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Preface

Preface to Special Issue on New Database Technology for Multimodal Data

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A new round of scientific and technological revolution marked by digital technology is in the ascendant, bringing mankind into the digital economy era. The amount of data is growing explosively, and data can be presented in various types and formats, such as relational tables, semi-structured JavaScript Object Notation (JSON)/eXtensible Markup Language (XML) data, unstructured texts/images/videos as well as graph data, stream data, and time-series data. The increase in application scenarios requires that database systems efficiently manage a range of types of data simultaneously, consequently imposing higher requirements on database systems and turning multimodal data management and analysis into an urgent problem. Mainly supporting multimodal data management and analysis by expanding the existing databases or integrating various management engines for different modes of data, the current solutions lack novel theories, methods, and technologies and fail to address many problems that need to be solved promptly. Focusing on the whole life cycle of multimodal data management and analysis, this special issue discusses the theories, methods, and technologies of new database systems by combining big data technology and artificial intelligence methods, mainly covering the topics of the unified modeling, storage and indexing, query and mining, and concurrency control of multimodal data as well as the construction of multimodal database systems and their typical applications. On this basis, new theories, methods, technologies, and systems of multimodal data management and analysis are proposed to endow database systems with new management capabilities, and the latest application results of multimodal data management and analysis in different industries are reported to promote further development of database systems.

Focusing on the innovative and ground-breaking outstanding research results in multimodal data management and analysis, this special issue is devoted to discussing related basic theories, key technologies, systems, and application methods, solving related problems and challenges, and applying the substantial progress made in theory, technology, or evaluation to related industries and fields. Mainly intended for researchers and engineers in fields such as databases,

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big data, and artificial intelligence, the special issue reflects the latest research progress achieved by Chinese scholars in the new database technology for multimodal data. The representative research findings can be summarized as follows.

(1) Multimodal data modeling based on tuples and encoding method considering data characteristics. Extending the existing relationship, graph, key-value, or JSON document models is not enough to fuse all these modes of data. Consequently, the schema mapping among different modes of data will cause a combinatorial explosion, and schema evolution will become more complicated. A team from the University of Helsinki in Finland made a comprehensive summary and analysis of multimodal databases, involving common data models, system classification, and the scalability of multimodal models. Delving into the issue of multimodal data modeling in the cloud-edge-device collaboration architecture, a team from Harbin Institute of Technology recently proposed a multimodal data model based on tuples to solve the problem of difficult unified data representation and presented a basic data operation architecture and integrity constraints. A team from Tsinghua University encoded time-series data in different modes, such as timestamp data, Boolean data, frequency-domain data, and text data, in a targeted manner according to data characteristics and included data quality into the consideration of the encoding system.

(2) Multimodal data query method and system benchmarking. The existing query languages are only designed for a few specific models, and "Esperanto" for multimodal data query remains unavailable. The capabilities of relational queries, tracing queries, and predictive queries are limited, and current query optimization does not make full use of the rich semantic relations of multimodal data. Recently, a team from the University of Helsinki in Finland designed a multimodal query processing method based on type theory and functional programming methods and achieved the transshipment of multiple data models by constructing schema types and instance types. A joint team from Qinghai University, Hong Kong University of Science and Technology, and Tsinghua University designed a natural language-powered data analysis system capable of automated visualization exploration. A team from Seoul National University in South Korea designed and developed a benchmark for evaluating multimodal database systems. Readily applicable to relational schemas, document schemas, property graph schemas, and arrays and providing three representative real-world task sets, this benchmark can accurately point out the advantages and disadvantages of a system under each model.

(3) Entity recognition method based on multimodal data fusion and retrieval method. Multimodal data allows diversified information representation, and the various data formats and data types present tremendous challenges for traditional entity recognition methods in semantic extraction and data analysis. Different types of data need to be extracted by different methods, and big data, data mining, machine learning, statistical analysis, and other methods can then be employed to analyze multimodal big data and thereby obtain useful information and knowledge. Recently, a team from Zhejiang University of Technology designed a few-shot named entity recognition model based on multimodal data fusion. Converting image information into textual information, this model effectively solved the modality alignment problem caused by the inconsistent granularity of the semantic information contained in different types of data and alleviated the influence of noise on the model. A joint team from Northeastern University and Beijing Institute of Technology designed a graph data retrieval and analysis algorithm named PageRank in a geo-distributed environment to reduce data transmission costs and the number of iterations by mapping graph data using a heuristic algorithm.

This special issue contains five representative papers reporting the above findings, and they are summarized as follows, respectively:

Multimodal Data Modeling Technology and Its Application for Cloud-edge-device Collaboration, approaching from the type of cloud-edge-device three-layer data, proposes a multimodal data modeling technology for cloud-edge-device collaboration and presents the definition of a multimodal data model based on tuples to solve the problem of difficult unified representation of multimodal data. Furthermore, the proposal examines the integrity constraints on a multimodal data model and highlights a demonstration application of the multimodal data model for cloud-edge-device collaboration.

Multimodal Data Encoding and Compression in Apache IoTDB, giving due consideration to different modes of data in the Apache IoTDB system, such as timestamp data, numerical data, Boolean data, frequency-domain data, and text data, proposes a data encoding and compression method utilizing the characteristics of different modes of data and includes data quality into the design of the encoding algorithm. Experimental evaluation is carried out on multiple datasets to verify the effect of multimodal data encoding and compression.

Navi: Data Analysis System Powered by Natural Language Interaction, a natural language-powered data analysis system is designed. A modular design philosophy is embraced to abstract three core functional modules from the mainstream data analytics workflows, namely, data querying, visualization generation, and visualization exploration, and thereby reduce the coupling in system design. Capable of automated visualization exploration and equipped with a pruning algorithm and a composite reward function that incorporates visualization-domain knowledge, this system serves as a good reference for interaction technologies for multimodal query processing.

Multimodal Data Fusion for Few-shot Named Entity Recognition Method proposes a few-shot named entity recognition model based on multimodal data fusion. By converting image information into textual information to serve as auxiliary modal information, the proposed model effectively solves the problem of poor modality alignment caused by inconsistent granularity of semantic information. The effectiveness of the proposed method is verified by testing on real multimodal datasets.

GPPR: Geo-distributed Personalized PageRank Algorithm focuses on a personalized PageRank algorithm for big graph analysis in a geo-distributed environment. The influence of heterogeneous network bandwidth on the algorithm iteration speed is reduced by preprocessing big graph data and mapping graph data with a heuristic algorithm. A random wandering approach and a related algorithm are adopted to alleviate the bandwidth load of data transmission between working nodes. Performance tests are carried out on eight open-source big graph data, revealing that the proposed algorithm significantly outperforms the existing methods in terms of efficiency.



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