

IEEE Standard for Technical Requirements and Evaluating Knowledge Graphs

IEEE Computer Society

Developed by the
Knowledge Engineering Standards Committee

IEEE Std 2807.1™-2024

STANDARDS

IEEE Standard for Technical Requirements and Evaluating Knowledge Graphs

Developed by the

Knowledge Engineering Standards Committee
of the
IEEE Computer Society

Approved 6 June 2024

IEEE SA Standards Board

Abstract: This standard defines technical requirements, performance metrics, evaluation criteria and test cases for knowledge graphs. The mandatory test cases include data input, metadata, data extraction, data fusion, data storage and retrieval, inference and analysis, and knowledge graph display. This standard can be applied in various organizations that plan, design, develop, implement, and apply knowledge and in organizations that develop support technologies, tools, and services to knowledge graphs.

Keywords: IEEE 2807.1™, knowledge graph, knowledge graph application, knowledge graph construction, knowledge graph evaluation, performance metrics

The Institute of Electrical and Electronics Engineers, Inc.
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PDF: ISBN 979-8-8557-1142-4 STD27267
Print: ISBN 979-8-8557-1143-1 STDPD27267

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Introduction

This introduction is not part of IEEE Std 2807.1-2024, IEEE Standard for Technical Requirements and Evaluating Knowledge Graphs.

Artificial intelligence (AI) applications, including machine translation, speech recognition, image classification, and information retrieval, have achieved remarkable success. AI applications are developing toward expertise AI, like medical diagnosis, autonomous vehicles with AI, and smart factories. Knowledge graphs can assist in linking machine learning experts with experts from different industries, for example, medical care and transportation, and further transform human knowledge into machine knowledge. Knowledge graphs provide a natural and efficient way to represent entities and their relationships in a format that is understandable by machines and humans.

However, knowledge graphs meet a critical need to many enterprises and organizations by providing the structured data and factual knowledge that drives product development. This standard addresses the customer need for a specific and objective way to evaluate the performance of knowledge graphs. This standard can promote the stability, availability, and usability of knowledge graphs, thus lowering the barriers for model selection by users and producers.

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IEEE Standard for Technical Requirements and Evaluating Knowledge Graphs

1. Overview

1.1 Scope

This standard defines technical requirements, performance metrics, evaluation criteria and test cases for knowledge graphs. The mandatory test cases include data input, metadata, data extraction, data fusion, data storage and retrieval, inference and analysis, and knowledge graph display.

1.2 Purpose

The purpose of the standard is to promote the stability, availability, and usability of knowledge graphs, thus lowering the barrier for model selection for users and producers.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

⁶The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEEE Std 2807TM-2022, IEEE Standard for Framework of Knowledge Graphs.^{8,9}

IEEE Std 7002TM-2022, IEEE Standard for Data Privacy Process.

ISO/IEC/IEEE 29119-1:2021, Software and systems engineering—Software testing—Part 1: General concepts.

3. Acronyms and abbreviations

API	application programming interface
CSV	comma-separated values
JSON	JavaScript object notation
OWL	Web Ontology Language
QPS	queries per second
RDF	resource description framework
SDK	software development kit
XML	extensible markup language

4. Quality evaluation framework

A knowledge graph is a structured form of collection including knowledge elements and their connections description. According to the knowledge graph technical framework proposed by IEEE Std 2807-2022 and general concepts of software testing proposed by ISO/IEC/IEEE 29119-1:2021,¹⁰ the knowledge graph construction and application system can be divided into the following functional modules for construction of knowledge graphs:

- Knowledge representation
- Knowledge modeling
- Knowledge acquisition
- Knowledge storage
- Knowledge fusion
- Knowledge computing
- Knowledge provenance
- Knowledge evolution

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⁹IEEE publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>).

¹⁰Information on references can be found in [Clause 2](#).

- Knowledge visualization
- Other related modules

The can also be divided into the following functional modules for application of knowledge graphs:

- Knowledge services
- Knowledge maintenance
- System management
- Other related modules

Accordingly, the quality evaluation framework of knowledge graph construction and application systems is shown in [Figure 1](#) and [Figure 2](#), which can be divided into the following:

- a) Quality evaluation framework for modules related to knowledge graph construction: This focuses on the level of support for various activities during the knowledge graph construction process.
- b) Quality evaluation framework for modules related to knowledge graph applications: This primarily focuses on ensuring the system features during the knowledge graph application process, including the following:
 - 1) Responsiveness: This measure evaluates the system and the accompanying knowledge graph's ability to provide prompt and accurate responses to external input requests or operations. This characteristic can be subdivided into sub-features such as knowledge graph scale, knowledge quality, response efficiency, response accuracy, real-time response, and more.
 - 2) Friendliness: The measure assesses the ease of use, understanding, and learnability of the system and the accompanying knowledge graph. This characteristic can be subdivided into sub-features such as usability, inheritability, maintainability, and more.
 - 3) Reliability: This measure evaluates the system's ability to maintain its availability in the face of external disruptions. This characteristic can be subdivided into sub-features such as availability, maturity, fault tolerance, ease of recovery, and more.
 - 4) Portability: This measure assesses the system and the accompanying knowledge graph's ability to run reliably across various software and hardware systems. This characteristic can be subdivided into sub-features such as compatibility, scalability, and more.
 - 5) Security: This measure evaluates the system and the accompanying knowledge graph's ability to avoid unauthorized access, use, theft, destruction, alteration, forgery, and other potential threats to security. This characteristic can be subdivided into sub-features such as security, confidentiality, controllability, privacy, auditability, and more.
 - 6) Scenario support: This measure assesses the system and the accompanying knowledge graph's capability to support and implement knowledge graph application scenarios across various industries and specific industry-specific use cases.

This framework focuses on key metrics related to knowledge graph construction and knowledge graph application. Some of the basic, general software-related quality evaluation metrics and measurement methods can be referred to in the standards for systems and software engineering. The requirements on data privacy can refer to IEEE Std 7002-2022.

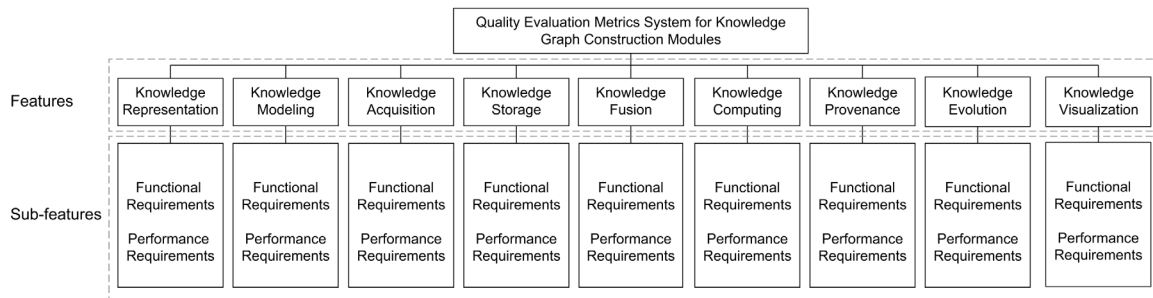


Figure 1—Quality evaluation indicator system for modules related to knowledge graph construction

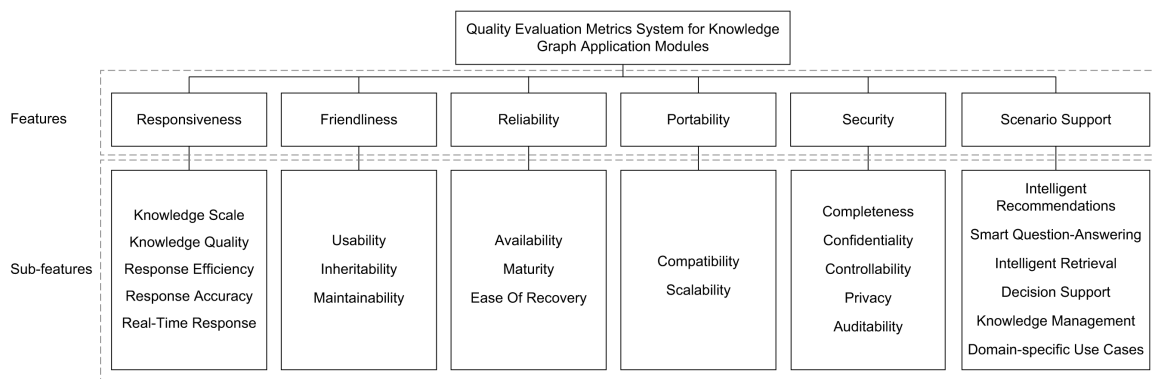


Figure 2—Quality evaluation indicator system for modules related to knowledge graph applications

5. Quality requirements for related modules of knowledge graph construction

5.1 Knowledge representation

5.1.1 Functional requirements

The functional requirements of knowledge representation related modules include, but are not limited to, the following:

- It shall support symbolic representation of knowledge, such as resource description framework (RDF), Web Ontology Language (OWL), rule language, etc.
- It shall support numerical representation of knowledge, such as vectors (including embedding and other forms), tensors, etc.
- It shall support the definition of frameworks, semantic web, ontology, XML, and logical systems, such as first-order logic, higher-order logic, etc.
- It shall support the representation of axioms, rules, constraints, etc.
- It shall support the setting, editing, and modification of namespaces.
- It should support description logic, terminology knowledge, assertion knowledge, etc.

5.1.2 Performance requirements

Performance testing metrics for knowledge representation related modules shall include, but are not limited to, the following:

- a) The expressive ability of knowledge representation models, which is to measure the generalization ability of knowledge representation models on multiple tasks, can be achieved through sampling testing. The expressive ability of knowledge representation models is calculated in [Equation \(1\)](#).

$$X_{R_P} = \frac{A_{R_P}}{B_{R_P}} \quad (1)$$

where

A_{R_P} is the number of representation tasks that the knowledge representation model can achieve
 B_{R_P} is the total number of representation tasks

- b) The computational efficiency of knowledge representation models, which is to measure the time efficiency of the model in generating knowledge representations in specific application scenarios, can be achieved through sampling testing. The computational efficiency of knowledge representation models is calculated in [Equation \(2\)](#).

$$X_{R_P} = \frac{T_{R_P}}{B_{R_P}} \quad (2)$$

where

T_{R_P} is the total time to generate knowledge representations through the knowledge representation model
 B_{R_P} is the total number of knowledge representations which generated by the knowledge representation model

5.2 Knowledge modeling

5.2.1 Functional requirements

The functional requirements of knowledge modeling related modules include, but are not limited to, the following:

- a) It shall support the definition of entity types, relationships, attributes, and events in the ontology model.
- b) It shall support the definition of ontology model constraints, such as upper and lower levels, range of values, and other constraints.
- c) It shall support manual ontology modeling.
- d) It shall support visualization of ontology models.
- e) It shall support manual editing of concepts, relationships, attributes, and other functions.
- f) It shall support the import and export of ontology models and schemas.
- g) It should support semi-automated ontology modeling.
- h) It should support the definition of logical systems.
- i) It shall support multiple presentation languages and storage formats.
- j) It shall support the merging of ontologies.

5.2.2 Performance requirements

Performance testing metrics for knowledge modeling related modules shall include, but are not limited to, the following:

- a) The semantic clarity of the ontology model, which is to measure whether the constructed ontology model provides clear and objective semantic definitions for the terms contained in it, shall be measured through sampling testing. Semantic clarity of ontology model is calculated in [Equation \(3\)](#).

$$X_{o_c} = \frac{A_{o_c}}{B_{o_c}} \quad (3)$$

where

A_{o_c} is the number of entity types and relationship types with semantic description or definition
 B_{o_c} is the total number of entity types and relationship types in the ontology model

- b) The completeness of the ontology model, which is to measure whether the constructed ontology model fully expresses the meaning of the terms in the described field, shall be measured through sampling testing. The completeness of the ontology model is calculated in [Equation \(4\)](#).

$$X_{o_l} = \frac{A_{o_l}}{B_{o_l}} \quad (4)$$

where

A_{o_l} is the number of entity types and relationship types that reach the completeness requirements
 B_{o_l} is the total number of entity types and relationship types in the ontology model

- c) The consistency of the ontology model, which is to measure whether the constructed ontology model can correctly and consistently present objects and information, whether there are conflicts in the definitions of entity types, relationship types, attributes, etc., in the constructed ontology model, and whether the reasoning or calculation results derived from the terms do not conflict with the meaning of the terms themselves, can be achieved through sampling testing. Consistency of ontology model is expressed in [Equation \(5\)](#).

$$X_{o_u} = \frac{A_{o_u}}{B_{o_u}} \quad (5)$$

where

A_{o_u} is the number of entity types and relationship types that meet consistency requirements
 B_{o_u} is the total number of entity types and relationship types in the ontology model

- d) The maximum monotonicity of the ontology model, which is to measure whether there are repeat or overlapping definitions of terms in the ontology model, can be achieved through sampling testing. The maximum monotonicity of the ontology model is calculated in [Equation \(6\)](#).

$$X_{o_m} = \frac{A_{o_m}}{B_{o_m}} \quad (6)$$

where

A_{o_m} is the number of entity types and relationship types that have definition repeat or overlapping
 B_{o_m} is the total number of entity types and relationship types in the ontology model

- e) The generalizability of the ontology models, which is to measure the semi-automatic ontology modeling ability of ontology models, whether they can be applied to new tasks and data sets without