

# Challenges in Computational Sustainability

Carla P. Gomes  
Cornell University  
Ithaca, NY, USA  
gomes@cs.cornell.edu

*Our Common Future*, the seminal report of the United Nations World Commission on Environment and Development, published in 1987, raised serious concerns about the state of our planet and introduced the notion of *sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their needs* (UNEP 1987). Twenty years later, the United Nations Environment Program in its fourth Global Environmental Outlook report (UNEP 2007) and the United Nations Intergovernmental Panel on Climate Change (IPCC 2007) reiterated the concerns raised in *Our Common Future*. For example, the fourth Global Environmental Outlook report stated that "there are no major issues raised in *Our Common Future* for which the foreseeable trends are favorable."

Key issues pertaining to the development of policies for sustainable development translate into decision making and policy making problems concerning the management of our natural resources. Often such problems involve significant computational challenges that fall into the realm of computing and information science and related disciplines, even though in general, they are not studied by researchers in those disciplines. In fact, the impact of modern information technology has been highly uneven, mainly benefiting large firms in profitable sectors, with little or no benefit in terms of the environment. It is therefore imperative and urgent that we turn our attention to computational problems that arise in the context of the environment and the way we use our natural resources.

We argue for the establishment of critical mass in the new emerging field of *Computational Sustainability*. Computational Sustainability is an interdisciplinary field that aims to apply techniques from computer science and related fields, namely information science, operations research, applied mathematics, and statistics, to help balance environmental, economic, and societal needs for 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, and biological and environmental engineering. Research in Computational Sustainability is therefore necessarily an interdisciplinary endeavor, where scientists with complementary skills must work together in a collaborative process. The focus of

Computational Sustainability is on developing computational and mathematical models, methods, and tools for decision making concerning the management and allocation of resources for sustainable development.

In this talk I will provide examples of computational sustainability challenge domains ranging from wildlife preservation and biodiversity, to balancing socio-economic needs and the environment, to large-scale deployment and management of renewable energy sources. I will discuss how computational sustainability problems offer challenges but also opportunities for the advancement of the state of the art of computing and information science and related fields, highlighting some overarching computational themes in constraint reasoning and optimization, machine learning, and dynamical systems. I will also discuss the need for a new approach to study such challenging problems in which computational problems are viewed as “natural” phenomena, amenable to a scientific methodology in which principled experimentation, to explore problem parameter spaces and hidden problem structure, plays as prominent a role as formal analysis (Gomes and Selman 2007). Such an approach differs from the traditional computer science approach that is mainly driven by worst-case analyses, based on abstract mathematical models. While formulations of real-world computational tasks lead frequently to worst-case intractable problems, often such real world tasks contain hidden structure enabling scalable methods. It is therefore important to develop new approaches to identify and exploit real-world structure, combining principled experimentation with mathematical modeling, that will lead to scalable and practically effective solutions.

In summary, the new field of Computational Sustainability brings together computer scientists, operation researchers, applied mathematicians, biologists, environmental scientists, and economists, to join forces to study and provide solutions to computational problems concerning sustainable development, offering challenges but also opportunities for the advancement of the state of the art of computing and information science and related fields.

## Acknowledgments

The author is the lead Principal Investigator of an Expedition in Computing grant on Computational Sustainability, supported by the National Science Foundation (NSF) (Award Number: 0832782). The author thanks the NSF Expeditions in Computing grant team members for their many contributions towards the development of a vision for Computational Sustainability, in particular, Chris Barrett, Antonio Bento, Jon Conrad, Tom Dietterich, Bistra Dilkina, Stefano Ermano, John Gunckenheimer, Yunsong Guo, John Hopcroft, Ashish Sabharwal, Bart Selman, David Shmoys, Steve Strogatz, and Mary Lou Zeeman. The author thanks NSF for supporting this research.

## References

- [1] Carla Gomes and Bart Selman. The science of constraints. *Constraint Programming Letters*, 1(1), 2007.
- [2] IPCC. Fourth assessment report (AR4). Technical report, United Nations Intergovernmental Panel on Climate Change (IPCC), 2007.
- [3] UNEP. Our common future. Published as annex to the General Assembly document A/42/427, Development and International Cooperation: Environment. Technical report, United Nations Environment Programme (UNEP), 1987.
- [4] UNEP. Global environment outlook 4 (GEO4). Technical report, United Nations Environment Programme (UNEP), 2007.