Guest Editors' Introduction: Special Section on Computational Sustainability—Where Computer Science meets Sustainable Development

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COMPUTATIONAL sustainability is concerned with the development and application of computational methods for balancing environmental, economic, and societal needs for a sustainable future [1]. Specifically, it considers the major problem domains that impact global sustainability, those technologies and processes that offer the greatest opportunity to increase sustainability in these domains, and the fundamental computational methods that support these technologies and processes. The literature demonstrates that key sustainability issues translate into decision and optimization problems that fall within the realm of computing and information science, but generally they have not been studied by computer scientists. Computational sustainability encompasses problems in disciplines as diverse as ecology, natural resources, atmospheric science, materials science, renewable energy, and biological and environmental engineering.

According to the Brundtland Commission [2], sustainable development is development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs. Computational sustainability is a new interdisciplinary field [1] that aims to apply techniques from computer science and related fields, namely information science, operations research, applied mathematics, and statistics, to applications related to sustainable development. The range of problems that fall under computational sustainability is rather wide, encompassing computational challenges in disciplines as diverse as ecology, natural resources, atmospheric science, biological and environmental engineering, and land use, conservation, or transportation planning. Research in computational sustainability is necessarily interdisciplinary.

The objective of this special section is to promote awareness and deepen understanding of the critical role computer science and computational methods can play in studying and providing solutions to sustainability-related problems. The special section also aims to provide a resource to the research community that we hope will assist in developing the expertise that society will need to address sustainability challenges by inspiring scientists to pursue sustainability-related research. Finally, this special section showcases a variety of cutting-edge techniques and methods that address the scale and complexity of the challenges facing societal efforts to move towards sustainability. Collaboration between computer scientists and fields more traditionally associated with sustainability-related research provides an opportunity to introduce enhanced or new computational methods and techniques to advance work in numerous disciplines. We hope that this special section will also appeal to those working outside computer science, demonstrating what that discipline has to offer to the broader sustainability agenda.

We have selected seven papers to be included in this special section, covering a variety of computational sustainability topics.

In "Nationwide Prediction of Drough Conditions in Iran Based on Remote Sensing Data," Mahdi Jalili, Joobin Gharibshah, Seyed Morsal Ghavami, Mohammadreza Beheshtifar, and Reza Farshi, propose the use of artificial neural networks to model and predict the drough conditions based on satellite imagery collecting indexes on vegetation and land cover as well as the temperature. The paper applies multi-layer neural networks, radial-base function networks and support vector machines to the drough forecasting. The three models have been trained with time series and predict the drough conditions in terms of Standardized Precipitation Index. The accuracy of the model achieves up to the 90 percent and the multi-layer perception model is the best performing predictor.

Marco Chiarandini, Niels H. Kjeldsen, and Napoleão Nepomuceno, in their paper entitled "Integrated Planning of Biomass Inventory and Energy Production," essentially merge two problems that have been traditionally kept separate, namely biomass provisioning and its use for heating or energy production of each power plant. The paper proposes a stochastic 0-1 MILP to model the problem. Due to the large instance size, a relaxation of the problem and a Benders decomposition approach are compared in terms of solution quality, ease of implementation, and scalability, showing good accuracy of the relaxed model, but a simpler implementation and higher scalability for the Benders decomposition approach.

Sensing and monitoring of environmental phenomena is an important part of computational sustainability; a promising approach is community sensing, where measurements are gathered by individual agents, and aggregated into publicly available maps by a public authority. In their paper entitled "Incentive Mechanisms for Community Sensing," Boi Faltings, Jason Jingshi Li, and Radu Jurca, present a novel, game theoretic incentive mechanism that rewards accurate and truthful measurements in a community sensing scenario, providing the necessary quality control, and ensuring that the results are valid despite the absence of a centralized control. The scheme is analyzed and evaluated in a testbed of

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simulating a network of air pollution sensors in the city of Straßbourg, France.

The paper entitled "A Decision Support System for the Design and Evaluation of Sustainable Waste Water Solutions," by Brent C. Chamberlain, Giuseppe Carenini, Gunilla Öberg, David Poole, and Hamed Taheri, proposes a decision support system (DSS) for the management of waste water enabling scenario evaluation and comparison of alternatives. The DSS uses logic programming for the design generation process, is based on an explicit ontology, defining components, products and community contexts and provides a visual interface enabling an easy-to-use access to alternative plans and the tradeoffs between them from an environmental, social and economic perspective.

The sustainable planning and management of forestry resources is a key sustainability challenge. In his paper entitled "Using Equilibrium Policy Gradients for Spatio-temporal Planning in Forest Ecosystem Management," Mark Crowley presents an approach that combines Markov decision processes, simulation and stochastic policy making for making decisions on forestry management. Spatio-temporal planning in a forestry context is a complex problem that is concerned with putting in place a plan of action related to harvesting, treatment planning, and so on, in many locations such that an overall utility measure is maximised over some defined time horizon, e.g. forest value or sustainabilty, etc. His approach is based on a global spatial policy, which aggregates multiple interrelated local policies, from which Markov Chain Monte Carlo simulation samples policies and estimates their gradients. An evaluation is conducted on a large forestry planing problem.

The consequences of harvesting from a renewable resource, such as a fishery, are considered from a game theoretic perspective by Sung Hoon Chung, Terry L. Friesz, and Robert D. Weaver, in their paper entitled "Dynamic Sustainability Games for Renewable Resources—A Computational Approach". The authors consider a dynamic Nash game in this context, and present a framework for modelling and solving it. A particularly interesting aspect of this paper is that they consider how various parameters of the context, such as harvest effort, catch, and resource sustainability, are affected by the length of the planning horizons of the agents, contrasting short to long term perspectives.

Particularly in urban areas, accurate modeling and prediction of land use and transportation will play a key role to improve the quality of life and use of resources; however, as the available data is often erroneous and sparse, calibration of such models from observations can be a challenging task for city planners. In the last paper entitled "Calibration of an Integrated Land-Use and Transportation Model Using Maximum-Likelihood Estimation," Parikshit Dutta, Elise Arnaud, Emmanuel Prados, and Mathieu Saujot, present an algorithm based on maximum likelihood estimation to robustly estimate model parameters in a combined land use and transportation model. The technique is applied to a model of the city of Grenoble, France, which has 111 parameters across different economy sectors that require calibration.

We hope that readers will find the selection of papers useful and inspiring. We also wish to take this opportunity to thank the contributing authors, reviewers, the editorial staff of *IEEE TC*, and the Editor-in-Chief, Professor Albert Zomaya, for their hard work and professionalism. Without their support, this special section would not have been possible.

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