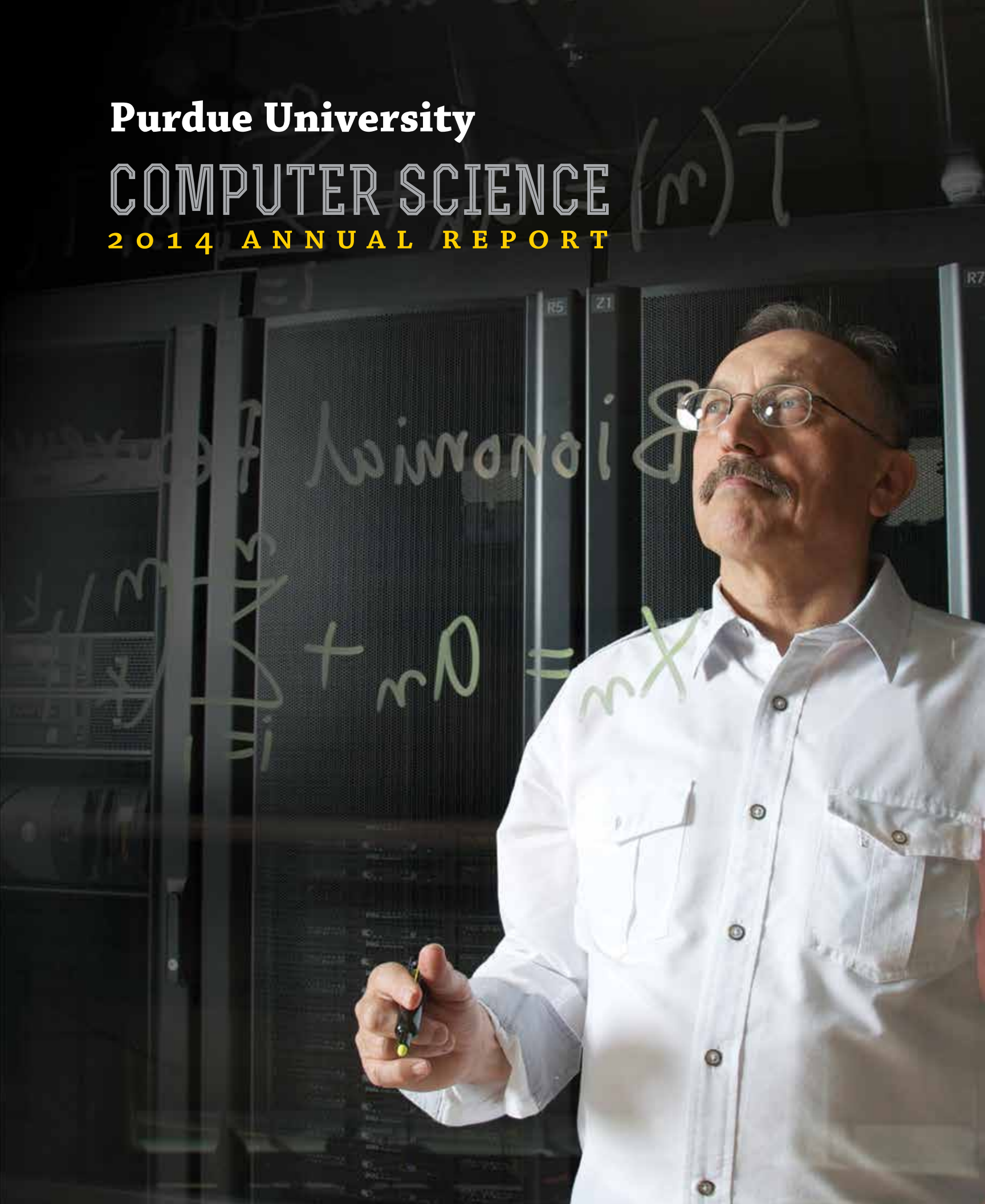
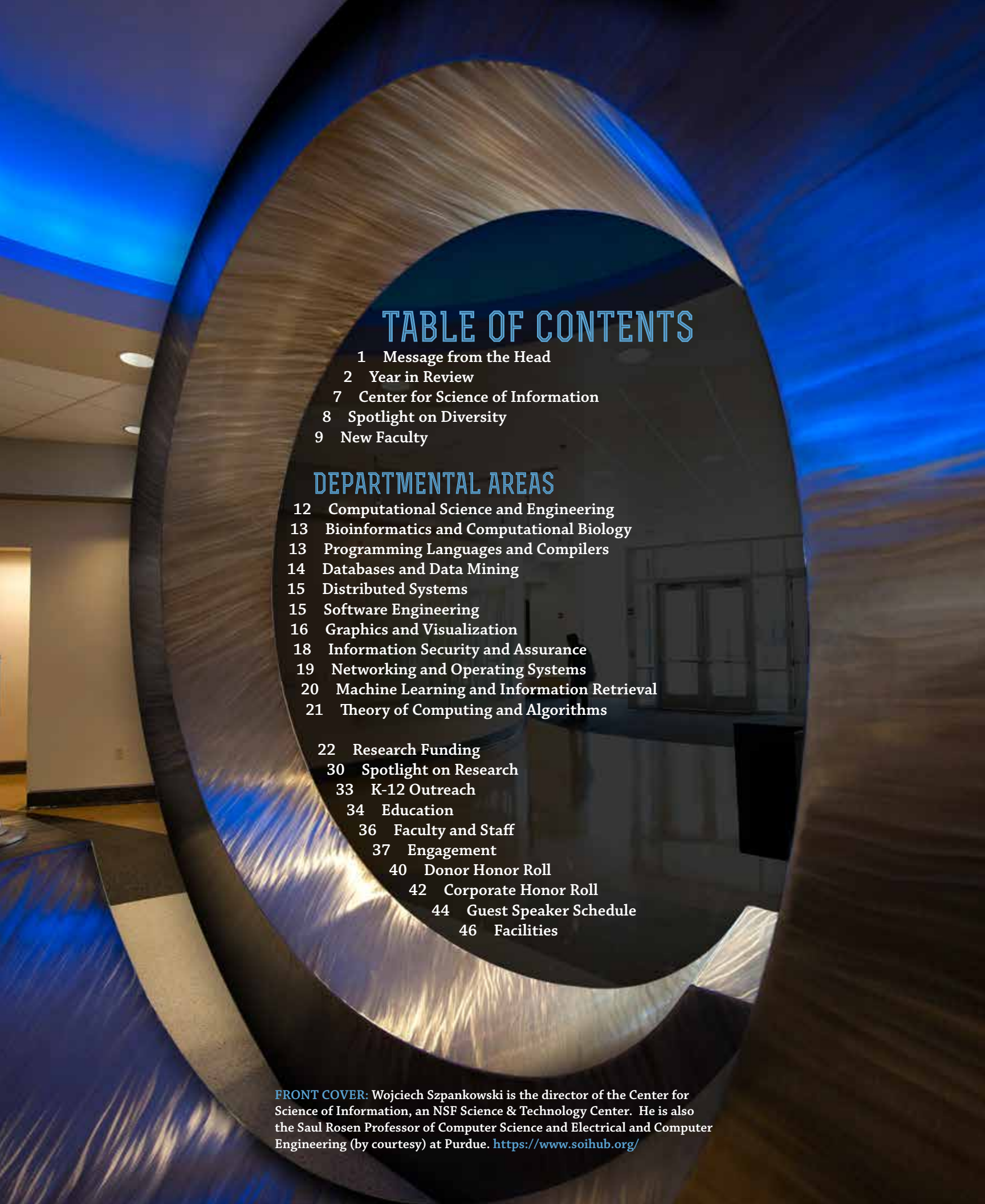
# Purdue University

# COMPUTER SCIENCE

## 2014 ANNUAL REPORT





# TABLE OF CONTENTS



## DEPARTMENTAL AREAS



FRONT COVER: Wojciech Szpankowski is the director of the Center for Science of Information, an NSF Science & Technology Center. He is also the Saul Rosen Professor of Computer Science and Electrical and Computer Engineering (by courtesy) at Purdue. https://www.soihub.org/

# MESSAGE FROM THE HEAD

## Breakneck speed

It's been a remarkable year! Less than two years ago, we were honored to be selected as one of Purdue's strategic areas of growth – an investment made by the University that will result in a 30% expansion of our entire department.

The excitement we feel and the actions we've taken since the announcement have been transformative for our department. I'd like to give you an update on our progress so far, and I'll begin with enrollment.

We set a goal to aggressively increase our enrollment because we've witnessed the dire need for our CS graduates, who are recruited as early as their sophomore year, and by graduation, earn among the highest starting salaries in business and industry.

Our efforts have been successful, as I'm happy to report that we've increased undergraduate enrollment more than 30%. And, our graduate enrollment is up 10%, as well. The growth in our enrollment has prompted us to hire 10, new outstanding faculty so that we maintain the same high quality of education our students have always experienced. We aren't stopping there! We plan to more than double faculty hires, before the expansion concludes.

To ensure our students success when they arrive to campus, we've launched a new summer program called the Bridge. The program targets students who have high potential in math, but little or no programming experience in high school.
In just two years, the program has demonstrated an 80% increase in retention rates among those participating in the program.

Through this, we've recognized that many of our Indiana high schools lack the resources they need to offer computer science courses. So, for the first time in our department's history, we launched a free, online-course available to any Indiana student. This course is equivalent to the freshman programming course we offer on campus, and helps level the playing field for students seeking a degree in computer science, while also preparing them for the CSAP exam. Due to the overwhelming success of this effort, we plan to make the course available to all students (across the nation) in the near future.

We are expanding in our graduate programs, as well, creating two new master's degree programs in the areas of Cyber Security and Data Science, which are extremely relevant and vital to our society. We also are in the process of upgrading our facilities (even though our building is relatively young) so that our students can continue to enjoy state-of-art labs and high-tech resources to enhance their educational experience.

Extending outside the walls of Lawson, we have initiated new, multidisciplinary relationships with other departments to solve some of the world's greatest challenges, including world hunger, as we work together to unleash the potential of big data.

It's a thrilling time to be part of Purdue Computer Science and witness the dramatic changes occurring in our department. Looking back at this time, if I said that we were moving forward, that would be a huge understatement! We've been running at an all-out sprint and we are seeing the results of our efforts. I am confident that we are poised to be successful in our journey and I look forward to your support as we continue moving – no racing – to our destination.

# YEAR IN REVIEW

## CS PhD Student Takes 3rd Place at Supercomputing Conference

CS PhD student Ariful Khan earned third place at the Supercomputing 2014 Conference (SC14) – one of the top-tier international conferences for high performance computing held in New Orleans, Louisiana.

## Professor Sonia Fahmy Named University Faculty Scholar

Professor Sonia Fahmy was one of four individuals selected by the College of Science for the notable distinction of Faculty Scholar. Her fellow recipients include: Tong Liu, associate professor of mathematics; Chengde Mao, professor of chemistry; and Qianlai Zhuang, professor of earth, atmospheric, and planetary sciences.

## Professor Elisa Bertino Receives ACM SIGSAC Outstanding Contributions Award

Professor Elisa Bertino received the ACM SIGSAC Outstanding Contributions Award for her seminal research contributions and leadership in data and applications security over the past 25 years.

## Purdue Hacker Teams Win Top Prizes at the World's Largest Collegiate Hackathon

Purdue Hackers Club sent 72 students to the University of Michigan to compete in MHacks, the world's largest collegiate hack-a-thon. Three Purdue teams took home prizes for their efforts.

## CS Recognizes Three Outstanding Alumni

Kathleen Mapes Campbell (M.S. '75), Michael Petersen (B.S. '72, M.S. '74) and Eric Simone (B.S. '88) were honored in an awards presentation and reception for their respective achievements in business and community.

## CS Students Win Best Student Paper at USENIX Security Symposium

CS researchers won the Best Student Paper award at the 23rd USENIX Security Symposium, a top-tier computer systems security conference. The paper, "DSCRETE: Automatic Rendering of Forensic Information from Memory Images via Application Logic Reuse," was co-authored by Brendan Saltaformaggio and Zhongshu Gu, along with the assistance of CS professors Xiangyu Zhang and Dongyan Xu.

## CS Moves Forward, Announces Three New Faculty

The department hired three new faculty members who began their careers as assistant professors in Fall 2014: Mathias Payer, Dan Goldwasser, and Tiark Rompf.

## National Science Foundation Sponsors Big Data Computing Workshop

Purdue CS hosted a workshop sponsored by the National Science Foundation to improve skills in working with big data using Hadoop, Spark and uRIKA for data processing and analysis.

## CS Students Have a Ball at VEX Robotics Competition

The ACM SIGBOTS competed in the VEX Robotics Competition with university students across the globe for the "Toss Up" which challenged team robots to score Buckyballs and Large Balls into the Middle Zone, Goal Zone, and Cylindrical Goal on a 12X12 field set up in the Lawson Commons.

## CS Professor Cristina Nita-Rotaru Earns CoS Research Award

The College of Science honored Associate Professor Cristina Nita-Rotaru with the College of Science Research Award. Chengde Mao of the Department of Chemistry, and Jayanta K. Ghosh of the Department of Statistics also were recognized.

## Robo Rally Packs a Punch at CS Summer Camp

Middle school students participated in Super Robo Rally, part of a week of events hosted by the department's K-12 Outreach Program. Students built robots from a 20,000 piece Lego robotics set and transformed the Lawson Commons into a competition arena for computer programming.

## Two CS Faculty Earn Promotions

Associate Professor Ninghui Li was promoted to Professor, and Assistant Professor Xavier Tricoche was promoted to Associate Professor with tenure.

## Undergraduate Student Board Expands CS Helproom Services

The CS Undergraduate Student Board (USB) was granted approval to expand the USB Helproom, a weekly tutoring program created to assist students with course work.

## Former CS Student Earns Karl V. Karlstrom Outstanding Educator Award

Susan H. Rodger was recognized for her contributions to the teaching of computer science theory in higher education, and the development of computer science education in primary and secondary schools. Susan earned her PhD in '89 and was a student of Professor Greg Frederickson, who still serves on the faculty.

## Back Home Again With Distinction

Anne Schowe (B.S. '72) was recognized with the department's highest award, Distinguished Alumna, during a reception held at the Lawson Computer Science Building. Anne achieved an impressive thirty-year career history, beginning at AT&T Bell Laboratories in 1972, where she was a member of the technical staff and worked on an early Computer Aided Design and Diagnosis system for digital switching systems.

## CS Student Honored for Teaching Excellence

Rohit Ranchal, PhD candidate in CS was honored with the Teaching Academy Graduate Teaching Award at the 16th Annual Celebration of Graduate Teaching Excellence Ceremony.

## CS Professor Awarded 2.5 Million From European Research Council

Associate Professor Patrick Eugster was awarded a $2.5 million grant from The European Research Council (ERC) to benefit his two main areas of research, distributed systems and programming languages.

## CS Student's Research Nets Microsoft Trustworthy Computing Reliability Award

The research done by PhD candidate Rahul Potharaju during his internship at Microsoft was selected to receive the Microsoft Trustworthy Computing Reliability Award.

## Military Kids Explore the World of Computer Science

CS Outreach and the Indiana 4-H Youth Development's Operation joined forces to host Operation: Military Kids (OMK)—a fun and educational day of computer programming and application development. Coming from distances as far as Colorado and Florida, thirteen students of military families attended the five-hour event, gaining hands-on experience with technology important to computer scientists.

## Purdue Teams Place Nationally In Code Wars

Two Purdue teams placed in the grand finals of the third annual Windward International Collegiate Programming Finals, better known as Codewars. Team Celery, consisting of Rendong Chen, Kaiwen Xu and Yuxi Chen placed first in the local competition and seventh nationally, while Logan Gore and Evan Arnold's team, Стая лошадей (Herd of Horses) took second place locally and tenth nationally.

## CS Professors, Engineering Students Sense the Future with New Business

Associate Professor Patrick Eugster, Matthew Tan Creti and Vinai Sundaram created a new software business, SensorHound Innovations LLC that makes sensors more reliable.

## CS Professors Lead the 2013 Splash Conference to Indianapolis

The international conference worked on solving problems faced by the software industry, including ways to improve tools the average person uses daily, like smartphones, Facebook and Google.


## CS Professor Creates Technology to "C" the Future

Professor Daniel Aliaga created a new technology that allows people to view digital content on tablets, smartphones and laptops with greater clarity – eliminating the need for corrective eyewear.

## Inspiration the Mother of Invention for CS Students Boilerlabs App

Five CS classmates in CS 307 (taught by Professor Buster Dunsmore) formed a team and created an application – Boilerlabs – that has transformed the way students are able to find computer lab space on the West Lafayette campus.

## IEEE Computer Society Board Names Bertino Editor-in-Chief

Professor Elisa Bertino was selected to serve on the Transactions Operations Committee for the IEEE Computer Society, which publishes and cosponsors a variety of high-quality, peer-reviewed, scholarly journals representing the best in all aspects of computer science, computer engineering, technology, and applications.

## CS Diamond Shines Bright as IBM Master Inventor

Ashish Kundu (PhD 2010) left Purdue and took the business world by storm, demonstrating early success with the award of IBM Master Inventor – a title shared among an elite group of individuals. In 2011, Ashish was presented with the CERIAS Diamond Award.

## CS Students Enlist: Facebook Open Academy

Six CS students traveled to Facebook headquarters in Menlo Park, CA., where they gathered for a weekend of learning and hacking with their instructor, Gustavo Rodriguez-Rivera.

## Xiangyu Zhang Named University Faculty Scholar

Associate Professor of Computer Science Xiangyu Zhang was named University Faculty Scholar by the Office of the Provost. This distinction recognizes faculty members who hold the rank of tenured associate professor, or professors who have been in the rank for no more than five years at the time of the designation.

## CS Students Storm Grace Hopper Conference

CS sent an entourage of 27 to attend the Grace Hopper Conference (GHC) – the world's largest technical conference for women in computing. Amber Johnson (PhD candidate) had the opportunity to meet Megan Smith, the Chief Technology Officer for President Obama, who asked Amber about her studies and interests.

## CS Dept. Offers Free Online Course

For the first time, the CS department is offering Indiana high school students the chance to take a free, online, non-credit course that covers the same material as CS 18000, the department's first course for computer science majors.

## Conte Distinguished Lecture Series Begins

Paul M. Van Dooren presented "Graph Optimization Problems in Data Mining", where he discussed graph-theoretic ideas useful in understanding modern large-scale data mining techniques, along with ideas for optimization that are useful in understanding the numerical behavior of the corresponding algorithms.

## SIGSOFT Distinguished Paper Award

Two faculty members and one graduate student in the department edged out more than 300 other entries to be recognized by the Association for Computing Machinery Special Interest Group on Software Engineering (SIGSOFT) for the Distinguished Paper Award.

## Arxan Technologies Developed by CS Professors Announcement

Arxan, an application security company specializing in software protection, was recently sold to TA Associates, one of the largest private equity firms. Founded by members of the CS department and a local entrepreneur, Eric Davis, in 2001, the company grew out of efforts by Distinguished Professor Mikhail (Mike) Atallah, his graduate student, Hoi Chang, Distinguished Professor John Rice, and Assistant Head Tim Korb.

## Corporate Partners Meetings and Job Fair Bring Employers, Students Together

Nearly 500 students from the CS department attended the annual CS Career Fair held at the newly renovated Mackey Arena. More than forty corporations attended, including Microsoft, Intel, and Twitter, as students anxiously lined up outside of the entrance nearly an hour before the event.

## Cyber Center Appoints New Director

Professor Sonia Fahmy has been appointed Scientific Director of Network Systems in the Cyber Center at Purdue's Discovery Park. Her research interests lie in the design and evaluation of network architectures and protocols and she is currently investigating network simulation/emulation, Internet measurement, network security, and wireless sensor networks. She is a member of the ACM and a senior member of the IEEE.

## BoilerMake It or Break It - CS Students Dominate Event

More than 400 computer programmers from 17 universities gathered for the weekend to create a new, interesting and marketable hack in an event sponsored by the Undergraduate Student Board and the Purdue Hackers.

## State Farm Gift to Benefits K-12 CS Outreach

State Farm presented a $50,000 gift to the department to benefit the K-12 Outreach programs. Two new projects in CS Outreach will be funded, in addition to existing summer camps for middle and high school students.

## Outstanding New Learning Community Award Given to CS Undergrad Advisors

Vicki Gilbert, Tracy Harrington-Atkinson, and Faith Giordano were presented with the Outstanding New Learning Community Award from Student Success at Purdue. The CS advisors were recognized for their excellence in the design and execution of a first-time community, while demonstrating a commitment to the vision and mission of the program.

# CENTER FOR SCIENCE OF INFORMATION

## Developing Fundamental Principles Regarding Information

The Center for Science of Information (CSoI) was established by the National Science Foundation in 2010 with Purdue University as the lead institution. CSoI is comprised of eleven partner universities, each with unique and complementary strengths in research, education, and outreach. The overarching vision of CSoI is to develop fundamental principles regarding information, including its extraction, manipulation, and exchange. Efforts to develop these principles are motivated by questions in various scientific and engineering domains including communications, electrical and computer engineering, physics, biology, and economics.

To realize this ambitious research mission, the Center for Science of Information "the CSoI" has pursued correspondingly ambitious technical goals. These technical goals revolve around the development of rigorous principles guiding all aspects of information, integrating elements of space, time, structure, semantics, and value in diverse dynamic contexts with limited resources and cooperation. As the Center seeks to create a comprehensive, quantitative paradigm for understanding information, it employs a variety of tools from information theory, computer science, statistics, numerical analysis, and motivating application domains. Achieving these goals is essential to critical advances in engineering, life sciences, and social sciences.

Building on considerable progress and synergies established during the last year, the Center's overarching theme is to develop fundamental principles and analytic approaches underlying various aspects of information when progressing from *data to information to knowledge*. The Center focuses on applications and impacts in three key research thrusts: life sciences, communication, and knowledge management.

The research mission of the Center is complimented by an education and outreach plan focused on training the next generation of students in this rapidly emerging discipline, significantly enhancing the diversity of students and researchers, and exposing them to novel concepts at the intersection of the science of information and its applications.

### Regarding our Outreach plans, CSoI

- Secured a large number of funded projects with a total revenue of over $1 million
- Facilitated a large number of personnel exchanges and international partnerships

### Regarding our Diversity plan, CSoI

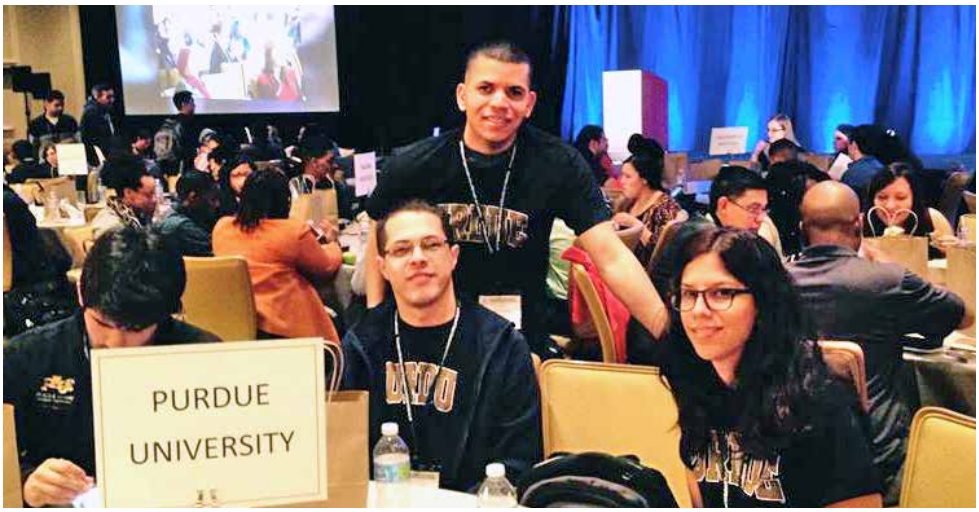
- Rapidly expanded our REU program, which connects students from traditionally underrepresented backgrounds with faculty mentors
- Exceeded national trends regarding diversity in STEM

### Regarding our Educational plan, CSoI

- Planned and hosted several extremely successful events ranging from large symposia to small, project-specific workshops
- Expanded our online presence through the development of a new content sharing and development platform

# SPOTLIGHT ON DIVERSITY

## Tipping the Scales – CS Puts Weight Behind Diversity Efforts




CS students and staff joined more than 800 students and faculty members across the nation to celebrate diversity, while making connections in computing.

The ACM Richard Tapia Celebration of Diversity in Computing Conference, held in Boston, brought the masses together for this year's theme – Diversity at Scale – addressing the larger problems faced by today's society.

CS students shared an information table with The College of Technology, connecting with more than 200 students and faculty from a variety of schools including Harvey Mudd, Georgia Tech, UMBC, Moorehouse, and Spelman College.

The conference aims to inspire students with great presentations and conversations covering many topics, including networking, cloud computing and security. Attendees can interact with representatives from well-recognized companies (during the career fair) and learn about the employment opportunities they offer.

Graduate student Victor Santos said it was his first time attending the conference and that he was pleasantly surprised.

"I met so many interesting people, so different, but at the same time pursuing the same goal, it was inspiring. I especially loved the organization and the networking among students and industry, pretty fun and professionally enriching. I even meet a few students from my home of Puerto Rico," Santos said.

This year's notable speakers included Freeman A. Hrabowski, III, President, UMBC; Dilma Da Silva, Department Head of Computer Science and Engineering, Texas A&M University; and Jacky Wright, Vice President of Microsoft IT Strategic Enterprise Services.

## Be the Change – Best Conference, Ever

**The CS Department sent an entourage of twenty-seven to attend the Grace Hopper Conference (GHC) – the world's largest technical conference for women in computing.**

**Be the Change was this year's theme as conference presenters (all leaders in their respective fields) represented industry, academia and government.**

**During the conference, top researchers present their work, while special sessions are held that focus on the role of women in today's technology fields.**
**Amber Johnson, Ph.D. candidate of computer science, said attending Grace Hopper is like no other experience.**

**"It is the best conference that I've ever attended, and I've even attended a conference at the Disney World theme park. I had the opportunity to meet Megan Smith, U.S. Chief Technology Officer for President Obama and she asked me about my studies and interests. It was definitely memorable."**

**Smith added, "I was especially proud when she lifted my badge, and stated, "Oh, so you go to Purdue!"**

**Renate Mallus-Madot, graduate office coordinator, said that it is important to expose the Department's young women to many different sides of computing and possibilities they may have never thought of.**

**"When they get to the conference, they feel empowered and energized by the large number of women surrounding them, by the attention they are getting from company recruiters, and the proximity to women in very high positions in academia, industry, and government," Mallus-Madot said.**

**Inspired by the legacy of Admiral Grace Murray Hopper, Anita Borg and Telle Whitney founded the conference in 1994. An unsung, female hero of technology, Hopper was one of the first programmers of the Harvard Mark 1, and in 1952 invented the first "compiler" which is software that translates programming language into numbers a computer understands.**

# NEW FACULTY

## Tiark Rompf

Tiark Rompf is interested in all aspects of programming, in particular programming languages, parallelism and compilers, with a focus on making very high-level programming abstractions more efficient. Overall, he aspires to bring theoretical insights into practical use.

Most of his recent work revolves around Lightweight Modular Staging (LMS) and Delite, technologies for integrating runtime code generation into high-level programs and building embedded compilers for domain specific languages (DSLs). LMS was featured as a research highlight in the Communications of the ACM journal and is used by research groups around the world, including the Stanford Pervasive Parallelism Lab.

From 2008 to 2014 he was a member of Martin Odersky's team at EPFL that developed the Scala programming language, and he made various contributions to the Scala language and toolchain (delimited continuations, efficient immutable data structures, compiler speedups, type system work). His work at Oracle Labs (since 2012) aims to turn JIT compilers into precision tools in future JVM generations, and is applying LMS to speed up data processing and query engines.

Recently, Tiark received a Best Paper Award at the Very Large Data Bases conference (VLDB) for his paper, Building Efficient Query Engines in a High-Level Language, a collaborative effort with Yannis Klonatos, Christoph Koch, and Hassan Chafi. The paper demands a radical rethinking of database systems design. It is the latest in a contribution to the arguement that developers can leverage high-level programming languages without having to pay a price in efficiency.

When not working with students, Tiark enjoys practicing martial arts, spending time outdoors, and traveling to far-off places.

## Dan Goldwasser

Dan conducted his postdoctoral research at the University of Maryland in College Park. Dan completed his PhD studies at the University of Illinois at Urbana-Champaign in the Department of Computer Science. His research falls in the intersection of machine learning and natural language processing, and he is broadly interested in connecting natural language with real world scenarios, and using them to guide natural language understanding. One example of this line of research is with interactive settings, where humans can give natural language commands to a computer system.

Another recent example, done in collaboration with researchers from the university of Maryland analyzes forum discussions of online students and identifying relevant points for instructor's intervention.
While earning his PhD at the University of Illinois at Urbana-Champaign, he received the C.L. and Jane Liu Award for Exceptional Research Promise in 2010.
When not in the classroom, Dan enjoys scuba diving, hiking and watching old films.

## Mathias Payer

Mathias Payer defines himself as a security nerd. His interests are related to system security, binary exploitation, software-based fault isolation, binary translation, and (application) virtualization. Before joining the faculty at Purdue, he spent two years as a post doctorate researcher in Dawn Song's BitBlaze group at UC Berkeley, where he worked on scalable symbolic execution and Code-Pointer Integrity, a defense mechanism that protects applications from memory safety vulnerabilities. He graduated from ETH with a Dr. sc. ETH in 2012, where he analyzed different exploit techniques and investigated how binary translation can protect existing software from attacks with TRuE and libdetox as a prototype implementation of the security framework.

Since coming to Purdue, he has engaged students in an activity known as Capture the Flag (CTF). The team (known as b01lers) gains experience in system security, reverse engineering, cryptography, and forensics while learning practical skills in these areas. Students go on to use these skills in competitions, where they measure their hacking skills against other teams from other universities, private companies, and underground teams.

When not inspiring young minds in the classroom, Mathias enjoys attending the arts and exploring the outdoors through running, hiking, biking, or Geocaching.

*In a few short decades, computing has gone from a scientific curiosity to a giant industry employing millions of people and fueling high technology growth throughout the economy.*

*This industry didn't just 'pop' out of the research labs, but was instead the product of steady flow of research advances . . .*

Carl De Boor

# Hacking with the b01lers Capture-The-Flag team!

By Mathias Payer

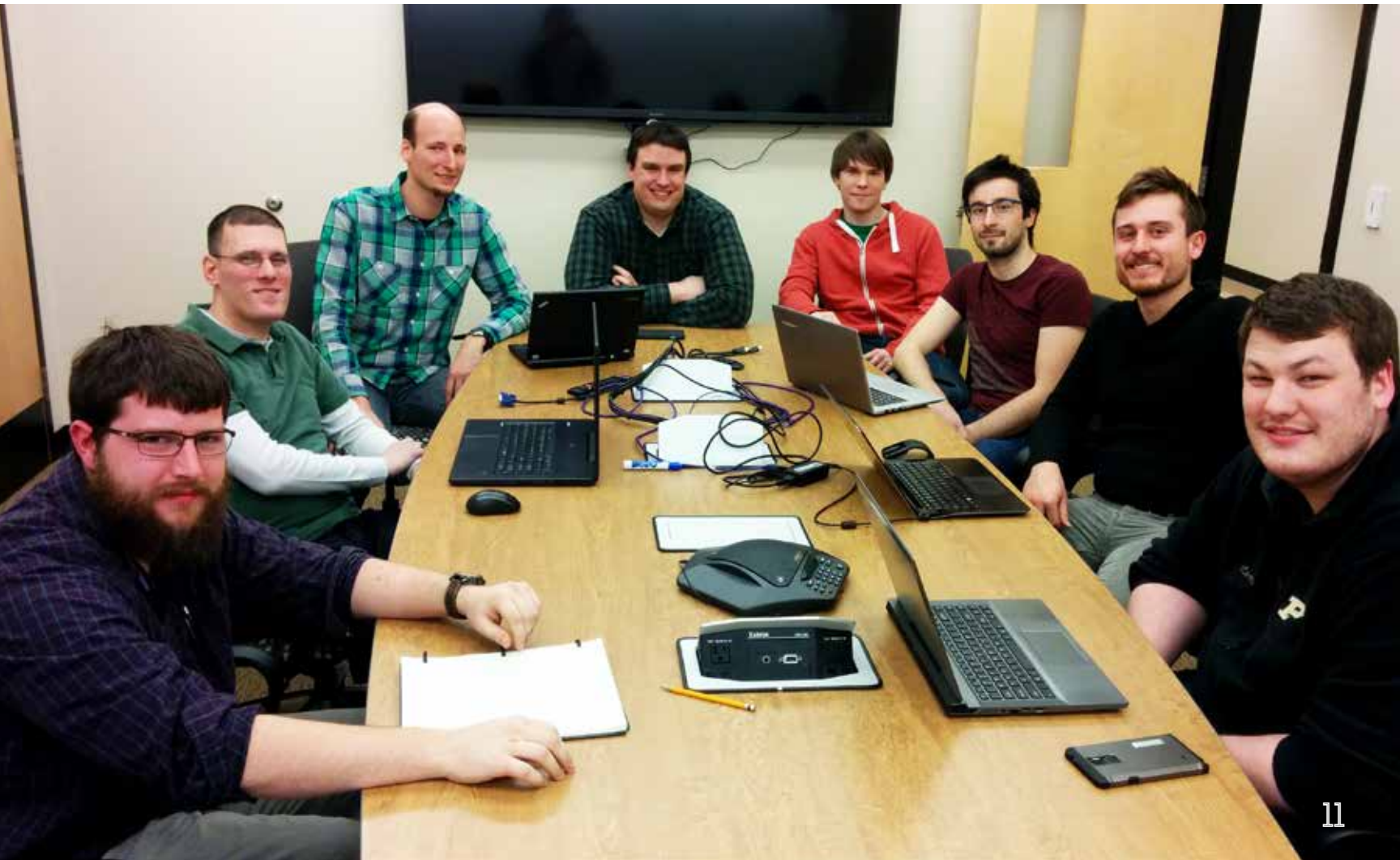
Capture-The-Flag (CTF) competitions are highly energetic hacking events where individual team members collaborate to find security vulnerabilities, recover hidden information, try to get into systems, and defend against attacks. These security hacking competitions are run in an organized, controlled, and bounded environment, and are organized by different parties from around the world.

In a CTF event, teams compete against each other to solve individual challenges, usually by capturing a "flag" from the organizers or other participants. The teams receive points for solved challenges. There are two CTF flavors: offense-defense and challenge-based (Jeopardy style). For offense-defense competitions, each team receives a virtual machine at the beginning of the competition and the team must both defend their own virtual machine against other teams and attack the virtual machines of the other teams. Points are awarded for keeping your own services running (availability) and successfully hacking and exploiting the other teams' services (integrity). For Jeopardy-style competitions, a scoreboard lists open challenges in different categories that can be solved to receive points. Many different categories exist for these challenges: trivia questions, captured network traffic analysis, exploitation of services run by the organizers, Web security, reverse-engineering, forensics, or cryptography.

CTF competitions are a beneficial way for students who are interested in security to test and train their skills in a competitive environment, to learn and practice new techniques, follow up on top security research, and to recognize the connections between different topics. The competitions allow students to take theoretical knowledge and apply it to practical challenges developing real-world skills.

We founded b01lers in Fall 2014 and it became the first official dedicated CTF team at Purdue. At the initial callout, more than 80 students from different departments who were interested in security came to learn about these hacking competitions. After a set of lectures and trainings, about 20 remained in the club. We have weekly hangouts where we learn about new techniques (presented by individual members), solve and discuss old challenges, and prepare for upcoming competitions.

Our world ranking has significantly improved even in our very first semester, and we are continuing to improve. We currently score in the top 25% of the teams at larger competitions and in the top 10% at smaller competitions. Our goal is to become one of the top 10 teams in the world, and compete in the largest, in-person CTF events hosted periodically in different parts of the world – in conjunction with major security conferences – with a tradition of more than 19 years.



# DEPARTMENTAL AREAS

## Computational Science and Engineering

Computational science and engineering, or scientific computing, provided the impetus for many of the early computer science departments in the 1960s. Purdue is one of the few programs nationwide that have consistently maintained a leadership position in this important discipline. The computational science and engineering group includes nine full-time faculty members (one with a joint appointment in Mathematics). The group's research activity focuses on the development of algorithms (numerical as well as combinatorial), parallel and distributed techniques, software infrastructure, and novel computing platforms. These research efforts are driven by state-of-the-art applications in modeling of materials and bio-chemical processes (ranging from atomistic to systems-level models), novel microelectromechanical systems, structural mechanics and control, robotics and advanced manufacturing, image processing and visualization (with applications in life-sciences and health-care), and critical infrastructure protection (e.g., power grids and other civil infrastructure).

The algorithmic research activities concern the development of novel solvers (linear and non-linear system solvers, eigenvalue/singular-value decompositions), techniques for real-time control, numerical methods for modeling many-body systems, combinatorial scientific computing, automatic differentiation, and computational geometry algorithms for reasoning about shapes and mechanisms. Systems development efforts support these applications through the development of advanced compilers, runtime systems, data management and storage, and data analysis on scalable parallel platforms and distributed infrastructure.

Faculty involved in computational science and engineering at Purdue include David Gleich, Ananth Grama, Christoph Hoffmann, Bradley Lucier, Alex Pothen, Elisha Sacks, Ahmed Sameh, Robert Skeel, and research faculty members Assefaw Gebremedhin and Faisal Saied.

## SELECTED PUBLICATIONS

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### Alex Pothen

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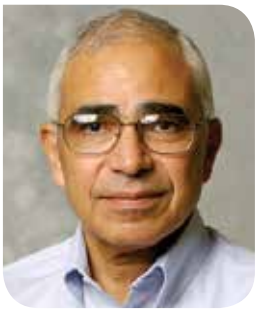
### Ahmed Sameh



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### Bradley Lucier

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### Robert Skeel

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# Bioinformatics and Computational Biology

Faculty in the area of bioinformatics and computational biology apply computational methodologies such as databases, machine learning, discrete, probabilistic, and numerical algorithms, and methods of statistical inference to problems in molecular biology, systems biology, structural biology, and molecular biophysics.

Bioinformatics and Computational Biology research enables researchers to process the massive data, becoming available with novel experimental methodologies in genomics and proteomics. Current work addressing this need includes the design and implementation of biological databases and text/data mining for life sciences - in particular, automatic gene function annotation from the literature. Advances in molecular biology and systems biology involve the extraction of information and patterns from data. Work in this area includes finding context-sensitive modules from multiple cancer networks, identifying protein-DNA binding sites, analyzing flow cytometry data to find cancer stem cells, algorithms and statistical approaches for functional annotation of molecules based on their sequences, identifying protein biomarkers for lung and prostate cancer using clinical data and experiments with model organisms, and studies of biomolecular networks.

Data for these projects are obtained by a variety of experimental technologies, including gene expression microarrays, protein-DNA binding data, flow cytometry data, sequence data, mass spectrometry-based proteomics and metabolomics, and ionomic profiling.

Biology and molecular biophysics require models that incorporate physical properties of biomolecules, as well as data. Work in this direction includes prediction and analysis of the relationship among protein sequence, structure, and function, determining protein structure via NMR, determining transition paths of conformational change of proteins and free energies of protein-ligand binding, and simulating DNA dynamics and self-assembly.

Faculty involved in bioinformatics and computation biology at Purdue include Ananth Grama, Daisuke Kihara, Alex Pothen, Yuan (Alan) Qi, Luo Si, Robert Skeel, Wojciech Szpankowski, and Olga Vitek.

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# Programming Languages and Compilers

The programming languages and compilers group at Purdue engages in research, spanning all aspects of software systems design, analysis, and implementation. Our faculty have active research projects in functional and object-oriented programming languages, both static and dynamic compilation techniques for scalable multicore systems, scripting languages, distributed programming abstractions and implementations, realtime and embedded systems, mobile and untrusted computing environments, and runtime systems with special focus on memory management and parallel computing environments.

Faculty involved in programming languages and compilers at Purdue include Patrick Eugster, Antony Hosking, Suresh Jagannathan, Zhiyuan Li, Jan Vitek, and Xiangyu Zhang.

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### Zhiyuan Li

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# Databases and Data Mining

The database and data mining group at Purdue is composed of Professors Walid G. Aref, Elisa Bertino, Bharat Bhargava, Christopher Clifton, Ahmed Elmagarmid, Susanne Hambrusch, Jennifer Neville, Ninghui Li, Sunil Prabhakar, and Luo Si; Research Associate Professor Mourad Ouzzani; and more than thirty graduate students. The group conducts fundamental and cutting-edge research in database systems, database privacy and security, data mining, web search, information retrieval, and natural language processing. Current projects and topics include:

**Context aware database management systems** **(Aref, Bhargava, Ouzzani)**

**Cyber infrastructure** **(Elmagarmid, Ouzzani)**

**Data and service integration and schema matching** **(Elmagarmid, Ouzzani)**

**Data quality** **(Elmagarmid, Ouzzani)**

**Database security and online auctions** **(Bertino, Bhargava)**

**Location privacy** **(Aref, Bertino, Bhargava)**

**Massively parallel spatiotemporal data management** **(Aref, Ouzzani)**

**Privacy enhancing technologies for data, text, and data mining** **(Clifton, Si)**

**Private and secure data dissemination** **(Aref, Bhargava, Clifton)**

**Scientific data management** **(Aref, Elmagarmid, Ouzzani)**

**Search and Intelligent Tutoring** **(Si)**

**Self-learning disk scheduling** **(Bhargava)**

**Statistical relational models** **(Neville)**

**Stream Data Management** **(Aref, Elmagarmid, Prabhakar)**

**Uncertainty data management** **(Hambrusch, Neville, Prabhakar)**

**Trustworthy data from untrusted servers** **(Prabhakar)**

Members of the database and data mining group engage in high-impact multidisciplinary projects and collaborations that involve multiple disciplines, including Agronomy, Biology, Chemistry, Chemical Engineering, Linguistics, Nursing, Physics, and Social Sciences.

In the past five years, the database and data mining group has graduated more than 20 PhD students, who have started their careers in various universities (e.g., Alexandria University, Arizona State University, University of Calgary, St. Jude Children's Research Hospital, SUNY Albany, Missouri University of Science and Technology, James Madison University, and Worchester Polytechnic Institute) and industry (e.g., Amazon, AT&T, Google, IBM, Microsoft, Teradata). Earlier graduates have distinguished themselves as faculty at top schools including IUPUI, University of Hong Kong, University of Minnesota, Rutgers University, University of South Florida, SUNY Stony Brook, University of Texas at Dallas, and Waterloo University.

Details about the above research conducted and the multidisciplinary projects can be found at www.cs.purdue.edu/icds.

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## Bharat Bhargava

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# Distributed Systems

The distributed systems group focuses on designing distributed systems that are scalable, dependable, and secure, behaving according to their specification in spite of errors, misconfigurations, or being subjected to attacks. Areas of focus include:

***Virtualization technologies.*** One thrust is developing advanced virtualization technologies for computer malware defense and cloud computing. Researchers at the Lab for Research In Emerging Network & Distributed Systems (FRIENDS) have been studying the security, reliability, and performance of virtual machines and virtual infrastructures in cloud computing environments.

***Ongoing research efforts in the computer malware defense area include:*** operating system level information flow tracking for user-level malware investigation; virtual machine (VM) introspection for stealthy malware monitoring and detection; and VM memory shadowing for kernel-rootkit prevention and profiling. In the virtual distributed computing area, the lab has proposed and instantiated the concept of "virtual networked environment" for creating virtual infrastructures on top of a shared physical hosting infrastructure. The concept and its enabling techniques have been applied to support a number of emerging applications such as scientific job execution, virtual organizations, and tele-immersion.

***Intrusion tolerant systems.*** Researchers at the Dependable and Secure Distributed Systems Laboratory (DS2) are designing distributed systems, networks, and applications that can tolerate insiders, while maintaining acceptable levels of performance. Recent research lies in designing intrusion-tolerant systems in the context of (1) replication services, (2) routing for wireless ad hoc networks, and (3) unstructured overlays for peer-to-peer streaming.

***Model checking and simulation testing.*** Another thrust is studying the utility of distributed-system model checking and simulation testing by coupling it with dynamic program slicing and machine learning. Each of these techniques have the ability to summarize and focus the massive amounts of available information so the programmer-designer can focus on the significant parts of the execution, while ignoring the rest. The goal is to develop enabling technologies and prototype frameworks for collaborative high-performance distributed computing and simulation that may be adapted and enhanced to deploy scalable and portable systems.

***Experimental analysis.*** Researchers at the RAID laboratory are conducting scientific research in a variety of subjects related to experimental analysis such as: communication experiments for distributed applications, network communication measurement experiments, experimental analysis of communication infrastructure, adaptability experiments for distributed systems, replication and recovery experiments for distributed database systems, concurrent check-pointing and rollback-recovery algorithms, concurrency control for distributed database systems, efficient implementation techniques for distributed systems, digital library, and mobile communication.

Faculty involved in distributed systems at Purdue include Bharat Bhargava, Patrick Eugster, Ananth Grama, Antony Hosking, Suresh Jagannathan, Charles Killian, Cristina Nita-Rotaru, Kihong Park, Vernon Rego, Dongyan Xu, and David Yau.

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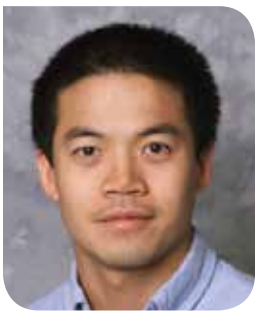
### Vernon Rego

### Dongyan Xu



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# Software Engineering

The software engineering group conducts research on applying advanced program analyses towards problems related to fault isolation, various kinds of bug detection, including those related to race conditions in concurrent programs, and specification inference for large-scale software systems. Aspect-oriented abstractions and new program slicing and mining techniques are some of the mechanisms that are being explored to address these issues.

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### Aditya Mathur

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# Graphics and Visualization

The graphics group performs research in graphics, visualization, computational geometry, and related applications. This report describes major projects on which the group focused.

***Model acquisition.*** The graphics and visualization group developed self-calibrating methods for acquiring high-quality geometric models (accuracy as high as 0.05mm) of objects and of room-size scenes. They combined photometric measurements with geometric measurements and used algebra to eliminate many calibration parameters. This approach led to better algorithms for capturing dynamic scenes, for acquiring models of highly specular and inter-reflective scenes, and for changing the appearance of objects. In collaboration with civil engineers, the graphics and visualization team produced a high-fidelity simulation of the 9/11 attack on the World Trade Center. The interest in such a simulation transcends civil engineering and includes emergency response, defense, and society in general. The simulation follows the laws of physics as closely as possible. The results are presented through a visualization that is eloquent to users outside of civil engineering. The visualization has been downloaded over five million times.

***Image generalization.*** Images are used in computer graphics and visualization to convey information in cases like 3-D scene exploration, remote visualization, acceleration of high-cost rendering effects, and video surveillance. Images are computed by sampling data with rays defined by a camera model, mostly by using the planar pinhole camera model, which suffers from important limitations. The camera model design paradigm is an infrastructure-level innovation with broad applicability used to overcome these limitations and advocates designing the set of rays that best suit a given application and optimizing it dynamically according to the data sampled. Camera model design is a flexible framework for generating images with multiple viewpoints and with a variable sampling rate. Like conventional images, the generated images are continuous, non-redundant, and can be computed efficiently with the help of graphics hardware.

***Scientific Visualization.*** Computer simulations and high-throughput measuring devices produce an overwhelming volume of data across science, engineering, and medicine. Current research spans a range of topics in visualization and geometric data processing to devise new models and efficient algorithms for the effective visual mapping and analysis of information. We have created new spatial data structures that dramatically increase the performance of a broad class of rendering and visualization methods. We have addressed the computational bottlenecks of advanced saliency models in fluid dynamics applications. We have investigated new representations and study the structural properties of large-scale particle assemblies in granular material simulations. We have applied topological concepts and advanced numerical algorithms to the efficient analysis and visualization of Hamiltonian systems in problems related to magnetic confinement and space mission planning. Finally, we have proposed a new hybrid CPU/GPU method for the extraction of ridge surfaces from three-dimensional datasets in scale space.

***Urban modeling.*** Faculty in the area of graphics and visualization are working on the modeling and simulation of large urban environments. The goal is to obtain digital models of large-scale urban structures in order to simulate physical phenomena (e.g., changes in weather, vegetation, etc.) and human activities (e.g., population and employment changes). Purdue researchers have developed algorithms that use ground-level imagery, aerial imagery, procedural modeling, and street and parcel data to create and modify 3D geometry and 2D layouts making models more easily modifiable.

***Robust computational geometry.*** Computational geometry algorithms are formulated in a model where arithmetic operations have infinite accuracy and unit cost. We developed robust versions of five core algorithms and validated them on examples that far exceed the capabilities of prior work.

***Geometric computations and constraints.*** Complementing computational geometry, computations on nonlinear geometric structures are developed and analyzed. Applications include discrete manufacturing / CAD. New techniques for solving geometric constraint problems and including into the vocabulary curves and surfaces from CAGD are of particular interest. Data formats for succinct archival of geometric data in manufacturing and sensory image acquisition, as well as new approaches to interoperability are also under consideration.

Faculty involved in graphics and visualization at Purdue include Daniel Aliaga, Christoph Hoffmann, Voicu Popescu, Elisha Sacks, and Xavier Tricoche.

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### Daniel Aliaga

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# Information Security and Assurance

Faculty involved with information security and assurance are often affiliated with the university-wide Center for Education and Research in Information Assurance and Security (CERIAS). CERIAS is generally considered to be the top-ranked such group in the world, with faculty from 18 departments at Purdue. Their research covers all aspects of computer and network security, privacy, and cyber crime investigation. Areas of special focus by CS faculty include:

***Identification, authentication, and privacy.*** There is a tension between increased confidence and granularity of authorization provided by better identification of on-line entities, with the need to protect the privacy rights of individuals and organizations. This area includes research in role-based access control, privacy-protecting transformations of data, privacy-protecting data mining methods, privacy regulation (e.g., HIPAA), oblivious multiparty computation, and digital identity management systems.

***Incident detection, response, and investigation.*** Systems are attacked and sometimes attacks succeed. This area of expertise includes intrusion and misuse detection, integrity management issues, audit and logging analysis, sensor and alarm design, strike-back mechanisms, dynamic reconfiguration, honeypots and jails, cyberforensics, and intrusion-tolerance.

***Cryptology and rights management.*** Controlling information from being read or altered by others, preserving marks of ownership and origin, and breaking the code of adversaries are all of interest in information security. Research interests include encryption, number theoretic foundations, cryptanalysis, and watermarking.

***Data security.*** Data is often the most important asset that organizations have and it is the target of almost all attacks. Relevant research includes: secure architectures for databases, security of streaming data, high-assurance integrity systems for databases, anomaly detection, and response system mechanisms for databases.

***System security.*** Advanced virtualization-based techniques are developed for the detection, prevention and profiling of both user-level and kernel-level computer malware. Research includes the use of these techniques for protection from botnets. New reverse engineering techniques are being developed for the analysis of binary programs and raw memory images. These techniques are being applied to computer forensics and software vulnerability discovery.

***Trusted social and human interactions.*** How does IT change our interactions, and how can more trustworthy IT change them further? This includes studies of online trust, e-commerce (business-to-business and business-to-consumer), digital government services, e-conferencing, online personae and anonymity, online news, online research and the ephemeral nature of information, online propaganda, and spam.

Faculty involved in information security and assurance at Purdue include Mikhail Atallah, Elisa Bertino, Bharat Bhargava, Christopher Clifton, Sonia Fahmy, Ninghui Li, Cristina Nita-Rotaru, Kihong Park, Sunil Prabhakar, Vernon Rego, Eugene H. Spafford, Jan Vitek, Samuel Wagstaff , Dongyan Xu, and David Yau.

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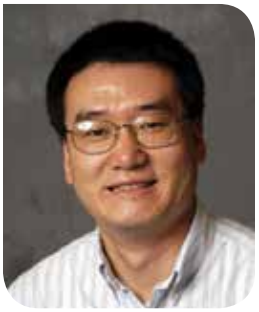

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# Networking and Operating Systems

Faculty in the area of networking and operating systems are tackling fundamental problems at different layers of the network protocol stack, from the medium access control layer all the way up to the application layer. The group uses theoretical models, simulation, emulation, and extensive testbed experimentation to develop and evaluate their proposed solutions. The group has leveraged techniques from game theory, information theory, complexity theory, optimization, and cryptography in their solutions. The group has implemented their methods on a variety of platforms, ranging from large clusters, to network processors and resource-constrained wireless sensor motes.

Projects that the faculty have recently undertaken include fault localization in enterprise networks; packet classification and scheduling in Internet routers; scalable Internet measurement; Internet routing policy analysis; secure and scalable media streaming over the Internet; secure network coding in wireless mesh networks; design of defenses against malware and denial of service attacks; scalable network simulation and emulation; and coverage, localization and data fusion in energy-constrained wireless sensor networks.

A project led by Professor Douglas Comer, which is part of the multi-institution Nebula grant sponsored by NSF and Cisco Systems, investigates future Internet architectures. Specifically, researchers led by Comer are exploring parallelism as a way to increase the communication throughput between cloud data centers and the core of the Internet. The group is also exploring Border Gateway Protocol defense systems, the use of GENI/OpenFlow technology, and distributed coordination and leadership algorithms for use inside a large core router, such as a Cisco CRS-1.

Another project, led by Professor Sonia Fahmy, considers scalable network security experiments. A primary reason for lack of deployment of network security mechanisms is that most mechanisms have not been validated under realistic conditions, or at sufficiently large scales. The project includes two complementary efforts to address both the fidelity and scale challenges in security experiments by designing: (1) high-fidelity yet scalable models for routers and other devices based on simple device measurements under a few well-crafted scenarios, and (2) techniques to simplify and map experimental scenarios before using simulation, emulation, or testbed experiments.

Professor Ramana Kompella conducts research on protocol design for data center networks. A recent project in this direction focused on fine-grained multi-path routing protocols for better network utilization in data center networks. In another project, he focused on improving TCP performance in virtualized environments, especially those where multiple virtual machines share one processor. As cloud computing gains more popularity, such networking issues become increasingly more important. He has also conducted research on scalable measurement solutions for low latency networks such as financial trading centers, data centers, storage and cluster networks. Specifically, it involved designing streaming algorithms for high-fidelity latency measurements within routers.

Faculty involved in networking and operating systems at Purdue include Douglas Comer, Sonia Fahmy, Charles Killian, Ramana Kompella, Cristina Nita-Rotaru, Kihong Park, Dongyan Xu, and David Yau.

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# Machine Learning and Information Retrieval

With massive data available from various engineering, scientific, and social disciplines, machine learning and information retrieval have played an imperative role in discovering hidden patterns or relationships between intertwined components (e.g., people, web pages, or genes, in a complex system), understanding properties of various systems, and making meaningful predictions for a variety of applications.

In the past few years, Purdue has grown a strong machine learning and information retrieval group with strengths in multiple areas of this field. In particular, Professor Jennifer Neville works on multiple problems in relational modeling, such as fusion and analysis of multi-source relational data, and modeling relational communication on distributed team effectiveness. Her team also integrates machine learning methods with agent-based models to form a compositional model, which will combine components that are learned from data with components that are hand-engineered using traditional methods. This combination will produce powerful tools for understanding the emergent behavior of complex social and organizational systems. Professor Luo Si develops federated text search, which is the search beyond traditional engines such as Google, Yahoo! or MSN by finding information that is "hidden'' behind many search engines. His team also uses cutting-edge computer science techniques to construct an exploratory, but fully functioning differentiated instructional system of mathematical word problem solving. Professor Christopher Clifton addresses problems in privacy-preserving data mining by developing technology that shares some information to calculate correct results, where the shared information can be shown not to disclose private data. Professor S.V.N. Vishwanathan works on kernel methods and interactions between machine learning and optimization. Professor Yuan (Alan) Qi's research interests span several areas in machine learning and computational biology. His team develops new methods to detect context sensitive modules for complex biological and social networks, combines statistical learning with ab-inito methods for computational materials design, and designs Bayesian matrix factorization methods for collaborative filtering (with applications to online recommendation systems) and text clustering.

Faculty in this area have obtained significant funding support for their research activities. They also have received external recognition such as the IEEE "AI's 10 to watch" for Professor Neville, an NSF career award for Professor Si, and a Microsoft Breakthrough research award (one out of ten nationally) for Professor Qi's response system mechanisms for databases.

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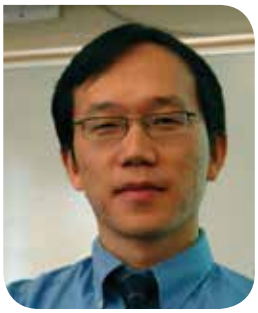


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# Theory of Computing and Algorithms

Research interests of the members of the theory of computing and algorithms group range over many areas of algorithms. These areas include analysis of algorithms, parallel computation, computational algebra and geometry, computational complexity theory, digital watermarking, data structures, graph algorithms, network algorithms, distributed computation, computational biology, information theory, analytic combinatorics, random structures, external memory algorithms, approximation algorithms, data mining, bioinformatics, and text indexing. Much of the research reflects interaction with other areas of the field, such as information security, databases, and geographic information systems.

The ongoing research at Purdue includes theoretical advances, theoretical improvements on applied problems, and algorithms with immediate potential for application. The group has made notable contributions on topics such as updating minimum spanning trees, shortest paths in planar graphs, computing approximate minimum spanning trees distributively, low-diameter P2P networks, parallel computational geometry, cascading divide and conquer, query indexing and velocity constrained indexing, external memory graph algorithms, compressed suffix arrays, and the analysis of Lempel-Ziv codes.

Faculty involved in theory of computing and algorithms at Purdue include Mikhail Atallah, Saugata Basu, Greg Frederickson, Susanne Hambrusch, and Wojciech Szpankowski.

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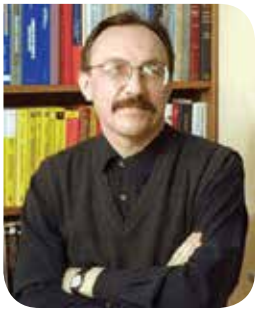

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# SPOTLIGHT ON RESEARCH

## Automatic Discovery of Protocol Manipulation Attacks in Large Scale Distributed Systems Implementations

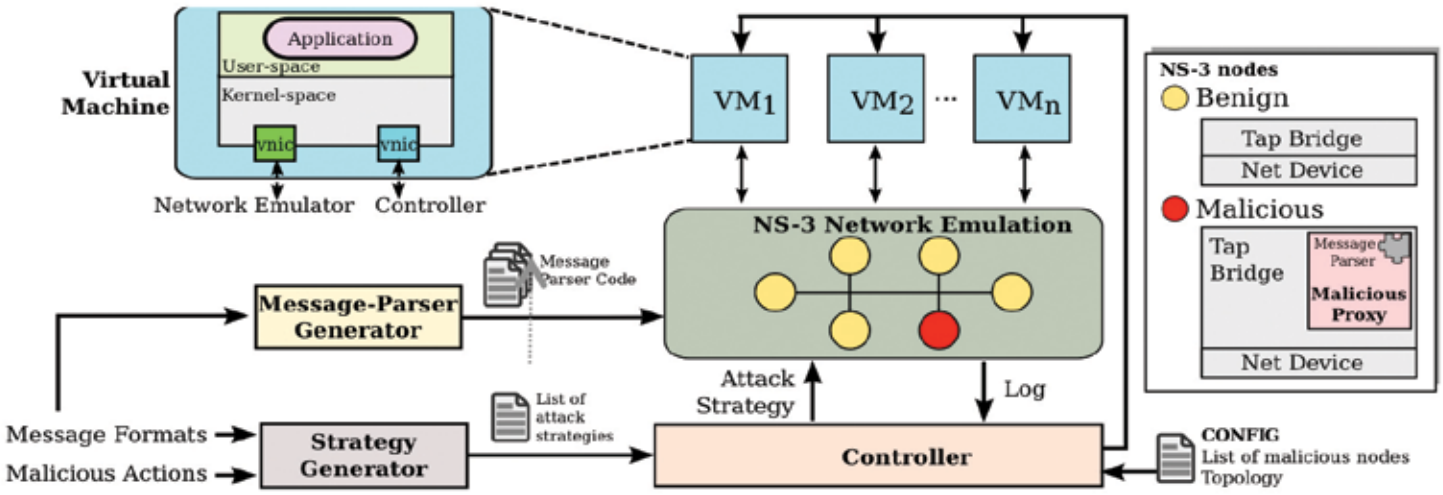
Cristina Nita-Rotaru and Charles Killian

Most distributed systems are designed to meet application-prescribed metrics that ensure availability and high-performance. However, attacks can significantly degrade performance, limiting the practical utility of these systems in adversarial environments. Specifically, compromised participants can manipulate protocol semantics through attacks that target the messages exchanged with honest participants.

Finding attacks against performance in distributed systems implementations is a very challenging task due to (1) state-space explosion that occurs as attackers are more realistically modeled, (2) diversity of programming language, software, operating systems and the subtle interactions between the software components, (3) diversity of communication channels (wired or wireless communication, TCP or UDP, encrypted or not-encrypted), (4) difficulty of expressing performance as an invariant in the system, (5) difficulty of capturing real-world performance in a reproducible way, not only the system performance but the network conditions when that performance was obtained.

This project aims to build an easy-to-use and maintain, low cost platform to find reproducible, real, high-impact, malicious performance attacks on distributed systems implementations in realistic environments.

One of the main results of the project is Turret, a platform for performance attack discovery on unmodified distributed system binaries in user-specified operating system images subject to controlled, realistic network conditions. Turret leverages virtualization to run arbitrary operating systems and applications, and the NS-3 network emulation mode to connect these virtualized hosts in a realistic network. Turret requires only a description of the external API of the service, the message protocol, and the ability to observe the application-performance of the system, which is generally linked to the workload of the system and easily discerned. Our platform can make a snapshot and restore the state of the entire distributed system, the state of all virtual machines and the network emulator including packets that are in the network. Turret supports a large class of services such as intrusion-tolerant replication, application-layer multicast, file sharing, locality services, and routing protocols, running in both wired and wireless networks. We applied Turret to five distributed systems and seven wireless routing protocols and found a total of 70 attacks and bugs.



# New Analysis Methods for Big Simulation Dataset Improve Confidence in Simulated Physics

By David Gleich

[Purdue CS Professor David Gleich and his colleagues at Sandia National Laboratories and the Colorado School of Mines helped develop and implement new algorithms to quantify the reliability of a scientific simulation.]

Simulation is now an established mechanism in the scientific process. Where scientists and engineers previously performed complex laboratory experiments and built physical models to test predictions, they now first turn to sophisticated software packages that encode the physical laws governing our world into a set of mathematical equations. When these equations are solved through computer algorithms, the result is a principled and realistic approximation of what would have happened in a real-world experiment.

The problem is: how much do we trust the results of the simulation? Answering this question is critical when using simulations to study situations that would be incredibly expensive or even impossible to perform in the real world.

Although simple to state, the resulting problem is incredibly difficult to answer and it has spawned an entire sub-discipline of computational science called "uncertainty quantification" that involves scientific computing, mathematics, statistics, and machine learning. The essence of the problem is that the real-world is subtly different from the computer simulation. For instance, a simple setup on the computer would assume that a piece of steel is essentially the same everywhere. But real-world instances display small variations in that structure due to minute manufacturing changes. For many problems, these changes are well approximated by their average; but most of the critical problems deal with simulating extreme situations where these small variations could have an impact. Simulation software is already flexible enough to handle this type of variation, but computing measures of confidence on the simulation outputs requires what amounts to a parametric study of many possible realizations of these minor differences. Performing a rigorous parametric study for these confidence bounds is so computationally demanding for real-world problems that it is essentially impossible. In a simplified case, this is akin to running the simulation for all possible variations in the steel, which could cost millions of dollars.

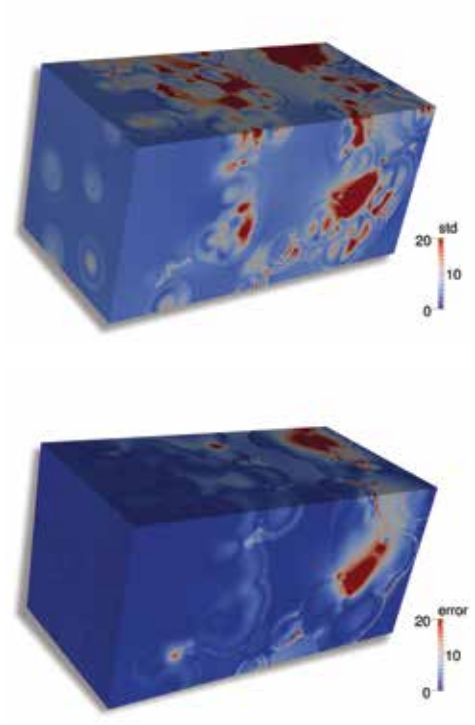
My collaborators and I took a data-driven approach that attempts to sidestep the problem. By studying large datasets from a single simulation, as these parameters vary, we realized that the variation in the behavior of a simulation could be decomposed into two pieces: one that shows predictable variation and one that is essentially unpredictable. This insight allowed us to design a new type of algorithm to produce a metric that works like the impossible-to-compute confidence bounds by only studying the predictable pieces. The unpredictable pieces become an introspective metric that suggests when the data-driven approximation is itself unreliable.

When the project started, Paul Constantine (my collaborator) and myself only had the initial workings of the idea and a rudimentary prototype. We wanted to demonstrate the idea in a realistic simulation. This led to collaboration with Jeremy Templeton at Sandia National Laboratories. Templeton designed a realistic-but-simplified model to represent the challenges that his group at Sandia regularly faces when using simulations. Meanwhile, PhD student Yangyang Hou and myself were busy translating the prototype method into a scalable piece of software that could handle the volume of data that Templeton would produce.

Once that was done, the final research effort to test this idea involved it's own complex logistics. The data had to be moved from Sandia, where it was generated by over 250,000 hours of time on a supercomputer, to a computer at Stanford University's Institute for Computational and Mathematical Engineering with enough storage space to process the data. We deemed this was the best place to put the data, due to the high bandwidth connection between Stanford and Sandia. It still took between two and three weeks to complete this step between data transfer errors and sporadic outages on the supercomputer. With almost 5 terabytes of data in place the software produced the decomposition into predictable and unpredictable pieces by creating a matrix that had 5-billion rows and computing its singular-value decomposition. The images shown along side this article show the results of their prediction for a simulation along with the introspective metric, normalized to be a "standard deviation". The introspective metric highlights the places the data-driven approximation could be slightly wrong. It worked for Templeton's application; the standard deviations identified locations where the error was large.

Overall, our team's data-driven approach enabled us to accurately estimate a simulation's result almost 1000 times faster. Moreover, this technique enables study on just a piece of the simulation output independently from the rest. These results can be computed millions of times faster than running the simulation, enabling a wide variety of methods for assessing confidence.

More information about this research is available in an article recently published in the SIAM Journal on Scientific Computing (SISC).



# Cities of Tomorrow

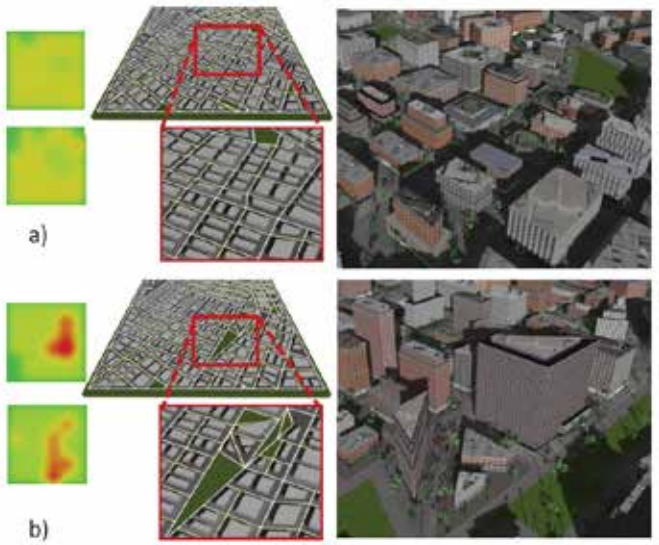
Daniel Aliaga

We are now in the first century of the anthropocene, the era of world domination by humans where consumption of water, production of food, and protection of biodiversity is exceeding planetary boundaries. An emblem of this era is the city. In fact, it is predicted that more than sixty percent of the world's population is going to live in urban areas by 2030. Our vision is to support the easy creation of "what-if" visual computing tools so that urban stake holders (e.g., researchers, policymakers, urban planners, city governments, environmental educators, concerned citizens) can investigate, analyze, and better understand - as well as mitigate - unwanted effects resulting from the complex interdependencies between the urban geometry (e.g., roads, parcels, buildings), urban behavior (e.g., urban development affected by social and economic factors), urban transportation (e.g., human mobility patterns, routes followed, tradeoffs performed), and urban environment (e.g., weather, air quality, human comfort). We will produce for the first time ever a cyclical, interactive, and fully coupled workflow system showing how individuals can affect and guide the urban design process of a region!

Our research group has been creating interactive 3D design tools and simulations of complex city systems with a focus on discovering minimal cost alterations to existing cities as well as new city designs that yield a desired set of indicator values measuring, for example, livability, sustainability, traffic flow, fuel/energy consumption, air quality, and urban meteorological forecasts. Our project produces frameworks and results at multiple scales including 3D urban geometry and urban behavior at the individualized level and regional transportation, weather, traffic, and air quality effects. A critically important and novel aspect is that our research enables predicting geometrical, social, and behavioral changes at the individual level again, yielding the aforementioned first ever cyclical and quantitative simulation of how individuals can affect and guide urban design.

The work has been done in collaboration with several departments on campus and across multiple universities and has produced many publications, grants, and international research visits. The Research has been funded by NSF, Metropolitan Transportation Commission, and Google.

**Traffic Animations for Urban Modeling:** Our approach enables a designer to specify a vehicular traffic behavior and the system will compute what realistic 3D urban model yields that behavior.




**Traffic Animations for Urban Modeling:** People/Jobs Changes. Such changes can impact network topology. a) Input city. b) City with changed roads and buildings satisfying new traffic.

# K-12 OUTREACH


## Programming the Success of Our Future

By Phil Sands, Outreach Coordinator

The Computer Science Department's K-12 Outreach program is committed to improving access to high quality computer science education for Indiana students, educators and communities. Outreach focuses on assisting teachers and students in a variety of ways. For teachers, the aim is to help support classroom instruction and the development of healthy and sustainable computer science programs. This can be done through professional development opportunities and work with the Indiana Hoosier Heartland chapter of the CSTA. For students, the focus is on engagement opportunities. The Outreach program works with students both on-site and on Purdue's campus in order to increase the effectiveness and reach of their efforts.

One of the key areas of focus for the Outreach program is to encourage underrepresented minority groups within the field of computer science. For too long, computer science has been overwhelmingly homogeneous with regards to its participants. In order to affect change in this area, K-12 Outreach developed the Mentors for Aspiring Girls in Computing (MAGIC) high school program to mentor young women in computer science. This program engages young women in several activities designed to develop interest in computing and build confidence in their abilities. Purdue student mentors will visit participating schools in order to help guide the young women on their way towards greater participation in computer science.

For nearly 20 years, Purdue CS has offered summer camp for middle school students. This program provides an introductory computer science experience for students at a time when it may make a significant impact on their future interests. The students learn to program, develop web applications, work with robotics, and create phone and tablet apps. Following on the heels of the first computer security camp for high school students, Outreach will offer a "Big Data"-themed summer camp to help students understand the scope and impact of data-driven computing.

Purdue's Reach Out for Computer Science (ROCS) student group continues to provide assistance to K-12 Outreach activities through their volunteer efforts. In addition to their regular focus on service, they are also committed to contributing to K-12 classrooms with a renewed focus on educational design. This year, ROCS participated in events with Learning for Life, Girls Scouts of America, Operation Military Kids, and several elementary and middle school students throughout the state.

# EDUCATION

## December 2013

**Pelin Angin**
*Autonomous Agents-Based Mobile-Cloud Computing*
Advisor: Bharat Bhargava
Employer: Purdue University

**Sahan Bamunavita Gamage**
*Improving Virtual Machine I/O Performance in Cloud Environments via I/O Functionality Offloading*
Advisor: Dongyan Xu
Employer: VMware

**Kevin Hoffman**
*Ribbons: A Partially Shared Memory Programming Model*
Advisor: Patrick T. Eugster
Employer: eFolder

**Scott D. Miller**
*Control-Theoretic Decision Support for Mitigation of Modeled Software Project Cost Overruns*
Advisor: Aditya P. Mathur
Employer: Microsemi Corp.

**Karthik Nagaraj**
*Enabling Richer Insight into Runtime Executions of Systems*
Advisor: Charles Killian
Employer: Google

**Pawan Prakash**
*Impact of Network Protocols on Data Center Applications*
Advisor: Ramana Kompella
Employer: Acelio

**Dannie Stanley**
*Improved Kernel Security through Code Verification, Diversification, and Minimization*
Advisor: Eugene H. Spafford
Employer: Miami University

**Nick Sumner**
*Automated Debugging through Comparing Executions*
Advisor: Xiangyu Zhang
Employer: Simon Fraser University

**Man Wang**
*Dependence-Based Source Level Tracing and Replay for Networked Embedded Systems*
Advisor: Zhiyuan Li
Employer: Synoptics

## May 2014

**MD Ariful Azad**
*An Algorithmics Pipeline for Analyzing Multi-parametric Flow Cytometry Data*
Advisor: Alex Pothen
Employer: Lawrence Berkley Lab

**Anmer Daskin**
*Quantum Circuit Design Methods and Application*
Advisor: Ananth Y. Grama

**Dung Hong**
*A Learning Approach for Relevance and Diversity in Federated Search*
Advisor: Luo Si
Employer: TellApart

**Chamikara Jayalath**
*Geo-Distributed Big Data Processing*
Advisor: Patrick T. Eugster
Employer: Google

**Rahul Potharaju**
*Data-Driven Approaches to Improve Dependability of Cloud Services*
Advisor: Cristina Nita-Rotaru
Employer: Microsoft

**Sunghwan Yoo**
*A Unified Framework for Transparent Concurrency and Fault-Tolerance in Distributed Systems*
Advisor: Dongyan Xu
Employer: Google

## August 2014

**Juan Esquivel Rodriguez**
*Computational Modeling of Macomolecular Structures*
Advisor: Daisuke Kihara
Employer: Google

**Ruchith Fernando**
*Privacy in Social Messaging and Identity Management*
Advisor: Bharat Bhargava
Employer: Amazon

**Christopher (Chris) Gates**
*Leveraging Machine Learning to Detect Abnormal Behavior and Communication Risk*
Advisor: Ninghui Li
Employer: Symantec

**Jaewoo Lee**
*Achieving Practical Differential Privacy*
Advisor: Christopher W. Clifton
Employer: Pennsylvania State University

**Kyu Hyuang Lee**
Advisors: Xiangyu Zhang & Dongyan Xu
Employer: University of Georgia

**Sebastian Moreno Araya**
*Network Hypothesis Testing for Relational Data*
Advisor: Jennifer L. Neville
Employer: Purdue University

**Andy Newell**
*Resilient Network Design with Network Coding and Diversity*
Advisor: Cristina Nita-Rotaru

**Gregor Richards**
*Gradual Typing of Real-World Languages: Enabling Assurance while Retaining Dynamism*
Advisor: Jan Vitek
Employer: University of Waterloo

**Shumiao Wang**
*Secure and Private Outsourcing to Untrusted Cloud Servers*
Advisor: Mikhail J. Atallah
Employer: Google

**Yunhui Zheng**
*Path Sensitive Static Program Analysis for Web Applications*
Advisor: Xiangyu Zhang
Employer: IBM

**Bowen Zhou**
*Techniques for Detecting Scalability Bugs*
Advisor: Xiangyu Zhang

## December 2014

**Tao Bao**
*Reliable Data Processing Enabled by Program Analysis*
Advisor: Xiangyu Zhang
Employer: Google

**Advait Dixit**
*Techniques for Improving the Scalability of Data Center Networks*
Advisor: Ramana Kompella

**Aditi Gupta**
*Secure Platforms for Enforcing Contextual Access Control*
Advisor: Elisa Bertino
Employer: Oracle

**Rohit Jain**
*Trustworthy Data from Untrusted Databases*
Advisor: Sunil K. Prabhakar
Employer: Google

**KC Sivaramakrishnan**
*Functional Programming Abstractions for Weakly Consistent Systems*
Advisor: Suresh Jagannathan
Employer: Cambridge University

**Hyojeong Lee**
*Automated Performance Attack Discovery in Distributed System Implementations*
Advisors: Charles Killian and Cristina Nita-Rotaru
Employer: Google

**Bin Shen**
*Relation Among Images: Modeling, Optimization, and Applications*
Advisor: Mikhail J. Atallah
Employer: Google

**Yingchong Situ**
*Scaling Finite Difference Methods in Large Eddy Simulation of Jet Engine Noise to the Petascale: Numerical Methods and Their Efficient and Automated Implementation*
Advisors: Zhiyuan Li and Ahmed H. Sameh
Employer: Google

**John Ross Wallrabenstein**
*Rational Multiparty Computation*
Advisor: Christopher W. Clifton
Employer: Sypris Electronics

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Ahmed Aly
Benjamin Goosman

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S M Iftekharul Alam
Balamurugan Anandan
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Ariful Azad
Mehdi Azarmi
Sahan Bamunavita Gamage
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# ENGAGEMENT

## Distinguished Alumni

### ANNE SCHOWE (B.S. '72)

The department presented Anne Schowe with CS's highest award, naming her Distinguished Alumna of 2014, during a reception held at Lawson.

Originally from Fort Wayne, Anne's thirty-year career in the computer industry led her around the nation, as she and her husband Tom (a graduate from the College of Technology '71) put down roots in Illinois, Minnesota, Tennessee, and New Jersey where their daughter Christina was born (also a proud Boilermaker and 2006 graduate from the College of Liberal Arts) before settling in her current home of California.

A life-long learner, Anne earned her bachelor's degree in computer science from Purdue, her master's in computer science from Northwestern University, an MBA from the University of St. Thomas in St. Paul, Minnesota, and conducted her post-retirement coursework at Purdue – studying human biology, neurobiology, genetics, and biochemistry.

In addition to her academic career, Anne achieved an impressive career history, in the course of nearly thirty years. Beginning at AT&T Bell Laboratories in 1972, she was a member of the technical staff who worked on an early Computer Aided Design and Diagnosis system for digital switching systems.

From Bell Labs, Anne moved to Control Data Corporation where she was Advanced Systems Program Manager in the Energy Management Systems Division that developed turnkey monitoring and control systems for power utility companies. Control Data honored Anne with its Sustained Management Excellence Award in 1979.

In 1982, Anne returned to AT&T and it's subsidiary, Lucent Technologies, where she held several positions in marketing, strategy and general management in the semiconductor business. As managing director of the Visual Solutions Business Unit, she led an organization responsible for developing chipsets for digital video conferencing, digital TV, and HDTV.

Anne moved to Sun Microsystems as vice president and general manager for Interactive Systems in 1994, where her business unit developed an early streaming video server. She held several executive positions in Sun's systems business, before her retirement in 2000. In 1999, she was honored with a YWCA Tribute to Women in Industry Award.

Anne is a former chairperson of the advisory board of the Johns Hopkins Center for Talented Youth. She also served on the Purdue Parent's Council, and the advisory boards of the Purdue College of Science and the North Carolina State University School of Computer Science. She is currently a member of the advisory board for Purdue University's Global Policy Research Institute and board chair of the Planned Parenthood Action Fund of Santa Barbara, Ventura, and Luis Obispo counties in California.

# 2014
## Outstanding Alumni

## Good Things Come in Threes: CS Recognizes Outstanding Alumni

Good things come in threes, and this past fall the department held a ceremony in Lawson to recognize the Outstanding Alumni of 2014. A reception hosted by the College of Science was held later in the day, honoring the 14 recipients from the seven areas of the college.

Faculty, staff, and students were on hand to celebrate this year's recipients: Kathleen Mapes Campbell (M.S. '75), Michael Petersen (B.S. '72, M.S. '74) and Eric Simone (B.S. '88) in an awards presentation and reception, where the three were honored for their respective achievements in business and community.

### MICHAEL PETERSEN (B.S. '72, M.S. '74)

Michael Petersen earned his bachelor's degree in both mathematics and computer science in 1972 with a minor in physics. Two years later, Michael also earned his master's degree from Purdue, and then went on to receive his MBA from Marist College. Michael enjoyed a career as an IBM computer scientist for 33 years. During his IBM career, Michael worked with computer engineering design software, a software library system, and advanced technology in data transmission, messaging, and text processing in a computer network. Michael was the first to send and retrieve load modules throughout the IBM computer network. In the middle of his career at IBM, Michael served as a software developer and project manager for a new automated materials handling facility. This involved an IBM World Trade assignment in Italy. Michael's project management work included a facility system test and two major system migrations. Michael also participated in the IBM Faculty Loan Program on the West Lafayette campus for the Colleges of Science and Engineering. He helped establish the College of Science's Minority Summer Science Program (MSSP) and for the next 15 years, returned to campus as a volunteer. Near the end of his IBM career, Michael worked as a software developer and technical consultant for software development and web site analysis products. His technical consultant assignments involved 79 clients in North America, Europe, and Asia. Michael is an advocate for adult literacy and volunteers with the Literacy Council of Wake County and Wake Technical Community College.

### KATHLEEN MAPES CAMPBELL (M.S. '75)

Kathleen (Mapes) Campbell graduated with a bachelor's degree in Business Education from Indiana State University and later earned her masters in Computer Science from Purdue in 1975. Kathleen then joined TRW, now part of Northrop Grumman. During Kathleen's 24-year career at TRW she held many management positions. Her early responsibilities included design of simulators to support training exercises for both the Army and Air Force. Later she managed several large software development efforts including the design and development of onboard payload software for the MILSTAR communication satellite constellation that provides secure communications capability for all branches of the military. Kathleen also served for several years as manager of a department of 50+ engineers and software developers. For 10 years Kathleen led a TRW team of Purdue alumni returning to Purdue for one week each semester to recruit graduating students. Since her retirement from TRW in 1999, Kathleen has been active in various nonprofit community activities. She resides with her husband in Manhattan Beach, California.

### ERIC SIMONE (B.S. '88)

In 1988, Eric earned his bachelor's degree from Purdue in computer science and has enjoyed great success as a businessman and entrepreneur. Eric is the founder and CEO of ClearBlade, an enterprise software company headquartered in Austin Texas. ClearBlade's primary product is the ClearBlade Platform, a secure, scalable server that connects enterprise systems to mobile, web and the Internet of Things. He also holds the position of Venture Partner at Corsa Ventures, an early stage information technology venture firm. Previously, Eric was the founder and Chief Technology Officer of Complete Incorporated, which sold to Perficient Inc. (PRFT) in May of 2000. With more than eleven years of experience in the computer industry as an application developer, test coordinator, project leader, client/server architect, and software marketing specialist, Eric also led a team of ten product specialists in marketing for IBM's application development products, across the nine-state Midwestern areas. He was recognized nationally as one of the company's top marketing representatives through several awards, including the 1993 IBM Golden Circle and the 1993 Area Leadership Award. Eric also serves on the Board of Trustees for St. Gabriel Catholic School and resides with his wife Toni, and two boys, Xander and Dexter, in Austin Texas.

# 2013
## Outstanding Alumni

### Two Computer Science Graduates Recognized "Outstanding Alumni" for Significant Contributions

**HELEN BAUER** graduated from Purdue with her bachelor's degree in mathematics/computer science in 1972 and her master's in computer engineering from Northwestern University in 1974. Helen worked for nearly 30 years in the global telecommunications industry with Lucent Technologies/AT&T Network Systems/AT&T Bell Laboratories. She gained extensive experience in product development including project management, system verification, software development, customer technical support, product management, and hardware development, working in cross-functional and multiple-location teams. Her outstanding contributions led to the development of speech recognition and signal processing systems products, and development of PacketStar Voice Gateway used in Voice Over Asynchronous Transfer Mode (VoATM) and Voice Over Internet Protocol (VoIP) networks to convert the bearer channel between packet and Public Switched Telephone Network. Currently, Helen is president and board member of Campton Historic Agricultural Lands, Inc., which is a local non-profit organization that owns and maintains 370 acres and 26 historic buildings used by an 1840's living history museum—the Garfield Farm Museum just outside of Chicago. Helen has been an avid volunteer with the museum for 12 years, and a lab director for the archaeology program.

**DR. KEVIN GRAZIER** earned three degrees from Purdue, including his associates of computer science in 1982, his bachelor of science in Computer Science in 1983, and his masters of science in physics in 1990. He also earned a bachelor's of science degree in physics from the University of Oakland, and a PhD in physics from the University of California. Well known in the entertainment industry, Grazier has worked as a science advisor for many acclaimed television and film productions, including the hit television series "Falling Skies" on TNT and "Defiance" on the SyFy network. Grazier's contributions as science advisor can be seen on the "big screen" for the current box office smash, "Gravity" staring Sandra Bullock and George Clooney. Prior to his work in the entertainment industry, he worked for 15 years as a research scientist and science planning engineer at NASA's Jet Propulsion Laboratory on the Cassini/Huygens Mission. He was the Investigation Scientist for the Imaging Science Subsystem, and wrote mission planning and analysis software that won both JPL- and NASA-wide awards. He appeared on several episodes of History Channel's "The Universe," Science Channel's "Alien Encounters," and Nat Geo's "Naked Science." Grazier teaches classes in basic astronomy, planetary science, cosmology, the search for extraterrestrial life, and the science of science fiction at UCLA and SMC. At this time, he is finishing a non-fiction book, "Hollyweird Science" for Springer Publishing.

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Mr. Jim Capadona
Dr. David Dodson and
Mrs. Darla Dodson

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# Corporate Partners Program

The Corporate Partners Program (CPP) was launched to foster close communication between the Department of Computer Science and private industry in the context of a mutually beneficial relationship. Corporate financial contributions aid the department in providing educational experiences for our students, while facilitating collaboration with industry leaders. Members in our CPP reap the benefit of increased visibility, gaining priority access to top students who may become future employees, as well as access to faculty, who are experts in relevant technical fields.

Companies participate through strategic, unrestricted donations at tier levels and are involved in many core activities of the department. Recent activities have enabled CS students to participate in conferences and programming competitions, in addition to providing support for student organizations to mentor incoming students. Gifts of equipment are used in the classrooms by faculty and students for research.

Company representatives take advantage of opportunities to speak in classes, sponsor student projects, and make significant contact with CS students and faculty. Members of the CPP include giants of the information technology industry, as well as companies in a wide variety of sectors, including retail healthcare, manufacturing and consumer products. Partner members represent local and global companies and other outstanding firms nationwide. This diverse and dynamic membership provides CS students with exposure to a myriad of career opportunities.

The Corporate Partners meet twice each year to provide input and feedback to departmental and college leadership. Recent contributions of the council include assistance in revising the undergraduate and graduate curricula; suggestions regarding recruiting, retention and enrollment issues; collaborative efforts with faculty and student research, as well as alerting the department to industry areas of concern.

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Sandia National Labs
Sonoma Partners
State Farm
Teradata
Twitter, Inc.
VMware, Inc.
Walmart
Yahoo
Yelp, Inc.

# GUEST SPEAKER SCHEDULE


**Haryadi Gunawi:** 9.23.2013
*The Case for LigHTS:*
*Limping-Hardware Tolerant Systems*
University of Chicago

**Madhu Sudan:** 12.2.13
*Communication Amid Uncertainty*
*Microsoft Research, New England*
Adjunct Professeor,MIT

**Yongguang Zhang:** 10.14.14
*From Software-Defined Radio to*
*Software-Defined Network, An Overview of*
*Networking Research at Microsoft Research Asia*
Microsoft Research, Beijing

**Rajiv Ghandi:** 10.21.13
*Potential to Promise - Developing Scholars,*
*One Eureka Moment at a Time*
Rutgers University

**Paul Van Dooren:** 10.28.14
*Graph Optimization Problems in Data Mining*
Universite Catholique de Louvain

**David Woodruff:** 11.13.13
*Sketching as a Tool for Numerical Linear Algebra*
IBM Almaden

**Julian Dolby:** 11.18.13
*Analysis of JavaScript Programs*
IBM, Thomas J. Watson
Research Center

**Feng Qian:** 1.30.14
*Cross-layer Interactions in Cellular Networks*
NEC Labs, Princeton, NJ

**Margareta Ackerman:** 1.13.14
*Formal Foundations of Clustering*
UC San Diego

**Frank Tip:** 1.15.14
*Data-Centric Synchronization*
University of Waterloo Conte Distinguished
Lecture Series

**Sivan Sabato:** 1.23.14
*Learning with Lower Information Costs*
Microsoft Research, New England

**Engin Kirda:** 1.24.14
*Detecting Malicious Activity Through*
*Large-Scale Data Analysis*
Northeastern University, Boston

**Mathias Payer:** 1.28.14
*WarGames in Memory: Ending Control-Flow*
*Hijack Attacks*
UC Berkeley

**Zhiyun Qian:** 1.30.14
*Differential Side Channel Attacks*
*against Network Stacks"*
NEC Labs, Princeton, NJ

**Saket Navlakha:** 2.3.14
*Analyzing and learning from biological networks*
Carnegie Mellon University

**Veljko Milutinovic:** 2.3.14
*DataFlow SuperComputing*
University of Belgrade, Serbia

**XiaoFeng Wang:** 2.6.14
*Destructive Research on Mobile Security:*
*Rethinking Security by Construction*
Indiana University

**Paul Bennett:** 2.11.14
*Mining and Learning from*
*Context in Web Search*
Microsoft Research

**Taesoo Kim:** 2.13.14
*Intrusion Recovery Using*
*Selective Re-execution (undo computing)*
MIT, CSAIL

**Aaron Turon:** 2.17.14
*Practical Foundations for Scalable Concurrency*
Max Planck Institute for
Software Systems

**Franz Erich Wolter:** 2.17.14
*Shape and Image Cognition,*
*Construction and Compression via*
*Tools from Differential Geometry*
Leibniz University
Hannover, Germany

**Abhishek Jain:** 2.24.14
*Computing on Private Data*
MIT CSAIL & Boston University

**Jeff Huang:** 2.24.14
*Effective Methods for*
*Debugging Concurrent Software*
University of Illinois

**Chris Jermaine:** 2.25.14
*Large Scale Machine Learning*
*with the SimSQL System*
Rice University

**Emina Torlak:** 2.27.14
*A Symbolic Virtual Machine for*
*Solver-Aided Host Languages*
U.C. Berkley

**Byron Boots:** 3.3.14
*New Machine Learning Approaches to*
*Modeling Dynamic Systems*
University of Washington


**Milad Shokouhi:** 3.3.14
*Recipes for PhD*
Microsoft Research, Cambridge

**Deepayan Chartavarti:** 3.5.14
*Large-scale Learning of Personalized Models with a Social Prior*
Facebook Inc.

**Chi Yau Hong:** 3.6.14
*Software Defined Transport*
University of Illinois

**Emil Stefanov:** 3.10.14
*Oblivious Computation and Storage: Building a More Secure Cloud*
UC Berkeley

**Dan Goldwasser:** 3.12.14
*Predicting Real World Outcomes Over Structured Latent Representations*
University of Maryland

**Jie Chen:** 3.13.14
*Predicting Real World Outcomes Over Structured Latent Representations*
Argonne National Laboratory

**Krishna Chintalapudi:** 3.24.14
*Wireless and Mobile Systems : Changing the Rules of the Game*
Microsoft Research India

**Bill Harris:** 3.24.14
*Secure programming via game-based synthesis*
University of Wisconsin-Madison

**Kenneth Clarkson:** 3.26.14
*Sketching Algorithms for Numerical Linear Algebra*
IBM Almaden, San Jose

**Tiark Rompf:** 3.27.14
*Abstraction Without Regret for High-Level High-Performance Programming*
Oracle Labs

**Peter Gammie:** 3.27.2014
*Verifying an On-the-Fly Concurrent Garbage Collector for x86-TSO*
Australian National University

**Heming Cui:** 4.3.14
*New Techniques on Improving Software Reliability and Security*
Columbia University

**Yang Wang:** 4.9.14
*Separating Data from Metadata for Robustness and Scalability*
University of Texas, Austin

**Tamara Denning:** 4.10.14
*Human-Centered Computer Security: Beyond the Desktop*
University of Washington

**Aditya Prakash:** 4.14.14
*Understanding and Managing Cascades on Large Graphs*
Virginia Tech

**Ravi Chugh:** 4.17.14
*Modern Type Systems for Dynamic Languages*
University of California, San Diego

**Katie Siek:** 4.17.14
*If You Build It*
Indiana University

**Milind Girkar:** 4.18.14
*Explicit Vector Programming*
Intel

**Lihong Li:** 4.21.14
*Machine Learning for Decision Making with Big Data*
Microsoft Research

**Ho (Stanley) Chan:** 4.24.14
*Sampling for Large-scale Image Restoration*
Harvard University

**Danny Perez:** 4.28.14
*Extending Atomistic Simulation Timescales using Accelerated Molecular Dynamics*
Los Alamos National Laboratory

**Camil Demetrescu:** 4.29.14
*From Asymptotics to Performance Profiling (and Back)*
Sapienza U Rome

**D. Manivannan:** 4.30.14
*A reliability-based routing protocol for vehicular ad hoc networks*
University of Kentucky

**Jana Diesner:** 4.30.14
*Computational Impact Assessment of Documentaries and Media*
University of Illinois (UIUC)

**Dr. Rean Griffith:** 9.16.14
*Enabling Hadoop for the Cloud: virtualization, data-management and storage optimizations*
VMware

**Dr. Maxim Naumov:** 7.9.14
*Algebraic Multigrid and Preconditioned Iterative Methods on GPUs*
NVIDIA Corporation

# FACILITIES


**The CS Department is committed to providing high-quality computing facilities for use by computer science faculty, students, and administrative personnel. The facilities are operated by an excellent, customer-oriented technical staff, who are not only responsible for the installation and maintenance of the systems, but are also dedicated to assist faculty and students in the development of software systems for research projects. The staff periodically attends training courses and workshops to complete certifications and upgrade their skills. CS is also a certified warranty repair center for Dell computers. The facilities staff includes a director, facilities manager, network engineer, hardware engineer, five system administrators, and several student assistants.**

## General Facilities

General computing facilities are available for both administrative activities (such as the preparation of research reports and technical publications) and research needs that are not supported by other dedicated equipment. The main server systems are multi-core multiprocessors with large main memories and large disk arrays for storage. Personal workstations and laptops from a variety of vendors are used by faculty, staff, and students throughout the department.

## Educational Facilities

The CS Department operates seven instructional laboratories in two buildings. These labs are used for both undergraduate and graduate computer science courses and include more than 200 Intel workstations. Supported operating systems include Windows 7 and Linux. Two labs are collaboration team project labs dedicated to group learning with the assistance of interactive SMARTboard technology. A later section lists equipment owned and maintained by ITaP but used by computer science students.

## I/O Equipment

The department operates both special-purpose output devices, as well as general output equipment, including laser printers, color printers, poster printers, and multi-functional printer/scanner/copier/fax machines. The department also provides video projectors, digital video recording and editing capabilities as well as phone conferencing and a variation of video conferencing equipment. The Lawson Commons is home to the massive 16'x 19' video wall where faculty, students, friends and guests gather to view everything from CS programming competitions to the FIFA World Cup.

## Networking Services

The department is strongly committed to the most current networking technology to provide access to and communication among its systems, as well as to those elsewhere on campus and throughout the world. Our departmental infrastructure supports gigabit per second data rates to the desktop throughout the two buildings using Ethernet VLAN-capable switches from Force10, Cisco Systems, and Dell. Wiring in the new Lawson Computer Science Building is based on Panduit augmented CAT6 data cable and patch panels, capable of 10 gigabit per second speeds. This network infrastructure is bi-connected to the campus backbone by two 1 gigabit per second redundant fiber links. The campus is connected to multiple high speed Internet backbones, including Abilene/Internet2 and I-Light. DSL, cable, and cellular data services are widely used for remote access.

## Information Technology at Purdue (ITaP)

In addition to the facilities described above, students and faculty have access to computing systems owned and operated by ITaP. General instructional facilities operated by ITaP include large Sun SPARCservers and several Sun and Intel workstation laboratories. In addition, ITaP provides systems for use in courses taught by the CS Department. These systems include UNIX-based Sun SPARC stations for undergraduate computer science courses and Microsoft Windows-based Intel personal computers for use in an introductory course for non-majors. Departmental research projects make use of other facilities provided by ITaP. These include a large IBM SP cluster and the Envision Center for Data Perceptualization.


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