

PROCEEDINGS OF THE 2019 INTERNATIONAL CONFERENCE ON FOUNDATIONS OF COMPUTER SCIENCE



FCS'19

Editors

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Foreword

It gives us great pleasure to introduce this collection of papers to be presented at the 2019 International Conference on Foundations of Computer Science (FCS'19), July 29 – August 1, 2019, at Luxor Hotel (a property of MGM Resorts International), Las Vegas, USA. The preliminary edition of this book (available in July 2019 for distribution on site at the conference) includes only a small subset of the accepted research articles. The final edition (available in August 2019) will include all accepted research articles. This is due to deadline extension requests received from most authors who wished to continue enhancing the write-up of their papers (by incorporating the referees' suggestions). The final edition of the proceedings will be made available at <https://americancse.org/events/csce2019/proceedings> .

An important mission of the World Congress in Computer Science, Computer Engineering, and Applied Computing, CSCE (a federated congress to which this conference is affiliated with) includes *"Providing a unique platform for a diverse community of constituents composed of scholars, researchers, developers, educators, and practitioners. The Congress makes concerted effort to reach out to participants affiliated with diverse entities (such as: universities, institutions, corporations, government agencies, and research centers/labs) from all over the world. The congress also attempts to connect participants from institutions that have **teaching** as their main mission with those who are affiliated with institutions that have **research** as their main mission. The congress uses a quota system to achieve its institution and geography diversity objectives."* By any definition of diversity, this congress is among the most diverse scientific meeting in USA. We are proud to report that this federated congress has authors and participants from 57 different nations representing variety of personal and scientific experiences that arise from differences in culture and values. As can be seen (see below), the program committee of this conference as well as the program committee of all other tracks of the federated congress are as diverse as its authors and participants.

The program committee would like to thank all those who submitted papers for consideration. About 52% of the submissions were from outside the United States. Each submitted paper was peer-reviewed by two experts in the field for originality, significance, clarity, impact, and soundness. In cases of contradictory recommendations, a member of the conference program committee was charged to make the final decision; often, this involved seeking help from additional referees. In addition, papers whose authors included a member of the conference program committee were evaluated using the double-blinded review process. One exception to the above evaluation process was for papers that were submitted directly to chairs/organizers of pre-approved sessions/workshops; in these cases, the chairs/organizers were responsible for the evaluation of such submissions. The overall paper acceptance rate for regular papers was 22%; 18% of the remaining papers were accepted as poster papers (at the time of this writing, we had not yet received the acceptance rate for a couple of individual tracks.)

We are very grateful to the many colleagues who offered their services in organizing the conference. In particular, we would like to thank the members of Program Committee of FCS'19, members of the congress Steering Committee, and members of the committees of federated congress tracks that have topics within the scope of FCS. Many individuals listed below, will be requested after the conference to provide their expertise and services for selecting papers for publication (extended versions) in journal special issues as well as for publication in a set of research books (to be prepared for publishers including: Springer, Elsevier, BMC journals, and others).

- *Prof. Hamid R. Arabnia (Congress Steering Committee); Graduate Program Director (PhD, MS, MAMS); The University of Georgia, USA; Editor-in-Chief, Journal of Supercomputing (Springer); Fellow, Center of Excellence in Terrorism, Resilience, Intelligence & Organized Crime Research (CENTRIC).*
- *Prof. Juan Jose Martinez Castillo; Director, The Acatelys Alan Turing Nikola Tesla Research Group and GIPEB, Universidad Nacional Abierta, Venezuela*
- *Prof. Emeritus Kevin Daimi (Congress Steering Committee); Director, Computer Science and Software Engineering Programs, Department of Mathematics, Computer Science and Software Engineering, University of Detroit Mercy, Detroit, Michigan, USA*

- *Prof. Zhangisina Gulnur Davletzhanovna; Vice-rector of the Science, Central-Asian University, Kazakhstan, Almaty, Republic of Kazakhstan; Vice President of International Academy of Informatization, Kazakhstan, Almaty, Republic of Kazakhstan*
- *Prof. Leonidas Deligiannidis (Congress Steering Committee); Department of Computer Information Systems, Wentworth Institute of Technology, Boston, Massachusetts, USA; Visiting Professor, MIT, USA*
- *Prof. Tai-hoon Kim; School of Information and Computing Science, University of Tasmania, Australia*
- *Prof. Dr. Guoming Lai; Computer Science and Technology, Sun Yat-Sen University, Guangzhou, P. R. China*
- *Dr. Vitus S. W. Lam; Senior IT Manager, Information Technology Services, The University of Hong Kong, Kennedy Town, Hong Kong; Chartered Member of The British Computer Society, UK; Former Vice Chairman of the British Computer Society (Hong Kong Section); Chartered Engineer & Fellow of the Institution of Analysts and Programmers*
- *Prof. Dr., Eng. Robert Ehimen Okonigene (Congress Steering Committee); Department of Electrical & Electronics Engineering, Faculty of Engineering and Tech., Ambrose Alli University, Edo State, Nigeria*
- *Chiranjibi Sitaula; Head, Department of Computer Science and IT, Ambition College, Kathmandu, Nepal*
- *Ashu M. G. Solo (Publicity), Fellow of British Computer Society, Principal/R&D Engineer, Maverick Technologies America Inc.*
- *Dr. Tse Guan Tan; Faculty of Creative Technology and Heritage, Universiti Malaysia Kelantan, Kelantan, Malaysia*
- *Prof. Fernando G. Tinetti (Congress Steering Committee); School of Computer Science, Universidad Nacional de La Plata, La Plata, Argentina; also at Comision Investigaciones Cientificas de la Prov. de Bs. As., Argentina*
- *Varun Vohra; Certified Information Security Manager (CISM); Certified Information Systems Auditor (CISA); Associate Director (IT Audit), Merck, New Jersey, USA*
- *Prof. Layne T. Watson (Congress Steering Committee); Fellow of IEEE; Fellow of The National Institute of Aerospace; Professor of Computer Science, Mathematics, and Aerospace and Ocean Engineering, Virginia Polytechnic Institute & State University, Blacksburg, Virginia, USA*
- *Prof. Jane You (Congress Steering Committee); Associate Head, Department of Computing, The Hong Kong Polytechnic University, Kowloon, Hong Kong*

We would like to extend our appreciation to the referees, the members of the program committees of individual sessions, tracks, and workshops; their names do not appear in this document; they are listed on the web sites of individual tracks.

As Sponsors-at-large, partners, and/or organizers each of the followings (separated by semicolons) provided help for at least one track of the Congress: Computer Science Research, Education, and Applications Press (CSREA); US Chapter of World Academy of Science; American Council on Science & Education & Federated Research Council (<http://www.americancse.org/>). In addition, a number of university faculty members and their staff (names appear on the cover of the set of proceedings), several publishers of computer science and computer engineering books and journals, chapters and/or task forces of computer science associations/organizations from 3 regions, and developers of high-performance machines and systems provided significant help in organizing the conference as well as providing some resources. We are grateful to them all.

We express our gratitude to keynote, invited, and individual conference/tracks and tutorial speakers - the list of speakers appears on the conference web site. We would also like to thank the followings: UCMSS (Universal Conference Management Systems & Support, California, USA) for managing all aspects of the conference; Dr. Tim Field of APC for coordinating and managing the printing of the proceedings; and the staff of Luxor Hotel (Convention department) at Las Vegas for the professional service they provided. Last

but not least, we would like to thank the Co-Editors of FCS'19: Prof. Hamid R. Arabnia, Prof. Fernando G. Tinetti, and Associate Editor, Ashu M. G. Solo.

We present the proceedings of FCS'19.

Steering Committee, 2019
<http://americancse.org/>