

# Understanding Extended Reality Technology & Data Flows

Extended reality (XR) environments, including those in virtual (VR), mixed (MR), and augmented (AR) reality, are powered by the interplay of multiple sensors, large volumes and varieties of data, and various algorithms and AI systems. These complex relationships enable functions like spatial mapping and eye tracking. However, these functions often depend on collecting, processing, and transferring sensitive personal data. This data use can pose privacy and data protection risks to both users and bystanders. Let's take a look:

## SENSOR DATA

Information gathered from device sensors about the user's body and surrounding physical environment. This data enables positional tracking, which is central to basic XR functionality. Many of the latest XR devices have embedded sensors to gather and process data. Here is an example of an XR sensor configuration:

**Inertial measurement units (IMU)** measure how fast and in what direction a device is moving, device orientation, and surrounding magnetic fields to facilitate positional tracking and other functions.

**Inward-facing cameras** may collect iris or retina features for user authentication. In the future, they could also gather gaze and pupil dilation data, which, when analyzed along with other information, could help make inferences about emotion.

**Microphones** capture the user's voice and their surroundings. This enables voice commands, user-to-user interactions, and in some devices, spatial mapping and realistic sound effects.

**Outward-facing cameras** capture the user's physical environment, which can include nearby individuals, personal property, and potential obstacles, to track a user's interactions with the surrounding space.

## EXPRESSIVE AVATARS

An XR experience may use body data to reflect the user's physical-world movements, facial expressions, and gaze in their virtual avatars within a digital environment.

## FORMS OF XR

### AUGMENTED REALITY (AR)

A view of the physical world with an overlay of digital elements.

### MIXED REALITY (MR)

A view of the physical world in which digital elements interact with the physical environment and vice versa.

### VIRTUAL REALITY (VR)

A fully immersive digital environment in which a virtual world is the user's main experience rather than their physical space.

## SHARED EXPERIENCES

Sensor and location data are used to accurately place the user within an experience, position them in relation to virtual content, and create maps of the physical space. In shared experiences, the user can then utilize physical controllers, hand gestures, and eye movement to interact with both content and other users.

## OPTIMIZED GRAPHICS

Devices can use eye data to simulate peripheral vision, ensure that images are crisp and in focus, and reduce the likelihood of motion sickness.

## USER AUTHENTICATION

Biometric data can be used to authenticate the user and ensure their profile and settings apply when they use a device.

## PERSONALIZED CONTENT

Body based data (e.g., gaze and body motion) can provide insight into a user's likes and interests, which could be used to create more personalized experiences and recommend content.

## USAGE & TELEMETRY DATA

Data from apps on a user's device, including time spent in an app and with what content they engage. One reason parties may collect this data is to address software crashes and bugs.

## XR DEVICE DATA

This includes hardware and software information, identifiers, and IP addresses, which can be used to track users across applications.

## LOCATION DATA

Information that indicates the device's precise or approximate geographical position, which can enable shared experiences.

## TECHNICAL PROCESSES

XR requires advanced data processing systems, such as simultaneous localization and mapping (SLAM) algorithms and machine learning, which map the user's environment and power other functions, like object recognition and gesture-based controls.

## RISKS & DATA SHARING

XR technologies require significant data processing to function safely, so collection limitations are often impractical. Some XR technologies transfer data to other users and third parties. Using and transferring sensitive data sharing may enhance XR experiences, but it must be accompanied by robust privacy safeguards.