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Information technology — Artificial intelligence — Reference architecture of knowledge engineering

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Foreword

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Introduction

Knowledge-driven AI applications have gradually gained attention. In knowledge engineering (KE), knowledge is automatically or semi-automatically acquired from information sources, which in turn are generated by processing huge-scale multi-source heterogeneous data. The knowledge is integrated into knowledge-based systems and used to provide intelligent knowledge-driven services. One of the objectives of KE is to represent and transfer human knowledge within industries such as finance, medical care, transportation and manufacturing to machine knowledge with representations understandable by both humans and AI systems. Now, KE, along with big data, deep learning, natural language processing etc., has become one of the core driving forces of AI development.

Key technologies of KE include knowledge representation, knowledge modelling, knowledge acquisition, knowledge storage, knowledge fusion, knowledge calculation, knowledge maintenance, knowledge visualization, etc. In addition, many knowledge service platform products and solutions have been developed to permit KE implementations to be more agile in organizations. The distributed KE systems can be integrated and deployed through knowledge exchange and knowledge maintenance among the systems. The distributed, autonomous agent systems and their collaboration across system of systems can further generate the necessary intelligence and knowledge driven behaviours for collaboration and cooperation.

Resource description framework (RDF),[1] resource description framework schema (RDFS),[2] RDFS-PLUS, ontology web language (OWL),[3] SPARQL protocol and RDF query language (SPARQL)[4] and ontology-related theories and standards[5-7] provide a solid foundation of tools and theories in the aspects of knowledge representation and knowledge modelling. Other related KE standards have been developed.

KE has been successfully applied to many industries including financial fraud identification, remote operation and maintenance of equipment, user profile and product recommendations, research focus tracking and forecasting, smart credit analysis, legal dispute and case prediction based on similar cases, intelligent distribution of news, intelligent computer-aided diagnosis and treatment, etc. Many organizations regard platforms or systems based on KE as important knowledge infrastructures. However, KE vocabularies, basic KE constructional components, KE processes and their relationships are not yet clearly defined. This causes misunderstandings and unnecessary communication and deployment costs amongst the data supplier, fundamental technology supplier, algorithm supplier, system coordinator and other stakeholders of KE systems.

To facilitate collaboration amongst KE stakeholders, KE characteristics and applications can be comprehensively described and categorized. Expected use of the document is to guide the construction of KE systems.

Information technology — Artificial intelligence — Reference architecture of knowledge engineering

1 Scope

This document defines a reference architecture of knowledge engineering (KE) in artificial intelligence (AI). The reference architecture describes KE roles, activities, constructional layers, components and their relationships amongst themselves and other systems from systemic user and functional views. This document also provides a common KE vocabulary by defining KE terms.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 22989:2022, *Information technology — Artificial intelligence — Artificial intelligence concepts and terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 22989 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
architecture
fundamental concepts or properties of an entity in its environment and governing principles for the realization and evolution of this entity and its related life cycle processes

[SOURCE: ISO/IEC/IEEE 42010:2022, 3.2]

3.2
architecture view
information part comprising portion of an architecture description

EXAMPLE An Information or Data View addresses information-relevant concerns framed by an Information viewpoint. It contains as view components, a conceptual data model, a data management model and a data access model and correspondences linking those components together.

[SOURCE: ISO/IEC/IEEE 42010:2022, 3.7]

3.3
data
reinterpretable representation of information in a formalized manner suitable for communication, interpretation, or processing

Note 1 to entry: Data can be processed by humans or by automatic means.

[SOURCE: ISO/IEC 20546:2019, 3.1.5]

3.4
information
data that are processed, organized and correlated to produce meaning

Note 1 to entry: Information concerns facts, concepts, objects, events, ideas, processes, etc.

[SOURCE: ISO/IEC 20547-3:2020, 3.3]

3.5
knowledge engineering
KE
discipline concerned with acquiring knowledge from domain experts and other knowledge sources and incorporating it into a knowledge base

Note 1 to entry: The term "knowledge engineering" sometimes refers particularly to the art of designing, building, and maintaining knowledge-based systems.

[SOURCE: ISO/IEC 2382:2015, 28.01.07, modified — replaced notes to entry.]

3.6
concept
<terminology> unit of thought differentiated by a unique combination of characteristics

Note 1 to entry: Concepts are not necessarily bound to particular languages. They are, however, influenced by the social or cultural background which often leads to different categorizations of concepts.

[SOURCE: ISO 1087:2019, 3.2.7, modified — replaced "knowledge" with "thought".]

3.7
entity
object of the environment or domain (real-world objects and events, abstract concepts, documents, etc.)

EXAMPLE In the case of a knowledge graph, entity descriptions forming a network and provides context for each other entity interpretation.

3.8
attribute
property of an entity with respect to a defined characteristic

EXAMPLE "Entity X has 5 kg mass" is an attribute, but "having mass" is a characteristic and "5 kg mass" is a property, and neither individually are attributes.

3.9
ontology
collection of terms, relational expressions, and associated natural-language definitions together with one or more formal theories designed to capture the intended interpretations of these definitions

Note 1 to entry: Background materials on the sources, rationale and interpretation of this definition are provided in ISO/IEC 21838-1:2021, Annex B.

[SOURCE: ISO/IEC 21838-1:2021, 3.14]

3.10
schema
formal description of a model

[SOURCE: ISO 19101-1:2014, 4.1.34]

3.11
relation
association amongst entities

[SOURCE: ISO/IEC 15938-5:2003, 3.3.2.29]

3.12
rule
statement in the form of a condition- action sentence that describe the logical inferences that can be drawn from an assertion in a particular form

EXAMPLE A rule can be constructed in the form of "IF-THEN" statements where the IF portion defines a context, and the THEN portion states a provision (which is applicable if the context is true or present).

3.13
structured knowledge
knowledge that are organized based on a pre-defined (applicable) set of rules

3.14
knowledge graph
graph representation of structured knowledge on concepts and relationships between them

Note 1 to entry: A knowledge graph can comprise an ontology and data related to the ontology.

Note 2 to entry: A knowledge graph can be represented as a collection of triples, with each triple (head, tail, relation) denoting the fact that relation exists between head entity and tail entity.

3.15
activity
specified pursuit or set of tasks

[SOURCE: ISO/IEC 22123-1:2023, 3.3.8]

3.16
conceptual model
description of common concepts and their relationships, particularly in order to facilitate exchange of information between parties within a specific domain

[SOURCE: ISO/TS 18864:2017, 3.6, modified — deleted "healthcare".]

3.17
knowledge representation
KR
process or result of encoding knowledge for communication or storage in a knowledge base

Note 1 to entry: As an analogy: data IS-TO code sets IS-TO data engineering AS knowledge IS-TO knowledge representation IS-TO knowledge engineering.

[SOURCE: ISO/IEC 2382:2015, 2123776, modified — replaced "and storing knowledge" with "knowledge for communication or storage"; replaced notes to entry.]

3.18
knowledge modelling
process that establishes and maintains the conceptual model for a knowledge base

3.19
knowledge acquisition
process of locating, collecting, and refining knowledge and converting it into a form that can be further processed by a knowledge-based system

Note 1 to entry: Knowledge acquisition via human learning involves a human learner participating in a learning experience. Knowledge acquisition within knowledge engineering typically implies the intervention of a knowledge engineer. Knowledge acquisition is also an important component of machine learning, both with and without human intervention.

[SOURCE: adapted from ISO/IEC 2382:2015, 28.01.09; replace notes]

3.20
knowledge fusion
process that merges, combines and integrates knowledge from different resources into a coherent form

3.21
knowledge storage
process that designs underlying storage methods based on the types of knowledge representation, utilizes hardware and software infrastructure to store, code and make indexes of the knowledge

3.22
knowledge computing
process that obtains new knowledge based on existing knowledge and their relationships

3.23
knowledge exchange
process that transfers, shares and fuses knowledge amongst multiple knowledge bases

3.24
knowledge visualization
process that visually represents knowledge to support human understanding

3.25
safety
freedom from risk which is not tolerable

[SOURCE: ISO/IEC Guide 51:2014, 3.14]

3.26
reliability
property of consistent intended behaviour and results

[SOURCE: ISO/IEC 27000:2018, 3.55]

3.27
availability
property of being accessible and usable on demand by an authorized entity

[SOURCE: ISO/IEC 27000:2018, 3.7]

3.28
accountable
answerable for actions, decisions and performance

[SOURCE: ISO/IEC 38500:2015, 2.2]

3.29
accountability
state of being accountable

[SOURCE: ISO/IEC 38500:2015, 2.3]

3.30
life cycle
evolution of a system, product, service, project or other human-made entity, from conception through retirement

[SOURCE: ISO/IEC/IEEE 15288:2023, 4.1.23]

3.31
data processing
DP
automated data processing
ADP
systematic performance of operations upon data

EXAMPLE Arithmetic or logic operations upon data, merging or sorting of data, assembling or compiling of programs, or operations on text, such as editing, sorting, merging, storing, retrieving, displaying, or printing.

Note 1 to entry: The term data processing is not a synonym for information processing. Information processing includes data communication (e.g. computer networks) and office automation (e.g. satisfying the business needs of an entity), whereas data processing does not include data communication and office automation.

[SOURCE: ISO/IEC 2382:2015, 01.01.06]

3.32
knowledge engineering system
KE system
system that acquires knowledge from domain experts and other knowledge sources and incorporates it into a knowledge base

3.33
knowledge engineering process
KE process
set of activities that acquires knowledge from domain experts and other knowledge sources and incorporates it into a knowledge base

4 Abbreviated terms

AI	artificial intelligence
IoT	internet of things
KE	knowledge engineering
KERA	knowledge engineering reference architecture
RDF	resource description framework
RDFS	resource description framework schema
OWL	web ontology language
SPARQL	SPARQL protocol and RDF query language
ML	machine learning
NLP	natural language processing
SHACL	shapes constraint language
SKOS	simple knowledge organization system
URL	uniform resource locator
URI	uniform resource identifier

5 Knowledge engineering system-of-interest

5.1 General

KE attempts to emulate the judgment and behaviour of a human expert in a given field. With the growing popularity of knowledge-based systems in recent years, there is a need for a systematic approach for building such systems, similar to methodologies used in software engineering. KE involves acquiring knowledge from domain experts, available data and other knowledge sources and incorporating it into a knowledge base. In addition, the rapid development of big data, cloud computing, natural language processing, computer vison among others have improved the capability of collecting and processing data, which also encourages enterprises and people to put more effort into knowledge-intensive applications based on the discipline of KE. KE began in the late 1980s and has a substantial history, including: knowledge interchange format,[21] knowledge query and manipulation language [22] (Knowledge Sharing Effort, early 1990s), knowledge acquisition data system (KADS) or COMMON KADS (mid 1990s), Cyc [23] (on-going).

5.2 Important elements of knowledge engineering

Important elements of KE involve concepts of:

— deployment;

— infrastructure;

— system;

— system operation restriction;

— demand;

— data;

— knowledge;

— construction;

— knowledge operating.

Figure 1 shows how these element concepts can be structured, decomposed and inter-related:

— The AI system associated with the KE process or KE system is supported through a construction process, which is based on data and information, a knowledge operating process and fundamental infrastructures under system operating restrictions.

— System operating restrictions are extracted from the KE system, such as application scenarios, performance requirements.

— After the KE system is developed, the deployment process is triggered, including integration, deployment and promotion of the KE system.

— During construction and knowledge operating, knowledge is acquired through extracted information from original data, including structured data, semi-structured data and unstructured data.

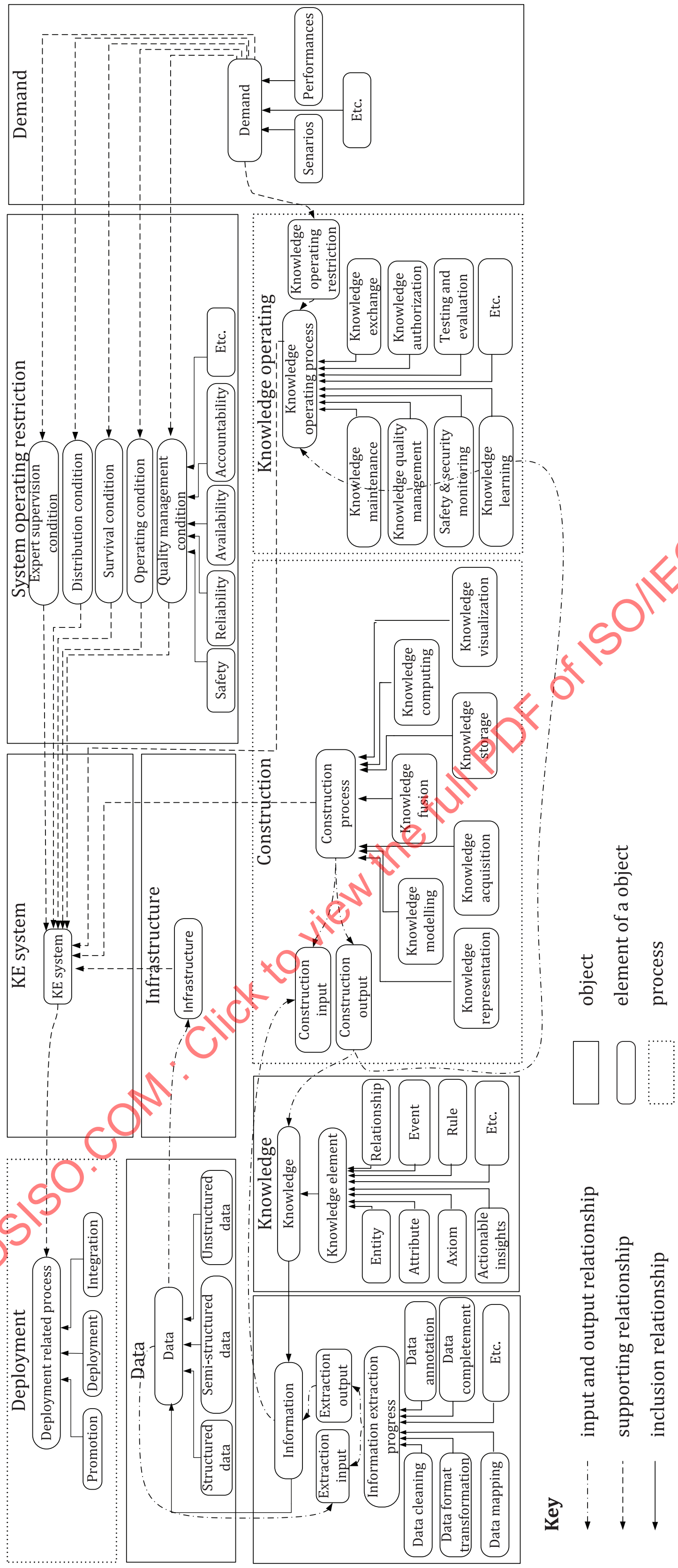


Figure 1 — Important elements of knowledge engineering

5.3 Relationship between KE and AI systems

According to the AI system functional view given in ISO/IEC 22989:2022, reproduced on the left of Figure 2, AI systems leverage existing information, or learning from the past, to build a model that approximates the behaviour of an environment to make recommendations on future behaviours of that environment. Through training data and continuous learning with the help of human in the loop, the machine learning model can be curated and regularly evaluated, updated and approved. The relationship of KE with respect to AI systems is depicted on the right of Figure 2. KE provides the further capability to acquire data, process the data to extract information, and store and exchange data, information or knowledge.

The AI system with KE can acquire knowledge directly from the information extracted from the data and further construct the knowledge base. During the process of data processing, the knowledge in the knowledge base can be applied to inspect and assist the process. At the same time, the knowledge base can maintain, update and verify itself as follows:

— by computing and reasoning new knowledge based on existing knowledge;

— through revisions and updates approved through the curation and synthesis into existing knowledge by an engineer;

— through discovering new knowledge during the data and information processing.

In addition, the knowledge in the knowledge base can be used to:

— govern the input data, such as transferring the data format, cleaning the error in data, supplementing relations among data;

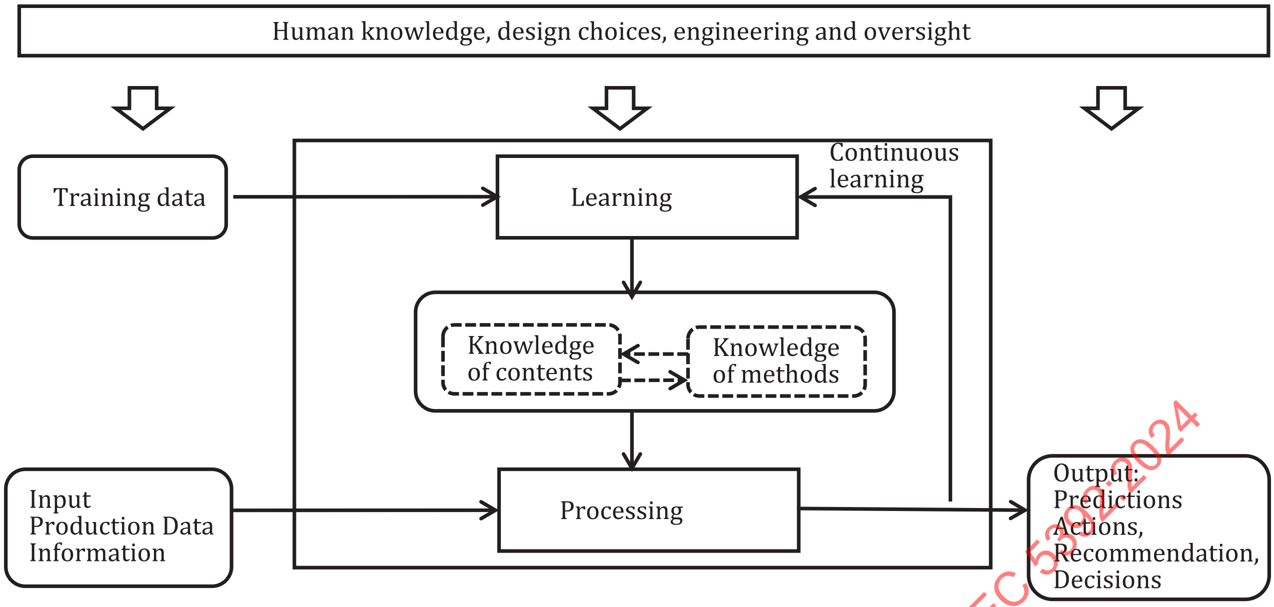
— supervise and explain the learning process or the learning result;

— participate in the learning process as training set.

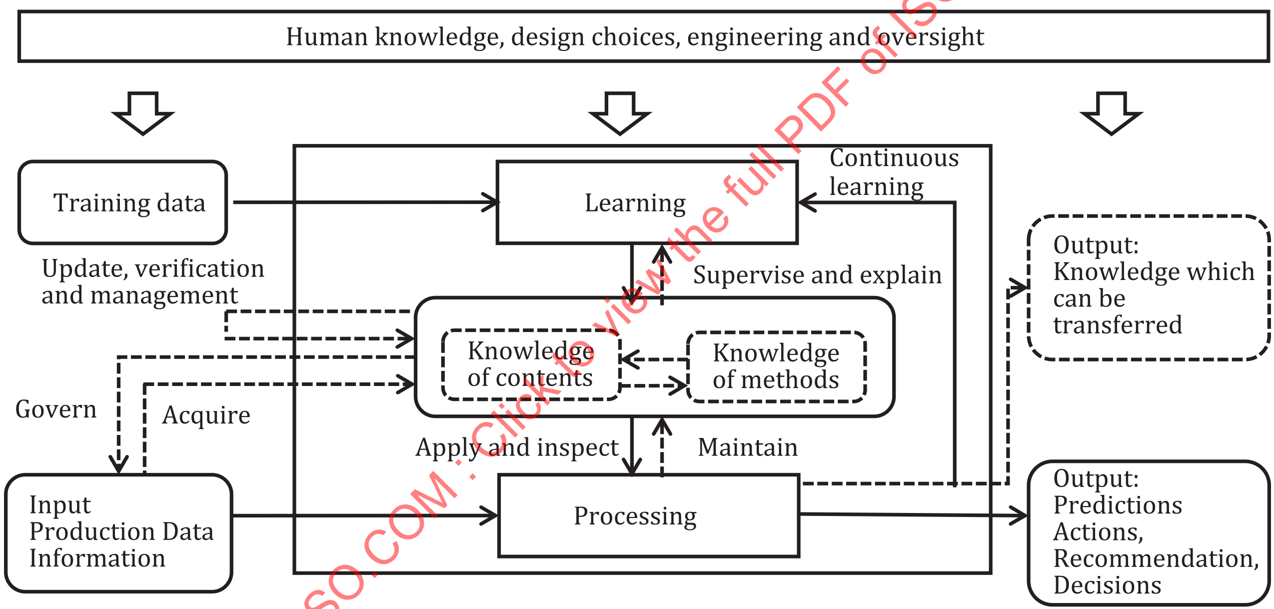
In the constructed knowledge base of the AI system, there are two types of knowledge.

— Knowledge of methods: for example, machine learning models and other models driven by approaches that include data driven and subject expertise captured from an expert.

— Knowledge of contents: the knowledge about subject area in the form of concepts, relationships, entities drawn from texts, videos, and so on, which is acquired from the input data or information and from first principles like physics-based models or biology-based models. The knowledge of contents can be used to supervise and explain the learning process and results as well as to assist to improve the quality of input data and information. At the same time, the knowledge of contents can be used to improve understanding, human knowledge and insight and can be transferred to or have an impact on other AI systems.



a) AI system functional view



b) AI system with KE functional view

Key

---> impact of knowledge engineering

NOTE 1 Revised from AI system functional view of ISO/IEC 22989:2022, Figure 5. The knowledge base is added into the AI system, and the model is set as a type of knowledge of methods. The process of acquiring, updating and maintain knowledge is added. The human knowledge is added into the input. The acquired knowledge can also have influence on the human knowledge. In addition, the output is curated by an expert and added into the knowledge which can be further transferred.

NOTE 2 Dashed lines as shown in the legend represent impacts of KE on AI system.

NOTE 3 The line of continuous learning is a trigger condition to the learning process.

Figure 2 — Relationship between KE and AI systems

Elements of AI systems and KE impact is shown in Table 1. Impact of KE on AI systems is shown in Table 2.

Table 1 — Elements of AI systems and KE impact

Elements of AI system			AI system	KE impact
Building blocking AI system	Learning (optional)		X	
	Knowledge		X	
	Part of Knowledge	Knowledge of content		X
	Part of knowledge	Knowledge of methods		X
	Processing		X	
Interaction with AI system	Human knowledge, design choices, engineering and oversight		X	
	Training data (optional)		X	
	Input (production data, information)		X	
	Output (prediction, actions)		X	
	Output (knowledge which can be transferred, actionable insights)			X

Table 2 — Impact of KE on AI systems

KE Activity	Description	Building blocks involved
Supervise and explain	Knowledge is collected and used as an input to learning	Knowledge, Learning
Update, verify and manage	Knowledge is updated, verified and managed	Knowledge of content, knowledge of methods
Acquire	Knowledge is acquired from input data	Input data, Knowledge
Govern	Knowledge is used to govern input	Knowledge
Maintain	Knowledge is maintained	Processing, Knowledge
Apply and inspect	Knowledge is used (inspected) and applied	Knowledge, processing
Impact methods	Knowledge of content impacts knowledge of methods	Knowledge of content, knowledge of methods
Impact contents	Knowledge of methods impact knowledge of content	Knowledge of content, knowledge of methods
NOTE Each entry in the table corresponds to an impact arrow in Figure 2.		

6 KE stakeholders

Distributed services and their delivery can be at the core of KE. KE stakeholder roles can be categorized as follows:

— data suppliers collect and provide data that can be used to acquire knowledge (see 8.2.1);

— fundamental technology suppliers provide fundamental systems or tools and technologies to support construction of KE (see 8.2.2);

— algorithm suppliers provide necessary algorithms to support construction of KE (see 8.2.3);

— system coordinators integrate tools, technologies, algorithms, data to achieve the construction of KE (see 8.2.4);

— knowledge service providers provide knowledge services based on constructed KE or bases (see 8.2.5);

— knowledge appliers apply KE and knowledge services (see 8.2.6);

— knowledge ecosystem partners support KE development and application (see 8.2.7).

A party can play more than one KE stakeholder role at any given point in time. When playing a KE stakeholder role, the party can restrict itself to playing one or more subroles. Subroles are a subset of the KE activities of a given role. Figure 3 represents the relationships between KE stakeholder roles.

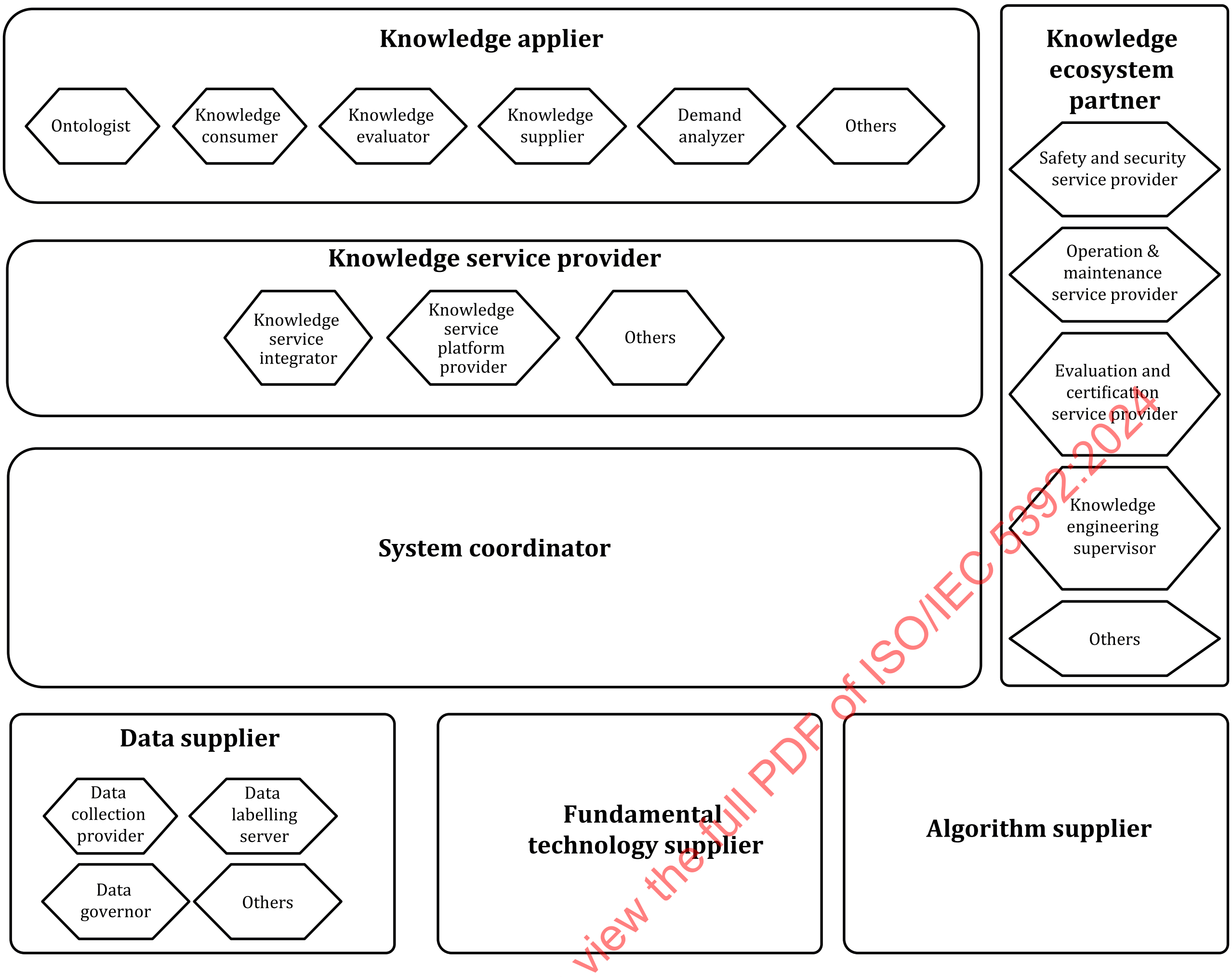


Figure 3 — KE stakeholder roles

KE stakeholder roles can be mapped to AI stakeholder roles from ISO/IEC 22989:2022 as shown in Table 3.

Table 3 — Relationship between AI stakeholder roles and the KE roles

AI stakeholder roles		KE stakeholder roles	Relationship
AI provider	AI platform provider	Knowledge service provider - Knowledge service platform provider	Knowledge service platform provider will provide the knowledge services or products based on the KE system through a platform.
	AI service or product provider		
AI customer		Knowledge applier	Knowledge applier uses the services from the KE system. This role is similar as the AI customer in AI stakeholder roles, which uses an AI product or service either directly or by its provision to AI users.
AI producer		System coordinator	The system coordinator, algorithm supplier and fundamental technology supplier are responsible to develop the KE system through their cooperation. These roles are similar to the AI producer role, which is concerned with the development of AI services and products.
		Algorithm supplier	
		Fundamental technology supplier	

NOTE Safety and security service, operation and maintenance service, evaluation and certification service also have impact on KE application. Thus, by comparing with AI stakeholder roles, Knowledge Ecosystem Partner includes another three subroles: safety and security service provider, operation and maintenance service provider, evaluation and certification service provider.

Table 3 *(continued)*

AI stakeholder roles		KE stakeholder roles	Relationship
AI partner	AI system integrator	Knowledge service provider - Knowledge service integrator	The knowledge service integrator is responsible for integrating tools, technologies, algorithms and data to achieve the construction of KE. This role is similar as the AI system integrator, which is concerned with the integration of AI components into larger systems, potentially also including non-AI components.
	AI data provider	Data supplier	The data supplier role is responsible for collecting and providing data. This role is similar as the AI data provider, which is concerned providing data used by AI products or services.
	AI auditor	Knowledge ecosystem partner - KE supervisor	KE supervisor is responsible for supervising process of construction and application of knowledge bases. This role is similar as the AI auditor, which is concerned with the audit of organizations producing, providing or using AI systems, to assess conformance to standards, policies or legal requirements.
NOTE Safety and security service, operation and maintenance service, evaluation and certification service also have impact on KE application. Thus, by comparing with AI stakeholder roles, Knowledge Ecosystem Partner includes another three subroles: safety and security service provider, operation and maintenance service provider, evaluation and certification service provider.			

7 Concerns of KE stakeholders

7.1 Safety and security

KE systems should ensure that knowledge models and acquired knowledge cannot be tampered with or revealed. Such systems can also ensure that private knowledge and data are secured and protected. The safety and security of KE can be divided into subcharacteristics, such as integrity, transparency, privacy, confidentiality, controllability, correctability and fairness.

Integrity: The KE system has several aspects of integrity, including conceptual integrity, data integrity, compliance of information with all explicitly specified rules, and prevention of knowledge from being altered or destroyed in an unauthorized manner.

NOTE During data integrity, the records include some core elements, such as reality of what happened, consistent according to predefined acceptance criteria, chronological information, i.e. a date and time stamp that is in the expected sequence, the original data without editing.

Transparency: A KE system makes knowledge, models or ontologies, algorithms, computational methods, quality assurance processes and training data available for inspection.

Privacy: A KE system can guarantee the rights of individuals to control the collection, recording, systematization, accumulation, storage, clarification (updating, changing), processing, extraction, use, transfer (distribution, provision, access), depersonalization, blocking, deletion, destruction, and disclosure of their information.

Confidentiality: A KE system can guarantee that the knowledge will not be leaked to unauthorized people at any stage of the knowledge life cycle, including confidentiality of acquired knowledge, computed knowledge and KE system behaviour.

Controllability: Based on a provided, reliable mechanism, an agent can control a KE system, including the verifiability and the predictability of the knowledge in the KE system and the KE system behaviour.

Correctability: A KE system can have the capability to be free from errors and to correct knowledge errors which are acquired and stored in the knowledge base.

7.2 Reliability

A KE system should resist specified interferences, recover from given failures, and so on. The reliability of KE can be divided into subcharacteristics, such as fault-tolerance and portability.

Fault-tolerance: When facing abnormal interference or input data, such as loss of communication and connectivity among the distributed subsystems, failure of the infrastructure, the KE system can maintain its suitably degraded performance level in the event of external interference or harsh environmental conditions. Fault-tolerance requires the KE system or its distributed subsystems to take reliable preventive measures to avoid risk, i.e. to minimize unintentional and accidental injuries and to prevent unacceptable injuries.

Portability: The KE system can be transferred from one or distributed hardware or software environments to another. Knowledge in the system should be retained and merged with knowledge that exists in the new environments.

Completeness: The KE system needs to be fit for the specific use it is put to, and therefore needs to be complete with respect to it. A KE system is complete if all possible conclusions can be reached by the system.

Consistency: The KE system should be free of anomalies and contradictions. A KE system is consistent if it lacks contradictive and redundant knowledge.

7.3 Availability

The KE system can be operational and accessible under the required conditions and within a specified time range. The availability of KE can be divided into subcharacteristics, such as robustness and interoperability.

Robustness: The KE system can have the ability to maintain its suitably degraded performance level under any circumstances.

Interoperability: The KE system can have the capability to exchange information and to use the information that has been exchanged between components or different systems.

7.4 Construction quality

Each phase during the construction of the knowledge base should have clear quality evaluation requirements in order to guarantee the overall construction quality. The construction quality of KE can be divided into subcharacteristics, such as:

— functional evaluation;

— efficiency evaluation;

— user evaluation;

— security evaluation;

— operational and audit evaluation.

NOTE These subcharacteristics are described in ISO/IEC/TS 25058.

7.5 Responsibility

The knowledge base and the applications based on it can:

— correctly represent knowledge about primary and related entities and the attributes and methods that describe them;

— correctly take action and respond to the requests;

— have opportunities to correct and curate knowledge and application bases – under supervision of human experts from the domain – following changes of the domain or environment.

7.6 Bias reduction

The KE system can rely heavily on human experts who are the source of knowledge. Therefore, a KE system should be designed in a way that minimizes human bias. Also, the system can effectively employ various practices-tools-techniques to also unearth inherent bias within the datasets being employed. Further information on human bias reduction can be found in the description of human cognitive bias in ISO/IEC TR 24027:2021,[25] and the degree of transparency and explainability as described in in ISO/IEC TR 24028:2020[26].

8 Reference architecture of KE

8.1 General

This clause provides an overview of architectural approaches used in KE systems. KE systems can be described using a viewpoint approach, including a user view, a functional view, an implementation view and a deployment view. In this document, the main content is focused on the user view and functional view. Transformation between architecture views and the relationship between the user view and the functional view are given in ISO/IEC 20547-3:2020. The description of each view is:

a) User view: describes the ecosystem of KE with the KE activities, the roles and the subroles. The activities, roles and subroles are described as follows.

— activities: KE activities have a purpose and deliver one or more outcomes. Activities are conducted using functional components.

— roles and subroles: A role is a set of KE activities that serve a common purpose. A subrole is a subset of the KE activities for a given role. Different subroles can share the KE activities associated with a given role.

b) Functional view: describes the architectural layers and the classes of functional components within those layers that implement the activities of the roles and subroles within the user view. The functional components of the KE system in the fundamental view have influences on the activities and related roles in the user view, such as the performances. During the implementation and deployment of KE system, the identified problems and updated demands on the KE system can influence its functional components.

c) Implementation view: describes the functions necessary for the implementation of KE.

d) Deployment view: describes how the functions of KE are technically implemented within already existing infrastructure elements or within new elements to be introduced in this infrastructure. During the implementation and deployment of KE system, the identified problems and updated demands on the KE system can influence its functional components.

8.2 User view of KE

8.2.1 Data supplier

8.2.1.1 Role

The data supplier role is responsible for collecting and providing data, which can be used to acquire knowledge from them. The subroles of data supplier include human expert, data collection provider, data labelling server, data governor, and so forth.

8.2.1.2 Activities

Data supplier activities include:

— providing expert knowledge;

— collecting data;

— transforming data;
— cleaning data;
— curating data;
— securing and storing data;
— archiving of data as per data policies;
— annotating data;
— checking for completeness;
— checking for bias.

8.2.2 Fundamental technology supplier

8.2.2.1 Role

The fundamental technology supplier role is responsible for providing fundamental systems or tools and technologies to support the construction of KE.

NOTE The open-source tools can support the knowledge representation, knowledge modelling, knowledge storage and other phases of KE that are included in the fundamental systems or tools.

8.2.2.2 Activities

Fundamental technology supplier activities include:

— researching and designing framework of fundamental tools and products or solutions of technologies;
— designing implementation path of the tools and products or solutions of technologies;
— testing tools and products or solutions of technologies;
— updating tools and products or solutions of technologies;
— maintaining and offering technical support for the provided tools, products and solutions.

8.2.3 Algorithm supplier

8.2.3.1 Role

The algorithm supplier role is responsible for providing necessary algorithms to support construction of KE.

NOTE The algorithms include machine learning algorithms supporting knowledge representation learning, natural language processing, algorithms supporting knowledge acquisition and other algorithms supporting the construction process of KE.

8.2.3.2 Activities

Algorithm supplier activities include:

— researching and designing framework of algorithms;
— designing implementation path of algorithms;
— testing algorithms;
— updating algorithms.

8.2.4 System coordinator

8.2.4.1 Role

The system coordinator role is responsible for integrating tools, technologies, algorithms and data to achieve the construction of KE.

8.2.4.2 Activities

System coordinator activities include:

— capturing knowledge;

— designing framework of knowledge bases;

— designing distributed framework of a KE system;

— integrating distributed subsystems;

— building knowledge model or ontologies;

— constructing knowledge bases;

— maintaining and managing knowledge bases;

— evaluating and guaranteeing quality of knowledge bases;

— updating knowledge;

— maintaining feedback with the stakeholders on the results of the application of the KE system.

8.2.5 Knowledge service provider

8.2.5.1 Role

The knowledge service provider role is responsible for providing knowledge services based on constructed knowledge bases. The knowledge service provider role includes knowledge service integrator, knowledge service platform provider, etc.

8.2.5.2 Activities

Knowledge service provider activities include:

— analyzing and modeling service demand;

— integrating knowledge bases;

— integrating KE applications;

— exchanging knowledge among knowledge bases;

— packaging capability of knowledge bases;

— designing and develop knowledge service platform;

— testing knowledge service platform and provide appropriate results, measures and metrices;

— interpreting newly generated knowledge;

— maintaining the knowledge service platform.

8.2.6 Knowledge applier

8.2.6.1 Role

The knowledge applier role is responsible for applying KE and the knowledge service. The subroles of knowledge applier include ontologist, knowledge consumer, knowledge evaluator, knowledge supplier, demand analyser, etc.

8.2.6.2 Activities

Knowledge applier activities include:

— constructing the ontologies for the knowledge and services according to the application scenarios and domain;

— managing applications;

— utilizing applications;

— managing content;

— evaluating and testing performance;

— confirming and outputting demand.

8.2.7 Knowledge ecosystem partner

8.2.7.1 Role

The knowledge ecosystem partner role is responsible for support on KE development and application. The subroles of knowledge ecosystem partner include safety and security service provider, operation and maintenance service provider, evaluation and certification service provider, KE supervisor, etc.

8.2.7.2 Activities

Knowledge ecosystem partner activities include:

— governing data and knowledge;

— supervising process of construction and application of knowledge bases;

— guaranteeing privacy of knowledge;

— providing computing and network infrastructure;

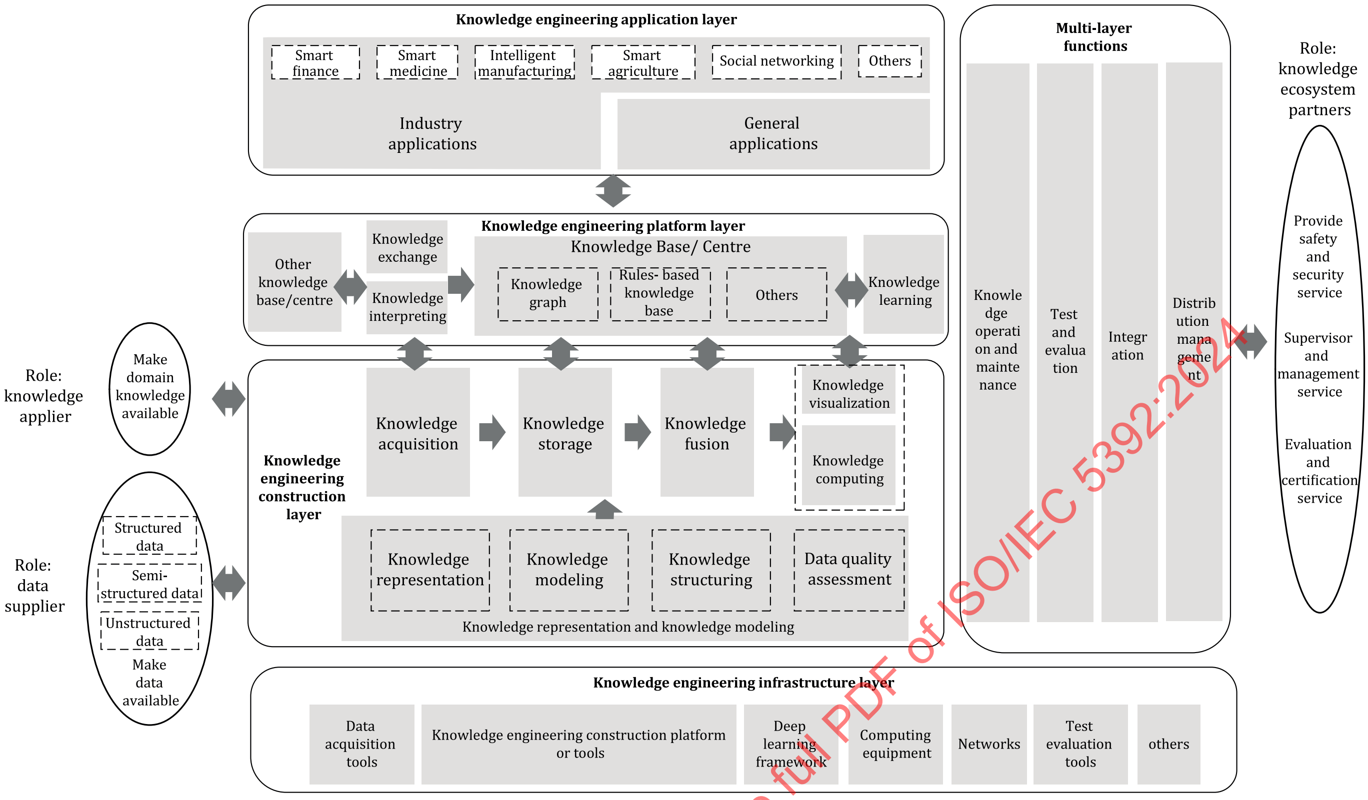
— maintaining the KE system.

8.3 Functional view of KE

8.3.1 Functional architecture of KE

The functional architecture of KE describes KE in terms of a high-level set of functional components layers. The layers represent sets of functional components with similar capabilities that are required to perform the KE activities described in 8.2 for the various roles and subroles involved in the specification and implementation of the KE architecture.

The functional architecture describes functional components in terms of a layering architecture where specific types of functions are grouped into each layer as illustrated in Figure 4. Table 4 shows the relationship between Figure 2 and Figure 4. Annex A shows examples of fundamental KE tools. Annex B illustrates existing standardization activities related to KE. Annex E shows a solution architecture integrating ISO/IEC/IEEE 42010.



Key

input of data, information or knowledge from one component to another component

mutual exchange of data, information or knowledge among the components

Figure 4 — Functional architecture of KE

Table 4 — Relationship table between Figure 2 and Figure 4

AI system with KE functional view	Functional architecture of KE	
	Layer	**Component**
Acquiring of knowledge	KE construction layer	Knowledge representation
		Knowledge modelling
		Knowledge structuring
		Knowledge acquisition
		Detection and reporting of knowledge conflicts
		Knowledge storage
		Knowledge fusion
Knowledge base	KE platform layer	Knowledge base or centre
Continuous learning	KE platform layer	Knowledge learning
Updating, verification and management of knowledge	Multi-layer functions	Test and evaluation
	KE construction layer	Knowledge computing
		Knowledge visualization

Table 4 *(continued)*

AI system with KE functional view	Functional architecture of KE	
	Layer	**Component**
Supervise and explain of learning process and results	KE application layer	Industry applications
		General applications
Apply and inspection of knowledge in data and information processing	KE infrastructure layer	Deep learning framework
	KE application layer	Industry applications
		General applications
Maintenance of knowledge	Multi-layer functions	Knowledge operation and maintenance
		Distribution management
Governance of data and information	KE construction layer	Knowledge representation
		Knowledge structuring
		Data quality assessment
	KE platform layer	Knowledge interpreting
Output of knowledge which can be transferred and actionable insights	KE platform layer	Knowledge exchange
Output of predictions and actions	KE application layer	Industry applications
		General applications

8.3.2 KE infrastructure layer

The KE infrastructure layer is where the resources reside. This includes necessary hardware and software infrastructure for construction, implementation and application of the KE, such as data acquisition tools, KE construction platform or tools (e.g. open-source knowledge processing software or tools), database, storage, open-source processing framework, deep learning framework, computing equipment, networks, testing evaluation tools, open-source library, etc.

8.3.3 KE construction layer

The KE construction layer provides framework and components to acquire, process and analyze knowledge and eventually construct the knowledge base. The knowledge applier and data supplier roles input the data and domain knowledge into this layer, which is the raw source of the knowledge. Data can be from open-source libraries, enterprise data or public data. At the same time, the realization of the component functions, including knowledge representation, knowledge modelling, knowledge structuring, data quality assessment, knowledge acquisition, knowledge storage, knowledge fusion, knowledge visualization and knowledge computing, etc. is supported by the knowledge engineering infrastructure layer. For example, knowledge representation learning depends on the machine learning framework and algorithms.

8.3.4 KE platform layer

The KE platform layer provides a knowledge base or centre and components for knowledge exchange with other knowledge bases. The knowledge base is constructed through the KE construction layer and can be categorized into different kinds according to the forms of its minimum knowledge element. A knowledge base can be based on knowledge graphs or a representation structure based on triples. It comprises ontologies and datasets (e.g. instantiation of the ontologies). The ontologies and datasets are used in a variety of information processing and management tasks.[27] Knowledge learning comprises of adaptive models to continuously interpret new knowledge to enhance the knowledge graph and to improve response. The constructed knowledge base can integrate other knowledge bases through knowledge exchange and knowledge interpreting.

EXAMPLE 1 The KE platform can support following application scenarios:

— enhanced (semantic) applications such as search, browsing, personalization, recommendation, advertisement and summarization;

— improving integration of data, including data of diverse modalities and from diverse sources through algorithms, such as reinforcement learning and unsupervised machine leaning algorithms;

— empowering machine learning (ML) and natural language processing (NLP) techniques;

— improving automation and support intelligent human-like behaviour and activities that can involve conversations or question-answering and robots.

8.3.5 KE application layer

The KE application layer provides the general KE applications and the industry applications, such as smart finance, smart medicine, intelligent manufacturing, smart agriculture, social networking. These functions are achieved through interfaces with the KE platform layer, KE construction layer, the knowledge service provider and the system coordinator roles. Annex C illustrates characteristics of typical KE applications.

8.3.6 Multi-layer functions

The multi-layer functions include a series of functional components that interact with functional components of the KE infrastructure layer, KE construction layer, KE platform layer and KE application layer to provide supporting capabilities including but not limited to:

— knowledge operation and maintenance capabilities;

— testing and evaluation capabilities;

— integration capabilities;

— distribution management;

— system management and maintenance capabilities, which can take the whole life cycle of KE into the consideration. Annex D describes different phases of the life cycle of KE.

8.4 KE distribution architecture

8.4.1 General

There can be several deployment scenarios depending on the size of the KE problem. A KE system and its components can be integrated within different architectures: cloud computing, devices or gateways. To build applications on constrained devices, there is a need to filter and only use what needs to be built in the application due to resource constraints. The KE system can be adapted to constrained devices, by filtering only a subset of the components that are required to build the applications. The distribution architecture of a KE system through web services or APIs is shown in Figure 5.

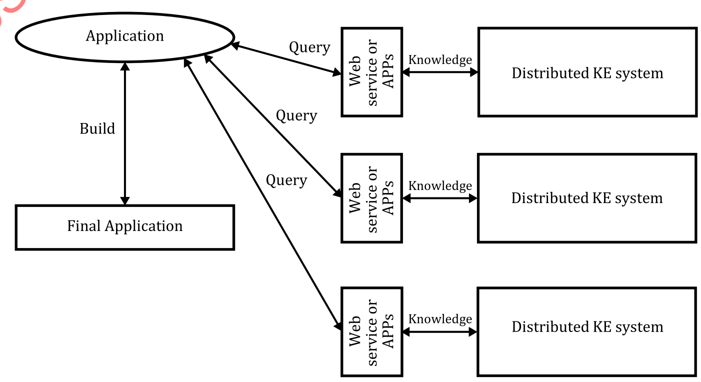
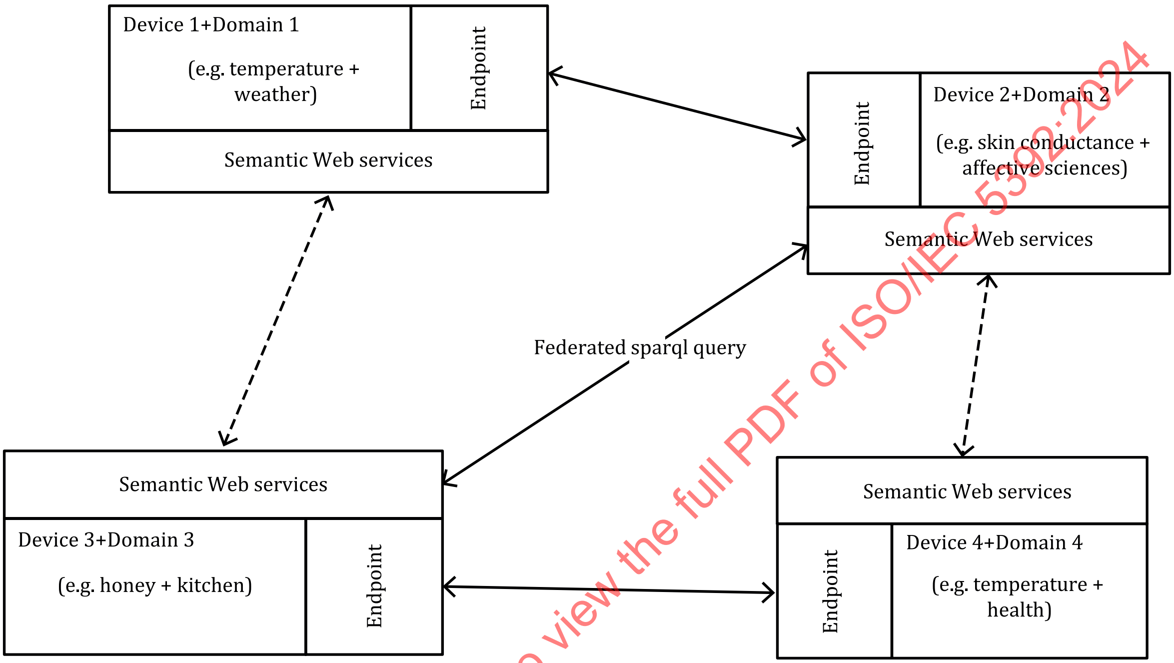


Figure 5 — KE distribution architecture

8.4.2 Distributed architecture with semantic web services

Distributed architecture can enable services to communicate with each other based on a unified language to describe data. Services can interface with each other using semantic web services [29].

The use of semantic web services eases interoperable domain knowledge. Semantic web services and SPARQL endpoints enable open access to data and its high-level abstraction via web services. Figure 6 shows how federated queries enable querying distributed semantic data applied to internet of things (IoT). Device X +Domain Y means that a specific device in a domain, and X and Y represent its number. The dashed lines mean the communication through sematic web services of devices and the solid lines mean the communication through endpoints of devices.



Key

<- - - - -> communication through sematic web services of devices

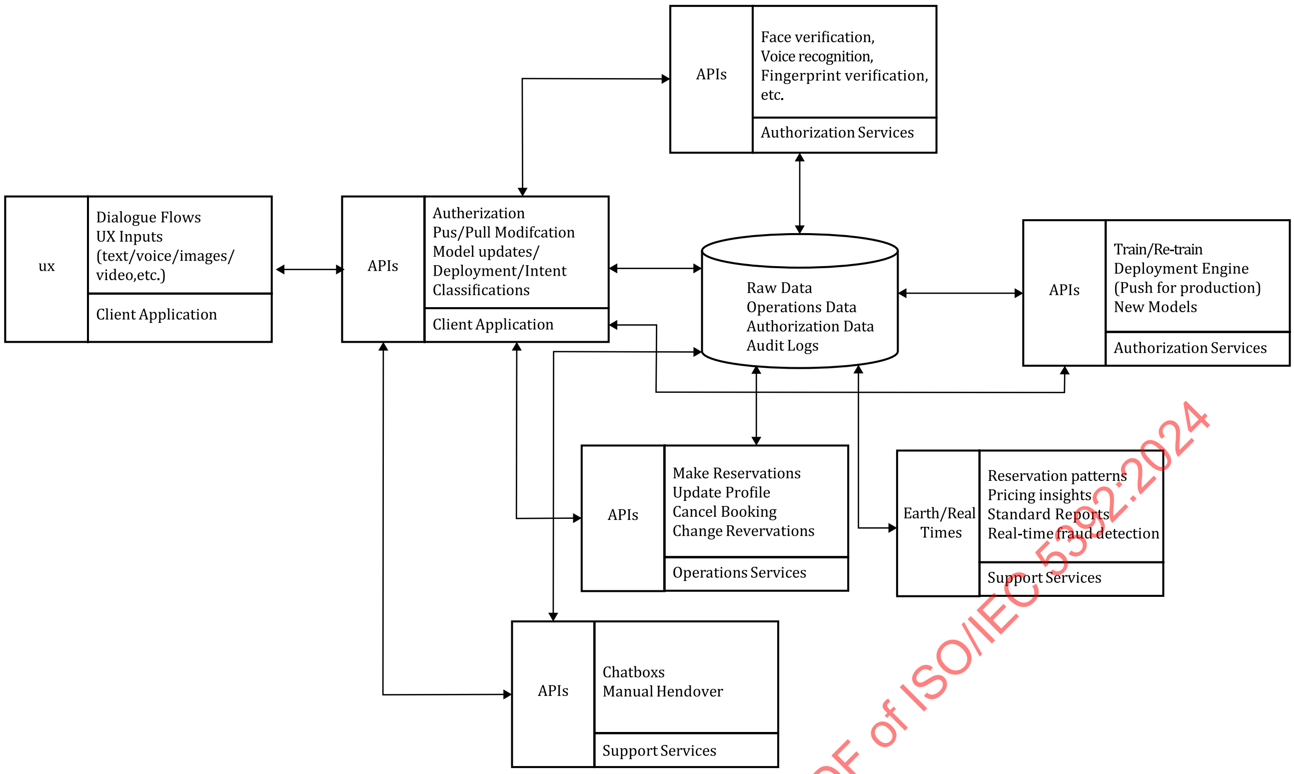
<———> communication through endpoints of devices

Figure 6 — Querying distributed RDF data applied to internet of things

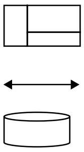
A real-world application of KE can constitute of multiple distributed KE systems as illustrated in Figure 5. Figure 7 depicts an application's architecture that can use chatbots or a website to enable its customers to make reservations for travel or events, etc. Such an application that can scale to cater to thousands of customers can potentially need several KE systems that power specific features.

For example, the client application can be a chatbot or website chat that can accept voice and text as inputs from the customer and deploys AI or ML models that convert speech to text, translate languages, etc. These models are trained and developed in a separate system and regularly updated or upgraded in the client application through the integration services layer. Similarly, Intent classification in the Integration services can be an NLP model that identifies specific intent of the customer and redirects to specific operations services or to a manual handover for support if the intent is not detected by the system. Each of these distributed KE systems are loosely integrated to form a complete system, and yet can be managed or upgraded, scaled and deployed independently.

Figure 7 shows the proposed distributed architecture.



Key



distributed systems

data exchanges among systems

data base

Figure 7 — Example of a distributed architecture

9 Key technologies of KE and computational methods

9.1 Knowledge representation

9.1.1 General

Knowledge representation is focused on designing and constructing symbolic systems, rules, frameworks or other methodologies used to express knowledge which software can recognize and process.

Knowledge representation requires the following capabilities:

— displaying knowledge representations (knowledge graphs and rules, etc.), completely and accurately;

— support for expression of various types of knowledge at any level of detail, such as object properties, rules, events, constrains, formulas and axioms;

— support for the expression of knowledge in a domain or a part of that domain, both fully and completely;

— easily readable by computers and humans;

— support for maintenance of knowledge expression;

— support for the design and implementation of algorithms related to knowledge reasoning and computing based on the forms of knowledge representation;

— traceability on how the knowledge was derived;

— maintenance of different versions of the same knowledge entity, depending on what data was used to derive it.

9.1.2 Knowledge representation quality

To design and maintain high-quality knowledge representation, requirements for the design of high-quality ontologies and datasets are needed. Examples of ontology best practices are shown in Table 5.

Table 5 — Ontology best practices: check list summary [30]

Rule Number	Description	Difficulty level
Rule 1	Finding a good ontology name	*
Rule 2	Finding a good ontology namespace	**
Rule 3	Sharing your ontology online	**
Rule 4	Adding ontology metadata	**
Rule 5	Defining ontology versioning, license and metadata for creators/owners, e.g. owl: versionIRI, owl:versionInfo, dcterms:license, dcterms:creator, vaem:hasOwner	*
Rule 6	Adding rdfs:label, rdfs:comment, skos:definition for each concept and property	*
Rule 7	All classes start with an uppercase and properties with a lowercase.	*
Rule 8	Submitting your ontology to ontology catalogues	**
Rule 9	Reusing and linking ontologies	***
Rule 10	Dereferenceable URI: copy paste the namespace URL of your ontology in a web browser to get the code	**
Rule 11	Checking syntax validator	*
Rule 12	Adding ontology documentation	*
Rule 13	Adding ontology visualization	*
Rule 14	Improving Ontology Design	***
Rule 15	Improving dereferencing URI and content negotiation	***
Rule 16	Ontology can be loaded with ontology editors	**
Rule 17	Registering your ontology on prefix catalogues	*

Key

* represents the lowest difficulty level.

** represents the higher difficulty level.

*** represents the highest difficulty level.

“rdfs: ”, “owl:”, “skos:” means define the concept, property or entity through the language of RDFs, OWL, SKOS, etc.

9.2 Knowledge modelling

Knowledge modelling is focused on establishing a conceptual model for a knowledge base architecture.

The conceptual model requires the following capabilities:

— support for the construction of a conceptual model or ontology for the application scenarios or domains including necessary concepts, relationships amongst different concepts, concept properties, rules and constraints;

— support for conversion of the conceptual model or ontology to the corresponding data format which can be both readable and processable by computer;

— support for the ability to easily edit, revise and update the conceptual model or ontology by the domain experts or maintainers, such as through a visual interface.

9.3 Knowledge acquisition

Knowledge acquisition is focused on extracting structured knowledge from information generated by processing the data sources.

Knowledge acquisition requires the following capabilities:

— support for acquisition of structural knowledge from structured data, semi-structured data and unstructured data, such as media, text and images;

— support for acquisition of knowledge from different sources;

— support for extraction of key concepts in ontologies;

— support for mapping the acquired knowledge to the corresponding concepts, concept properties and relationships in the designed concept models;

— support for conflict detection and resolution.

9.4 Knowledge storage

Knowledge storage is focused on designing the underlying storage method based on the types of knowledge representation, utilizing hardware and software infrastructure to store, code and make indexes of the knowledge.

Knowledge storage requires the following capabilities:

— support for the storage of the knowledge completely and accurately;

— support for knowledge storage under different deployment models, such as distributed or local storage;

— support for storage of metadata that can include audit logs, rules or logic and reasoning applied.

9.5 Knowledge fusion

Knowledge fusion is focused on merging, combining and integrating knowledge from different resources into a more coherent form. Knowledge fusion can involve the following capabilities:

— integration of knowledge from different knowledge resources into a single knowledge base;

— merging of different concept models or ontologies through matching of similar concepts and development of mappings that allow concept instances to be imported or interlinked between knowledge bases;

— support for maintenance of the consistency and accuracy amongst fused knowledge and its corresponding concepts, relationships, properties in the fused conceptual model or ontology;

— support for traceability of how fusion was done.

9.6 Knowledge computing

Knowledge computing is focused on discovering and forming new knowledge, delivering and outputting capabilities based on the constructed knowledge base, which includes statistics and mining of knowledge, knowledge reasoning, etc.

Knowledge computing requires the following capabilities:

— support for conduction of statistics and induction about structure and characteristics of existing knowledge in the knowledge library;

— support for inquiry of complex relationships amongst existing knowledge in the knowledge library;

— support for discovery of hidden knowledge from existing knowledge in the knowledge library.

NOTE In some scenarios related to IoT, the knowledge computing algorithms can be designed based on the defined relation types and entity types in ISO/IEC 21823-3 [31].

9.7 Knowledge visualization

Knowledge visualization is a display capability to support human understanding.

Knowledge visualization assumes the use of a standardized representation to allow for interoperability. It requires the following capabilities:

— support for users to display the knowledge at any level of detail;

— support for users to display the knowledge at the form needed to analyze the knowledge base in a manual or semi-automatic manner.

9.8 Knowledge maintenance

Knowledge maintenance requires the following capabilities:

— support for updating of the existing knowledge to a new version by changing of input data sources, time, top-level concepts, or basic operation or business rules;

— support for managing the different versions of the knowledge;

— support for complement of missed knowledge based on existing knowledge according to axiom, rules, common sense, etc.;

— support for recovering any knowledge that is deleted or handled incorrectly.

9.9 Knowledge exchange

Knowledge exchange is focused on transferring, sharing and fusing knowledge amongst multiple knowledge bases from different organizations.

Knowledge exchange requires the following capabilities:

— support for exchanging the full content of certain knowledge;

— support for indicating the ownership of the exchanged knowledge;

— support for exchanging statistics or computation information of some knowledge under the safety, security and privacy constraints.

10 Enabling technologies and digital infrastructure of KE

10.1 Enabling technologies

10.1.1 Machine learning

Machine learning is an important support technology for knowledge acquisition, knowledge fusion, knowledge modelling, knowledge computing, etc. through algorithms based on unsupervised learning, reinforcement learning, etc. For example, complex reasoning can be realized based on rules, neural networks, etc. In addition, the machine learning based algorithms can be used to acquire knowledge from pictures, videos and other data.

10.1.2 Natural language processing

During KE construction, knowledge is often located or expressed across many documents or audio files. Natural language processing can identify and acquire elements of knowledge from these sources automatically. In addition, the existing knowledge in a KE system can be output to humans through question answering, automatic content generation and other knowledge service forms based on NLP.

10.1.3 Speech processing

Speech is an important input resource for knowledge acquisition. Speech can include the information that the person wants to express and can reflect the emotional information and environmental information.

10.2 Digital infrastructure

10.2.1 Big data

Continuous KE construction and KE applications need to collect, transmit and distribute large amounts of data. At the same time, the collected data can be different in the aspects of sources, formats, data qualities, etc. Thus, data needs to be organized, cleaned and transformed to support subsequent knowledge acquisition. Big data systems can give basic support to these processes through a digital infrastructure.

10.2.2 Cloud computing

Distributed computing is an important deployment model for KE systems. Cloud computing can provide support through distributed storage, large-scale parallel computing, visualization tools, trained AI models, etc. For example, computation capability using cloud computing can help efficiency improvement of complex knowledge computing and distributed storage based on cloud services can support scaling of KE systems. Cloud computing additionally provides ability to scale resources and provide high-scale computing and storage on-demand. KE systems can leverage this to ensure that they scale down and scale out as per requirements instead of securing and committing resources throughout.

Annex A
(informative)

Examples of fundamental KE tools

A.1 WebVOWL ontology visualisation tool

WebVOWL is a tool for visualizing ontologies which are used in knowledge graphs.

A.2 Protégé ontology editing tool

Protégé is a free, open-source ontology editor and framework for building intelligent systems.

— Protégé is extensible and provides a plug-and-play environment that makes it a flexible base for rapid prototyping and application development.

— Protégé supports the OWL 2 web ontology language and RDF specifications.

— Protégé supports the creation, visualization and manipulation of ontologies which can then be integrated with other systems.

Annex B
(informative)

Specifications related to KE

KE standardization activities include the following:

— W3C, *RDF*[1] (resource description framework) is used to represent resources on the Web and their associations. RDF can support knowledge representation in KE construction.

— W3C, *RDF Schema 1.1*[2] is used to provide a data-modelling vocabulary for RDF data. RDF Schema is an extension of the basic RDF vocabulary and is the basic element used to describe ontological information. It can support the knowledge modelling in KE construction.

— W3C, *Ontology web language*[3] (OWL) is used to describe ontological information including class hierarchy and relationship attribute definitions.

— W3C, *SPARQL*[4] (protocol and RDF query language) defines a query language and data acquisition protocol developed for RDF, which is defined by the RDF data model developed by W3C. However, it can be used for any information resource that can be represented by RDF, as well. It can support the knowledge storage in KE construction.

— W3C, *SKOS*[32] (Simple knowledge organization system) is used to express the description of the controlled structured word list, including the word list, taxonomy, title table system. It can support the knowledge modelling in KE construction.

— W3C, *Shapes constraint language (SHACL)*[33] defines a language for validating RDF graphs against a set of conditions. These conditions are provided as shapes and other constructs expressed in the form of an RDF graph. It can support the knowledge representation and knowledge computing in KE construction.

— ISO 15836-1 establishes 15 core metadata elements for cross-domain resource description.

— ISO/IEC 21838-1 specifies required characteristics of a domain-neutral top-level ontology (TLO) that can be used in tandem with domain ontologies at lower levels to support data exchange, retrieval, discovery, integration and analysis.

— ISO/TS 19150-1 defines the framework for semantic interoperability of geographic information. This framework defines a high-level model of the components required to handle semantics in the ISO geographic information standards with the use of ontologies.

— ISO/IEC 24800-2 specifies a series of interfaces to allow disparate systems to support an interoperable management of image repositories. It also specifies the general rules which govern the usage of metadata in JPSearch and provides a specification which:

  — provides rules for the representation of image metadata descriptions, consisting of the definition of the JPSearch Core Metadata Schema;

  — provides rules for the publication of machine-readable translations between metadata terms belonging to proprietary metadata schemas and metadata terms in the JPSearch Core Metadata Schema;

  — provides rules for the registration and request of metadata schemas and its translation rules or links to them.

— ISO/IEC TR 20943-6 describes a method to generate ontologies for a context using concepts in ISO/IEC 11179-3.[36] Most ontologies are basically composed of classes (concepts), properties, relations between classes and instances (objects or individuals).

— ISO/TS 15926-8 provides rules for implementing the upper ontology specified by ISO 15926-2[37] and the template methodology specified by ISO 15926-7[38] in the RDF and OWL languages, including models for reference data as specified by ISO/TS 15926-3[39] and ISO/TS 15926-4[40] and for metadata.

Annex C
(informative)

Characteristics of typical KE applications

Typical KE applications include question answering, recommendation, conversation, automatic content generation, expert systems, decision making systems, preservation and formalization of knowledge, agnostic communication between software components and systems etc. The characteristics of a typical KE application are described in Table C.1.

Table C.1 — Characteristics of typical KE applications

No.	Typical KE application	Introduction
1	Question answering	The traditional question-and-answer system uses the configuration of question-and-answer pairs to achieve a variety of question-and-answer scenarios. With applying KE and NLP, the question can be analysed more deeply in order to find the relationship of the core element in the question and possible hidden meanings. At the same time, the corresponding answer can be more accurate and flexible based on the content of the knowledge base.
2	Recommendation	By analyzing user behaviour, interests, demands and other information, the recommendation KE application makes personalized recommendations most related to the user's actual or deeper concerns through searching and reasoning in the knowledge base. For example, troubleshooting measures can be recommended based on the specific scenario and description of the failure.
3	Conversation	The completion of the conversation task is inseparable from knowledge. Both semantic understanding and conversation management can apply the knowledge library to obtain a more natural and friendly knowledge service mode, which can meet the user's needs and complete specific tasks through multiple human-computer interactions.
4	Automatic content generation	By combining existing data-driven and knowledge-driven text generation models or algorithms, text information can be based on existing knowledge in order to improve its correctness and accuracy. In addition, by introducing common sense knowledge and necessary industry knowledge, the risk of large deviations to the reader can be avoided to a certain extent.
5	Expert systems	The expert system is an AI system that encapsulates the topical knowledge of a human expert and enables nonexperts to use that knowledge to infer solutions to problems. The expert system is composed of a knowledge base and knowledge processing capability and some form of the user interface. The knowledge base stores the specific knowledge on a domain that contains both factual and heuristic information. For more information on expert systems see ISO/IEC 22989.
6	Decision-making systems	In some verticals, such as manufacturing, medical and finance, decision-making systems based on KE can apply rapid search and reasoning of a knowledge base and its relationship to input business data in order to find trends, anomalies and commonalities. Furthermore, the decision-making system can use the acquired knowledge to achieve additional decision-making. For example, it can be used for financial fraud identification, remote operation and maintenance of equipment, research focus tracking and forecasting, computer-aided diagnosis and treatment, etc.

Table C.1 *(continued)*

No.	Typical KE application	Introduction
7	Preservation and formalization of knowledge	Traditionally, knowledge is stored in text, pictures, databases, videos and especially in the minds of experts or business analysts. Structured knowledge in a large scale can be obtained and acquired from these different sources through construction of a KE base. In addition, the acquired knowledge can be formalized based on a selected ontology and can be preserved in a KE base.
8	Agnostic communication between software components and systems	A KE system realizes the unified and specialized expression and storage of knowledge. This provides the foundation for the knowledge exchange amongst different KE systems, which can include more semantic information or information related to the application scenarios and date. In contrast, traditional intersystem communication relies on a large number of set and fixed information models and can just exchange specific information.
When deciding to deploy a particular KE application, it is recommended to always keep in mind that it can be used for harmful, unethical, or criminal activities. For example, "Recommendations" can be used for intrusive target advertising, and "Decision-making systems" to increase inequality between different social groups.		

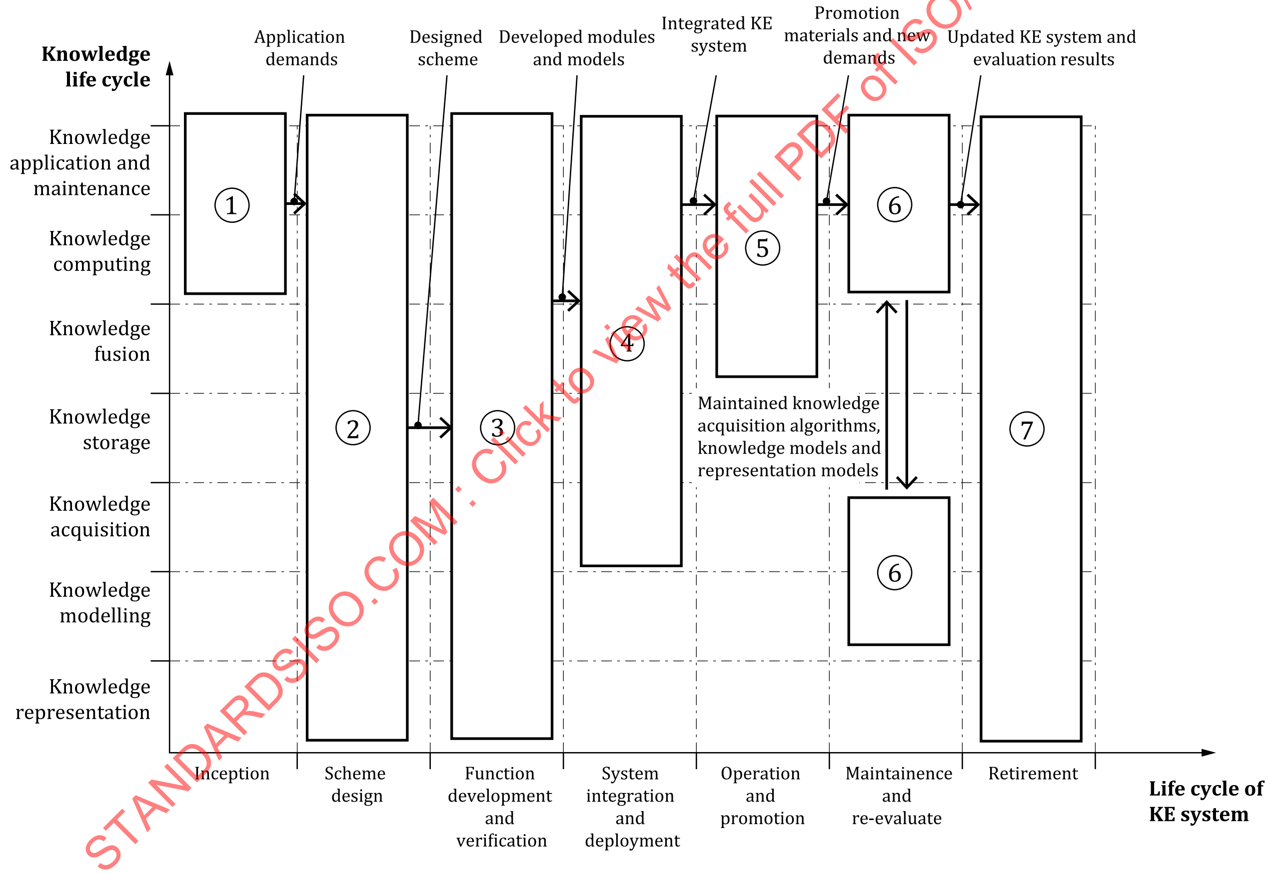
Annex D
(informative)

KE life cycle

The KE life cycle can be described based on the knowledge life cycle and the life cycle of a KE system. The knowledge life cycle can include the stages of knowledge representation, knowledge modelling, knowledge acquisition, knowledge storage, knowledge fusion, knowledge computing, knowledge application and maintenance, etc.

The life cycle of a KE system can include the stages of inception, scheme design, function development and verification, system integration and deployment, operation and promotion, maintenance and re-evaluate, retirement, etc. based on the life cycle of an AI system described in ISO/IEC 22989 and ISO/IEC/TS 25058.

At different stages of a KE system, there are different concerns on the parts of the knowledge life cycle. The process of a KE system is illustrated in Figure D.1.



Key

ⓧ sequence of each block

⟶ output from one stage to the next stage

Figure D.1 — KE life cycle

In each stage, the concerns of stakeholders are described as follows.

— In the inception stage, the stakeholders analyze scenarios and demands of knowledge computing and knowledge application, and determine related performance requirements. At the same time, input data of the KE system to be built, the support system and business system to be connected need to be clarified. The stakeholders can put forward the requirements for data governance when necessary.

— In the scheme design stage, the stakeholders analyze and deconstruct the knowledge representation mode, knowledge model framework, knowledge acquisition requirements, knowledge storage structures, knowledge fusion constraints and other related schemes according to the results from the inception stage. Then, the stakeholders complete the whole scheme of the KE system.

— In the function development and verification stage, the stakeholders complete the development or training of each module in the KE system according to the designed scheme. At the same time, the stakeholders verify and correct the functions and performances of each module based on the basic data.

— In the system integration and deployment stage, the stakeholders integrate the support system and business system related to the functions of the KE system and the application scenarios. At the same time, the stakeholders complete the knowledge base construction according to the obtained business data, domain expert knowledge, industry knowledge and common sense, and finally carry out the actual deployment and joint debugging at the application site.

— In the operation and promotion stage, the stakeholders conduct comprehensive training for system management and application related personnel based on the deployed KE system. At the same time, the stakeholders carry out continuous promotion within the organization or industry to improve the performance and service capabilities of the KE system.

— In the maintenance and re-evaluate stage, the stakeholders adjust and improve the knowledge model, knowledge representation, knowledge computing ability and knowledge application function in the long-term use of the system. Further, the stakeholders ensure the effectiveness and applicability of the system in the application life cycle.

— In the retirement stage, the stakeholders carry out a comprehensive assessment of the KE system composition based on conditions such as cost, technical complexity, when the system functions and performances are difficult to meet the demands of users. The need to retire the KE system also cause some ethical or social concerns about its further use, the requirements of national legislation, etc. At the same time, the stakeholders determine whether to carry out a comprehensive update or retirement of the KE system.

Annex E
(informative)

Building a solution architecture integrating ISO/IEC/IEEE 42010

E.1 Context of ISO/IEC/IEEE 42010 architecture description

ISO/IEC/IEEE 42010 [11] defines two terms: entities of interest and environments:

— an entity of interest represents the subject of an architecture description;

— the environment of an entity represents the context of surrounding things, conditions, or influences upon this entity.

An environment is the "container" for all possible stakeholders and concerns. Figure E.1 shows an entity of interest with an environment where the development environment, the test environment and the operational environment have been displayed.

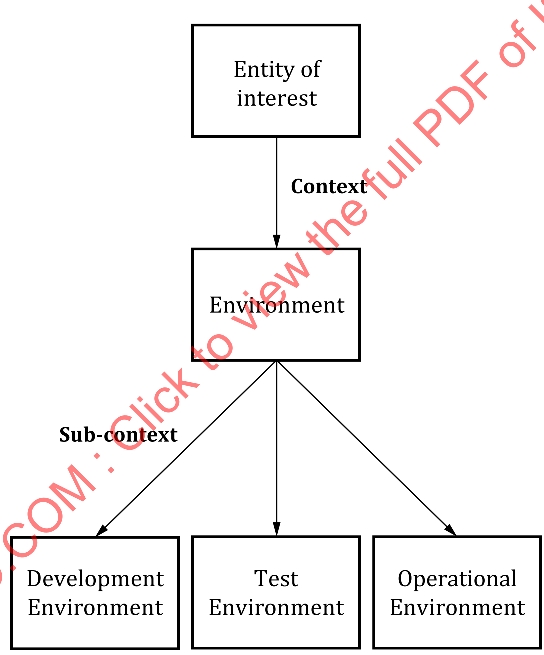


Figure E.1 — Example of entity of interest with three environments

E.2 Reference architecture guidance

According to ISO/IEC/IEEE 42010, the specification of a reference architecture includes the following common views:

— The foundational view: the associated model captures the essential characteristics applicable to the entire set of entities of interest in a domain.

— The business view: the associated model captures business goals to enable the derivation of functional and non-functional requirements.

— The usage view: the associated user model captures expected interactions of users with the entity of interest.