Overview of DIMACS

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DIMACS

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About DIMACS

• DIMACS catalyzes and conducts research and education in mathematical, computational, and statistical methods, algorithms, modeling, analysis, and applications.

• Founded as an NSF Science and Technology Center in 1989 as a partnership among Rutgers, Princeton, Bell Labs, Bellcore, and the New Jersey Commission on Science and Technology.

• Now 14 partner institutions, including Microsoft
About DIMACS

- DIMACS was founded as the Center for Discrete Mathematics and Theoretical Computer Science.
- In some sense, this has become a misnomer.
- DIMACS has significantly expanded its scope with continuous mathematics, data science, and all kinds of application areas.
- Still, we like to put some emphasis on our roots.
Who is DIMACS?

- Offices are located at Rutgers in Piscataway, NJ; programs often held elsewhere.
- Management and staff at Rutgers.
- Over 350 members, most (but not all) from DIMACS partner institutions.
DIMACS Activities: Overview

- Special foci
- Seminar series
- International programs
- Research projects
- Women in computing
- K-12 teacher training

- CCICADA Center for data analysis and homeland security
- Implementation challenges
- Curriculum development
- Graduate student support
- Research experiences for undergraduates
Special Focus Programs

- A multi-year program of coordinated activities addressing a research topic that requires expertise from one or more DIMACS areas, that is poised for advances, and that has potential benefit to society.
- Often multi-disciplinary. Always integrate research and education.
- Typical activities:
  - workshops
  - tutorials
  - research working groups
  - seminars
  - visitors
Current Special Foci and Themed Programs

• Cryptography* 2015-2019
• Bridging Continuous and Discrete Optimization* 2018-2020
• Lower Bounds in Computational Complexity* 2019-2021
• NEW: Mechanisms and Algorithms to Augment Human Decision Making 2019-2022

• *Collaboration with Simons Institute at Berkeley
Selection of Past Special Foci and Themed Programs

• Mathematics of Planet Earth 2013-2018
• Energy and Algorithms 2012-2017
• Algorithmic Decision Theory 2010-2013
• Algorithmic Foundations of the Internet 2007-2014
• Discrete Random Systems 2006-2010
• Information Processing in Biology 2004-2011
• Computational and Mathematical Epidemiology 2001-2011
Potential Special Foci

- Computational Foundations of Automation and Robotics
- Socially Responsible Algorithms
- YOUR IDEAS
Implementation Challenges

- Complements analysis with experimentation:
  - provides guides to realistic algorithm performance where analysis fails.
  - brings algorithmic questions closer to the motivating problems.
  - tests assumptions about implementation methods and data structures.
  - develops problem instances, instance generators, and other methods of testing and comparing algorithms.
  - provides leading edge implementations of algorithms.

- We have received funding for the 12th Implementation Challenge, on Vehicle Routing Problems.
  - the first since David Johnson’s death, held in his honor
  - culminating workshop to be held in Fall 2020
Curriculum Development

• Module development projects partner subject matter experts and education experts, working with partner schools, to develop curricular materials on topics of importance.

• Biology and mathematics:
  – 5-day modules for high school biology and mathematics classes.
  – a senior-level biomathematics course.

• Computational thinking across the curriculum:
  – 5-day modules that introduce computational thinking ideas and skills intended for use in a wide variety of high school courses.
  – expected new project on professional development for high school teachers in computational thinking

• Sustainability:
  – 5-day modules for high school in mathematical, computational, and modeling topics related to planning for a sustainable future.
Curriculum Development

- Computational thinking professional development online
  - How to teach computational thinking in your classroom
- Intelligence community center of academic excellence
  - Developing a critical technologies studies program
- Responsible computer science
  - Bringing ethics into data science and machine learning courses
  - Under development

Responsible Computer Science Challenge
With Great Code Comes Great Responsibility

ResponsibleCS.org  #ResponsibleCS
Research Experiences for Undergraduates

- Around 35 students each summer
- Students are matched with faculty mentors for one-on-one or small-group research experiences
- NSF site grant
- International partnership with DIMATIA at Charles University in Prague
Reconnect Program

- Introducing undergraduate faculty to current research topics ripe for their classroom
- Mostly faculty no longer doing research
- Weeklong program at different locations each year
- Not just lectures: Participants develop modules for classroom use
- Modules reached over 35,000 students
Reconnect Program: Recent Topics

- 2019: Cryptography
  - Champlain College
- 2018: Not in My Backyard: Mathematical and Computational Tools for Decision Making
  - Muhlenberg College
- 2017: Energy Efficiency and Reliability of Data Centers and the Electrical Grid
  - Appalachian State University
- 2016: Cyber security
  - West Point
- 2015: Social Networks and Homeland Security
  - Rochester Institute of Technology
- 2020: Topic TBD
Douglass-DIMACS Computing Corps

- A technical, leadership, and outreach program for Rutgers undergraduates interested in computing.

- Students carry out computing activities (including Girls Who Code modules) with Piscataway and other local middle schools and Girl Scout troops.
Computer Science Living-Learning Community for Women

- Students live in a common dorm on the Rutgers Busch campus where the CS department is.
- A first-year seminar course on “Great Ideas and Applications in Computer Science.”
- Multi-layered mentoring including a graduate mentor, an undergraduate peer leader, a faculty advisor, and dedicated Douglass Project staff members.
- Community-building programs and events to promote student-faculty engagement.
New Initiative on Women in CS

• Curricular Revision: starting with introductory CS course.
  — Topics that might appeal to women, keep them engaged
• Co-curricular programs: Living-Learning Community
• Outreach to Middle and High Schools
• Collaboration with Big Ten universities and others
• Research on what appeals to women, what turns them away
CCICADA

- Command, Control, and Interoperability Center for Advanced Data Analysis
- Founded as a DHS University Center of Excellence
- 11 years of DHS funding
- Builds mathematical and computational foundations for data science to extract both knowledge and practical consequences from massive, complex or unstructured data.
- Mostly multidisciplinary research
- Focus on results for near-term transfer and close collaboration with agencies
- 17 academic and industrial partners
  - CMU, USC, RPI, Howard, Morgan State, Bell Labs, etc.
CCICADA

- Algorithms for efficient allocation of Coast Guard boats and aircraft
  - Large mixed integer programming problem
- Best practices for stadium security
  - Collaboration with NFL, NBA, MLB, and all major sports leagues
- Web scraping tools to counter human trafficking
  - Collaboration with FBI
- Resource allocation to prepare for oil spills in the Arctic
  - Collaboration with Coast Guard
- Voice forensics to catch serial hoax callers
  - Collaboration with Coast Guard Investigative Service
- Maritime cyber security
  - Pioneered in developing this field
- Crowd management simulation
  - For Port Authority Bus Terminal NYC
CCICADA

• Development of new fundamental tools:
  – Natural language processing
  – Higher order learning
  – Information based testing
  – Social media analytics
  – Split and conquer for penalized regression

• Education and workforce development programs
  – Fellowships/Internships
  – Reconnect
  – REU
  – Modules
  – Minority serving institution program
CCICADA: Current Projects

• With TSA: algorithms to adjudicate criminal history records in applications for transport worker identification card
• With DHS Criminal Investigations University Center of Excellence: Cyber Forensics
• Drones
• Future of Work at the Human-Technology interface in the Security Arena
• Could CCICADA be a model for another DIMACS research-oriented activity?
TRIPODS Program:

- New NSF grant; 3 year program
- Transdisciplinary Institute on Data Science
- Institute on Data Science for INtelligent Systems and People Interaction = DATA-INSPIRE.
- Math-CS-Stat
- Theoretical Foundations of Data Science
- Premise: advances in data science principles are needed to impact the emerging paradigm of intelligent machines and their convergence with human society
TRIPODS INSTITUTE

• Research Groups
• Workshops
• “Boot Camps”
• Seminars
  – Including with industrial partners
• Interaction with other TRIPODS Institutes
• REU program
TRIPODS INSTITUTE

• Formal tools are needed to remove ambiguity about what causes intelligent machines to perform in certain ways
  – Accidents with autonomous vehicles, robotic surgery
• Reducing machine learning methods' dependence on large amounts of task-specific supervision
• Most intelligent machines need to react to sensing data under critical deadlines – need more effective real-time decision making
Some New Initiatives/Directions for DIMACS

- Data science
- AI/ML
- Future of work at the human-technology Interface
- Ethics in algorithms
- Cyber security
- Resilience of ecosystems, urban systems, food systems
How to Get Involved

- Organize a workshop
- Suggest a workshop or special focus or research project
- Attend workshop or seminar
- Mentor REU student
- Co-sponsor a postdoc
- Organize/teach tutorials
- Write an educational module
- Serve on a DIMACS committee
DIMACS is Turning 30

- Major birthday conference
- Looking to the future in fields of DIMACS
  - Future challenges for DM/TCS
  - Future challenges for algorithms
  - Connections to AI/ML
  - Connections to Applications
    - Statistical physics, sustainability, epidemiology, security
  - Bias/Fairness
  - New educational initiatives
  - Broadening participation in STEM
  - What is the future of centers?

Nov. 21-22, 2019
Parallels between MSR-NYC and DIMACS

David M. Pennock
Principal Researcher, MSR-NYC -> Director, DIMACS in January 2020
Microsoft Research Mission
- Expand the state of the art
- Rapidly transfer innovations
- Ensure Microsoft’s vibrancy and future

New York City Research Areas
- Machine learning
- Computational social science
- Digital economy
- Computer systems
- Ethical machines
DIMACS Philosophy

- DIMACS believes that progress will come at the intersection of disciplinary boundaries, motivated by problems in fields like chemistry, ecology, economics, engineering, environmental science, medicine, neuroscience, physics, and sociology.
- DIMACS cherishes its academic and corporate partners who both advance and guide its mission.
- DIMACS believes in quantifying problems and addressing them using math, statistics, and computer science tools, including algorithms, models, competitions, and analysis.
- DIMACS seeks to educate a diverse cross section of students, from high school to grad school, about both the wonders and the limitations of technology.
Some Items of Common Interest

- DIMACS Special Focus on Mechanisms & Algorithms to Augment Human Decision Making
  1. Eliciting Complex Information
  2. Algorithmic Social Choice
  3. Eliciting Beyond Labels from the Crowd
  4. Preference Aggregation
  5. Learning from Partially Reliable Data

- DIMACS funding under one of NSF’s “10 Big Ideas”: Harnessing the Data Revolution
  - Transdisciplinary Research In Principles Of Data Science (TRIPODS)
  - Interaction of people and intelligent machines

- DIMACS Research Experience for Undergraduates | MSR Data Science Summer School
- Rutgers Computer Science Living-Learning Community of undergraduate women interested in majoring in CS
Some Items of Common Interest

- Fairness, Accountability, Transparency, and Ethics in algorithms
  - MSR-NYC and Tri-Labs now leaders in the field, organically
  - Proposed DIMACS Special Focus on Algorithms and Society
  - Rutgers committed to adding FATE to data science and ML courses
- Optimization
  - DIMACS/Simons Collaboration on Bridging Continuous and Discrete Optimization
  - Sep 16-18, 2019: DIMACS Workshop on Randomized Numerical Linear Algebra, Statistics, & Optimization, New Brunswick - 4 people from MSR registered already!
  - Oct 7-10, 2019: CRM/DIMACS Workshop on Mixed-Integer Nonlinear Programming, Montreal
  - May 18-21, 2020: Mixed Integer Programming Workshop & DANniversary, New Brunswick
  - March, 2021: Frontiers of Optimization Research Conference, New Brunswick
  - More: Polynomial Optimization; Continuous Approaches to Computing Discrete Partition Functions
Biggest Commonality: Great People

- MSR-NYC is the best place in the world to do research
- MSR-NYC has some of the most amazing researchers who are brilliant, tireless, and nice
- I recognized some of the same kinds of people at DIMACS: smart, effective, and kind