Challenges for AI in Computational Sustainability

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Expeditions in Computing (CISE)

AI * IA
November 2017
Thank you!

1st Expeditions in Computational Sustainability (2008)

- To nucleate the Computational Sustainability field
- To identify a number of core research directions for maximal impact, both in terms of Computer Science and Sustainability.

2nd Expeditions: Large-Scale Research Network for Expanding the Horizons of Computational Sustainability

CompSustNet

125+ faculty, students, and collaborators!!!
Computational Sustainability

New interdisciplinary field that aims to develop computational methods for Sustainable Development.

Sustainable development

“Development that meets the needs of the present without compromising the ability of future generations to meet their needs.”


Gro Brundtland
Norwegian Prime Minister
Chair of WCED
Sustainability: Interlinked environment, economic, and social issues

**Sustainable Development encompasses balancing environmental, economic, and societal needs.**

Ultimate goal of Sustainable Development

**HUMAN WELL-BEING**

of current and future generations.
Main Causes of Damage to Earth:
Poor Management of our Natural Resources

- Climate Change
- Poor Management of Natural Resources
- Pollution
- Habitat Loss and Fragmentation
- Over-Harvesting
- Climate Change
Urgent need of better management of our natural resources
Sustainable Development: Concerns Managing Complex Systems

Sustainability problems unique in scale and complexity

Smart Power Grid: Complex Digital Ecosystem

Natural Ecosystems

Complex Dynamics
Highly Interconnected Components / Agents
Uncertainty
Big Data and Multiple Scales
Prediction and Management

Significant Computational Challenges
We need critical mass in Computational Sustainability

2008 - Inst. for Computational Sustainability

2016 - CompSustNet
125+ faculty, students, and collaborators!!!
III Conservation and Biodiversity (Expanding Previous Themes)

- Bird Conservation
- Prioritizing Conservation Decisions
- Wildlife Corridors
- Protecting Endangered Species

II Balancing Socio-Economic Needs (NEW COMPSUSTNET THEMES)

- Improving Weather Observations in Africa
- Social-Economic Ecological Corridor (Ecuador)
- Poverty & Crop Mapping
- Impacts of Dam Proliferation in the Amazon Basin
- AI for Social Good (e.g. HIV)
- AI & Ethics and Safety

I Renewable Energy, Accelerating Discovery of Sustainable Materials, and Smart Cities (NEW COMPSUSTNET THEMES)

- Accelerating the Discovery of Solar Fuels and Microbial Fuel Cells
- Energy Storage
- Integration of Renewables in Smart Grid
- Smart Bike Sharing

Wide range of sustainability applications:

To build a **coherent and cohesive computer science sub-field** it’s paramount to **go deep** in terms of **Cross-Cutting Core Computational Problems** and apply them to different sustainability areas.
CompSustNet: 3 Core Computational Thrusts

Main computational thrusts:

(1) **Big data and Machine Learning**
(2) **Constraint Optimization, Dynamical Models and Simulation**
(3) **Multi-Agent Systems, Citizen Science, and Crowdsourcing**

Interdisciplinary Research Projects (IRPs) lead to transformative syntheses across sustainability domains and computer science sub-areas
Pattern Decomposition in Big Data
Citizen Science/ Crowdsourcing
Agents: Mechanism Design
Large Scale Spatio-Temporal Modeling and Prediction
Stochastic, Probabilistic Inference, and Optimization
Large Scale Sequential Decision Making

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Subway Lines:
Examples of Cross-Cutting Computational Themes and Interactions of some Computational Sustainability Projects
Pattern Decomposition in Big Data

Dimensionality Reduction, Source Separation, and Segmentation with Complex Constraints

- Dark Ecology: Identifying Bird Migrations from Weather Radar
- Characterization of Power Grid State
- Inferring Crystal Structures from X-Ray Diffraction Data
- High-throughput Plant Phenotyping
- Eelgrass Wasting Disease Identification
- Individual Andean Bear Identification from Camera Traps
- Flight Call Detection
- Elephant Call Detection
- Rangeland Mapping in East Africa
- GrazeIt
Wildlife Conservation
Key Causes of Dramatic Rate of Biodiversity Reduction

Habitat Loss and Fragmentation

Important to maintain landscape connectivity
Wildlife Corridors

link core biological areas

allow animal movement between areas.

increase genetic diversity
Yellowstone to Yukon
Conservationists hope to create a new
wildlife refuge that would link reserves
from Yellowstone National Park to the
Yukon. Among the threats facing the
region are these:

- Disjointed conservation areas
  - Secure large wildlife corridor.

- Roads and railroads
  - Minimize human-caused
    fragmentation of the animals' natural habitat. Wildlife either avoid the roads or are killed by
    vehicles. Engineers are widening roads in areas with high wildlife density.

- Human sprawl
  - Integrate human use
    into the landscape and
    creating wildlife corridors
    around towns.

Animals in Retreat
The concentration of large carnivores and hoofed animals in North America has declined significantly over the past three centuries.
Number of 14 selected species living in each area

1700-1800

1-3
4-6
7-9
9-14

1999-2002

Guiding Wildlife Past Danger

Y2Y

The New York Times
(Science) 2006

Home on the Range: A Corridor for Wildlife, May 23, 2006
Project:

Wildlife corridors for grizzly bears connecting 3 reserves:

Yellowstone National Park
Glacier Park
Salmon-Selway Ecosystem

Low budgets to implement corridors.
Wildlife Corridors
Computational Challenges

Wildlife corridor design – Minimum Cost Solution

Computational problem \(\rightarrow\) Steiner Tree Problem

Steiner Tree Problem
Given a network with a set of reserves:
Find a sub-network that:

- Contains the reserves;
- Fully connected;
- With minimum cost

Hard Computational Problem
Cross-Cutting Computational Models
Steiner Tree Problem

Given: A network and a set of terminals,
Find: The shortest possible way of connecting the terminals.

Wildlife Corridor problem –
min cost is the baseline…
Connection subgraph problem:
Max utility of a corridor which is a connected component subject to a budget constraint

Other Example of Applications:
• Water Piping
• Electronic Design Automation
• Many other applications

Multicast Routing
(e.g., distributed video conferencing)
Real world instance:

Corridor for grizzly bears in the Northern Rockies, connecting:
Yellowstone
Salmon-Selway Ecosystem
Glacier Park

(12788 parcels) $\rightarrow 2^{12788} \approx 2.4 \times 10^{3726}$

Scaling up Solutions by Exploiting Structure

Typical Case Analysis
Identification of Tractable Sub-problems
Streamlining for Optimization
Static/Dynamic Pruning

Approach allows us to find optimal or near-optimal solutions (with guarantees) for large-scale problem instances and reduce corridor cost dramatically.
Multiple Species

- Grizzly Bear
- Wolverines
- Canada Lynx

- How to factor in different habitat requirements
- Dynamics of species interactions

Partners:
Socio-Ecological Corridor in Ecuador for Andean Bear

Goal:

Design a corridor for the Andean Bear and other species

Supporting local communities

Umbrella Species: Andean Bear

Habitat needs represent minimal requirements for numerous co-occurring species

PI: Fuller, Co-PIs: Lassoie, Gomes, Poe, Royle, 2015
Wildlife Corridor for Andean Bear in Ecuador: Integrating Socio-Economic Factors

Ecology Students

J. Bai  A. Gupta  B. Rappazzo  Yexiang Xue

CS Students

C. Gomes  B. Dilkina

Faculty

Ecology:  A. Fuller  A. Royal  A. Rodewald  C. Sutherland
How do we choose which habitats to protect so that landscapes will stay robustly well-connected for wild animal species?

Steiner tree problem, Survivable network design, etc

Network Design

New general models and methodologies

• Connection subgraph problem
• Minimum Steiner Multigraph Problem
• Budget-Constrained Steiner Connected Subgraph Problem with Node Profits and Node Costs

How do factor in specific features of wildlife conservation, e.g., different species requirements, interactions of species, etc?
Big Data:
Connecting Models to the Real World
Models provide abstractions for expressing decision and optimization problems. We fit models to data to obtain model parameters and we also use models for data acquisition, integration, and analysis.
Fundamental question in biodiversity research:
How different species are distributed across landscapes over time.
Sensors, sensor networks, and remote sensing

LandSat
~50 years old

LandSat images

Very sophisticated sensor

Photo courtesy of www.carboafrica.net
eBird: Citizen Science at the Cornell Lab. Of Ornithology

- **Increase scientific knowledge**
  Gather meaningful data to answer large-scale research questions

- **Increase conservation action**
  Apply results to science-based conservation efforts

- **Increase scientific literacy**
  Enable participants to experience the process of scientific investigation and develop problem-solving skills

The Citizen Science project at the Lab of Ornithology at Cornell empowers everyone interested in birds to contribute to research by submitting bird observations to the eBird webportal.
Computational Sustainability for Bird Conservation

Adaptive Spatial and Temporal Machine Learning Models & High-Performance Computing

Relate environmental predictors to observed patterns of occurrences and absences of the species

Patterns of occurrence of Northern Pintail for different months of the year Source: Daniel Fink

The models reveal the habitat preferences of the birds, at a fine resolution, allowing for High-Precision Bird Conservation

300,000+ volunteer birders
300,000,000+ bird observations
22,000,000+ hours of field work (2500+ years)

Land Cover
Weather
Remote Sensing
Environmental Data

Bird Observations
Deep Multi-Species Embedding

Species dependencies
• Competition, cooperation, etc.

Deep Joint Embedding

Correlations of bird species
State of The Birds Report

Officially released by the Secretary of Interior

Novel Approaches To Conservation Based on eBird Models

Distribution Models for 400+ species with weekly estimates at fine spatial resolution (3km²)
High-Precision Bird Conservation: Bird Returns, a Nature Conservancy Program

Protecting Migratory WaterBirds in California Against Drought

1. Pacific Migration Flyway
2. eBird Models
3. Target areas to protect Bird Migration in Sacramento Valley

Sacramento Valley, CA
High-Precision Bird Conservation
The Bird Returns Program

1. Pacific Migration Flyway
2. eBird Models
3. Target Areas
4. Reverse Auction Bid Selection

Farmers submit bids to keep the target rice fields flooded during short periods of bird migration in California.

Sacramento Valley, CA
Sacramento Valley, CA

Pacific Migration Flyway

eBird Models

Target Areas

Reverse Auction Bid Selection

Over 30,000 acres of additional habitat for waterbirds in California

Radically novel way of doing bird conservation. Possible only because of advanced computational methods for high precision conservation.
Africa is very poorly sensed
(limited environmental data, vegetation maps, only a few reliable weather stations)

Improving Forage Maps in Africa
to protect farmers and herders

Herders Submit Vegetation Images and Surveys with Smartphones:
incentives: real money (small for us, good money for pastoralists)

3 month Pilot project:
→ 100,000+ surveys
Poverty Mapping: Combining satellite imagery and machine learning to predict poverty

Neal Jean, Marshall Burke, Michael Xie, W. Matthew Davis4, David B. Lobell, Stefano Ermon,
Science 19 Aug 2016:
Vol. 353, Issue 6301, pp. 790-794
DOI: 10.1126/science.aaf7894

Deep learning and transfer learning
Avicaching: A Two Stage Game for Incentivizing Bias Reduction in Citizen Science

Data Bias Problem

Principal-Agent Framework

Field: Pilot Program

Distribution of eBird Observations in the US

Prevalent problem in citizen science
Collected data are often aligned with the participants’ preferences rather than scientific objectives.

How to incentivize Citizens to visit under-sampled areas?

Very Successful in Two US Counties
(19% shift to undersampled areas in a 6 month period)

Incentivize eBirders to visit undersampled locations.

Incentives:
- Avicaching points,
- leaderboards
- Lotteries (e.g. binoculars.)

Yexiang Xue, Ian Davies, Daniel Fink, Christopher Wood, Carla P. Gomes. AAMAS 2015, CP 2016, NIPS 2016
Computational Sustainability: Cross-Cutting Computational Approaches

Fei Fang, Milind Tambe et al

Green Security Games:
Preventing Poaching and Illegal Fishing

Where to place patrols to prevent poaching and illegal fishing?

Mechanism Design: Game-Theory Model

Similar problems from a computational point of view
Avicaching: A Two Stage Game for Bias Reduction in Citizen Science

Deep Multi-Species Embedding: Multi species modeling using deep embedding
**Optimal Biocontrol in Predator-Prey Networks**

Johan Bjorck, Yiwei Bai, Yexiang Xue, Xiaojian Wu, Mark Whitmore, Carla P. Gomes

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**Motivation**

Invasive species is a species not native to an ecosystem. Invasive species cause billions of dollars in economic damage. Biocontrol is the most promising strategy. It entails releasing a natural predator to control the invasive population.

The challenging problem here is to utilize available biocontrol resources across complicated ecosystems for maximum impact.

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**Experiments**

Outcome of the strategy suggested by our algorithm.

Our algorithm outperforms all the competing methods in terms of performance and time.

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**Predator-Prey World**

Formulate the Predator-Prey world based on metapopulation models describing the population dynamics of habitat patches in a landscape.

Make some assumptions with regard to the ecology literature, which makes the whole model more tractable.

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**Our Algorithm**

- Our goal is to generate a strategy of releasing the predators that could maximize the number of nodes that are saved. Under the reasonable assumptions, our problem itself is submodular.
- We provide a novel approximation algorithm that relies on a width relaxation and randomized rounding. Essentially we increase our budget, select items with a primal-dual strategy and then randomly remove items.

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**Reinforcement Learning**

- We want to address more general case of Predator-Prey world.
- We explicitly model the number of prey and predators rather than the metapopulation with less ecological assumptions.
- The model in this case is not submodular anymore.
- The intrinsic property of each locations is analogical.

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**Acknowledgement**

We are grateful for funding by:

• The model in this case is not submodular anymore.

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**Combating Invasive Species with Bio Control:**

Exploiting Submodularity and Reinforcement Learning
Ecosystem-Service Impact of Hydropower Dam Proliferation in the Amazon Basin
Ecosystem Services in the Amazon Basin: Benefits from Ecosystem

500+ hydropower dams are proposed or planned in Amazon Basin!

Examples of Ecosystem Services

Computational Perspective: Multi-objective Optimization Problem

We are interested in understanding the trade-offs between the objectives for different non-dominated solutions of dams: the Pareto frontier
What Hydropower Dam configurations are better than others? Pareto Frontier: Tradeoff Analysis

Two dam configurations with similar hydropower yields, but different degrees of river connectivity

Each point along this curve correspond to a particular set of dams

Fast drop in connectivity

Our work:

- Exact Pareto Frontier for multiple criteria
- Efficiently Approximate the Pareto Frontier (FPTAS: DP based approach using $O(n\log n)$ alg. for finding non-dominated set of solutions)
- MIP based approach for sampling the Pareto frontier: it produces fewer solutions but can be effective in practice

Figure adapted from Opperman et al. 2015
Entire Amazon: Energy and Connectivity - **Exact** Pareto Frontier (39841 solutions: 212 secs)

<= 0.1% from optimal solution in 11 secs)
We can now approximate the **Pareto frontier** for **Entire Amazon basin** (energy, connectivity, sediment, and seismic risk)

→ Within **15%** from optimal Pareto frontier containing **1,067,540** non-dominated solutions (~ 1 hour)

→ Within **25%** from optimal Pareto frontier containing **79,389** non-dominated solutions (**230 secs**)
Efficiently Approximation the Pareto Frontier: Hydropower Dam Placement in the Amazon Basin

Students

Qinru  Roos  Xiaojuan  Jonathan  Yexiang  Brendan  Erin

Faculty

Results

- Our DP and MIP Pareto frontier approximations have complementary strengths and are surprisingly effective, scaling up to real-world size problems.
- We can compute the Pareto frontier for the entire Amazon (EPS1 solutions: 85% accuracy in 1.1 minutes).
- For the entire Amazon, 95% accuracy: 15,007,540 non-dominated solutions (DP-based) and 75% accuracy: 79,389 non-dominated solutions (MIP-based).

Visualization Tool

- The results of this computational sustainability project will be openly accessible through a web-based visualization tool to policy decision-makers.
- This framework for sustainable use of hydro-energy, without compromising important ecosystem services, can then be replicated in other parts of the world where pressing needs for energy are degrading natural environments in unsustainable ways.

Background

More than 900 dams are proposed, planned, or under construction in the whole Amazon basin, one of the world's most biodiverse river basins.

Worldwide, the impacts of dams on the environment are currently evaluated individually without consideration of their basin-wide cumulative impacts on important ecosystem services.

- Ecosystem services are the benefits humans receive from ecosystems.
- Services provided by ecosystems in the Andes-Amazon basin include fisheries productivity, sediment and nutrient transport, seasonal floodplain topography, biodiversity, eco-tourism, etc.

Fig 1: Trade-offs between hydropower and ecosystem services (example of a Pareto frontier).

Fig 2: A sample Pareto frontier of two objectives: energy and connectivity (e.g., fish migration, transportation, sediment export) for the whole Amazon basin.

Collaborators

In collaboration with more than 20 scientists from a broad array of disciplines (hydrology, geophysics, ecology, biochemistry, computer science, governmental and non-governmental institutions, and countries), we set to develop a multi-objective optimization framework for dam placement while conserving important ecosystems.

Methods

- The problem is a multi-objective optimization problem that can be naturally captured by a tree-structured formulation.
- The problem is difficult. We developed a DP-based fully polynomial-time approximation scheme (FPTAS) for approximating the Pareto frontier for tree-structured problems.

Efficiently Approximating the Pareto Frontier: Hydropower Dam Placement in the Amazon Basin

Students and Postdoc Research Group Members: Jonathan Garner, Qinru Ren, Roos van der Heid, Brendan Pappas, Qinru Ren, Xiaojuan Xu, Yaqi Han, and Canaan Amazon Dams Working Group

Faculty and collaborators: Alex Frickman, Garcia Gomes, Sibinak Boru, Scott Meltz, and Rob Walter - 26 more
Accelerating the Materials Discovery for Sustainable Materials
Accelerating the Development of Solar Fuel Generators

Goal: Accelerate the pace and reduce the cost of discovery of new materials (Obama 2010)

Solar fuels can be substantially produced and stored

Very Exciting Research Area for Computer Science
High-Throughput Materials Discovery

Simultaneous synthesis of thousands of materials

How to determine the crystal structure of the materials, based on the X-ray diffraction patterns?

Co-sputtering (similar to atomic spray painting)

FCC Crystal Structure

Goal:
Achieve High-Throughput Crystal Structure Identification

Difficulty: Often X-ray diffraction patterns correspond to a mixture of crystal structures

Challenging to un-mix the X-ray diffraction patterns

Rapid characterization of thousands of materials

10^2 - 10^3 materials/day

10^3 - 10^5 materials/day

Crystal Structure Map Problem:
Infer the crystal structures of the materials from the X-ray diffraction patterns

Source Separation Problem

Mainly manual task requiring expert knowledge!
1 system/month (~10 – 100 materials)
Pattern (Factor) Decomposition or Source Separation

Elephant Listening Project; Elephant Call Detection

Flight Call Detection for Bird Conservation

Materials Discovery: Phase Map Identification

Topic Modeling: Identifying the Key Topics of a collection of articles (or an article)
Blei, ACM 2012
Crystal Structure Map Problem

Standard ML techniques: fail to capture the underlying physics of the phenomena.

Rich set of combinatorial constraints to capture the physics and the relationships among thousands of X-ray diffraction patterns.

Computational Synthesis:
Integration of machine learning techniques with constraint and probabilistic reasoning, sampling, and optimization techniques.

Our General Approach (Interleaved Agile Factor Decomposition – IAFD):
Decompose complex scientific data interpretation problems into more tractable reasoning and learning tasks performed by specialized algorithms, exploiting problem relaxations and parallelism to enable large-scale computations.

We can now automatically generate a physically meaningful phase-diagram in ~5 min!!!!

Crowdsourcing and Human Expert Input

UDiscover.It
Puzzles, Games, Tasks

Cornell Summer College
EXPLORATIONS IN ENGINEERING
ENGRG 1060 ~90 High-School students

Amazon Mechanical Turk
Our group has made several contributions for Phase-Mapping in Materials Discovery


Scale up the SMT approach using **human computation** and **parallel computing**:

Human Feedback:
Easy for humans to Identify partial patterns with Heat Maps

Slices of Sample Points
Different Visualizations of X-Ray Diffraction Patterns

[Diagram showing a triangle with labeled elements and sample points, along with heatmaps and spectrograms for different samples.]
UDiscoverIt: Task #116

Task #116 (1/17)

Research Participant Disclosure: This task is part of a study being conducted by Cornell University researchers and data will be collected for research purposes.

Identify Patterns of Vertical Lines

Identify the most prominent pattern (Pattern A) and, if applicable, up to two additional patterns (Pattern B and Pattern C) intersecting the Target Row. Mark the most definite and identifiable vertical lines/blobs by clicking on them with the appropriate mode selected.

© Instructions (click to show/hide)
© Example (click to show/hide)

Messages:

Any comments or notes on this particular image?

Any feedback on the instructions or the design of the task?

Cornell Summer College
EXPLORATIONS IN ENGINEERING
ENGRG 1060
~ 90 students
(Bruce van Dover)
84 % participants answered that this slice involves one single pattern (8 or more peaks)
Our group has made several contributions to Phase-Mapping in Materials Discovery

- **Dataset**

- **CombiFD: Constrained Pattern Decomposition**

- **Phase-Mapper: An AI Platform to Accelerate High Throughput Materials Discovery**
  [Xue et al. IAAI 2017] AI Platform and Visualizer Deployed System at JCAP at Caltech

- **Relaxation Methods for Constrained Matrix Factorization Problems: Solving the Phase Mapping Problem in Materials Discovery**
  [Bai et al. CPAIOR 2017] Speeding up solvers with relaxations and divid-and-conquer strategy
**Phase-Mapper: An AI Platform to Accelerate High Throughput Materials Discovery**

* Main solver AgileFD – Novel Convolutional NMF approach using a set of **lightweight** multiplicative update rules

* Embedding of additional light fast solvers to enforce physical constraints and incorporate human feedback

* Very Fast enabling **high throughput analysis** and real-time human interaction.

Phase Mapper: Discovery of a New Platinum free Catalyst for Methanol Oxidation

**Ortho-** $(\text{Pd,Rh})_2\text{Ta}$

$\text{Pd}_{0.14}\text{Rh}_{0.40}\text{Ta}_{0.46} \rightarrow$ best known Pt-free catalyst for methanol oxidation
Phase-Mapper led to the discovery of a new family of solar light absorbers


*ACS Combinatorial Science – 2017 Cover article, and ACS Editors' Choice award.*

Phase-Mapper with different solvers

Joint Center Artificial Photosynthesis *(Caltech)*
Scientific Autonomous Reasoning (Multi) Agent

**Goal:** Automating the Full Scientific Discovery Cycle for Materials Discovery

- **High-throughput Measurements**
- **Data Mining and Machine Learning**
- **Active Learning**
- **Probabilistic Constraint Reasoning & Optimization**
- **Underlying Physics** (e.g., XRD Shifts, known phases, lattice structure and lattice parameters, etc)

**Formulating Hypotheses, Devising & Planning Experiments and Measurements**

- **Robotic Agent** physically running experiments

**Human Computation**
- Expert and Non-Expert

**Crowdsourcing**

**Quantum Theory**

**Human Computation**
- Expert and Non-Expert

**Scientific Literature & Databases**

**Quantum Theory**

**Scientific Literature & Databases**

**Scientific Literature & Databases**

**Scientific Literature & Databases**
**Cross-Cutting Computational Theme:**

**Pattern Decomposition in Big Data**

**High Throughput Materials Structure Identification**

**Dimensionality reduction with complex constraints**

**Similiar computational problems:**
Both involve the decomposition of a signal (X-rays / audio / images) into patterns (crystal structures / types of sounds/ bears)

**Our Philosophy:**
Students should work on similar computational problems in different domains.
Grad students working on material discovery also work on the elephant calls, bear ID, eelgrass problem.

**Elephant Listening Project**
Project to monitor elephant populations by analyzing forest recordings

**Individual Andean Bear Identification from Camera Traps**

**Eelgrass Wasting Disease Identification**

We represent these cross-cutting computational themes with colored “subway lines.”
Pattern Decomposition in Big Data is the blue line.
Examples of Cross-Cutting Computational Themes and Interactions of some Computational Sustainability Projects

- Pattern Decomposition in Big Data
- Citizen Science/ Crowdsourcing
- Agents: Mechanism Design
- Large Scale Spatio-Temporal Modeling and Prediction
- Stochastic, Probabilistic Inference, and Optimization
- Large Scale Sequential Decision Making

- Economic Dispatch of Power Generation: High Renewables Penetration
- Large-scale Socio-Economic Modeling of Pastoralists’ Movements (Kenya)
- Microbial Fuel Cells
- Bike Sharing
- Dynamic Precision Bird Conservation
- Crop Yield Mapping
- Population Estimation: Spatial Capture-Recapture
- Citizen Science Avicaching, Estimating Bird Populations and Migrations
- Monitoring Sea Star Wasting Disease Outbreak
- Eelgrass Wasting Disease Application
- Wind & Solar Forecasting
- Poverty Mapping and Targeting
- Design and Control of Electricity Storage Systems
- Eelgrass Wasting Disease Application
- Battery Optimization
- Landscape-Scale Conservation and Rural Communities (Ecuador)

- HIV Prevention Among Homeless Youth
- HIV
- Battery
- Optimization
- Landscape-Scale Conservation and Rural Communities (Ecuador)

- High Throughput Plant Phenotyping
- High-throughput Materials Structure Identification
- Improved Rangeland Mapping in East Africa, Citizen Science
- Individual Bear Identification
- Dynamic Precision Bird Conservation
- Population Estimation: Spatial Capture-Recapture

- Low-Cost Weather Stations in Africa (TAHMO)
- Flight Call Detection
- High-throughput Plant Phenotyping
- TAHMO
- Low-Cost Weather Stations in Africa (TAHMO)

- Individual Bear Identification
- Dynamic Precision Bird Conservation
- Population Estimation: Spatial Capture-Recapture

- Wind & Solar Forecasting
- Poverty Mapping and Targeting
- Design and Control of Electricity Storage Systems
- Eelgrass Wasting Disease Application

- High Throughput Materials Structure Identification
- Improved Rangeland Mapping in East Africa, Citizen Science

- HIV Prevention Among Homeless Youth
- HIV
- Battery
- Optimization
- Landscape-Scale Conservation and Rural Communities (Ecuador)

- Nitrogen Management
- Dark Ecology

- Characterization of Power Grid State
- Generating Functions - Population Ecology

- Electricity Usage Disaggregation
- High Throughput Plant Phenotyping

- High Throughput Materials Structure Identification
- Improved Rangeland Mapping in East Africa, Citizen Science

- Elephant Call Detection
- Individual Bear Identification

- Flight Call Detection
- High-throughput Plant Phenotyping

- eBirders
- GrazeIt

- Green Security Games: Preventing Poaching and Illegal Fishing
- Agent (attacker): Trophy poaching
- Principal (protection): Policing

- Adapt-N
- TAHMO

- eBird
- eButterfly
- Subway Lines:

- www.UDiscover.lt
Pattern Decomposition in Big Data

Dimensionality Reduction, Source Separation, and Segmentation with Complex Constraints

- Dark Ecology: Identifying Bird Migrations from Weather Radar
- Characterization of Power Grid State
- Inferring Crystal Structures from X-Ray Diffraction Data
- Electricity Usage Disaggregation
- Flight Call Detection
- Elephant Call Detection
- High-throughput Plant Phenotyping
- Individual Andean Bear Identification from Camera Traps
- Rangeland Mapping in East Africa
- Eelgrass Wasting Disease Identification
- GrazeIt
Conclusions
NSF Expeditions in Computational Sustainability

Expedition allowed us:

- **To nucleate** the Computational Sustainability field
- **To identify** a number of **core research directions** for **maximal impact**, both in terms of Computer Science and Sustainability.

**Big Challenge:**
How to get involved and navigate in this highly interdisciplinary area.

Growing number of computer scientists eager to get involved in computational sustainability research, but **don’t have the connections and access to sustainability projects.**
CompSustNet: Large Research Network for Expanding Horizons of Computational sustainability

**Research**
- Coordinating transformative synthesis collaborations
- Interdisciplinary Research Projects (IRPs)

**Community Building**
- Web Portal
- Catalog Of Problems
- Panels & tutorials at major conferences
- Annual Conference
- Host visiting Scientists

**Education**
- Doctoral students
- Postdocs
- Honors projects
- Research virtual seminar series
- Summer REU program targeting minority students
- Students’ conference
- Distributed Courses

**Outreach**
- Citizen Science Projects
- K-12 Outreach
- Diversity
- Engaging Gov., NGOs Institutions and Companies
- General Public Outreach
- Broad Dissemination of scientific results
CompSust Conference Series:
(international researchers from several disciplines and institutions (universities, labs, government)

CompSust-2016
4th International Conference on Computational Sustainability
July 6-8, 2016
Cornell University, Ithaca, NY

Workshops at Conferences

Neural Information Processing Systems Foundation

SustKDD 2012
Workshop on Data Mining Applications In Sustainability

STOC 2012 – 44th ACM Symposium on Theory of Computing

Tracks at Established Conferences

Theme of IJCAI-2013 (CHINA)
AI and Computational Sustainability

Kristian Kersting
Technical University of Dortmund, Germany
Nov 17, 2017, 1:30-2:30pm EST (UTC-5)

Michela Milano,
Univ Bologna, Italy
Dec 1, 2017, 1:30-2:30pm EST (UTC-5)
Computational Sustainability aims to develop computational methods to help balance economic, environmental, and societal needs for sustainable development.
Computational Sustainability aims to develop computational methods to help balance economic, environmental, and societal needs for sustainable development.
Computational Sustainability aims to advance computational methods to help balance economic, environmental, and societal needs for sustainable development.

1. New challenging problems
2. New formalisms and concepts from other disciplines

→ New Core Paradigmatic problems in Comp. Sci.

→ Societal Impact

Computational Thinking providing new insights, methodologies, and solutions to sustainability problems
Expeditions in Computing (CISE)

Cornell University  Caltech  Carnegie Mellon University  Bowdoin  Georgia Tech  Howard University  The Ohio State University  Oregon State University  Stanford University  Princeton University  UMass Amherst  USC University of Southern California  Vanderbilt University

and Gov and NGOs and several International Universities as collaborators

CompSustNet
125+ faculty, students, and collaborators!!!
From the Cloud Institute, NY

Computational Sustainability
Computing for a Better World

Thank you!