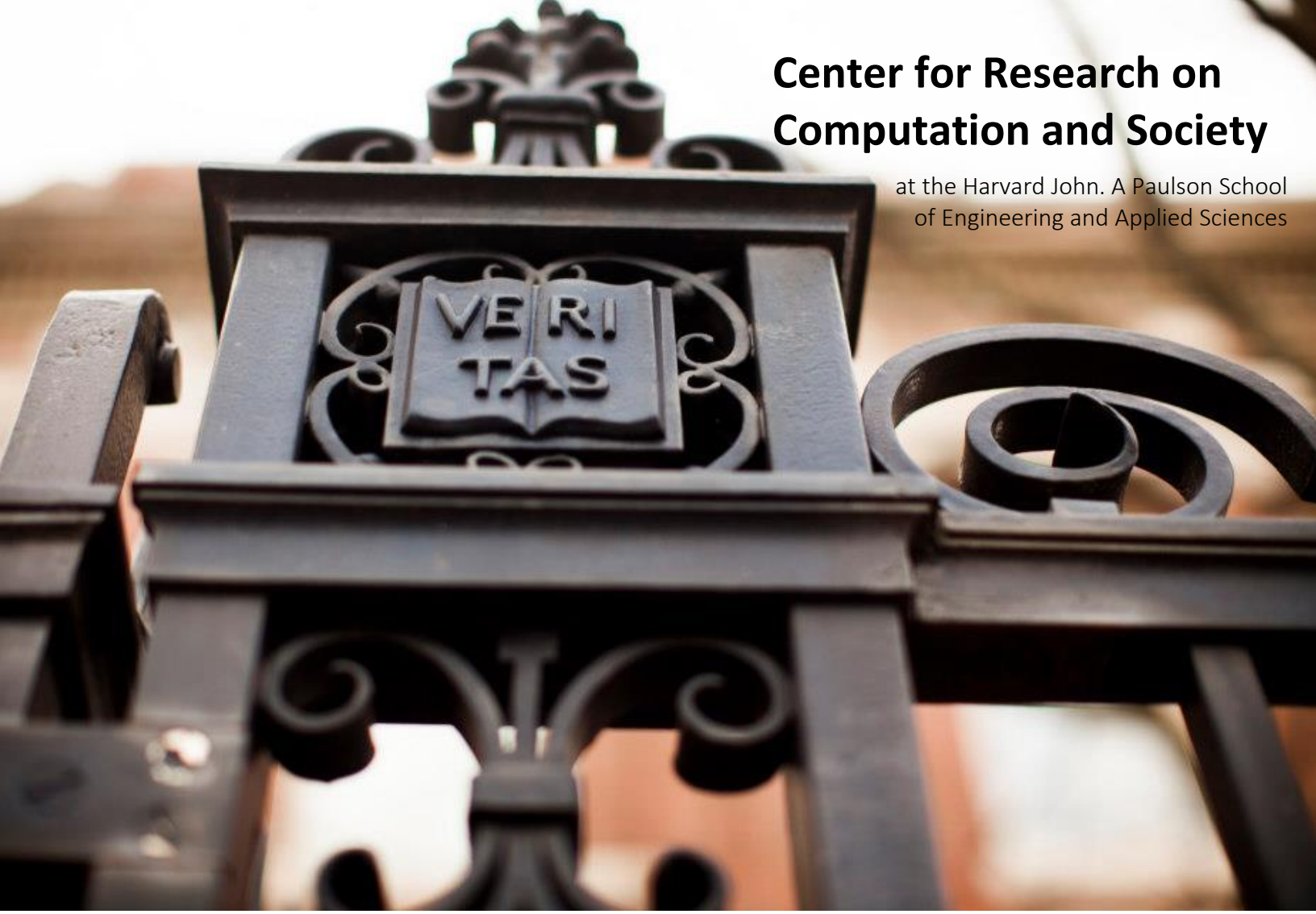


Center for Research on Computation and Society

at the Harvard John. A Paulson School of Engineering and Applied Sciences

Computation and technology permeate our lives. Today, they impact everything from consumer preferences to healthcare delivery, military operations, popular culture, education, the environment, and more. Historically, technological advances have been driven by concrete needs. Prehistoric man discovered how to control fire for cooking and heat. Neolithic man invented the wheel to meet transportation needs. Modern man built the printing press, telephone, and Internet, each a tool designed to meet the need for communication across vast distances. Concrete needs like survival, transportation, and communication have motivated our conversion of natural resources into increasingly complex tools. And yet, if technological advances are driven only by concrete needs, a number of society's more abstract needs will never be addressed.

21st century innovation must also be driven by societal need. Scholars from a broad range of fields are needed to advance computer science research that serves the public interest, informed by a deep knowledge of the societal issues at stake. Harvard is uniquely positioned to lead in research and teaching on computation and society. Drawing on expertise in computer science and the many disciplines that study and regulate society—including law, government, economics, business, and public health—computer scientists at Harvard work in a research context that sets them apart from applied science and engineering-focused programs at peer institutions. Harvard's Center for Research on Computation and Society is the critical nexus for identifying societal objectives and inventing the technical means to achieve them.

Dynamic Context

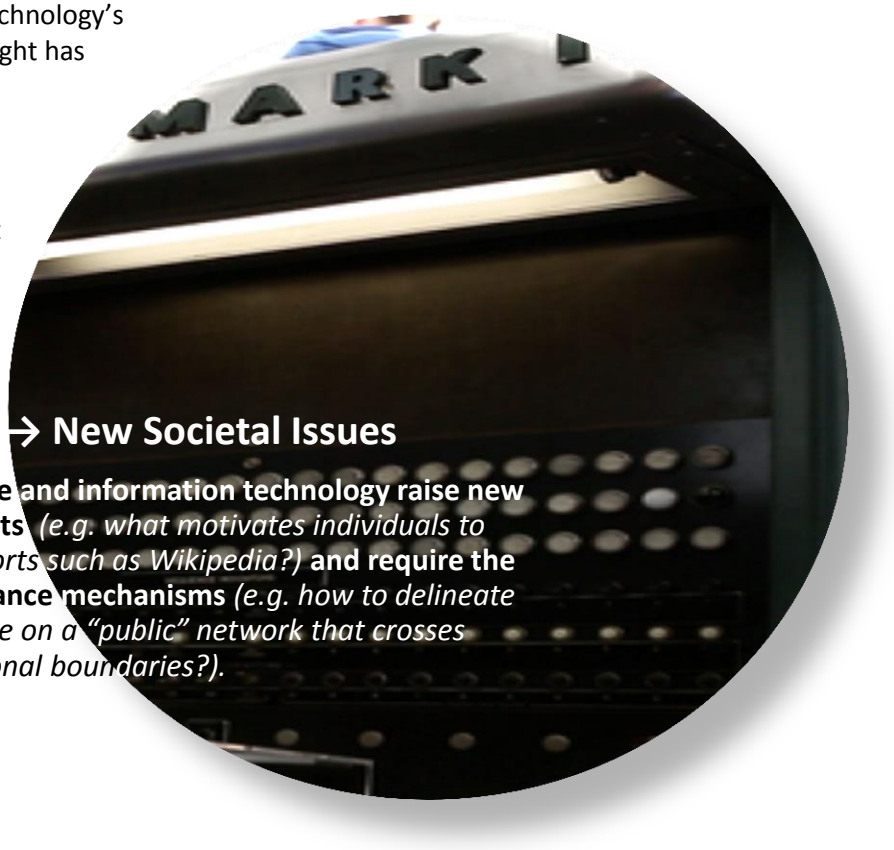
The Center for Research on Computation and Society (CRCS) sits within the rapidly-expanding Harvard John A. Paulson School of Engineering and Applied Sciences. Founded in 1847 as the Lawrence Scientific School, the Harvard Paulson School was elevated to a School in its own right in 2007. Since then, its growing momentum has produced the most popular course at Harvard (*Computer Science 50)*, several new undergraduate concentrations, new master's programs in computational science and engineering and in design engineering, faculty growth by nearly 30 percent, concentrator increases of over 300 percent, and course enrollment increases of more than 250 percent.

Recognizing the School's pivotal importance within Harvard, the University and its alumni have rallied to its support. Groundbreaking gifts include that of John A. Paulson, whose philanthropy promises to sustain and grow the expertise of current and future faculty; and of Steve Ballmer, whose support will increase the computer science faculty by half. These transformative gifts are part of a broader plan which anticipates the expansion of the Harvard Paulson School into the purpose-built Science and Engineering Complex in Allston. In addition to these forward-thinking investments, Francis J. Doyle III has taken the School's helm as its John A. Paulson Dean, cementing the leadership needed to capitalize on this momentum.

In this era of applied science innovation, CRCS harnesses Harvard's research expertise in computation to develop socially-responsive ideas and technologies. CRCS brings leading computer scientists together with economists, psychologists, legal scholars, ethicists, neuroscientists, and other experts from across the University and the globe to develop fundamentally new computational solutions that address societal needs.

Progressive Vision

CRCS is driving new ways to think about technology's relationship with humanity. Scholarly thought has traditionally taken a passive stance in the man/machine relationship. Using new technology as the orienting, static point, scholars study how society responds to technological developments, and how that response can be improved for societal function. In this passive model:

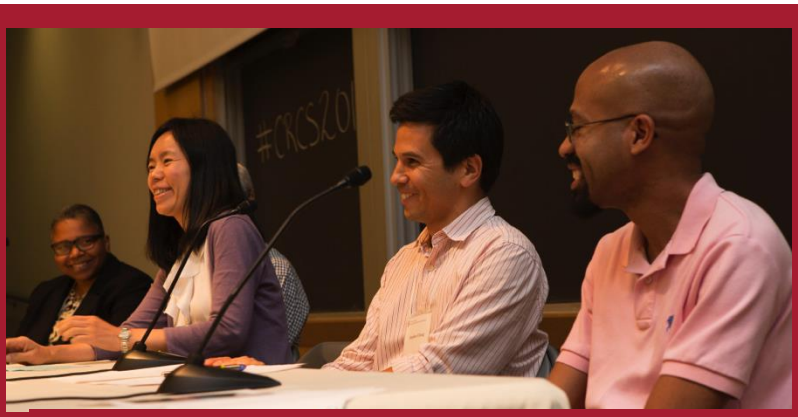


Computer Science → New Societal Issues

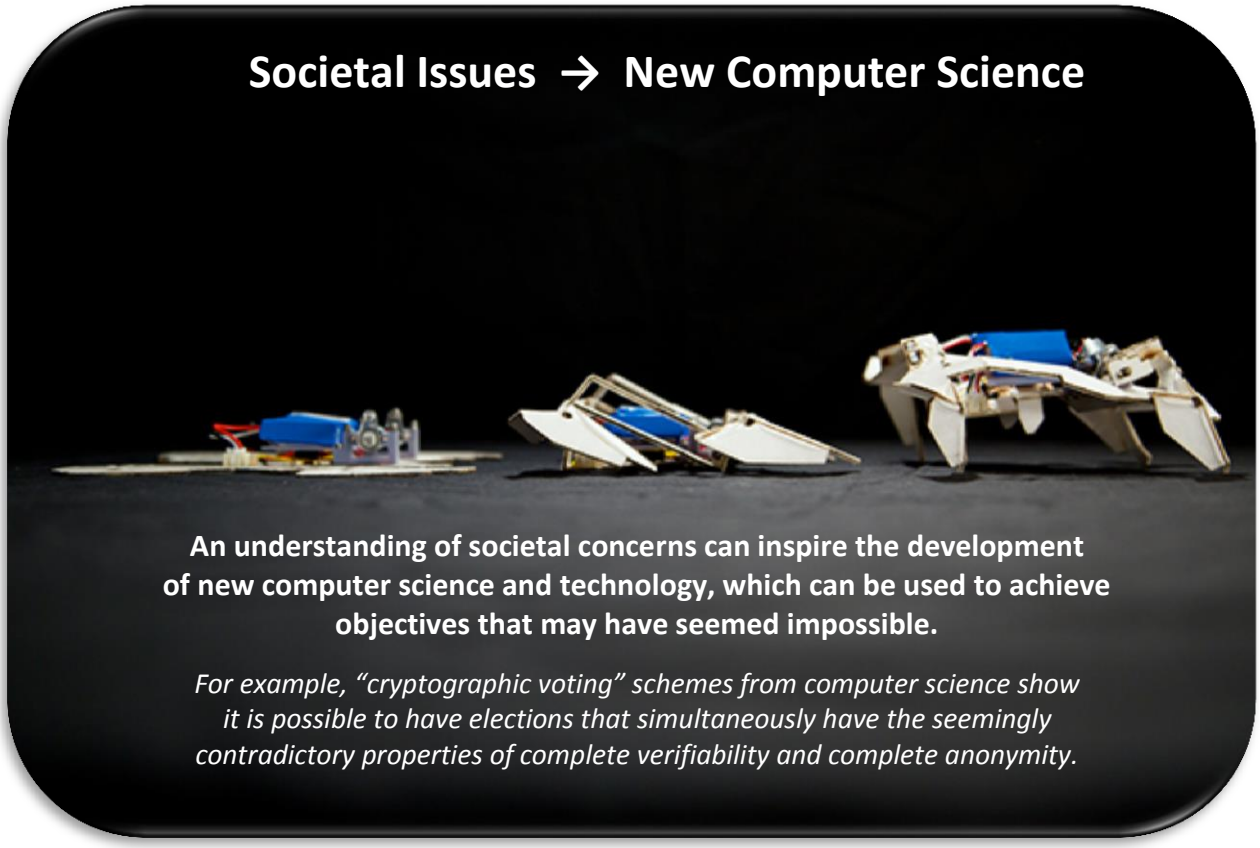
The products of computer science and information technology raise new issues for study by social scientists *(e.g. what motivates individuals to contribute to collaborative efforts such as Wikipedia?)* **and require the development of new governance mechanisms** *(e.g. how to delineate the constraints on surveillance on a "public" network that crosses jurisdictional boundaries?).*

We invert the question.

At CRCS, we ask: *How might our technologies take shape if we invest our expertise in an active model?* This active model is what makes our vision distinctive among efforts that study the interaction between computing and society. Computation can be a powerful tool, capable of creating new solutions for some of our most complex problems. In this active model:



2015 CRCS Symposium: Societal Impact through Computing

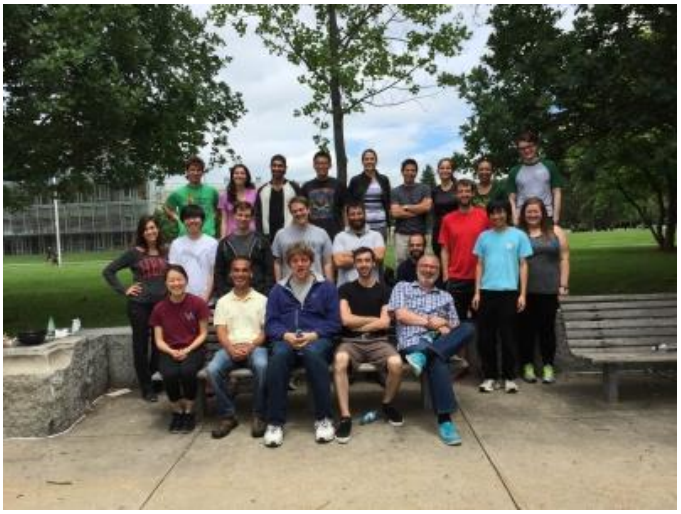


CRCS takes a uniquely integrative and forward-looking approach to cross-disciplinary collaboration. Beyond merely examining the effects of existing technology on society, CRCS supports inquiry into innovative computer science and technology informed by today's real-world contexts, anticipating tomorrow's real-world needs. Efforts within CRCS are fueled by a deep knowledge of the societal issues at stake.

High-Impact Research

The following are just a few of the areas where CRCS research is opening new possibilities for computer science and technologies to address societal goals:

Crowdsourcing: The Internet has enabled collective efforts on unprecedented scales, resulting in remarkable artifacts such as Wikipedia, and providing the potential for laypeople and diverse groups of experts to contribute to scientific research (as in our Lab in the Wild, labinthewild.org), detect Internet censorship (as in the Berkman Center's Herdict project, herdict.org), and translate books while fighting spam (as in Google's Recaptcha, google.com/recaptcha). Research on the design of crowdsourcing systems that optimize incentives, usability, efficiency, and quality will enable us to realize the full potential of "human computation" in existing and new application domains.



Cybersecurity: The Internet provides a new battleground for conflict between state and non-state actors, with the possibility of a cyber-attack wreaking havoc on critical infrastructure or the economy. Research on computer security is essential to understanding the vulnerabilities in our computer systems and protecting them against attack.

Privacy and Big Data: The vast troves of data available for collection and analysis by companies, the government, researchers, and the public promise to provide many societal benefits, but also pose a serious threat to privacy. The research challenge is to identify the optimal tradeoff between "privacy" and "data utility," and design technologies that achieve this tradeoff.

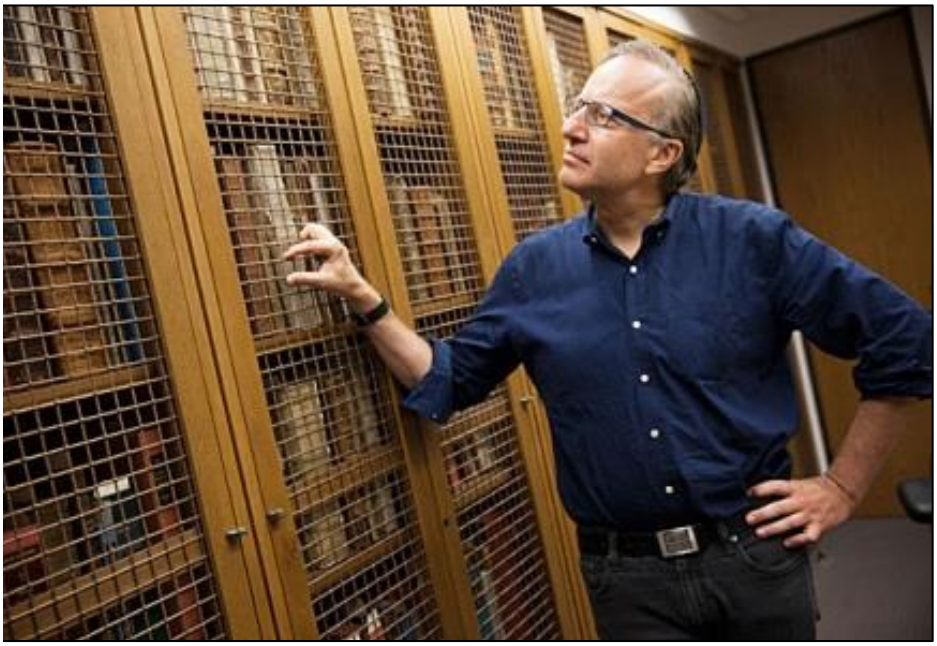
Education: Massive Online Open Courses (MOOCs) enable educational offerings on a dramatically increased scale, at a fraction of the cost of traditional classroom-based models. MOOCs and other educational technologies provide an unprecedented opportunity for researchers in education, computer science, and statistics to analyze how students learn and then design more effective pedagogical tools. At CRCS, we ask how such learning technologies can improve education globally; to date, MOOCs have mostly been "educating the educated." How do we transition to a world where we can educate those who do not have access to traditional education?

Professor Salil Vadhan, Vicky Joseph Professor of Computer Science and Applied Mathematics and former Faculty Director of CRCS, is collaborating with his team on a project entitled ***Privacy Tools for Sharing Research Data***. This project is a broad, multidisciplinary effort to help enable the collection, analysis, and sharing of personal data for research in social science and other fields while providing privacy for individual subjects. The goal is to build an array of computational, statistical, legal, and policy tools that can be incorporated into already-existing data repositories. Collaborators include CRCS, Institute for Quantitative Social Science, Berkman Center for Internet and Society, Data Privacy Lab, and MIT Libraries' Program on Information Science. Initially receiving seed funding from Google, the project has gained support through a National Science Foundation Secure and Trustworthy Cyberspace Frontier grant and a grant from the Sloan Foundation.

Markets and networks: The explosive growth of electronic commerce, mobile commerce, and social networks has enabled completely new modes of economic production, information aggregation and dissemination, and social interaction. This rapid transformation has brought on numerous research opportunities for economics, computer science, and statistics, ranging from the design of electronic markets to the modelling and analysis of interactions involving humans, algorithms, and networks.

Healthcare: The movement toward consumer-driven healthcare has given patients, their families and caregivers the freedom and the responsibility to make important decisions about their care. However, they are frequently asked to make those decisions without adequate information. Technology offers the promise of alleviating this information gap through the effective and timely delivery of quality information, while also supporting improved coordination of the care provided by diverse types of caregivers.

In 2009, Harvard Medical School Professor Isaac Kohane and colleagues were able to display the potential of mining existing medical records, showing that they could diagnose a patient suffering domestic abuse a full two years before the system would detect it, simply by using discharge data from emergency room patients across Massachusetts.



Social Computing: Social computing is a broad research area situated at the intersection of computer science, economics, and other social sciences. It concerns both harnessing human intelligence for computational tasks and designing computational systems that support social behavior and interactions. Examples that showcase the power of social computing include Wikipedia, a crowd-generated online encyclopedia; Zooniverse, a crowdsourcing platform for scientific problems; and Iowa Electronic Markets, a crowdsource for eliciting and aggregating information for political events, to name only a few. Despite the potential for broad applications, surprisingly little is known about the methodologies for designing effective and efficient social computing systems, and their limitations remain largely unexplored.

Automating Data Analysis: One of the significant challenges for science is bringing effective and rigorous analysis tools to bear on important problems. While ideally statisticians and machine learning researchers would be involved in many applied projects that demand sophisticated methods, it is not always possible to find such collaborators. This deficit motivates the development of new tools that not only automate analysis in ways that mimic statistical thought processes, but also that help scientists explore their data without damaging significance via, for example, implicit testing of multiple hypotheses.

Designed for Collaboration

Harvard provides the ideal venue for this cross-disciplinary research initiative because of the strength of its diverse faculty. Within computer science, Harvard has world-class teams of researchers in artificial intelligence, cryptography and algorithms, learning theory, systems, computational economics, and more. The Center's intellectual scope is broadened by collaborations with faculty outside of computer science, including faculty from the Law School, Kennedy School of Government, Business School, the Harvard Berkman Center for Internet and Society, and more. Just a few of the Harvard Paulson School faculty who are involved in CRCS research and collaborations include:

The research of **Margo Seltzer**, *Herchel Smith Professor of Computer Science,* and *Director, Center for Research on Computation and Society,* focuses on how to make computer systems faster, more reliable, or easier to use. Her research activities range from designing and building new storage systems to creating new operating systems to developing systems for collecting and tracking provenance of data.

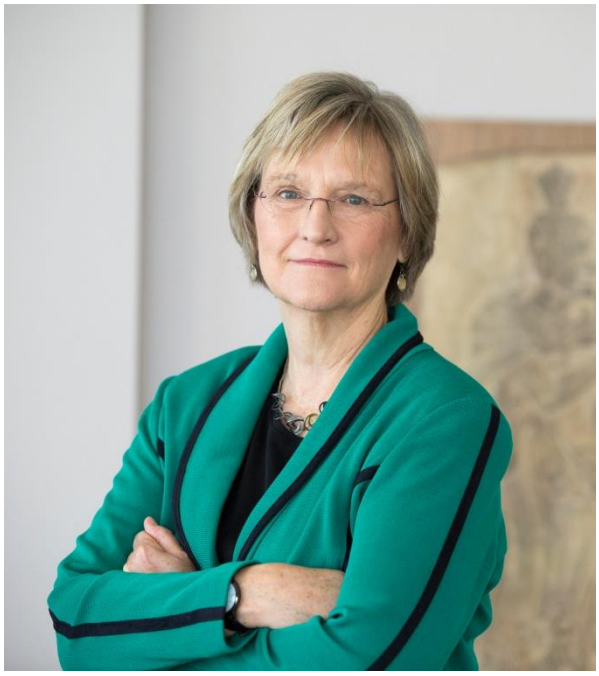
The research of **Barbara Grosz**, *Higgins Professor of Natural Sciences,* addresses fundamental problems in modeling collaborative activity, developing systems ("agents") able to collaborate with each other and their users, and constructing collaborative, multi-modal systems for human-computer communication.

The research of **Harry Lewis**, *Gordon McKay Professor of Computer Science,* focuses on the algorithmic solvability of logical, computational, and combinatorial systems, attempting to clarify the relations between them and to identify their common characteristics. He is also actively involved in the use of computers in education, and is influential in the teaching of the foundations of computer science to undergraduates.

The research of **Yiling Chen**, *Gordon McKay Professor of Computer Science,* is situated at the interface between computer science and economics in the emerging area of social computing, where human creativity and resources are harnessed for the purpose of computational tasks.

The research of **David Malan**, *Gordon McKay Professor of the Practice of Computer Science,* has focused on cybersecurity and digital forensics, as well as pedagogy and instructional technologies. He teaches Harvard College's largest course, *Computer Science 50*, otherwise known as *CS50*, and edX's largest course, *CS50x*.

The research of **Jonathan Zittrain**, *Professor of Computer Science, George Bemis Professor of Law,* and *Professor at Harvard Kennedy School,* includes battles for control of digital property and content, cryptography, electronic privacy, the roles of intermediaries within Internet architecture, and the useful and unobtrusive deployment of technology in education. He is a co-founder of the Berkman Center for Internet and Society at Harvard.



"We must harness the power of One Harvard to advance discovery and learning across fields, disciplines, and our broad range of Schools to change knowledge and to change the world. Students and faculty must be enabled to draw easily on Harvard's widely distributed strengths as they explore answers to intellectual questions, both enduring and new, and seek solutions to society's most consequential problems."

-Drew Gilpin Faust
President, Harvard University