## Very Large Data Bases VLDB Endowment

Volume 13, No. 13 – September 2020

Editors in Chief: Magdalena Balazinska and Xiaofang Zhou

Associate Editors:

Azza Abouzied, Amr El Abbadi, Phil Bernstein, Xin Luna Dong, Zi (Helen) Huang, Nick Koudas, Georgia Koutrika, Guoliang Li, Alexandra Meliou, Felix Naumann, Dan Olteanu, M. Tamer Özsu, Aditya Parameswaran, Andy Pavlo, Xiaokui Xiao, Jeffrey Xu Yu, Meihui Zhang, Jingren Zhou

> Publication Editors: Hiroaki Shiokawa and Sen Wang

PVLDB – Proceedings of the VLDB Endowment Volume 13, No. 13, September 2020.

PVLDB is indexed in Scopus (Elsevier) as well as covered by the following Clarivate Analytics services:

- Science Citation Index Expanded (also known as SciSearch®)
- Journal Citation Reports/Science Edition, and
- Current Contents®/Engineering Computing and Technology

All papers published in this issue will be presented at the 46th International Conference on Very Large Data Bases, Tokyo, Japan, 2020.

# **Copyright 2020 VLDB Endowment**

This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view a copy of this license, visit http://creativecommons.org/licenses/by-nc-nd/4.0/. For any use beyond those covered by this license, obtain permission by emailing info@vldb.org.

Volume 13, Number 13, September 2020 Pages i – viii and 3517 - 3616 ISSN 2150-8097

Available at: http://www.pvldb.org and https://dl.acm.org.

## **TABLE OF CONTENTS**

### **Front Matter**

	Copyright Notice Table of Contents PVLDB Organization and Review Board – Vol. 13 Distinguished PVLDB 2020 Review Board Members- Vol. 13 Additional Reviewer - Vol. 13	i ii iii vii xi
Research Papers		
	The Simpler The Better: An Indexing Approach for Shared-Route Planning Queries	3517
	An Analysis of Concurrency Control Protocols for In-Memory Database with CCBench Takayuki Tanabe, Takashi Hoshino, Hideyuki Kawashima, Osamu Tatebe	3531
	Improving Utility and Security of the Shuffler-based Differential Privacy <i>Tianhao Wang, Min Xu, Bolin Ding, Jingren Zhou, Cheng Hong, Zhicong Huang, Ninghui Li,</i> <i>Somesh Jha</i>	3545
	Cuckoo Index: A Lightweight Secondary Index Structure Andreas Kipf, Damian Chromejko, Alexander Hall, Peter Boncz, David G Andersen	3559
	MorphoSys: Automatic Physical Design Metamorphosis for Distributed Database Systems Michael Abebe, Brad Glasbergen, Khuzaima Daudjee	3573
	Parallel Graph Algorithms in Constant Adaptive Rounds: Theory meets Practice Soheil Behnezhad, Laxman Dhulipala, Hossein Esfandiari, Jakub Łącki, Vahab Mirrokni, Warren So	3588 chudy
	DeltaPQ: Lossless Product Quantization Code Compression for High Dimensional Similarity Search Runhui Wang, Dong Deng	3603

#### **PVLDB ORGANIZATION AND REVIEW BOARD - Vol. 13**

#### **Editors in Chief of PVLDB**

Magdalena Balazinska (University of Washington, USA) Xiaofang Zhou (University of Queensland, Australia)

#### **Associate Editors of PVLDB**

Azza Abouzied (New York University Abu Dhabi, UAE) Amr El Abbadi (University of California, Santa Barbara, USA)

Phil Bernstein (Microsoft Research, USA)

Xin Luna Dong (Amazon, USA)

Zi (Helen) Huang (University of Queensland, Australia) Nick Koudas (University of Toronto, Canada) Georgia Koutrika (Athena Research Center, Greece)

Guoliang Li (Tsinghua University, China)

Alexandra Meliou (University of Massachusetts, Amherst, USA)

Felix Naumann (Hasso Plattner Institute, University of Potsdam, Germany)

Dan Olteanu (University of Oxford, United Kingdom) M. Tamer Özsu (University of Waterloo, Canada) Aditya Parameswaran (University of California, Berkeley, USA)

Andy Pavlo (Carnegie Mellon University, USA) Xiaokui Xiao (National University of Singapore, Singapore)

Jeffrey Xu Yu (The Chinese University of Hong Kong, China)

Meihui Zhang (Beijing Institute of Technology, China) Jingren Zhou (Alibaba Group, China)

#### **Publication Editors**

Hiroaki Shiokawa (University of Tsukuba, Japan) Sen Wang (University of Queensland, Australia)

#### **PVLDB Managing Editor**

Wolfgang Lehner (TU Dresden, Germany)

#### **PVLDB Advisory Committee**

Divesh Srivastava (AT&T Labs-Research, USA) M. Tamer Özsu (University of Waterloo, Canada) Juliana Freire (New York University, USA) Xin Luna Dong (Amazon, USA) Peter Boncz (CWI, Netherlands) Xiaofang Zhou (University of Queensland, Australia) Magdalena Balazinska (University of Washington, USA) Lei Chen (Hong Kong University of Science and Technology, China) Fatma Ozcan (IBM Almaden, USA) Graham Cormode (University of Warwick, United Kingdom) Felix Naumann (HPI, Germany)

#### **Review Board**

Ziawasch Abedjan (TU Berlin, Germany) Ashraf Aboulnaga (Qatar Computing Research Institute, Oatar) Pelin Angın (Middle East Technical University, Turkey) Arvind Arasu (Microsoft Research, USA) Joy Arulraj (Georgia Tech, USA) Manos Athanassoulis (Boston University, USA) Zhifeng Bao (RMIT University, Australia) Ilaria Bartolini (University of Bologna, Italy) Leilani Battle (University of Maryland, USA) Kaustubh Beedkar (TU Berlin, Germany) Arnab Bhattacharya (IIT Kanpur, India) Sourav S Bhowmick (Nanyang Technological University, Singapore) Carsten Binnig (TU Darmstadt, Germany) Spyros Blanas (The Ohio State University, USA) Matthias Boehm (Graz University of Technology, Austria) Alexander Böhm (SAP SE, Germany) Michael Böhlen (University of Zürich, Switzerland) Peter Boncz (Centrum Wiskunde & Informatica, Netherlands) Angela Bonifati (Lyon 1 University, France) Philippe Bonnet (IT University of Copenhagen, Denmark) Renata Borovica-Gajic (University of Melbourne, Australia) Huiping Cao (New Mexico State University, USA) Lei Cao (MIT, USA) Lijun Chang (The University of Sydney, Australia) Surajit Chaudhuri (Microsoft Research, USA) Lei Chen (Hong Kong University of Science and Technology, China) Hong Cheng (The Chinese University of Hong Kong, China) Revnold Cheng (The University of Hong Kong, China) Fei Chiang (McMaster University, Canada) Xu Chu (Georgia Tech, USA) Bobbie Cochrane (IBM, USA) Gao Cong (Nanyang Technological University, Singapore) Brian Cooper (Google, USA) Natacha Crooks (University of Texas at Austin, USA) Andrew Crotty (Brown University, USA) Bin Cui (Peking University, China) Sudipto Das (Amazon Web Service, USA) Akash Das Sarma (Facebook, USA) Khuzaima Daudjee (University of Waterloo, Canada) Niv Dayan (Harvard University, USA) Dong Deng (Rutgers University, USA) Bailu Ding (Microsoft Research, USA) Bolin Ding (Alibaba Group, China) Jens Dittrich (Saarland University, Germany) Harish Doraiswamy (New York University, USA) Eduard C. Dragut (Temple University, USA) Curtis Dyreson (Utah State University, USA) Mohamed Y. Eltabakh (Teradata Labs, USA)

Jose M. Faleiro (Microsoft Research, USA) Ju Fan (Renmin University of China, China) Raul Castro Fernandez (The University of Chicago, USA) Avrilia Floratou (Microsoft Research, USA) Avigdor Gal (Technion, Israel) Alex Galakatos (Brown University, USA) Johann Gamper (Free University of Bozen-Bolzano, Italy) Jing Gao (University at Buffalo, USA) Yunjun Gao (Zhejiang University, China) Tingjian Ge (University of Massachusetts, Lowell, USA) Floris Geerts (University of Antwerp, Belgium) Johannes Gehrke (Microsoft Research, USA) Jonathan Goldstein (Microsoft Research, USA) Torsten Grust (University of Tübingen, Germany) Wook-Shin Han (POSTECH, South Korea) Takahiro Hara (Osaka University, Japan) Oktie Hassanzadeh (IBM Research, USA) Michael Hay (Colgate University, USA) Xi He (University of Waterloo, Canada) Melanie Herschel (University of Stuttgart, Germany) Katja Hose (Aalborg University, Denmark) Wen Hua (The University of Oueensland, Australia) Xin Huana (Hong Kong Baptist University, China) Yan Huang (University of North Texas, USA) Seung-won Hwang (Yonsei University, South Korea) Christopher Jermaine (Rice University, USA) Ruoming Jin (Kent State University, USA) Eser Kandogan (Megagon Labs, USA) Murat Kantarcioglu (University of Texas at Dallas, USA) Verena Kantere (University of Ottawa, Canada) Pinar Karagoz (Middle East Technical University, Turkey) Manos Karpathiotakis (Facebook, United Kingdom) Batya Kenig (University of Washington, USA) Oliver Kennedy (University at Buffalo, USA) Arijit Khan (Nanyang Technological University, Singapore) Daniel Kifer (Pennsylvania State University, USA) Hideaki Kimura (Oracle, USA) Sanjay Krishnan (University of Chicago, USA) Arun Kumar (University of California, San Diego, USA) Chuan Lei (IBM Research - Almaden, USA) Viktor Leis (Technical University of Munich, Germany) Ulf Leser (Humboldt-Universität zu Berlin, Germany) Chengkai Li (The University of Texas at Arlington, USA) Feifei Li (University of Utah, USA) Rong-Hua Li (Beijing Institute of Technology, China) Sebastian Link (The University of Auckland, New Zealand) Chengfei Liu (Swinburne University of Technology, Australia) Hua Lu (Aalborg University, Denmark) Jiaheng Lu (University of Helsinki, Finland) Wei Lu (Renmin University of China, China) Shuai Ma (Beihang University, China) Nikos Mamoulis (University of Ioannina, Greece) Ioana Manolescu (INRIA, France) Essam Mansour (Concordia University, Canada)

**PVLDB** Vol. 13, No. 13

Ryan Marcus (MIT, USA) Sergey Melnik (Google, USA) Mohamed Mokbel (Qatar Computing Research Institute, Oatar) Mirella Moura Moro (Universidade Federal de Minas Gerais, Brazil) Davide Mottin (Aarhus University, Denmark) Parth Nagarkar (New Mexico State University, USA) Faisal Nawab (University of California, Santa Cruz, USA) Thomas Neumann (Technical University of Munich, Germany) Milos Nikolic (The University of Edinburgh, United Kingdom) Beng Chin Ooi (National University of Singapore, Singapore) Ismail Oukid (SAP SE, USA) Mourad Ouzzani (Qatar Computing Research Institute, Oatar) Themis Palpanas (Paris Descartes University, France) George Papadakis (University of Athens, Greece) Olga Papaemmanouil (Brandeis University, USA) Thorsten Papenbrock (Hasso Plattner Institute, Germanv) Paolo Papotti (EURECOM, France) Stefano Paraboschi (Universita' degli Studi di Bergamo, Italv) Yongjoo Park (University of Michigan, USA) Jignesh M. Patel (University of Wisconsin-Madison, USA) Peter Pietzuch (Imperial College London, United Kinadom) Holger Pirk (Imperial College London, United Kingdom) Fábio Porto (National Laboratory for Scientific Computing (LNCC), Brazil) Dan R. K. Ports (Microsoft Research, USA) Lu Qin (University of Technology Sydney, Australia) Abdul H. Quamar (IBM Research – Almaden, USA) Tilmann Rabl (TU Berlin, Germany) Karthik Ramachandra (Microsoft Research, USA) Maya Ramanath (IIT Delhi, India) Berthold Reinwald (IBM Research, USA) Theodoros Rekatsinas (University of Wisconsin-Madison, USA) Uwe Roehm (The University of Sydney, Australia) Jennie Rogers (Northwestern University, USA) Florin Rusu (University of California, Merced, USA) Diptikalyan Saha (IBM Research AI India, India) Ken Salem (University of Waterloo, Canada) Semih Salihoglu (University of Waterloo, Canada) Maria Luisa Sapino (University of Torino, Italy) A. Erdem Sarivuce (University at Buffalo, USA) Mohamed Sarwat (Arizona State University, USA) Maximilian Schleich (University of Oxford, United Kingdom)

Mohamed Sharaf (University of Queensland, Australia) Yanyan Shen (Shanghai Jiao Tong University, China) Kyuseok Shim (Seoul National University, South Korea) Prashant Shiralkar (Amazon, USA) Alkis Simitsis (Hewlett Packard Enterprise, USA) Kostas Stefanidis (Tampere University, Finland) Rebecca Taft (Cockroach Labs, USA) Nan Tang (Qatar Computing Research Institute, Qatar) Yufei Tao (The Chinese University of Hong Kong, China) Jens Teubner (TU Dortmund, Germany) Andreas Thor (University of Applied Sciences for Telecommunications Leipzig, Germany) Yongxin Tong (Beihang University, China) Anthony K. H. Tung (National University of Singapore, Singapore) Yannis Velegrakis (Utrecht University, Netherlands) Stratis Viglas (University of Edinburgh, United Kingdom) Daisy Zhe Wang (University of Florida, USA) Guoren Wang (Beijing Institute of Technology, China) Jiannan Wang (Simon Fraser University, USA) Junhu Wang (Griffith University, Australia) Sibo Wang (The Chinese University of Hong Kong, China) Eugene Wu (Columbia University, USA) Yingjun Wu (Amazon Web Service, USA) Yinglong Xia (Huawei Research America, USA) Chuan Xiao (Osaka University, Japan) Yanghua Xiao (Fudan University, China) Li Xiong (Emory University, USA) Jianliang Xu (Hong Kong Baptist University, China) Xiaochun Yang (Northeastern University, China) Juniie Yao (East China Normal University, China) Hongzhi Yin (The University of Queensland, Australia) Man Lung Yiu (Hong Kong Polytechnic University, China) Haruo Yokota (Tokyo Institute of Technology, Japan) Masatoshi Yoshikawa (Kyoto University, Japan) Xiangyao Yu (University of Wisconsin-Madison, USA) Demetrios Zeinalipour-Yazti (University of Cyprus, Cyprus) Baihua Zheng (Singapore Management University, Singapore) Rui Zhang (University of Melbourne, Australia) Wenjie Zhang (University of New South Wales, Australia) Xiaofei Zhang (The University of Memphis, USA) Ying Zhang (University of Technology Sydney, Australia) Yuanyuan Zhu (Wuhan University, China) Lei Zou (Peking University, China) Kostas Zoumpatianos (Harvard University, USA)

#### DISTINGUISHED PVLDB2020 REVIEW BOARD MEMBERS- Vol. 13

Arvind Arasu (Microsoft Research, USA) Ashraf Aboulnaga (Qatar Computing Research Institute, Qatar) Carsten Binnig (TU Darmstadt, Germany) Dan Kifer (Pennsylvania State University, USA) Erdem Sariyuce (University at Buffalo, USA) Eugene Wu (Columbia University, USA) Faisal Nawab (UC Santa Cruz, USA) Floris Geerts (University of Antwerp, Belgium) George Papadakis (University of Athens, Greece) Hideaki Kimura (Oracle, USA) Holger Pirk (Imperial College London, United Kingdom) Ioana Manolescu (INRIA, France) Jiannan Wang (Simon Fraser University, Canada) Jose Faleiro (Yale University, USA) Ken Salem (University of Waterloo, Canada) Maximilian Schleich (University of Oxford, USA) Melanie Herschel (Universität Stuttgart, Germany) Michael Hay (Colgate University, USA)

Mourad Ouzzani (Oatar Computing Research Institute, Qatar) Oktie Hassanzadeh (IBM Research, USA) Oliver Kennedy (University at Buffalo, SUNY, USA) Paolo Papotti (EURECOM, France) Peter Pietzuch (Imperial College London, United Kinadom) Prashant Shiralkar (Amazon, USA) Sanjay Krishnan (University of Chicago, USA) Semih Salihoglu (University of Waterloo, Canada) Sourav S Bhowmick (Nanyang Technological University, Singapore) Thorsten Papenbrock (Hasso Plattner Institute, Germany) Tingjian Ge (University of Massachusetts, Lowell, uSA) Torsten Grust (Universität Tübingen, Germany) Xu Chu (Georgia Tech, USA)

Yongxin Tong (Beihang University, China) Yuefei Tao (Chinese University of Hong Kong, China)

#### **ADDITIONAL REVIEWER - Vol. 13**

Akhil Arora Ali Sadeghian Andrew Schneider Anh Ding Ankur Sharma Anthony Colas Brad Glasbergen Brian Hentschel Can Lu Chen Ye Cheng Xu Chenhao Ma Christian Konig Chrysanthi Kosyfaki Constant Marks Daevoung Hong Damian Jimenez Dawei Gao Dawei Wang Dian Ouyang Dimitrios Tsitsigkos Dippy Aggarwal Dong Wen Donaging Xiao Dumitrel Loghin Ellis Michael Ester Livshits Fahad Shaon Felix Martin Schuhknecht Feng Kaiyu Feng Zhang Gabriel Ghinita Giacomo Bergami Gönenc Ercan Gongsheng Yuan Gourav Kumar Gwangho Song HAN Yaowei Hanjun Goo Hans Behrens Haoyu Liu Haridimos Kondylakis Hengtong Zhang Henning Koehler Hieu Hanh Le

Hongtao Yu Imrul Anindya Israa Jaradat Janghyuk Seo Jason Yellick Jaydeep Sen Jian Lou Jianbin Oin Jinbin Huang Jinfei Liu Jing Ma Junxu Liu K Venkatesh Emani Kaiping Zheng Karima Echihabi Kostas Zoumpatianos Libin Wang Lihona He Liuvi Yao Manolis Terrovitis Mao-Lin Li Marco Paterlla Matteo Lissandrini Menadi Huai Michael Abebe Michele A. Brandão Miguel Rodriguez Mustafa Ozdayi **Olivier Ruas** Pei Wang Pengfei Xu Qian Lin Qingsong Guo Oiulina Suo Ren Chen Rui Li Seongwoong Oh Sergey Pupyrev Shaofeng Cai Shuaicheng Ma Shubhankar Mohapatra Srinath Setty Subhadeep Sarkar Surabhi Gupta Suyong Kwon

Theodora Toutountzi Tiangi Wang Tianxing Wu Tobias Grubenmann Tomer Sagi Toshiyuki Shimizu Tsz Nam Chan Vasilis Efthymiou Venkatesh Emani Weiguo Zheng Wenya Sun William Spoth Woohwan Jung Xavier Defago Xiao Shi Xiao Wang Xiaodong Li Xiaoiie Wang Xiaolin Han Xiaovi Fu Xinting Huang Xuliang Zhu Xupeng Miao Yan Xie Yan Zhou Yang Cao Yang Wang Yang Yang Yang Zhou Yaging Wang Yash Garg Yeonsu Park Yifan Wang Yizhou Yan Yonggi Zhang Youngjun Ahn Yuanyuan Liu Yue Wang Yunming Zhang Yuyang Dong Zeyu Zhang ZHENG Shuyuan Zhiwei Zhang

#### LETTER FROM THE EDITORS IN CHIEF

The Proceedings of the VLDB Endowment (PVLDB) provides a high-quality journal publication service to the data management research community. Each volume offers twelve monthly submission deadlines on the first day of each month and a quick, six week reviewing cycle. This publication model was pioneered by PVLDB and combines a journal-style reviewing process, which includes a three-month revision cycle, with the agility and visibility provided by rapid on-line publication, and presentation at the annual VLDB conference.

PVLDB attracts many submissions spanning diverse data management topics, and the PVLDB reviewing process is implemented by a large team of dedicated researchers. The Review Board of PVLDB Volume 13 consists of 186 expert researchers, and reviewing is coordinated by 18 Associate Editors. Review Board members provide timely (within a 3-week deadline) high-quality reviews, and participate actively in online discussions led by the Associate Editors for each paper. When needed, the Associate Editors together with the Editors-in-Chief solicit additional reviews from external experts. We give special thanks here to those additional reviewers who in most cases need to complete their expert reviews on a very short notice.

Most of the accepted papers go through a revision process that requires a second round of reviews after the authors have addressed an initial set of issues and concerns raised by the reviewers during the first round. Some papers are further accepted with shepherding, which means that one of the reviewers works with the authors to address a final set of comments.

The 46th International Conference on Very Large Data Bases (PVLDB 2020), originally planned to be held in Tokyo, Japan during August 31 to September 4, 2020, has been successful held for the same period of time but completely online due to the coronavirus pandemic. This international conference has been organized in such a way that from any time zone people can participate the conference at a time convenient to them. Our online conference has attracted a record number of participates – nearly 5000 people registered to attend.

This is the thirteenth and the last issue of the thirteenth volume of PVLDB. The 7 papers in this issue are accepted for PVLDB 2020 but will be presented in PVLDB 2021 as their financial acceptance is too close to or even after this year's PVLDB conference. With monthly submission cycles and the review process that can include revision and shepherding phases, every year a small number of accepted papers are published after the conference with their presentations rolled over the next year's PVLDB conference. The 7 papers in this issue have a good coverage of PVLDB topics, including indexing structures, query processing methods, graph and high-dimensional data management, concurrency control mechanisms, database systems with novel hardware and architecture, and data privacy protection.

As the PC co-chairs and editors-in-chief, we take this final opportunity to thank our 18 associate editors, 186 review board members, 26 external reviewers who helped us when specialized expertise were required, as well as 133 additional reviewers who provided assistance to the main reviewers. Thirty-three review board members have been nominated by the Associate Editors to receive Distinguished Review Board Member Awards. In this issue, we publish their names again to acknowledge their excellent services and great contributions. We also want to specially thank our publication chairs, Sen Wang and Hiroaki Shiokawa, who have worked relentlessly and meticulously to ensure these 13 issues are published timely and accurately.

We hope that the readers will find the selected papers engaging, and thought provoking. We also hope that the selected papers will provide valuable insights and inspire novel systems contributions and follow-up research.

Magdalena Balazinska and Xiaofang Zhou PVLDB Volume 13 Editors in Chief