
Encyclopedia of Database Systems

Ling Liu • M. Tamer Özsu
Editors

Encyclopedia of Database Systems

Second Edition

With 1374 Figures and 143 Tables

 Springer

Editors

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Preface to the Second Edition

Since the release of the first volume of this Encyclopedia, big data has emerged as a central feature of information technology innovation in many business, science, and engineering fields. Databases are one of the fundamental core technologies for big data systems and big data analytics. In order to extract features and derive values from big data, it must be stored, processed, and analyzed in a timely manner. Not surprisingly, big data not only fuels the development and deployment of database systems and database technologies, it also opens doors to new opportunities and new challenges in the field of databases. As data grows in volume, velocity, variety, and with the attendant veracity issues, there is a growing demand for volume-scalable databases, velocity-adaptive databases, and variety-capable databases that can handle data quality issues properly. As machine learning and artificial intelligence renew their momentum with the power of big data, there is an increasing demand for new generation of database systems that are built for extracting features from databases as efficient and effective as conventional database systems are capable of for querying databases.

The first edition of the *Encyclopedia of Database Systems* is a comprehensive, multivolume collection of over 1,250 in-depth entries (3,067 including synonyms), covering important concepts on all aspects of database systems, including areas of current interest and research results of historical significance. This second edition of *Encyclopedia of Database Systems* expands the first edition by enriching the content of existing entries, expanding existing topic areas with new entries, adding a set of cutting-edge topic areas, including cloud data management, crowdsourcing, data analytics, data provenance management, graph data management, social networks, and uncertain data management to name a few. The new entries and the new topic areas were determined through discussions and consultations with the Advisory Board of the *Encyclopedia of Database Systems*. Each of the new topic areas was managed by a new Area Editor who, together with the editor-in-chief, further developed the content for each area, soliciting experts in the field as contributors to write the entries, and performed the necessary technical editing. We also reviewed the entries from the first edition and revised them as needed to bring them up-to-date.

We would like to thank the members of the Advisory Board, the Editorial Board, and all of the authors for their contributions to this second edition. We would also like to thank Springer's editors and staff, including Susan Lagerstrom-Fife, Michael Hermann, and Sonja Peterson for their assistance and support throughout the project, and Annalea Manalili for her involvement in the early period of this project.

In closing, we trust the Encyclopedia can serve as a valuable source for students, researchers, and practitioners who need a quick and authoritative reference to the subject on database systems. Suggestions and feedbacks to further improve the Encyclopedia are welcome from readers and from the community.

Preface to the First Edition

We are in an information era where generating and storing large amounts of data are commonplace. A growing number of organizations routinely handle terabytes and exabytes of data, and individual digital data collections easily reach multiple gigabytes. Along with the increases in volume, the modality of digitized data that requires efficient management and the access modes to these data have become more varied. It is increasingly common for business and personal data collections to include images, video, voice, and unstructured text; the retrieval of these data comprises various forms, including structured queries, keyword search, and visual access. Data have become a highly valued asset for governments, industries and individuals, and the management of these data collections remains a critical technical challenge.

Database technology has matured over the past four decades and is now quite ubiquitous in many applications that deal with more traditional business data. The challenges of expanding data management to include other data modalities while maintaining the fundamental tenets of database management (data independence, data integrity, data consistency, etc.) are issues that the community continues to work on. The lines between database management and other fields such as information retrieval, multimedia retrieval, and data visualization are increasingly blurred.

This multi-volume *Encyclopedia of Database Systems* provides easy access to important concepts on all aspects of database systems, including areas of current interest and research results of historical significance. It is a comprehensive collection of over 1,250 in-depth entries (3,067 including synonyms) that present coverage of the important concepts, issues, emerging technology and future trends in the field of database technologies, systems, and applications. The content of the *Encyclopedia* was determined through wide consultations. We were assisted by an Advisory Board in coming up with the overall structure and content. Each of these areas were put under the control of Area Editors (70 in total) who further developed the content for each area, soliciting experts in the field as contributors to write the entries, and performed the necessary technical editing. Some of them even wrote entries themselves. Nearly 1,000 authors were involved in writing entries.

The intended audience for the *Encyclopedia* is technically broad and diverse. It includes anyone concerned with database system technology and its applications. Specifically, the *Encyclopedia* can serve as a valuable and authoritative reference for students, researchers and practitioners who need a quick and authoritative reference to the subject of databases, data management, and database systems. We anticipate that many people will benefit from this reference work, including database specialists, software developers, scientists and engineers who need to deal with (structured, semi-structured or unstructured) large datasets. In addition, database and data mining researchers and scholars in the many areas that apply database technologies, such as artificial intelligence, software engineering, robotics and computer vision, machine learning, finance and marketing are expected to benefit from the *Encyclopedia*.

We would like to thank the members of the Advisory Board, the Editorial Board, and the individual contributors for their help in creating this *Encyclopedia*. The success of the *Encyclopedia* could not have been achieved without the expertise and the effort of the many contributors. Our sincere thanks also go to Springer's editors and staff, including Jennifer Carlson, Susan Lagerstrom-Fife, Oona Schmid, and Susan Bednarczyk for their support throughout the project.

Finally, we would very much like to hear from readers for any suggestions regarding the *Encyclopedia's* content. With a project of this size and scope, it is quite possible that we may have missed some concepts. It is also possible that some entries may benefit from revisions and clarifications. We are committed to issuing periodic updates and we look forward to the feedback from the community to improve the *Encyclopedia*.

Ling Liu
M. Tamer Özsu

List of Topics

Peer-to-Peer Data Management

Section Editor: *Karl Aberer*

Approximate Queries in Peer-to-Peer Systems
Declarative Networking
Distributed Hash Table
Load Balancing in Peer-to-Peer Overlay Networks
Overlay Network
Peer Data Management System
Peer-to-Peer Content Distribution
Peer-to-Peer Data Integration
Peer-to-Peer Overlay Networks: Structure, Routing and Maintenance
Peer-to-Peer Publish-Subscribe Systems
Peer-to-Peer Storage
Peer-to-Peer System
Reputation and Trust
Semantic Overlay Networks
Social Networks
Structured Data in Peer-to-Peer Systems
Trust and Reputation in Peer-to-Peer Systems
Updates and Transactions in Peer-to-Peer Systems

Database Management System Architectures

Section Editor: *Anastasia Ailamaki*

Application Server
Architecture-Conscious Database System
Buffer Manager
Buffer Pool
Cache-Conscious Query Processing
Client-Server Architecture
Concurrency Control Manager

Connection
Data Partitioning
Database Management System
DBMS Component
DBMS Interface
Disk
Distributed DBMS
Execution Skew
Inter-query Parallelism
Intra-query Parallelism
Locality
Logging/Recovery Subsystem
Main Memory DBMS
Main Memory
Memory Hierarchy
Memory Locality
Multitier Architecture
Operator-Level Parallelism
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Process Structure of a DBMS
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Query Processor
Session
Staged DBMS
Stop-&-Go Operator
Storage Manager
Transaction Manager

Information Retrieval Models

Section Editor: *Giambattista Amati*

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BM25
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Divergence-from-Randomness Models
Document Field

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 Document Links and Hyperlinks
 Entity Resolution
 Field-Based Information Retrieval Models
 Fuzzy Models
 Information Retrieval Models
 Information Retrieval
 Inverse Document Frequency
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 WEB Information Retrieval Models

XML Data Management

Section Editor: *Sihem Amer-Yahia*

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 Microbenchmark
 Ranked XML Processing
 Semi-structured Data
 XML Access Control
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 XML Benchmarks
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 XML Indexing
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Database Middleware

Section Editor: *Cristiana Amza*

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 Java Enterprise Edition
 Mediation
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 Middleware Support for Precise Failure Semantics
 Replication in Multitier Architectures
 Transactional Middleware

Database Management Utilities

Section Editor: *Philippe Bonnet*

Administration Wizards
 Performance Monitoring Tools

Visual Interfaces

Section Editor: *Tiziana Catarci*

Adaptive Interfaces
 Browsing
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 Direct Manipulation
 Dynamic Web Pages
 eAccessibility
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Multimedia Presentation Databases
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 Ontology Visual Querying
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 Visual Interfaces
 Visual Metaphor
 Visual Perception
 Visual Query Languages for Data Stream
 Visual Query Language
 Visual Representation
 Web Mashups
 WIMP Interfaces

Stream Data Management

Section Editor: *Ugur Cetintemel*

Adaptive Stream Processing
 Big Stream Systems
 Continuous Query
 Data Stream Management Architectures
 and Prototypes
 Data Stream
 Distributed Data Streams
 Event and Pattern Detection over Streams
 Fault Tolerance and High Availability in
 Data Stream Management Systems
 Load Shedding
 Nonrelational Streams
 One-Pass Algorithm
 Publish/Subscribe Over Streams
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 Scheduling Strategies for Data Stream
 Processing
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 Stream Processing
 Stream-Oriented Query Languages
 and Operators
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 Transactional Stream Processing
 Window-Based Query Processing

Windows
 XML Stream Processing

Querying over Data Integration Systems

Section Editor: *Kevin Chang*

Information Integration
 Ontology-Based Data Access and Integration
 Query Processing in Data Integration Systems
 Query Translation
 Rewriting Queries Using Views
 View-Based Data Integration

Self-Management

Section Editor: *Surajit Chaudhuri*

Database Tuning Using Combinatorial Search
 Database Tuning Using Online Algorithms
 Database Tuning Using Trade-Off Elimination
 Self-Management Technology in Databases

Text Mining

Section Editor: *Zheng Chen*

Cross-Language Mining and Retrieval
 Information Extraction
 Opinion Mining
 Text Categorization
 Text Clustering
 Text Generation
 Text Indexing and Retrieval
 Text Mining
 Text Representation
 Text Segmentation
 Text Semantic Representation
 Text Streaming Model
 Text Summarization
 Text Visualization
 Topic Detection and Tracking
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Extended Transaction Models

Section Editor: *Panos K. Chrysanthis*

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 ConTract
 Correctness Criteria Beyond Serializability
 E-Commerce Transactions

Extended Transaction Models and the ACTA Framework

Flex Transactions
 Generalization of ACID Properties
 Multilevel Transactions and Object-Model Transactions
 Nested Transaction Models
 Open Nested Transaction Models
 Polytransactions
 Real-Time Transaction Processing
 Sagas
 Semantic Atomicity
 Semantics-Based Concurrency Control
 Split Transactions
 Transactional Processes
 Web Transactions
 Workflow Transactions

Privacy-Preserving Data Mining

Section Editor: *Chris Clifton*

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 Individually Identifiable Data
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 Privacy Metrics
 Privacy-Preserving Data Mining
 Randomization Methods to Ensure Data Privacy
 Secure Multiparty Computation Methods
 Statistical Disclosure Limitation for Data Access
 Vertically Partitioned Data

Digital Libraries

Section Editor: *Amr El Abbadi*

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 Cataloging in Digital Libraries
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 Dewey Decimal System
 Digital Archives and Preservation
 Digital Curation
 Digital Libraries
 European Law in Databases
 Gazetteers
 Georeferencing
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LOC METS

Resource Identifier
 Searching Digital Libraries

Data Models

Section Editor: *David W. Embley*

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 Object Constraint Language
 Object Data Models
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 Object-Role Modeling
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 Semantic Data Model
 Specialization and Generalization
 Unified Modeling Language

Complex Event Processing

Section Editor: *Opher Etzion*

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 Event Channel
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 Event Driven Architecture
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 Event Processing Network
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 Event Stream
 Event Transformation
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Section Editor: *Elena Ferrari*

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Section Editor: *Avigdor Gal*

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Data Cleaning

Section Editor: *Venkatesh Ganti*

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Web Data Extraction

Section Editor: *Georg Gottlob*

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Section Editor: *Le Gruenwald*

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Section Editor: *Dimitrios Gunopulos*

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Section Editor: *Amarnath Gupta*

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Section Editor: *Ralf Hartmut Güting*

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Section Editor: *Hans Hinterberger*

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Section Editor: *Hans-Arno Jacobsen*

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Section Editor: *Manfred Jeusfeld*

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Section Editor: *Vipul Kashyap*

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Section Editor: *Daniel A. Keim*

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Section Editor: *Bettina Kemme*

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Section Editor: *Masaru Kitsuregawa*

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Views and View Management

Section Editor: *Yannis Kotidis*

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Section Editor: *Jaap Kamps*

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Information Quality

Section Editor: *Yang W. Lee*

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Relational Theory

Section Editor: *Leonid Libkin*

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Section Editor: *Weiyi Meng*

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 Average Precision Histogram
 Average Precision
 Average R-Precision
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 D-Measure
 Discounted Cumulated Gain
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 ERR-IA
 Expected Reciprocal Rank
 F-Measure
 GMAP
 MAP
 Mean Reciprocal Rank
 Precision at n
 Precision-Oriented Effectiveness Measures
 Precision
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 R-Precision
 Recall
 Standard Effectiveness Measures
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 U-Measure

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Section Editor: *Renée J. Miller*

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 Schema Mapping
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Database Design**Section Editor:** *Alexander Borgida*

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 Database Design
 Database Reverse Engineering
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 Logical Database Design: From Conceptual to
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Text Indexing Techniques**Section Editor:** *Mario A. Nascimento*

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Data Quality**Section Editor:** *Felix Naumann*

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 Data Quality Assessment
 Data Quality Dimensions
 Data Quality Models
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Web Search and Crawl**Section Editor:** *Cong Yu*

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 Search Engine Metrics

Test Collection
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 Web Information Extraction
 Web Page Quality Metrics
 Web Question Answering
 Web Search Query Rewriting
 Web Search Relevance Feedback
 Web Search Relevance Ranking
 Web Search Result Caching and Prefetching
 Web Search Result De-duplication and
 Clustering
 Web Spam Detection

Multimedia Databases**Section Editor:** *Vincent Oria,
Shin'ichi Satoh*

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 Audio Content Analysis
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 Content-Based Video Retrieval
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 Video Content Analysis

Video Content Modeling
 Video Content Structure
 Video Metadata
 Video Querying
 Video Representation
 Video Scene and Event Detection
 Video Shot Detection
 Video Summarization
 Video
 Visual Content Analysis

Active Databases

Section Editor: *M. Tamer Özsu*

Active Database Coupling Modes
 Active Database Execution Model
 Active Database Knowledge Model
 Active Database Management System
 Architecture
 Active Database Rulebase
 Active Database, Active Database (Management)
 System
 Atomic Event
 Composite Event
 Database Trigger
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Section Editor: *Dimitris Papadias*

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Section Editor: *Torben Bach Pedersen, Stefano Rizzi*

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Section Editor: *Jian Pei*

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Section Editor: *Edie Rasmussen*

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Section Editor: *Dennis Shasha*

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Section Editor: *Kyuseok Shim*

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Section Editor: *Christian S. Jensen,
Richard T. Snodgrass*

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Section Editor: *Divesh Srivastava*

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Section Editor: *Kian-Lee Tan*

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Section Editor: *Val Tannen*

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Section Editor: *Frank Tompa*

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Section Editor: *Vassilis J. Tsotras*

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Section Editor: *Patrick Valduriez*

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Section Editor: *Ouri Wolfson*

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Section Editor: *Jeffrey Xu Yu*

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Section Editor: *Xiaofang Zhou*

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Section Editor: *Amr El Abbadi*

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Section Editor: *Fatma Özcan*

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Section Editor: *Ramez Elmasri*

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Section Editor: *Ling Liu and M. Tamer Özsu*

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Section Editor: *Lei Chen*

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Section Editor: *Juliana Freire*

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Section Editor: *Ihab F. Ilyas*

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Section Editor: *Minos Garofalakis*

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Section Editor: *Reynold Cheng*

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Crowd Database Systems
Crowd Mining and Analysis
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Indexing with Crowds

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Ling Liu is Professor of Computer Science in the College of Computing at Georgia Institute of Technology. She holds a Ph.D. (1992) in Computer and Information Science from Tilburg University, The Netherlands. Dr. Liu directs the research programs in the Distributed Data Intensive Systems Lab (DiSL), examining various aspects of data intensive systems, ranging from big data systems, cloud computing, databases, Internet and mobile systems and services, machine learning, to social and crowd computing, with the focus on performance, availability, security, privacy, and trust. Prof. Liu is an elected IEEE Fellow and a recipient of IEEE Computer Society Technical Achievement Award (2012). She has published over 300 international journal and conference articles and is a recipient of the best paper award from numerous top venues, including ICDCS, WWW, IEEE Cloud, IEEE ICWS, and ACM/IEEE CCGrid. In addition to serving as general chair and PC chairs of numerous IEEE and ACM conferences in big data, distributed computing, cloud computing, data engineering, and very large databases fields, Prof. Liu served as the Editor-in-Chief of *IEEE Transactions on Service Computing* (2013–2016) and also served on editorial boards of over a dozen international journals. Her current research is sponsored primarily by NSF and IBM.



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His research is in data management focusing on large-scale data distribution and management of nontraditional data, currently focusing on graph and RDF data. His publications include the book *Principles of Distributed Database Systems* (with Patrick Valduriez), which is now in its third edition. He was the Founding Series Editor of *Synthesis Lectures on Data Management* (Morgan & Claypool) and is now the Editor-in-Chief of *ACM Books*. He serves on the editorial boards of three journals and two book series.

He is a Fellow of the Royal Society of Canada, American Association for the Advancement of Science (AAAS), Association for Computing Machinery (ACM), and the Institute of Electrical and Electronics Engineers (IEEE). He is an elected member of the Science Academy, Turkey, and a member of Sigma Xi. He was awarded the ACM SIGMOD Test-of-Time Award in 2015, the ACM SIGMOD Contributions Award in 2006, and the Ohio State University College of Engineering Distinguished Alumnus Award in 2008.

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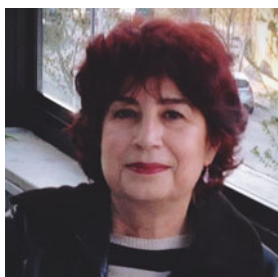
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Information Retrieval Evaluation Measures



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Logical Data Integration



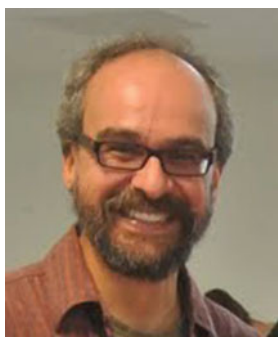
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Text Indexing Techniques



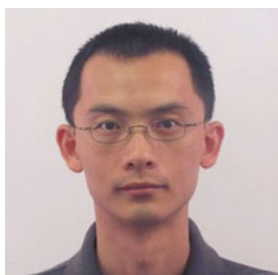
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Database Tuning and Performance



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Classification and Decision Trees

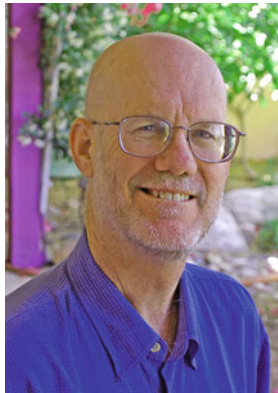


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Temporal Databases



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Structured and Semi-structured Document Databases



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Indexing



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Transaction Management



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Mobile and Ubiquitous Data Management



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Multimedia Information Retrieval



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Approximation and Data Reduction Techniques



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Social Networks



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Cloud Data Management



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Data Management Fundamentals



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NoSQL Databases



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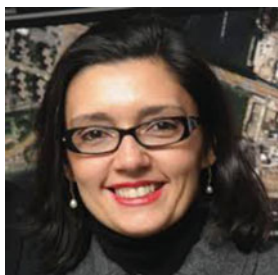
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Graph Data Management



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Data Provenance Management



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Ranking Queries



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Uncertain Data Management



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Crowd Sourcing



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