Computational Sustainability

(CPSC 530M, Term 2)

Alan Mackworth

Image source (Poole & Mackworth, 2010)

Sustainability

Sustainability The ability to maintain balance of a process in a system

Ecological Sustainability The ability of an ecosystem to maintain ecological processes, functions, biodiversity and productivity into the future

Human Sustainability The ability to meet the needs of the present without compromising the ability of future generations to meet their own needs

Green IT

Sustainability meets computation.

Green IT: “the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems—such as monitors, printers, storage devices, and networking and communications systems — efficiently and effectively with minimal or no impact on the environment.”

Computation & Dematerialization

Computation has, at its core, an inherent sustainable dynamic: dematerialization - from atoms to bits.

Green IT is worthwhile and important, but dematerialization is much more significant.

Computational Sustainability

Computational Sustainability is an interdisciplinary field that applies techniques from computer science, information science, operations research, applied mathematics, and statistics for balancing environmental, societal and economic needs for sustainable development.

Three main themes:

1. Developing computational models and methods for decision making for the management and allocation of ecosystem resources
2. Developing computational modules embedded directly in ecosystem monitoring, management and control systems
3. Study of the impact of the deployment of information and communication technologies (ICT) on sustainability.

Constraint satisfaction is at the core of computational sustainability.

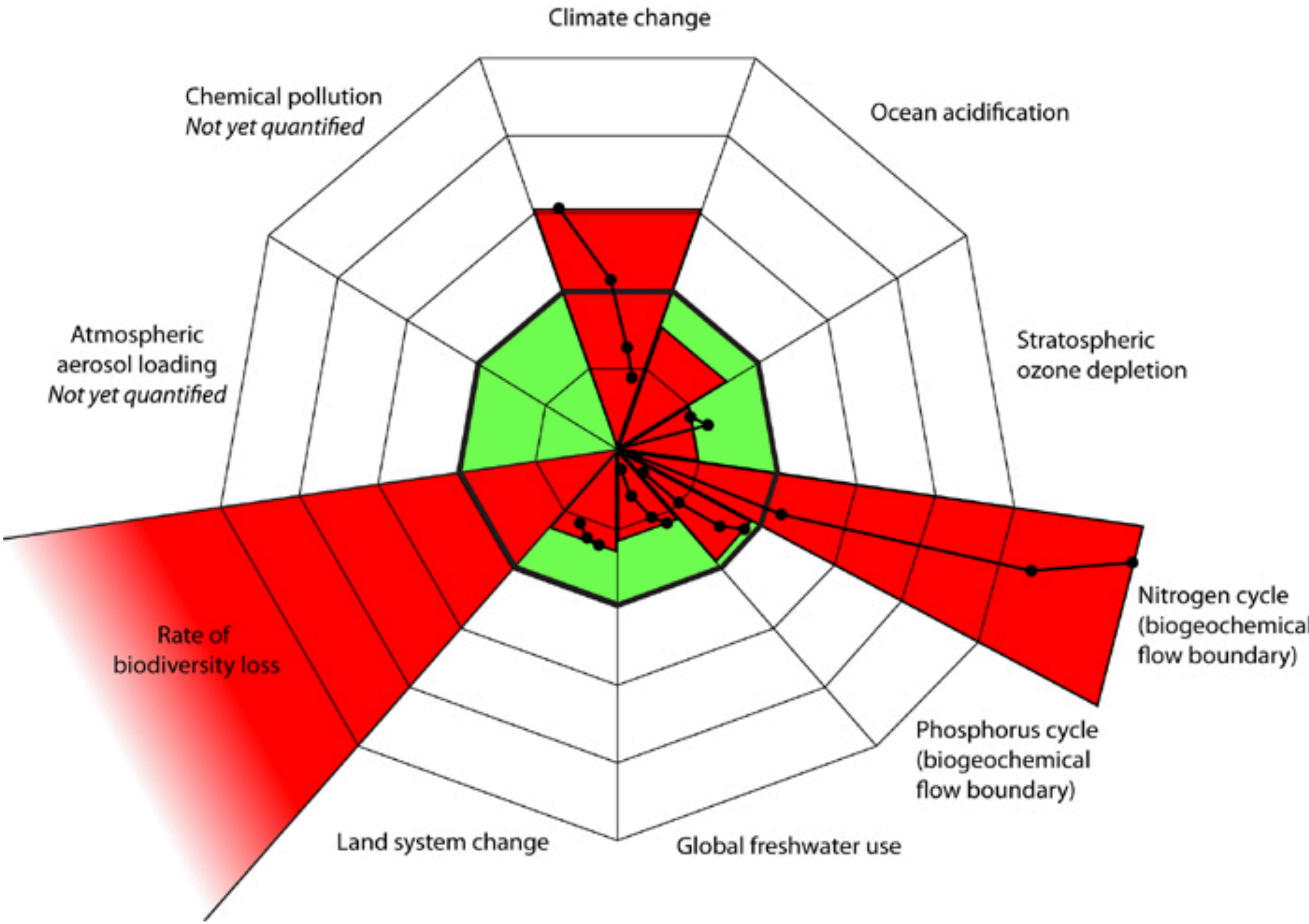
Constraint-based Sustainability

Sustainable systems must satisfy physical, chemical, biological, psychological, social and economic constraints.

Consider constraints such as energy supply, waste management, GHG, ocean acidity, climate, ecological footprint, biodiversity, habitat, harvesting and global equity.

Sustainability = Constraint Satisfaction

Planetary Boundaries as Constraints



[Source: "Planetary Boundaries: Exploring the Safe Operating Space for Humanity", Rockström *et al.*, *Ecology and Society* (2009)]

Design Space for Computational Sustainability Systems

Five dimensions:

1. *Level*

   Primary level that constraints operate at: *biophysical, biological, social* or *economic*. Note that most systems operate with constraints at several levels.

2. *Domain*

   Application sphere: *climate, ocean, fisheries, energy, agriculture, transportation, urban design, education, healthcare, ...*

3. *Type*

   Role: *model* or *embedded*

4. *Spatial Scale*

   From *nano (10^{-9}m)* to *global (10^{7}m)*

5. *Temporal Scale*

   From *fast (10^{-3}s)* to *slow (10^{9}s)*

Computational Tools

- dynamical systems
- simulation
- control theory
- constrained optimization
- machine learning
- artificial intelligence
- software engineering
- information visualization
- human-computer/robot interaction
- game theory and mechanism design
- …

Exploring the Design Space

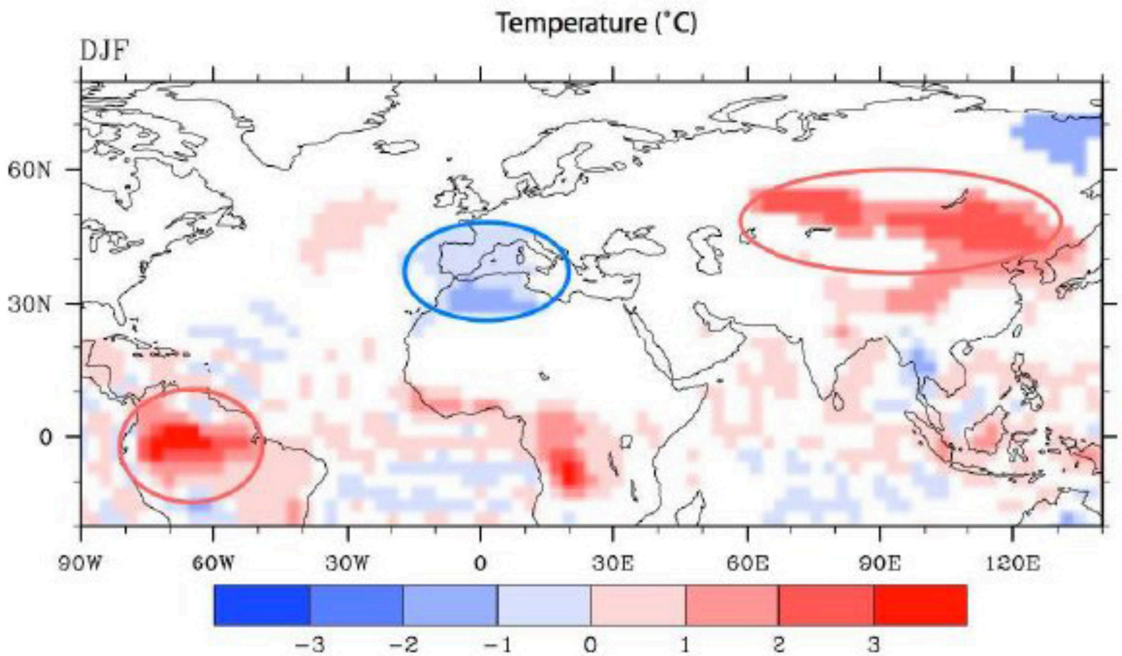
Application case studies:

- climate change
- oceanographic modeling
- wildlife corridor design, social life of zebras
- energy management, smart buildings
- self-driving cars, urban design
- wheelchair mobility, aging and technology
- crop disease monitoring, livestock insurance, rural agricultural market design
- mobile phones and social change

Climate Models

Level: biophysical; Domain: climate; Type: model

IPCC models



Simulated global surface temperature changes as a result of converting the tropical forest basins of the Amazon, Africa, and the Indian archipelago from rainforest to bare ground. In this simulation, changes in the tropical forest vegetation cover of the Amazon cause widespread temperature changes in the region, but also significant tele-connections to other parts of the world, including western Europe and central Asia. This simulation was performed by the CCM3 climate model, coupled to the IBIS land surface / ecosystem model (Snyder et al. 2004a,b) [Source: (Rockström *et al.*, 2009)]

Climate change threatens outdoor hockey in Canada

Outdoor hockey season already shortened.

"If we extend the trends into the future, there could be no outdoor skating rinks with global warming taking place"

(Mysak et al., 2011)

Smart Cars

Level: social; Domain: transportation; Type: embedded

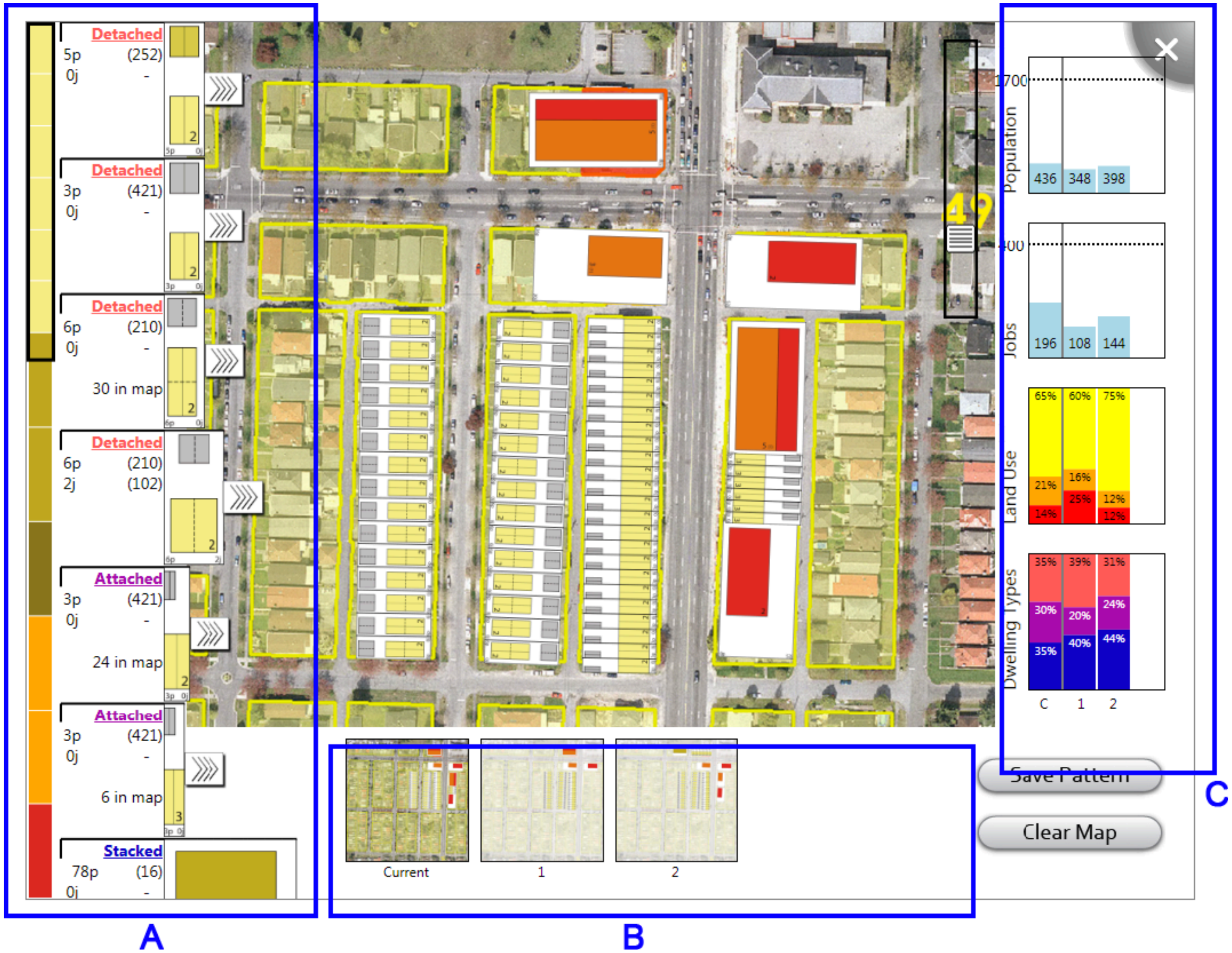
Social sustainability consequences:

- Auto, pedestrian and cyclist safety
- (Human) driver can relax
- Increase in road capacity
- Fuel efficiency, platooning
- Shared cars, less material waste
- Fewer parking lots
- Truly self parking auto-taxis
- Inter-vehicular communication and coordination
- Intersections: no stop signs or traffic lights, 2-3x capacity increase?
- Autonomous traffic control: autonomous intersection management protocol (AIM) avoids deadlock (gridlock) and livelock (Stone *et al.*, 2004-12)

Google self-driving Prius

Urban Design

Level: social; Domain: urban planning; Type: model



A Collaborative Planning Support System for a Multi-Touch Tabletop

[Source: Fernquist (2010)]

Crop Disease Monitoring

Level: economic; Domain: agriculture; Type: embedded

Crop Disease Monitor

Automated diagnosis and mapping of crop disease in Uganda

Healthy and Diseased Cassava

[Source: “Modeling and Monitoring Crop Disease in Developing Countries” (Quinn, Leyton-Brown & Mwebaze, 2011)]

More Information

Classes:

Tuesday & Thursday, 11:00-12:20, DMP 101

Organization:

Lectures, seminar discussions, guest lecturers, student papers, ….

Websites:

www.cs.ubc.ca/~mack/ComputationalSustainabilityCourse/

www.cs.ubc.ca/~mack/ComputationalSustainabilityResources/

Ask me:

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