



IEEE Standard Adoption of Moving Picture, Audio and Data Coding by Artificial Intelligence (MPAI) Technical Specification MPAI Metaverse Model (MMM) Architecture—Version 1

Developed by the
Collaborative Activities Governance Board

IEEE SA Industry Affiliated Network (IAN)
Base specification contributed by MPAI community



IEEE Std 3305™-2024

IEEE Standard Adoption of Moving Picture, Audio and Data Coding by Artificial Intelligence (MPAI) Technical Specification MPAI Metaverse Model (MMM) Architecture—Version 1

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Collaborative Activities Governance Board
of the
IEEE SA Board of Governors

Approved 26 September 2024

IEEE SA Standards Board

Abstract: This standard adopts MPAl Technical Specification Version 1 as an IEEE Standard. The Technical Specification MPAl Metaverse Model (MMM) Architecture specifies terms and definitions, operation models, functional requirements of processes, etc.

Keywords: adoption, avatar, IEEE 3305™, metaverse, MPAl metaverse model, MPAl-MMM, use cases

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

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PDF: ISBN 979-8-8557-1456-2 STD27485
Print: ISBN 979-8-8557-1457-9 STDPD27485

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MPAI Technical Specification

MPAI Metaverse Model (MPAI-MMM) Architecture

V1

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Technical Specification

MPAI Metaverse Model (MPAI-MMM)

– Architecture V1

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1 Introduction (Informative)

Metaverse is a word conveying different meanings to different persons and to date some 150 definitions have been formulated. In this document the word metaverse is characterised as “a system that captures data from the real world (in the following, called Universe¹), processes it, and combines it with internally generated data to create virtual environments that users can interact with”. So far, the developers of many systems responding to this characterisation have made technology decisions that best responded to their needs, often without considering the choices that other developers might have made for similar purposes.

Recently, however, there have been mounting concerns that such metaverse “walled gardens” do not fully exploit the opportunities offered by current and expected technologies. Calls have been made to make metaverse instances (in the following, M-Instances) “Interoperable”.

MPAI – Moving Picture, Audio, and Data Coding by Artificial Intelligence – the international, unaffiliated, non-profit organisation developing standards for AI-based data coding – has provided initial contributions to M-Instance Interoperability with two Technical Reports:

1. **Technical Report: MPAI Metaverse Model (MPAI-MMM) – Functionalities** [1] has introduced the following elements:
 - 1.1. A set of definitions.
 - 1.2. A set of assumptions, the most important of which are that metaverse:
 - 1.2.1. Is a broad notion that may be used by different industries for different purposes.
 - 1.2.2. Needs technologies, some of which do not even exist with satisfactory performance.
 - 1.2.3. The notion of profile may help improve Interoperability.
 - 1.3. A collection of high-level use cases.
 - 1.4. A collection of exemplary service providers.
 - 1.5. An organised set of ~150 Functionalities.
 - 1.6. A review of the main metaverse-enabling technologies.
 - 1.7. An analysis of metaverse governance needs.
 - 1.8. The MPAI metaverse standardisation roadmap.
2. **Technical Report: MPAI Metaverse Model (MPAI-MMM) – Functionality Profiles** [12] has introduced the following elements:
 - 2.1. A revised and extended list of definitions.
 - 2.2. An operation model of the metaverse based on the notion of Processes performing or requesting other Processes to perform Actions on Items (Items are Data supported by an M-Instance).
 - 2.3. A specification of a first set of Actions, Items, and Data Types enabling:
 - 2.3.1. Detailed descriptions of Use Cases using Actions, Items, and Data Types.
 - 2.3.2. The definition of Functionality Profiles, i.e., subsets of Actions, Items, and Data Types that satisfy a selected subset of identified Functionalities.
 - 2.4. A collection of representative use cases tested against the Operation Model.
 - 2.5. Four initial Functionality Profiles.

Technical Specification – MPAI Metaverse Model (MPAI-MMM) – Architecture provides means to achieve M-Instance Interoperability by specifying the Functional Requirements of Processes, Actions, Items, and Data Types that allow Interoperation of two or more M-Instances implementing the Operation Model, executing Processes, and producing Data with Formats that

¹ Words beginning with a capital letter are defined in Chapter 3.

comply with the Functional Requirements of this Technical Specification, possibly via a Conversion Service.

Chapters, Sections, and Annexes are Normative unless they are explicitly identified as Informative.

2 Scope

Technical Specification: MPAI Metaverse Model (MPAI-MMM) – Architecture specifies:

1. Terms and Definitions
2. Operation Model
3. Functional Requirements of Processes, Actions, Items, and Data Types
4. Functional Profiles

enabling Interoperability of two or more metaverse instances (M-Instances) if they:

1. Rely on the Operation Model, and
2. Use the same Profile Architecture, and
 - 2.1. Either the same technologies, or
 - 2.2. Independent technologies while accessing Conversion Services that losslessly transform Data of an M-Instance_A to Data of an M-Instance_B.

Note: Full Interoperability may not be achieved if the M-Instances implement different Profiles.

The contents of this Technical Specification: MPAI Metaverse Model (MPAI-MMM) – Architecture is:

1.	Scope	Normative
2.	Terms and Definitions	Normative
3.	Metaverse Functionalities	Informative
4.	Metaverse Operation Model	Normative
5.	Functional Requirements of:	
5.1.	Processes, i.e., Programs executing in an M-Instance	Normative
5.2.	Actions, i.e., Functionalities provided by Processes	Normative
5.3.	Items, i.e., Data and Metadata supported by an M-Instance	Normative
5.4.	Data Types, i.e., Data used in Actions and Items	Normative
6.	Use Cases	Informative
7.	Functional Profiles	Normative

This Technical Specification has been developed by the MMM group of the Requirements Standing Committee. MPAI may decide to publish extensions or new versions of this Technical Specification, or other Technical Specifications of the MPAI-MMM series.

3 Terms and Definitions

Terms beginning with a capital letter have the meaning defined in Table 1. Terms beginning with a small letter have the meaning commonly defined for the context in which they are used. For instance, Table 1 defines *Object*, *Scene*, and *User* but does not define *object*, *scene*, and *human*.

A dash “-” preceding a Term in Table 1 means the following:

1. If the font is normal, the Term in the table without a dash and preceding the one with a dash should be placed before that Term. The notation is used to concentrate in one place all the Terms that are composed of, e.g., the word Decentralised followed by one of the words

Application, Autonomous Organisation, Finance, System, and User Identifier, or definitions belonging to the same class, e.g., Action and Items.

2. If the font is *italic*, the Term in the table without a dash and preceding the one with a dash should be placed after that Term. The notation is used to concentrate in one place all the Terms that are composed of, e.g., the word Interface preceded by one of the words Brain-Computer, Haptic, Speech, and Visual.

Table 1 – General Terms and Definitions

Terms	Definitions
Account	An Item that uniquely references a Registered human.
Action	A Functionality provided by a Process.
- Authenticate	The Action of requesting that a Service confirm that an Entity is what it claims to be.
- Author	The Action of Calling a Service to obtain an Entity with associated Out-Rights to Act on the Entity.
- Change	The Action of requesting that a Service modify the Rights of a User and provide OutRights, e.g., to further Change the Rights.
- Convert	The Action of requesting that a Service change the Format of the Data of an Item into a Format specified by a FormatID.
- Discover	The Action of requesting that a Service provide a DiscoveryOut Item containing: 1. The IDs of the Items relevant to the User's request to Discover expressed in the DiscoverIn Item 2. The OutRights to Act on the DiscoverOut Item.
- Execute	The Action of requesting that a Process execute a Contract.
- Hide	The Action of requesting that a Service make the ID of an Item unavailable and provide OutRights, e.g., to make the ID available again.
- Identify	The Action of requesting that a Service produce an Item from Data & Metadata.
- UM-Import	The Action of a User requesting that a Service read Data & Metadata stored at an Address.
- Inform	The Action of requesting that a Service provide an InformOut Item containing information about an InItem, such as the Metadata of the InItem, with the OutRights to Act on the InformOut Item.
- Interpret	The Action of requesting that a Service provide an InterpretOut Item containing interpretation of an InItem, such as translation or extraction of Personal Status, with the OutRights to Act on the InterpretOut Item.
- MM-Add	The Action of requesting that a Service add an Entity at an M-Location with a Spatial Attitude and provide OutRights to Act on the MM-Added Entity.
- MM-Animate	The Action of requesting that a Service change the features of a Model MM-Embedded at an M-Location with a Stream and provide the OutRights to Act on the MM-Added Entity.
- MM-Disable	The Action of requesting that a Service stop MM-Enabling selected Entities Embedded at an M-Location and provide OutRights to Act on the MM-Disabled Entities.
- MM-Embed	The Composite Action of requesting that a Service MM-Add and MM-Enable an Entity either located at a Service or at an M-Location at a

	destination M-Location with a Spatial Attitude and provide OutRights to Act on the MM-Embedded Entity.
- MM-Enable	The Action of requesting that a Service accept requests to MM-Send selected Entities MM-Added at an M-Location or to MM-Embed those selected Entities at a destination M-Location and provide OutRights to act on the M-Entities.
- MM-Send	The Action of requesting that a Process forward an Item or Data/Metadata to a Process with appropriate granting Rights.
- Modify	The Action of requesting that a Service produce a new Item from an existing Item by providing new Data and Metadata with the OutRights to further Act on the new Item.
- MU-Actuate	The Action of requesting that a Device present an Entity available at a Device to a U-Location as Media with a Spatial Attitude.
- MU-Render	The Composite Action of requesting that: 1. A Service MM-Send selected Entities Embedded at an M-Location to a Device. 2. The Device MU-Actuate at a U-Location with a Spatial Attitude the Entity received.
- MU-Send	The Action of requesting that a Process transmit an Item to a Device or store an Item at an Address.
- Post	The Action of requesting that a Marketplace include an Asset to its repository of Assets.
- Register	The Action of a human requesting that an M-Instance grant their Users the Rights to perform Actions in the M-Instance.
- Resolve	The Action of requesting that a Service forward a Request-Action or a Response-Action to a Resolution Service in another M-Instance.
- Track	The Composite Action of requesting that a Service: 1. MM-Embed a Model at an M-Location with a Spatial Attitude. 2. MU-Animate the Model MM-Embedded at an M-Location. 3. MU-Render specified Entities at the M-Location to a U-Location.
- Transact	The Action of a User ₁ requesting that a Service: 1. Assign Rights on an Asset to User₂ (“buyer”). 2. Cause: 2.1. Wallet₁ of User₁ (“seller”) to be increased by Value₁. 2.2. Wallet₂ of User₂ to be decreased by Value₂. Wallet ₃ of the Service enabling/facilitating the Transaction to be increased by Value ₃ (optionally).
- UM-Animate	The Composite Action of a User requesting: 1. A Device to 1.1. UM-Capture an animation stream extracted from a scene at a U-Location. 1.2. UM-Send the animation stream and Metadata to a User. 2. A Service to Identify the Animation Stream. 3. A Service to MM-Animate the Model MM-Embedded at the M-Location using the Animation Stream.
- UM-Capture	The Action of requesting that a Device capture Media from a scene at a U-Location.
- UM-Render	The Composite Action of a User requesting: 1. A Device to:

	1.1. UM-Capture a scene at U-Location. 1.2. MM-Send Data and Device-provided Metadata to a User. 2. A Service to: 2.1. Identify an Entity from UM-Sent Data and Metadata. 2.2. MM-Embed the Entity at an M-Location with a Spatial Attitude.
- UM-Send	The Action of a Device acquiring Data & Metadata from an Address.
- Validate	The Action of requesting that a Service verify that a Process has the Rights to perform or request a Process to perform an Action on an Item.
Avatar	A rendered User (synonym of Persona).
Blockchain	A shared immutable ledger stored on a peer-to-peer network of computers.
Certification	The attestation that a Process or Item has specified characteristics.
Connected Autonomous Vehicle	(CAV) A vehicle able to autonomously reach a U-Location by using its own sensing and processing capabilities to generate an M-Instance, sharing its M-Instance with other CAVs and issuing actuation commands.
Conversion	The process of changing the Format of Data.
Data	Information represented in digital form.
- Format	The syntax and semantics of Data.
DataMdata	The combination of Data and Metadata that is not (yet) an Item.
Data Type	Data used in Actions and Items.
- Address	The URL of a storage facility.
- Amount	A number expressing a Value in a Currency.
- Cognitive State	The representation of a User's Personal Status that reflects the way they understand the environment, such as "Confused", "Dubious", "Convinced".
- Coordinates	A set of numbers representing a Position in a Metaverse environment using a coordinate system.
- Currency	A medium of exchange enabling Transactions in a Metaverse environment.
- Emotion	The representation of a User's Personal Status that results from their interaction with an environment, such as "Angry", "Sad", "Determined".
- Orientation	The set of the 3 roll, pitch, yaw angles indicating the rotation around the principal axis (x) of an Object, its y axis having an angle of 90° counter-clockwise (right-to-left) with the x axis and its z axis (pointing up toward a viewer viewing from above).
- Personal Status	The representation of the information internal to a User characterising their behaviour.
- Point	A point in an M-Environment identified by the set of local Coordinates.
- Point of View	The Spatial Attitude of a Persona watching an Environment.
- Position	The Coordinates of a point in a Metaverse Environment using a Coordinate system.
- Social Attitude	The representation of a User's Personal Status related to the way it intends to position vis-à-vis an environment, e.g., "Respectful", "Confrontational", "Soothing".
- Spatial Attitude	The Position and Orientation of an Entity, and their velocities and accelerations.
- Time	The representation of the measure of time.
Decentralised	
- Application	(dApp) A Process that runs on a decentralised computing system.
- Autonomous Organisation	(DAO) An organisation without centralised leadership, where the main governing rules are typically encoded by means of a Smart Contract.

- Finance	(DeFi) A financial technology based on a secure infrastructure of distributed ledgers like those used by crypto currencies.
- System	A set of dApps enabling a group of Users to make decisions without a centralised entity.
Device	Equipment enabling: - A U-Environment to interact with an M-Instance and/or - An M-Instance to interact with a U-Environment.
Duty	A moral or legal obligation to act or behave.
Entitlement	The state of a User having certain Rights in an M-Instance.
Functional Re-requirement	A Functionality that is expected to be provided by an entity.
Human	
- <i>Digital</i>	Either a Digitised or a Virtual Human.
- <i>Digitised</i>	The digital representation of a human.
- <i>Virtual</i>	A computer-created Object that has a human appearance when rendered but is not a Digitised Human.
Governance	The action or manner of directing and controlling actors of the Metaverse Ecosystem.
Information and Communication Technologies	(ICT) Technologies that enable the processing and distribution of information via the network.
Interface	A communication pathway enabling systems to interact.
- <i>Brain-Computer</i>	(BCI) A communication pathway that allows a human to interact with an M-Instance by sensing and processing the electrical activity of the brain.
- <i>Haptic</i>	A communication pathway that allows a human to interact with an M-Instance through bodily movements and sensations.
- <i>Speech</i>	A communication pathway that allows a human to interact with an M-Instance using spoken language.
- <i>Visual</i>	A communication pathway that allows a human to interact with an M-Instance through bodily movements and visual messages.
Interoperability	The ability of an M-Instance to exchange and make use of the data of another M-Instance.
Item	Data and Metadata supported and identified by an M-Instance.
- Account	An Item that uniquely references a human who has Registered. A User may have more than one Account with one or more Services.
- Activity Data	An Item containing the record of all the Actions made by a User.
- Asset	An Item that may be the object of a Transaction. It may be MM-Embedded at an M-Location or Posted to a Service.
- AuthenticateIn	An Item containing: 1. The Entity or the ID of the Entity to be Authenticated. 2. Information related to the rendering of AuthenticateOut.
- AuthenticateOut	An Item containing the result of processing the Request-Authenticate Action and its rendering.
- Contract	A Program and its Metadata stored on a Device. It is activated by an external entity, e.g., a User, or another activated Contract.
- DiscoverIn	An Item containing: 1. A description of the Items to be Discovered. 2. Information related to the rendering of DiscoverOut.

- DiscoverOut	An Item containing the description of the Items Discovered and information related to its rendering.
- Entity	Any of the following Items that can be MU-Rendered: Object, Model, Scene, Event, and Experience.
- Event	An Entity that includes selected Entities at an M-Location and their Animations during a period.
- Experience	An Entity comprising User-selected Entities of an Event and the User Interactions with the Entities of the Event.
- Identifier	An Item that uniquely references an Item in an M-Instance.
- InformIn	An Item containing: 1. A description of the Item about which information is requested. 2. Information related to the rendering of InformOut.
- InformOut	An Item containing the description of the Item object of an InformIn.
- Interaction	An Item containing the Request-Action issued by a User on an Entity at an M-Locations and the corresponding Times.
- InterpretIn	An Item containing: 1. The ID or the Item to be Interpreted. 2. Information related to the rendering of InterpretOut.
- InterpretOut	An Item containing the description of the Item object of an InterpretIn Item.
- Ledger	An Item containing a list of Transactions involving Assets.
- Map	An Item containing a structure establishing a correspondence between U-Locations with M-Locations.
- M-Environment	An Identified subset of an M-Instance.
- Message	An Item containing application-specific Data MM-Sent by a Source Process to a Destination Process.
- M-Instance	An implementation of the Common Metaverse Specifications.
- M-Location	An Identified delimited space of an M-Environment.
- Model	An Object representing an object with its features ready to be MM-Animated or UM-Animated.
- Object	An Item with at least one of Audio, Visual, or Haptic perceptibility attributes.
- Obligation	An Item expressing the promise of a Process to perform Actions on Items at M-Locations during a Time.
- Persona	A Model representing a human.
- Personal Profile	An Item containing the Data about the human represented by a User.
- Program	Data that can be executed
- Provenance	The Ledger associated with a specific Asset.
- Request-Action	An Item of the request to a Process to perform an Action as defined in this document.
- Response-Action	An Item containing the response of a Process to a Request-Action as defined in this document.
- Rights	An Item expressing the Process's authorisation to perform Actions on Items at M-Locations during a Time.
- Rules	An Item expressing the terms and conditions under which a User operates in an M-Instance or M-Environment.
- Scene	A possibly hierarchical Composition of Objects having Spatial Attitudes.
- Social Graph	A representation of a User's network of connections with Items, M-Locations, and Processes.

- Stream	An Item made by a continuous flow of Data.
- Transaction	Item representing the changed state of the Accounts and the Rights of a seller User and a buyer User on an Asset and optionally of the Service facilitating/enabling the Transaction
- U-Location	An identifiable delimited portion of the Universe.
- Personal Data	An Item containing Activity Data, Personae, and Social Graph of a User.
- Value	An Amount and the Currency with which the Amount is expressed.
- Wallet	A container of Currency units. In general, a Wallet is implemented outside of the M-Instance.
Level	A subdivision of a Profile indicating the completeness of the user experience provided by the Profile.
Media	1. Data acquired by a Device using a Sensor. 2. Data converted by a Device from an Item to a format that can be presented.
Metadata	An attribute of Data, e.g., of a human, a Process, an M-Location, a U-Location, or an Item.
Metaverse Instance	(M-Instance) A set of Processes providing some or all the following functions: 1. To sense data from U-Locations. 2. To process the sensed data and produce Data. 3. To produce one or more M-Environments populated by Objects that can be either digitised or virtual, the latter with or without autonomy. 4. To process Objects from the M-Instance or potentially from other M-Instances to affect U- and/or M-Environments using Objects in ways that are: 4.1. Consistent with the goals set for the M-Instance. 4.2. Effected within the capabilities of the M-Instance. 4.3. Complying with the Rules set for the M-Instance and applicable laws.
- Actuator	A component of a Device able to MU-Render an Entity and environment Data to a U-Environment.
- Asset	An Item Embedded at an M-Location or Posted to a Service that may be the object of a Transaction.
- Ecosystem	The ensemble of entities and rules ensuring that Metaverse Instances operate in the interest of Metaverse Stakeholders.
- Enabling Service Layer	The set of Services such as payment, security, identity, privacy, etc. that enable operation of an M-Instance.
- Entity	Any of the following Items that can be MU-Rendered: Scene, Object, Model, Event, and Experience.
- Environment	(M-Environment) A portion of an M-Instance run by a Registration system.
- Experience Layer	The set of functions, such as Devices, that generate Experiences.
- Functionality	The attribute of a Process of being endowed with the capability of performing particular Action(s).
- Industry	The collection of players that support the design, development, deployment, operation, and content and service provisioning to Metaverse Instances.
- Instance	(M-Instance) An implementation providing all or a subset of the Metaverse Functionalities.

- Interoperability	The ability of M-Instance #1 to use data from and as intended by M-Instance #2. Interoperability can be Direct or Mediated by a Conversion Service.
- Infrastructure Layer	The set of functions such as network, transport, storage, and (cloud, edge) processing that enable an M-Instance to operate.
- Item	Metaverse-specific Data that may include Metadata that may include Rights.
- Level	A subdivision of a Profile that indicates the degree of completeness of the user experience provided by that Level.
- Location	(M-Location) An identifiable delimited portion of the Metaverse.
- Manager	The entity overseeing the operation of an M-Instance.
- Operation Model	The components and sequence of steps involved in an M-Instance provides Functionalities.
- Operator	The entity overseeing the operation of an M-Environment.
- Partner	A User participating in activities of a Metaverse Operator (i.e., a business customer of an Operator)
- Platform Layer	The set of Services, such as content creation, content discovery, and content access functions that enable an M-Instance to operate.
- Process	The instance of a program being executed.
- Profile	A recognised subset of the Functionalities (Functionality Profile) or Technologies (Technology Profile) specified by the Common Metaverse Specifications.
- Sensor	A Device able to UM-Capture a scene and other environment information as Data.
- Specification	The collection of standards specifying the Technologies and Technology Profiles enabling Metaverse Interoperability.
- Stakeholder	An entity performing a function aimed at achieving a goal in an M-Instance.
- State	The set of values and stored data of an M-Instance at a given time.
- Tool	A Technology or group of Technologies enabling an M-Instance to provide a Functionality.
- Technology	A structured application of scientific and/or technical methods that supports a Functionality.
- User	One or a set of Processes representing a human.
Object	
- <i>Audio</i>	The digital representation of an object or a computer-generated Object that can be rendered to and perceived by a human ear.
- <i>Autonomous</i>	A Virtual Object animated by a Process giving it the ability to act (e.g., move, speak, respond, execute) with a degree of autonomy.
- <i>Composite</i>	An Object that includes more than one Object Type.
- <i>Digital</i>	A Digitised or a Virtual Object.
- <i>Digitised</i>	The digital representation of an object.
- <i>Haptic</i>	An Object with the haptic features of an object able to be rendered to provide haptic sensations in a human.
- <i>Human</i>	An Object representing a human.
- <i>Speech</i>	The digital representation of a sound emitted by the vocal tract of a human or generated by a computer with similar audio characteristics.
- <i>Type</i>	One of Audio, Visual, Haptic, Olfaction, and Gustation.
- <i>Virtual</i>	A computer-generated Object that is not a Digitised Object.

- <i>Visual</i>	The digital representation of an object captured by an electromagnetic or high-frequency audio signal or computer-generated that can be rendered to and perceived by a human eye.
Oracle	A Service providing information from a U-Environment to a Blockchain.
Privacy	The Rights of a User to keep their Personal Profile secret.
Process	
- App	An application-specific Program executed on a Device.
- Capability	The characteristics of a Process.
- Device	A Process able to: 1. UM-Capture Data from a U-Location 2. UM-Send Data and Metadata to a User. and/or 1. MM-Send an Entity from an M-Location to the Device. 2. MU-Render an Entity at a U-Location.
- Service	A Process that can be called to provide specific Functionalities.
- User	A Process representing a human that is UM-Animated by a Stream or MM-Animated by an autonomous agent.
- App	An application-specific Program executed on a Device.
- User	A Process representing a UM-Captured human as a Persona that are either UM-Animated by a Stream or MM-Animated by an autonomous agent.
Profile	A set of base standards and/or their subsets.
- <i>Functional</i>	The set of Functionalities offered by a Metaverse Profile.
- <i>Technology</i>	The set of Technologies offered by a Metaverse Profile.
Registration	The provisioning by a human of a subset of Personal Data to an M-Instance/Environment to obtain an Account.
Render	The process of making an Item perceptible by human senses.
Representation	Data that represent an entity of a U-Environment in an M-Instance.
Sense of	
- Agency	The subjective awareness of being able to decide, execute, and control one's own actions in an M-Environment.
- Embodiment	The engagement of senses to form a complete M-Instance Experience.
- Presence	The feeling of being in an M-Instance with other Digital Humans for real.
Service	
- <i>Conversion</i>	A Service converting the Data produced by an M-Instance _A into Data understood and acted upon by M-Instance _B as intended by M-Instance _A .
Smart Contract	A Program stored on a Blockchain that runs when activated by an external entity, e.g., a User or another Smart Contract.
Token	
- <i>Fungible</i>	A representation of an Asset that is interchangeable with other Assets of the same type.
- <i>Non-Fungible</i>	(NFT) A unique digital identifier of an Asset that: - Cannot be copied (i.e., a copy is known to be a copy), substituted, or subdivided. - Is recorded in a digital ledger. - Is used to certify Object authenticity and ownership.
Trust-less system	A system allowing a User to make reliable Transactions without trusting or knowing the parties the User makes Transactions with.
Universe	The physical world.
- Location	(U-Location) An identifiable delimited portion of the Universe.

Use Case	An example of how an application domain can be supported by an M-Instance/Environment.
User Keys	The pair of public and private keys where the public key is used to encrypt, and the private key is used to both encrypt and decrypt Data.
User Identifier	
- <i>Decentralised</i>	An Identifier that enables the verifiable association with a User without requiring a centralised registry.
- <i>Self-Sovereign</i>	A Decentralised Identifier derived from the User's Public Key owned and managed directly by the User based on the knowledge of their own Private Key, e.g., stored in the Crypto Wallet enabled by the Blockchain underpinning the Metaverse Instance.
Wallet	
- <i>Crypto</i>	Software or hardware holding the Public and Private Keys of a User to enable them to make Transactions by accessing their Account on a Blockchain.

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5 Metaverse Functionalities

This Chapter collects the Functionalities of an M-Instance supported by this Technical Specification. Terms beginning with a small letter have the common meaning, Terms beginning with a capital letter are defined in Chapter 3.

5.1 M-Instance

An M-Instance

1. Is characterised as a set of Processes providing some or all the following functions:
2. Sensing data from U-Locations using Devices.
3. Processing the sensed data and producing Items.
4. Producing one or more M-Environments populated by Items either imported or internally generated.
5. Processing Objects from the M-Instance or potentially from other M-Instances to affect U-and/or M-Environments in ways that are:
 - 5.1. Consistent with the goals set for the M-Instance.
 - 5.2. Effected within the capabilities of the M-Instance.
 - 5.3. In compliance with the Rules set for the M-Instance and the applicable laws.
6. May operate in a centralised or decentralised way.
7. May be subdivided in administratively separated M-Environments.
8. Monitors:
 - 8.1. The Rights held by Processes on Processes to Act on Items at M-Locations.
 - 8.2. The Entities placed at M-Locations with a Spatial Attitude.
9. Should be secure, e.g., to prevent malicious Users from:
 - 9.1. Accessing the Account of a human who is not the human represented by the User.
 - 9.2. Taking control of a Process.
 - 9.3. Acting on Items for which it does not have Rights.
10. Should withstand denial of service attacks.

5.2 Processes

1. Process types
 - 1.1. Devices: they connect U-Locations with M-Locations and vice-versa.
 - 1.2. Users: they represent humans and are humans' agents in the M-Instance or on Devices.
 - 1.3. Apps: they run on Devices. A User may be an App running on a Device.
 - 1.4. Services: they are generic Processes providing Functionalities.
2. Certification
 - 2.1. Processes may be connected or imported to an M-Instance if they have passed Certification.
 - 2.2. Contracts may be imported to an M-Instance if they have passed a Certification Process.

5.3 Rules

An M-Instance may be governed by Rules that may include:

1. The Personal Data retention, processing, and access policy.
2. The Rights and Obligations, e.g., ethical behaviour of Users.
3. The permission-based or permission-less access policy to M-Environments.
4. The trusted or trust-less relationship between Users and M-Instance.
5. The subset of required for each Account type.
6. The sanctions applied to a User whose Actions do not comply with the Rules.

5.4 Registration

1. A human, possibly on behalf of a legal entity, may Register with an M-Instance.

2. The M-Instance may
 - 2.1. Request:
 - 2.1.1. A subset of the human's Personal Profile.
 - 2.1.2. WalletIDs
 - 2.1.3. Users
 - 2.1.4. Personae
 - 2.2. Create an Account with AccountID including:
 - 2.2.1. The subset of the human's Personal Profile.
 - 2.2.2. WalletIDs
 - 2.2.3. Users
 - 2.2.4. Personae
 - 2.2.5. Rights and Obligations
3. Personal Profile may have a scalable representation to enable an easy creation of a subset.

5.5 Rights

5.5.1 General Rights

Rights may include:

1. The maximum number of:
 - 1.1. Users a human can deploy.
 - 1.2. Personae a User can be rendered as.
 - 1.3. Concurrent Users and Objects an M-Location can support.
2. The ability to:
 - 2.1. Create persistent (as opposed to ephemeral) Scenes at M-Locations.
 - 2.2. Store, search, and retrieve Experiences.
 - 2.3. Develop economic activities.
 - 2.4. Book M-Locations for a duration.
 - 2.5. Support persistent storage.
 - 2.6. Connect with or import Processes to an M-Instance.
 - 2.7. Make Transactions to acquire Rights.

5.5.2 Perception Rights

A User may, depending on the Rights it holds:

1. Perceive scenes at U-Locations as captured by Devices endowed with audio, visual, haptic, and BCI capabilities, and the spatial attitudes of their objects.
2. Receive Messages from a U-Location as a result of an event there.
3. Import audio, speech, visual, and haptic models.
4. Perceive Entities.
5. Render perceived Entities at a U-Location with spatial attitudes.
6. Import Data and Metadata from and export Items to an Address.

5.5.3 Interaction Rights

A User may, depending on the Rights it holds:

1. Interrogate a Process about its Functionalities.
2. Interact with Entities.
3. Send public or private Speech, Visual, and Haptic Messages to Users.
4. Send selected Entities to a User.
5. Place Entities with Spatial Attitudes.
6. Animates Models.

5.5.4 Service access Rights

A User may, depending on the Rights it holds, perform or request a Process to perform:

1. Author an Item.
2. Authenticate an Item.
3. Change the Rights of a Process.
4. Discover Objects, Processes, Events, or Experiences.
5. Find the Transactions involving an Asset under specified conditions.
6. Obtain an interpretation of an Item, e.g.:

Request	From	To
Extract	Text	Personal Status
Extract	Speech	Text
Translate	Text or Speech	Text or Speech
Extract	Face and/or Gesture	Personal Status

7. Obtain Conversion of an Item from a Format to another Format.
8. Obtain information about a Process or an Item.
9. Obtain a recommendation of Processes or Items.
10. Record all the Actions made by a User (Activity Data) at an M-Location during a time.
11. Create a representation of a User's network of connections with Items, M-Locations, and Processes (Social Graph).
12. Posts an Item that can be Transacted (Asset) to a marketplace.
13. Retrieve Objects, Events, or Experiences.
14. Store Objects, Events, or Experiences.
15. Formulate:
 - 15.1. The information it intends to obtain from a Service.
 - 15.2. The Rights it intends to acquire on the response of the Service.
 - 15.3. How the response should be rendered.

5.5.5 Acquisition of Rights

A User may acquire, or have as part of its Account the Rights to:

1. Perform or request another User to perform Actions on Items.
2. Develop an economic activity in an M-Environment.
3. Make an Asset out of an Item.
4. Make a Transaction on an Asset specifying which Rights to the Asset it grants to the buyer.
5. Make an agreement with another user, e.g., via a Contract.
6. Copy or Modify, i.e., change Data (e.g., by editing it) and/or Metadata of an Item.
7. Change the settings and attributes of Entities of an M-Locations (e.g., SFX during a concert).
8. Set the Point of View from which it perceives a Scene.
9. Make inaccessible to any User an Item for which it has Rights.
10. Make or request a Process to make Actions in its own or another M-Instance.
11. Be rendered as one of the Personae uploaded at registration time.

5.6 Personae

A Persona may:

1. Faithfully reproduce the visual appearance of the human.
2. Have their visual appearance altered, compared to that of the human.
3. Have an unrelated visual appearance.
4. Display a presumptive Personal Status in speech, face, and gesture.

5. Be driven by
 - 5.1. The movements of the human.
 - 5.2. A Process.

5.7 Locations

1. An M-Location may be:
 - 1.1. Private, i.e., only a User or a group of Users have Rights to it.
 - 1.2. Public, i.e., a Metaverse Operator or a User grant anybody the Rights to enter, move in, and perceive the M-Location.
 - 1.3. Persistent
 - 1.4. Ephemeral.
2. A U-Location
 - 2.1. May require that a User hold Rights to Capture a scene, Render a Scene, or store Data at an Address.

5.8 Objects and Scenes

1. An Object may:
 - 1.1. Be Virtual, i.e., Authored in an M-Instance.
 - 1.2. Be Digitised, i.e., Digital Twins of objects.
 - 1.3. Be Autonomous, i.e., Animated by a Process.
 - 1.4. Have Audio, Visual, or Haptic attributes, or combinations of these attributes.
2. A Scene may be composed of:
 - 2.1. Only Virtual Objects.
 - 2.2. Only Digitised Objects.
 - 2.3. Partly Virtual and partly Digitised Object.

5.9 Identifiers

1. All Items have an Identifier.
2. An Identifier:
 - 2.1. Uniquely references an Item or a Process.
 - 2.2. May be issued by a central, distributed, or no authority.
 - 2.3. May have a Format accepted by more than one M-Instance.
 - 2.4. May enable to trace the Identifier of an Item back to the Item that spawned the Asset.
 - 2.5. May enable to trace the Identifier of a Modified Item back to the Item that spawned the Modified Item.

6 Metaverse Operation Model

A M-Instance operates according to the following Metaverse Operation Model.

1. An M-Instance is an Information and Communication Technology platform operating according to this Technical Specification and providing the following general functions:
 - 1.1. To sense data from U-Locations.
 - 1.2. To process the sensed data and produce Data.
 - 1.3. To produce one or more M-Environments populated by Objects that can be either digitised or virtual, the latter with or without autonomy.
 - 1.4. To process Objects from the M-Instance or potentially from other M-Instances.
 - 1.5. To affect U- and/or M-Environments using Objects in ways that are:
 - 1.5.1. Consistent with the goals set for the M-Instance.
 - 1.5.2. Within the Capabilities of the M-Instance.

- 1.5.3. According to the Rules of the M-Instance.
- 1.5.4. Respecting applicable laws and regulations.
2. An M-Instance
 - 2.1. May be subdivided in administratively separated M-Environments.
 - 2.2. May make its Capabilities known.
 - 2.3. May allow a human to Register with the M-Instance or one of its M-Environments.
 - 2.4. May request a Registering human to provide a subset of their Personal Profile.
 - 2.5. May give a Registered human the Rights to deploy one or more:
 - 2.5.1. Users and Devices each with M-Instance-specific Rights.
 - 2.5.2. Personae, i.e., human-like, or humanoid Models used by deployed Users to render themselves.
 - 2.6. May establish Rules that the Users in the M-Instance shall comply with.
 - 2.7. May penalise Users for lack of compliance with the Rules.
3. An M-Instance
 - 3.1. Is implemented as a set of Processes providing Functionalities defined by this Technical Specification.
 - 3.2. Creates Items by processing sensed data and autonomously produced data.
 - 3.3. Employs Data Types to represent entities such as Amount (of a Currency), length, area, and volume etc.
4. An M-Instance may support four types of Processes:
 - 4.1. User represents and is under the control of a human who has Registered with the M-Instance. A User may run on the M-Instance or on a Device connected to the M-Instance.
 - 4.2. Device is one or more Processes running on a physical device connecting M-Locations to U-Locations, specifically the Registered human, by:
 - 4.2.1. Capturing scenes as Media and providing Media as Data/Metadata (U-Location to M-Location). Data/Metadata shall be Identified as an Item to enable Processes to perform Actions.
 - 4.2.2. Receiving an Entity and rendering it as Media with a Spatial Attitude (Position and Orientation) – M-Location to a U-Location.
 - 4.3. Service provides specific functionalities.
 - 4.4. App runs on a Device. A Device may run the User Process as an App.

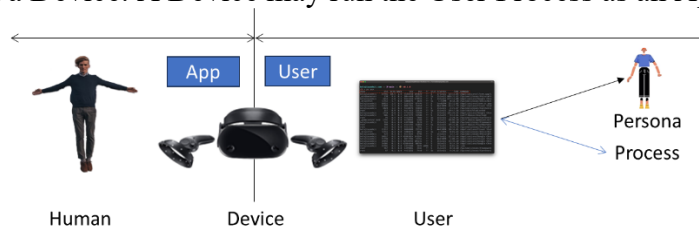


Figure 1 - The human-device-user-persona chain

5. A Process in an M-Instance:
 - 5.1. Is composed of:
 - 5.1.1. A Program having a Format supported by the M-Instance.
 - 5.1.2. Metadata describing the Program and containing the following as a minimum:

Table 2 – Minimum Metadata of a Process

Metadata elements	Details
ProcessID	The ID of the Process.
InRightsID	The ID of the User's Rights to Act granted to the Process.
OutRightsID	The ID of the Rights a User may acquire on the Process.