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COMPUTATIONAL SUSTAINABILITY: AN EMERGING RESEARCH AND ACADEMIC DISCIPLINE

Swati V. Chande
Department of Computer Science
International School of Informatics and Management
Jaipur, India

ABSTRACT

Sustainability is the need of the hour. It has been prioritized in all business, innovation, social, environment and education strategies and planning. The United Nations General Assembly, at its 58th Session in December 2002, started the Decade of Education for Sustainable Development from January 2005. The focus therefore is on all aspects of education contributing to sustainable development. The need is to systematize education about underlying principles and techniques including computational techniques to solve problems in sustainability. This paper is an attempt to view Computational sustainability as an academic and research subject and understand how it could be incorporated as a course in academic programmes.

Keywords- Sustainability, Computational Sustainability, Research, Academics

1. INTRODUCTION

Scientific and technological progress has resulted in an incontestable environmental consequence. Progress cannot be obstructed, and there is no intention to even hint at it, but there is a pressing need to realign and revise our actions in almost all spheres so as to sustain the ecological balance. Sustainability aims at creating and maintaining conditions under which humans and nature can exist in productive harmony.

Balance is an essential aspect of sustainability. Sustainable development seeks to balance social, economic and environmental objectives in order to secure the well-being of present and future generations. These objectives are interdependent and thus equally important. The need to identify, analyze and develop theory, tools, models, concepts and practices that counter the imbalance and enable sustainability is a burning need in the current century.

Mathematical and computational sciences ought to play a primary role in facing the challenges in achieving sustainable development. Mathematical and Computational thinking involves cracking problems, devising systems, and understanding human behavior, by deriving from the concepts elemental to these sciences. Computational thinking and approach therefore seem essential to provide effective and efficient solutions that comprise balancing environmental, economic and societal needs.

Computational Sustainability is an interdisciplinary field that aims to apply techniques from computer science, information technology, operations research, applied mathematics, and statistics for balancing ecological, financial, and community needs for sustainable development. Environmental problems often translate into decision optimization and statistical learning problems involving combinatorial decisions, dynamic modeling, and uncertainty, and hence there is a need to form a common language for mathematicians, environmental scientist, conservationists and computer scientists to exchange their ideas. [1] [2]

This common language can be formed through sufficient cross-domain idea-exchange at industrial, academic and research forums. Recent workshops, seminars and conferences [3][4][5][6] on related topics indicate initiation of developments in this direction.

In addition to the common vocabulary, a computational way of thinking is necessary to approach complex issues. Thinking like a computer scientist requires thinking at multiple levels of abstraction. Computational thinking represents a universally applicable attitude and skill set that is fast becoming a necessity for everyone, not just computer scientists to learn and use. [7]

With the acceptance of Computational Thinking as a component at the intersection of almost all disciplines, it seems apt to consider Computational Sustainability as a promising academic and research field. To solve a problem using computers or using mathematical and/or statistical techniques, it is necessary that the problem solver is aware of the utility of these techniques.

Researchers' studies have explored the possibility of introduction and potential content of Computational Sustainability education at different levels [8][9][10]. Sources such as [11] [12] reveal that academic institutions are beginning to include Computational Sustainability as a structured component in academic curriculum.

This paper explores the scope to integrate Computational Sustainability in Academic learning and research methodology. Section 2 describes Sustainability as an interdisciplinary subject. Section 3 discusses Computational approach to problem solving in the Sustainability domain. Section 4 discusses the introduction of Computational Sustainability as a component of an academic programme while Section 5 touches upon the use of computational methods in research on different facets of sustainability. Section 6 concludes the paper.

2. SUSTAINABILITY: A MULTIDISCIPLINARY SCIENCE

Sustainability is about solving the interlinked issues of environmental, economic, and societal needs. The issues are unique in scale, impact, complexity and richness, and often involve multiple an highly interconnected componenets and players in highly dynamic and uncertain environments.

Climate change, Energy problems, poverty & hunger, loss of multiplicity of species, region specific shortage of fresh water, new and emerging diseases etc. are the challenges raised by diminishing resources. Science and math educators are increasingly being called upon to develop interdisciplinary or multidisciplinary pedagogies that can change the types of problems we work on and how we address these problems in the classroom.

To deal with universal problems that traverse disciplines students must be equipped with effective cross-disciplinary skills, particularly the capability to blend knowledge of different fields and create new concepts and theories. [13]

Sustainability science is a new academic discipline emerging in response to threatened sustainability of the global environment. The idea of this discipline is to help build a sustainable society by developing solutions to climate variations, resource collapse or scarcity, ecological extiction, and other environmental crises that intimidate humankind and civilization.[14]

The necessity for sustainability education is getting increased attention, sustainable development however poses a challenge for pedagogy in all fields. As for its nature, sustainable development should not be treated monolithically in the educational system but in a more holistic manner. [15] It demands a realignment of existing academic domains so as to address the ever-changing needs of nature and society. Whereas academia has moved increasingly toward fields of higher specialization, sustainability science seeks all-inclusive wide-ranging integrated solutions to complex problems. It therefore requires a restructuring of education and research that spans multiple disciplines. [16]

3. COMPUTATIONAL APPROACH TO SUSTAINABILITY ISSUES

Computer, the omnipresent machine that has brought in speed, versatility and accuracy to all computational tasks has influenced human beings in every possible way, even the way we think. Computational thinking is taking an approach to finding solutions to problems, designing systems and understanding human conduct, that draws on concepts fundamental to computing [17]. Computational approach aids in design, optimization, modeling and impact monitoring of natural and artificial systems.

It is influencing research in nearly all disciplines, both in the sciences and the humanities. Researchers are using computational allegories to supplement and implement theories. Computing has enabled researchers to be inquisitive and to accept new kinds of answers to new kind of questions, for example, questions that require the processing of huge amounts of data and questions as to how this huge amount of data can be processed. Computational concepts provide a new language for describing hypotheses and presumptions. [18]

Solutions to sustainability problems could be addressed by applying computational techniques. These problems could range from human built structures and systems to economics to ecosystem modeling and mangamenet to human behaviour as given in [19].

The sustainability issues, as discussed above, are categorized into environmental, economic, and societal issues. A review of the studies carried out to find solutions to the issues in each category using the computational approach discloses Computational Sustainability to be a fast evolving discpline.

It is an amalgamation of issues and requirements for design of sustainable solutions in economic, environmental and societal domains, and the technological, mathematical and computational approaches to problem solving. Figure 1 shows sustainability and computational techniques with the contributing fields.

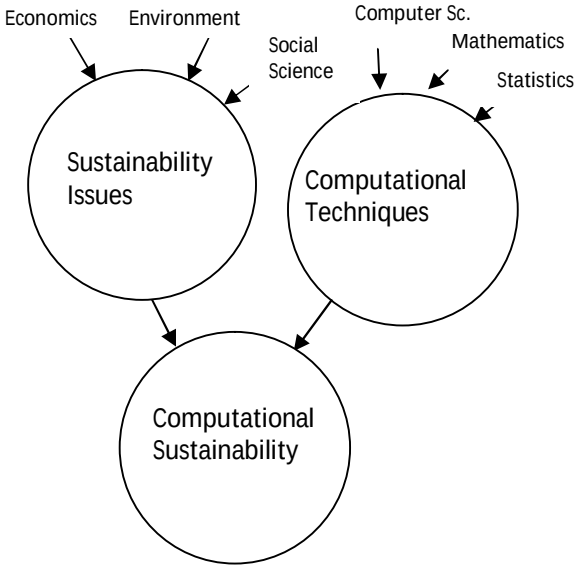

Figure. 1: Computational Sustainability, the multidisciplinary academic field

Authors in studies including [20][21][22][23][24] have approached environmental issues with the perspective of computational problem solving.

Economic Sustainability has been addressed using the computation approach in [25][26][27] and the application of Computational Models and Techniques for societal sustainability is evident from studies such as in [28][29][30][31].

The use of computational approach to problem solving and improvement in the different facets of sustainability implies a growing need for adding to the awareness and application of these techniques to sustainability. There hence is a necessity of imbibing the computational skills which are and may be used to solve problems in sustainability field at an early stage among students and researchers.

Recognizing this need, as mentioned above, some educational institutions are providing courses in the field. The highly interdisciplinary nature of the field however requires more research in charting out a systematic curriculum for courses and programmes in Computational Sustainability.

Pedagogical goals and strategies need to be designed for computational sustainability, for helping humans to become better problem solvers for a sustainable future.

4. COMPUTATIONAL SUSTAINABILITY AS A COMPONENT OF AN ACADEMIC PROGRAMME

It is natural that sustainability forms a part of academic programmes in economics, environmental sciences and social sciences, and when sustainability is introduced as component of these programmes, study of computational techniques has to follow.

The objective to achieve a sustainable future for all humankind has set a new milieu for professional engineering activity, and has resulted in national and international engineering organisations evolving strategies and action plans for sustainability through engineering. Engineering education has thus to redirect itself into sustainability mode. The challenge for engineering educators is to ensure that their academic and professional activities are directed toward achieving a sustainable future through engineering. [15].

Programmes in Computer Applications, Computer Science, Information Technology, Mathematics, and Statistics may also include Computational Sustainability as a component.

According to the report of the International Workshop on Information and Communications Technology (ICT) and Environmental Challenges, Copenhagen, 2008, there is an increasing requirement in particular of the infusing of computing curricula with sustainability, and inversely the infusion of computation into sustainability curricula as depicted in figure 2.

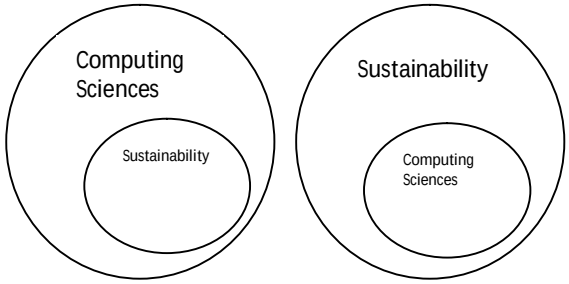

Figure 2: Infusing Computing and Sustainability in eachother's curricula

The computing techniques finding substantial use in the solution of sustainibility issues include, data collection and evidence-based decision making, modelling, simulation, social computing, optimization, scheduling, pattern matching, statistical analysis, mathematical modelling etc. The Sustainability curriculum therefore should include these components to be computationally loaded and the computing sciences curriculum could begin with concepts of Sustainability and go on to have specializations in different sustainability domains. Both the approaches will need extensive use of case study based teaching and learning.

5. RESEARCH IN COMPUTATIONAL SUSTAINABILITY

Research in sustainability has grown considerably over the last decade and researchers have increasingly applied computational techniques to design, authenticate and advance their studies and have widened their scope of research. This has led to a need to create a broad-based research programme in the area of computational sustainability that integrates 'islands' of research into more strategically aligned initiatives.

Workshops, seminars, conferences, discussions, studies, research projects in computer science and applications, economics, biology, environmental sciences, societal issues, social sciences, bioinformatics, architecture, engineering, geoinformatics all increasingly have sustainability as an integral component.

Research studies and projects in computational sustainability that have discussed designing models and implementing computational techniques for solving sustainability issues [32][33][34][35] indicate evolution in application of mathematical, computer based and statistical techniques to sustainability.

The Research methodology course meant for research scholars should include computational techniques for problem solving, particularly for sustainability problems in the

curriculum so that researchers are aware of and can map the techniques with the problem at hand.

6. CONCLUSION

Computational techniques have been used to solve all sorts of problems. With the focus of researchers from almost all domains turning to sustainability, the application of computers in the field is bound to increase. There hence is a need to incorporate computing techniques as a component in the sustainability curriculum or vice versa.

Researchers from all sustainability and computational domains could therefore get together to frame a generic curriculum and pedagogy for computational sustainability which may further be customized by each school/ university/ programme as per their primary area of study.

REFERENCES

[1] Gomes, Carla P., "Computational Sustainability: Computational methods for a sustainable environment, economy, and society", The Bridge, National Academy of Engineering, vol 39 no. 4, December 2009.

[2] Frankel, Karen A., "Computer Science Meets Environmental Science: Scientists share knowledge and seek collaborators at computational sustainability conference". Communications of the ACM vol 52 no. 9, September 2009.

[3] Levin S A and Clark W C, "Toward a Science of Sustainability", Report of the Toward a Science of Sustainability Conference, Virginia, November 29 - December 2, 2009, Harvard Kennedy School Center for International Development working paper # 196, May 2010.

[4] Fred S. Roberts, "The Challenges of Multidisciplinary Education in Computer Science", Journal of Computer Science and Technology, Volume 26, Number 4, July 2011, pp. 636-642(7).

[5] Special Track on Computational Sustainability and AI, Proceedings of the Twenty-Fifth AAAI Conference on Artificial Intelligence.

[6] Proceedings of the IEEE IndiaConference INDICON 2011 on the theme, "Engineering Sustainable Solutions", December 16-18, 2011, Hyderabad, India.

[7] Wing Jeannette M, "Computational Thinking", Communications of the ACM March 2006, Vol. 49, No. 3.

[8] Pat Phillips, "Computational Thinking A Problem-Solving Tool For Every Classroom", CSTA and Microsoft Publication, CS & IT Symposium, 2008.

[9] Yu Cai, "Integrating sustainability into undergraduate computing education", Proceedings of the 41st ACM technical symposium on Computer science education, March 10-13, 2010.

[10] A Kurkovsky, "Educational aspects of sustainable development analysis: computational models and software", Journal of Computing Sciences in Colleges, Volume 21, Issue 4, April 2006, Pages 24-31.

[11] Syllabus for Csci 688–Introduction to Computational Sustainability, Spring 2012, New Mexico Tech http://infohost.nmt.edu/~schung/csci688.pdf accessed on October 30, 2013.

[12]CPSC 530M, Computational Sustainability, University of British Columbia, Department of Computer Science, Winter Session 2013-14, Term 2 http://www.cs.ubc.ca/~mack/ComputationalSustainabilityCourse/ accessed on October 30, 2013.

[13] Michael Rogers, Jason Hamilton, Tom Pfaff, and Ali Erkan. "In Preparation, Preparing Students to Solve Twenty-First Century Problems Through Multidisciplinary Sustainability Modules", International Journal of Sustainability in Higher Education, 2011

[14] Komiyama H, Takeuchi K, Shiroyama H, "Sustainability Science: A Multidisciplinary Approach", United Nations University Press, 2011

[15] Jabareen Yosef, "Teaching Sustainability: A Multidisciplinary Approach", Creative Education 2011, Vol.2, No.4, 388-392

[16] "Complex Problems. Integrated Solutions", 2013 http://www.aecom.com/News/Sustainability/_featuredStories/AECOM+publishes+its+second+corporate+sustainability+report+%E2%80%9CComplex+problems.+Integrated+solutions.%E2%80%9D

[17] Bundy Alan, "Computational Thinking is Pervasive", http://homepages.inf.ed.ac.uk/bundy/drafts/Chen_Li_Article.pdf

[18] O'Sullivan B, "Computational Sustainability", agenda of the 2010 CompSust Conference at MIT, 2010.

[19] Gunn, I W, "Education for sustainability through engineering", Computational Mechanics, USA, 270 pp. 1996.

[20] Ayako Takei, Alan G. E. Wilson, "Application of Computational Approaches for Toxicity Prediction of Environmental Chemicals", Foods & Food Ingredients J. Jpn., Vol. 215, No.4, 2010.

[21] "Computational Ecology: Mathematics, computational technology, and ecology merge to meet environmental challenges" http://www.tiem.utk.edu/~gross/compecol.newsarticle.txt accessed on October 31, 2013.

[22] Almas Iqbal et al, "Nanoneurotoxicity to Nanoneuroprotection Using Biological and Computational Approaches", Journal of environmental science and health. Part C, Environmental carcinogenesis & ecotoxicology reviews, pp. 256-84.

[23] O.O. Ugwu, M.M. Kumaraswamy, A Wong, S.T. Ng, "Sustainability appraisal in infrastructure projects (SUSAIP): Part 2: A case study in bridge design", Automation in Construction, Volume 15, Issue 2, March 2006, Pages 229–238.

[24] Ruhl, J. B., Sustainable Development: A Five-Dimensional Algorithm for Environmental Law (March 26, 2009). Stanford Environmental Law Journal, Vol. 18, 1999

[25] Clark, C. 1976. Mathematical bioeconomics: the optimal management of renewable resources. Wiley, New York.

[26] Niels Röling, The soft side of land: socio-economic sustainability of land use systems, ITC Journal 1997-3/4

[27] Marc J. Epstein, Making Sustainability Work: Best Practices in Managing and Measuring Corporate Social, Environmental, and Economic Impacts, Berrett-Koehler Publishers, 2009.

[28] Bernd Kasemir, Public participation in sustainability science: a handbook, Cambridge University Press, 2003.

[29] Miller J H, Page S E, "Complex Adaptive Systems: An Introduction to Computational Models of Social Life", Princeton University Press, 2007.

[30] Lazer David et al, Life in the network: the coming age of computational social science, Science, February 2009, Vol. 323 no. 5915 pp. 721-723.

[31] Goldstone R L and Janssen M A, Computational models of collective behavior. Trends in Cognitive Science, 9:424–430, 2005.

[32] Kramer O, "Computational Intelligence an Sustainable Energy: Case Studies and Applications", TR-10-010, International Computer Science Institute Berkley University, November 2010.

[33] Monendra Grover, Rajesh Kumar, Tapan Kumar Mondal and S. Rajkumar, "Computational Models for Sustainable Development", Indian Journal of Computer Science and Engineering, Vol. 2 No. 1, ISSN: 0976-5166, pp 55-60, 2011.

[34] Fisher, D., "Computing and AI for a Sustainable Future", IEEE Intelligent Systems, vol. 26, no. 6, Nov-Dec 2011.

[35] Angela Chen and Truong Nguyen, Computing-driven social and industrial ecology research solving problems at the interface of environment and culture for market and regulatory analysis project at the Social Computing for Sustainability Lab., http://www.i3.calit2.net/scs.php accessed on November 15, 2013.