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Recommendation

ITU-T F.747.13 (09/2023)

SERIES F: Non-telephone telecommunication services

Multimedia services

Requirements and reference framework of cloud-edge collaboration in industrial machine vision systems

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Recommendation ITU-T F.747.13

Requirements and reference framework of cloud-edge collaboration in industrial machine vision systems

Summary

Recommendation ITU-T F.747.13 specifies requirements and reference framework of cloud-edge collaboration in industrial machine vision systems and provides use cases. The cloud-edge collaboration is a process (or method) that coordinates cloud computing and edge computing, dynamically allocates required computing, algorithm models, data, or other resources and jointly completes the same tasks (or objectives) agreed in advance. In industrial machine vision systems, cloud-edge collaboration includes resource collaboration (computing, network and storage), service collaboration (data, intelligence and task) and application collaboration (capability and management).

This Recommendation is intended to guide the design and development of industrial machine vision systems.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
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The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Recommendation ITU-T F.747.13

Requirements and reference framework of cloud-edge collaboration in industrial machine vision systems

1 Scope

This Recommendation specifies the requirements and reference framework of cloud-edge collaboration in industrial machine vision systems.

The scope of this Recommendation includes:

– Overview;

– Requirements; and

– Reference framework.

Use cases of cloud-edge collaboration in industrial machine vision systems are provided in Appendix I.

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 F.743.22] Recommendation ITU-T F.743.22 (2022), *Requirements and architecture of an algorithm-training system for intelligent video surveillance.*

[ITU-T F.747.12] Recommendation ITU-T F.747.12 (2022), *Requirements for artificial intelligence based machine vision system in smart logistics warehouse.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 algorithm training [ITU-T F.743.22]: A technology that learns the experience or the environment represented by the input data and upgrades the algorithm.

3.1.2 cloud computing [b-ITU-T Y.3500]: Paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand.

NOTE – Examples of resources include servers, operating systems, networks, software, applications and storage equipment.

3.1.3 collaboration [b-ISO 13374-2]: A relation between two objects in a collaboration diagram, indicating that messages can pass back and forth between the objects.

3.1.4 edge computing [b-ITU-T Y.3073]: This refers to a strategy to deploy the processing capability at the network edge where end terminals are connected, and to perform the processing of data which is derived from and fed to the end terminals.

3.1.5 federated machine learning [b-IEEE 3652.1]: Federated machine learning is a framework or system that enables multiple participants to collaboratively build and use machine learning models without disclosing the raw and private data owned by the participants while achieving good performance.

3.1.6 homomorphic encryption [b-ISO/IEC 20009-4]: Symmetric or asymmetric encryption that allows third parties to perform operations on plaintext data while keeping them in encrypted form.

3.1.7 incremental learning [b-ISO/IEC 2382]: Multistage adaptive learning in which knowledge learned at one stage is transformed in order to accommodate new knowledge provided at subsequent stages.

3.1.8 inference [b-ISO/IEC 2382]: Reasoning by which conclusions are derived from known premises.

3.1.9 machine vision [b-ITU-T F.748.16]: Signal processing to acquire, process and interpret an image or video to support visual analysis for applications, such as automatic inspection, process control and guidance.

3.1.10 orchestration [b-ISO/IEC TR 30102]: Composition for which there is one particular element used by the composition that oversees and directs the other elements.

NOTE – The element that directs an orchestration by definition is different than the orchestration (composition instance) itself.

3.1.11 optical character recognition (OCR) [b-ISO/IEC 22989]: Conversion of images of typed, printed, or handwritten text into machine-encoded text.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 cloud-edge collaboration: A process (or method) that coordinates cloud computing and edge computing, dynamically allocates required computing, algorithm models, data, or other resources, and jointly completes the same tasks (or objectives) agreed in advance.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

3D Three-Dimension

AGV Automated Guided Vehicle

AI Artificial Intelligence

AMR Automated Mobile Robot

CPU Central Processing Unit

ERP Enterprise Resource Planning

FPGA Field Programmable Gate Array

GPU Graphics Processing Unit

MES Manufacturing Execution System

NPU Neural-network Processing Unit

OCR Optical Character Recognition

OCV Optical Character Verification

ONNX Open Neural Network Exchange

QMS Quality Management System

WMS Warehouse Management System

5 Conventions

In this Recommendation:

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

– The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement needs not be present to claim conformance.

– The keywords "**can optionally**" indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

6 Overview of cloud-edge collaboration in industrial machine vision systems

With the continuous improvement of industrial automation and intelligence requirements, industrial machine vision technology is widely used in intelligent manufacturing, smart logistics warehousing, smart energy and other scenarios. The data-intensive applications and computing intensive-applications are continuously increasing, and the powerful computing and network resources of cloud computing collaborative with the high-speed response capability of edge computing can greatly improve the application level of machine vision systems in the industrial field.

Cloud-edge collaboration is a process (or method) that coordinates cloud computing and edge computing, dynamically allocates required computing, algorithm models, data, or other resources, and jointly completes the same tasks (or objectives) agreed in advance.

Cloud computing can achieve global, non-real-time, long-term big data processing and analysis, and can play an important role in the fields of long-term maintenance, service decision support, etc. Edge computing can achieve local, real-time and short-term data processing and analysis, and can better support real-time intelligent decision-making and execution of local services.

The application of cloud-edge collaboration in industrial machine vision systems can optimize the allocation and utilization of resources, achieve effective collaboration of data and computing processes, and strengthen the perception capability of industrial machine vision systems. Real-time data processing can relieve bandwidth pressure, and complete the data perception, analysis, decision-making and evaluation in the whole cycle.

In this Recommendation, the cloud is equivalent to cloud computing, and the edge is equivalent to edge computing.

Typical scenarios of cloud-edge collaboration in industrial machine vision systems (see Appendix I for use cases) include:

Scenario A: High real-time performance requirements

In the industrial production environment, certain processes require high real-time performance. For example, the defect detection processes use the industrial camera to collect the image of the product surface, analyses whether the product has defects in real-time, and classifies the defective products through the mechanical arm. This requires real-time inference on the edge which closes to the pipeline. The cloud completes the algorithm training and deploys the algorithm models to the edge. Through cloud-edge collaboration algorithm models achieve efficient and fast iterations that continuously improve the accuracy of defect identification.

Scenario B: High data security requirements

For enterprises and factories with high requirements for data security, the raw data collected by industrial devices cannot be uploaded to the cloud. The edge deployed in the trusted domain uses technologies such as federated machine learning and homomorphic encryption to upload the processed data (such as intermediate computing results and desensitization data) to the cloud to complete the training, analysis and applications.

Figure 1 shows the conceptual diagram of a cloud-edge collaboration.

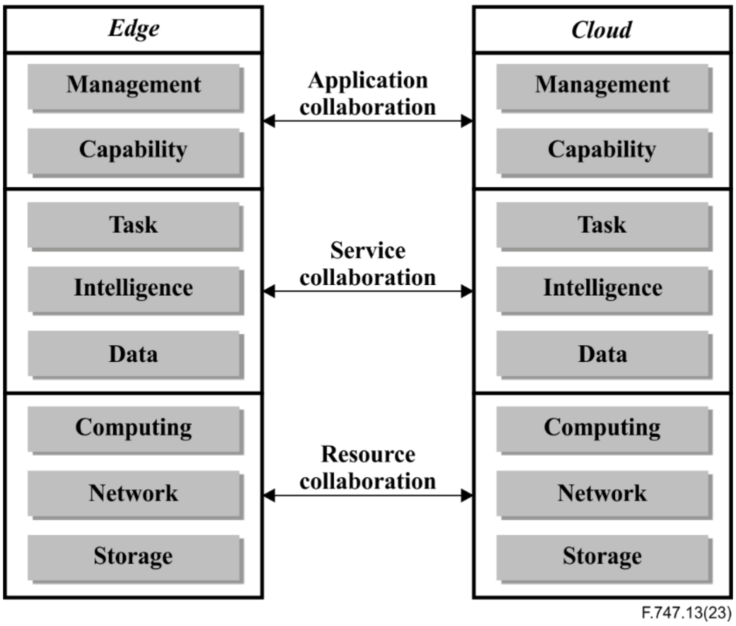

Figure 1 – Conceptual diagram of a cloud-edge collaboration

Cloud-edge collaboration mainly includes resource collaboration, service collaboration and application collaboration.

Resource collaboration is the collaboration of computing, network and storage resources between the cloud and edge. Through the unified management of resources, resource collaboration enriches the types of resource entities, expands the area of resource management, and improves the decision-making capability of resource scheduling. The orchestration and scheduling of resources extend from the resource-rich cloud to the resource-constrained edge, providing an overall view of the resources, so that edge-to-cloud and edge-to-edge resources can be scheduled and collaborated on demand, to optimize the resource utilization from a global perspective.

Service collaboration is the collaboration of tasks, intelligence and data between the cloud and the edge. Based on the resource collaboration and scheduling capabilities between cloud and edge, the service collaboration establishes a multi-layer collaboration of cloud and edge, decomposes large-scale and complex services into tasks, and reasonably plans the storage and transmission of data between cloud and edge. Combined with technologies such as federated machine learning and incremental learning, the orchestrated tasks are allocated to the cloud and edge for joint training and joint inference on-demand, which can realize the mutual extension and collaborative operation of intelligence services between cloud and edge and improve the efficiency and performance.

Application collaboration is the collaboration of management and capability between cloud and edge. Based on the resource and service collaboration between cloud and edge, the application collaboration realizes the unified registration and access of edge applications, consistently distributes the deployment and centralized full-lifecycle management, including push, installation, update, and the uninstall of applications. Based on the capability hierarchy of cloud and edge, the allocation strategies are designed according to the priority and dependencies of service attributes, while completing the high availability guarantee and live migration of applications to meet the requirements of users.

Figure 2 shows the information interaction model between the cloud and the edge.

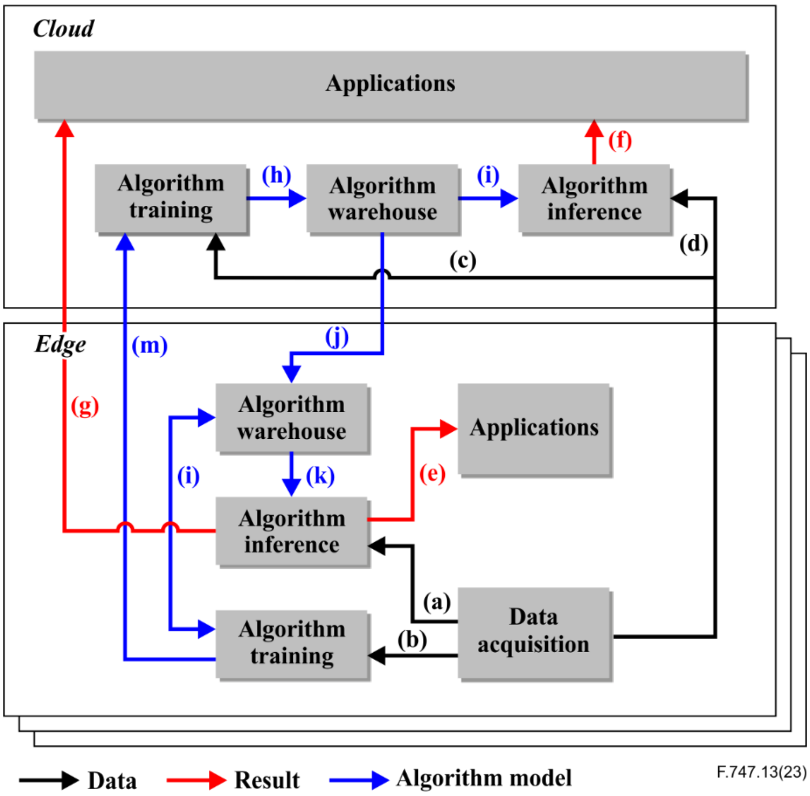

Figure 2 – Information interaction model between cloud and edge

The information interaction between cloud and edge mainly includes the data, results and the algorithm models. In the information interaction model, edge includes data collection/acquisition, algorithm inference, algorithm training, algorithm warehouse, edge application, etc.; cloud includes algorithm training, algorithm warehouse, algorithm inference, cloud application, etc.

Typical information interaction process is as follows:

a. Cloud training and edge inference

– The edge uploads the collected data to the algorithm training unit on cloud for algorithm training unit through (c);

– The algorithm training unit on cloud performs algorithm training and sends the trained algorithm models to the algorithm warehouse unit on cloud through (h);

– The algorithm warehouse unit on cloud sends the algorithm models to the algorithm warehouse unit on edge based on requirements through (j);

– The algorithm warehouse unit on edge deploys the algorithm models to the algorithm inference unit on edge through (k) and starts the inference tasks;

– The data acquisition unit on edge sends the original data to the algorithm inference unit on edge for inference through (a);

– The algorithm inference unit on edge sends the inference results to the edge application through (e) or uploads the inference results to the cloud application through (g).

b. Cloud and edge joint training based on federated machine learning

– The edge sends the collected data to the algorithm training unit on edge through (b);

– The algorithm training unit on edge performs algorithm training and uploads the intermediate results generated during the training process to the algorithm training unit on cloud through (m);

– The algorithm training unit on cloud uses the federated learning framework to aggregate the intermediate results generated by multiple edge to a global algorithm model, and then sends the global algorithm model to the algorithm warehouse unit on cloud through (h).

c. Cloud and edge joint training based on incremental learning

– The edge uploads the collected data to the algorithm training unit on cloud for algorithm training unit through (c);

– The algorithm training unit on cloud performs algorithm training and sends the trained algorithm models to the algorithm warehouse unit on cloud through (h);

– The algorithm warehouse unit on cloud sends the algorithm models to the algorithm warehouse unit on edge based on requirements through (j);

– The algorithm warehouse unit on edge sends the algorithm models to the algorithm training unit on edge through (i);

– The edge sends the collected data to the algorithm training unit on edge through (b);

– The algorithm training unit on edge sends the incremental learning algorithm models to the algorithm warehouse unit on edge through (i).

d. Cloud and edge joint inference

– The algorithm warehouse unit on edge deploys the algorithm models to the algorithm inference unit on edge through (k) and starts the inference tasks;

– The data acquisition unit on edge sends the original data to the algorithm inference unit on edge for inference through (a);

– The algorithm inference unit on edge uploads the inference results to the cloud application through (g).

– The algorithm warehouse unit on the cloud deploys the algorithm models to the algorithm inference unit on the cloud through (i) and starts the inference tasks;

– The data acquisition unit on edge uploads the original data to the algorithm inference unit on the cloud for inference through (d);

– The algorithm inference unit on the cloud sends the inference results to the cloud application through (f);

– The edge and cloud side inference results are aggregated into cloud applications to achieve specific service requirements.

7 Requirements of cloud-edge collaboration in industrial machine vision systems

In this Recommendation, requirements specific to the cloud-edge collaboration in industrial machine vision systems (hereafter "the system") are identified.

7.1 Requirements of resource collaboration

– RRC1: The system is recommended to support the application, reservation and release of resources (computing, storage and network);

– RRC2: The system is recommended to support resources self-discovery, self-maintenance and self-management;
– RRC3: The system is recommended to support resources reuse mechanisms, including reuse by time and reuse by domain;
– RRC4: The system is recommended to support resource scheduling between cloud and edge on-demand;
– RRC5: The system is recommended to support the computing capability model generation, computing resource normalization of heterogeneous computing devices, and provide attribute and status information for scheduling;
– RRC6: The system is recommended to support resource information modelling and overall view generation of resources scheduling between cloud and edge;
– RRC7: The system is recommended to support the heterogeneous computing resources virtualization and pooling, computing resources including central processing unit (CPU), graphics processing unit (GPU), neural-network processing unit (NPU) and field programmable gate array (FPGA);
– RRC8: The system is recommended to support the resource status synchronization between cloud and edge, including the idle and occupied status of computing resources, storage resources and bandwidth resources;
– RRC9: The system is recommended to support resource fault isolation, performance isolation and security isolation.

7.2 Requirements of service collaboration

7.2.1 Requirements of data collaboration

– RDC1: The system is recommended to support data aggregation, storage, retrieval, invocation and association;
– RDC2: The system is recommended to support data synchronization between cloud and edge, including structured data, unstructured data and semi-structured data;
– RDC3: The system is recommended to support unified processing and the conversion of different data formats;
– RDC4: The system is recommended to support data conversion under different spatiotemporal coordinate systems;
– RDC5: The system is recommended to support sample data aggregation between cloud and edge;
– RDC6: The system is recommended to support sample data de-duplication between cloud and edge;

NOTE – The sample data is used for training.

– RDC7: The system is recommended to support redundant, multiple copies, or erasure code data storage;
– RDC8: The system is recommended to support data compression and encrypted transmission.

7.2.2 Requirements of intelligence collaboration

– RIC1: The system is recommended to support operating machine learning frameworks on cloud and edge, such as TensorFlow and PyTorch;
– RIC2: The system is recommended to support the algorithm models updating and maintenance on cloud and edge;

– RIC3: The system is recommended to support cloud training with edge inference mode;
– RIC4: The system is recommended to support the cloud and edge joint inference mode;
– RIC5: The system is recommended to support unified metadata description of inference results between cloud and edge;
– RIC6: The system is recommended to support the cloud and edge joint training mode based on federated machine learning;
– RIC7: The system is recommended to support cloud and edge joint training mode based on incremental learning;
– RIC8: The system is recommended to support algorithm model lightweight to adapt the computing capabilities on cloud and edge;
– RIC9: The system is recommended to support the general representation of algorithm models, so that the trained algorithm models can be deployed and operated without conversion between cloud and edge.

7.2.3 Requirements of task collaboration

– RTC1: The system is recommended to support unified tasks scheduling and tasks distribution for execution between cloud and edge;
– RTC2: The system is recommended to support the tasks migration to the cloud or edge for execution when edge devices have insufficient computing resources or when abnormal conditions occur;
– RTC3: The system is recommended to support priority definition and resource pre-emption of tasks;
– RTC4: The system is recommended to support the generation of task scheduling strategies based on task timing, network bandwidth, computing resources and data proximity;
– RTC5: The system is recommended to support dynamic adjustment, flexible configuration and combined use of task scheduling strategies;
– RTC6: The system is recommended to support the execution isolation of task instances, to ensure user data security and hardware device safety.

7.3 Requirements of application collaboration

7.3.1 Requirements of capability collaboration

– RCC1: The system is recommended to support unified metadata description of capabilities on cloud and edge;
– RCC2: The system is recommended to support capabilities convergence and synchronization between cloud and edge;
– RCC3: The system is recommended to support capabilities, including analysis, enhancement, and retrieval of video and image data;
– RCC4: The system is recommended to support capabilities, including acquisition, transmission, storage, display and control of multimedia data;
– RCC5: The system is recommended to support overall view generation of capabilities on cloud and edge.

7.3.2 Requirements of management collaboration

– RMC1: The system is recommended to support the splitting of services into multiple collaborative task execution units for scheduling and operation;
– RMC1: The system is recommended to support planning collaboration strategies based on service attributes (priorities, dependencies) and cloud and edge capabilities.

8 Reference framework of cloud-edge collaboration in industrial machine vision systems

Figure 3 shows the reference framework of cloud-edge collaboration in industrial machine vision systems.

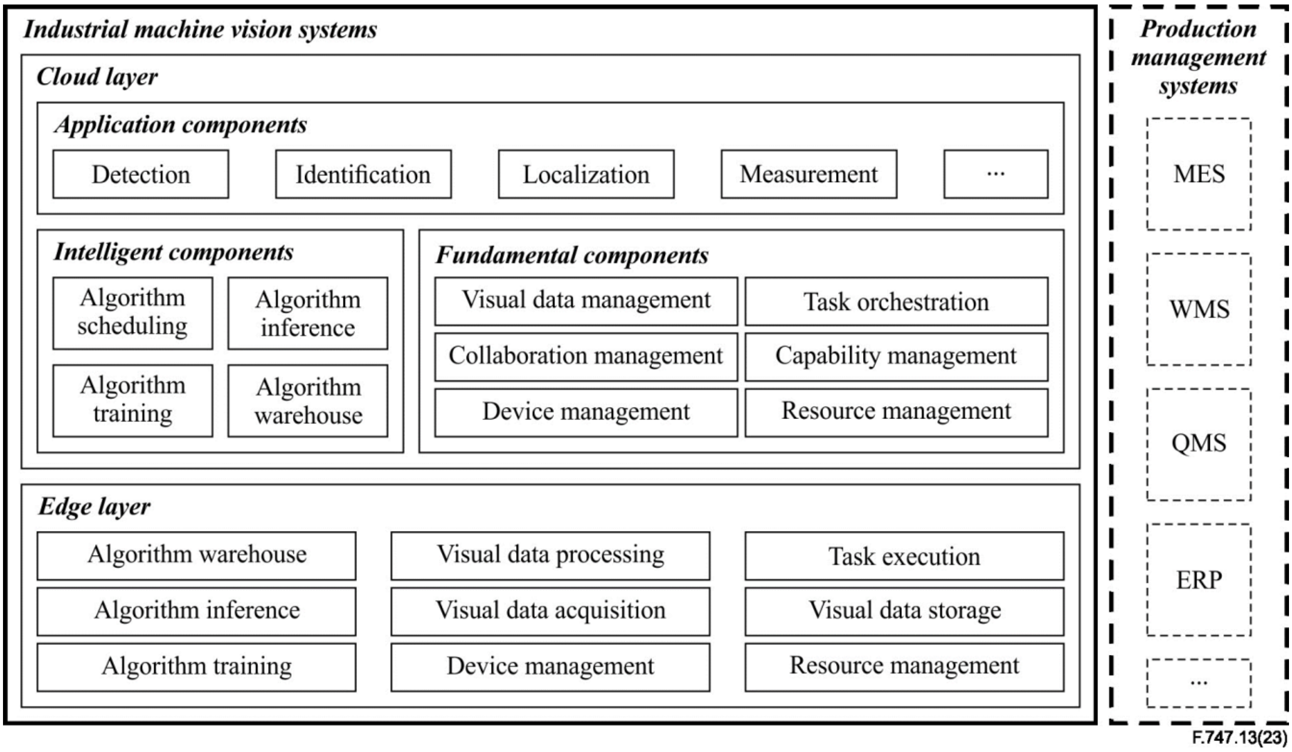

Figure 3 – Reference framework of cloud-edge collaboration in industrial machine vision systems

The reference framework of cloud-edge collaboration in industrial machine vision systems consists of the cloud layer and edge layer. At the same time, industrial machine vision systems can interact with external production management systems, such as manufacturing execution systems (MES), warehouse management systems (WMS), quality management systems (QMS), enterprise resource planning (ERP), etc.

The cloud layer includes application components, intelligent components and fundamental components. Applications include detection, identification, localization, measurement, etc. Intelligent components include algorithm training, algorithm warehouse, algorithm scheduling and algorithm inference. The fundamental components include visual data management, task orchestration, collaboration management, capability management, device management and resource management.

The edge layer includes algorithm warehouse, algorithm inference, algorithm training, resource management, device management, visual data collection/acquisition, visual data storage, visual data processing and task execution.

The requirements for cloud and edge layers are as follows:

8.1 Requirements of the cloud layer

8.1.1 Requirements of application components

The requirements of application components on the cloud include:

– RA1: It is recommended to support machine vision applications for industrial fields, such as detection, identification, localization, measurement, etc.;

– RA2: It is recommended to support application management, including push, installation, update and uninstall;
– RA3: It is recommended to support application disassembly as a service, deploying to the edge in the form of containers;
– RA4: It is recommended to support multi-tenant application isolation.

8.1.2 Requirements of intelligent components

The requirements of intelligent components on the cloud include:

– RICO1: It is recommended to support sample data management and algorithm training [ITU-T F.743.22];
– RICO2: It is recommended to support multiple algorithm model management in the cloud algorithm warehouse, including addition, deletion and deployment;
– RICO3: It is recommended to support the management of the edge algorithm warehouse, including querying, deploying and uploading;
– RICO4: It is recommended to support algorithm inference tasks operation, including start, pause and stop;
– RICO5: It is recommended to support unified scheduling of algorithm tasks between cloud and edge;
– RICO6: It is recommended to support the algorithm model in a general format such as open neural network exchange (ONNX) [b-Onnx] format;
– RICO7: It is recommended to support algorithm model clipping, compression and optimization.

8.1.3 Requirements of fundamental components

The requirements of fundamental components on the cloud include:

– RFC1: It is recommended to support the management of the edge including access, control, operation and maintenance;
– RFC2: It is recommended to support physical resource information aggregation and usage monitoring on cloud and edge;
– RFC3: It is recommended to support data management by cloud storage;
– RFC4: It is recommended to support unified management of visual data, including storage, backup and migration;
– RFC5: It is recommended to support the management of collaboration strategies, including adding, deleting, modifying and querying;
– RFC6: It is recommended to support the management of task scheduling strategies, including adding, deleting, modifying and checking;
– RFC7: It is recommended to support the execution of task scheduling strategies, including creating, starting, stopping and deleting tasks on cloud and edge;
– RFC8: It is recommended to support task operation status querying and resource consumption monitoring;
– RFC9: It is recommended to support cloud and edge capability aggregation and management, and provide an overall view of the entire domains;
– RFC10: It is recommended to support computing resource virtualization on the cloud, including CPU, GPU, or other artificial intelligence (AI) accelerating processors;
– RFC11: It is recommended to support a unified container orchestration framework on cloud and edge, and applications with unified distribution and unified governance.

8.2 Requirements of the edge layer

8.2.1 General requirements

The general requirements on edge include:

– RGR1: It is recommended to support registering to the cloud, reporting edge capabilities to the cloud, and management by cloud;

– RGR2: It is recommended to support signalling interaction and data sharing with multiple edge devices;

– RGR3: It is recommended to support offline operation strategies, including autonomous operation and task migration.

8.2.2 Requirements of resource management

The requirements of resource management on edge include:

– RRM1: It is recommended to support edge resource information and usage monitoring;

– RRM2: It is recommended to support reporting resource information and usage status to the cloud.

8.2.3 Requirements of device management

The requirements of device management on edge include:

– RDM1: It is recommended to support multiple types of edge devices access such as industrial cameras, automated guided vehicles (AGV), automated mobile robots (AMR), mechanical arms, surveillance cameras, code readers, three-dimension (3D) cameras, laser radars, etc.;

– RDM2: It is recommended to support edge devices configuration, including codec configuration, network configuration and storage configuration;

– RDM3: It is recommended to support edge devices control, including restarting, upgrading, suspending operation and resuming operations;

– RDM4: It is recommended to support edge devices event subscription and notification;

– RDM5: It is recommended to support edge devices operation and maintenance, including status information collection, status abnormality alarm;

– RDM6: It is recommended to support edge devices detection, including network link detection, video and image quality diagnosis;

– RDM7: It is recommended to satisfy the device requirements defined in [ITU-T F.747.12].

8.2.4 Requirements of algorithm warehouse

The requirements of algorithm warehouse on edge include:

– RAW1: It is recommended to support multiple algorithm model management, including addition, deletion and deployment;

– RAW2: It is recommended to support algorithm model deployment to edge devices on-demand.

8.2.5 Requirements of algorithm inference

The requirements of algorithm inference on edge include:

– RAI1: It is recommended to support algorithm inference and cache the inference results locally for task use;

– RAI2: It is recommended to support reporting inference results to cloud applications;

– RAI3: It is recommended to support common machine vision algorithm models including but not limited to target localization, target measurement, target identification, etc.;

– RAI4: It is recommended to support the decomposition and allocation of algorithm inference tasks to multiple edge devices.

NOTE – Edge devices jointly complete partial inference tasks to reduce inference pressure.

8.2.6 Requirements of algorithm training

The requirements of algorithm training on edge include:

– RAT1: It is recommended to support algorithm training and storage of the trained algorithm model into the algorithm warehouse;

– RAT2: It is recommended to support federated machine learning with multi-edge;

– RAT3: It is recommended to support incremental learning.

8.2.7 Requirements of visual data collection

The requirements of visual data collection on edge include:

– RVDC1: It is recommended to support multiple types of industrial data collection, including video, images and point clouds;

– RVDC2: It is recommended to support multiple resolutions, including 1 million, 3 million, 5 million, 10 million and 12 million pixels;

– RVDC3: It is recommended to support multiple pixel depths, including 8 bits, 10 bits, 12 bits and 14 bits;

– RVDC4: It is recommended to support multiple frame rates, including 5, 10, 50, 100 and 200 frames per second (fps).

8.2.8 Requirements of visual data storage

The requirement of visual data storage on edge includes:

– RVDS1: It is recommended to support expandable storage capacity;

– RVDS2: It is recommended to support data redundancy protection and backup;

– RVDS3: It is recommended to support universal data storage formats, such as block storage, file storage and object storage.

8.2.9 Requirements of visual data processing

The requirements of visual data processing on edge include:

– RVDP1: It is recommended to support data pre-processing, including image zooming, image filling, image rotation and image enhancement;

– RVDP2: It is recommended to support data analysis, including data filtering, data classification and data retrieval;

– RVDP3: It is recommended to support multi-modal data fusion of multiple edge devices.

8.2.10 Requirements of task execution

The requirements of task execution on edge include:

– RTE1: It is recommended to support the execution of tasks, such as target localization, target measurement and target identification;

– RTE2: It is recommended to support reporting task execution status to the cloud;

– RTE3: It is recommended to support task execution in the form of containers on edge devices;

– RTE4: It is recommended to support multi-tenant task isolation.

Appendix I

Use cases of cloud-edge collaboration in industrial machine vision systems

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

Figure I.1 shows the service scenario of cloud-edge collaboration in industrial machine vision systems.

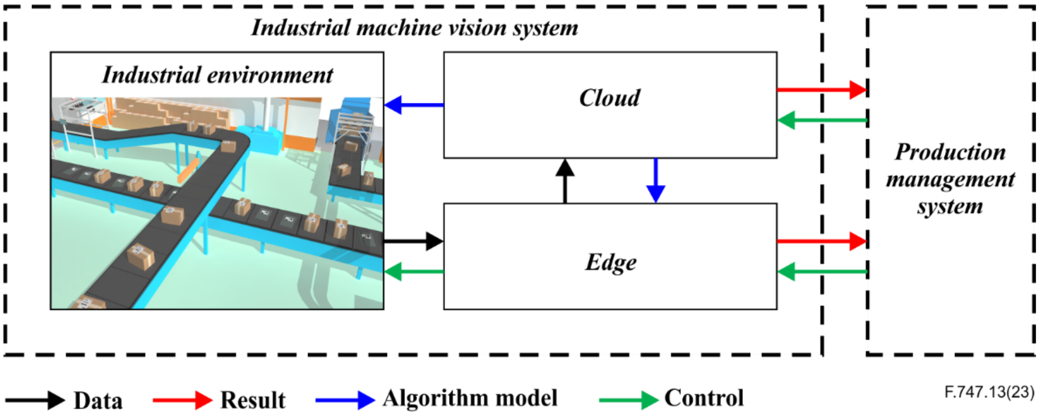

Figure I.1 – Service scenario of cloud-edge collaboration in industrial machine vision systems

The data collected by devices in an industrial production environment can be analysed and processed in real-time at the edge, and the results can be sent to the production management system for decision-making and control. At the same time, the processed data can be uploaded to the cloud to complete the algorithm training, and the cloud deploys the algorithm model to the edge and the industrial devices. The cloud can conduct big data analysis based on data, and the production management system can conduct decision-making and control devices in the industrial production environment based on the results produced by the cloud.

I.1 Quality inspection

In automated assembly lines, a certain number of defective products are produced in various stages of continuous mass production. To improve the yield rate of manufacturing enterprises, industrial machine vision technology plays a significant role in defective product elimination, quality control and cost control. Industrial cameras and X-ray machines can be used to collect internal and external defects of the products. The collected information on the edge can be identified and analysed at a high speed to determine the defective products. The defect recognition algorithm models are continuously trained and upgraded on the cloud which improves the recognition accuracy. It can be applied to the pharmaceutical industry, electronic component processing industry, precision equipment quality inspection industry, etc.

I.2 Logistics sorting

[ITU-T F.747.12] defines the general requirements and framework for intelligent logistics warehousing machine vision systems. In the logistics and warehousing industry, massive package information needs to be classified and processed according to the destination or type. This requires industrial cameras' high-speed acquisition of text, barcode, and other information on package surface labels, real-time identification and analysis of label images at the edges, and cloud-completed algorithm training to improve identification accuracy, thereby completing optical character recognition (OCR) and optical character verification (OCV).

I.3 Industrial manufacturing robots

In industrial manufacturing scenarios, the industrial machine vision system can locate the position and direction of the target, compare the target with the specified tolerance, determine the target position, and verify whether the grasping and placement actions are correct. In scenarios such as mechanical arm grabbing and goods handling, real-time path planning at the edge can achieve accurate grabbing and transportation. Big data analysis of data is performed in the cloud, and a grabbing path model and transportation global map are constructed. At the same time, industrial machine vision technology can replace laser, magnetic conductivity and other technologies, greatly reducing costs.

Bibliography

[b-ITU-T F.748.16] Recommendation ITU-T F.748.16 (2022), *Requirements for applications and services in smart manufacturing based on machine vision.*

[b-ITU-T Y.3073] Recommendation ITU-T Y.3073 (2019), *Framework for service function chaining in information-centric networking.*

[b-ITU-T Y.3500] Recommendation ITU-T Y.3500 (2014), *Information technology – Cloud computing – Overview and vocabulary.*

[b-IEEE 3652.1] IEEE 3652.1-2020, *IEEE Guide for Architectural Framework and Application of Federated Machine Learning.*
<https://ieeexplore.ieee.org/document/9382202>

[b-ISO 13374-2] ISO 13374-2:2007, *Condition monitoring and diagnostics of machines – Data processing, communication and presentation – Part 2: Data processing.*
<https://www.iso.org/standard/36645.html>

[b-ISO/IEC 20009-4] ISO/IEC 20009-4:2017, *Information technology – Security techniques – Anonymous entity authentication – Part 4: Mechanisms based on weak secrets.*
<https://www.sis.se/produkter/informationsteknik-kontorsutrustning/itsakerhet/isoiec-20009-42017/>

[b-ISO/IEC 22989] ISO/IEC 22989:2022, *Information technology – Artificial intelligence – Artificial intelligence concepts and terminology.*
<https://www.iso.org/standard/74296.html>

[b-ISO/IEC 2382] ISO/IEC 2382:2015, *Information technology – Vocabulary.*
<https://www.iso.org/standard/63598.html>

[b-ISO/IEC TR 30102] ISO/IEC TR 30102:2012, *Information technology – Distributed Application Platforms and Services (DAPS) – General technical principles of Service Oriented Architecture.*<https://www.iso.org/standard/53222.html#:~:text=ISO%2FIEC%20TR%2030102%3A2012%20describes%20the%20general%20technical%20principles,of%20terms%20relevant%20to%20SOA.>

[b-Onnx] *Open Neural Network Exchange.*
<https://onnx.ai/>

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