# Computing in Civil Engineering 2019

## Smart Cities, Sustainability, and Resilience

Selected Papers from the ASCE International Conference on Computing in Civil Engineering 2019

- Atlanta, GA
- June 17–19, 2019

Edited by Yong K. Cho, Ph.D.; Fernanda Leite, Ph.D.; Amir Behzadan, Ph.D.; and Chao Wang, Ph.D.

ASCE

# COMPUTING IN CIVIL ENGINEERING 2019

## *SMART CITIES, SUSTAINABILITY, AND RESILIENCE*

SELECTED PAPERS FROM THE ASCE INTERNATIONAL CONFERENCE ON COMPUTING IN CIVIL ENGINEERING 2019

June 17–19, 2019
Atlanta, Georgia

SPONSORED BY
Computing Division of the
American Society of Civil Engineers

EDITED BY
Yong K. Cho, Ph.D.
Fernanda Leite, Ph.D.
Amir Behzadan, Ph.D.
Chao Wang, Ph.D.

ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

1801 ALEXANDER BELL DRIVE
RESTON, VIRGINIA 20191–4400

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org



***Errata:*** **Errata, if any, can be found at https://doi.org/10.1061/9780784482445**


ISBN 978-0-7844-8244-5 (PDF)
Manufactured in the United States of America.

# Preface

The ASCE International Conference on Computing in Civil Engineering (i3CE) 2019 was hosted by the Georgia Institute of Technology with sponsorship from ASCE's Computing Division and held in the city of Atlanta, Georgia from June 17-19, 2019. The conference is the Computing Division's major meeting event and is held bi-annually in the United States, with participation from scholars worldwide. i3CE 2019 is aimed at presenting current research being carried out in the area of computing in civil engineering by attracting a strong and active researchers and audience through keynote sections, dedicated topic sessions, industry sessions, and technical committee meetings.

The 2019 Conference, as a standalone event, received 454 abstracts, 288 full papers, and 58 extended abstracts for the poster and demonstration sessions. A total of 230 full papers from 26 countries around the globe were accepted and included in the proceedings. The final set of papers was selected through a rigorous peer-review process, which involved the collection of at least two blinded reviews per paper. The review process was performed for both abstracts and full papers, ensuring that only the best contributions were selected. Finally, the authors had the chance to incorporate reviewers' comments into the final version. We are very pleased with the high quality of selected papers, and we wish to thanks both authors and reviewers for their efforts. All papers were divided into three books with the following three research focus areas:

- Visualization, Information Modeling, and Simulation
- Data, Sensing, and Analytics
- Smart Cities, Sustainability, and Resilience

Organizing this conference has been possible only with the support of many. We are particularly grateful to the School of Civil and Environmental Engineering at the Georgia Institute of Technology for their support and infrastructure. We would also like to thank the guidance from the Computing Division's Executive Committee and the assistance from ASCE.

We hope that you enjoyed the technical sessions, posters, demonstrations, technical committee meetings, and industry panel discussion during the conference and that you had a memorable and meaningful i3CE 2019 experience in Atlanta, Georgia.

**Yong Cho, Ph.D.**
Conference Chair, Organizing Committee, Georgia Institute of Technology

**Fernanda Leite, Ph.D.**
Conference Vice Chair, Organizing Committee University of Texas at Austin

**Amir Behzadan, Ph.D.**
Chair, Technical Committee, Texas A&M University

**Chao Wang, Ph.D.**
Manager, Technical Committee Proceedings, Louisiana State University

# Acknowledgments

The members of the Organizing Committee are recognized for their dedication, support, and contributions for the success of the 2019 ASCE International Conference on Computing in Civil Engineering.

**Yong K. Cho, Ph.D.**
Conference Chair, Georgia Institute of Technology

**Fernanda Leite, Ph.D.**
Conference Vice Chair, University of Texas at Austin

**Amir Behzadan, Ph.D.**
Technical Committee Chair, Texas A&M University

**Chao Wang, Ph.D.**
Technical Committee Proceedings Manager, Louisiana State University

Special thanks are due to the following Poster Session Chair, Demo Session Chair, Best Paper Award Committee Chair, and Student Assistants for their help with the related process.

**Poster Session Chair:**
Semiha Ergan New York University

**Demo Session Chair:**
Fei Dai West Virginia University

**Best Paper Award Committee Chair:**
Chao Wang Louisiana State University

**Student and Postdoc Assistants:**

| | |
|---|---|
| Kinam Kim | Georgia Institute of Technology |
| Jitae Kim | Georgia Institute of Technology |
| Jisoo Park | Georgia Institute of Technology |
| Jingdao Chen | Georgia Institute of Technology |
| Pileun Kim | Georgia Institute of Technology |
| Rachel Samuels | Georgia Institute of Technology |
| Youjin Jang, Ph.D. | Georgia Institute of Technology |
| Inbae Jeong, Ph.D. | Georgia Institute of Technology |

The Organizing Committee acknowledges the support of the technical committee session chairs and members who helped in the peer-review and selection process of the articles that are part of these proceedings.

**Technical Committee (Session Chairs):**

*Artificial Intelligence and Machine Learning:*

| | |
|---|---|
| Abbas Rashidi | West Virginia University |
| Reza Akhavian | California State University, East Bay |
| Youngjib Ham | Texas A&M University |

*Building and Urban Systems:*

| | |
|---|---|
| Carol Menassa | University of Michigan |
| Zoltan Nagy | University of Texas, Austin |

*Data Sensing:*

| | |
|---|---|
| Hubo Cai | Purdue University |
| Pingbo Tang | Arizona State University |
| Yong-Cheol Lee | Louisiana State University |

*Disaster Preparedness and Response:*

| | |
|---|---|
| Masoud Gheisari | University of Florida |
| Nan Li | Tsinghua University |

*Facilities and Blockchain:*

| | |
|---|---|
| Sharareh Kermanshachi | University of Texas, Arlington |

*Information Modeling:*

| | |
|---|---|
| Farrokh Jazizadeh | Virginia Tech |
| Fei Dai | West Virginia University |
| Semiha Ergan | New York University |

*Infrastructure and Energy:*

| | |
|---|---|
| Rui Liu | University of Florida |
| Zhenhua Zhu | Concordia University |

*Professional Issues:*

| | |
|---|---|
| Amirhosein Jafari | Louisiana State University |

*Project and Construction Management:*

| | |
|---|---|
| Mohammed Mehany | Colorado State University |
| Youngcheol Kang | Yonsei University |

*Reality Capture:*

| | |
|---|---|
| Behzad Esmaeili | George Mason University |
| Dong Zhao | Michigan State University |

*Robotics and Human-Computer Interaction:*

| | |
|---|---|
| Jiansong Zhang | Purdue University |
| Joseph Louis | Oregon State University |

*Safety and Health:*

| | |
|---|---|
| Jun Wang | Mississippi State University |
| Ryan Ahn | Texas A&M University |

*Simulation:*

| | |
|---|---|
| Wenying Ji | George Mason University |

*Visualization:*

| | |
|---|---|
| Steven Ayer | Arizona State University |

*Special Topics:*

| | |
|---|---|
| Chen Feng | New York University |
| Lina Sela | University of Texas, Austin |
| Qianwei Xu | Tongji University |
| Yang Wang | Georgia Institute of Technology |

The Organizing Committee would also like to thank the following Executive Committee of ASCE Computing Division, Local Conference Committee, and Conference Event Planning and Registration Administrator for their assistance and support for the success of the conference.

**Executive Committee:**

| | |
|---|---|
| Burcin Becerik-Gerber | University of Southern California |
| Lucio Soibelman | University of Southern California |
| Nora M. El-Gohary | University of Illinois at Urbana-Champaign |
| Heather M. Brooks | CTA Liaison |
| Yong K Cho | Georgia Institute of Technology |
| Robert Keith Goldberg | University of Akron |
| Christian Koch | Bauhaus-Universität Weimar |
| Ken-Yu Lin | University of Washington |
| James M Neckel | ASCE Administrator, Technical Advancement |

**Local Conference Committee:**

| | |
|---|---|
| John E. Taylor | Georgia Institute of Technology |
| Eric Marks | Georgia Institute of Technology |
| Yi-Chang James Tsai | Georgia Institute of Technology |
| Yang Wang | Georgia Institute of Technology |
| Javier Irizarry | Georgia Institute of Technology |

**Conference Event Planning and Registration Administrator:**

| | |
|---|---|
| Robin Finey | Global Learning Center at Georgia Institute of Technology |
| Catherin Shaw | Global Learning Center at Georgia Institute of Technology |
| Jamia Luckett | Georgia Institute of Technology |

Finally, a sincere appreciation goes to the EasyChair LTD. for providing the Organizing Committee free access to EasyChair's Conference Management Software System and for customizing the online platform for the conference.

# Contents

*Built Environment and Infrastructure Monitoring, Assessment, and Maintenance*