Kasthurirangan Gopalakrishnan, Halil Ceylan,
and Nii O. Attoh-Okine (Eds.)

Intelligent and Soft Computing in Infrastructure Systems Engineering

Recent Advances

Springer

Prof. Kasthurirangan Gopalakrishnan
354 Town Engineering Bldg.
Dept. of Civil, Constr. & Env. Engg.
Iowa State University
Ames, IA 50011-3232
USA
E-mail: rangan@iastate.edu

Dr. Nii O. Attoh-Okine
343B DuPont Hall
Dept. of Civil and Environmental Engineering
University of Delaware
Newark, DE 19716
USA

Prof. Halil Ceylan
482B Town Engineering Bldg.
Dept. of Civil, Constr. & Env. Engg.
Iowa State University
Ames, IA 50011-3232
USA

ISBN 978-3-642-04585-1 e-ISBN 978-3-642-04586-8

DOI 10.1007/978-3-642-04586-8

Studies in Computational Intelligence ISSN 1860-949X

Library of Congress Control Number: 2009937151

© 2009 Springer-Verlag Berlin Heidelberg

This work is subject to copyright. All rights are reserved, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilm or in any other way, and storage in data banks. Duplication of this publication or parts thereof is permitted only under the provisions of the German Copyright Law of September 9, 1965, in its current version, and permission for use must always be obtained from Springer. Violations are liable to prosecution under the German Copyright Law.

The use of general descriptive names, registered names, trademarks, 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.

Typeset & *Cover Design:* Scientific Publishing Services Pvt. Ltd., Chennai, India.

Printed in acid-free paper

9 8 7 6 5 4 3 2 1

springer.com

Preface

The term "soft computing" applies to variants of and combinations under the four broad categories of evolutionary computing, neural networks, fuzzy logic, and Bayesian statistics. Although each one has its separate strengths, the complementary nature of these techniques when used in combination (hybrid) makes them a powerful alternative for solving complex problems where conventional mathematical methods fail.

The use of intelligent and soft computing techniques in the field of geomechanical and pavement engineering has steadily increased over the past decade owing to their ability to admit approximate reasoning, imprecision, uncertainty and partial truth. Since real-life infrastructure engineering decisions are made in ambiguous environments that require human expertise, the application of soft computing techniques has been an attractive option in pavement and geomechanical modeling.

The objective of this carefully edited book is to highlight key recent advances made in the application of soft computing techniques in pavement and geomechanical systems. Soft computing techniques discussed in this book include, but are not limited to: neural networks, evolutionary computing, swarm intelligence, probabilistic modeling, kernel machines, knowledge discovery and data mining, neuro-fuzzy systems and hybrid approaches. Highlighted application areas include infrastructure materials modeling, pavement analysis and design, rapid interpretation of nondestructive testing results, porous asphalt concrete distress modeling, model parameter identification, pavement engineering inversion problems, subgrade soils characterization, and backcalculation of pavement layer thickness and moduli.

This book belongs to the "Studies in Computational Intelligence (SCI)" series published by Springer Verlag. Each chapter contained in this book has been peer-reviewed by at least two anonymous referees to assure the highest quality. The valuable contributions of the following individuals in assisting with the review process are greatly appreciated: Sunghwan Kim (Iowa State University), Roger W. Meier (The University of Memphis), Fwa Tien Fang (National University of Singapore), P. Chris Marshall (Golder Associates Inc.), Abhisek Mudgal (Iowa State University), and Amit Pande (Iowa State University).

Researchers and practitioners engaged in developing and applying soft computing and intelligent systems principles to solving real-world infrastructure engineering problems will find this book very useful. This book will also serve as an excellent state-of-the-art reference material for graduate and postgraduate students in transportation infrastructure engineering.

August 13, 2009

Kasthurirangan (Rangan) Gopalakrishnan
Ames, Iowa

About This Book

The use of intelligent and soft computing techniques in the field of geomechanical and pavement engineering has steadily increased over the past decade owing to their ability to admit approximate reasoning, imprecision, uncertainty and partial truth. Since real-life infrastructure engineering decisions are made in ambiguous environments that require human expertise, the application of soft computing techniques has been an attractive option in pavement and geomechanical modeling. The objective of this carefully edited book is to highlight key recent advances made in the application of soft computing techniques in pavement and geomechanical systems. Soft computing techniques discussed in this book include, but are not limited to: neural networks, evolutionary computing, swarm intelligence, probabilistic modeling, kernel machines, knowledge discovery and data mining, neuro-fuzzy systems and hybrid approaches. Highlighted application areas include infrastructure materials modeling, pavement analysis and design, rapid interpretation of nondestructive testing results, porous asphalt concrete distress modeling, model parameter identification, pavement engineering inversion problems, subgrade soils characterization, and backcalculation of pavement layer thickness and moduli. Researchers and practitioners engaged in developing and applying soft computing and intelligent systems principles to solving real-world infrastructure engineering problems will find this book very useful. This book will also serve as an excellent state-of-the-art reference material for graduate and postgraduate students in transportation infrastructure engineering.

Written for

Researchers and practitioners engaged in developing and applying soft computing and intelligent systems principles to solving real-world geomechanical and pavement engineering problems.

Keywords

Pavement engineering; artificial intelligence; artificial neural networks; evolutionary computing; genetic algorithms; particle swarm optimization; shuffled complex evolution; support vector machines; data mining; rough set; neuro-fuzzy; decision trees; genetic polynomial; relief ranking filter; extended Kalman filter.

Contents

Rapid Interpretation of Nondestructive Testing Results Using Neural Networks
Imad N. Abdallah, Soheil Nazarian 1

Probabilistic Inversion: A New Approach to Inversion Problems in Pavement and Geomechanical Engineering
Rambod Hadidi, Nenad Gucunski 21

Neural Networks Application in Pavement Infrastructure Materials
Sunghwan Kim, Kasthurirangan Gopalakrishnan, Halil Ceylan 47

Backcalculation of Flexible Pavements Using Soft Computing
A. Hilmi Lav, A. Burak Goktepe, M. Aysen Lav 67

Knowledge Discovery and Data Mining Using Artificial Intelligence to Unravel Porous Asphalt Concrete in the Netherlands
Maryam Miradi, Andre A.A. Molenaar, Martin F.C. van de Ven 107

Backcalculation of Pavement Layer Thickness and Moduli Using Adaptive Neuro-fuzzy Inference System
Mehmet Saltan, Serdal Terzi 177

Case Studies of Asphalt Pavement Analysis/Design with Application of the Genetic Algorithm
Bor-Wen Tsai, John T. Harvey, Carl L. Monismith 205

Extended Kalman Filter and Its Application in Pavement Engineering
Rongzong Wu, Jae Woong Choi, John T. Harvey 239

Hybrid Stochastic Global Optimization Scheme for Rapid Pavement Backcalculation
Kasthurirangan Gopalakrishnan 255

Regression and Artificial Neural Network Modeling of Resilient Modulus of Subgrade Soils for Pavement Design Applications
Pranshoo Solanki, Musharraf Zaman, Ali Ebrahimi 269

Application of Soft Computing Techniques to Expansive Soil Characterization
Pijush Samui, Sarat Kumar Das, T.G. Sitharam 305

Author Index 325