

Computational Intelligence Techniques in Earth and Environmental Sciences

Tanvir Islam • Prashant K. Srivastava
Manika Gupta • Xuan Zhu
Saumitra Mukherjee
Editors

Computational Intelligence Techniques in Earth and Environmental Sciences

 Springer

Editors

Tanvir Islam
NOAA/NESDIS Center for Satellite
Applications and Research
College Park, MD, USA

Cooperative Institute for Research
in the Atmosphere
Colorado State University
Fort Collins, CO, USA

Manika Gupta
Department of Civil Engineering
IIT Delhi
Delhi, India

Saumitra Mukherjee
School of Environmental Sciences
Remote Sensing
Jawaharlal Nehru University
New Delhi, India

Prashant K. Srivastava
NASA Goddard Space Flight Center
Greenbelt, MD, USA

ESSIC, University of Maryland
College Park, MD, USA

Xuan Zhu
School of Geography and Environmental
Science

Monash University
Melbourne, Australia

ISBN 978-94-017-8641-6

ISBN 978-94-017-8642-3 (eBook)

DOI 10.1007/978-94-017-8642-3

Springer Dordrecht Heidelberg New York London

Library of Congress Control Number: 2014931489

© Springer Science+Business Media Dordrecht 2014

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system, for exclusive use by the purchaser of the work. Duplication of this publication or parts thereof is permitted only under the provisions of the Copyright Law of the Publisher's location, in its current version, and permission for use must always be obtained from Springer. Permissions for use may be obtained through RightsLink at the Copyright Clearance Center. Violations are liable to prosecution under the respective Copyright Law.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

While the advice and information in this book are believed to be true and accurate at the date of publication, neither the authors nor the editors nor the publisher can accept any legal responsibility for any errors or omissions that may be made. The publisher makes no warranty, express or implied, with respect to the material contained herein.

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

Computational intelligence (CI) techniques have garnered considerable interest in recent decades within the earth and environmental science research communities because of its capacity to solve and understand various complex problems achieving a sustainable planet. This book is a collection of recent developments and applications of the computational intelligence techniques in earth and environmental sciences. Topics addressed in this volume include meteorology, atmospheric modeling, climate change, environmental engineering, water resources, and hydrological modeling. The editors hope that this volume will promote increased collaboration of scientists with backgrounds in computer sciences with earth and environmental scientists.

The main focus of the contents are divided into three broad categories—classical intelligence techniques, probabilistic and transforms intelligence techniques, and hybrid intelligence techniques. Part I of the volume serves as an overview of computational intelligence techniques and their application in earth and environmental sciences. In Part II, which covers classical intelligence techniques, the contributions related to the classical methods applied to earth and environmental sciences are gathered. Part III concerns probabilistic and transforms intelligence techniques, more specifically, the application of Markov analysis and wavelet transforms to the earth and environmental sciences. Lastly, the analyses of problems that cannot be adequately solved with traditional techniques are addressed in Part IV. Hybrid approaches are highlighted.

The editors would like to thank all the contributors to this volume for their valuable contributions and their patience with the editing of the manuscript.

College Park, MD, USA
Greenbelt, MD, USA
Delhi, India
Melbourne, Australia
Delhi, India

Tanvir Islam
Prashant K. Srivastava
Manika Gupta
Xuan Zhu
Saumitra Mukherjee

Contents

Part I General

- 1 Computational Intelligence Techniques and Applications 3
Xuan Zhu

Part II Classical Intelligence Techniques in Earth and Environmental Sciences

- 2 Vector Autoregression (VAR) Modeling and Forecasting of Temperature, Humidity, and Cloud Coverage 29
Md. Abu Shahin, Md. Ayub Ali, and A.B.M. Shawkat Ali
- 3 Exploring the Behavior and Changing Trends of Rainfall and Temperature Using Statistical Computing Techniques 53
Abdus Salam Azad, Md. Kamrul Hasan, M. Arif Imtiazur Rahman, Md. Mustafizur Rahman, and Nashid Shahriar
- 4 Time Series Model Building and Forecasting on Maximum Temperature Data 79
Amrina Ferdous, Md. Abu Shahin, and Md. Ayub Ali
- 5 GIS Visualization of Climate Change and Prediction of Human Responses 93
P.K. Nag, Priya Dutta, Varsha Chorsiya, and Anjali Nag

Part III Probabilistic and Transforms Intelligence Techniques in Earth and Environmental Sciences

- 6 Markov Chain Analysis of Weekly Rainfall Data for Predicting Agricultural Drought 109
A.T.M. Jahangir Alam, M. Sayedur Rahman, and A.H.M. Sadaat

7 Forecasting Tropical Cyclones in Bangladesh: A Markov Renewal Approach	129
Md. Asaduzzaman and A.H.M. Mahbub Latif	
8 Performance of Wavelet Transform on Models in Forecasting Climatic Variables	141
Md. Jahanur Rahman and Md. Al Mehedi Hasan	
9 Analysis of Inter-Annual Climate Variability Using Discrete Wavelet Transform	155
Md. Khademul Islam Molla, A.T.M. Jahangir Alam, Munmun Akter, A.R. Shoyeb Ahmed Siddique, and M. Sayedur Rahman	
Part IV Hybrid Intelligence Techniques in Earth and Environmental Sciences	
10 Modeling of Suspended Sediment Concentration Carried in Natural Streams Using Fuzzy Genetic Approach	175
Özgür Kişi and Halil İbrahim Fedakar	
11 Prediction of Local Scour Depth Downstream of Bed Sills Using Soft Computing Models	197
A. Zahiri, H. Md. Azamathulla, and Kh. Ghorbani	
12 Evaluation of Wavelet-Based De-noising Approach in Hydrological Models Linked to Artificial Neural Networks	209
Vahid Nourani, Aida Hosseini Baghanam, Aida Yahyavi Rahimi, and Farzad Hassan Nejad	
13 Evaluation of Mathematical Models with Utility Index: A Case Study from Hydrology	243
Dr. Renji Remesan and Dr. Dawei Han	
Index	265

Contributors

Munmun Akter Department of Computer Science and Engineering, The University of Rajshahi, Rajshahi, Bangladesh

A.T.M. Jahangir Alam Department of Environmental Sciences, Jahangirnagar University, Savar, Dhaka, Bangladesh

Md. Ayub Ali Department of Statistics, University of Rajshahi, Rajshahi, Bangladesh

A.B.M. Shawkat Ali School of Engineering and Technology, Central Queensland University, North Rockhampton, QLD, Australia

Md. Asaduzzaman Institute of Statistical Research and Training (ISRT), University of Dhaka, Dhaka, Bangladesh

Abdus Salam Azad Department of Computer Science and Engineering, Bangladesh University of Engineering and Technology, Palashi, Dhaka, Bangladesh

H. Md. Azamathulla REDAC, Universiti Sains Malaysia, Georgetown, Pulau Penang, Malaysia

Aida Hosseini Baghanam Faculty of Civil Engineering, Department of Water Resources Engineering, University of Tabriz, Tabriz, Iran

Varsha Chorsiya National Institute of Occupational Health, Ahmedabad, India

Priya Dutta Indian Institute of Public Health Gandhinagar, Public Health Foundation of India, Ahmedabad, India

Halil İbrahim Fedakar Faculty of Engineering and Natural Sciences, Civil Engineering Department, Abdullah Gül University, Kayseri, Turkey

Amrina Ferdous Department of Mathematics, Washington State University, Pullman, WA, USA

Department of Statistics, University of Rajshahi, Rajshahi, Bangladesh

Kh. Ghorbani Water Engineering Department, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Golestan Province, Iran

Manika Gupta Department of Civil Engineering, Indian Institute of Technology Delhi, New Delhi, India

Dawei Han Department of Civil Engineering, University of Bristol, Bristol, UK

Md. Al Mehedi Hasan Department of Computer Science and Engineering, Rajshahi University of Engineering and Technology, Rajshahi, Bangladesh

Md. Kamrul Hasan Department of Computer Science and Engineering, Bangladesh University of Engineering and Technology, Palashi, Dhaka, Bangladesh

Tanvir Islam NOAA/NESDIS Center for Satellite Applications and Research, College Park, MD, USA

Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, CO, USA

Özgür Kişi Faculty of Engineering and Architecture, Civil Engineering Department, Canik Başarı University, Samsun, Turkey

A.H.M. Mahbub Latif Institute of Statistical Research and Training (ISRT), University of Dhaka, Dhaka, Bangladesh

Md. Khademul Islam Molla Department of Information and Communication Engineering, The University of Tokyo, Bunkyo, Tokyo, Japan

Department of Computer Science and Engineering, The University of Rajshahi, Rajshahi, Bangladesh

Saumitra Mukherjee Remote Sensing, School of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India

Anjali Nag National Institute of Occupational Health, Ahmedabad, India

P.K. Nag National Institute of Occupational Health, Ahmedabad, India

Farzad Hassan Nejad Faculty of Civil Engineering, Department of Water Resources Engineering, University of Tabriz, Tabriz, Iran

Vahid Nourani Faculty of Civil Engineering, Department of Water Resources Engineering, University of Tabriz, Tabriz, Iran

Aida Yahyavi Rahimi Faculty of Civil Engineering, Department of Water Resources Engineering, University of Tabriz, Tabriz, Iran

M. Arif Imtiazur Rahman Department of Computer Science and Engineering, Bangladesh University of Engineering and Technology, Palashi, Dhaka, Bangladesh

Md. Jahanur Rahman Department of Statistics, University of Rajshahi, Rajshahi, Bangladesh

Md. Mustafizur Rahman Department of Computer Science and Engineering, Bangladesh University of Engineering and Technology, Palashi, Dhaka, Bangladesh

M. Sayedur Rahman Department of Statistics, The University of Rajshahi, Rajshahi, Bangladesh

Renji Remesan Cranfield Water Science Institute, Cranfield University, Cranfield, Bedfordshire, UK

A.H.M. Sadaat Department of Environmental Sciences, Jahangirnagar University, Savar, Dhaka, Bangladesh

Md. Abu Shahin Department of Statistics, University of Rajshahi, Rajshahi, Bangladesh

Nashid Shahriar Department of Computer Science and Engineering, Bangladesh University of Engineering and Technology, Palashi, Dhaka, Bangladesh

A.R. Shoyeb Ahmed Siddique Department of Computer Science and Engineering, The University of Rajshahi, Rajshahi, Bangladesh

Prashant K. Srivastava NASA Goddard Space Flight Center, Greenbelt, MD, USA

ESSIC, University of Maryland, College Park, MD, USA

A. Zahiri Water Engineering Department, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Golestan Province, Iran

Xuan Zhu School of Geography and Environmental Science, Monash University, Clayton, VIC, Australia

About the Editors

Dr. Tanvir Islam received the Ph.D. degree in remote sensing from the University of Bristol in Bristol, UK, in 2012. His Ph.D. research was focused on the remote sensing of precipitation through the use of radar polarimetry, especially towards algorithm developments and data quality improvements.

Following his Ph.D., he joined the University of Tokyo as a visiting scientist, more specifically, as part of the NASA/JAXA precipitation measurement missions (PMM) algorithm development team, which was supported by JAXA. Since 2013, he has been with the NOAA/NESDIS Center for Satellite Applications and Research, as a CIRA/CSU fellow, working on the development of satellite remote sensing algorithms with an emphasis on microwave variational inversion techniques. Currently, he is the scientific algorithm developer for the NOAA's Microwave Integrated Retrieval System (MiRS), where he is leading a number of efforts to enhance the performance of geophysical retrievals and extend the capability of the system to new passive microwave sensors.

Dr. Tanvir was the recipient of the Faculty of Engineering Commendation from the University of Bristol for his outstanding Ph.D. thesis (nominated for a University Prize) in 2012, the JAXA visiting fellowship award in 2012, and the CIRA postdoctoral fellowship award in 2013. He has been a member of the American Geophysical Union (AGU), International Association of Hydrological Sciences (IAHS), and American Society of Civil Engineers (ASCE). His primary research interests include satellite retrieval algorithms, cloud and precipitation system, radiative transfer modeling, data assimilation, radar polarimetry, mesoscale modeling, and artificial intelligence techniques applied to remote sensing and hydrometeorology.

Dr. Prashant K. Srivastava received his bachelors degree in Agriculture Sciences from the Institute of Agricultural Sciences, Banaras Hindu University (BHU), India, in 2004 and masters degree in Environmental Sciences from the School of Environmental Sciences (SES), Jawaharlal Nehru University (JNU), India in 2006. He worked on remote sensing applications as a Council of Scientific and Industrial Research-Junior Research Fellow in SES, JNU, for a year and then joined as an

Assistant Professor in the Department of Environmental Sciences, NVPAS, Sardar Patel University, Gujarat, in 2007. In 2010, he began work on his Ph.D. from the Department of Civil Engineering, University of Bristol. His research was sponsored and funded by India's Ministry of Human Research Development and under the United Kingdom's Commonwealth Scholarship and Fellowship Plan (CSFP). His Ph.D. research was focused on the soil moisture retrieval algorithm development from SMOS satellite and mesoscale model for hydrological applications. Following receipt of his Ph.D. in 2013, he moved to a position as a research scientist in the ESSIC/NASA Goddard Space Flight Center, Hydrological Sciences Branch, conducting work on SMAP satellite soil moisture retrieval algorithm development. Dr. Prashant K. Srivastava has been a recipient of many awards including Commonwealth fellowship, UK, CSIR fellowship (twice), MHRD, and UGC fellowships from India. He has published more than 45 peer-reviewed journal papers and more than 20 conference papers. Currently he is serving as an editorial board member of five journals related to remote sensing and environmental sciences. He is currently a member of the Indian Society of Geomatics, Indian Society of Remote Sensing, Indian Association of Hydrologists (*IAH*), International Society for Agrometeorology (INSAM), and International Association of Hydrological Sciences (IAHS).

Dr. Manika Gupta received her Master's degree in Environmental Sciences from the School of Environmental Sciences (SES), Jawaharlal Nehru University (JNU), India, in 2006. She worked as a researcher on remote sensing applications from SES, JNU, for a year and then joined the Department of Civil Engineering, Indian Institute of Technology, New Delhi, India, for her Ph.D. in 2007 as a UGC fellow. Her Ph.D. focused on numerical modeling for water resource management. Following receipt of her Ph.D. in 2012, she worked as a research consultant in Jaipur, India, on GIS and remote sensing for slum area delineation. She is currently working in collaboration with a number of pioneering global organizations such as University of Bristol, NOAA, and NASA on remote sensing advancements. Her current research involves assimilation of hyperspectral and microwave (precipitation) data in numerical models for pesticide and soil moisture prediction. Dr. Gupta has been a recipient of many awards including EIPRS (Australia), COSPAR (China), CSIR, ICMR, and UGC fellowships from India. She has published more than 25 peer-reviewed journal papers and more than 15 conference papers. She is a member of Indian Society of Geomatics, Indian Society of Remote Sensing, Indian Association of Hydrologists (*IAH*), and International Society for Agrometeorology (INSAM).

Dr. Xuan Zhu is Senior Lecturer in the School of Geography and Environmental Science at Monash University, where he is Director of Centre for GIS. He is also Guest Professor at Sichuan University. He has nearly 30 years of international experience with GIS development, application, and education in China, the UK, Ireland, Singapore, and Australia. He holds a Master's degree from Nanjing University in Cartography and Remote Sensing and a Ph.D. from the University

of Edinburgh in GIS. His primary research areas are GIS for environmental management, spatial decision support systems for regional sustainable development, land use analysis and modeling, and remote sensing of the environment. He is the author of more than 50 scholarly works including a co-authored textbook on *Principles and Techniques of Geographical Information Systems* (East China Normal University Press, 2006). He teaches various GIS and remote sensing courses at Monash University.

Dr. Saumitra Mukherjee is Professor of Geology, Remote Sensing and Space Sciences at the School of Environmental Sciences, Jawaharlal Nehru University, Delhi. He obtained his M.Sc. and Ph.D. in Geology from the Banaras Hindu University, Varanasi, India. Prior to joining JNU in 1992, Professor Mukherjee served as Hydrogeologist and Remote Sensing Scientist for the Government of India. He has vast experience on satellites like IRS, LANDSAT, SPOT, Indian Remote Sensing Satellites, Hyperion, ResourceSat, LIDAR, and SOHO data for Sun–Earth Environment. He has authored seven books in the field of remote sensing and environmental sciences. He has published more than 80 papers in the peer-reviewed journals with nearly 60 conference contributions. He has supervised 18 doctoral theses and completed 14 collaborative projects funded by the national and international agencies, and is also involved in the projects funded by NASA on sun–earth connections. Professor Mukherjee has been designated as UGC Professor of Geology and Remote Sensing in view of his contribution in the field of Geology and Remote Sensing. He has also served as an executive commonwealth Fellow at University of Liverpool, UK. Prof. Mukherjee received many awards including the award given by the Government of India’s Ministry of Environment and Forest for his academic contributions. He serves as an editorial board member of four journals. Currently, he is a member of number of pioneer organizations in the world including American Geophysical Union, European Space Agency, European Geosciences Union, SOC, JPL/CALTECH/NASA, European Fleet for Airborne Research, Canadian Remote Sensing Society, Indian Society of Remote Sensing, and Executive Fellow (Earth Sciences—India).