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SERIES F: NON-TELEPHONE TELECOMMUNICATION SERVICES

Multimedia services

Use cases and requirements for multimedia communication enabled vehicle systems using artificial intelligence

Recommendation ITU-T F.749.4

ITU-T

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Recommendation ITU-T F.749.4

Use cases and requirements for multimedia communication enabled vehicle systems using artificial intelligence

Summary

Recommendation ITU-T F.749.4 describes use cases and scenarios, high-layer architecture, service and network requirements, functional requirements and non-functional requirements for multimedia communication enabled vehicle systems using artificial intelligence.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T F.749.4	2021-06-13	16	11.1002/1000/14683

Keywords

ADAS, artificial intelligence, autonomous vehicles, ITS, requirements, use cases.

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Use cases and requirements for multimedia communication enabled vehicle systems using artificial intelligence

1 Scope

This Recommendation specifies use cases and requirements for multimedia communication enabled vehicle systems using artificial intelligence, including overview, use cases, high-layer architecture, service and network requirements, functional requirements, and non-functional requirements.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T X.805] Recommendation ITU-T X.805 (2003), *Security architecture for systems providing end-to-end communications*.

[ITU-T X.1111] Recommendation ITU-T X.1111 (2007), *Framework of security technologies for home network*.

[ITU-T X.1371] Recommendation ITU-T X.1371 (2020), *Security threats to connected vehicles*.

[ITU-T X.1372] Recommendation ITU-T X.1372 (2020), *Security guidelines for vehicle-to-everything (V2X) communication*.

[ITU-T X.1373] Recommendation ITU-T X.1373 (2017), *Secure software update capability for intelligent transportation system communication devices*.

[ITU-T X.1811] Recommendation ITU-T X.1811 (2021), *Security guidelines for applying quantum-safe algorithms in IMT-2020 systems*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 application [b-ITU-T Y.2091]: A structured set of capabilities, which provide value-added functionality supported by one or more services, which may be supported by an API interface.

3.1.2 service [b-ITU-T Y.2091]: A set of functions and facilities offered to a user by a provider.

3.1.3 intelligent transport systems (ITS) [b-ITU-R handbook]: ITS can be defined as systems utilizing the combination of computers, communications, positioning and automation technologies to improve the safety, management and efficiency of terrestrial transport systems.

3.1.4 artificial intelligence (AI) [b-ISO/IEC 2382]: An interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning.

3.1.5 deep learning [b-ISO/IEC TR 29119-11]: Approach to creating rich hierarchical representations through the training of neural networks with one or more hidden layers.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 advanced driver-assistance systems (ADAS): ADAS are systems to help the driver in the driving process. When designed with a safe human-machine interface, they should increase car safety and more generally road safety.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ADAS	Advanced Driving Assistance System
AI	Artificial Intelligence
C-V2X	Cellular-V2X
HUD	Head Up Display
Lidar	Light detection and ranging
RSU	Roadside Unit
WWAN	Wireless Wide Area Network

5 Conventions

In this Recommendation:

– The keywords "shall" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

– The keywords "should" indicate an optional requirement which is permissible. This term is not intended to imply that the vendor's implementation must provide the option, and the feature can be optionally enabled by the vendor. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Overview

Artificial intelligence technology can be applied to many scenarios of multimedia communication enabled vehicle systems, such as lane keep assistance, lane departure warning system, traffic sign recognition, driver drowsiness detection, blind zone detection, obstacle detection, route planning, etc.

Figure 1 shows scenarios of multimedia communication enabled vehicle systems using artificial intelligence.

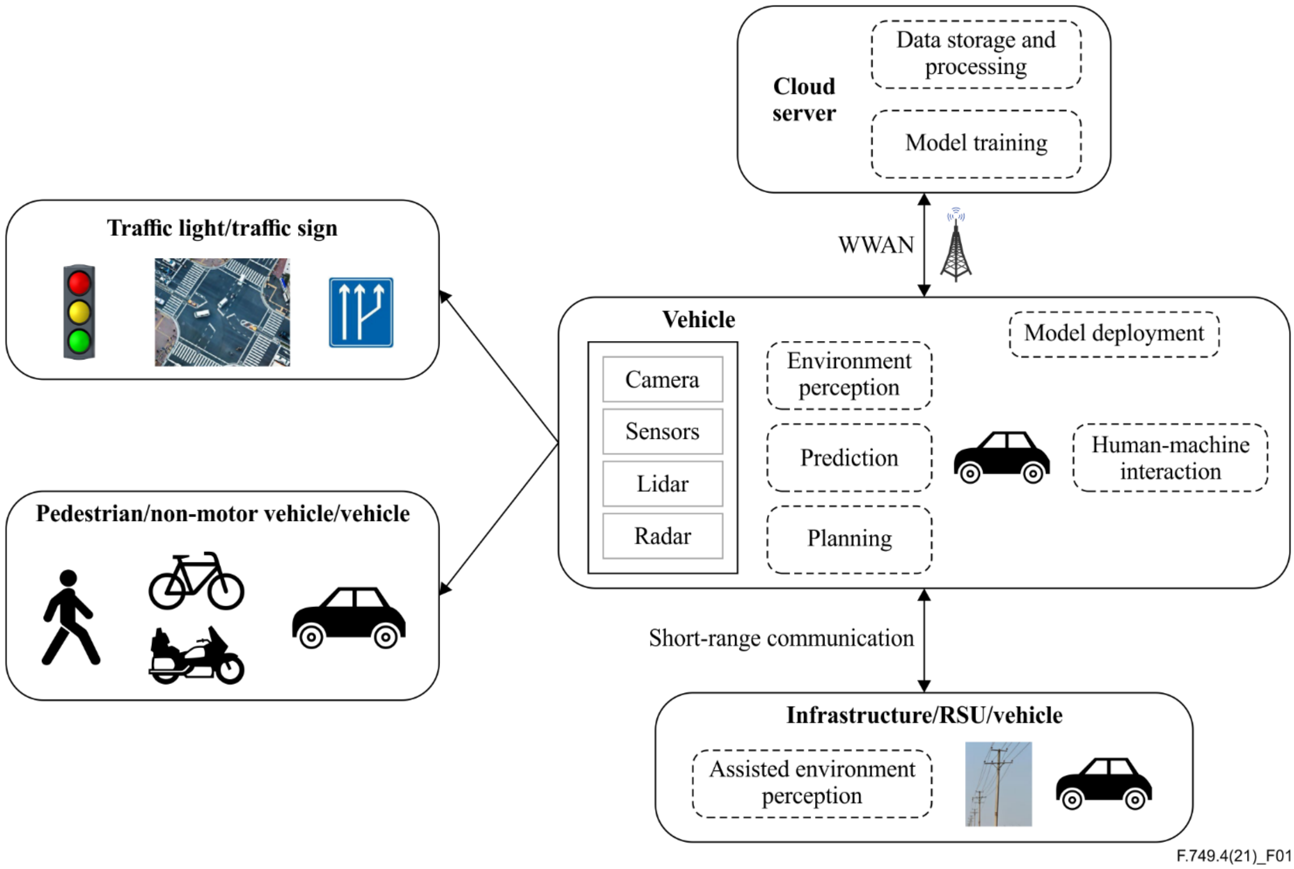

Figure 1 – Scenarios of multimedia communication enabled vehicle systems using artificial intelligence

There are five major scenarios. Environment perception scenario, prediction scenario, planning scenario and human-machine interaction scenario describe the application scenarios inside/outside the vehicle. Model training/deployment scenario describes the common functional scenario which can be used in all other scenarios.

6.1 Environment perception scenario

The environment perception scenarios mainly include the scenarios that use cameras, radars/light detection and ranging (Lidar) and sensors in vehicles for obtaining data from the vehicle driving environment, and then use machine learning models for data analysis. The data should include lane information, traffic sign information, traffic light information, pedestrian information, bicycle information, other vehicles information, location information, etc. Environment perception scenarios should also include the scenarios that use V2X communication technology to exchange assisted environment perception information (such as the speed/location of bicycle/other vehicles, blind zone information, etc.) and use machine learning models to analyse the data for driving environment perception.

6.2 Prediction scenario

The prediction scenarios mainly include the scenarios that use machine learning models to predict the action of moving objects to calculate the route of the objects. The prediction function shall achieve high accuracy and low latency for safety. Prediction should also support the function of continuous acquisition of new knowledge based on driving data to improve prediction accuracy using a machine learning model.

6.3 Planning scenario

The planning scenarios mainly include the scenarios that plan the proper trajectory of the surrounding vehicle in various scenes (such as turning, obstacle avoidance, overtaking, etc.) according to the results of environment perception and surrounding objects moving trajectory prediction using a machine learning model.

6.4 Human-machine interaction scenario

The human-machine interaction scenarios mainly include the scenarios that achieve intelligent cockpit (such as intelligent central screen, head up display (HUD), rear mirror and telematics unit, etc.) and analyse image, video, speech and text information for gesture recognition, voice recognition/nature language processing, face recognition, driver monitoring, etc. using a machine learning model.

6.5 Model training/deployment scenario

The artificial intelligence model training/deployment scenarios mainly include the scenarios that continuously train and optimize the models in the cloud servers using machine learning algorithms based on the data that is collected from vehicles and roadside units (RSUs). Once tested, the models should be deployed to the vehicles from cloud servers to continuously improve the advanced driving assistance system (ADAS)/autonomous driving capability.

7 High-layer architecture

Figure 2 presents the high-layer architecture for multimedia communication enabled vehicle systems using artificial intelligence according to the use cases.

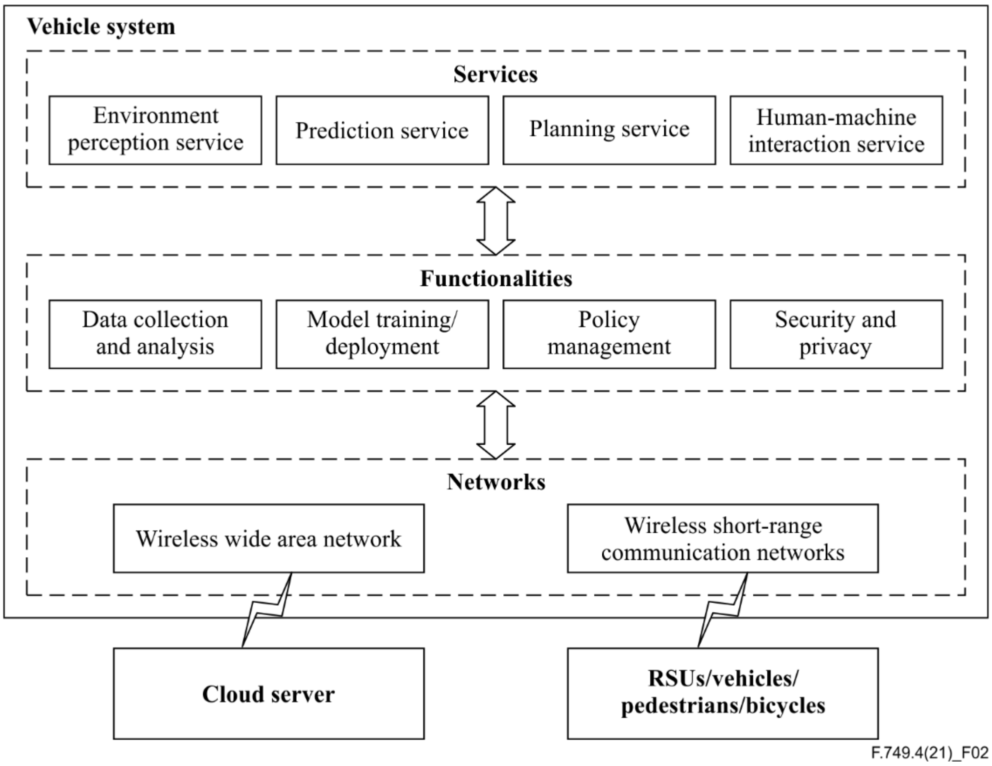

Figure 2 – High-layer architecture for multimedia communication enabled vehicle systems using artificial intelligence

The high-layer architecture for multimedia communication enabled vehicle systems using artificial intelligence covers three layers: services, functionalities and networks. A general description of these three blocks is presented below.

– **Services**: Services are the software that implement the artificial intelligence-related automotive multimedia communication applications. Services include the environment perception service, the prediction service, the planning service, and the human-machine interaction service.
– **Functionalities**: Functionalities are the basic functional modules for supporting services and applications. Functionalities include data collection and analysis, model training/deployment, policy management, and security and privacy.
– **Networks**: Networks are the communication networks for data exchange between vehicle system and cloud server/RSUs/vehicles/pedestrians/bicycles. Networks include wireless wide area networks and wireless short-range communication networks.

8 Requirements

8.1 Services and network requirements

8.1.1 Environment perception service requirements

The artificial intelligence requirements for the environment perception service are as follows:

– The vehicle system shall support one or more environment perception methods (e.g., camera, lidar, radar, etc.) to capture the driving environment data.
– The vehicle system shall support machine learning algorithms/models to process driving environment data.
– The vehicle system shall support object recognition, object detection and semantic segmentation of the driving environment using machine learning algorithms/models in different weather conditions.
– The vehicle system shall support recognition, detection and semantic segmentation of the driving environment objects using machine learning algorithms/models with low latency and high accuracy.
– The vehicle system should upload driving environment data to the cloud server.
– The vehicle system shall obtain driving environment information from other vehicles, RSUs and pedestrians/bicycles through wireless short-range communication networks.
– The vehicle system shall support high precision positioning according to the high-definition map.

8.1.2 Prediction service requirements

The artificial intelligence requirements for prediction service are as follows:

– The vehicle system shall support the prediction of the trajectory using multiple environment data that are captured through camera, lidar, radar, etc.
– The vehicle system shall support the prediction of the trajectory of pedestrians, other vehicles and obstacles using machine learning algorithms/models with low latency and high accuracy.
– The vehicle system shall obtain motion information from other vehicles, RSUs and pedestrians/bicycles through wireless short-range communication networks.

8.1.3 Planning service requirements

The artificial intelligence requirements for the planning service are as follows:

– The vehicle system shall support the planning of a moving path and moving speed using machine learning algorithms/models with low latency and high accuracy.
– The vehicle system shall support safety/smoothness/comfort of moving path/speed planning.

8.1.4 Human-machine interaction service requirements

The artificial intelligence requirements for human-machine interaction service are as follows:

– The vehicle system shall support speech recognition according to the voice of the driver/passengers.
– The vehicle system should support voiceprint recognition according to the voice of the driver/passengers.
– The vehicle system shall support natural language understanding based on the speech recognition.
– The vehicle system should support computer vision applications (e.g., face recognition, eyeball tracking, gesture recognition, etc.) using machine learning algorithms/models.
– The vehicle system should support speech recognition, voiceprint recognition, natural language understanding and computer vision applications through a cloud server.

8.1.5 Network requirements

The artificial intelligence requirements for the network are as follows:

– The vehicle system should support wireless wide area networks (WWANs) with high bandwidth and low latency (e.g., IMT-2020).
– The vehicle system should support wireless short-range communication networks (e.g., IEEE 802.11p or cellular-V2X (C-V2X)).

8.2 Functional requirements

8.2.1 Data collection and analysis requirements

The requirements for data collection and analysis are as follows:

– The vehicle system shall gather environment perception data, vehicle running data and human-machine interaction data.
– The vehicle system should provide data analysis functionality in order to produce intermediate information for further analysis.
– The vehicle system shall transmit necessary data to the cloud server through WWAN.

8.2.2 Model training/deployment service requirements

The artificial intelligence requirements for the model training/deployment service are as follows:

– The vehicle system should support multiple machine learning algorithms/models and deep learning frameworks.
– The vehicle system should support local artificial intelligence (AI) model training based on cooperation with other vehicles or RSUs.
– The vehicle system shall deploy/update the AI models from the cloud server through WWAN.

8.2.3 Policy management

Policies shall be used to constrain the operation of the vehicle. The policies may be either a set of commands or recommendations, such as traffic laws or moral rules.

The requirements for policy management are as follows:

- The vehicle system shall be constrained by predefined policies when a decision is being made.
- The vehicle system shall use policies that are triggered by one or more events.
- When an event indicates that a policy violation is detected, the vehicle system shall perform appropriate actions.
- The vehicle system shall perform policy conflict resolution.
- The vehicle system shall update the latest policies timely.

8.2.4 Security and privacy requirements

This clause lists the requirements related to security and privacy issues. For more details, see [ITU-T X.1371], [ITU-T X.1372], [ITU-T X.1373], [ITU-T X.805], [ITU-T X.1111] and [ITU-T X.1811]. The requirements for security and privacy are as follows:

- The vehicle system and the cloud server shall provide secure data storage.
- The vehicle system and the cloud server shall provide secure data transmission through WWAN.
- The vehicle system shall provide secure data transmission between vehicles and RSUs.
- The vehicle system and the cloud server shall provide secure models deployment.
- The vehicle system and the cloud server shall provide privacy protection for the personal data.

8.3 Non-functional requirements

8.3.1 Performance requirements

The performance requirements are as follows:

- The vehicle system shall identify traffic signs, obstacles and status of surrounding vehicles/pedestrians/bicycles, etc. quickly and accurately under various natural conditions, and give alarms or perform safe and compliant actions.
- The vehicles system shall identify surrounding vehicles, pedestrians, bicycles, etc. quickly and accurately under various natural conditions, give alarms or plan appropriate paths, and pass various types of traffic intersections safely and compliantly.

8.3.2 Regulatory requirements

The regulatory requirements are as follows:

- The privacy of the users shall be properly protected during the collection, storage and analysis of the data in the vehicle's systems and the cloud server.
- It shall be possible to analyse the vehicle data without exposing its users.
- The vehicle system and the cloud server shall comply with the data protection regulations.

Appendix I

Use cases of multimedia communication enabled vehicle systems using artificial intelligence

(This appendix does not form an integral part of this Recommendation.)

I.1 Use cases

I.1.1 Environment perception use cases

I.1.1.1 Overview

The environment perception mainly includes visual perception related scenarios. First, cameras, driving recorders and vehicle sensors are used to collect information from the surrounding environment. Then, the machine learning model is used to process the collected information. Finally, the vehicle's driving trajectory is determined to ensure the vehicle safety and efficient arrival at the destination. The specific environment perception scenario is shown in Figure I.1.

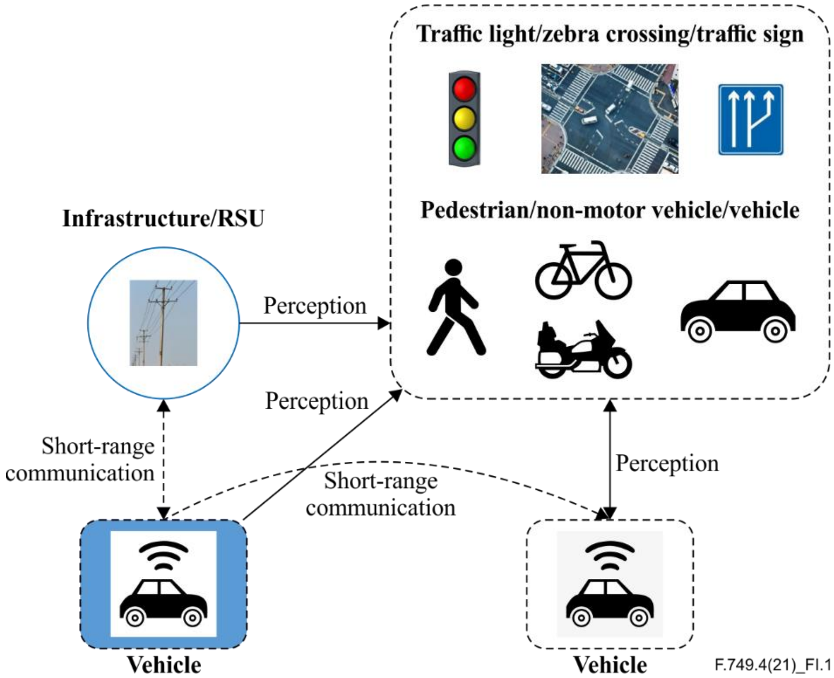

Figure I.1 – Scenario of environment perception

I.1.1.2 Automatic identification of traffic environment scenario

The vehicles mainly identify driving behaviours in traffic environment scenarios using computer vision technology. The main function of visual perception is that the vehicles use cameras, lidar/radars, driving recorders and other equipment to capture the surrounding environment of the vehicle from different angles. It identifies traffic conditions (such as lane conditions and traffic signs) according to the obtained images or video information and makes correct surrounding environment detection using a machine learning model (such as lane detection, identification of traffic signs and markings, identification of traffic lights, identification of driving status of vehicles ahead, obstacle identification, pedestrian and non-motorized vehicle identification, etc.). In the intelligent driving mode, the vehicles can recognize the surrounding environment according to the image/video stream that is captured by the cameras/lidar/radars in the vehicle, so that the vehicle can achieve lane keeping, car following, pull over, overtaking, merging, intersection passing, roundabout intersection passing, automatic emergency braking and other operations.

I.1.1.3 Obstacle detection and classification scenario

In the obstacle recognition and classification scenarios, there are mainly static obstacle and dynamic obstacle recognition/classification. Static obstacles include walls, trees, utility poles and buildings, etc., and the dynamic obstacles include pedestrians, non-motor vehicles, automobiles, etc. In this scenario, the vehicle needs to identify/classify the location of the obstacles. For example, the vehicle can determine the path and speed of its move based on the type of object being sensed: if the vehicle senses that there is a bicycle ahead, the vehicle can slow down or change lanes to safely drive past the bicycle. If the vehicle detects that there is another vehicle ahead (target vehicle), and predicts that the target vehicle in front will also travel at a speed close to the speed limit, then the vehicle can maintain its speed, distance and lane. In the traffic signal detection and classification scenario, the vehicle can locate the traffic lights in the captured images, and then classify the traffic lights according to the colour of the light display. This is based on computer vision technologies, and uses deep learning algorithms (such as convolutional neural networks and its variant algorithms) to detect/classify traffic lights or other obstacles.

I.1.1.4 Assisted environment perception scenario

This scenario includes vehicle-to-vehicle communication and vehicle-to-RSU communication scenarios. The vehicles and RSUs can transmit real-time information such as vehicle speed, position, braking information, driving direction and surrounding traffic conditions (such as blind spot detection information that is detected using machine learning technology) to nearby vehicles through wireless short-range communication networks (i.e., IEEE 802.11p, Cellular-V2X (C-V2X)) to prevent accidents (such as the early warning of intersection collision avoidance, the early warning of vehicles in front of vehicles, the early warning of road blind spots, motor vehicles, non-motor vehicles and pedestrian warnings, traffic light warnings, etc.).

I.1.1.5 High-definition map generation scenario

The vehicles collect point cloud data, road images and location information using cameras, lidar and other sensors. After overlaying the point cloud data, road images and location information, it can recognize and identify the road lines, curb, traffic signs and traffic lights, etc. using machine learning models. It can improve the efficiency and accuracy of high-definition map generation.

I.1.2 Prediction use cases

The prediction scenarios include the motion prediction of the target lane, pedestrians, vehicles and obstacles. For example, if the vehicle detects a nearby target vehicle, the vehicle needs to predict the driving trajectory of the target vehicle. If the target vehicle will be overtaking, following or driving in parallel, lane prediction should be made, and then vehicle short-range communication technology with automatic driving technology could be combined to realize real-time target vehicle trajectory prediction. If the target vehicle is driving towards an intersection, and may make a left turn, a right turn, or a straight run, the autonomous vehicle may predict the path of the target vehicle in advance through a machine learning model. In another scenario, the vehicle at the intersection with a large flow of pedestrians could also predict the pedestrians' movement trajectories and perform deceleration or a steering operation in advance.

I.1.3 Planning use cases

The planning scenarios are mainly for path planning and speed planning of vehicles in motion. For example, to avoid static or dynamic obstacles, path planning is required. The vehicles perceive the surrounding environment through cameras or radars, and use a machine learning model to generate the candidate paths. Next, using the cost function to evaluate each path, the factors affecting the cost function include smoothness, safety, deviation from the centre of the lane, etc. Then the paths are ranked by cost and the path with the lowest cost is selected. This is followed by speed planning, which needs to collect a series of speeds related to the path points, and then the data is processed by the machine learning model. It is possible to select the driving speed that is limited by various environments, thereby determining whether to change the speed or keep the original speed traveling on the path. Finally, the vehicle's trajectory could be constructed by combining path planning and speed planning.

I.1.4 Human-machine interaction use cases

I.1.4.1 Overview

By obtaining useful information through relevant equipment, and analysing it with machine learning models, the human-machine interaction scenarios could help drivers to focus on driving, reduce traffic accidents, and improve driving comfort. The specific human-machine interaction scenarios are shown in Figure I.2.

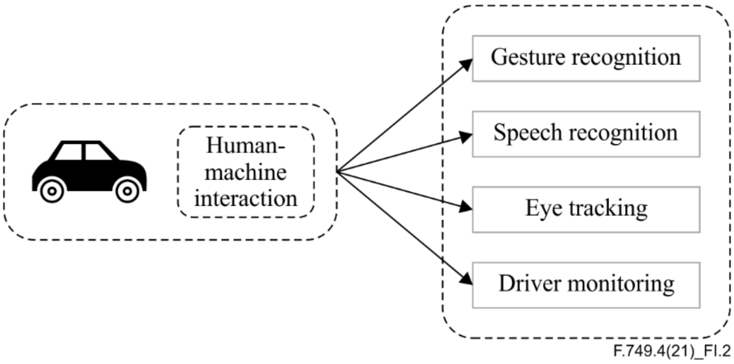

Figure I.2 – Scenario of human-machine interaction

I.1.4.2 Gesture recognition scenario

The gesture recognition scenarios mainly include static gesture recognition and dynamic gesture recognition. The human-machine interaction interface of the smart cockpit controls vehicle navigation, information entertainment and other systems by capturing gestures performed by the drivers. It can then capture gestures and detect/return gestures or actions in pictures or videos. Then, it can parse the user's behaviour information, thus solving common gesture operations, such as determining, clicking, sliding left and right, opening/closing, etc.

I.1.4.3 Speech recognition scenario

In the voice control scenario, the driver performs voice communication through the human-machine interaction interface in the smart cockpit. Through voice communication, drivers can make phone calls, play music, switch navigation routes, remote control of smart home appliances, etc. It could be combined with natural language processing technology to identify driver's identity information and analyse driver's emotions, etc.

I.1.4.4 Eye tracking scenario

In the eyeball tracking scenario, the sensors first recognize the feature points of the human eyes to establish a model. Next, through the camera and other devices, the rotation motion is captured during the rotation of the eyeball. Finally, the machine learning model is used to analyse the state of the human eyes, the position of the gaze, etc. Therefore, driver distraction and low vigilance are prevented during driving.

I.1.4.5 Driver monitoring scenario

In the driver monitoring scenario, the cameras in the smart cockpit monitor the driver's driving state in real time using face recognition and eyeball tracking technology, which can promptly remind the driver to ensure the correctness of the driver's driving operation in the state of distraction, fatigue, bowing, chatting, etc.

I.1.5 Model training/deployment use cases

I.1.5.1 Model training scenario

Artificial intelligence technology includes two steps: model training step and inference step. The model training step should generate a proper model based on mass data, mass storage and enormous computing power. In the model training scenario, the vehicles should upload mass data (e.g., video, audio and vehicle running data) to the cloud server through a wireless wide area network (WWAN). The cloud server trains and optimizes the models and algorithms continuously to adapt to the changing road circumstances based on the mass data that was uploaded from the vehicles.

I.1.5.2 Model deployment scenario

The cloud server should deploy previously tested and optimized machine learning models to each vehicle through a WWAN. The vehicles have the ability of inference and can implement environment perception, prediction, planning and human-machine interaction in vehicles through the downloaded machine learning models.

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