or constrain any particular dimension, timeline, or environment of immersive technologies.

Audience

1.3

The intended audience of this document is XR stakeholders, potentially including developers, technologists, providers, and consumers of immersive technologies.

SECTION 2

The XRSI Definition of Extended Reality (XR)

Extended Reality (XR) is a fusion of all the realities – including Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) – which consists of technology-mediated experiences enabled via a wide spectrum of hardware and software, including sensory interfaces, applications, and infrastructures. XR is often referred to as immersive video content, enhanced media experiences, as well as interactive and multi-dimensional human experiences.

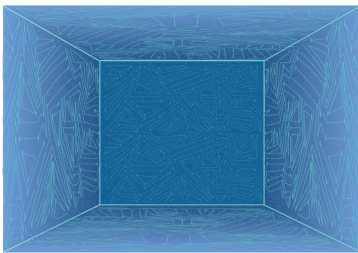
“XR does not refer to any specific technology. It’s a bucket for all of the realities.”

Jim Malcolm, Humaneyes

SECTION 3

Common Forms of Extended Reality (XR)

VIRTUAL REALITY (VR)



Completely **artificial**
digital environment

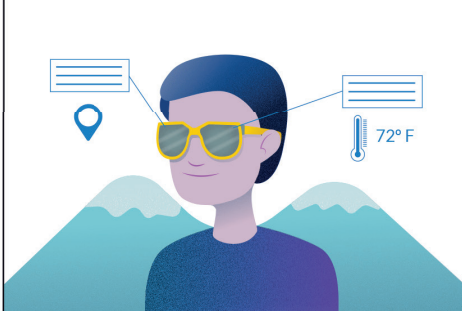


Full immersion in the experience
with **no sense** of the **real world**

AUGMENTED REALITY (AR)

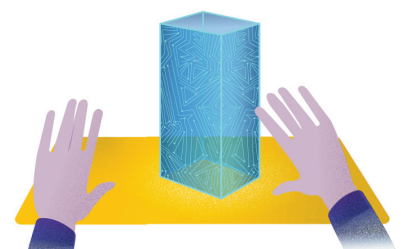


Digitally-created content on top
of the user's **real-world** environment



Real-world experience is **central**,
enhanced by **digital** and **virtual** objects

MIXED REALITY (MR)



Digitally-created content **blended**
with user's **real-world** environment



Both environments can **coexist**
and **interact** with each other

3.1 **Virtual Reality (VR)**

Virtual Reality (VR) is a fully immersive software-generated artificial digital environment. VR is a simulation of three-dimensional images, experienced by users via special electronic equipment, such as a Head Mounted Display (HMD). VR can create or enhance characteristics such as presence, embodiment, and agency.

Augmented Reality (AR) overlays digitally-created content on top of the user's real-world environment, viewed through a device (such as a smartphone) that incorporates real-time inputs to create an enhanced version of reality. Digital and virtual objects (e.g., graphics, sounds) are superimposed on an existing environment to create an AR experience.

3.2 **Augmented Reality (AR)**

3.3 **Mixed Reality (MR)**

Mixed Reality (MR) seamlessly blends the user's real-world environment with digitally-created content, where both environments can coexist and interact with each other. In MR, the virtual objects behave in all aspects as if they are present in the real world, e.g., they are occluded by physical objects, their lighting is consistent with the actual light sources in the environment, and they sound as though they are in the same space as the user. As the user interacts with the real and virtual objects, the virtual objects will reflect the changes in the environment as would any real object in the same space.

Volumetric Video Capture is a technique that captures a three-dimensional space, such as locations, people, and objects, including depth data, so that it can be later viewed from any angle at any moment in time. It allows six degrees of freedom (see section 4.2 for an explanation of the concept of degrees of freedom).

3.4 **Volumetric Video Capture**

3.5 360 Degree Video

360 Degree Video is an immersive video format consisting of a video – or series of images – mapped to a portion of a sphere that allows viewing in multiple directions from a fixed central point.

The mapping is usually carried out using equirectangular projection, where the horizontal coordinate is simply longitude, and the vertical coordinate is simply latitude, with no transformation or scaling applied. Other possible projections are Cube Map (that uses the six faces of a cube as the map shape), Equi-Angular Cubemap – EAC (detailed by Google in 2017 to distribute pixels as evenly as possible across the sphere so that the density of information is consistent, regardless of which direction the viewer is looking), and Pyramid (defined by Facebook in 2016).

This type of video content is typically viewable through a head-mounted display, mobile device, or personal computer and allows for three degrees of freedom (see section 4.2 for an explanation of the concept of degrees of freedom).

SECTION 4

Common Terms of XR

4.1 Field of View (FOV)

Field of View (FOV) defines an observable area or the range of vision seen via an XR device such as HMD, when the user is static within a given XR environment. The standard human FOV is approximately 200 degrees, but in immersive experience it may vary. A higher FOV contributes to a more immersive feeling.

Degrees of Freedom (DoF) describes the position and orientation of an object in space. DoF is defined by three components of translation and three components of rotation.

4.2 Degrees of Freedom (DoF)

An experience with three degrees of freedom (3DoF) is one which allows for:

- Swiveling left and right (yawing);
- Tilting forward and backward (pitching);
- Pivoting side to side (rolling).

3DoF applications can be experienced on devices such as Google Cardboard and GearVR.

An experience with six degrees of freedom (6DoF) allows for:

- Moving up and down (elevating/heaving – Y Translation);
- Moving left and right (strafing/swaying – X Translation);
- Moving forward and backward (walking/surging – Z Translation);
- Swivels left and right (yawing);
- Tilts forward and backward (pitching);
- Pivots side to side (rolling).

6DoF applications can be experienced on devices such as the Oculus Rift and HTC Vive.

4.3 Head Mounted Display (HMD)

Head Mounted Display (HMD) usually refers to a device with a small display such as projection technology integrated into eyeglasses or mounted on a helmet or hat. It's typically in the form of goggles or a headset, standalone or combined with a mobile phone (Gear VR).

Haptics is a mechanism or technology used for tactile feedback to enhance the experience of interacting with onscreen interfaces via vibration, touch, or force feedback. While an HMD can create a virtual sense of sight and sound, haptic controllers create a virtual sense of touch.

4.4 Haptics

4.5 Positional Tracking

Positional Tracking (Head/Eye/Full Body/ Inside-Out/Outside-In) is a technology that allows a device to estimate its position relative to the environment around it. It uses a combination of hardware and software to achieve the detection of its absolute position. Positional tracking is an essential technology for XR, making it possible to track movement with six degrees of freedom (6DOF). Some XR headsets require a user to stay in one place or to move using a controller, but headsets with positional tracking allow a user to move in virtual space by moving around in real space.

4.5.1 Head tracking

Head tracking refers to software detection and response to the movement of the user's head. Typically, it's used to move the images being displayed so that they match the position of the head. Most XR headsets have some form of head tracking in order to adjust their visual output to the user's point of view. Orientation tracking uses accelerometers, gyroscopes, and magnetometers to determine how the user's head is turned. Position tracking systems, like those in the HTC Vive or the HoloLens, require extra sensors set up around the room.

4.5.2 Eye tracking

Eye tracking enables software to capture which way the user's eyes are looking and respond accordingly. Light from infrared cameras is directed toward the participant's pupils, causing reflections in both the pupil and the cornea. These reflections, otherwise known as pupil center corneal reflection (PCCR), can provide information about the movement and direction of the eyes. Eye position can also be used as input.

Eye tracking can be used to capture and analyze visual attention using:

- gaze points: what the eyes are looking at. If your eye tracker collects data with a sampling rate of 60 Hz, you will end up with 60 individual gaze points per second.
- fixation: if a series of gaze points is very close – in time and/or space – this gaze cluster constitutes a fixation, denoting a period where the eyes are locked towards an object.
- heatmaps: visualizations which show the general distribution of gaze points
- areas of interest (AOI): a tool to select regions of a displayed stimulus, and to extract metrics specifically for those regions. While not strictly a metric by itself, it defines the area by which other metrics are calculated.

And provide output metrics, such as:

- time to first fixation: the amount of time that it takes to look at a specific AOI from stimulus onset
- time spent: the amount of time spent looking at a particular AOI
- Fixation sequences: based on both spatial and temporal information – when and where a user looked. This allow a picture to be built up of what is prioritized

4.5.3 **Full body tracking**

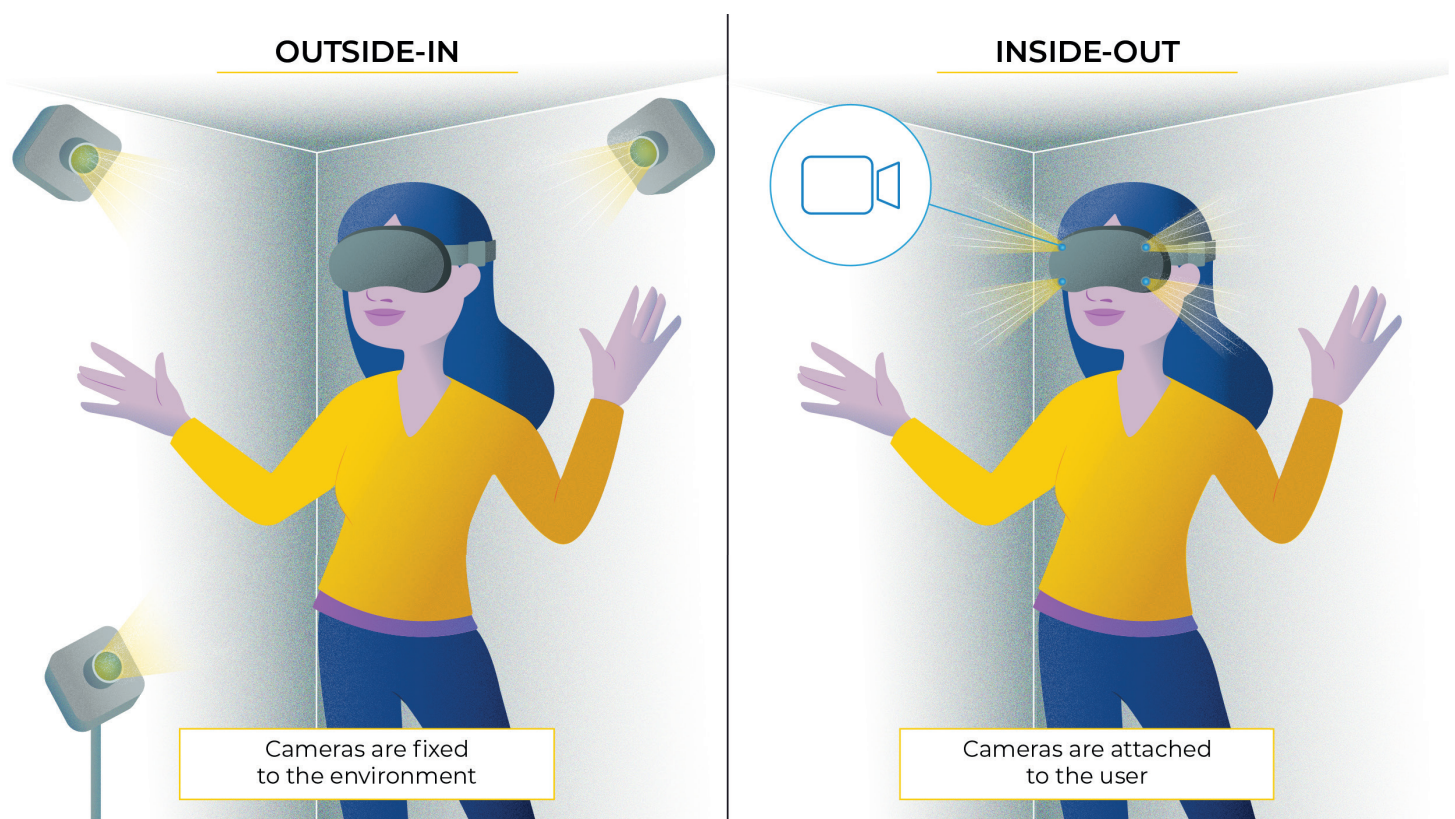
Full body tracking is the process of tracing the humanlike movements of the virtual subject within the immersive environments. The location coordinates of moving objects are recorded in real-time via head-mounted displays (HMDs) and multiple motion controller peripherals to fully capture the movement of the entire body of the subject and represent them and their movements inside the virtual space.

4.5.4 **Inside-Out tracking**

Inside-Out tracking is a method of positional tracking commonly used in XR technologies, specifically for tracking the position of head-mounted displays (HMDs) and motion controller accessories. It differentiates itself from outside-in tracking by the location of the cameras or other sensors that are used to determine the object's position in space (Fig 1). For inside-out positional tracking, the camera or sensors are located on the device being tracked (e.g., an HMD) while for outside-out positional tracking, the sensors are placed in stationary locations. An XR device using inside-out tracking looks out to determine how its position changes in relation to the environment. When the headset moves, the sensors readjusts the user's place in the room and the virtual environment responds accordingly in real time. This type of positional tracking can be achieved with or without markers placed in the environment. The latter is called markerless inside-out tracking.

4.5.5 Outside-In tracking

Outside-In tracking is a form of positional tracking where fixed external sensors placed around the viewer are used to determine the position of the headset and any associated tracked peripherals. Various methods of tracking can be used, including, but not limited to, optical and infra-red.



Biometric Tracking goes beyond just the how one moves, coordinates, and uses their body in immersive environments. It complements the XR technology by monitoring and feeding back the user's heart rate, respiration rate, pulse oximetry, and blood pressure. In traditional XR systems, tracking is used to provide a more immersed experience, ranging from head position and angle, hand movements, eye tracking and full body tracking capabilities. Biometrics tracking enable even more personalized data collection that can potentially be used for both good and bad purposes.

4.6 Biometric Tracking

4.7 Gaze

By using eye tracking technology, one can track the direction (ray) where the user is looking in the virtual scene as well as potentially attribute the emotional response, such as increased heart rate, dilated pupils or triggering variety of human emotions.

SECTION 5

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About XRSI



XR Safety Initiative (XRSI) is a 501(c)(3) worldwide not-for-profit charitable organization focused on promoting privacy, security, ethics in the XR domain (virtual reality, mixed reality, and augmented reality). Our mission is to help build safe immersive environments so that XR stakeholders are able to make informed and pragmatic decisions. We do so by discovering novel cybersecurity, privacy, and ethical risks and proposing potential solutions to mitigate them. XRSI, being first such global effort, finds itself in a unique position to provide impartial, practical information about XR related risks to individuals, corporations, universities, government agencies, and other organizations worldwide. XRSI develops standards, frameworks as well as knowledge-based documentation in the XR domain by partnering with global institutions, such as STOP.THINK.CONNECT. Campaign and Open AR Cloud.

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