

# Encyclopedia of Database Systems

Ling Liu, M. Tamer Özsu (Eds.)

# Encyclopedia of Database Systems

With 3,067 Entries

With 871 Authors

With 1,176 Figures and 101 Tables

With 6,900 Cross-references

With 10,696 Bibliographic references

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To our families

# Preface

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*.

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# Editors-in-Chief



Ling Liu is a Professor in the School of Computer Science, College of Computing, at Georgia Institute of Technology. Dr. Liu directs the research programs in Distributed Data Intensive Systems Lab (DiSL), examining various aspects of data intensive systems, ranging from database and Internet data management, data storage, network computing, and mobile and wireless computing, with the focus on performance, availability, security, privacy, and energy efficiency in building very large database and data management systems and services. She has published over 200 international journal and conference articles in the areas of databases, data engineering, and distributed computing systems. She is a recipient of the best paper award of ICDCS 2003, the best paper award of WWW 2004, the 2005 Pat Goldberg Memorial Best Paper Award, and the best data engineering paper award of Int. Conf. on Software Engineering and Data Engineering (2008). Dr. Liu served on the editorial board of *IEEE Transactions on Knowledge and Data Engineering* and *International Journal of Very Large Databases* from 2004 to 2008 and is currently serving on the editorial board of several international journals, including *Distributed and Parallel Databases Journal*, *IEEE Transactions on Service Computing* (TSC), *International Journal of Peer-to-Peer Networking and Applications* (Springer), and *Wireless Network* (Springer). Dr. Liu's current research is primarily sponsored by NSF, IBM, and Intel.



M. Tamer Özsu is a Professor of Computer Science and Director of the David R. Cheriton School of Computer Science at the University of Waterloo. He holds a Ph.D. (1983) and an MS (1981) in Computer and Information Science from The Ohio State University (1983) and a B.S. (1974) and M.S. (1978) in Industrial Engineering from the Middle East Technical University, Turkey (1974).

Dr. Özsu's current research focuses on three areas: (a) Internet-scale data distribution that emphasizes stream data management, peer-to-peer databases, and Web data management; (b) multimedia data management, concentrating on similarity-based retrieval of time series and trajectory data; and (c) the integration of database and information retrieval technologies, focusing on XML query processing and optimization. His previous research focused on distributed databases, interoperable information systems, object database systems and image databases. He is the co-author of the book *Principles of Distributed Database Systems* (Prentice Hall), which is now in its second edition (third edition to publish in 2009).

He currently holds a University Research Chair and has held a Faculty Research Fellowship at the University of Waterloo (2000-2003), and a McCalla Research Professorship (1993-1994) at the University of Alberta where he was faculty member between 1984 and 2000. He is a fellow of the Association for Computing Machinery (ACM), a senior member of Institute of Electrical and Electronics Engineers (IEEE), and a member of Sigma Xi. He was awarded the ACM SIGMOD Contributions Award in 2006. He is also the 2008 recipient of Ohio State University College of Engineering Distinguished Alumnus Award.

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Dr. Özsu serves on the editorial boards of *ACM Computing Surveys*, *Distributed and Parallel Databases Journal*, *World Wide Web Journal*, *Information Technology and Management*, and Springer Book Series on *Advanced Information & Knowledge Processing*. Previously he was the Coordinating Editor-in-Chief of *The VLDB Journal* (1997-2005) and was on the Editorial Board of *Encyclopedia of Database Technology and Applications* (Idea Group). He has served as the Program Chair of VLDB (2004), WISE (2001), IDEAS (2003), and CIKM (1996) conferences and the General Chair of CAiSE (2002), as well as serving on the Program Committees of many conferences including SIGMOD, VLDB, and ICDE. He is also a member of Association for Computing Machinery's (ACM) Publications Board and is its Vice-Chair for New Publications.

Dr. Özsu was the Chair of *ACM Special Interest Group on Management of Data* (SIGMOD; 2001-2005) and a past trustee of the *VLDB Endowment* (1996-2002). He was a member and chair of the Computer and Information Science Grant Selection Committee of the Natural Sciences and Engineering Research Council of Canada during 1991-94, and served on the Management Committee of the Canadian Genome Analysis and Technology Program during 1992-93. He was Acting Chair of the Department of Computing Science at the University of Alberta during 1994-95, and again, for a brief period, in 2000.



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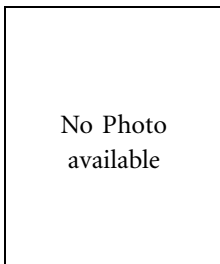
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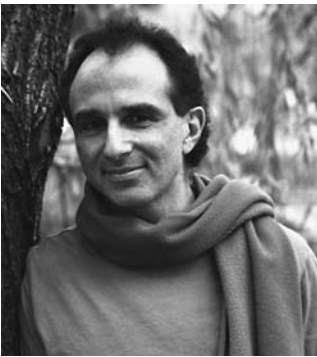
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