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|  | Moving Picture, Audio and Data Coding  by Artificial Intelligence  www.mpai.community |

**Public document**

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# Abstract

XR Venues (MPAI-XRV) is an MPAI project addressing a multiplicity of use cases enabled by Extended Reality (XR), the combination of Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR) technologies and enhanced by Artificial Intelligence (AI) technologies. The word venue is used as a synonym for real and virtual environments.

So far MPAI-XRV has identified 9 Use Cases. The analysis of Live Theatrical Performance has been completed and a Call for Technologies will be published soon. It will include the functional requirements of this document and the commercial requirements (Framework Licence).

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# Introduction

This document describes the Use Case and identifies the Functional Requirements of Live Theatrical Stage Performance, part of MPAI XR Venues (MPAI-XRV) project addressing contexts enabled by Extended Reality (XR) – any combination of Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR) technologies – and enhanced by Artificial Intelligence (AI) technologies. The word “Venue” is used as a synonym for real and virtual environments. This document should be considered jointly with the MPAI-XRV Call for Technologies [1] and the Commercial Requirements part of the MPAI-XRV Framework Licence [3].

This document accompanies with the Call for Technologies [] which seeks to obtain technologies that support some of and preferably all the Functional Requirements identified in this document. Proposers of technologies applicable to the eventually developed Live Theatrical Stage Performance standard are requested to state availability to license the technologies if adopted by MPAI, in conformity with the Framework Licence. Availability of proposed technologies will enable MPAI to develop the XR Venues (MPAI-XRV) Technical Specification for Live Theatrical Stage Performance.

Those intending to respond to the Call for Technologies, are advised to become familiar with the MPAI approach to AI-based data coding standards summarily described in Annex 1 - Basics about MPAI and with the MPAI process to develop standards [4].

MPAI is also considering other Use Cases:

1. eSports Tournament.
2. Experiential retail/shopping.
3. Collaborative immersive laboratory.
4. Immersive art experience.
5. DJ/VJ performance at a dance party.
6. Live concert performance.
7. Experiential marketing/branding.
8. Meetings/presentations.

Annex 2 - Other MPAI-XRV Use Cases provides a summary descriptions of these Use Cases. Interested parties should contact the MPAI Secretariat (secretariat@mpai.community) in order not to miss future MPAI Calls for Technologies related to those Use Cases.

# Terms and definitions

The meaning of terms used in capital letters in this document have the meaning given in *Table 1*. The Terms of MPAI-wide applicability are defined in Table 5.

*Table 1* *–Terms used in this document*

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Action Generation | The process that triggers a response to the information the machine has acquired and processed, either in the original or in a different Environment, modulating the target Experience. |
| Actuator | A mechanism for modulating an experience in a real or virtual world. |
| AI Module | (AIM) A processing element receiving AIM-specific Inputs and producing AIM-specific Outputs according to according to its Function. An AIM may be an aggregation of AIMs. |
| Avatar | An animated 3D object representing a real or fictitious person in a Real or Virtual Space. |
| Cognitive State | An estimation of the internal status of a human or avatar or a group thereof reflecting their understaning of the Environment, such as:  For a person: “Confused”, “Confident” and “Assured”.  For a group: “my team is going to lose”, or “we are winning”. |
| Data | Information in digital form. |
| * Format | The syntax and semantics of Data. |
| Descriptor | Digital representation of a Feature. |
| * Extraction | The process that extracts Descriptors from Data. |
| * Generation | The application of attributes to a scene or object. |
| * Interpretation | The process that assigns a semantic value to a Descriptor. |
| Dome | Wrap-around immersive display surrounding an audience, using a projection screen or LED panels. |
| Emotion | An estimation of the internal status of a human or avatar or a group thereof resulting from their interaction with the Environment, such as:  For a person, “Victorious”, “Fearful” and “Angry”.  For a group: “Victorious”, “Fearful” and “Disappointed” |
| Environment | A real or a virtual world, experienced by participants, sensed by Sensors, and affected by Actuators. |
| Extended Reality (XR) | Any combination of Augmented Reality (AR), Virtual Reality (VR) and Mixed Reality (MR). |
| Feature | An attribute of the Real or Virtual Environment. |
| Participant | A human in a Real or Virtal Environment (Venue). |
| * Data | Data provided by or collected from Participants. |
| * Status | The ensemble of information, expressed by Emotion, Cognitive State and Attitude, derived from observing the collective behaviour of real world and on-line spectators (via audio, video, interactive controllers, and smartphone apps) in response to actions of a team, a player, or the game. |
| Performer | A live actor performing on the Real Environment stage or represented by an avatar in the Virtual Environment. |
| Sensor | A mechanism capturing data from a real or virtual world.. |
| Social Attitude | An element of the internal status related to the way a human or avatar intends to position vis-à-vis the Environment, e.g.:  For person: “Confrontational”, “Collaborative” and “Aggressive”.  For groups: “Confrontational”, “Collaborative” and “Aggressive” |
| Use Case | A particular instance of the Application domain target of an MPAI Application Standard. |
| XR Venue | A combination of real or virtual world Environments addressed by MPAI-XRV Use Cases. |

# References

1. MPAI; MPAI XR Venues (MPAI-XRV) - Live Theatrical Stage Performance Call for Technologies; https://mpai.community/standards/mpai-xrv/call-for-technologies/
2. MPAI; MPAI XR Venues (MPAI-XRV) - Live Theatrical Stage Performance Use Case and Functional Requirements; https://mpai.community/standards/mpai-xrv/
3. MPAI; MPAI XR Venues (MPAI-XRV) - Live Theatrical Stage Performance Framework Licence; https://mpai.community/standards/mpai-xrv/framework-licence/
4. MPAI; Patent Policy; https://mpai.community/about/the-mpai-patent-policy/
5. MPAI; Technical Specification - Artificial Intelligence Framework (MPAI-AIF) V1.1; https://mpai.community/standards/mpai-aif/.
6. MPAI; Technical Specification - Multimodal Conversation (MPAI-MMC) V1.2; https://mpai.community/standards/mpai-mmc/.
7. MPAI; Technical Specification - Context-based Audio Experience (MPAI-MMC) V1.4; https://mpai.community/standards/mpai-mmc/.
8. MPAI; Technical Specification - The Governance of the MPAI Ecosystem V1, 2021; https://mpai.community/standards/mpai-gme/.
9. MPAI; Technical Report – MPAI Metaverse Model (MPAI-MMM) – Functionalities; V1; https://mmm.mpai.community/.

# A Real-Virtual Interaction Model

An important feature of MPAI-XRV is the strong interaction with – and sometimes even interchangeability of – a Real/Virtual Environment and a Virtual/Real World Environment. The MPAI-XRV model, depicted in *Figure 1,* is helpful to guide the analysis of the MPAI-XRV use cases.

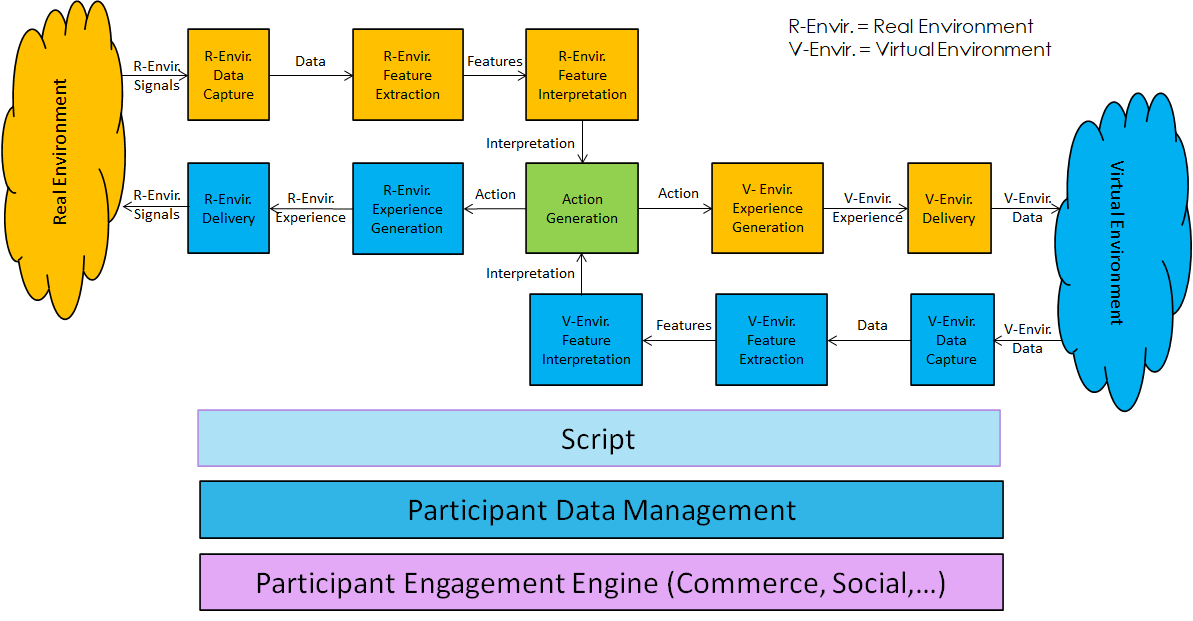


Figure – Real World (yellow) and Virtual (blue) Interactions In specific Use Cases, it is necessary to introduce new functions called Script and the Participant Data Management function.

|  |  |
| --- | --- |
| Script | A collection of descriptors that the director/producer selects for execution at runtime as a sequence of descriptors controlling the action/experience in both Real and Virtual Worlds. |
| Participants Data Management | The set of legal and ethical rules guiding the acquisition, retention, and processing of Data related to and provided by Participants. |
| Participant Engagement Engine | Algorithms to engage participants during or after the event allowing social interaction, commerce, and other engagement modalities. |

Table 2 defines the functions of the processing elements that capture and process data from a Real Environment and deliver an Environment to a virtual world Environment and from here back to the real world Enrironment. Table 2 describes the functions of the identified components.

Table 2 - The functions of the components in the MPAI-XRV Model

|  |  |
| --- | --- |
| **Data Capture** | Captures Environment as collections of signals and/or Data. |
| **Feature Extraction** | Analyses Data to extract Descriptors. |
| **Feature Interpretation** | Analyses Descriptors to yield Interpretations. |
| **Action Generation** | Analyses Interpretations to generate Actions. |
| **Experience Generation** | Analyses Actions to generate Environment. |
| **Environment Delivery** | Delivers Environment as collections of signals and/or Data. |

The model assumes that there is a complete symmetry between the actions performed and the data formats exchanged between a Real Environment and a Virtual Environment.

# Important Information

All MPAI-XRV use cases and many of those not considered here involve the collection of large amounts of potentially sensitive Participant Data. This document does not address the processes that oversee the collection and processing of Participant Data. Rather, this document assumes that whatever processing is carried out, it conforms with the necessary and ethical/legal constraints, e.g., with the consent of the right holders of the data[[1]](#footnote-2),[[2]](#footnote-3).

Implementers must take great care in data security, assuring the correct possibility to opt-in/opt-out offered and proper use of the data. Also, care must be taken in training and testing AI Models to assure conformance with local laws and regulations and to prevent offensive or unintended experiences.

# Use Case

### Purpose

To define interfaces and components to facilitate live multisensory immersive stage performances which ordinarily require extensive on-site show control staff to operate. Use of the XRV allows more direct, precise yet spontaneous show implementation and control to achieve the show director’s vision by freeing staff from repetitive and technical tasks and focusing their artistic and creative skills.

Theatrical stage performances such as Broadway theatre, musicals, dramas, operas, and other performing arts increasingly use video scrims, backdrops, and projection mapping to create digital sets rather than constructing physical stage sets, allowing animated backdrops, and reducing the cost of mounting shows.

The use of immersion domes – especially LED volumes – promises to surround audiences with virtual environments that the live performers can inhabit and interact with.

Use of AI in these XRV systems will allow:

1. Orchestration of the complex lighting, video, audio, and stage set cues that must adapt to the pace of live performers without extensive staff.
2. Large shows to tour to smaller venues that otherwise could not support complex productions.
3. Virtual- and real-environment attendance and audience interactivity.
4. A more direct connection between the artist and participants by consolidating many complex experiential modalities into a simple user interface.
5. Artists to access a large amount of data from opted-in individuals and incorporated into the visual and musical performance. Each show can thus be unique for each audience.

### Description and flow of actions

The typical set up can be described as follows:

1. A physical stage.
2. Lighting, projections (e.g., dome, holograms, AR goggles), and Special Effects (SFX).
3. Audience (standing or seated) in the real and virtual venue and external audiences via interactive streaming.
4. Interactive interfaces to allow audience participation (e.g., voting, branching, real-virtual action generation).
5. Performers on stage, platforms around domes or moving through the audience (immersive theatres).
6. Multisensory experience delivery system (immersive video and spatialised audio, touch, smell).
7. Capture of biometric data from audience and/or performers from wearables, sensors embedded in the seat, remote sensing (e.g., audio, video, lidar).
8. Show operator(s) to allow manual augmentation and oversight of an AI that has been trained by show operator activity.
9. Metaverse that mirrors selected elements of the Real Environment. For example, performers on the stage are mirrored by digital twins in the metaverse, using:
   1. Capture body motion (MoCap) to animate an avatar.
   2. Keyed 2D image mapped on a plane.
   3. Volumetrically captured 3D images producing photorealistic digital embodiments.
10. Real Environment can also mirror selected elements of the Metaverse, similar to in-camera visual effects/virtual production techniques. For instance, elements of the Metaverse such as, avatars, landscape, sky, objects can be represented in the Real Environement through:
    1. Immersive displays
    2. The floor of the stage itself and set pieces on the stage may be projection-mapped or wrapped with LED to integrate them into the immersive environment. This allows, for instance set pieces such as a tree, to come alive with moving leaves, blooming flowers, or ripening fruits, and for the tree to cast a virtual shadow across the stage from a virtual light source moving across an immersive dome. Many of these elements may be extracted from the metaverse and projected into the real-world immersive environment.
    3. Augmented reality overlays.
    4. Lighting and SFX.
11. The physical stage and set pieces blend seamlessly into the virtual 3D backdrop projected onto the dome that the spectators perceive as a single immersive environment.
12. Real performers enter the stage. As they move about the stage, whether dancing, acting, etc., their performance may be mirrored in the metaverse by tracking performer’s motion, gesture, vocalisation, and biometrics. The performance is accompanied by music, lighting, and SFX.
13. In addition, virtual performers in the metaverse may be projected onto the real-world immersive environment via immersive display, AR, etc.
14. The Script or cue list describe the show events, guide and synchronise the actions of all AI Modules (AIM) as the show evolves from scene to scene. In addition to performing the show, the AIMs might spontaneously innovate show variations within scripted guidelines.

# Functional requirements

### Operation

A comprehensive view of the devices and data relevant to the XR Theatre Use Case are provided by Figure 2*.*

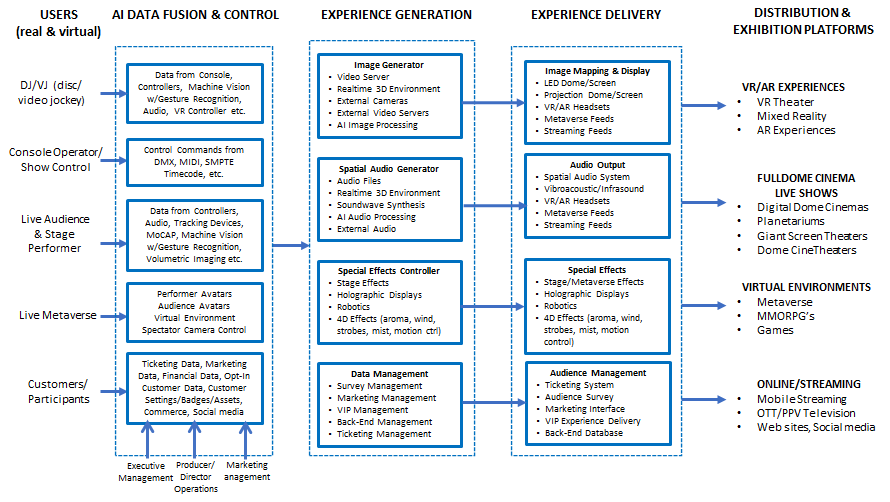


Figure 2 - Devices and data of the XR Theatre Use Case

VJ/DJ/Console operator (real-time show control team) inputs command into systems via:

1. Buttons
2. Joysticks
3. Controllers (inertial, proximity, consoles etc.)
4. Hand gestures
5. Headset

The commands into the Action Generator Engine (AGE) modify the multisensory elements (visual, audio, …) of both the Real and the Virtual World Experiences, including:

1. Video/audio clips from media servers.
2. Real-time 2D/3D generated graphics/audio (from a game engine, AI engines generating 3D).
3. Additional video/audio sources
4. 3D objects, characters, scenes.
5. Lighting and special effects.
6. Other experiential elements in both the Real and Virtual Worlds.

Multisensory elements may further be modified by additional real-world and virtual-world data, including:

1. Audience behaviour.
2. Performer behaviour.
3. Events on the stage/dome/metaverse.

### Reference Architecture

Figure 3 provides the Reference Model of the Live theatrical stage performance Use Case.

Action Generation provides Scene and Action Descriptors to enable multisensory Experience Generation and Camera Orientation in both the Real and Virtual Environments.

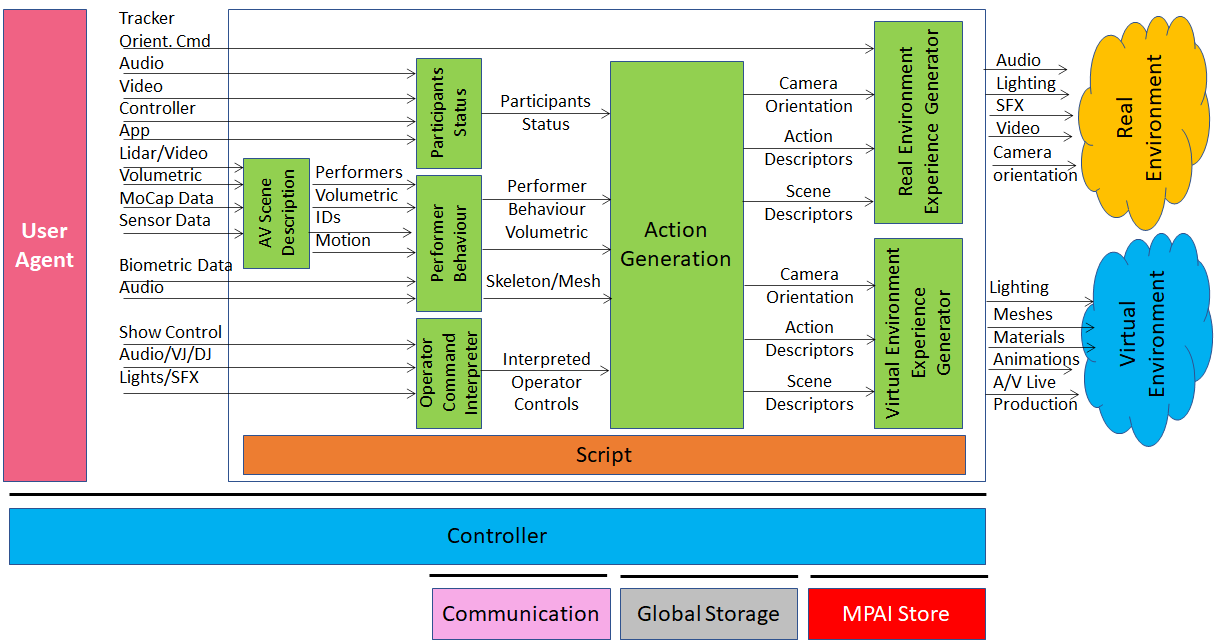


Figure 3 - Live theatrical stage performance architecture (AI Modules shown in green)

### AI Modules

Table 3 gives the list of AIMs, their functions, and their input/output data.

Table 3 - AIMs, their functions, and I/O data

|  |  |  |  |
| --- | --- | --- | --- |
| **AIM name** | **Function** | **Input** | **Output** |
| Visual Scene Description | (Feature extraction) Separate and track the individual performers | * Lidar/Video of the stage * MoCap data * Volumetric data * Sensor data | * Performer objects * IDs * Movements |
| Performer’s behaviour | Interpret performer movement to create a digital twin and control environment | (Performer’s)   * Object & IDs * Biometric data * Audio * Movements | * Performer behaviour. * Performer’s digital twin * Volumetric data |
| Operator command interpreter | Interprets operator commands | * Operator consoles (DJ consoles VJ, lighting and show control console) | * Interpreted operator commands |
| Participants Status | Extract Participants Status | * Audio * Video * Controllers * Apps | * Participants Status |
| Action Generator | Generates action to RE, VE, based on interpretation of participants, performers, operators, according to the Script, and accessing stored assets | * Participants Status * Performer Behaviour * Operator control * Volumetric * Interpreted Sensor data (e.g., human & object tracking) | * Camera orientation * Multisensory Scene and Actions Descriptors (volum. & model-based) for RE &VE. Descriptors have a generic data format. |
| RW experience generation | Creates RW multisensory experience for spectators (RW/live streaming) | * Camera orientation * Multisensory Scene and Actions Descriptors. | * Audio, lighting, SFX * Video * Camera orientation |
| VW experience generation | Creates VW multisensory experience | * Camera orientation * Multisensory Scene and Actions Descriptors. | * Audio * Video and Lighting * Meshes * Materials * Animations * Camera orientation |

### AIM I/O Data Formats

Table 4records comments on the data formats.

Table 4 – Commented data formats

|  |  |
| --- | --- |
| **Data formats** | **Comments** |
| MoCap | e.g., Text[[3]](#footnote-4), Rokoko[[4]](#footnote-5) |
| Volumetric data | e.g., USD, FBX[[5]](#footnote-6) |
| Lidar | e.g., LAS[[6]](#footnote-7), E57[[7]](#footnote-8) |
| Sensor data |  |
| * Accelerometer | D2x,D2y,D2z |
| * Positional tracker | x,y,z;a,b,c;t |
| * Object tracker | x,y,z;a,b,c;t |
| Performer behaviour | Gestures (waving, pointing, etc.), Mudra[[8]](#footnote-9), Dance notation (Choreography)[[9]](#footnote-10), BMN[[10]](#footnote-11), DanceForms software[[11]](#footnote-12), Gesture recognition[[12]](#footnote-13) |
| Operator consoles | Sliders, knobs, etc. (DMX, MIDI, NDI, Dante, ArtNet, UltraLeap, etc.), Gesture and speech recognition and interpretation |
| Participant Controllers | Wand, control boxes on the seats, mobile device, vision system capturing audience motion |
| Participants Status | Data formats expressing Participants Status composed of Emotion, Cognitive State and Attitude. |
| Script | Organised list of directions for all RE-VE Actions and Experiences based on time or events. |
| SFX | Fog, strobes, wind, mist, pyrotechnics, stage robotics, motion-base, etc. |
| Video for display | In the form of pixels for dome, stage, set pieces, scrims, “hologram” effects, AR glasses. |
| Audio | Spatial Audio including 5.1, 7.1, 11.2, Atmos, Ambisonic, Stereo Binaural, Wavefront synthesis, etc. |
| Camera orientation commands | The commands to capture participants, performers, virtual characters etc. Commands include 6D camera position/orientation, zoom, focus, and aperture of any number of real or virtual cameras. |

# Technologies requested

## Scene Description

The AIM should

1. Receive data from sensors that capture the scene that contains:
   1. Objects and set elements.
   2. One or more performers.
2. Produces a visual scene description with a format that is either known and existing or new.
3. Produces an audio scene description with a format that is either known and existing or new.
4. The performers and objects
   1. AV component accurately described
   2. Can be individually accessed and processed.
   3. Have position and movement.
   4. Have a representation that is independent of the capturing technology.
   5. Can be associated with the identity of each performer or object.
   6. Clear association of Audio objects with Visual objects.

## Participants status

1. Receive data from
   1. Sensors that capture audio and video signals and their originating positions from the audience.
   2. Apps and controllers.
   3. Online particiapnts?
2. Produces a standard description of participants status in the form of
   1. Semantics of a limited number of statuses
   2. Language describing actual status and trend
   3. …

## A/V live production

The AIM should:

1. Camera control
   1. Camera #n
   2. Camera on/off
   3. Keyframe based
      1. Spatial Attitude
      2. Optical parameters (aperture, focus, zoom)
      3. Frame rate
      4. Camera
2. Audio Mixing
   1. M Audios
   2. Mixing console commands
3. Mixing
   1. N Videos
   2. Mixing console commands
4. Basics about MPAI

In recent years, Artificial Intelligence (AI) and related technologies have been applied to a broad range of applications, have started affecting the life of millions of people and are expected to do so even more in the future. As digital media standards have positively influenced industry and billions of people, so AI-based data coding standards are expected to have a similar positive impact. Indeed, research has shown that data coding with AI-based technologies is generally *more efficient* than with existing technologies for, e.g., compression and feature-based description.

However, some AI technologies may carry inherent risks, e.g., in terms of bias toward some classes of users. Therefore, the need for standardisation is more important and urgent than ever.

The international, unaffiliated, not-for-profit MPAI – Moving Picture, Audio and Data Coding by Artificial Intelligence Standards Developing Organisation has the mission to develop *AI-enabled data coding standards*. MPAI Application Standards enable the development of AI-based products, applications, and services.

As a part of its mission, MPAI has developed standard operating procedures to enable users of MPAI implementations to make informed decision about their applicability. Central to this is the notion of Performance, defined as a set of attributes characterising a reliable, trustworthy, and ethical implementation.

For the aforementioned reasons, to fully achieve the MPAI mission, Technical Specifications must be complemented by an ecosystem designed, created and managed to underpin the life cycle of MPAI standards through the steps of specification, technical testing, assessment of product safety and security, and distribution.

In the following, Terms beginning with a capital letter are defined in *Table 1* if they are specific to this project and in Table 5 if they are common to all MPAI Standards.

The MPAI Ecosystem is fully specified in [8]. It is composed of:

* MPAI as provider of Technical, Conformance and Performance Specifications.
* Implementers of MPAI standards.
* MPAI-appointed Performance Assessors.
* The MPAI Store which takes care of secure distribution of validated Implementations.
* End Users who use Implementations from the MPAI Store.

*Figure 4* depicts the MPAI-AIF Reference Model under which Implementations of MPAI Application Standards and user-defined MPAI-AIF conforming applications operate.

An AIF Implementation allows execution of AI Workflows (AIW), composed of basic processing elements called AI Modules (AIM).

MPAI Application Standards normatively specify Syntax and Semantics of the input and output data and the Function of the AIW and the AIMs, and the Connections between and among the AIMs of an AIW.

In particular, an AIM is defined by its Function and data, but not by its internal architecture, which may be based on AI or data processing, and implemented in software, hardware or hybrid software and hardware technologies.



Figure 4 - The AI Framework (AIF) Reference Model and its Components

MPAI defines Interoperability as the ability to replace an AIW or an AIM Implementation with a functionally equivalent Implementation. MPAI also defines 3 Interoperability Levels of an AIW executed in an AIF:

*Level 1* – Conforming withthe MPAI-AIF Standard.

*Level 2* – Conforming with an MPAI Application Standard.

*Level 3* – Positively Assessed by a Performance Assessor.

MPAI offers Users access to the promised benefits of AI with a guarantee of increased transparency, trust and reliability as the Interoperability Level of an Implementation moves from 1 to 3. Additional information on Interoperability Levels is provided in Annex 5 - .

1. Other MPAI-XRV Use Cases

# eSports Tournament (XRV-EST).

## Purpose

To define interfaces between components enabling an XR Theatre (RW) to host any pre-existing VW game for the purpose of producing an esports tournament with RW and VW audience interactivity. To the extent that the game possesses the required interfaces, the XR Theatre can drive action within the VW.

## Description

The eSports Tournament Use Case consists of the following:

1. Two teams of 5 RW players are arranged on either side of a RW stage, each using a computer to compete within a common real-time Massively Multiplayer Online (MMO) VW game space.
2. The 10 players in the VW are represented by avatars each driven by
   1. Role (e.g., magicians, warriors, soldier, etc.).
   2. Properties (e.g., costumes, physical form, physical features).
   3. Actions (e.g., casting spells, shooting, flying, jumping) operating in the VW
3. The VW is populated by
   1. Avatars representing the other players.
   2. Autonomous characters (e.g., dragon, monsters, various creatures)
   3. Environmental structures (e.g., terrain, mountains, bodies of water).
4. The action in the VW is captured by multiple VW cameras and
   1. Projected onto an immersive screen surrounding RW spectators
   2. Live streamed to remote spectators as a 2D video.

with all related sounds of the VW game space.

1. A shoutcaster calls the action as the game proceeds.
2. The image of RW players, player stats or other information or imagery may also be displayed on the immersive screen and the live stream.
3. The RW tournament venue is augmented with lighting and special effects, music, and costumed performers.
4. Interactions:
   1. Live stream viewers interact with one another and with commentators through live chats, Q&A sessions, etc.
   2. RW spectators interact through shouting, waving and interactive devices (e.g., LED wands, smartphones) through processing where:
      1. Data are captured by camera/microphone or wireless data interface (see RW data in *Figure 1*).
      2. Features are extracted and interpreted.
5. RW/VW actions can be generated as a result of:
   1. In-person or remote audience behaviour (RW).
   2. Data collected from VW action (e.g., spell casting, characters dying, bombs exploding)
6. At the end of the tournament, an award ceremony featuring the winning players on the RW stage is held with great fanfare.

# Experiential retail/shopping.

## Purpose

To define components and interfaces to facilitate a retail shopping experience enhanced using immersive/interactive technologies driven with AI.

Enhancements includes:

1. Faster locating of products
2. Easy access to product information and reviews.
3. Delivery if special offers
4. Collaborative shopping (members of a group know what other members have purchased)
5. Product annotation according to user preference and theming of the environment according to season and user preferences.
6. Analytics of data collected to inform sales and marketing decisions, inventory control and business model optimisation.
7. Offering remote shoppers the ability to enter a digital twin of real world store as an avatar (as a 3D Graphics or as a volumetric “hologram”) and interact with friends who are physically or virtually present in the real world store.

## Description and flow of actions

The environment displays the following features:

1. It gives the user the impression that it is intelligent because the environment has access to the user’s identity/behaviour/preferences/shopping history/shopping list and is capable to guide the buyer to the area containing products of their supposed interest, propose products, annotate products and to display a particular product and make it flash because the environment thinks it is of interest to the buyer.
2. It broadcasts music etc. to all buyers in the environment driven by the preferences. Friends in the shop at the same time can “meet”, but buyers can opt out from being discoverable (by the store, by friends etc.). Buyers can opt out from the loyalty card and not have the product they buy recorded by the shop.
3. It can be digitally rethemed for different occasions.
4. It offers experience that can takes shape can be anywhere, e.g., in a vehicle or in a public transit space.
5. It enables remote shoppers to virtually enter a digital twin of the store and interact with friends who are physically present in the store for a collaborative shopping experience.

# Collaborative immersive laboratory

## Purpose

Create a collaborative immersive environment allowing citizen scientists and researchers to join physically or virtually via avatar or volumetric representation of themselves for navigation, inspection, analysis, and simulations of scientific or industrial 3D/spatial models/datasets ranging from microscopic to macroscopic.

Examples are:

* View data in its actual 3D or 4D (over time) form through Immersive Reality.
* Present very large data sets that are generated by microscopes, patient, and industrial scanners.
* Format/reformat, qualify, and quantify sliced dataset with enhanced visualisation and analysis tools or import results for rapid correction of metadata for volumetric import.
* Provide tools for investigators to understand complex data sets completely and communicate their findings efficiently.

Objective of an exemplary case: to define interfaces of AI Modules that create 3D models of the fascia from 2D slices sampling microscopic medical images, classify cells based on their spatial phenotype morphology, enable the user to explore, interact with, zoom in the 3D model, count cells, and jump from a portion of the endoderm to another.

## Description

There is a file containing the digital capture of 2D slices, e.g., of the endocrine system.

An AIM reads the file and creates the 3D model of the fascia.

Another AIM finds the cells in the model and classifies them.

A human

1. navigates the 3D model.
2. interacts with the 3D model.
3. zooms in the 3D model (e.g., x2000).
4. converts a confocal image stack into a volumetric model.
5. Analyses the movement of an athlete for setting peak performance goals.

Relevant data formats are:

1. Image Data: TIFF, PNG, JPEG, DICOM, VSI, OIR, IMS, CZI, ND2, and LIF files
2. Mesh Data: OBJ, FBX, and STEP files
3. Volumetric Data: OBJ, PLY, XYZ, PCG, RCS, RCP and E57[[13]](#footnote-14)
4. Supplemental Slides from Powerpoint/Keynote/Zoom
5. 3D Scatterplots from CSV files

## Specific application areas

### Microscopic dataset visualisation

1. Deals with different object types, e.g.:
   1. 3D Visual Output of a microscope.
   2. 3D model of the brain of a mouse.
   3. Molecules captured as 3D objects by an electronic microscope.
2. Create and add metadata to a 3D audio-visual object:
   1. Define a portion of the object – manual or automatic.
   2. Assign physical properties to (different parts) of the 3D AV object.
   3. Annotate a portion of the 3D AV object.
   4. Create links between different parts of the 3D AV object.
3. Enter, navigate and act on 3D audio-visual objects:
   1. Define a portion of the object – manual or automatic.
   2. Count objects per assigned volume size.
   3. Detect structures in a (portion of) the 3D AV object.
   4. Deform/sculpt the 3D AV object.
   5. Combine 3D AV objects.
   6. Call an anomaly detector on a portion with an anomaly criterion.
   7. Follow a link to another portion of the object.
   8. 3D print (portions of) the 3D AV object.

### Macroscopic dataset visualisation and simulation

1. Deals with different dataset types, e.g.:
   1. Stars, 3D star maps (HIPPARCOS, Tycho Catalogues, etc.).
   2. Deep-sky objects (galaxies, star clusters, nebulae, etc.).
   3. Deep-sky surveys (galaxy clusters, large-scale structures, distant galaxies, etc.).
   4. Satellites and man-made objects in the atmosphere and above, space junks, planetary and Moon positions.
   5. Real-time air traffic.
   6. Geospatial information including CO2 emission maps, ocean temperature, weather, etc.
2. Simulation data
   1. Future/past positions of celestial objects.
   2. Stellar and galactic evolution.
   3. Weather simulations.
   4. Galaxy collisions.
   5. Black hole simulation.
3. Create and add metadata to datasets and simulations:
   1. Assign properties to (different parts) of the datasets and simulations.
   2. Define a portion of the dataset – manual or automatic.
   3. Annotate a portion of the datasets and simulations.
   4. Create links between different parts of the datasets and simulations.
4. Enter, navigate, and act on 3D audio-visual objects:
   1. Search data for extra-solar planets.
   2. Count objects per assigned volume size.
   3. Detect structures and trends in a (portion of) the datasets and simulations.
   4. Call an anomaly detector on a portion with an anomaly criterion.

### Educational lab

1. Experiential learning models simulations for humans.
2. Group navigation across datasets and simulations.
3. Group interactive curricula.
4. Evaluation maps.

### Collaborative CAD

1. Building information management.
2. Collaborative design and art.
3. Collaborative design reviews.
4. Event simulation (emergency planning etc.).
5. Material behaviour simulation (thermal, stress, collision, etc.).

# Immersive art experience.

## Purpose

Define interfaces and components to enhance magical Environments created by skilled artists to provide each user with a unique interactive experience including the ability to modify the environment per their personal style and preferences.

## Description

Immersive art experiences such as Immersive Van Gogh provide visitors with a visually and aurally immersive experience, often based on the work of a specific artist. These are typically passive walk-through and sit-down experiences. The addition of AI to these Environments allows numerous enhancements including the recognition of individual visitors, allowing them to interact with and modify these environments based on pre-selected preferences and style choices. AI style transfer allows the featured artist’s style to be applied to unique visitor interactions which might include AI voice or text-based image diffusion, gesture-based interactions, proximity effects and more. The addition of AR glasses allows visitors to experience, create and interact with “holograms” within the Environment. Biometric wearables allow the AI to monitor and adjust the multisensory experience to maximize target brain/nervous system states related to well-being, restorative states and more. The XR Venue model also allows visitors in the RW and VW to interact.

# DJ/VJ performance at a dance party.

## Purpose

Define interfaces and components to enhance the overall experience within a nightclub, lounge or dance party Environment. The goal is to empower the DJ/VJ to create and control entertaining immersive and interactive experiences that reduce social inhibitions, encourage play, invoke a greater sense of togetherness, encourage personal connections, evoke altered states of consciousness, amplify user’s self-expression and generally create a highly pro-social experience for participants.

## Description

Dance parties, lounges, clubs, and electronic music festivals use powerful visuals, sound and other effects to captivate participants. The DJ (disc jockey) mixes audio tracks, energizes the crowd and is central to the experience. However, the visual artist or VJ (video jockey) is also an important contributor, often supported by lighting, laser and effects operators, dancers, performers and more. Quite often these venues offer peripheral activities as well to further engage participants off of the dance floor, including interactive screens, spatial art, vendors offering costumes and LED accessories. These venues can be thought of as play spaces. Pro-social intoxicants such as alcohol are sometimes used to lower inhibitions that would otherwise limit social connections. XR Venues can supercharge the dance party experience by providing powerful immersive visuals and by including VW participants Assisted by AI, all music, visuals, lights, and effects can be controlled by a single DJ (or immersive jockey) using gestures, simple control surfaces, vocal commandsm and such. In addition, expanded peripheral activities for deeper engagement might include immersive visuals that respond to emergent crowd behaviours, “photonic go-go booths” that modulate immersive visuals to amplify the creative expression of dancers’ movements, and AI-based matchmaking that fosters connections between like-minded attendees.

# Live concert performance.

## Purpose

Define interfaces and components to enhance live musical concerts with AI-driven visuals and special effects and allow enhanced audience participation while extending concert performances into the metaverse.

## Description

Similar to live theatrical stage performances, musical concerts – whether orchestral or popular music – are increasingly using visuals and other effects to enhance the audience experience. A band or orchestral musicians on stage can be substantially enhanced by video projections from a live VJ, audio responsive visuals, image magnification from cameras and other effects. In addition, skilful live mixing of audio is critical to the audience experience, but it complicated by architectural properties of the physical venue. AI can dynamically optimize the listening experience and allow tight synchronization of visuals with spontaneous musical performances in addition to optimizing the VW experience for remote attendees.

# Experiential marketing/branding.

## Purpose

Define interfaces and components to enhance a wide range of experiences in support of corporate branding.

## Description

Wherever there are a lot of people gathered we often find advertisers or corporate brands seeking visibility. Experiential marketing goes beyond simple advertising or signage by offering memorable experiences to attendees. Experiential marketing often makes use of pop-up venues or storefronts co-located at festivals, sporting events, concerts and more. Digital interactive or immersive experiences are increasingly employed, often incorporating branded story-worlds or iconic brand elements. The XRV allows delivery of a unique experience to each participant and deeper engagement to build brand loyalty. In addition, the experience can be extended into the VW to reach a larger number of attendees.

# Meetings/presentations.

## Purpose

Define interfaces and components to enhance live presentations and dialog, both in RW and VW, using rich multimedia, dialog mapping, AI-based mediation and fact checking.

## Description

Meetings and presentations are increasingly hybrid, including both live and virtual attendees, allowing the sharing of rich multimedia content including documents, videos and website links. Use of an XRV for presentations and especially dialog - including political discourse - presents an opportunity for AI to monitor, track, organize and summarize numerous data in real-time to overlook hyperbole and guide the conversation toward rapid convergence on positive outcomes. Real-time fact-finding/fact-checking, dialog mapping (creating a logical tree showing relationships and dependencies between various points raised), group polling and other advanced methods can be employed in an XRV to guide dialog or facilitate presentations.

1. MPAI-wide terms and definitions

The Terms used in this standard whose first letter is capital and are not already included inTable 2are defined in Table 5*.*

Table 5 - MPAI-wide Terms

|  |  |
| --- | --- |
| **Term** | **Definition** |
| Access | Static or slowly changing data that are required by an application such as domain knowledge data, data models, etc. |
| AI Framework (AIF) | The environment where AIWs are executed. |
| AI Module (AIM) | A processing element receiving AIM-specific Inputs and producing AIM-specific Outputs according to according to its Function. An AIM may be an aggregation of AIMs. |
| AI Workflow (AIW) | A structured aggregation of AIMs implementing a Use Case receiving AIW-specific inputs and producing AIW-specific inputs according to its Function. |
| AIF Metadata | The data set describing the capabilities of an AIF set by the AIF Implem­enter. |
| AIM Metadata | The data set describing the capabilities of an AIM set by the AIM Implem­enter. |
| Application Programming Interface (API) | A software interface that allows two applications to talk to each other |
| Application Standard | An MPAI Standard specifying AIWs, AIMs, Topologies and Formats suitable for a particular application domain. |
| Channel | A physical or logical connection between an output Port of an AIM and an input Port of an AIM. The term “connection” is also used as a synonym. |
| Communication | The infrastructure that implements message passing between AIMs. |
| Component | One of the 9 AIF elements: Access, AI Module, AI Workflow, Commun­ication, Controller, Internal Storage, Global Storage, MPAI Store, and User Agent. |
| Conformance | The attribute of an Implementation of being a correct technical Implem­entation of a Technical Specification. |
| Conformance Tester | An entity authorised by MPAI to Test the Conformance of an Implementation. |
| Conformance Testing | The normative document specifying the Means to Test the Conformance of an Implementation. |
| Conformance Testing Means | Procedures, tools, data sets and/or data set characteristics to Test the Conformance of an Implementation. |
| Connection | A channel connecting an output port of an AIM and an input port of an AIM. |
| Controller | A Component that manages and controls the AIMs in the AIF, so that they execute in the correct order and at the time when they are needed. |
| Data | Information in digital form. |
| Data Format | The standard digital representation of Data. |
| Data Semantics | The meaning of Data. |
| Device | A hardware and/or software entity running at least one instance of an AIF. |
| Ecosystem | The ensemble of the following actors: MPAI, MPAI Store, Implementers, Conformance Testers, Performance Testers and Users of MPAI-AIF Im­plementations as needed to enable an Interoperability Level. |
| Event | An occurrence acted on by an Implementation. |
| Explainability | The ability to trace the output of an Implementation back to the inputs that have produced it. |
| Fairness | The attribute of an Implementation whose extent of applicability can be assessed by making the training set and/or network open to testing for bias and unanticipated results. |
| Function | The operations effected by an AIW or an AIM on input data. |
| Global Storage | A Component to store data shared by AIMs. |
| Identifier | A name that uniquely identifies an Implementation. |
| Implementation | 1. An embodiment of the MPAI-AIF Technical Specification, or 2. An AIW or AIM of a particular Level (1-2-3). |
| Internal Storage | A Component to store data of the individual AIMs. |
| Interoperability | The ability to functionally replace an AIM/AIW with another AIM/AIW having the same Interoperability Level |
| Interoperability Level | The attribute of an AIW and its AIMs to be executable in an AIF Implementation and to be:   1. Implementer-specific and satisfying the MPAI-AIF Standard *(Level 1)*. 2. Specified by an MPAI Application Standard (*Level 2)*. 3. Specified by an MPAI Application Standard and certified by a Performance Assessor (*Level 3)*. |
| Knowledge Base | Structured and/or unstructured information made accessible to AIMs via MPAI-specified interfaces |
| Message | A sequence of Records. |
| Normativity | The set of attributes of a technology or a set of technologies specified by the applicable parts of an MPAI standard. |
| Performance | The attribute of an Implementation of being Reliable, Robust, Fair and Replicable. |
| Performance Assessment | The normative document specifying the procedures, the tools, the data sets and/or the data set characteristics to Assess the Grade of Performance of an Implementation. |
| Performance Assessment Means | Procedures, tools, data sets and/or data set characteristics to Assess the Performance of an Implementation. |
| Performance Assessor | An entity authorised by MPAI to Assess the Performance of an Implementation in a given Application domain |
| Port | A physical or logical communication interface of an AIM. |
| Profile | A particular subset of the technologies used in MPAI-AIF or an AIW of an Application Standard and, where applicable, the classes, other subsets, options, and parameters relevant to that subset. |
| Record | Data with a specified structure. |
| Reference Model | The AIMs and theirs Connections in an AIW. |
| Reference Software | A technically correct software implementation of a Technical Specific­ation containing source code, or source and compiled code. |
| Reliability | The attribute of an Implementation that performs as specified by the Application Standard, profile and version the Implementation refers to, e.g., within the application scope, stated limitations, and for the period of time specified by the Implementer. |
| Replicability | The attribute of an Implementation whose Performance, as Assessed by a Performance Assessor, can be replicated, within an agreed level, by another Performance Assessor. |
| Robustness | The attribute of an Implementation that copes with data outside of the stated application scope with an estimated degree of confidence. |
| Scope | The domain of applicability of an MPAI Application Standard. |
| Service Provider | An entrepreneur who offers an Implementation as a service (e.g., a recommendation service) to Users. |
| Specification | A collection of normative clauses. |
| Standard | The ensemble of Technical Specification, Reference Software, Conformance Testing and Performance Assessment of an MPAI application Standard. |
| Technical Specification | (Framework) the normative specification of the AIF.  (Application) the normative specification of the set of AIWs belon­ging to an application domain along with the AIMs required to Im­plem­ent the AIWs that includes:   1. The formats of the Input/Output data of the AIWs implementing the AIWs. 2. The Connections of the AIMs of the AIW. 3. The formats of the Input/Output data of the AIMs belonging to the AIW. |
| Testing Laboratory | A laboratory accredited by MPAI to Assess the Grade of Performance of Implementations. |
| Time Base | The protocol specifying how AIF Components can access timing information. |
| Topology | The set of AIM Connections of an AIW. |
| Use Case | A particular instance of the Application domain target of an Application Standard. |
| User | A user of an Implementation. |
| User Agent | The Component interfacing the user with an AIF through the Controller |
| Version | A revision or extension of a Standard or of one of its elements. |
| Zero Trust | A cybersecurity model primarily focused on data and service protection that assumes no implicit trust. |

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1. The Governance of the MPAI Ecosystem (Informative)

**Level 1 Interoperability**

Concerning *Figure 4* MPAI issues and maintains a standard – called MPAI-AIF – whose components are:

1. An environment called AI Framework (AIF) running AI Workflows (AIW) composed of inter­connected AI Modules (AIM) exposing standard interfaces.
2. A distribution system of AIW and AIM Implementation called MPAI Store from which an AIF Implementation can download AIWs and AIMs.

A Level 1 Implementation shall implement the MPAI-AIF Technical Specification executing AIWs composed of AIMs able to call the MPAI-AIF APIs.

|  |  |
| --- | --- |
| Implementers’ benefits | Upload to the MPAI Store and have globally distributed Implementations of   * AIFs conforming to MPAI-AIF. * AIWs and AIMs performing prop­rietary functions executable in AIF. |
| Users’ benefits | Rely on Implementations that have been tested for security. |
| MPAI Store’s role | * Tests the Conformance of Implementations to MPAI-AIF. * Verifies Implementations’ security, e.g., absence of malware. * Indicates unambiguously that Implementations are Level 1. |

**Level 2 Interoperability**

In a Level 2 Implem­entation, the AIW must be an Implementation of an MPAI Use Case and the AIMs must con­form with an MPAI Applicati­on Standard.

|  |  |
| --- | --- |
| Implementers’ benefits | Upload to the MPAI Store and have globally distributed Implementations of   * AIFs conforming to MPAI-AIF. * AIWs and AIMs conforming to MPAI Application Standards. |
| Users’ benefits | * Rely on Implementations of AIWs and AIMs whose Functions have been reviewed during standardisation. * Have a degree of Explainability of the AIW operation because the AIM Func­tions and the data Formats are known. |
| Market’s benefits | * Open AIW and AIM markets foster competition leading to better products. * Competition of AIW and AIM Implementations fosters AI innovation. |
| MPAI Store’s role | * Tests Conformance of Implementations with the relevant MPAI Standard. * Verifies Implementations’ security. * Indicates unambiguously that Implementations are Level 2. |

**Level 3 Interoperability**

MPAI does not generally set standards on how and with what data an AIM should be trained. This is an important differentiator that promotes competition leading to better solutions. However, the performance of an AIM is typically higher if the data used for training are in greater quantity and more in tune with the scope. Training data that have a large variety and cover the spec­trum of all cases of interest in breadth and depth typically lead to Implementations of higher “quality”.

For Level 3, MPAI normatively specifies the process, the tools and the data or the characteristics of the data to be used to Assess the Grade of Performance of an AIM or an AIW.

|  |  |
| --- | --- |
| Implementers’ benefits | May claim their Implementations have passed Performance Assessment. |
| Users’ benefits | Get assurance that the Implementation being used performs correctly, e.g., it has been properly trained. |
| Market’s benefits | Implementations’ Performance Grades stimulate the development of more Performing AIM and AIW Implementations. |
| MPAI Store’s role | * Verifies the Implementations’ security * Indicates unambiguously that Implementations are Level 3. |

**The MPAI ecosystem**

*Figure 5* is a high-level description of the MPAI ecosystem operation applicable to fully conforming MPAI implementations as specified in the Governance of the MPAI Ecosystem Specification [8]:

1. MPAI establishes and controls the not-for-profit MPAI Store.
2. MPAI appoints Performance Assessors.
3. MPAI publishes Standards.
4. Implementers submit Implementations to Performance Assessors.
5. If the Implementation Performance is acceptable, Performance Assessors inform Implementers and the MPAI Store.
6. Implementers submit Implementations to the MPAI Store tested for Confor­mance and security.
7. Users download and use Implementations and submit experience scores.

*Diagram

Description automatically generated*

Figure 5 - The MPAI ecosystem operation

1. https://openvoicenetwork.org/documents/ovn\_ethical\_guidlines\_voice\_experiences.pdf [↑](#footnote-ref-2)
2. https://ec.europa.eu/futurium/en/ai-alliance-consultation.1.html [↑](#footnote-ref-3)
3. https://en.wikipedia.org/wiki/List\_of\_motion\_and\_gesture\_file\_formats [↑](#footnote-ref-4)
4. https://www.rokoko.com/ [↑](#footnote-ref-5)
5. https://www.hhi.fraunhofer.de/en/departments/vca/research-groups/multimedia-communications/research-topics/volumetric-video-formats.html [↑](#footnote-ref-6)
6. https://en.wikipedia.org/wiki/LAS\_file\_format [↑](#footnote-ref-7)
7. https://library.carleton.ca/guides/help/lidar-formats [↑](#footnote-ref-8)
8. https://en.wikipedia.org/wiki/List\_of\_mudras\_(yoga) [↑](#footnote-ref-9)
9. https://en.wikipedia.org/wiki/Dance\_notation [↑](#footnote-ref-10)
10. https://en.wikipedia.org/wiki/Benesh\_Movement\_Notation [↑](#footnote-ref-11)
11. https://amt-lab.org/reviews/2020/3/lets-get-digital-visualizing-movement-in-danc [↑](#footnote-ref-12)
12. https://www.researchgate.net/publication/335436965\_An\_Automated\_Structural\_Approach\_to\_Support\_Theatrical\_Performances\_by\_Introducing\_Gesture\_Recognition\_to\_a\_Cuing\_System [↑](#footnote-ref-13)
13. https://info.vercator.com/blog/what-are-the-most-common-3d-point-cloud-file-formats-and-how-to-solve-interoperability-issues [↑](#footnote-ref-14)