

IEEE Guide for Application of Knowledge Graphs for Financial Services

IEEE Computer Society

Developed by the
Standards Activities Board Committee

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STANDARDS

IEEE Guide for Application of Knowledge Graphs for Financial Services

Developed by the

Standards Activities Board Committee
of the
IEEE Computer Society

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IEEE SA Standards Board

Abstract: The application guide of knowledge graphs for financial services is defined in this standard, the knowledge model of knowledge graphs for financial services is proposed, the general framework of technical activities of knowledge graphs for financial services is given, the process and application methods of constructing knowledge graphs for financial services is described, and the practical application factors for use cases of knowledge graphs for financial services is expounded.

Keywords: consumer finance, credit fund flow tracking, data security, enterprise association analysis, enterprise credit risk management, enterprise risk identification, event evolutionary graph, financial equity-interest analysis, financial fraud detection, financial knowledge assessment, financial knowledge extraction, financial knowledge fusion, financial knowledge modeling, financial knowledge reasoning, financial knowledge retrieval, financial knowledge storage, financial report analysis and reasoning, financial reputational risk management, financial standards and regulations compliance benchmarking, IEEE 2807.2™, intelligent insurance claim settlement, intelligent investment research, knowledge graphs for financial services, practical application factors, property graph, semantic graph, stock forecasting

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Introduction

This introduction is not part of IEEE Std 2807.2-2024, IEEE Guide for Application of Knowledge for Financial Services.

Knowledge graphs are a core technology of artificial intelligence, which is playing a more important role in the financial field. Compared with general knowledge graphs, knowledge graphs for financial services, which are characterized by strong dynamics, complex associations, and risk resistance of financial scenarios. Abstract knowledge management is divided into three categories: events, entities, and concepts by applying object-oriented class/instance independent definition and construction methods to enhance knowledge management effectively. Events that are used to better manage financial risk events, such as policy regulations, enterprise risks, and industry dynamics, which are diverse and changing over time, facilitate prediction of events trending, historical event backtesting, and so on. Entities such as merchants, enterprises, products, services, etc., are multi-factor compositional entity types relevant to business decision-making and are often related to privacy and security, which are described using multidimensional factors to depict their profiles. Concepts are relatively static knowledge classification systems or atomic-level knowledge constraints, such as financial product classifications, event classifications, etc.

Due to the unique characteristics of financial scenarios, there are high demands for maintaining a sound financial ecosystem, combating financial crimes, and protecting user privacy and security. The cross-institutional and cross-platform nature of user/merchant financial behavior also complicates the problem. Each financial institution can only render part of the risk profiling with partial data, while the data of long-tail financial institutions is even sparser. User credit or risk tracking is challenging, and each stage requires the completeness of clues/evidence to achieve credibility and verifiability. Therefore, in addition to the requirements for knowledge management, knowledge graphs for financial services also have high demands for privacy and security, interpretable reasoning, cross-institutional knowledge federation under privacy protection, and knowledge value confirmation and tracking.

Knowledge graphs for financial services can promote knowledge fusion, data communication, knowledge reasoning, and application to improve organization, management, and the understanding of massive amounts of information in the financial field. It can provide technical support for risk assessment, risk prediction, anti-fraud analysis, precision marketing, and intelligent search in the financial services industry. Nowadays, financial institutions and enterprises put more resources into the implementation of knowledge graph technology to provide a more accurate and reliable basis for decision-making in the financial field. There is an urgent need to support the implementation of knowledge graphs for financial services, including the design, development, testing, use, operation, and maintenance of the technology.

However, there is no standardized guide for application of knowledge graphs for financial services yet. Thus, this guide is proposed. This guide defines the application guide of knowledge graphs for financial services, proposes the knowledge model of knowledge graphs for financial services, provides the general framework of technical activities of knowledge graphs for financial services, describes the process and application methods of constructing graphs for financial knowledge, and expounds the practical application factors for use cases of knowledge graphs for financial services.

This guide can help institutions and enterprises to develop knowledge graph applications in the financial field by following the general implementation approach. In addition, it can help suppliers to provide compatible knowledge graph systems under unified financial knowledge models. Under the guidance of this guide, knowledge graph systems for financial services can be simply and effectively constructed and applied so as to form a more complete and standard knowledge service system in the financial industry.

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IEEE Guide for Application of Knowledge Graphs for Financial Services

1. Overview

1.1 Scope

This standard defines guidelines for application of knowledge graphs for financial services. The standard specifies technical framework, workflows, implementation guidelines, and application scenarios of financial knowledge graphs.

1.2 Purpose

This guide assists institutions and enterprises, which develop knowledge graph applications in the financial field to follow a general implementation method. In addition, it may assist the suppliers, such as developers and engineers, to provide more efficient tools to support knowledge graphs in the financial services industry.

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

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.¹⁰

attribute: Describable features (IEEE Std 2807™-2022).

NOTE—It can be expressed by string, numerical value, and other literals.¹¹

concept: *See:* **entity type**.

entity: An object existed independently in the real world (IEEE Std 2807™-2022).

entity type: An abstraction of a certain set of entities with the same attribute. (IEEE Std 2807™-2022) *Syn:* **concept**.

event: Changes of states comprised by one or more actions with the participation of one or more roles, which occurs at a specific point in time or within a specific geographical area or time period (IEEE Std 2807™-2022).

NOTE—An event can be expressed as a combination of entities and relations with the information of time.

event evolutionary graph: A knowledge graph that describes the logic relationship between events, such as continuation and causality, etc.

knowledge: Facts, opinions, actions, or skills acquired through learning, practicing, or exploring (IEEE Std 2807™-2022).

knowledge acquisition: An activity of extracting knowledge from input data with different sources and structures (IEEE Std 2807™-2022).

NOTE—The data source can be classified into three categories by data organization: structured data, semistructured data, and nonstructured data (e.g., plain text, audio, and video data).

knowledge computing: An activity that discovers or acquires implicit knowledge by using constructed knowledge graphs and algorithms to provide knowledge services (IEEE Std 2807™-2022).

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¹⁰*IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>. An IEEE account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹¹Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

NOTE—Types of knowledge computing can be categorized into statistical analysis, knowledge inference, and so on. Statistical analysis refers to statistics and induction of knowledge structures and characteristics of knowledge graphs. Knowledge inference refers to discovery and mining of implicit knowledge from existing facts or relations.

knowledge element: Knowledge unit describing a certain object or concept that is independent and inseparable (IEEE Std 2807™-2022).

NOTE—Knowledge element is an umbrella name for the terms of an entity, concept (entity type), attribute, relation, relation type, event, or rule in this document.

knowledge evolution: An activity that replenishes, updates, or reorganizes original knowledge by using new produced knowledge with changing of ontology models and data resources (IEEE Std 2807™-2022).

NOTE—Knowledge completion may trigger knowledge evolution.

knowledge fusion: An activity that integrates knowledge cell(s) to form a knowledge graph with global unified knowledge identifications (IEEE Std 2807™-2022).

knowledge graph: Assemblies of knowledge elements and their relations described in a structured form (IEEE Std 2807™-2022).

knowledge graph ecosystem partner for financial services: Organizations that provide suppliers, integrators, and users of knowledge graphs for financial services with information infrastructure, data, tools, methods, standards, and mechanisms necessary for the construction and application of knowledge graphs for financial services.

knowledge graph integrator for financial services: Organizations that integrate knowledge graphs for financial services, information systems or services according to knowledge application requirements, and provide knowledge graph application systems and services for financial services.

knowledge graph supplier for financial services: Organizations that use financial industry data, knowledge, etc., to build knowledge graphs to meet specific financial needs, and provide basic tools or services based on knowledge graphs for financial services.

NOTE—Foundational tools and services refer to middleware upon which complex applications or systems can be built.

knowledge graph user for financial services: Organizations or individuals who use the knowledge graph application system and supporting services for financial services to support their own needs.

NOTE—Users of the knowledge graph for financial services can export necessary data or knowledge.

knowledge modeling: An activity that constructs the ontology of a knowledge graph and its formal expressions (IEEE Std 2807™-2022).

NOTE—Knowledge modeling activities include the definition of entity types, relation types, and attributes.

knowledge provenance: An activity that tracks transformation from raw data to knowledge in knowledge graph lifecycle (IEEE Std 2807™-2022).

knowledge reasoning: Knowledge reasoning over knowledge graphs aims to identify errors and infer new conclusions from existing data.

knowledge representation: An activity that describes knowledge acquired by humans while discovering or understanding the real world through machine interpretable symbols and methods (IEEE Std 2807™-2022).

knowledge storage: An activity that designs the storage architecture and conducts knowledge storing, querying, maintaining, and managing by using software and hardware infrastructures (IEEE Std 2807™-2022).

NOTE—Types of knowledge storage usually include, but are not limited to, storage based on relational databases, graph database, and resource description framework (RDF) database.

ontology: A model to describe entity types, entity attributes, and relations among them (IEEE Std 2807™-2022).

NOTE—Ontology is also described as an “ontology model.”

reasoning interpretability: The degree to which people can understand the reason of knowledge reasoning results.

relation: Connection between entities, entity types, combination of entities, or combination of entity types (IEEE Std 2807™-2022).

NOTE—Relation describes the connections between entities, entity types, or an entity and an entity type.

schema: Formalized expression of ontology models (IEEE Std 2807™-2022).

time series analysis: Analyzing time series data in order to extract meaningful statistics and other characteristics of the data.

3.2 Acronyms and abbreviations

API	application programming interface
ATM	automated-teller machine
CV	computer vision
EEG	event evolutionary graph
IT	information technology
NLP	natural language processing
KOL	key opinion leader
OCR	optical character recognition
ODM	original design manufacturer
RDF	resource description framework

4. Model

4.1 Knowledge elements

Model of knowledge graphs for financial services, like general knowledge graphs, includes five types of knowledge elements: entity, event, concept, relationship, and attribute. Related descriptions refer to IEEE Std 2807-2022.¹² In addition, the model of knowledge graphs for financial services also includes extended elements such as property graphs and semantic graphs.

¹²Information on references can be found in [Clause 2](#).

4.1.1 Property graph

A property graph is a graph data structure consisting of two types of elements: vertices and edges. Each element in the graph contains a set of key-value pairs that represent attributes. The property graph is the most concise representation of the knowledge graph. In order to facilitate the rapid landing of financial scenario business, it is necessary to provide expression of property graph which is compatible with standardized concept semantic.

4.1.2 Semantic graph

A semantic graph is equivalent to a knowledge managed by RDF triples based on concept standardization, which has the following properties:

- Each type of element has a domain standardized model, with concept type definitions, such as brand, category, disease classification, etc.
- Each concept type has an entity linking operator for standardization, linking, etc.

4.2 Ontology model

Based on the conceptual model of knowledge graph given by IEEE Std 2807-2022, this standard proposes a set of standardized common ontology models of knowledge graph of the financial industry. IEEE 2807.2 original design manufacturer (ODM), which uses a set of glossary and constraint rules containing terms related to each subject field of finance to define the entity type of financial knowledge, relationship type, attribute of entity or relationship, attribute definition field and naming rules of various financial knowledge elements. It also stipulates the requirements for extension method of IEEE 2807.2 ODM public ontology model.

4.2.1 The research objects

The research objects of knowledge graphs for financial services are listed and described in [Table 1](#).

Table 1—The research objects

Mode of existence		Description	Example
Objective things		Objects that really exist in the objective world	A specific bank
The concept of objective things		An abstraction that represents a set of objective things	bank
Methods		Methods and rules	Bank lending programs
Measurement results		A measure of a certain aspect of something, including constants and variables.	—
—	Constant	Fixed measured value	The size of a certain automated-teller machine (ATM)
—	Variable	Variable measured value	exchange rate
Sets		Can be subdivided into smaller granularity objects	—
—	Spatial set	Objects that can be spatially divided	—
—	—	Physical set	Spatial set in the objective world
—	—	Logical set	The collection of logical cognition
—	Time set	Objects that can be re-divided in time	A bank's plan to go public
—	—	Space-time set	Objects that can be divided in time and space
—	—		A bank listing event

The correlation modes among the research objects of knowledge graphs for financial services can be divided according to [Table 2](#).

Table 2—Correlation modes among the research object

Association mode	Associative symmetry	Object types of interrelated objects	Object scope	Example
Connection	Symmetric	Objective things	Two objects	Inter-enterprise competition
Composition	Asymmetric	Objective things, Set	Multiple objects	Bank card number composition
Belong to	Asymmetric	Objective things, The concept of objective things	Two objects	Banks belong to financial institutions
Functional relationship	Asymmetric	Measurement results	Two objects	Interest and interest rates
Various business contacts	—	All types	—	Exchange

4.2.2 The subject domain

In the model of knowledge graphs for financial services, the modeling object domain can be divided into credit domain, security domain, insurance domain, financial management domain, marketing domain, consumer finance domain, and other subject domains.

The credit domain contains the abstraction of the objects involved in the process of financial credit and their relationships. The security domain contains the abstraction of the objects involved in transaction security and their relationships. The insurance domain contains the abstraction of the objects involved in the insurance claim settlement as well as the underwriting process and their relationship between them. The financial management domain contains the abstraction of the objects involved in the financial management process and their relationships. The marketing domain includes the abstraction of the objects involved in the marketing process of financial products and services and the relationship between them. The consumer finance domain includes the abstraction of the objects involved in consumer finance and the relationship between them.

4.2.3 Modeling method

Knowledge modeling is the definition of the process of abstracting various modeling objects into knowledge elements in knowledge graphs for financial services.

4.2.3.1 Knowledge modeling of the existence mode of the research object

In order to facilitate storage, retrieval, and reasoning in the knowledge graph, except for the measurement results of the constant type, other types of data objects are abstracted as entities in knowledge graphs for financial services. Constant type measurements are recorded as attributes of the entity, as shown in [Table 3](#).

Table 3—Knowledge modeling of the existence mode of the research object

Object type		Knowledge element
Objective things		Entity
The concept of objective things		Entity
Methods		Entity
Measurement results		Entity type
—	Constant	Entity attribute
—	Variable	Entity
Sets		Entity type

Table continues

Table 3—Knowledge modeling of the existence mode of the research object (continued)

Object type		Knowledge element
—	Spatial set	Entity type
—	—	Physical set
—	—	Logical set
—	Time set	Entity
—	—	Space-time set

4.2.3.2 Knowledge modeling of association between research objects

Only binary relationships can be described in general knowledge graphs, while multi-entity association expressions are widely used in financial business scenarios. Therefore, IEEE 2807.2 ODM constructs an event type (entity) to represent the correlation of multiple entities and concept types due to a specific event, adding the expression of time, space, behavior, and other elements to the general entity type.

4.2.3.3 Equivalence relationship modeling

In knowledge graphs for financial services, there are often equivalent relationships between some entities. On one hand, multiple entities with equivalence relations can be fused into one entity; on the other hand, the same entity may play multiple roles in the knowledge graph and need to pay attention to different attributes. In this case, the equivalence relationship between entities can be recorded. There are many businesses in the financial field, and knowledge graphs for financial services shall have the cross-business integration ability of equivalent relational entities.

4.2.4 Representation method

Knowledge representation is the process of using a property graph to represent various knowledge elements of knowledge graphs for financial services.

All objects (including entity types) abstracted as “entities” are represented by nodes.

All associations abstracted as “relation” are represented by directed edges, pointing from the node that represents the head entity to the node that represents the tail entity.

4.2.5 Naming rules of ontology model

Entity type name: Use upper camel case, e.g., Powersystemresource.

Relationship name: Use lower camel case, e.g., connectto, instanceof.

Attribute name: Use lower camel case, e.g., name, id.

4.2.6 IEEE 2807.2-ODM model schema

In order to verify the compatibility and consistency between different knowledge graphs for financial services, the common basic ontology model of knowledge graphs for financial services shall be used, and the standard method can be used to extend the basic ontology model according to the specific application requirements. The ontology model defines the storage and expression method and constraint rules of the knowledge graph. A schema is a standardized form for describing an ontology model, which consists of a vocabulary of terms related to a topic domain and formulas, tables, or graphs that reflect constraint rules.

Knowledge graphs for financial services are consistent with the specification of IEEE Std 2807-2022, and are also composed of ontology layer and instance layer, but in order to facilitate business knowledge management,

knowledge graphs for financial services make an explicit distinction between entities, events, and concepts in modeling. Such distinction is as follows:

- a) Entity: Objective examples with strong business relevance through entity properties (attributes, relationships) to portray individual portraits (such as users, enterprises, merchants, products and securities, etc., entities) because they are the core subjects of business decisions. They also closely relate to privacy security, under the financial graph and usually around the entity to define privacy security capabilities, such as de-identification, encryption desensitization, cross-subject privacy computing, etc.
- b) Concept: Entities represent a set of entities from concrete to general abstraction. It is relatively static and has strong reusability, such as crowd tags, domain standard types, semantic words (such as HowNet), etc. There is also a relatively standardized hierarchical structure within the concept, such as multi-level categories, parent-son brands, etc.
- c) Event: Entity types with time, space, object, and other constraints, such as industry events, enterprise events, and diagnosis and treatment events extracted through natural language processing (NLP), computer vision (CV), etc.

Ontology model of knowledge graphs for financial services, knowledge representation model for semantic enhancement of property graph, and knowledge management framework of knowledge graphs for financial services as shown in Figure 1, Figure 2, and Figure 3.

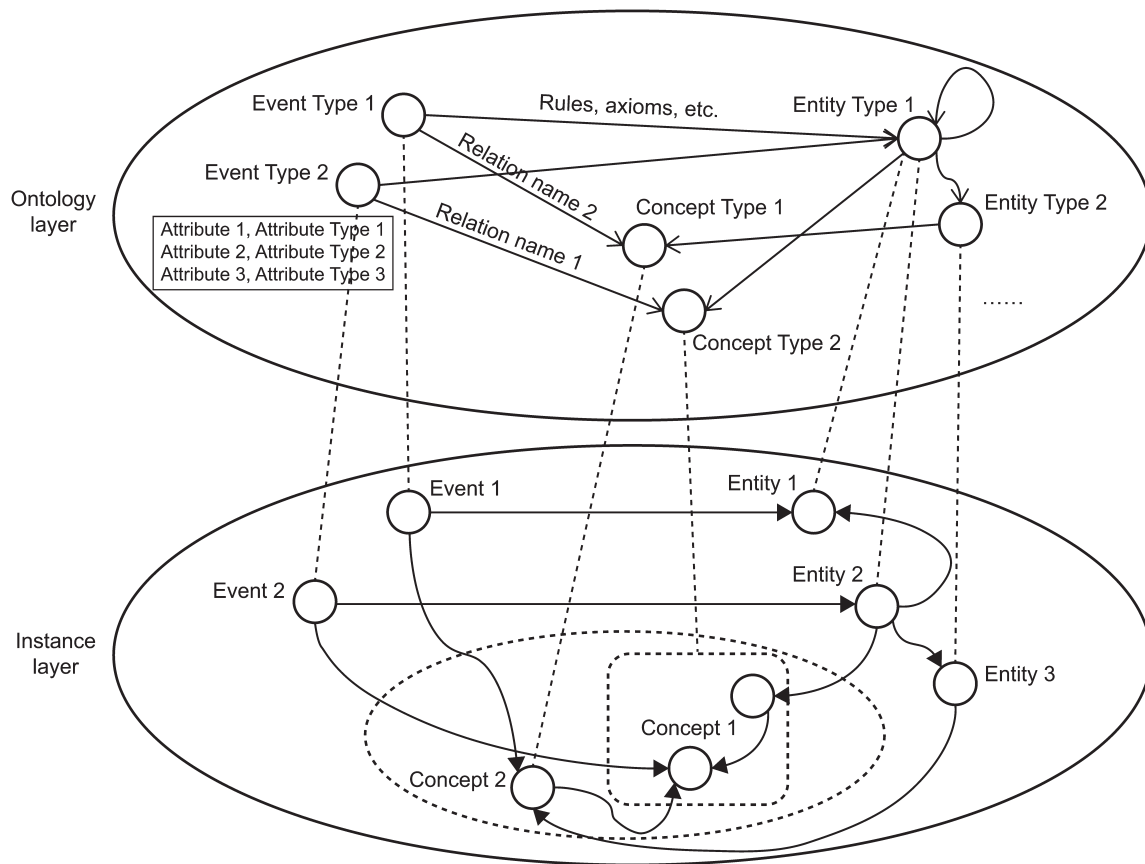


Figure 1—Ontology model

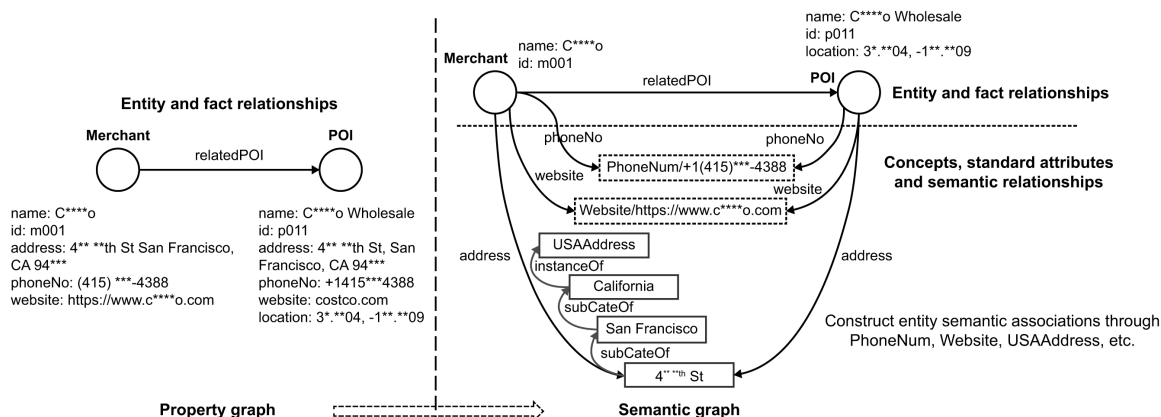


Figure 2—Knowledge representation model of semantic enhanced property graph

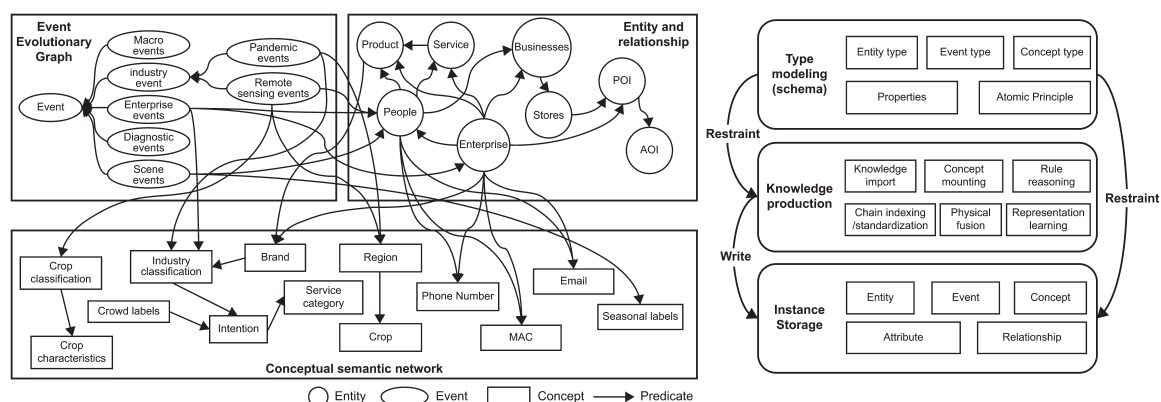


Figure 3—Knowledge management framework

Data security issues of financial scenarios are often related to users, enterprises, merchants, and other entities, while brands, categories, financial products, risk classification, etc., are relatively general knowledge. As the key driver of risk discovery, events cannot be simply attributed to the combination of multiple entities, but also can describe the evolution due to changes in time and space. With a clear definition of the previous classification, it can better describe the risk law, better service supervision and data security, and effectively realize the precipitation of financial core knowledge elements.

4.2.6.1 Entity type definition

Each entity type needs to declare its type name, superior entity type, proprietary attributes, and explain its meaning and other supplementary information. Taking the bank entity type as an example, the entity type is described by Table 4.

Table 4—Example of entity type definition

Entity type name	Bank
Meaning	Financial institutions that absorb deposits from the public, issue loans, handle settlements, etc.
Superior entity type definition	Financial institution

Table continues

Table 4—Example of entity type definition (continued)

Entity type name	Bank			
Description	Financial institutions include banks, securities enterprises, insurance enterprises, trust and investment enterprises and fund management enterprises, etc. Banks are a type of financial institutions.			
Proprietary attribute	Attribute name	Attribute value type	Attribute value range	Description
	Reserve requirement ratio	percentage	0% to 100%	The ratio of the bank's deposit reserves to the central bank to its total deposits.

4.2.6.2 Relationship type definition

Each relationship type needs to declare its type name, relationship attributes, and relationship constraints (the definition domain declared by the starting entity type and the value range declared by the end entity type) as well as explain its meaning and other supplementary information. Take the transactional relationship as an example, which is described by Table 5.

Table 5—Example of relationship type definition

Relationship type name	Transaction		
Meaning	It is the act of exchanging valuable goods and services between buyers and sellers		
Description	It can be money as a medium of exchange or barter.		
Relational constraints	Start entity type	End entity type	Description
	Natural persons/enterprises	Natural persons/enterprises	The buyer and seller can be natural persons or corporations
Relational attribute	None		

4.2.7 Extension of model

The extension of knowledge graphs for financial services should follow the principle of downward compatibility. That is, the extended ontology model is compatible with the ontology model before expansion.

Extensions can follow any of the following ways, from simple to complex, including:

- Adding attribute(s) to an entity type without subclasses.
- Adding attribute(s) to a relationship type.
- Adding attribute(s) to entity types with subclasses, and all descendant types of this type inherit the newly added attributes.
- Adding a new entity type, which is a subclass of an existing type and inherits the attribute definition of the parent class.
- Adding new relationships to connect existing entity types.
- Adding attribute(s) to an attribute.

4.3 Expert rules

There are a large number of expert rules in the financial field. The answer as to how to combine expert skill rules with knowledge definitions and form effective representations needs to include the following capabilities: