



IEEE Standard Adoption of Moving Picture, Audio and Data Coding by Artificial Intelligence (MPAI) Technical Specification Connected Autonomous Vehicle-Architecture (MPAI-CAV) V1

Developed by the
Collaborative Activities Governance Board

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



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IEEE Standard Adoption of Moving Picture, Audio and Data Coding by Artificial Intelligence (MPAI) Technical Specification Connected Autonomous Vehicle-Architecture (MPAI-CAV) V1

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IEEE SA Standards Board

Abstract: This is an adoption of the Moving Picture, Audio and Data Coding by Artificial Intelligence (MPAI)—Technical Specification Connected Autonomous Vehicle-Architecture as a standard. This Technical Specification specifies the architecture of connected autonomous vehicle (CAV) based on a reference model. The CAV is broken down into subsystems for each of which are as follows: functions, input/output data, and topology of components.

Keywords: adoption, AI framework, Artificial Intelligence, CAV, connected autonomous vehicle-architecture, IEEE 3307™

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

MPAI Technical Specification

Connected Autonomous Vehicle - Architecture MPAI-CAV

V1

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Readers are invited to review Annex 3 - Notices and Disclaimers.

Technical Specification

Connected Autonomous Vehicle (MPAI-CAV)

- Architecture V1

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1 Introduction (Informative)

Since the first Motorwagen saw the light in 1886, many inventions have given automobiles the ability to be more responsive to human needs and to facilitate their use. A short list includes electric ignition starter, car radio, car key, power steering, cruise control, electric windows, intermittent windshield wipers, anti-lock braking system (ABS), digital dashboard displays, electromagnetic parking sensors, on-board diagnostics, mobile connection, satellite navigation, reversing camera, automatic parking, driver assistance features, etc.

Starting from the first 1939 experiments, many efforts have given automobiles some “self-driving” capabilities. Recently, the Society of Automotive Engineers (SAE) in the USA has developed a Level-based classification of cars that have “self-driving” capabilities [14]. Today, self-driving cars are not only technically possible, but several implementations also exist. They promise to bring benefits that will positively affect industry, society, and the environment, such as:

1. Replacing human error with a machine less prone to errors.
2. Giving humans more time for rewarding activities, such as interpersonal communication.
3. Optimising the use of vehicles and infrastructure.
4. Reducing congestion and pollution.
5. Supporting elderly and disabled people.

Therefore, the transformation of what can be called today’s “niche market” into tomorrow’s vibrant mass market is a goal of high industrial importance with positive impacts on society and individuals. The goal could be achieved by relying on market forces and waiting for users to demand cars with progressively higher SAE Levels. Moving Picture, Audio, and Data Coding by Artificial Intelligence (MPAI), the international unaffiliated, non-profit organisation developing AI-enabled data coding standards, believes that a component-based standardisation process is more effective.

The approach should be implemented in three standardisation steps:

1. A Reference Model specifying functions and interfaces of subsystems and components.
2. Functional Requirements of Data Types exchanged between components.
3. Technologies supporting the processing of Data Types.

This approach offers various advantages:

1. Research can:
 - 1.1. Concentrate on different individual components.
 - 1.2. Optimise components while keeping unchanged the Functional Requirements of interfaces.
2. Industry can promote the definition of Data Formats when:

- 2.1. Research results are mature.
- 2.2. A component is needed.
3. Component manufacturers can:
 - 3.1. Develop optimised component solutions based on publicly available specifications.
 - 3.2. Bring their standard-confirming components to market.
4. Car manufacturers can:
 - 4.1. Access an open global market of components.
 - 4.2. Benefit from components with standard functions and interfaces.
 - 4.3. Test components for conformance using standard procedures.
5. Regulators can use tools to oversee the development of the market.
6. Users can rely on CAVs whose operation they can explain.

In this Introduction and in the following Chapters, the following conventions apply:

1. Terms beginning with a capital letter are defined in Table 1 if they are specific to this Technical Specification and in Table 17 if they are shared with other MPAI Technical Specifications.
2. Words beginning with a capital letter that have an equivalent word beginning with a small letter represent the “digital twin” of that word.
3. Chapters and the Annexes are Normative unless they are labelled as Informative.

2 Scope

Technical Specification: Connected Autonomous Vehicle (MPAI-CAV) – Architecture (in the following also called MPAI-CAV – Architecture) specifies the Architecture of a Connected Autonomous Vehicle (CAV) based on a Reference Model comprising:

1. A CAV broken down into Subsystems for each of which the following is specified:
 - 1.1. Functions
 - 1.2. Input/output Data
 - 1.3. Topology of Components
2. Each Subsystem broken down into Components of which the following is specified:
 - 2.1. Functions
 - 2.2. Input/output Data.

Each Subsystem is assumed to be implemented as an AI Workflow (AIW) made of Components implemented as AI Modules (AIM) executed in an AI Framework (AIF) as specified by the AI Framework (MPAI-AIF) Technical Specification [4]. In the following, Systems will be Annex 1 - Chapter 2 provides a high-level introduction to MPAI-AIF.

The structure of MPAI-CAV – Architecture is the following:

- Chapter 3 collects Normative definitions applicable to this Technical Specification.
- Chapter 4 collects Normative and some Informative references.
- Chapter 5 Normatively specifies the Subsystem-level Architecture.
- Chapters 0-7-0-9 Normatively specify the individual Subsystem Architectures.
- Chapter 10 includes Informative elements of the so-called Communication Device enabling CAV Subsystems to communicate with their peers in other CAVs.

Users of this Technical Specification should note that:

1. The input/output Data of Subsystems and Components have known semantics to maximise CAV Explainability.
2. No support of specified CAV Subsystems and Components is mandated.

3. Only the software Interfaces with the mechanical components of a CAV are specified, but not the mechanical components activated by the Interfaces.
4. An implementation may merge a set of Components into one provided the external interfaces are preserved. Merged Components, however, may have reduced Explainability.
5. No assumption is made on the location carrying out the processing required by the CAV.
6. Processing, collection, and storage of information should be performed according to the laws applicable to the location.

This Technical Report has been developed by the Connected Autonomous Vehicle group of the Requirements Standing Committee. MPAI plans on specifying the Functional Requirements of the Formats of the I/O Data to/from Subsystems (AIW) and AIMs and other aspects in future Technical Specifications.

3 Terms and definitions

Table 1 and Table 17 define the CAV-specific Terms and the general MPAI Terms, respectively.

Table 1 - Terms and Definitions

Note A dash “-” preceding a Term in this Table 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 Audio followed by one of the words Object, Scene, and Scene Descriptors.
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 Attitude preceded by one of the words Social or Spatial.

Term	Definition
Accelerometer Data	A Data Type representing the acceleration forces acting on a CAV.
Alert	A Data Type representing environment-related elements that should be treated with <u>priority</u> by the Obstacle Avoider AIM.
AMS-MAS Command	A Data Type representing the command issued by the Autonomous Motion Subsystem instructing the Motion Actuation Subsystem to change the Ego CAV's Spatial Attitude SA_A at time t_A to Spatial Attitude SA_B at time t_B .
AMS-HCI Response	A Data Type representing the response of the Motion Actuation Subsystem during and after the execution of an HCI-AMS Command.
Attitude	
- <i>Social</i>	A Data Type representing an element of the internal status of a human or avatar related to the way they intend to position themselves vis-à-vis the context, e.g., “Confrontational”, “Respectful”.
- <i>Spatial</i>	A Data Type representing the CAV's Position, Orientations and their velocities and accelerations at a given time.
Audio	A Data Type representing analogue signals generated by information perceptible by a human using the sense of sound.
- Data	A Data Type representing the output of a microphone array capturing the target environment to create the Audio Scene Description used to

	incorporate Environment Audio information in the Basic and Full Environment Representation.
- Object	A Data Type representing an audio object and associated metadata.
- Scene	A Data Type representing an audio scene.
- Scene Descriptors	A Data Type representing the Audio Data and produced by the Audio Scene Description AIM using previous Basic Environment Representations.
Audio-Visual	A Data Type representing analogue signals generated by information perceptible by a human using the sense of sound and sight.
- Object	A Data Type representing Audio-Visual information and associated metadata.
- Scene	(AV Scene) A Data Type representing an audio-visual scene.
- Scene Descriptors	A Data Type representing the outdoor and indoor Audio-Visual Scene in terms of Audio-Visual Objects that includes the following features: 1. Having a common time-base. 2. Associating co-located audio and visual objects if both are present. 3. Supporting the physical displacement and interrelation (e.g., occlusion) of Audio and Visual Objects over time.
Avatar	A Data Type representing a real or fictitious person in a virtual space rendered to a physical space.
- Model	A Data Type representing the model of a human that a User selects to impersonate the CAV's HCI as rendered by the Personal Status Display AIM.
Basic Environment Representation (BER)	A Data Type representing Environment using information provided by a variety of sensors and including: 1. The Audio-Visual Scene Geometry. 2. The Ego CAV's Spatial Attitude. 3. The Scene Description produced from the available Environment Sensing Technologies. 4. The Road Topology. 5. Other Environment Data.
Body Descriptors	A Data Type representing the motion and conveying information on the Personal Status of the body of a human or an avatar.
Brake	
- Command	A Data Type representing the command issued to the Brakes by the Motion Actuation Subsystem after interpreting an AMS-MAS Command.
- Response	A Data Type representing the Brakes' response to the AMS Command Interpreter in response to a Brake Command.
CAV	See Connected Autonomous Vehicle.
- Aware	An attribute of physical entities possessing some of the sensing and communication capabilities of a CAV without being a CAV, e.g., Roadside Units and Traffic Lights.
- Centre	The point in the Ego CAV selected to have coordinates (0,0,0).
- Ego	The Object in the Environment that the CAV recognises as itself.
- Identifier	A Data Type uniquely identifying a CAV and carrying information, such as: 1. Country code where the CAV has been registered. 2. Registration number in that country. 3. CAV manufacturer identifier.

	4. CAV model identifier.
Cognitive State	A Data Type representing the internal status of a human or avatar reflecting their understanding of the context, such as “Confused” or “Dubious” or “Convinced”.
Connected Autonomous Vehicle	(CAV) The information technology-related components of a vehicle enabling it to autonomously reach a Pose by: 1. Understanding human utterances in the Subsystem (HCI). 2. Planning a Route (AMS). 3. Sensing and building a Representations of the external Environment (ESS). 4. Exchanging such Representations and other Data with other CAVs and CAV-aware entities (AMS). 5. Making decisions about how to execute the Route (AMS). 6. Acting on the MAS (AMS).
Data	Information in digital form.
- Format	The standard digital representation of Data.
- Semantics	The meaning of Data.
- Shape	A Data Type representing the volume occupied by a CAV.
- Type	An instance of Data with a specific Data Format.
Decision Horizon	The time interval within which a decision is planned to be implemented.
Descriptor	Coded representation of a text, audio, speech, or visual feature.
Digital Representation	Data corresponding to and representing a physical entity.
Emotion	A Data Type representing the internal status of a human or avatar resulting from their interaction with the context or subsets of it, such as “Angry”, and “Sad”.
Environment	The Digital Representation of the portion of the external world of current interest to a CAV.
- Representation	A Data Type representing the Environment such as produced by an Environment Sensing Technology or derived from the Basic or Full Environment Representation.
- Sensing Technology	(EST) One of the technologies used to sense the environment by the Environment Sensing Subsystem, e.g., RADAR, Lidar, Visual, Ultrasound, and Audio. The Offline Map is considered as an EST.
Face	The portion of a 2D or 3D Digital Representation corresponding to the face of a human.
- Descriptors	A Data Type representing the motion and conveying information on the Personal Status of the face of a human or an avatar.
- ID	The Identifier of a human belonging to a group of humans inferred from analysing the face of the human.
Factor	One of Cognitive State, Emotion, and Social Attitude
Full Environment Representation	(FER) A Data Type representing the Environment that extends the Basic Environment Representations of the Ego CAV with elements of those of other CAVs in range or Roadside Units.
- Audio	The ready-to-render Audio component of the Full Environment Representation Viewer.
- Commands	A Data Type representing the commands issued by a CAV passenger to the HCI to enable navigation in the Full Environment Representation, e.g., select a Point of View, zoom in/out, control sound level.