Research on the Construction of Event Logic Graphs for Major Emergencies: Postprint

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Abstract

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Full Text

Preamble

Research on the Construction of Event Knowledge Graphs for Major Emergencies

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Abstract

[**Purpose/Significance**] Major emergencies constitute an important component of the overall national security concept. To respond to major emergencies more rapidly and efficiently, and to reduce threats to national security, social stability, and people's lives and property, this paper proposes constructing an event knowledge graph for the major emergencies domain. By revealing the evolutionary patterns and logic of major emergencies, this approach can assist relevant departments in responding to and making decisions about major emergencies. [**Method/Process**] This study selects media reports, research reports, and academic papers on the COVID-19 pandemic that have attracted international attention and widespread impact. Through ontology construction, event extraction, and event relationship extraction, we construct an event knowledge graph for major emergencies and analyze the logical knowledge and transmission paths of event evolution. [**Result/Conclusion**] The research results demonstrate that the event knowledge graph for major emergencies can reveal the evolutionary logic and patterns of such events, enabling macro-level understanding of event development trajectories and providing scientific and accurate foundations for emergency response and governance.

Keywords: major emergency; event knowledge graph; ontology; event logic mining
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Introduction

Since the 21st century, major emergencies have erupted worldwide, including the 2003 SARS outbreak, the 2004 Indian Ocean tsunami, the May 12, 2008 Wenchuan earthquake, the 2011 Tōhoku earthquake and subsequent Fukushima nuclear leak, the 2014 Ebola virus outbreak, and the COVID-19 pandemic declared a "Public Health Emergency of International Concern" by the World Health Organization (WHO) [1]. These major emergencies, encompassing natural disasters, accidents, public health incidents, and social security events, pose enormous threats to life and property in affected regions. Their inherent urgency and uncertainty present tremendous challenges to stable development worldwide. Meanwhile, the advent of the big data era has rendered traditional expert-based emergency decision-making inadequate for processing massive volumes of data. Consequently, exploring a method for major emergency response that aligns with contemporary developments is particularly crucial. This paper proposes integrating event knowledge graph methodology with major emergencies to construct a major emergency event knowledge graph, examining relevant content from a knowledge-driven perspective and providing a new research angle for addressing domain-specific challenges.

2 Research Status

A review of domestic and international research on event knowledge graph construction reveals that Chinese scholars primarily focus on building domain-specific knowledge graphs for particular event types. Feng et al. [2] constructed an urban waterlogging event knowledge graph, proposing a causal analysis application framework that extracts causal event sentences from Chinese urban waterlogging corpora using rule-based templates, employs a deep neural network fusion method based on voting mechanisms to extract events from causal sentences, and integrates manual rules to build the waterlogging event knowledge graph. Sun Xinrui [3] utilized open-source data to construct traffic knowledge graphs and event knowledge graphs, using traffic knowledge graphs for traffic event identification in Weibo text and object detection for images in Weibo posts to further improve identification accuracy for three event types. Hu Huan [4] constructed a causal event knowledge graph for hot topics, using event extraction technology to extract event elements and event relationship extraction technology to obtain logical relationships between events, thereby implementing topic query and intelligent question-answering functions. Liu Zhongbao et al. [5] proposed a method for extracting historical events and their components from the *Records of the Grand Historian* based on the BERT model and LSTM-CRF model, constructing a *Records of the Grand Historian* event knowledge graph.

Foreign scholars generally define event-centered knowledge graphs as "event knowledge graphs," with events as nodes. Their research directions primarily fall into two categories: practical applications and algorithmic improvements. Compared to domestic scholars, foreign researchers place greater emphasis on practical applications, tightly integrating knowledge graph theory with real-world industries to leverage predictive and decision-making capabilities and solve practical problems through industry data. Research demonstrates that foreign scholars have applied knowledge graphs in financial stock prediction, aviation accident decision-making, chemical accident decision-making, special operations risk warning, disaster events, and healthcare, confirming that knowledge graph methods perform well in solving real-world problems. This problem-oriented research perspective holds significant meaning for addressing societal challenges. Q. Mao et al. [6] introduced Evolutionary Event Ontology Knowledge (EEOK), which constructs evolutionary patterns for five event domains: explosions, fires, geological disasters, traffic accidents, and personal injuries, proposing an event prediction model to capture intrinsic evolutionary patterns. H. L. Nguyen et al. [7] proposed a novel method for representing social events and their relationships as knowledge graphs to discover and decompose social events, effectively enhancing event comprehensibility and traceability. P. Heyvaert et al. [8] introduced the Semantic Academic Event Dissemination (SAD) generator for producing RDF and academic event websites, which includes CSV files of academic event data and uses annotations to generate knowledge graphs and event information websites for querying event knowledge graphs. Y. Zhao et al. [9] focused on event detection tasks, constructing an event-centered knowl-

edge graph for event extraction and detection that can identify event triggers in document sentences and classify event types.

Based on this literature review, although event knowledge graph research has achieved rich results, two critical gaps remain: (1) diverse knowledge graph construction methods exist, but no systematic research paradigm for major emergencies has formed; and (2) deep logical relationship mining and understanding of major emergency event knowledge graphs are lacking. In response, this paper collects data related to major emergencies to construct an event knowledge graph, mining logical relationships between events and summarizing evolutionary patterns.

3 Major Emergency Event Knowledge Graph Construction Process

The construction process for major emergency event knowledge graphs in this paper is shown in Figure 1 [Figure 1: see original paper]. Combining the characteristics and nature of major emergency research, the construction process primarily includes three major components: major emergency event ontology construction, major emergency event extraction, and inter-event relationship extraction. Ontology construction encompasses event representation models and core concept determination. Event extraction includes event framework construction, event type identification, event element recognition, and event generalization. Relationship extraction mainly involves template acquisition and template generalization.

3.1 Major Emergency Event Ontology Construction

3.1.1 Event Ontology Representation Model Domain ontology is an important tool for representing and describing knowledge structure systems in specific domains based on semantic relationships between concepts, and has become an indispensable foundational element for domain knowledge mining [10]. Ontology representation models can pre-analyze and determine event component frameworks, complex event element roles, and relationships between events such as causal and sequential relationships, enabling unified event representation. Ontology describes the most basic concepts, relationships, and attributes. The major emergency event domain ontology possesses typical characteristics of event ontologies, representing a normalized and formalized expression of generalized, shared conceptual models for the major emergency knowledge domain. It can reuse foundational conceptual models and knowledge structures from existing event ontologies, as shown in Table 1 , such as StoriesOntology [11], StorytellingOntology [12], ABCOntology [13], Activity Ontology [14], and the Event Six-Element Model [15], which are primarily applicable to general domain texts. The core concepts of each event semantic model are presented in Table 1.

Through reviewing and summarizing currently general ontology representation

models, we can grasp domain-general concepts at the macro level, laying the foundation for determining core concepts in the upper ontology discussed later.

3.1.2 Core Concepts for Major Emergency Events The design of major emergency event ontology concepts includes two components: ontology reuse and custom concepts. First, **ontology reuse**: based on major emergency characteristics and referencing general domain event semantic representation models and semantic vocabulary classification dimensions, we selectively reuse Event, Situation, and Action from ABC Ontology, as well as Type, Time, and Place from SEM. Second, **custom concepts**: referencing various emergency plans issued by the State Council and other emergency management departments, we collected and organized domain ontologies for environmental pollution events, natural disasters, fire emergency management, social security incidents, and food safety emergencies. We extracted and generalized core concepts involved in these ontologies while also referencing existing emergency domain ontology models. Combining crawled major emergency corpus data, we identified custom concepts through keyword extraction, synonym sets, and concept extraction. The final core concepts for major emergencies are shown in Table 2 .

The upper ontology layer [16] includes concepts of Event, Situation, and Action. The domain ontology layer includes event type, level, time, location, event situational risk, solution, event subject, and event object. Location comprises specific locations and reference locations. Event situational risk includes casualties, property loss, and event impact. Event impact consists of public opinion and public policy components.

3.2 Event Extraction in the Major Emergency Domain

Event extraction is the core component of knowledge graph construction, referring to the process of extracting user-interested events from unstructured information and presenting them in structured form. Our event extraction process primarily includes event framework construction, event type identification, event element recognition, and event generalization. First, we preprocess sentences in the major emergency corpus, including word segmentation, part-of-speech tagging, syntactic analysis, and semantic analysis. Then, based on the major emergency ontology, we construct event frameworks. According to these frameworks, combined with event triggers and domain-specific feature words, we construct rules to identify triggers and event types. Next, we use a BERT-BILSTM-CRF model to extract event elements. Finally, we employ word embedding models and K-Means to cluster events, achieving event generalization. The BERT+BILSTM+CRF model architecture is shown in Figure 2 [Figure 2: see original paper].

3.3 Event Relationship Extraction in the Major Emergency Domain

Event relationship extraction examines external associations between events. Inter-event relationships describe event transformation states, so extracting

these relationships can reveal event evolution logic and enable macro-level understanding of event development trajectories. This paper employs pattern matching methods for event relationship extraction, using a domain causal relationship template library-based approach combined with semantic-syntactic kernel functions to extract causal connectives. We constructed three types of event relationship extraction templates; due to space limitations, only partial template content is shown in Table 3 .

We use syntactic analysis to process sentences and generate syntactic structure trees. Then, we compare sentence similarity to extract sentences with similar syntactic structures to those in the corpus, calculating similarity using the number of common subtrees between syntactic trees. Finally, we employ the BERT model to express semantic features of sentences, obtaining causal relationship instance sentences with identical semantics and similar syntactic structures.

4 Empirical Study on Major Emergency Event Knowledge Graph Construction

4.1 Major Emergency Event Knowledge Graph

This study selected 13,378 media reports, research reports, and academic papers on COVID-19 from China News Service, WHO websites, and *The Lancet*, among others. Using Python-based web crawlers, we collected data from these platforms on January 20, 2021. Following the knowledge graph construction steps described above, we obtained an event knowledge graph for public health emergencies within the major emergency domain. This graph is a dynamic knowledge graph centered on events, containing 14,413 events and 14,252 edges, as shown in Figure 3 [Figure 3: see original paper].

To more clearly display event nodes in the graph, we extracted the subgraph "COVID-19 Pandemic" from the public health emergency event knowledge graph, shown in Figure 4 [Figure 4: see original paper]. Figure 4 represents a portion of the public health emergency event knowledge graph, where nodes represent individual events. The COVID-19 pandemic serves as the central node, with other nodes representing representative cause and effect events related to this event. Edges represent causal logical relationships between events. The COVID-19 pandemic knowledge graph contains 26 nodes and 38 directed edges, where directed edges connect pairs of causal events and the direction represents causal relationships. For example, in the chain "information disorder → politics → healthcare → community transmission → COVID-19 pandemic," information disorder is the cause event for politics, politics is the effect event of information disorder and the cause event for healthcare, and healthcare is the effect event of politics, forming a complete logical evolution chain. The event knowledge graph thus constitutes a dynamic logical knowledge base about a specific event.

4.2 Analysis of Event Causal Logic Knowledge

Event knowledge graphs represent logical linkages centered on events. Analyzing logical knowledge within these graphs can deduce event evolution logic and entire processes. Using COVID-19 as an empirical case, we extracted event logic knowledge after event extraction and causal relationship extraction, shown in Table 4 .

Analyzing the extracted event logic knowledge reveals that COVID-19 produces numerous consequences with extensive impact scope, affecting multiple aspects of social life including economy, entertainment, tourism, aviation, medical supplies, and oil markets. During event evolution, the COVID-19 pandemic interacts with people and information while also causing resultant events such as information epidemics and information disorder. Additionally, the COVID-19 knowledge graph presents objective facts, including cause events that trigger the novel coronavirus, such as COVID-19 being caused by the novel coronavirus, healthcare impacts on the pandemic, and community transmission leading to the pandemic. Notably, the knowledge graph also derives implicit knowledge beyond human reasoning, such as information disorder leading to racial discrimination. In summary, major emergency event knowledge graphs establish associations between events under a specific theme, and deep mining can present event development contexts. The logical knowledge in event knowledge graphs helps people understand events, clarify event essence, and comprehensively mine associated events, providing event managers with response directions and enabling decision support [17].

4.3 Mining Event Transmission Paths

4.3.1 Event-Driven Transmission Paths Driven transmission paths represent the logic that guides overall event logical context development and drives event evolution. The event-driven transmission chain in knowledge graphs contains logical chain information for major emergencies. By defining event-driven transmission links and mining this information, we can discover driving contexts of major emergencies and depict transmission mechanisms of event logical chains. As shown in Figure 5 [Figure 5: see original paper], driven transmission paths connect cause and effect events through single paths without interconnections or cross-relationships between events—each cause event corresponds to a unique effect event, and each effect event corresponds to a unique cause event. Event evolution-driven transmission paths are represented by bold lines in the knowledge graph. In the COVID-19 knowledge graph, driven transmission paths include COVID-19 pandemic → racial discrimination, COVID-19 pandemic → medical and livelihood supply shortage, and COVID-19 pandemic → global pandemic.

Analysis of these driven transmission paths reveals that the pandemic primarily involves driving events including COVID-19, community transmission, information epidemic, and information disorder, indicating these events are important

indicators affecting pandemic evolution and key factors driving event development. Effective identification of driven transmission paths can provide crucial practical support for relevant departments. Analysis shows that the coronavirus pandemic causes community transmission, information epidemics, and information disorder, demonstrating that event evolution is greatly influenced by online information dissemination. Real-world event occurrence and development trigger public opinion dissemination, which creates information disorder phenomena during propagation, further generating rumors and negative public opinion. For COVID-19, most people obtain information through social media and search engines rather than official media. Compared with official media and news agencies, these unofficial channels provide less credible event-related information. Combined with weak public ability to identify information authenticity online, information disorder phenomena become increasingly severe. If relevant departments fail to intervene and control information disorder in a timely manner, public skepticism toward authoritative sources and professional news agencies will threaten authentic event information and expand negative event impacts. Mining and analyzing driven transmission paths can clarify event development contexts and provide important foundations for event decision-making management. During event response, particular attention should be paid to events on driven transmission paths through focused analysis to control negative event impacts.

4.3.2 Event Semantic Transmission Paths As described above, event relationship templates in knowledge graph construction contain vocabulary that semantically represents event evolution logic processes, forming event evolution semantic transmission paths. Semantic transmission paths in knowledge graphs supplement the revelation of event evolution processes in driven transmission paths. Additionally, semantic transmission paths more easily associate with domain knowledge graphs related to events, thereby better helping understand the complete process of event logical evolution. The semantic transmission path for COVID-19 events is shown in Figure 6 [Figure 6: see original paper], including politics → healthcare, economy → oil market, and healthcare → infectious diseases.

Analysis of COVID-19 semantic transmission paths can clarify factors affecting the event during evolution and other results triggered by the event. For example, politics influences healthcare, and economy affects oil markets. Events in semantic transmission paths can form closed loops with related external domain knowledge graphs, thereby explaining driven transmission paths and mining event evolution causes and influencing factors. The COVID-19 semantic transmission path includes "novel coronavirus belongs to infectious diseases" and "COVID-19 pandemic risk threatens the world," demonstrating that semantic relationships such as risk and impact shown in semantic logic transmission paths supplement and explain events on driven paths, better helping people understand event evolution processes.

Conclusion

Event knowledge graphs enable deep processing of event information with powerful knowledge updating and computing capabilities. Major emergencies are complex objective phenomena with rich logical relationship chains between elements. Integrating major emergencies with event knowledge graph theory and methods can not only mine driven transmission chain information and reveal causal relationships between events but also study event evolution and propagation patterns from a knowledge graph perspective. Based on event knowledge graphs, this paper mines logical knowledge in major emergency evolution mechanisms, deeply analyzing and describing event evolution patterns and models to address previous research gaps. From a knowledge-driven perspective, through analysis of event logical knowledge evolution and mining of event transmission paths, this research reveals the evolution logic and patterns of major emergencies, enabling macro-level understanding of development contexts and providing scientific and accurate foundations for major emergency response and governance.

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Author Contributions

Zhang Haitao: Conceived research ideas and methods, performed data analysis, revised the paper;
Li Jiawei: Collected data, performed analysis and processing, wrote the initial draft;
Liu Weili: Collected and organized data;
Liu Yashu: Revised the paper.

English Abstract

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Abstract: [Purpose/significance] Major emergencies are an important part of the overall national security concept. In order to respond to major emergencies more quickly and efficiently and reduce threats to national security, social stability, and people's lives and property, this article proposes constructing an event knowledge graph for the major emergencies domain, revealing the evolution patterns and logic of major emergencies to assist relevant departments in responding to and making decisions on major emergencies. [Method/process] This paper selected media reports, research reports, and academic papers on the COVID-19 epidemic that attracted international attention and widespread influence, and through ontology construction, event extraction, and event relationship extraction, constructed an event knowledge graph of major emergencies, analyzing the logical knowledge and transmission paths of event evolution. [Result/conclusion] The research results show that the event knowledge graph of major emergencies can reveal the evolution logic and patterns of major emergencies, grasp the development context of events from a macro level, and provide scientific and accurate foundations for the response and management of major emergencies.

Keywords: major emergency; event knowledge graph; ontology; event logic mining

Note: Figure translations are in progress. See original paper for figures.