PRESENCE

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A toolset for hyper-realistic and XR-based human-human and human-machine interactions, PRESENCE

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D5.2 Integration and Demonstration II – Intermediate integration, testing and validation

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CHANGE HISTORY

VERSION	DATE	PARTNERS	DESCRIPTION/COMMENTS
V0.1	16-05-2025	All	First iteration of the document by all partners.
V0.2	04-06-2025	All	Second iteration of the document by all partners.
v1.0	12-06-2025	All	Internally reviewed and adapted document.
v2.0	14-08-2025		Adapting review comments from internal review
v3.0	02-09-2025		Adapting review comments from internal review
v3.1	03-09-2025	i2CAT	Minor modifications

Executive summary

The primary aim of Work Package (WP) 5 is to develop and validate two demonstrators that highlight the technological advancements achieved in WP2 (Holoportation), WP3 (Haptics), and WP4 (Intelligent Virtual Humans). These advancements will be demonstrated through four distinct use cases: (i) Professional Collaboration, (ii) Manufacturing, (iii) Health (Pain Relief), and (iv) Cultural Heritage. The validation will be done by showing higher usability and acceptance rates in studies and interviews conducted for all sectors targeted in the use cases.

Deliverable D5.2 provides a comprehensive outline of the goals, objectives, KPIs, and timelines. It also includes detailed descriptions and deployment diagrams of the four use cases, emphasizing the integration and development plan crucial for creating the two demonstrators. A detailed process and plan to achieve the KPI's and goals are under development and will be successfully executed before the end of Phase 2 of the project.

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1. Introduction

1.1. Purpose of the Document

The aim of Deliverable 5.2 is to present an overview of the objectives and tasks outlined in Work Package 5 (WP5). This document describes the evolution of the Initial Version of Use Case Demonstrators integrated with the Technological Pillars WP2 (Holoportation), WP3 (Haptics), and WP4 (Intelligent Virtual Humans). The integration and demonstration efforts focus on real-world applications, illustrated through four specific use cases. Ultimately, WP5 seeks to validate these technological advancements in two demonstrator's groups, targeting both professional and social XR applications, thereby highlighting the practical capabilities and benefits of the PRESENCE project. A detailed validation plan and process for feedback and error/ issue management are under development and will be completed by November, and after review and acceptance with leadership of Presence, execution of the validation plan will begin.

1.2. Scope of this Document

This document aims to fulfil Milestone 4 by delivering two demonstrator groups, i.e., 4 Use Case Demonstrators deployed and thereby validating the technological advancement in the project.

(Milestone 4: Phase II ends: UX, Usability and Presence intermediate evaluation, requirements 1st validation, 1st Demonstrators deployed and validated, impact max. strategy 1 delivered.)

1.3. Status of this Document

This document is being developed to meet Milestone 4. It reflects the ongoing efforts to compile, integrate, and plan the technological advancements and demonstrations within the PRESENCE project, ensuring alignment with the overall project goals and timelines.

1.4. Relation with other activities in the Presence Project

This document synthesizes the contributions from WP1, WP2, WP3, and WP4, which serve as foundational inputs for WP5. The work package (2-4) plays a critical role in developing different technological components—Holoportation (WP2), Haptics (WP3), and Intelligent Virtual Humans (WP4). These components are integrated within WP5 to create two demonstrators. WP1 provides the experimental protocols and requirements necessary to guide this integration and ensure that the demonstrations are aligned with the overall project objectives

2. Work Package 5

2.1. Objectives of Work Package 5

The primary objectives of Work Package 5 (WP5) are:

1. **Provide APIs for Integration**: Develop a set of APIs to enable seamless integration of the technological components—Holoportation (WP2), Haptics (WP3), and Intelligent Virtual Humans (WP4)—into external Extended Reality (XR) applications, specifically focusing on the two project demonstrators.

2. **Define, Implement, and Validate Demonstrators**: Outline, create, and evaluate two demonstrators that integrate the technological components. These demonstrators will facilitate comprehensive validation and assessment of the PRESENCE solutions from an end-user perspective.

3. **Enable Integration and Collaboration**: Align with the other work packages to enhance collaboration among partners, streamline the integration of technologies, define and generate APIs, and finalize integration within applications used for user experience tests and demonstrations.
4. **Enhance UX Design and Best Practices**: Offer design oversight, technical support, and best practices to ensure consistent design, interoperability, performance, and accessibility across the integrated technologies. This includes conducting usability and presence evaluation tests.
5. **Execute Demonstrators**: Efficiently execute two demonstrators—one for professional XR setups focusing on collaboration and manufacturing training, and another for social XR setups emphasizing health and cultural heritage. The demonstrators will be developed through a phased approach, from initial planning to final integration and demonstration.

Overall, WP5 plays a crucial role in integrating and demonstrating the technological advancements developed within the PRESENCE project, with the aim of advancing XR technology and enhancing user experiences in various domains.

3. Methodology

3.1. Overview

To effectively integrate and demonstrate the various technological advancements developed in the PRESENCE project, we plan for a process that ensures thorough testing, validation, and refinement. Each work package has their Weekly Meeting for alignment as well as WP5 have the Weekly alignment where Technological Pillars (WP2-4) and Use Case Partners (WP5) share the progress of their work, issues faced and get the interim and long-term solutions. Further Integration plan is detailed later in Section 6.

3.2. Approach for Integration and Demonstration

For the successful integration of Technological Pillar to the respective use cases, we have planned for several Integration workshops. In preparation for the Integration workshop, held in the past. The WP5 Leads have supported the success of the workshops by organising multiple Technological Pillar briefing sessions for WP2, WP3 and WP4 and with the Use Case development Partners (Vection, SyncVR and Zaubar) prior to the workshops.

Integration Workshop: i2Cat, Barcelona

The first integration workshop was held at the i2Cat facility at Barcelona, where developers from the Technological Pillars (Holoportation, Haptics, and Intelligent Virtual Humans) collaborated with the Use Case Partners to define an approach and plan for the integration of each technology pillar and the features it offered into the use cases. By the end of the workshop an initial approach and plan was decided for the integration of the technological components into the respective use cases.

To further enhance the integration, the goal was to add the Haptic SDK to the remaining Use Cases. During the workshop, several findings emerged: the Haptic Vest was not yet functioning as desired, and the Holopresence setup proved to be complex, requiring additional refinement and coordination.

As part of the outcomes, video recordings showcasing the integrated status of the Use Cases were created and are available for review. These videos will guide the ongoing development and help prepare for the next phase of user testing.

Figure 1: Project members attending integration workshop at i2cat in Barcelona

Figure 2: Project members during integration workshop in Barcelona

The Outcomes of the meetings with the Use case integrated status video recordings are available under [250331-0401 Integration meeting BCN - TCM13](#).

Integration Workshop: VUB

The second integration workshop took place at University of Brussels (VUB) where the developers from the Technological Pillars (Holoportation, Haptics and Intelligent Virtual Humans) and along with the developers from the Use Case Partners participated. This session was intended to test the initial version of the use case demonstrators, but due to issues with the SDK integrations and use case implementation, time during the integration workshop was spent on trying to fix these issues and perform re-integration. A realignment on the approach and plan was performed. It was a productive session where the Technological Pillars were integrated into the Use Cases.

Figure 3: Project members during tests at integration workshop at Vrije Universitet Brussel

To improve the communication during the critical integration phase, it was decided to have a weekly meeting to collaborate on the Integration Status to prepare Version 0 of the use case before the User Evaluation Test at VUB. Also, as part of this, the Second Integration workshop took place at VUB and the User Application has progressed further to have a demonstrator for the user evaluation test.

Although the initial purpose of the workshop was to allow IMEC to internally test all use case applications, the focus shifted toward collaborative development and integration work with the technological pillars. As a result, the applications were not yet in a state suitable for IMEC to begin full internal testing. To address this, each of the technological components was presented and explained separately to IMEC at the end of the workshop, allowing them to prepare the setups themselves in time for the upcoming user tests in Brussels.

At that point, only the health use case was in a testable state, though still without Holoportation. The main issue identified during the workshop involved the interaction design: the Intelligent virtual human avatars were not facing each other, which significantly impacted the user experience.

Next step is to build Version 1 of the Use Case application from the Use Case Partner, for this detailed plan is provided in the respective use case section.

4. Work Package 5 Activities

4.1. Overview of Work Package 5 tasks

WP5 consists of 4 concrete tasks:

4.1.1. Task 5.1 APIs, Integration and Architecture

Focuses on creating APIs for the technology developed in previous work packages (WP2, WP3, and WP4). The list of API's are elaborated under section 4.1.5. These APIs will help integrate the technology into various applications for testing and demonstration purposes. The task also involves defining how these technologies will work together and designing the software architecture needed for implementation. The deployment diagram can be found in Figure 5

4.1.2. Task 5.2 UI/UX

Focuses on improving user experience and design for interactive Extended Reality (XR) environments. Capgemini leads this task, with support from other project contributors. The goal is to enhance the integration of three key technologies: Holoportation, Haptics, and Intelligent Virtual Humans, developed in previous work packages. Capgemini will provide guidance, best practices, and technical support to ensure a seamless execution of Task 5.2. This includes ensuring that the technology can be applied to a wide range of XR use cases beyond the initial demonstrations. Additionally, the task aims to maintain a consistent design across the three technologies, ensuring cohesive user interfaces and experiences. Since there exists a unity template by Vection at the time of Unity to Capgemini take over. It was decided to use this template and all the technological pillars were integrated into this template as a first step. Later the Unity Template is then merged to each use case. So that all Use cases were built upon this Unity Template.

4.1.3. Task 5.3 XR for Professional XR Activities

Focuses on creating immersive XR environments for professional collaboration and manufacturing training. VECTION leads this task, with support from other project contributors. The goal is to efficiently execute Demonstrator 1 for XR Professional Setups, following the guidelines and achievements of previous technology development work packages. This task aligns its activities with the experimental protocol T1.4 and is divided into two use cases: Use Case 1.1 focuses on collaborative environments, while Use Case 1.2 centres' on manufacturing industry training scenarios.

Figure 4: Professional Collaboration - Overview of the room

More people can be present in the room to discuss the project of a new chair.

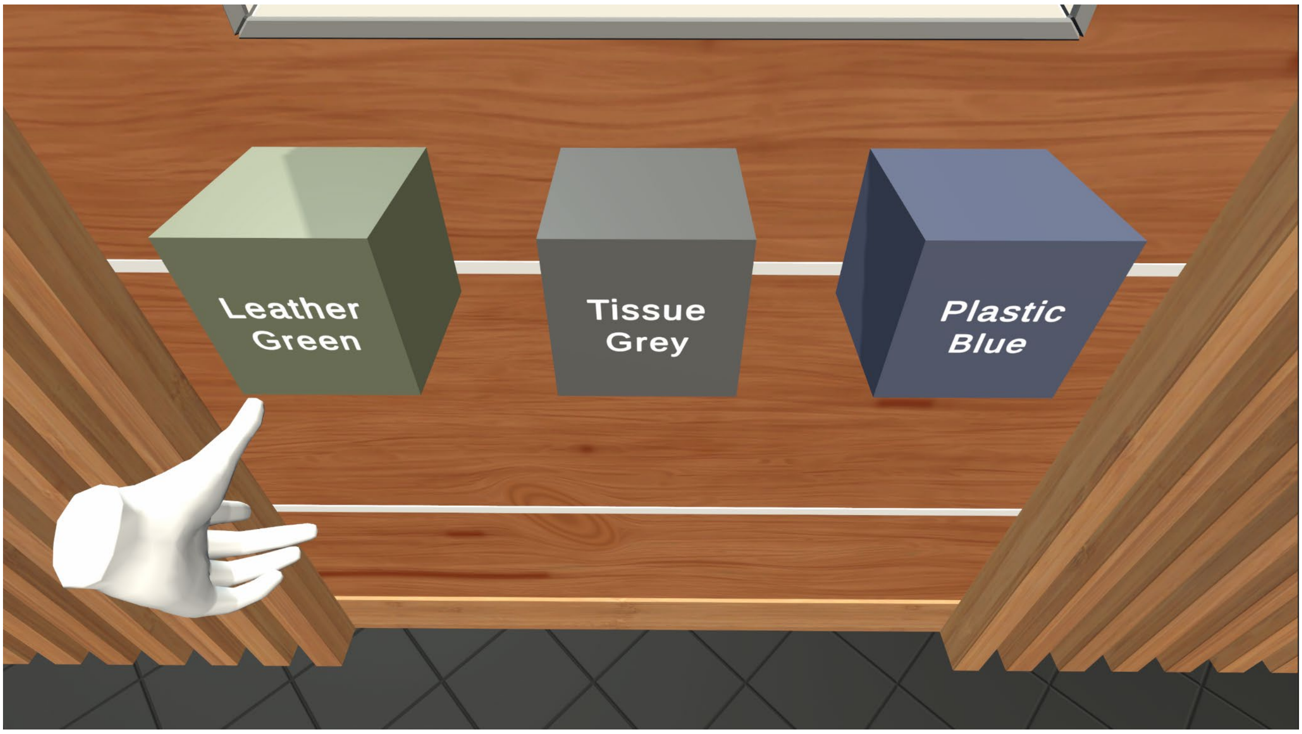

Figure 5: Professional Collaboration - Change colours and materials on the chair

Just touching one of the cubes, the chair will change accordingly with the right colour and material applied

Figure 6: Professional Collaboration - Chair with the new colour

Visualization of the chair with the new color

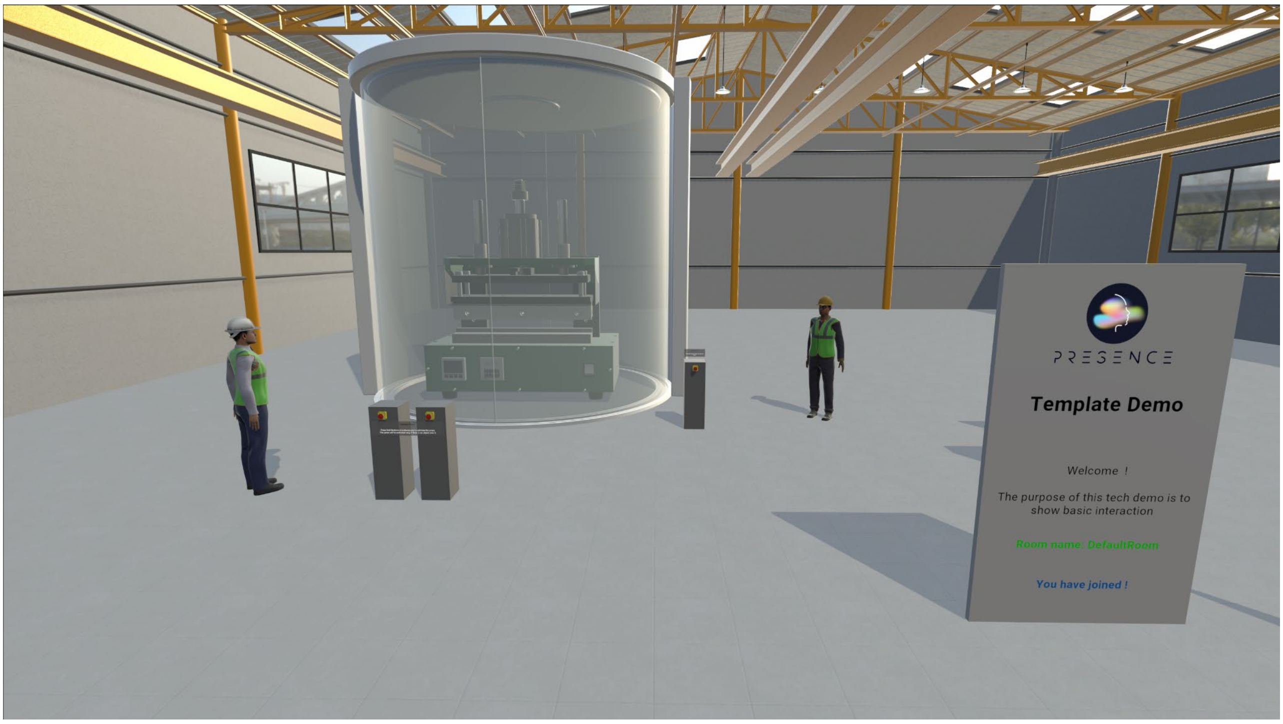

Figure 7: Manufacturing Training - Overview of the scene

More people, teachers and students, can be on the scene to operate in a safe environment.

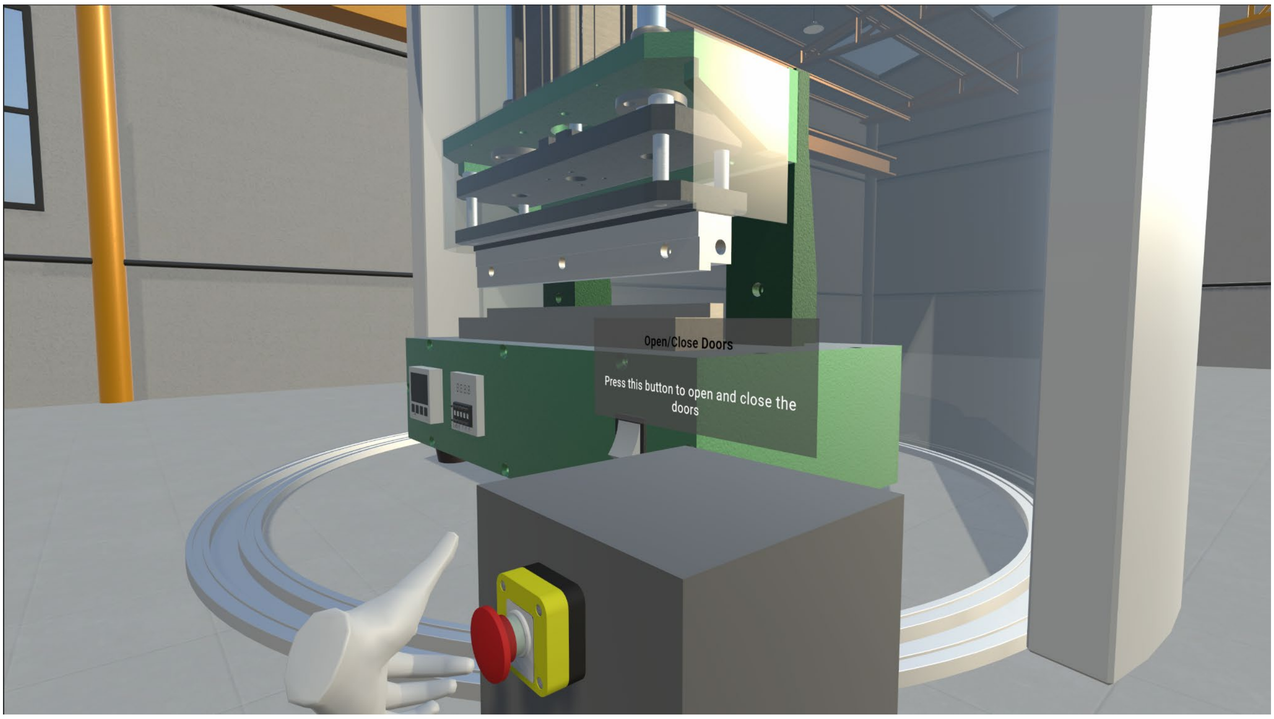

Figure 8: Manufacturing Training - Open door

One of the steps of the procedure is to open doors (and then close them) to insert the billet in the press machine. Doors can be closed only if the press room is empty.

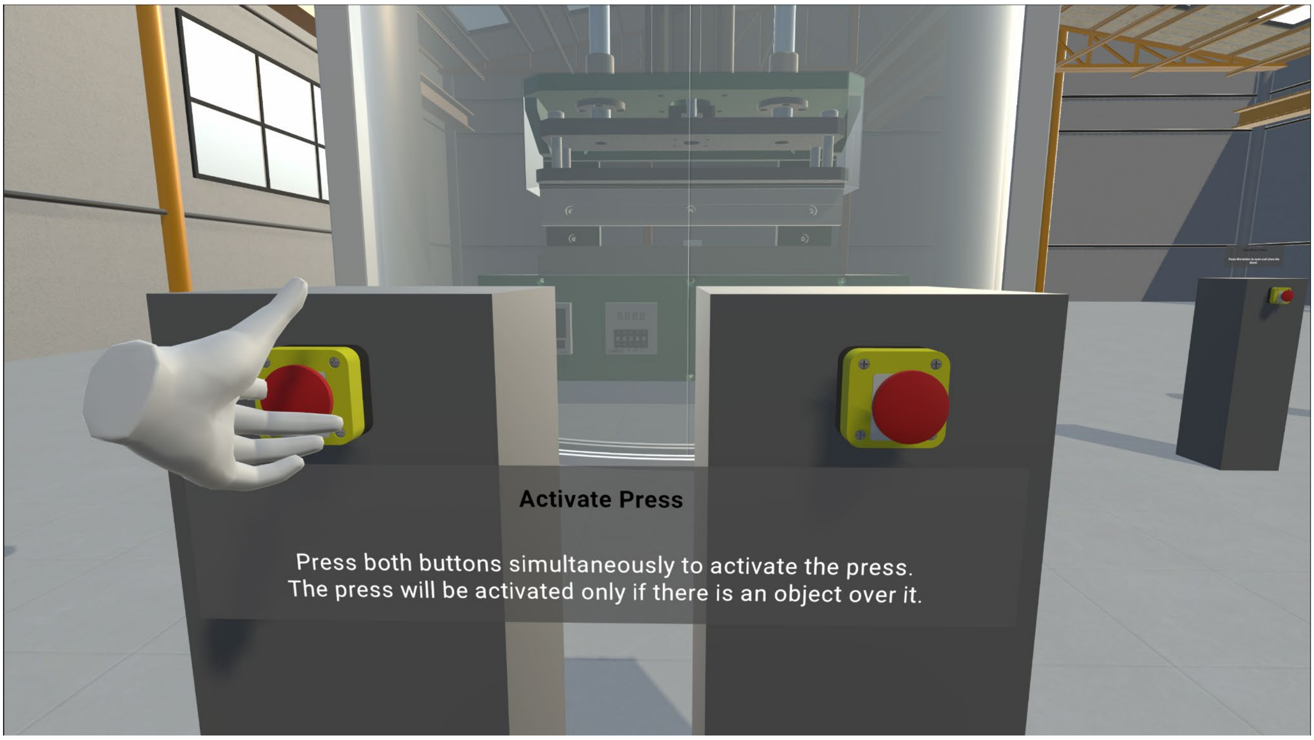

Figure 9: Manufacturing Training - Press buttons

To operate safely, both buttons must be pressed simultaneously. Doors must be closed and the room press must be empty.

4.1.4. Task 5.4 XR for Social & Cultural XR Activities

Focuses on developing XR environments for social and cultural activities related to health and cultural heritage. SVR leads this task, with support from other project contributors. Following the guidelines and technology developed in previous work packages (WP2, WP3, WP4), this task ensures the efficient execution of Demonstrator 2 for XR Social Setups. The goal is to create two scenarios outside the professional corporate sphere: Use Case 2.1 focuses on developing an XR application for the health domain, specifically demonstrating immersive technologies in a pain relief scenario.

Use Case 2.2 covers the cultural heritage domain, integrating technological pillars into a touristic cultural experience. Similar to Task 5.3, the implementation of this task follows three phases: initial planning and definition, integration of technological pillars, and final delivery. Activities are aligned with the experimental protocol (WP1), focusing on validating and evaluating the PRESENCE technology, with particular attention to integration-related parameters.

For all use cases a specific hardware and software evaluation will be conducted on the integrated technologies to assess parameters relevant for the integration process, such as level of detail, API/SDK definition and documentation quality, computational resource usage, frame rate, robustness, security, and module interconnection.

4.1.5. API Definition and Integration Interfaces

Since no external APIs are planned to be used (beside the 3 pillars SDKs), the focus will be on defining the internal APIs between the different SDKs and the local application.

This will involve specifying the data formats and protocols used for communication between the components.

Table 1: High-Level description of used components and hardware

Target Platforms
• Windows Desktop using a VR head-mounted display (Meta Quest 3)
System Components:
• Intelligent Virtual Humans SDK: Manages Intelligent Virtual Agents (IVAs) that can move and interact with the humans.
• Holoconferencing SDK: Creates realistic avatars from live camera feeds for realistic interactions.
• Photon: Networking solution for multiplayer capabilities.
• Unity: Client Application

API Description

A brief overview of the API functions is provided below, with references to the detailed documentation.

Haptics SDK API

The WP3 Haptics API provides a unified framework for integrating haptic feedback into XR applications using Unity. It supports multiple haptic devices (e.g. SenseGlove, Actronika, Interhaptics) and enables developers to trigger vibrotactile and force-feedback effects on specific body parts.

The API includes tools for creating, managing, and playing haptic effects, as well as components for collision-based feedback (emitters and receivers). It also supports file transcoding between formats and offers extensibility for custom device implementations.

Overall, it simplifies the integration of haptics into immersive experiences, making it scalable across different hardware platforms and interaction systems.

The detailed description can be found under this link:WP3 API Documentation.

Intelligent Virtual Humans SDK API

The Intelligent Virtual Humans (IVH) toolkit offers a modular and extensible API for creating and interacting with Intelligent Virtual Agents (IVAs) in XR environments. The core of the system is built around an **Agent Base Class**, which allows developers to define agent attributes (e.g., name, age, gender) and customize behaviour through interchangeable modules.

Key API components include:

- **Cloud Service Manager**: Manages integration with STT (speech-to-text), TTS (text-to-speech), and LLM/VLM services (e.g., GPT-4o, Gemini, LLaMA).
- **Action Manager**: Maps agent actions to animation states, with support for culturally contextual behaviours and motion datasets (e.g., Mixamo, CC4).
- **Facial Expression Manager**: Supports both mocap-based animations and blendshape presets (based on FACS), triggered by LLM outputs.
- **Gaze Behaviour Manager**: Controls eye and head movements using IK and realistic gaze simulation.
- **Gesture Recognizer**: Enables trajectory-based gesture recognition for hand/controller input.
- **Vision Module**: Provides egocentric visual input via a virtual camera, enabling image-based prompting and contextual responses.

The API supports multimodal prompting, combining user speech, gestures, and visual input with structured system prompts. These prompts guide the LLM/VLM to generate coordinated agent behaviours, including speech, facial expressions, gaze, and body movements.

Developers can extend or replace modules to suit specific use cases, and the toolkit supports both cloud-based and local AI models. The system is implemented in Unity (URP) and is compatible with standard avatar formats. A more detailed explanation is available at the following links: https://git.informatik.uni-hamburg.de/presence/WP4/intelligent-virtual-humans-sdk/packages/ivh-sdk-core/-/blob/main/Runtime/Scripts/IntelligentVirtualAgent/ConversationalAgent.cs?ref_type=heads

https://git.informatik.uni-hamburg.de/presence/WP4/intelligent-virtual-humans-sdk/packages/ivh-sdk-core/-/blob/main/Runtime/Scripts/IntelligentVirtualAgent/AgentBase.cs?ref_type=heads

Holoconferencing SDK API

The Holoconferencing SDK provides Unity-based APIs for managing real-time 3D conferencing experiences. Its core functionality includes initializing multi-user sessions, capturing and streaming point cloud data from depth cameras, and rendering avatars in shared virtual spaces. Developers interact with the API through Unity components and configuration files to control camera input, media transmission, and avatar placement. The SDK also supports REST-based services for user authentication and session orchestration and includes tools for switching between live and pre-recorded data pipelines. All functionality is exposed via Unity scripts and prefabs, enabling rapid integration without low-level coding. The detailed description of the API is stored under following link: SDK Documentation_v3.2.0.docx

4.2. Architecture Design

The system architecture is designed to accommodate the interaction between the various SDKs (Haptics, Intelligent Virtual Humans, and Holoconferencing) and the local application. The architecture will ensure real-time communication between the components and handle data exchange in real-time. Refer to the figure below ***Figure 3: System Architecture***

Each Technological pillar SDK is detailed below.

Holoportation SDK - Complete details of the SDK is available in deliverable D2.1 and under Section 4.
https://docs.google.com/document/d/1JYTa245288I7xdEnoIM5k3vaSHWOESPZ/edit?usp=drive_link&ouid=117049536360338438346&rtpof=true&sd=true

The Holoportation SDK is a comprehensive solution designed to enable real-time volumetric telepresence. It provides the ability to capture, process, compress, transmit, and render 3D holographic data, allowing immersive, life-like communication experiences. By leveraging lightfield imaging, GPU acceleration, and cloud-based optimizations, the SDK delivers high-fidelity holographic streams across multiple platforms while maintaining scalability and performance.

The SDK consists of six interconnected modules that form the end-to-end holographic data pipeline. Each module plays a specific role in capturing and delivering volumetric content in real time.

A. **Light Field capture system:** the capturing system is responsible for acquiring synchronized multi-camera RGB and depth frames in real time. Each camera connects via a Coaxial PCIe frame grabber, with an ideal setup of one camera per GPU, though optimizations allow up to two cameras per GPU. The internal camera parameters are calibrated using Raytrix camera calibration solution. On the other hand, the extrinsics parameters of the camera are estimated using CERTH Multi-Camera Calibrator, ensuring precise alignment across all viewpoints. The module outputs synchronized RGB and depth frames from all cameras, ready for further processing.
B. **Volumetric capture and reconstruction module:** once the frames are captured, they are processed to build a unified 3D representation for each frame of the session. This module performs several preprocessing steps including depth cleaning, noise reduction, outlier filtering, and color correction. After these operations, the data is reconstructed into a complete volumetric frame that is optimized for subsequent compression and transmission. In this last step, the algorithm requires the extrinsic calibration parameters estimated using CERTH Multi-Camera Calibrator.
C. **Volumetric video compression and transmission:** the reconstructed volumetric frames are then encoded and compressed using our proprietary GPU-accelerated CUDA algorithms. This step ensures that the data can be efficiently transmitted over the network while maintaining visual fidelity. Each packet of compressed data is accompanied by necessary metadata headers that allow correct decoding on the client side.
D. **Volumetric cloud services optimization:** this service is currently hosted in Azure. Once received in the cloud, the volumetric data stream is decompressed and analysed to apply client-specific optimizations. These optimizations consider available bandwidth, computing capabilities of the target device, and field of view constraints. After adjustment, the optimized data is re-encoded, compressed and transmitted to the appropriate client endpoints, ensuring smooth playback and rendering.
E. **Reception and rendering on client:** on the client device, the incoming data stream is decompressed and decoded into volumetric frames. These frames are prepared for visualization and passed to the Unity SDK, where they are rendered in real time for AR, VR, or desktop experiences. The rendering pipeline ensures that the holographic representation is displayed with low latency and high quality.
F. **Orchestration layer:** the orchestration services oversee the entire process, handling user authentication, session and event management, and real-time audio processing and distribution. This

layer ensures synchronization across participants, manages session health, and maintains a seamless end-to-end experience.

The Holoportation SDK processes data in a linear yet optimized flow. First, multi-camera RGB and depth frames are captured and synchronized. These frames are then pre-processed and reconstructed into a 3D volumetric frame, which is compressed for efficient transmission. The compressed packets are streamed to the Azure cloud, where they are decompressed, optimized for each client's capabilities, and re-encoded for delivery. Upon reaching the client, the data is decoded, prepared for rendering, and displayed through Unity SDK. Parallel to these operations, the orchestration layer manages session integrity, user permissions, and audio distribution, ensuring a coordinated and immersive experience.

The Holoportation SDK operates at a minimum of 15 frames per second, delivering real-time performance across the entire pipeline. It supports multi-camera calibration for precise 3D reconstruction, utilizes GPU acceleration for intensive processing and compression tasks, and integrates cloud-based adaptive streaming to match client conditions. The Unity SDK integration ensures platform flexibility, while the orchestration layer provides robust session management and spatial audio support.

Haptics SDK - Complete details of the SDK is available in deliverable D3.1 and Under Section 2.3.
https://docs.google.com/document/d/1VxKaiUNyCM3Wlw4h07h6I2xgKTdTKlXg/edit?usp=drive_link&ouid=117049536360338438346&rtpof=true&sd=true

The Haptics SDK allows developers to add various forms of real-life tactile feedback (e.g. Vibration or a resistive force) into XR experiences from different haptic devices to improve immersion. From controllers to gloves to vests, this SDK provides a standardized 'layer' for developers to work with haptics, without needing to worry about individual device APIs. Effects created for one device are 'transcoded' into other formats at compile time, so they can be replicated on similar devices - provided these are also integrated into the Haptics SDK.

The Haptics SDK consists of multiple parts, each working together to transform actions in XR into tactile experiences:

A. **Core API:** A static layer of code with simple Play / Stop / Load functionality, which can be used to control haptic effects from anywhere within the simulation. Most of these functions take Haptic (base) effects and/or location information as a parameter. Based on these parameters, the Core API ensures that effects are passed on to the relevant Devices.
B. **Device Implementations:** Each device commonly has its own APIs, command structure, and plugins. The Core API exposes an interface that must be implemented by device manufacturers such as SenseGlove and InterHaptics. The Core API passes its function calls to this implementation, and it's up to the device manufacturer to handle the effect.
C. **Transcoding Pipeline:** Part of the functions a Device Implementation must handle are methods to convert between their own haptic format (.haps, .wav, etc) and a 'standard haptic format' (.hjif). When a Haptic Effect is assigned to a BaseEffect in the Haptics SDK, it is encoded into the 'standard' format, from which it is decoded across the other implementations in the project. During runtime, a device implementation can grab its own format from this BaseEffect and play it through their own APIs. Aside from 'loading' the effect, there is no additional computational cost.
D. **Haptic Receivers / Emitters:** Used to quickly add haptic functionality to colliders within the scene. Receivers represent a body part and can be equipped to Avatars to allow users to feel effects from Haptic Emitters. When emitters come into contact with receivers, they play their assigned haptic effect on the relevant body part(s) via the Core API. Collision information is converted into a location parameter, which is used by device implementation to determine which actuators to power.

The logic for the Haptics SDK runs entirely on the client side, ensuring that haptics are played when the local user sees their action(s). Using the Transcoding pipeline, effects made for one device are converted to that of others before a build, ensuring other implementations can play them without the need for runtime resources.

Intelligent Virtual Human SDK - Complete details of the SDK is available in deliverable D4.1 and under Section 4

https://docs.google.com/document/d/1FPlNIlKyM9dO9vUpls-MN_sUYUijKSKu/edit?usp=drive_link&ouid=117049536360338438346&rtpof=true&sd=true

The Intelligent Virtual Human (IVH) SDK aims to deliver a cost-efficient toolkit designed to provide real-time photorealistic humanoid 3D models using a technology capable of representing users (as avatars) or autonomous agents (as IVAs).
It enables natural, multimodal communication and interaction through speech, facial expressions, gaze, and full-body motion.

User Input & Initial Capture
The interaction begins when the user engages with the system through the Meta Quest and its controllers, which track head, face, eyes, and hands. Additionally, an external RGB-D camera captures full-body gestures and spatial behaviour. These multimodal inputs—audio, gestures, and visual cues—form the basis for interaction with Intelligent Virtual Agents (IVAs).

T4.3 – ivh-sdk-core: Core Intelligence & Interaction Loop
This module is the cognitive engine of the IVA system. It processes speech and drives the agent's verbal and non-verbal responses:

- Speech-to-Text (STT): Audio input is streamed to the **Google Cloud STT API**, which transcribes it into text.
- Large Language Models (LLMs): This prompt is sent to **OpenAI**'s chat creation endpoint. The LLM returns a structured output:
    - Textual response
    - Facial expression
    - Body action
- Text-to-Speech (TTS): The text response is sent to the **Google Cloud TTS API**, which synthesizes natural-sounding speech.
- Lip Synchronization: The audio is synchronized with the IVA's facial movements using **Oculus OVR Lip Sync**.
- Animation Control: A single animator manages both facial and body animations.

T4.2 – ivh-sdk-actions: Action Recognition & Visual Analysis
This module captures and interprets user behaviour through external RGB-D cameras. The **Visual Analyzer** detects gestures, posture, and proximity-based actions. These recognized actions are routed to **T4.5,** where they are integrated to influence the IVA's final behaviour and response.

T4.1 – ivh-sdk-humanoids: Virtual Humanoid 3D Models
This module provides the visual embodiment of IVAs and Smart Avatars (SAs). It uses the **Didimo Service, hosted on AWS,** to generate photorealistic 3D humanoid models from user selfies. These models can represent:

- **Smart Avatars (SAs)** - representation of Users.
- **Intelligent Virtual Agents (IVAs)** - AI-driven characters

The **Customization Service** allows for adjustments in height, weight, hair, and garments.
These modules produce two architectural outputs:

- A Unity prefab sent to T4.3 used in the final use case application.
- An animation-ready model sent to T4.4 for animation training purposes.

T4.4 – ivh-sdk-animations: Animation & Motion Synthesis
This module is responsible for generating expressive and physics-based animations.
It also focuses on proximal space interaction, ensuring that IVA movements are socially and spatially appropriate for the real user. Outputs from this module are sent to T4.5 for integration.

T4.5 – ivh-sdk-integration: Multimodal Interaction Layer
This final integration layer fuses all components—visual models, animations, behavioural logic, and external inputs—into a coherent IVA system.
T4.5 ensures that all modalities—speech, gesture, gaze, facial expression, and spatial behaviour—are harmonized into a seamless and immersive experience within the XR environment.

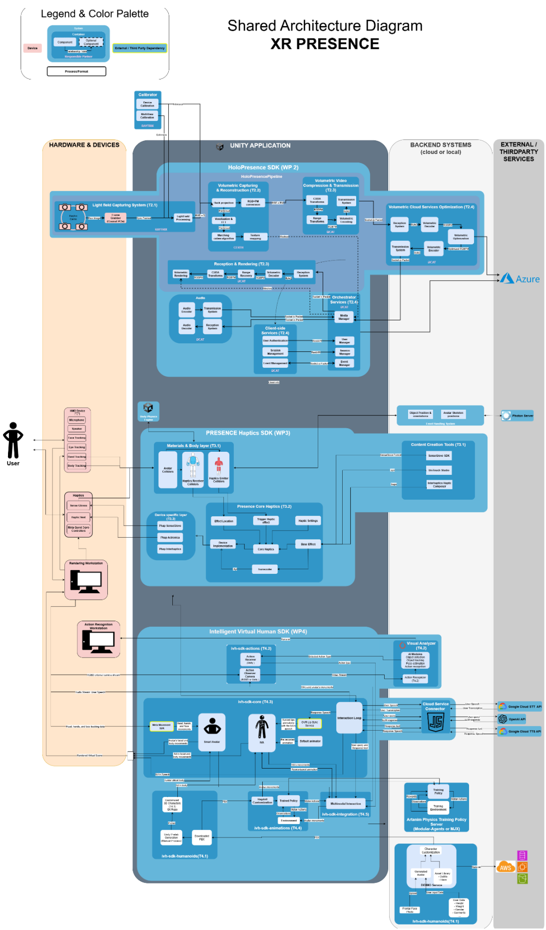

Figure 10: System Architecture

5. Use Cases - Immersive Scenarios

5.1. Use Case: Professional Collaboration

5.1.1. Use Case Description

Description: **Collaborative Armchair Design Discussion in XR Environment**

In this XR-based professional collaboration scenario, four actors wearing VR headsets come together in a virtual meeting room while physically being in different places to discuss the design of an armchair. The meeting room is equipped with a meeting table, a pedestal showcasing a 3D model of the armchair under review, a whiteboard, and a wall panel displaying a PDF document detailing the chair's specifications. **Actor 1** updates colleagues on recent chair modifications, while **Actor 2** visually illustrates these changes on the whiteboard. **Actor 3** consults the PDF document, indicating to **Actor 4** the required functionalities of the armchair. Actor 4 interacts with the virtual armchair, grabbing and moving it in different positions. All actors inspect the armchair's features, confirming its capabilities and exploring material alternatives presented on a menu. After collaborative discussion, they reach a consensus on the preferred material and conclude the meeting, exchanging farewells before disconnecting from the application.

Table 2: User description of use case: Professional Collaboration

Actor name	Function / role	Represented in experience via…	Location + HW needed
Emma (actor 1)	Furniture Designer	Avatar	Design studio + VR Headset
Tom (actor 4)	Materials Specialist	Avatar	Home Office + VR Headset, Haptic glove
Lisa (actor 2)	Industrial Engineer	Holoportation	Meeting room + VR Headset
Alex (actor 3)	Sales Representative	Avatar	Home office + VR headset

Step 1: Starting the experience

Actor 1 logs into the PRESENCE platform for professional collaboration from her studio. In setting up the meeting, Actor 1 is assisted by Actor 2 takes notes on the whiteboard, visually illustrating Actor 1's explanations. Actor 1 is joined by three colleagues: Actor 4, a materials specialist from her office; Actor 2, an industrial engineer from the company meeting room; and Actor 3, a sales representative from his home. They are all wearing VR headsets. Actor 4 is wearing haptic gloves. Actor 1 in VR, Actor 4 is in VR with Digital Touch and can feel the digital environment, Actor 2 is in VR with Holoportation, Actor 3 in VR. As they enter the virtual meeting room, they see a meeting table surrounded by chairs, a pedestal showcasing a 3D model of an armchair, a whiteboard, and a wall panel displaying a PDF document detailing the chair's specifications.

Step 2: Completing tasks in the experience

Actor 1 starts the meeting by updating her colleagues on recent modifications to the armchair design. She gestures towards the 3D model while explaining the changes. Actor 4 nods in agreement, while Actor 2 takes notes about Actor 1's explanation that will immediately be displayed on a whiteboard. In the meanwhile, Actor 3 accesses the PDF document on the wall panel, reviewing the chair's functionalities and features. Actor 3 points out specific requirements to Actor 4 in the PDF document, who adjusts his material suggestions accordingly.

On the wall, there will be three cubes that represent the three different possible combinations of colours and materials, with different consistencies that Actor 4 can feel with his haptic gloves **(haptics).** Actor 4 interacts with the virtual armchair and gives feedback on the material alternatives presented on the wall, exploring their suitability for the design.

Throughout the discussion, all actors inspect the armchair's features and capabilities, sharing insights and suggestions. They collaborate on refining the design, exploring different options until they reach a consensus on the preferred material.

Step 3: Concluding the experience

After a productive discussion, they conclude the meeting and exchange farewells before disconnecting from the application, all satisfied with the progress made in designing the armchair. Thanks to PRESENCE, the team was able to discuss, evaluate, and refine the armchair design efficiently in a virtual environment, leveraging XR technology for effective communication and collaboration. They successfully reached a consensus on the preferred material, ensuring that the project will continue moving forward smoothly.

Table 3: Used technology pillar in use case: Professional Collaboration

Tech pillar	Summary of how it is integrated in the use case
Holoportation	Actor 2 needs to be holoported because this allows her to feel more comfortable to explain the technical characteristics of the chair.
Haptics	Actor 4 uses the haptic glove to manipulate the chair

Figure 11: Screenshot from use case: Professional Collaboration

Figure 12: Example screenshot of a virtual chair with different colour/material

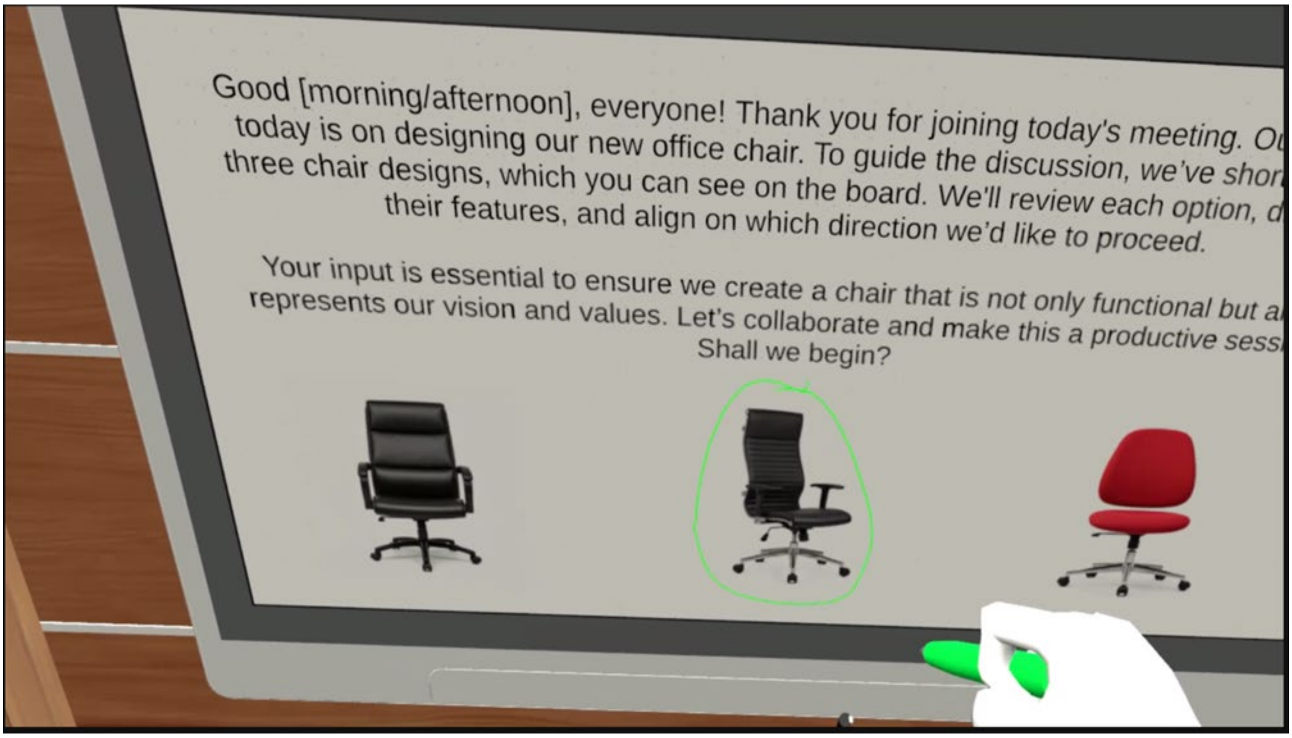

Figure 13: Example screenshot of discussion on the whiteboard

Video References:

Presence - Collaborative Armchair Design Discussion in XR Environment - Use of the Marker *https://youtu.be/lFFVi_gu34c*

Presence - Collaborative Armchair Design Discussion in XR Environment - Grabbing chair

https://youtu.be/iPVmUcda58o

Presence - Collaborative Armchair Design Discussion in XR Environment - Playing with Gravity

https://youtu.be/11nb3gZfEoI

Presence - Collaborative Armchair Design Discussion in XR Environment - Browsing PDF

https://youtu.be/7vaSeX3m_ZM

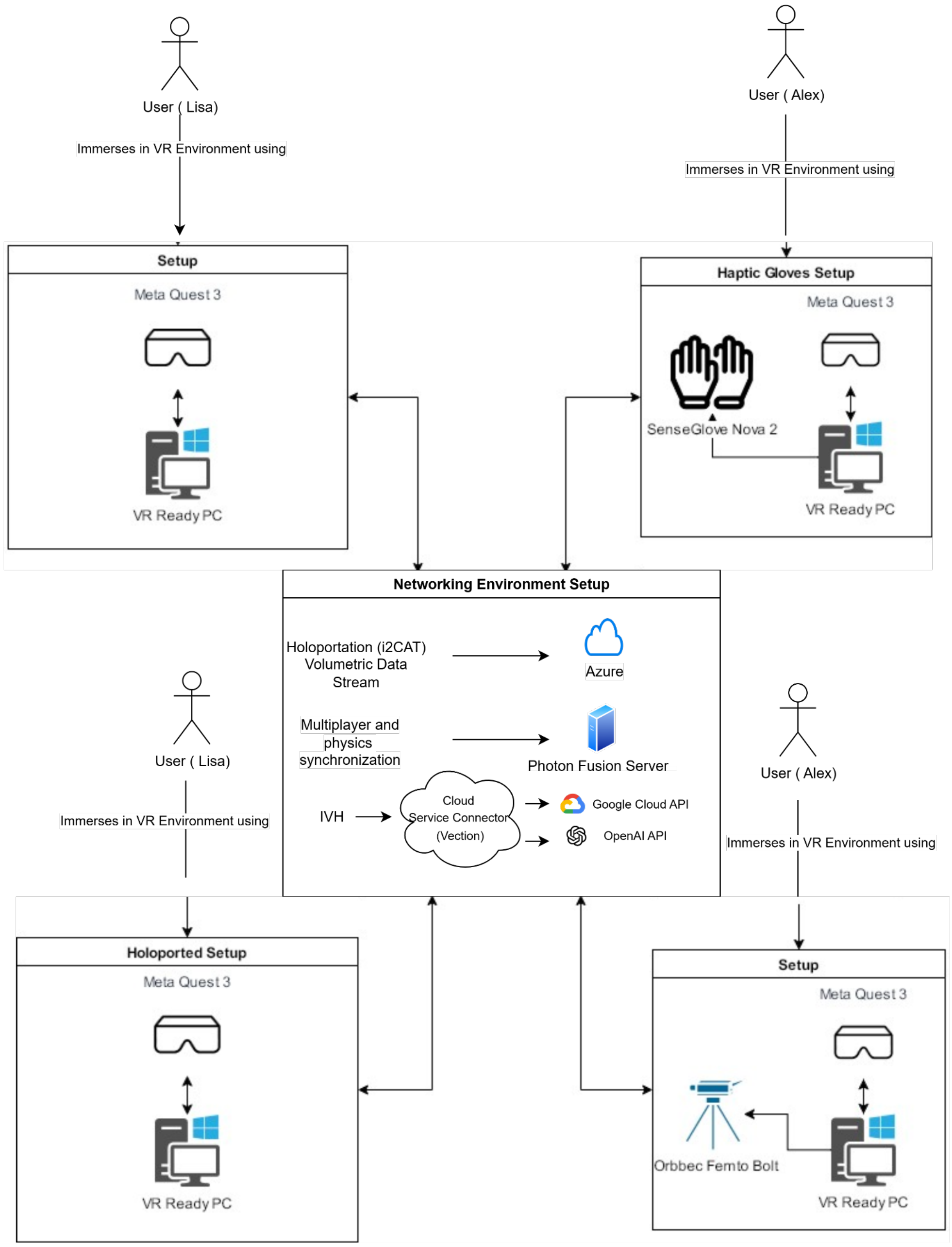

Figure 14: Deployment Diagram of use case: Professional Collaboration

5.1.2. Playable App UC1.1

Builds

Build with haptics gloves feature **enabled:**

https://drive.google.com/file/d/1QpM8Moaz-A5BU7dydNIcDgTopf5rjoEP/view?usp=drive_link

Build with haptics gloves feature **disabled:**

https://drive.google.com/file/d/1KyDtE_-VTSNiZeagvQj5hvL22BSh3nEy/view?usp=drive_link

Builds are split in two different versions (with and without haptics gloves feature), because for V0 there was not a plan to create a configuration file which could have been read at runtime to enable/disable this feature (based on which actor is running the app). It is in the roadmap for the next version.

What you need to use the experience:

- VR Ready Windows computer (laptop or desktop) with the following specs:
- Operating System: Windows 10 or 11
- Processor: Intel i7 12th generation or better (or AMD equivalent performance)
- RAM: 16 GB Ram or more
- Video Graphics: RTX 30XX or better
- Meta Quest 3 headset connected with USB cable to the computer

OPTIONAL:

- SenseGlove connected via Bluetooth to enable haptics gloves features with the specific build.
- One or more Orbbec Femto Bolt 3D Vision Devices to enable Holoportation.

How to run the experience:

- Click on the link above to download the build you need (with or without haptic gloves support);
- Unzip the file on your computer.
- Double click on the “PRESENCE demo.exe” file to launch the experience.

Description

The Playable App represents the most updated version (V0 as of today) of the UC1.1 experience. This early version was developed to validate the foundational concept and user interaction flow in a multi-user setting, even before the complete integration of all advanced PRESENCE technological pillars (haptics vest and IVA does not present for now, but already in the roadmap). It serves as the baseline for integrating and testing the core technologies that enable hyper-realistic and effective remote collaboration.

Despite its simplified nature, it helped test:

- The overall experience structure
- The visual environment
- The interaction loop (grabbing the seat while other people speak about its features, others can change the aspect of the seat clicking by interacting with different coloured cubes, and others in the room take notes on the whiteboard)

Core Flow

The user experience is designed to be intuitive and immersive:

- The user launches the application and is presented with a configuration screen where he can select in which room they would like to join (or create a new one).
- Upon entering the virtual meeting room, the user is joined by other participants, who are represented either as standard avatars or as high-fidelity Holoportation models.
- The 3D model of the armchair is centrally located, and users can manipulate it, apply different materials by touching the relative-coloured cubes, and discuss its design features.
- The user can use the markers to write notes on the whiteboard.

- Haptic feedback provides a tangible sense of interaction, enhancing the realism of the experience.
- The session concludes when the users have completed their collaborative tasks and disconnect from the application.

This playable app serves as a robust foundation for the continued development and integration of the PRESENCE technologies, with the goal of creating a truly immersive and effective platform for professional collaboration in XR.

5.1.3. Use Case UC1.1 Demonstrator V0

Introduction

UC1.1 Version 0 represents the first functional prototype that integrates all major technological pillars of the PRESENCE project within the Professional use case. It serves as a proof of concept for how immersive technologies can help and improve professional collaboration.

Integrated Technological Pillars

The current prototype includes the integration of the following components. These pillars were specifically chosen to elevate the quality of professional collaboration by focusing on two critical aspects: enhancing the realism of human interaction (Holoportation) and introducing a tangible sense of the product being designed (Haptics).

1. Holoportation (Remote Presence)

The primary motivation for including Holoportation is to vastly improve the quality of communication and social presence within the virtual environment. In a professional design review, nuanced, non-verbal cues such as gestures, posture, and facial expressions are critical for effective collaboration. Traditional avatars can fail to convey this vital information. Holoportation bridges this gap by rendering a realistic, 3D representation of a participant in real-time, allowing for more natural and intuitive interactions that closely mimic an in-person meeting. This fosters a stronger sense of co-presence and leads to more productive and engaging discussions.

  - **Implementation:** Allows a remote companion (visitor) to appear in the VR space using a 3D camera. Currently functional at a basic level; full real-time avatar mapping is under refinement.

2. Haptics gloves

The motivation for integrating haptics is to introduce a crucial sense of tangibility to the virtual design process. When evaluating a physical product like an armchair, touch is a key sense. Haptics allows participants to move beyond a purely visual inspection and physically interact with the digital model. This enables them to perceive the force required to move the chair and receive tactile confirmation when using interactive elements. This hands-on interaction leads to a deeper, more intuitive understanding of the product and facilitates more informed and confident design decisions.

  - **Implementation:** The following activities can be done with the gloves in this UC version:
    - **Grab the chair and move it around** - Haptic effects: vibration and haptic force
    - **Configuration buttons feedback** - Haptic effects: vibration and haptic force

- **PDF viewer buttons** - Haptic effects: vibration and haptic force
- **Cubes with active physics** - Haptic effects: vibration and haptic force

5.1.4. Plan for UC1.1 Demonstrator V1

Holoportation (WP2)

Work is ongoing to improve the Holoportation experience. Currently, we're addressing an issue where the remote player is not properly displayed as a holoported entity (this fix is in progress). Additionally, a task to correct avatar orientation remains to be completed.

Haptics (WP3)

Several enhancements are planned to increase the robustness and interactivity of the haptic system. These include improving the detection of wearable haptic devices and adding support for snap rotation via the SenseGlove. Both features are still pending implementation.

Intelligent Virtual Human (WP4)

Progress continues the virtual agent functionality. A future update will also involve replacing the existing Didimo avatar with a more customizable CC4 character model. If time allows, we would like to utilize more WP4 features like Vision, so the IVH can reason about the virtual environment. It also needs more body and facial animations, and it would be more realistic if it has the possibility to show the users how to interact with the environment.

Use Case & User Experience (UC-Specific)

In parallel with technical integration, we are planning a round of UI/UX improvements to refine the overall user experience. This includes both general interfaces polishing and a potential redesign of core UI elements, especially to improve clarity and usability during the procedure. Also, we need to integrate the Haptics Vest to be able to feel the touch of other people in the room and we need to integrate IVH to be able to talk about the UC with an AI in the room. These features will be implemented for the next update of the experience:

- **Create a configuration file** that can be modified by users to set up the options of the experience such as use of the haptics gloves, use of IVH, instructions for IVH, IP Address to communicate with the IVH, etc.
- **The whiteboard content must be resettable:** we will implement a feature to clean the white board after the users write on it, and they want to start a new project discussion.
- **Integrate a Virtual Agent capable of reacting to LLM-triggered events**, such as executing interactive tutorials (including necessary animations, step-by-step operations, etc.).
- **Add Human-like Avatars**: right now, we are using a simple white “capsule avatar” to represent the user in the scene. We will change this to a human-like avatar for better realism.
- **Add Haptics Vest feature:** we will integrate the Haptics Vest feature to give the user the feeling of being touched by other users and to be hit by props present in the environment.
- **Implement different interactions with the chair,** such as rotating only the upper part, raising it and lowering it.
- **Improve the overall environmental design**: props and objects on the scene could have a better positioning, can be more realistic and can be better integrated to interact with them using the haptics gloves. We will also improve the general 3D Graphics of the environment.
- **Improve the overall audio design**: we will add more sound effects to make the scene more realistic.

- **Implement tutorials for the end user**: we will add interactive tutorials to let the user understand the key mapping and the possible interactions with the environment.

5.1.5. Roadmap on Demonstrator Enhancement and Use Case Application Tests

From June to September, we will run internal tests with colleagues not involved in the project to have their first feedback, also, we are planning to involve some of our partners, skilled on VR technologies, to have more constructive inputs and feedback.

The current roadmap outlines the planned feature enhancements, including improvements to Holoportation, haptic interaction, virtual agent capabilities, and UI/UX design, with the goal of delivering a more stable and polished version.

Table 4: Plans for integration and testing for use case: Professional Collaboration

Q3-25	Q4-25	Q1-26	Q2-26
Tests with users and partners	Implement different interactions with the chair	Integrate human avatar	Add Haptic Vest support
Create a configuration file	Improve the overall environmental design.	Improve the overall audio design.	Implement tutorials for the end user
Add “Clean” function on whiteboard	Integrate a Virtual Agent	Improve UX/UI	Virtual Agent reacts to LLM specific commands

5.2. Use Case: Manufacturing and Training

5.2.1. Use Case Description

Description: **XR-Based Training for Safe Operation of Hydraulic Press**

There are four actors in this use case scenario: **one virtual trainer** and **four trainees**. All of them are physically located in the training room and put their VR headsets on to participate in this training scenario. They all enter a virtual environment that has the appearance of a production department of industrial manufacturing where the hydraulic press will be placed, and users will be trained on its safe usage. The virtual trainer will explain the general operation of the machine and indicate the three main systems that users will have to learn to use: (i) hydraulic clamp for the placement of the heavy sheet of steel inside the press and for the removal of the scrap after pressing, the actor must wait 25 seconds to let the sheet cool down before taking it to avoid being burned (Alex, the person with haptic gloves will feel vibration from the sheet if they touch the sheet before the 25 second interval), (ii) safety door (opening/closing, locking/unlocking), and (iii) pressing two buttons to start the blanking action. The virtual trainer (IVH) showcases the incorrect usage and the potential consequences of each of these actions in VR while the other actors stay still and observe the virtual trainer. After that, the trainer invites the trainees to carry out all these actions on their own in VR. While they do so, the Supervisor

(Tom) evaluates the correctness of what has been done by them to make a judgment on the level of preparation achieved. In the end, they agree to conclude the training and disconnect from the VR application.

Table 5: User description of use case: Manufacturing and Training

Actor name	Function / role	Represented in experience via	Location + HW needed
Alex	Trainee	Avatar	Training room manufacturer + VR headset, haptic glove
Sarah	Trainee	Avatar	Joining from home + VR headset
Lisa	Trainee	Avatar	Joining from home + VR headset
Tom	Supervisor	Holoportation	Training room manufacturer + VR headset
Alloy	Virtual trainer	IVH	NA

Step 1: Starting the experience

Alex, Sarah, and Lisa are new hires at a steel factory. They are about to undergo training on the safe operation of a hydraulic press. This training is crucial as the proper handling of machinery is essential to ensure their safety. All four trainees are aware of the potential risks involved in operating the hydraulic press, and they understand the importance of receiving thorough training before starting their work. To provide them with comprehensive training in a safe and controlled environment, their supervisor, Tom, has arranged the PRESENCE VR-based training session with a virtual trainer **(IVH)**. The trainees (**avatars**) put on their headsets, and haptic gloves (Alex only), immersing themselves in the virtual environment that simulates a production department of industrial manufacturing. In this virtual space, they see the hydraulic press they'll be trained to operate.

Figure 15: Screenshot from the use case: Manufacturing and Training

Step 2: Completing tasks in the experience

The supervisor, Tom (**Holoportation**), introduces the trainees to the general operation of the hydraulic press. Tom explains the three main systems that the trainees will need to learn: the hydraulic clamp, safety door, and double buttons for starting the blanking action.

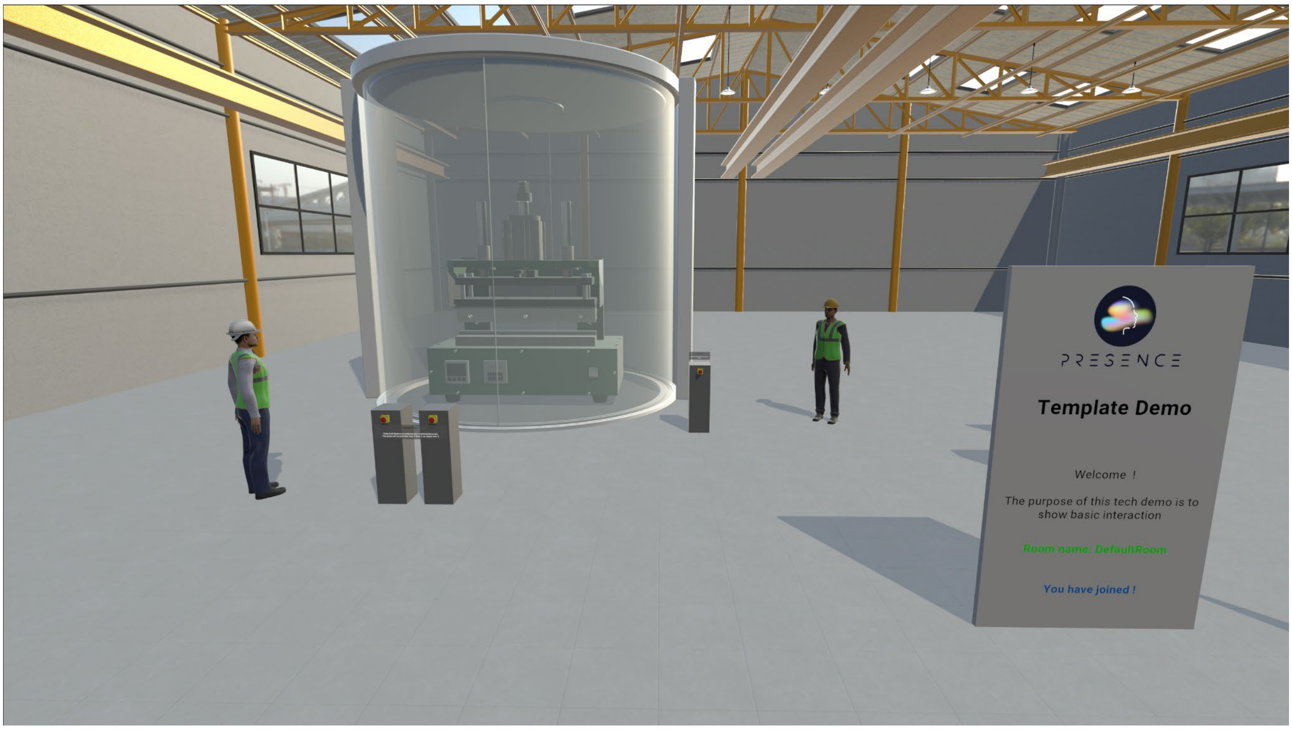

Figure 16: Screenshot from the hydraulic clamp from the use case: Manufacturing and Training

While Tom is explaining how to use the hydraulic clamp, open/close the safety door, and initiate the blanking action, the virtual trainer (IVA) is showcasing how to operate the systems in an incorrect and correct way.

After the demonstration, Tom invites the trainees to carry out the actions themselves in VR. One by one, each trainee, starting from Alex (with haptics), takes turns practicing the operation of the hydraulic clamp(i), safety door(ii), and double buttons(iii) while the supervisor observes their performance.

> (i) Hydraulic clamp: for the placement of the heavy sheet of steel inside the press and for the removal of the scrap after pressing, the actor must wait 25 seconds to let the sheet cool down before taking it to avoid being burned. All participants receive strong and intense haptic vibrations caused by the heat of the sheet through the gloves or controllers if they touch it before the 25-second interval has elapsed.
>
> (ii) Safety door: the actors take turns in opening/closing and locking/unlocking the safety door. Alex, the person with haptic gloves receives force feedback from the physical elements of the door he touches while all others receive slight vibrations via the controllers.
>
> (iii) Pressing two buttons: the actors take turns in pressing both buttons to start the blanking action. Alex, the person with haptic gloves receives force feedback from the buttons he touches while all others receive slight vibrations via the controllers.

As the trainees perform the actions, the supervisor Tom evaluates the correctness of their movements and procedures. They provide feedback and guidance to help the trainees improve their skills and ensure they understand the proper operation of the hydraulic press.

Step 3: Concluding the experience

Once all trainees have had the opportunity to practice and receive feedback, the supervisor Tom concludes the training session. He comments on the trainees' efforts and progress, emphasizing the importance of safety in the workplace. The trainees thank the virtual trainer for their guidance. Thanks to the PRESENCE XR-based training, Alex, Sarah, and Lisa feel more confident and prepared to operate the hydraulic press safely in their workplace.

Table 6: Used technology pillar in use case: Manufacturing and Training

Technology pillar	Summary of how it is integrated in the use case
Holoportation	Tom + role/advantages of Holoportation for Tom
Haptics	Alex needs a haptic vest to feel when the steel is still too hot or cold enough to handle
IVA	Shows the proper /improper way to safely conduct the tasks that are part of the training

Video References:

Presence - XR-Based Training for Safe Operation of Hydraulic Press - Complete Procedure

https://youtu.be/pLePGGXkviU

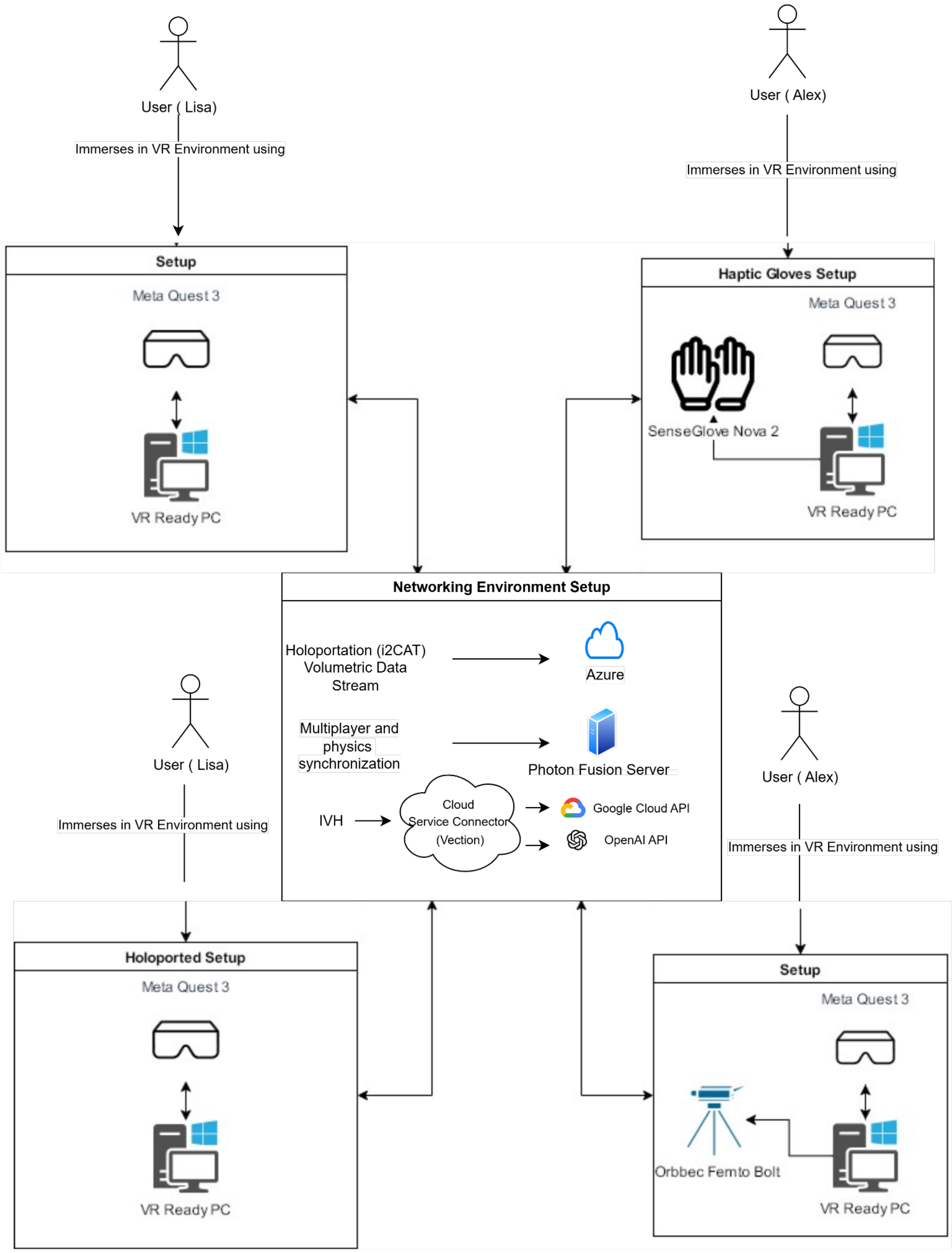

Figure 17: Deployment diagram for use case: Manufacturing and Training

5.2.2. Playable App UC1.2

Build with haptics gloves feature **enabled:**

https://drive.google.com/file/d/1U3IiVqe7GuUABzjy-CX9rvuhBb25iwcT/view?usp=drive_link

Build with haptics gloves feature **disabled:**

https://drive.google.com/file/d/1I41ZTG8sqrym4HbV-O_cm1-2gl6utZ7L/view?usp=drive_link

Builds are split in two different versions (with and without haptics gloves feature), because for V0 there was not a plan to create a configuration file which could have been read at runtime to enable/disable this feature (based on which actor is running the app). It is in the roadmap for the next version.

What you need to use the experience:

- VR Ready Windows computer (laptop or desktop) with the following specs:
- Operating System: Windows 10 or 11
- Processor: Intel i7 12th generation or better (or AMD equivalent performance)
- RAM: 16 GB Ram or more
- Video Graphics: RTX 30XX or better
- Meta Quest 3 headset connected with USB cable to the computer

OPTIONAL:

- SenseGlove connected via Bluetooth to enable haptics gloves features with the specific build.
- One or more Orbbec Femto Bolt 3D Vision Devices to enable Holoportation.

How to run the experience:

- Click on the link above to download the build you need (with or without haptic gloves support);
- Unzip the file on your computer.
- Double click on the “PRESENCE demo.exe” file to launch the experience.

Description

The Playable App represents the most updated version (V0 as of today) of the UC1.2 experience. This early version was developed to validate the foundational concept and user interaction flow in a multi-user setting, even before the complete integration of all advanced PRESENCE technological pillars (haptics vest is not present for now, but already in the roadmap). It serves as the baseline for integrating and testing the core technologies that enable hyper-realistic and effective remote collaboration.

Despite its simplified nature, it helped test:

- The overall experience structure
- The visual environment
- The interaction loop (open the double doors, grab the billet and place it to the mechanical press, close the double doors if no one is inside them, press two buttons to let the press work).

Core Flow

The user experience is designed to be intuitive and immersive:

- The user launches the application and is presented with a configuration screen where he can select in which room they would like to join (or create a new one).
- Upon joining the room, the user spawns in a virtual manufacturing environment, where he can see other participants.
- The user can perform a sequence of interactive tasks using haptic gloves, including operating a hydraulic clamp to move materials, opening and closing a safety door with a button press, and activating the machine with a two-button system.
- The user can receive haptic feedback through the gloves that simulates physical interactions, such as the force of pressing buttons, and provides critical safety alerts, like a warning vibration for touching a hot object.
- The user's actions are observed, and they can receive real-time feedback to help them learn the correct procedures.
- The user can ask the IVA what he can do inside the UC and the IVA can describe in a very precise way how to press the billet step-by-step.
- The training session concludes after the user has successfully practiced and demonstrated proficiency in all the required tasks.

This playable app serves as a robust foundation for the continued development and integration of the PRESENCE technologies, with the goal of creating a truly immersive and effective platform for professional collaboration in XR.

5.2.3. Use Case (UC1.2) Demonstrator V0

Introduction

UC1.2 Version 0 represents the first functional prototype that integrates all major technological pillars of the PRESENCE project within the Manufacturing and Training use case. It serves as a proof of concept for how immersive technologies can help operators to learn how to use mechanical objects in a safe way.

Integrated Technological Pillars

The current prototype includes the integration of the following components:

1. Intelligent Virtual Human

Provides prompts and procedural guidance. It works properly in a multiplayer environment: this means that it can answer the question of one client, and every other client can hear the answer and see its animation. It also handles a queue of requests, so it never misses a question from the clients, even if made concurrently.

  - **Implementation:** Right now, the IVH is only able to answer questions and to show facial and body animation while speaking. The user can ask the IVH all the questions he wants, in particular, he can ask information and instructions about the UC.

2. Holoportation (Remote Presence)

The primary motivation for including Holoportation is to vastly improve the quality of communication and social presence within the virtual environment. In a professional design review, nuanced, non-verbal cues such as gestures, posture, and facial expressions are critical for effective collaboration. Traditional avatars can fail to convey this vital information. Holoportation bridges this gap by rendering a realistic, 3D representation of a participant in real-time, allowing for more natural and intuitive interactions that closely mimic an in-person meeting. This fosters a stronger sense of co-presence and leads to more productive and engaging discussions.

- **Implementation:** Allows a remote companion (visitor) to appear in the VR space using a 3D camera. Currently functional at a basic level; full real-time avatar mapping is under refinement.

3. Haptics gloves

The motivation for integrating haptics is to introduce a crucial sense of tangibility to the virtual design process. When evaluating a physical product like an armchair, touch is a key sense. Haptics allows participants to move beyond a purely visual inspection and physically interact with the digital model. This enables them to perceive the force required to move the chair and receive tactile confirmation when using interactive elements. This hands-on interaction leads to a deeper, more intuitive understanding of the product and facilitates more informed and confident design decisions.

- **Implementation:** The following activities can be done with the gloves in this UC version:
  - **Grab the billet and move it around** - Haptic effects: vibration and haptic force
  - **Grab the pressed billet and move it around** - Haptic effects: for the first 25 seconds since the billet was pressed, there is a very strong vibration (stronger than the vibration felt when using other objects) when touching it (warning the user about the warmness of the object) and haptic force.
  - **Configuration buttons feedback** - Haptic effects: vibration and haptic force
  - **Cubes with active physics** - Haptic effects: vibration and haptic force

5.2.4. Plan for UC1.2 Demonstrator V1

Holoportation (WP2)

Work is ongoing to improve the Holoportation experience. Currently, we're addressing an issue where the remote player is not properly displayed as a holoported entity (this fix is in progress). Additionally, a task to correct avatar orientation remains to be completed.

Haptics (WP3)

Several enhancements are planned to increase the robustness and interactivity of the haptic system. These include improving the detection of wearable haptic devices and adding support for snap rotation via the SenseGlove. Both features are still pending implementation.

Intelligent Virtual Human (WP4)

Progress continues on the virtual agent functionality. A future update will also involve replacing the existing Didimo avatar with a more customizable CC4 character model. If time allows, we would like to utilize more WP4 features like Vision, so the IVH can reason about the virtual environment. It also needs more body and facial animations, and it would be more realistic if it has the possibility to show the users how to interact with the environment.

Use Case & User Experience (UC-Specific)

In parallel with technical integration, we are planning a round of UI/UX improvements to refine the overall user experience. This includes both general interface polishing and a potential redesign of core UI elements, especially to improve clarity and usability during the procedure. Also, we need to integrate the Haptics Vest to be able to feel the touch of other people in the room. These updates are in the planning phase.

- **Create a configuration file** that can be modified by users to set up the options of the experience such as: use of the haptics gloves, use of IVH, instructions for IVH, IP Address to communicate with the IVH, etc.
- **Include a rack to hold the crushed metal bar:** after the metal billet has been pressed, the user should have the possibility to place the newly spawned metal bar inside a rack to store them instead of having them floating in the scene.
- **Add Haptics Vest feature:** we will integrate the Haptics Vest feature to give the user the feeling of being touched by other users and to be hit by props present in the environment.
- **Add Human-like Avatars**: right now, we are using a simple white “capsule avatar” to represent the user in the scene. We will change this to a human-like avatar for better realism.
- **Integrate a Virtual Agent capable of reacting to LLM-triggered events**, such as executing interactive tutorials (including necessary animations, step-by-step operations, etc.).
- **Improve the overall environmental design**: props and objects on the scene could have a better positioning, can be more realistic and can be better integrated to interact with them using the haptics gloves. We will also improve the general 3D Graphics of the environment.
- **Improve the overall audio design**: we will add more sound effects to make the scene more realistic.
- **Implement tutorials for the end user**: we will add interactive tutorials to let the user understand the key mapping and the possible interactions with the environment.

5.2.5. Roadmap on Demonstrator Enhancement and Use Case Application Tests

From June to September, we will run internal tests with colleagues not involved in the project to have their first feedback, also, we are also planning to involve some of our partners, skilled on VR technologies, to have more hints.

The current roadmap outlines the planned feature enhancements, including improvements to Holoportation, haptic interaction, virtual agent capabilities, and UI/UX design, with the goal of delivering a more stable and polished version.

Table 7: Plans for integration and testing for use case: Manufacturing and Training

Q3-25	Q4-25	Q1-26	Q2-26
Tests with users and partners	Integrate human avatar	Improve the overall audio design	Add Haptic Vest support
Create a configuration file	Include a rack to hold the pressed bar	Improve UX/UI	Implement tutorials for the end user
	Improve the overall environmental design		Virtual Agent reacts to LLM specific commands

5.3. Use Case: Pain Relief in the Health Sector

5.3.1. Use Case Description

Description: **Pain/Stress Relief**

Manuel, a 46-year-old with a strong fear of needle procedures, is at the clinic today for a joint injection procedure. To aid him, Dr. Garcia, his doctor aware of his needle phobia, has prepared a specialized session using PRESENCE technology designed to help Manuel cope effectively during the procedure. Unfortunately, Manuel's usual source of support, his long-time friend Ben, is unable to be present physically this time. However, using PRESENCE technology, Ben can be virtually holoported into the VR environment to provide Manuel with his customary support and reassurance during the procedure.

Upon arriving at the clinic, Manuel is visibly tense, dreading the upcoming procedure. Dr. Garcia greets him with a comforting smile and gives him a professional briefing on how to use the PRESENCE technology. With the help of Dr. Garcia, Manuel puts on a VR Headset and dives into a distracting virtual environment where he finds his friend Ben and Ava, a virtual assistant, ready to support him throughout the procedure. The virtual environment is seamlessly synced with the medical procedure and guided by Ava, ensuring Manuel receives the ideal distractions and support tailored to his needs. This allows Dr. Garcia to concentrate on the procedure, which can be successfully completed without any complications, as Manuel is kept in a state of comfort and reassurance.

Table 8: User description of use case: Pain Relief in the Health Sector

Actor name	Function/role	Representation	Location	Hardware
Manuel	Patient with needle phobia undergoing the procedure	Virtual hands	Hospital	VR headset, haptic vest
Dr. Garcia	Doctor performing procedure	-	Hospital	-
Ava	Virtual assistant	IVA	-	-
Ben	Supporting friend	Holoportation	Quiet room	Holoportation camera, VR headset, haptic gloves

Step 1: Starting the experience

Three weeks before the scheduled injection, Dr. Garcia arranges a phone consultation with Manuel to explain the upcoming joint injection procedure and introduce the PRESENCE technology. During the call, they discuss the role of VR in reducing anxiety and how Holoportation will allow Manuel to receive support from his friend Ben, despite Ben being unable to attend physically due to a business trip. Manuel later contacts Ben, who confirms his virtual availability during the procedure. Thereupon, Dr. Garcia also provides Ben with information about the PRESENCE technology and the necessary equipment to attend the procedure virtually.

On the day of the procedure, Manuel arrives at the clinic and is greeted by Dr. Garcia, who provides reassurance and guides him to the specially prepared treatment room. The room is equipped with PRESENCE technology, including a VR headset and a haptic vest. It is designed to be calming and controlled, minimizing external stimuli that could increase Manuel's anxiety. Ben has received a call from Dr. Garcia’s secretary to ensure he will be there at the planned time of the procedure.

Step 2: Participating in the experience

Upon putting on the VR headset, Manuel is greeted by Ava, a virtual assistant. Ava's role is to provide information about the VR experience, including its purpose: to help distract and relax him during a needle procedure. Her presence is designed to reduce the cognitive burden on Dr. Garcia, who can then focus on the medical procedure itself. The virtual environment is a cozy and calming room, designed to reduce anxiety and immerse Manuel in a peaceful setting.

During Ava's introduction, Ben—Manuel's friend is also present in the environment, appearing via Holoportation from a separate quiet room. Ben's presence provides comfort and familiarity, helping Manuel feel emotionally supported.

As the experience continues, Dr. Garcia prepares the joint injection. She ensures that all instruments are sterilized, the medication is properly dosed, and the injection site is cleaned and marked. These preparations occur in the real world while Manuel remains immersed in the calming virtual scene.

To further support relaxation, Manuel wears a Skinetic haptic vest, which provides subtle, rhythmic sensations that simulate deep breathing. This encourages Manuel to remain calm and still during the procedure. The visitor, Ben, is wearing a SenseGlove, allowing him to interact with Manuel, who feels the touch of Ben's virtual hand on the haptic vest. This way, the system is designed to convey a sense of shared presence and interaction.

Manuel remains deeply engaged in the experience as he watches calming visuals, such as softly drifting notes tied to the musical background, and feels synchronised tactile sensations from the vest. These multisensory cues help divert his attention away from the injection.

When Dr. Garcia administers the injection, Manuel still experiences light discomfort, but due to the immersive distraction and perceived support from Ava and Ben, he handles it with noticeably reduced stress and anxiety.

Step 3: Concluding of the experience

After the injection has been performed, Ben congratulates Manuel, says goodbye, and leaves the virtual environment. Ava informs Manuel about the required restriction of strenuous activity, the option to use ice in case of swelling, and other practical points. She further seeks feedback from Manuel and gathers feedback about his experience such as his level of comfort throughout the procedure. Manuel's responses are overwhelmingly positive, noting a significant reduction in anxiety and an increased sense of control over the situation.

Figure 18: Example scenario of use case: Pain relief in the Health Sector

Finally, Dr. Garcia then takes off the devices from Manuel and guides him to the exit of the procedure room. Dr. Garcia has only had to focus on the procedure, while Ava provided relevant information and Ben gave comforting support. After Dr. Garcia gave the devices to Manuel, she did not have to control anything other than the medical equipment required for the procedure, which was a great support for her.

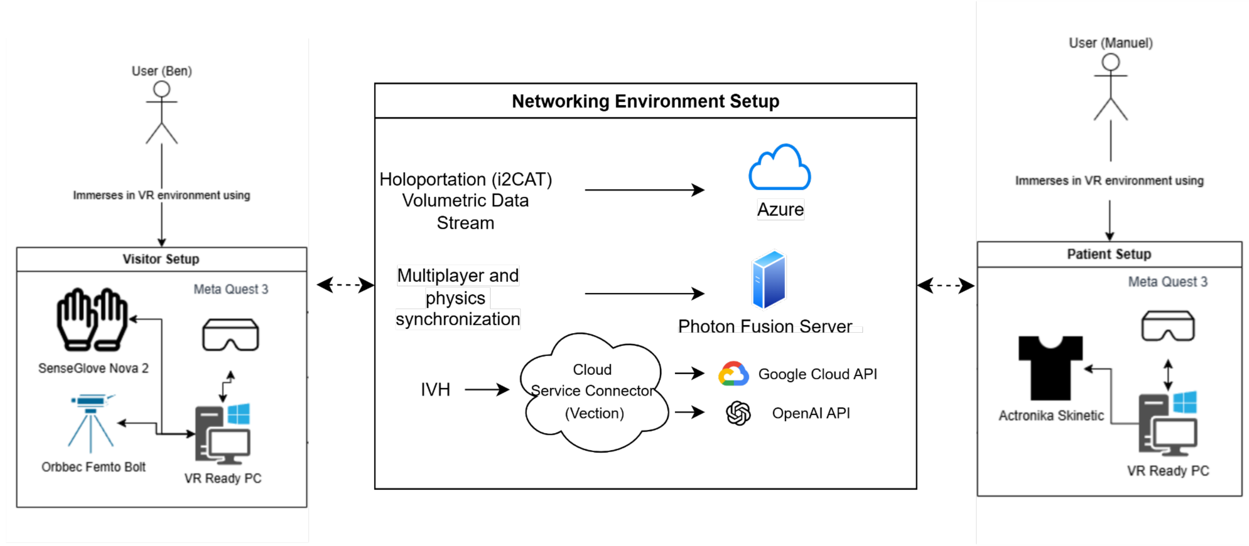

Figure 19: Deployment diagram of the use case: Pain Relief in the Health Sector

Table 9: Used technology pillar in use case: Pain Relief in the Health Sector

Technology pillar	Summary of how it is integrated into the use case
Holoportation	Ben is holoported into the VR environment to comfort Manuel and allow Dr. Garcia to focus on the procedure.
Haptics	Manuel receives a haptic vest to create haptic stimuli to distract him from the procedure in sync with the visuals of the virtual environment and help him manage his stress levels while also receiving physical feedback from his friend Ben.
IVA	Ava provides Manuel with the necessary patient information before and after the procedure and guides him through the virtual experience.

5.3.2. Playable App UC2.1

Description

The Playable App represents the earliest VR prototype for UC2.1. It was developed to validate the core concept and user flow in a simplified form, without yet integrating the full PRESENCE technological pillars (e.g., IVA, haptics, or Holoportation).

Despite its simplified nature, it helped test:

- The overall experience structure
- The visual environment
- The interaction loop (music, note-catching, tutorial flow)

It is a standalone VR prototype that runs on Meta Quest 3 and does not require a high-performance PC, unlike the actual Use Case Demonstrator.

Core Flow

- The user enters the virtual environment
- A virtual guide (placeholder avatar) gives brief tutorial instructions
- Music plays and magical notes appear in the air
- The user reaches out to catch the notes, providing a calming and distracting activity
- The session ends after a short duration

Screenshots

Figure 20: First playable app simulating Intelligent Virtual Agent (IVA) behaviour

The build for the first playable app (without any integrated technical pillar) is available here: https://drive.google.com/file/d/133ue6u7meV0eWMJBwtsLrwLz8WBF1oRh/view?usp=drive_link

5.3.3. Use Case (UC2.1) Demonstrator Version 0

Introduction

UC2.1 Version 0 represents the first functional prototype that integrates all major technological pillars of the PRESENCE project within the healthcare use case. It serves as a proof of concept for how immersive technologies can reduce pain and anxiety during needle-related medical procedures.

Integrated Technological Pillars

The current prototype includes the integration of the following components:

1. Intelligent Virtual Agent (IVA – "Ava")
Provides voice-based guidance and information during specific moments in the experience.

Interaction is limited: users can only speak during predefined turns, cannot interrupt, and Ava does not interact with the virtual environment (e.g. moving, grabbing objects). She replies based on prior conversation and a fixed context.

In multi-user sessions, the IVA's responses are broadcast to all participants so everyone hears the same message. However, only the patient can initiate the conversation. The IVA component connects to a service deployed on SyncVR's Google Cloud infrastructure, utilizing technology developed in WP4 (Service Connector).

2. Holoportation (Remote Presence)

Enables a remote companion to appear in VR via a 3D camera. Currently with no user control over how the visitor is represented (e.g., avatar, hologram, or pre-recorded 3D data).

The application assumes a single-camera setup.

3. Haptics

Patient side: The Skinetic haptic vest provides feedback during the experience, both from remote touches (e.g. when the visitor uses the SenseGlove) and from in-app events like music pulses or collisions with floating objects.

Visitor side: SenseGlove used to simulate touch, synchronized with the haptic vest.

The current version detects haptic devices during a brief onboarding flow. Their use is optional, allowing users to proceed without them.

Screenshots

Figure 21: Intelligent Virtual Agent (IVA) processing user audio input

Figure 22: The mini-game featuring floating elements, shown from the patient's perspective

Figure 23: Teleporting within the environment using the SenseGlove, from the visitor's perspective

A zipped Windows build featuring the previously described feature set:
https://drive.google.com/file/d/1S5V1cMd6wKpJw1Y0NoR30RpT3K6_Xsk2/view?usp=drive_link

5.3.4. Plan for UC2.1 Demonstrator V1

Holoportation (WP2)

Work is ongoing to improve the Holoportation experience. Currently, we're addressing an issue where the remote player is not properly displayed as a holoported entity. Additionally, a task to correct avatar orientation (in case no 3D camera is used) remains to be completed.

Haptics (WP3)

Several enhancements are planned to increase the robustness and interactivity of the haptic system. These include improving the detection of wearable haptic devices.

Intelligent Virtual Human (WP4)

Progress continues on the virtual agent functionality. A future update will also involve replacing the existing Didimo avatar with a more customizable CC4 character model. If time allows, we would like to utilize more WP4 features like Vision, so the IVH can reason about the virtual environment.

Use Case & User Experience (UC-Specific)

In parallel with technical integration, we are planning a round of UI/UX improvements to refine the overall user experience. This includes both general interface polishing and a potential redesign of core UI elements, especially to improve clarity and usability during the procedure.

5.3.5. Roadmap on Demonstrator Enhancement and Use Case Application Tests

The current roadmap outlines the planned feature enhancements, including improvements to holoportation, haptic interaction, virtual agent capabilities, and UI/UX design. These upgrades will be integrated into the demonstrator iteratively.

2025 Q3 – Foundation & Critical Integration

- **Photon to HoloMIT Migration**
  WP2 is delivering an updated HoloMIT SDK that may cover key features currently handled by Photon (an SDK for real-time multiplayer networking and physics synchronization). While Photon remains reliable, the goal is to evaluate if HoloMIT can fully support networking needs, offering greater flexibility, simplifying cross-location holoportation, and expanding developer options.
- **Experience Mechanics & Flow**
  Refine the core application mechanics based on insights from user testing. The feedback received already highlights which elements should be removed or improved, and which features are essential for enhancing the overall user experience.
- **Patient Avatar (Stage 1)**
  Basic replacement and initial facial expressions to make the avatar character (currently a simple capsule model) more relatable.
- **UI/UX (Stage 1)**
  - Move from linear to flexible flow (e.g. improved navigation, ability to skip the onboarding, etc.)
  - Accessibility improvements (e.g. text display instead of only audio)
  - Implement settings panel
  - Handle edge cases and error states (e.g. no network available)
- **Setup & Maintenance (Stage 1)**
  - Simplify hardware/software setup (minimizing friction for the end users)

2025 Q4 – Extended User Features & Support

- **UI/UX (Stage 2)**
  - Implement fallback options (e.g. pre-recorded data in case of missing 3D camera, controller-only mode if haptics devices are not available)
  - Implement session stop and relevant “admin mode” features (was requested by healthcare professionals).
  - Multilanguage support (e.g. Dutch)
- **VR Enhancements**
  - Add hints, teleportation markers, improved locomotion/rotation
- **User Support**
  - FAQs, how-to-use guidance, troubleshooting resources

2026 Q1 – Advanced Integrations & Customizations

- **Potential Integration of Additional WP4 Features**
  - Vision - Enables the IVA to reason about the virtual environment.
  - Action Classification - Allows triggering of gestures and in-app notifications.
  - Other relevant components - To be defined based on WP4 development progress.
- **Patient Avatar (Stage 2)**
  - Enhanced character & facial expressions

- **Analytics & Feedback (Stage 1)**
    - Lightweight logging to capture user interaction data.

2026 Q2 – Final Polishing & Analytics

- **Analytics & Feedback (Stage 2)**
    - In-app session scoring to gather insights on user experience (e.g., like/neutral/dislike).
- **Setup & Maintenance (Stage 2)**
    - Hygiene considerations for safe use in medical settings (e.g., easy cleaning, non-porous surfaces).
- **Wrap-up & Testing**
    - Final QA and user testing
    - Incorporation of any adjustments from reviews

Planned Events and User Testing Activities

This section outlines the public events and user testing sessions selected to disseminate the use case, gather professional feedback, and support ongoing validation of the Pain Relief demonstrator. These activities aim to involve healthcare professionals and real users to ensure the solution aligns with clinical expectations and patient needs.

Table 10: Plans for integration and testing for use case: Pain Relief in the Health Sector

Event	Date	Organised by	Location	Full Name
GOED MC	*19-Jun-2025*	*GOED & SyncVR*	Good Medical Centre, Breda	*GOED Medisch Centrum*
PROSA2026 Conference	*10-Sep-2026*	*Klinkhamer Group*	*Maastricht, The Netherlands*	*4rd European conference on pediatricprocedural sedation and analgesia*
Euroanaesthesia 2026	*6-Jun-2026*	*ESAIC*	*Rotterdam, The Netherlands*	*Euroanaesthesia 2026*

5.4. Use Case: Cultural Heritage

5.4.1. Use Case Description: Tunnel underneath Berlin Wall

Description: **Tunnel 57 Experience**

This use case scenario is about exploring the escape "Tunnel 57" under the former Berlin Wall. The following actors are involved in this scenario: the tourist and time witness as a pre-recorded holoportation.

To start, the tourist puts on the XR headset, haptic gloves, and vest. The virtual environment loads and immerses the tourist in the virtual space (avatar). The tourist enters a replica of a cellar (anteroom of the tunnel in Berlin) and can explore the room. The app starts introducing the tourist to the experience and the room with popups and immersive UI/UX and invites the tourist to explore the digital points of interest (POIs) and some virtual elements laying around.

With the ability to freely explore, interact, and engage with POIs and scanned 3D models in the room, the tourist delves into the past while uncovering hidden stories from history around the tunnel digging under the Berlin wall. Upon discovering a triggering POI, a time-witness also starts talking about his experiences (recorded holoportation), transporting the tourist deeper into the narrative as he discovers a mystical shovel that opens a whole other level... Navigating through a virtual tunnel, the tourist experiences the tension and urgency of an escape, culminating in a pivotal moment of decision and consequence. Emerging from the tunnel, the tourist witnesses the aftermath of historical events unfold before their eyes, shedding light on the complexities of division and reconciliation. With immersive haptic feedback from the vest and gloves and audio cues amplifying the emotional journey, the tourist is not merely a spectator but an active participant in revisiting the narrative of the past.

Table 11: User description of use case: Cultural Heritage

Actor name	Function / role	Represented in experience via	Location + HW needed
Sophia	Tourist	Avatar	Berlin + VR headset, haptic gloves, vest
Hannes	Historical expert (Time Witness)	Avatar (Interactive 3D)	-
David	Tour guide	Pre-recorded Holoportation (as guides are volunteering and not available; plus we need to express the feeling of solitude and isolation)	-

Figure 24: AI rendered picture of use case: Cultural Heritage

Figure 25: AI generated picture of user in equipment for use case: Cultural Heritage

Step 1: Starting the experience

Sophia is a history enthusiast visiting Berlin for the first time. She's always been fascinated by the stories of the Berlin Wall and is eager to explore its history in a unique and immersive way. Today, she's embarking on the PRESENCE "Tunnel 57" XR experience. Sophia arrives at the site, where she's greeted by the PRESENCE staff and equipped with an XR headset, haptic gloves, and a vest.

She is excited to dive into the virtual world and uncover the secrets of Tunnel 57. Sophia puts on the XR headset, haptic vest and glove and is transported into the virtual space of Tunnel 57. She finds herself in a volumetric scan of a cellar, the anteroom of the tunnel in Berlin.

Figure 26: AI generated example picture of 3D tunnel placed inside the museum at entrance of tunnel & David and Sofia

Step 2: Completing tasks in the experience

Sophia is welcomed to the experience by sophisticated UI/UX and popups that lure her increasingly into the historical story, providing an overview of Tunnel 57 and its significance during the Cold War era. Other toasts and popups encourage Sophia to explore the digital points of interest (POIs) in the room and interact with the environment. Sophia teleports freely into the virtual cellar, examining artifacts and listening to audio explanations about each point of interest. **Haptic gloves** are used for simulating interacting with POI that must be found by the user to trigger actions.

As Sophia delves deeper into the narrative, Sophia stumbles upon a volumetric scan of a time-witness, a pre-recorded holoportation of Burkhard Veigel, who helped several hundreds of people escaping the GDR and can be talked to with prerecorded interview questions.

Sophia then further explores the room, finding an interactive 3D shovel that she can grab and start digging which finally opens the way to the bespoken escape tunnel. Several tasks as an escape helper transport her deeper into the story, guiding her through a virtual tunnel as she experiences the tension and urgency of an escape. The haptic vest and gloves will simulate and underline storyline points:

- Rain and wetness from the tunnel will hit Sophia's shoulders via the haptic west
- Shooting of a gun will have a kickback effect via the haptic gloves
- Tightness in the tunnel will be transmitted via the haptic vest
- Wind is simulated through vest, gloves and fans

Emerging from the virtual tunnel, Sophia witnesses the aftermath of historical events, seeing firsthand the impact of division and the journey toward reconciliation. Immersive **haptic** feedback and audio cues amplify the emotional journey, allowing Sophia to feel connected to the past in a profound way.

Step 3: Concluding the experience

Sophia emerges from this experience and reflects on the lessons learned and the importance of understanding history to shape a better future. As she removes her XR gear, she carries with her a newfound appreciation for the power of immersive storytelling in preserving and sharing the past.

Table 12: Used technology pillar for use case: Cultural Heritage

Tech pillar	Summary of how it is integrated in the use case
Haptics	Simulate interaction with POIs and underline the storyline. Sophia needs a haptic vest and gloves as they help her to understand the experience on an emotional and physical level.

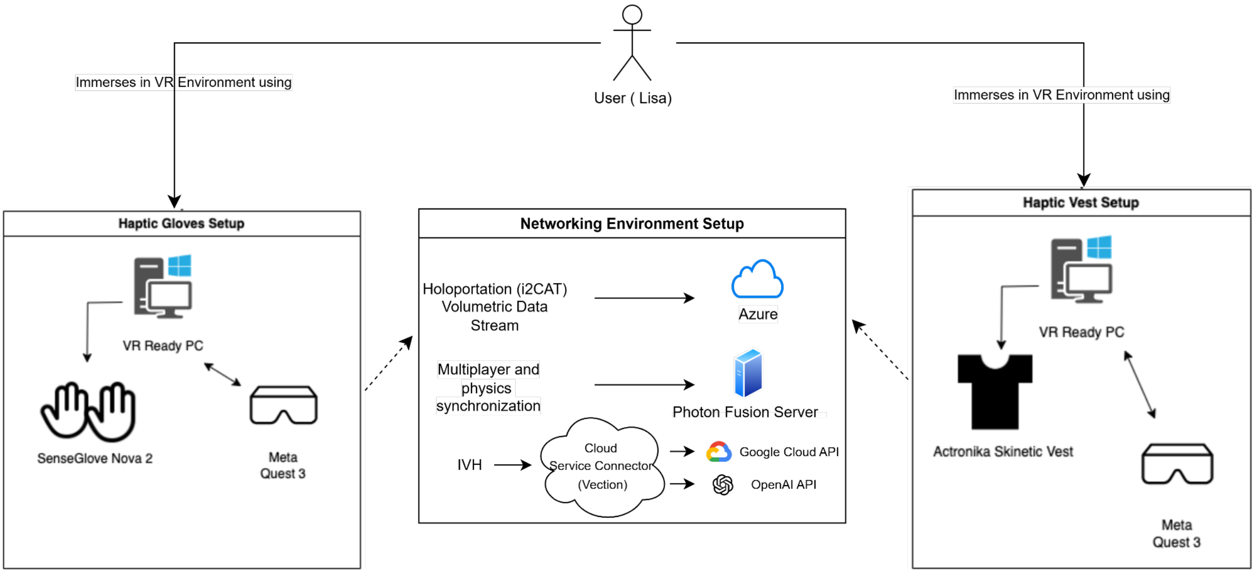

Figure 27: Deployment diagram of use case: Cultural Heritage

5.4.2. Playable App UC2.2

The app represents implementation of the version 0 of cultural heritage use case which has Haptic Vest implementation included.

this version helped to evaluate overall experience:

- Visual environment - 3D scan of the tunnel
- Basic interactions like haptic vest feedback and XR interactions

This VR prototype runs on Meta Quest 3 and Meta Quest Pro.

Figure 28: POV of user inside reconstruction of Tunnel 57: Scanned time witness

Figure 29: POV of user inside reconstruction of Tunnel 57: Photos from current day museum

Figure 30: POV of user inside reconstruction of Tunnel 57: Narrow rescue tunnel

Figure 31: POV of user inside reconstruction of Tunnel 57: Swing leading down to tunnel

5.4.3. Use Case (UC2.2) Version 0 Demonstrator

Introduction

UC2.2 Version 0 represents the first functional prototype that integrates haptic vest pillar of the PRESENCE project within the cultural heritage use case.

The experience begins as the user, equipped with her XR headset, haptic vest, and gloves, is transported into an authentic, dimly lit cellar anteroom beneath Cold War Berlin. The images reveal a space steeped in history and clandestine effort: rough brick archways curve overhead, supported by sturdy pillars, and the floor is paved with uneven cobblestones. The air feels thick with untold stories.

The user is guided through the experience with minimal interface to experience immersion and presence. The focus is on the practicalities of the secret excavation: a large, dark pile of excavated earth and rubble dominates the centre, evidence of the immense labour involved. Hovering above it is a rudimentary wooden and metal hoist with a hanging scale, tools essential for discreetly removing tons of soil. A lone shovel leans against a pillar, a silent invitation and a critical interactive element. This is where Sophia first orients herself, exploring these tangible remnants of the past.

Another perspective will present a strong narrative to the user. Here, a 3D interactive avatar of a time witness, distinguished by his red scarf, stands ready to offer context and guidance. Around the room, plaques bearing historical text and rolled-up documents or maps serve as Points of Interest, beckoning Sophia to delve deeper into the courage and ingenuity behind Tunnel 57. A striking poster of individuals involved in Tunnel 57 on another wall adds to the period atmosphere, hinting at the political climate of the time. Sophia, and any user, can freely move through this space, examining these elements, with her haptic gloves potentially offering subtle feedback when interacting with these POIs to trigger information or audio cues.

The narrative intensifies when Sophia discovers and interacts with the "mystical shovel." This action, likely involving a grabbing motion simulated by her haptic gloves, becomes the key, dramatically opening the way to the next stage of her journey: the escape tunnel itself.

Suddenly, the environment shifts dramatically. Sophia finds herself at the bottom of a narrow, steeply inclined, and roughly hewn tunnel. The textured walls, appearing as damp stone or concrete, converge towards a distant, small patch of light far above, emphasizing the claustrophobic and perilous nature of the passage. A single blue line stretches along the tunnel floor, offering a faint path forward.

It's within this oppressive, confined space that the haptic vest and gloves truly bring the experience to life, transforming Sophia from a mere observer into an active participant feeling the physical toll of the escape:

Haptic Vest: As she navigates this tight passage, the haptic vest simulates the oppressive tightness of the tunnel, making her physically sense the confinement.

If the virtual environment depicts damp conditions, she will feel simulated "rain and wetness" on her shoulders through the vest, adding to the realism of being underground. This is expressed through rain drops falling on the shoulders of the users alongside a rain drop sound.

The vest, in conjunction with real fans, would also transmit the sensation of "wind," perhaps a draft blowing through the tunnel, adding to the chilling atmosphere.

Haptic Gloves: Whenever interacting with user interfaces or any virtual element in space, an appropriate vibration reaction is played to provide the feeling of being in this tight space.

Through these combined visual and haptic stimuli, Sophia experiences the tension, urgency, and physicality of what it might have been like to traverse Tunnel 57, making the historical narrative profoundly personal and memorable.

Integrated Technological Pillars

The current prototype includes the integration of the following components:

1. Haptics SDK (Haptic Vest and Gloves)

Allows to feel wind and water drops effects when entering the tunnel.

2. 3D Scans of the environment

Provides the representation of the environment and plays a key role to position the 3D scans and detail its integration with the Intelligent Virtual Humans, pre-recorded Holoportation, and Haptics SDKs.

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2. High-Fidelity Scanned Environment as a Technical Pillar

The foundation of the user experience is a high-fidelity digital twin of the "Tunnel 57" historical site, engineered as a core technical pillar. This involves more than simple 3D modelling; it is an integrated pipeline of asset creation, optimization, and interactive rigging designed to serve as the physical grounding for all other technological components.

- **Data Acquisition and Optimization:** The process begins with high-resolution photogrammetry and volumetric scans of the real-world tunnel, anteroom, and key artifacts. These raw, high-polygon assets are then processed through a rigorous optimization pipeline. This involves retopology, normal map baking, and the creation of multiple Levels of Detail (LODs) to ensure the environment runs performantly on standalone VR headsets (Meta Quest 3/Pro) while preserving visual authenticity.

- **Integration with the Haptics SDK (WP3):** The environment is not merely a static backdrop; it is an interactive surface for the haptics system.
    - **Collision Meshes and Physics Materials:** Precise collision meshes are built into the environment geometry. These colliders are assigned specific physics material properties. When the user's avatar (via the haptic gloves) touches a surface, these properties trigger corresponding API calls to the Haptics SDK. For example, a surface defined as "damp stone" will trigger a specific, pre-defined vibrational effect on the haptic vest and gloves, while interacting with a solid object like the shovel will generate force-feedback resistance.
    - **Trigger Zones:** Specific zones within the environment are defined as triggers that call haptic events. Entering the narrow tunnel, for instance, activates an API call to the vest to create a continuous pressure sensation, simulating the feeling of confinement.
- **Integration with Pre-recorded Holoportation (WP2):** The scanned environment serves as the stage for the pre-recorded holoportation of the time witness.
    - **Anchor and Playback Points:** The environment mesh contains defined anchor points that dictate the precise placement, orientation, and scale of the holoportation playback. This ensures the holographic witness appears naturally within the scene, for example, standing in a specific spot or interacting with a virtual artifact.
    - **Lighting and Cohesion:** The environment's lighting is baked and configured to match the lighting used during the holoportation recording, creating a seamless visual composition that enhances the sense of co-presence and realism.

- **Integration with Virtual Humans as Avatars (WP4):** The environment provides the necessary framework for the user's avatar to exist and move believably.
    - **Navigation Mesh (NavMesh):** A detailed navigation mesh is generated from the floor geometry of the scanned environment. This NavMesh is used by avatars for navigation, allowing the user's avatar to teleport or move realistically through the space without walking through walls or obstacles.
    - **Physical Grounding:** The environment's colliders provide the physical grounding for the avatar, enabling physics-based interactions and preventing the avatar from falling through the floor, thereby maintaining the user's sense of immersion and presence.

5.4.4. Next Steps

As the project moves into its second half, the focus will shift from initial integration to refinement, robust user validation, and final delivery of the full-featured demonstrators. The following steps outline a clear vision and roadmap to achieve the final objectives by the project's conclusion, addressing the need for continuous improvement and a comprehensive evaluation of the PRESENCE toolset.

Step 1: Complete Core Feature Integration (Q3 2025 - Q4 2025)

This step prioritizes the integration of the remaining core technologies to complete the foundational feature set for all use cases.

Continue with integration of remaining work packages: The immediate priority is to finalize the integration of all key technological pillars as planned for Demonstrator V2.

Holoportation: For UC2.2 (Cultural Heritage), this involves integrating the **pre-recorded holoportation** of the time-witness to provide an engaging and authentic narrative guide. For all use cases, work will continue resolving current issues, such as correcting avatar orientation and ensuring the pre-recorded time witness is correctly displayed and transformed as a holoported entity that can properly be viewed by the live player.

Intelligent Virtual Humans: A key next step is replacing the current placeholder avatars with more advanced and customizable **Virtual Humans** (CC4 character models) to act as avatars for the players. This will enhance user representation and social presence.

Haptics: The robustness of the haptic system will be improved by enhancing device detection and adding more nuanced feedback.

Step 2: Initial User Testing & Iterative Refinement (Q4 2025 - Q2 2026)

With a complete basic feature set, the project will pivot to end user testing and validation of the use cases in addition to iterative development cycles.

Conduct end user testing with basic feature set: Once the core integrations are stable, end user testing sessions will be conducted. This will involve both internal tests with non-project members and external sessions with target users (e.g., healthcare professionals, manufacturing trainees).

- **Methodology:** A mix of qualitative (interviews, think-aloud protocols) and quantitative (questionnaires on presence, usability, and user experience) data will be collected.
- **Goal:** The feedback gathered will be crucial for identifying usability issues, validating the effectiveness of the integrated technologies, and gathering insights to guide the next development phase.

Iterative UI/UX and Gameplay Enhancements: Based on user feedback, a significant effort will be dedicated to refining the user experience.

- **UI/UX:** This includes redesigning core UI elements for better clarity, creating flexible user flows (e.g., skippable onboarding), improving accessibility (e.g., text displays for audio), and implementing user settings panels.
- **Experience Mechanics:** The core mechanics will be polished to enhance engagement and immersion, removing elements that detract from the experience and improving those that are essential.

Step 3: Performance Optimization and Final Validation (Q2 2026 - M36)

The final step will focus on creating a polished, stable, and robust final demonstrator ready for final validation.

Optimize graphical rendering to maintain a high and stable frame rate, even with multiple complex avatars and environments.

Minimize computational resource usage to ensure the applications run smoothly on the target hardware.

Final Demonstrator Enhancement and Use Case Application Tests: The last period will be dedicated to final polishing and comprehensive testing leading up to Deliverable 5.3.

- **Advanced Features:** Implement advanced functionalities such as "admin mode" for session facilitators (especially in the health use case), multi-language support, and enhanced in-app tutorials.
- **Final QA and User Testing:** Conduct final, large-scale user tests to validate the complete PRESENCE toolset against the project's initial goals and experimental protocols.
- **Analytics and Feedback:** Integrate lightweight, in-app feedback mechanisms (e.g., session scoring) to gather continuous data on the user experience.

5.4.5. Roadmap plan for UC2.2 Demonstrator V1 & Roadmap on Demonstrator Enhancement and Use Case Application Tests

Following the upcoming GA Amsterdam technical milestone at the beginning of **Q3 2025** (marking the completion of the UC 2.2 Version 0 Demonstrator with basic haptics and 3D scans), the development plan for UC 2.2 will proceed as follows:

1. **Q3 2025: Integration of Holoportation**
    - **Roadmap Item:** "Playback of Holo-Recorded Time Witness."
    - **Focus:** Integrate the pre-recorded holoportation technology for the tour guide (David).
    - **Outcome:** Users will be able to see and receive information from these holographic representations within the experience.
2. **Q4 2025: Development of Avatars**
    - **Roadmap Item:** "Avatar for Tourist."
    - **Focus:** Develop and implement the virtual representations (avatars) for the tourist (Sophia).
    - **Outcome:** Enhanced user representation and potential for more dynamic interaction with guide figures.
3. **Post Q4 2025 / Early Q1 2026: Initial User Testing**
    - **"Next Step" Item:** "Conduct initial user testing with basic feature set."
    - **Focus:** Once Holoportation and initial Avatars are integrated (forming the "basic feature set" alongside existing 3D environments and haptics), we will conduct user testing sessions.
    - **Outcome:** Gather crucial qualitative and quantitative feedback on the user experience, immersion, and effectiveness of the integrated features.
4. **Q1 & Q2 2026: Iterative Improvements Based on User Feedback**
    - **Roadmap Item:** "Improvements in graphics, sounds, VFX to increase feeling of presence based on user feedback" (spanning Q1 and Q2 2026).
    - **Focus:** Analyse feedback from user testing to implement targeted enhancements to the visual fidelity, audio design, and special effects. The goal is to significantly increase the user's sense of presence and immersion.
    - **Outcome:** A more polished, engaging, and impactful final experience.

6. WP5 Timeline & Milestones

Figures 17 to 20 present detailed roadmaps that define the key milestones required to achieve the objectives of each use case by the end of the project. These roadmaps serve as a strategic guide, ensuring that all necessary steps are completed in a timely and coordinated manner. Figure 20 specifically focuses on the integration and validation activities, highlighting the processes and checkpoints essential for ensuring system coherence and performance. Additionally, Figure 21 outlines the planned participation in conferences and trade fairs, which are crucial for collecting user feedback and conducting real-world user testing to refine and validate the developed solutions. The detailed planning on the roadmap can be found here:

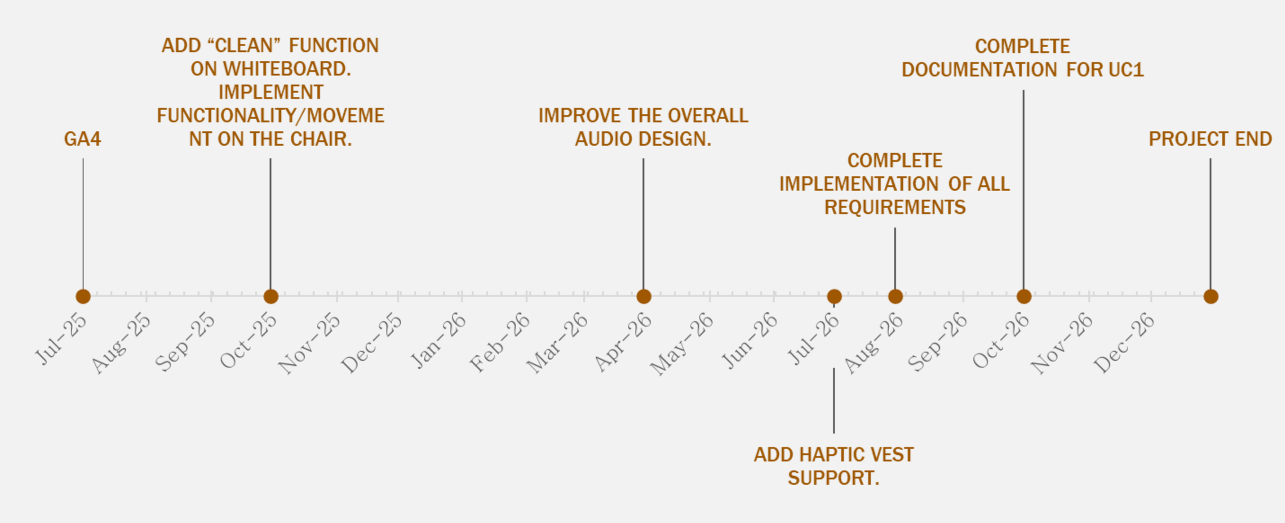

Figure 32: Project timeline UC1 - Vection

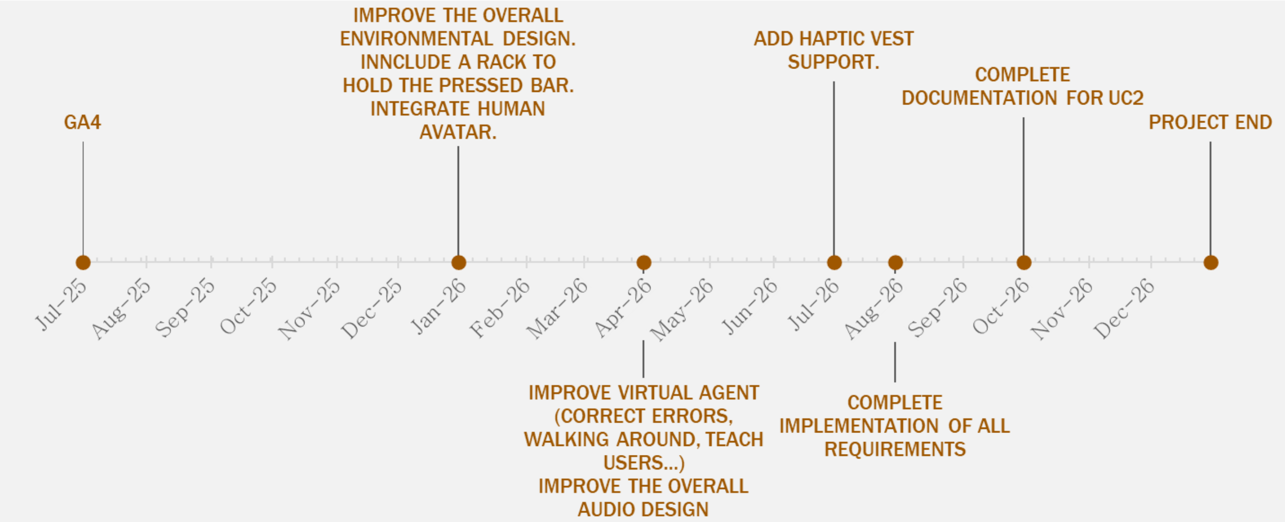

Figure 33: Project timeline UC2 - Vection

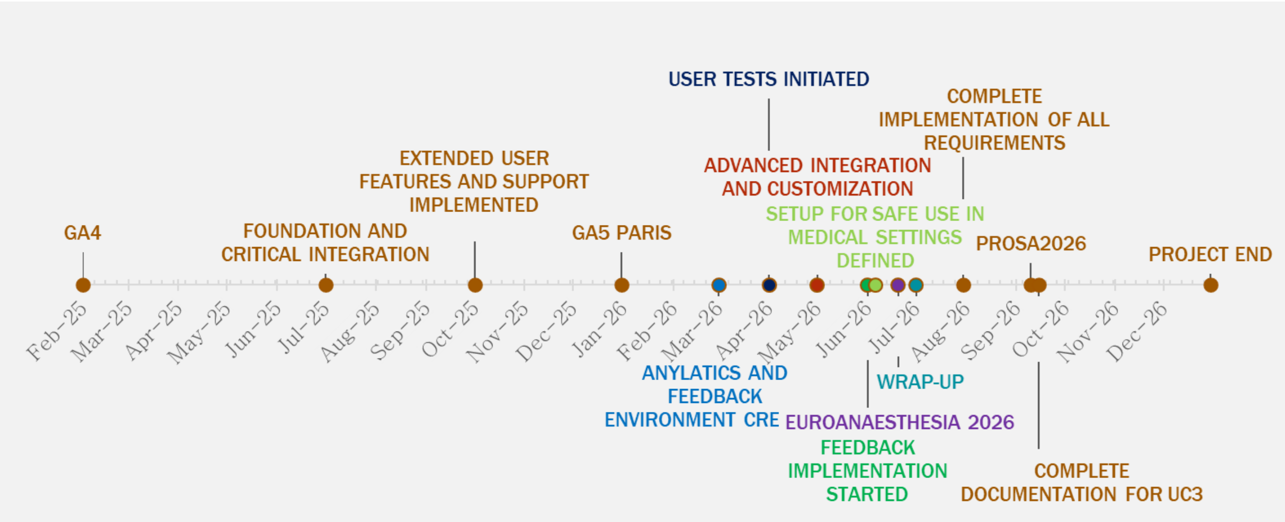

Figure 34: Project timeline UC3 - SyncVR

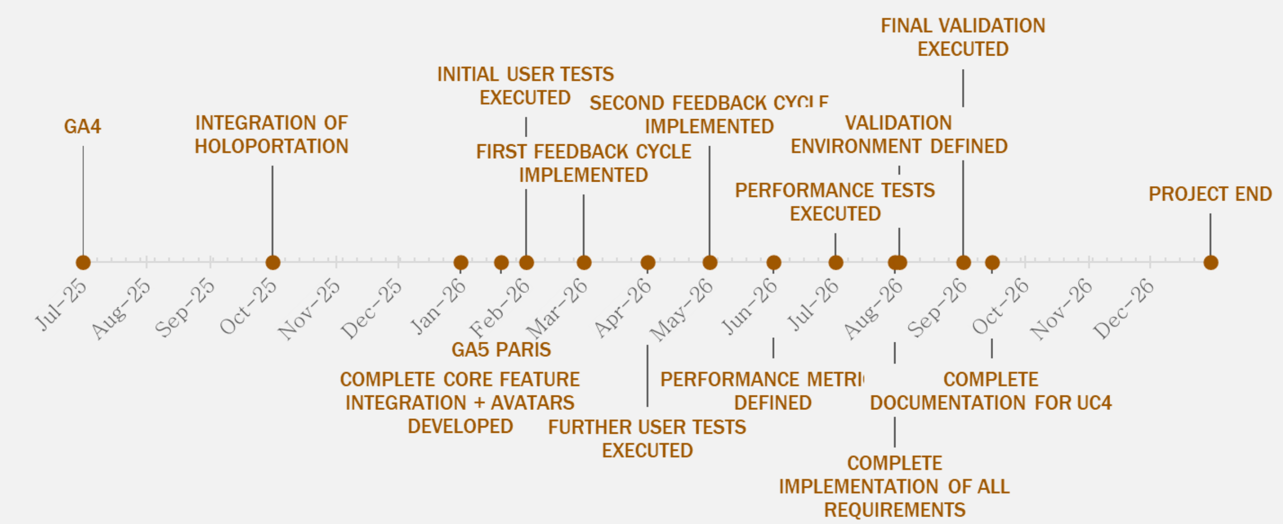

Figure 35: Project timeline UC4 - Zaubar

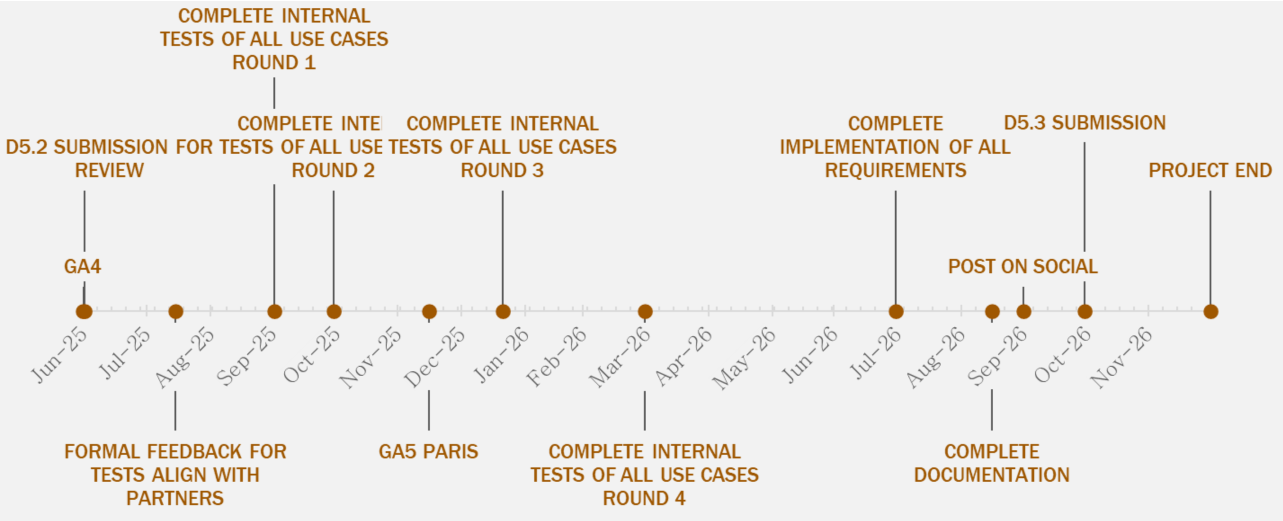

Figure 36: Project timeline Integration - Capgemini

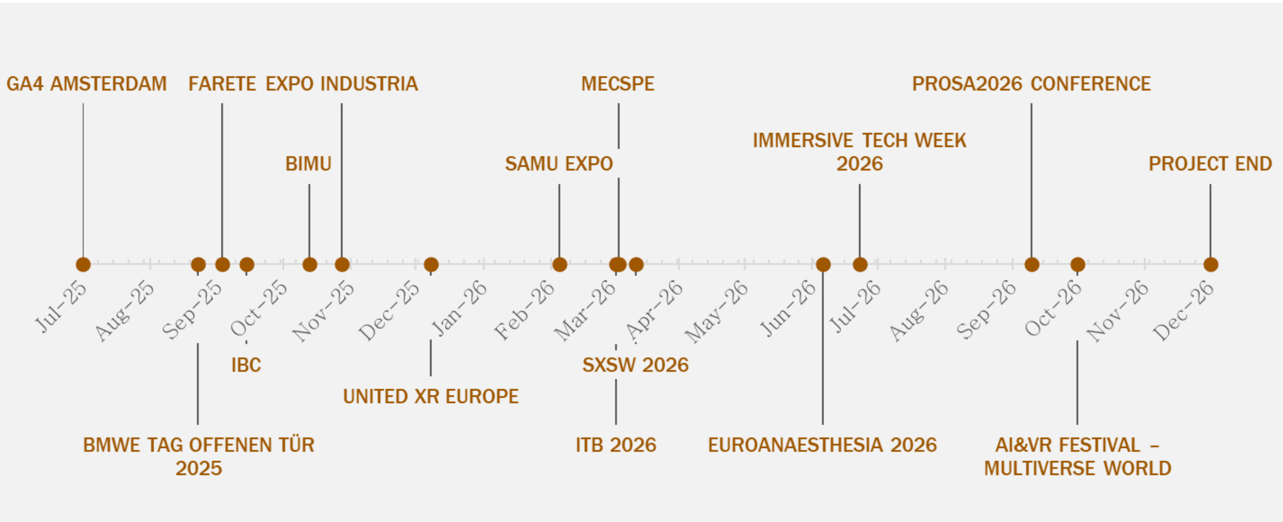

Figure 37: Events calendar

7. Conclusions

7.1. Summary

Deliverable D5.2 of the PRESENCE project documents the intermediate integration, testing, and validation activities of Work Package 5 (WP5), which aims to demonstrate the technological advancements from WP2 (Holoportation), WP3 (Haptics), and WP4 (Intelligent Virtual Humans) through four immersive XR use cases: Professional Collaboration, Manufacturing & Training, Pain Relief in Healthcare, and Cultural Heritage.

The report outlines the integration methodology, including dedicated workshops in Barcelona and Brussels, weekly alignment meetings, and the creation of common Unity templates for consistent UI/UX. Each use case has been developed into a Version 0 demonstrator, integrating relevant technological pillars to validate core concepts, interaction flows, and multi-user XR functionality.

Across the use cases, the technological pillars are combined to enhance realism, interactivity, and user engagement:

Holoportation improves social presence through real-time, 3D remote participant representation.

Haptics provides tactile and force-feedback for richer, more immersive interaction.

Intelligent Virtual Humans offer guidance, procedural support, and natural multimodal communication.

Each demonstrator includes a roadmap towards Version 1, focusing on deeper integration of the pillars, improved detection and robustness of hardware, enhanced avatars, enriched environmental and audio design, and expanded interaction possibilities. User testing phases, iterative refinements, and targeted UI/UX enhancements are planned to ensure technological maturity and high usability.

Overall, D5.2 confirms that WP5 is on track to deliver two fully integrated demonstrator groups—covering professional and social XR scenarios—showcasing the PRESENCE toolkit's potential to transform human-human and human-machine interaction across diverse domains.

7.2. Next Steps

The upcoming steps involve clarifying the remaining open requirements (see Annex) in close collaboration with project partners. This includes also developing concrete plans with the partners to address the remaining unmet requirements and ensuring alignment across all stakeholders.

A key part of this process will be the creation of formal templates for integration testing and validation procedures. These templates will be applied across various levels, such as the SDK layer and specific use cases, to ensure consistency and traceability in testing outcomes.

Based on the findings from previous test cycles, targeted actions must be initiated to resolve identified issues. These actions may involve adjustments to the SDK API, modifications to the hardware setup, or changes to the runtime environment. The goal is to systematically address technical gaps and enhance the overall robustness and usability of the system.

A further step which will be done next is to ensure that all project partners are adequately equipped with the required hardware to enable consistent and effective execution of tests across multiple locations. This step is essential for validating system components and use cases in real-world, distributed environments.

The following steps are planned for the further development of the four use case demonstrators towards Version 1.
All activities are prioritized, with clearly defined responsibilities, target dates, dependencies, and measurable success criteria.

Table 13: Overview on the next steps, times, dependencies and success criteria's

Task	Responsible	Target Date	Dependencies	Success Criterion
Improve holoportation (correct avatar orientation, stable rendering)	WP2 Lead (i2CAT)	Nov 2025	Delivery of updated HoloMIT SDK	>90% stable frame rate in internal tests, error-free rendering
Extend haptics integration (wearable detection, haptics vest support)	WP3 Lead (Interhaptics/SenseGlove)	Dec 2025	Final hardware API, Unity integration	Successful operation in ≥95% of test runs
Integrate extended IVH functionality (Vision, more animations, environment interaction)	WP4 Lead (UHAM)	Jan 2026	Completion of new IVH modules	Positive feedback in ≥80% of usability tests
Implement new UI/UX features (configurable options, whiteboard reset, tutorials)	WP5 Lead (Capgemini)	Feb 2026	Finalization of Unity template	≥80% satisfaction in internal tests
Expand environment and audio design	Use Case Leads	Feb 2026	Approval of final assets	At least 3 new interactive objects + improved soundscape per UC
Conduct internal tests with partners outside the consortium	WP5 Lead (Capgemini)	Oct–Nov 2025	Availability of stable builds	Completion of 3 test cycles with documented feedback

External pilot tests per UC (with target groups)	WP5 Lead (Capgemini) + UC Leads	Mar–Apr 2026	Successful internal tests	Min. 20 participants per UC, ≥75% positive rating

8. Abbreviations and definitions

8.1. Abbreviations

AI	Artificial Intelligence
API	Application Programming Interface
HW	Hardware
IVA	Intelligent Virtual Agents
MS	Milestone
SDK	Software Development Kit
TC	Technical Committee
TRL	Technology Readiness Level
UX	User Experience
VR	Virtual Reality
WP	Work Package
XR	eXtended Reality

9. References

Ref. 1 Grant Agreement nº 101135025 (incl. DoA Description of the Action, Parts A and B)

Ref. 2 Blanckaert, E., Mostajeran, F., Hallström, L., & Jennes, I. (2025). Methodological Reflections on Early-Stage Requirement Gathering and Prioritization for Immersive Extended Reality Applications. In *Proceedings of ACM IMX Workshops, June 3 - 6, 2025* Sociedade Brasileira de Computação.

Ref. 3 Küçüktütüncü, E., Macia-Varela, F., Llobera, J., & Slater, M. (2025). The Role of Sensorimotor Contingencies and Eye Scanpath Entropy in Presence in Virtual Reality: a Reinforcement Learning Paradigm. IEEE Transactions on Visualization and Computer Graphics.

Ref. 4 Wiesing, M., Clocchiatti, A., Ryan, B., Montserrat, R., Soccini, A. M., & Slater, M. (2025). The Elephant in the Room: People Respond with Greater Stress in Mixed Compared to Virtual Reality. Zenodo. https://doi.org/10.5281/zenodo.15196164

Ref. 5 Radclyffe, C., Ribeiro, M., & Wortham, R. H. (2023). The assessment list for trustworthy artificial intelligence: A review and recommendations. Frontiers in artificial intelligence, 6, 1020592.

Ref. 6 Schubert, T., Friedmann, F., & Regenbrecht, H. (2001). The experience of presence: Factor analytic insights. Presence: Teleoperators & Virtual Environments, 10(3), 266-281.

Ref. 7 Creswell, J. W., & Plano Clark, V. L. (2018). Designing and Conducting Mixed Methods Research (3rd ed.). Sage Publications.

10. Annex

Table 14: Requirement fulfilment status

Spreadsheets	Partner	Percentage Complete	Invalid or To be clarified	Total number of Req	Remaining	100%	51-99	1-50	0	invalid
Requirements - Raytrix - Fogli Google	Raytrix	69.00%	6	19	31.00%	3	2	6	0	8
Requirements - ZAUBAR - Fogli Google	Zaubar	20.00%	5	72	80.00%	2	9	10	17	33
Requirements - Vection - Fogli Google	Vection	65.00%	45	184	35.00%	65	5	53	16	45
Requirements - SyncVR - Fogli Google	SyncVR	38.00%	12	82	62.00%	5	9	23	19	26
Requirements - CERTH - Fogli Google	CERTH	43.00%	1	19	57.00%	1	5	8	4	1
Requirements - Artanim - Fogli Google	Artanim	46.00%	0	9	54.00%	0	2	6	1	0
Requirements - UHAM - Fogli Google	UHAM	93.00%	8	44	7.00%	26	9	1	0	8
Requirements - I2CAT - Fogli Google	I2CAT	88.00%	3	15	12.00%	6	6	0	0	3
Requirements - Interhaptics - Fogli Google	Interhaptics	92.00%	7	38	8.00%	25	3	3	0	7
Requirements - DIDIMO - Fogli Google	DIDIMO	82.00%	3	18	18.00%	7	8	2	0	1
Requirements - Capgemini - Fogli Google	Capgemini	30.00%	1	90	70.00%	15	6	21	49	-1
Requirements - JRS - Fogli Google	JRS	52.00%	0	19	48.00%	1	4	13	1	0
Requirements - SenseGlove - Fogli Google	SenseGlove	89.00%	7	45	11.00%	29	4	4	1	7
Actronika	Actronika	0.00%	7	23	100.00%	0	0	0	100	0.00

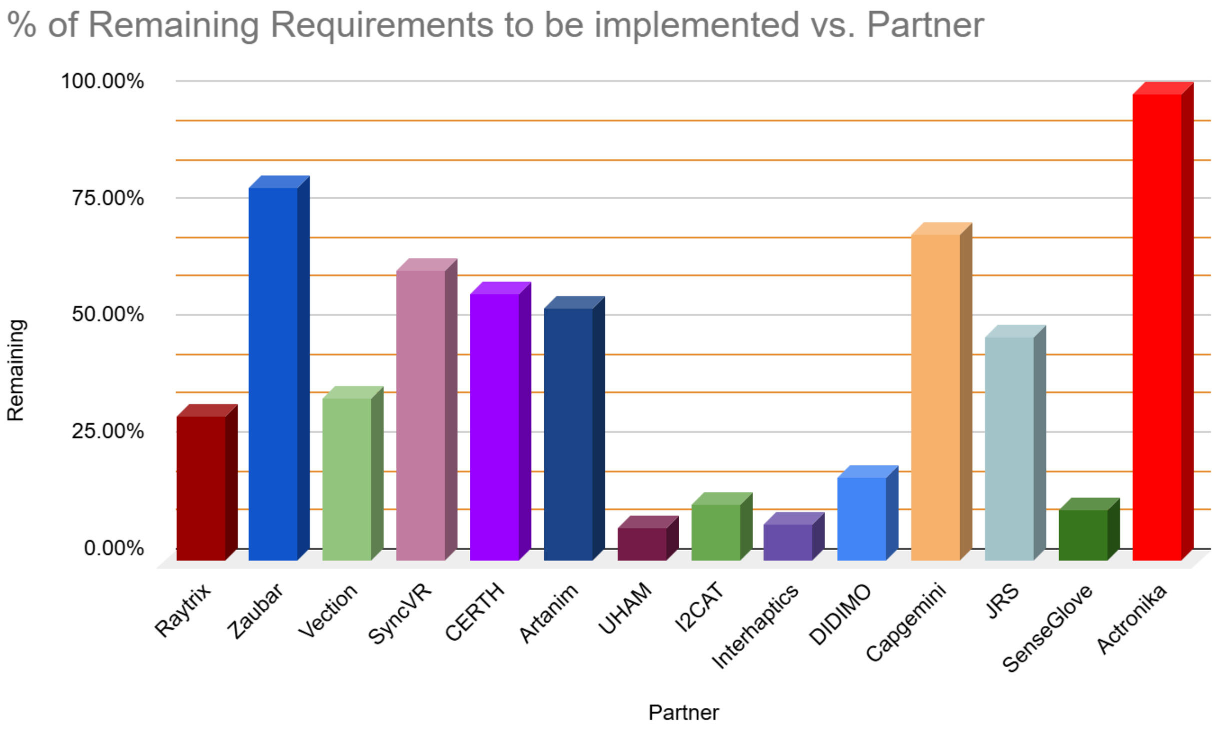

Figure 38: Chart indicating remaining requirements to be implemented in Phase 2