PURDUE
UNIVERSITY

COMPUTER SCIENCE ANNUAL REPORT 2012-2013

Celebrating

years of Computer Science

The Department of Computer Science at Purdue University commemorated its 50th anniversary with celebrations, guest speakers, and special events. It was a year of reflection—reflection on a rich history of more than 50 years of continued progress, always striving to meet the needs of a dynamic student body, their potential employers, and a society who greatly benefits from advances in computer science. With humble respect, the department's success is attributed to an ongoing achievement of leadership in research and education. Purdue Computer Science stands proudly on the shoulders of the giants who pioneered the way, generously leaving a harvest of knowledge to build upon.

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MESSAGE FROM THE HEAD

LOOKING BACK, MOVING FORWARD

SUNIL PRABHAKAR

It was a time of jubilation, but also of reflection as we celebrated Purdue Computer Science's 50th anniversary. Established in October 1962, our department has the unique distinction of being the oldest computer science department in the country. For an entire year we celebrated our history with special events, distinguished guests, relishing the fellowship with our friends and alumni.

As far as history goes, computer science is a relatively modern discipline. However, its roots emerged from the ancient sciences with a history dating back to 2700 BCE with the invention of the abacus – the first tool for computing. We've come a long way since the abacus, but some of the greatest challenges lie ahead. Computer science and its integration into our daily lives is increasing at break-neck speed – heavily integrated in our home and work environments.

How the future unfolds, no one knows for sure—just ten years ago, Facebook, Twitter, Instagram and smart phones didn't exist! What are the next discoveries that will transform our lives and how do we prepare the next generation, who will create and shape the new technologies?

One thing is for certain . . . we must attempt to imagine the next fifty years, so we can lay the groundwork for the future of our department. Data from the Bureau of Labor Statistics show that by 2020, there will be 1.4 million new computer science jobs, but only 400,000 computer science students to fill them, as recently published in an article in U.S. News and World Report. Findings also indicate that the number of computer science jobs is growing at a pace two times the national average for job growth.

This report merely reiterates what our department has been experiencing the past few years, if we hope to accommodate the exploding population of students seeking a computer science degree and a workforce eager to hire them. The future also challenges us to improve our diversity, especially among underrepresented populations, meanwhile bolstering our recruitment and retention rates.

Moving forward through the next 50 years, we are excited to be part of the university supported Purdue Moves – a strategic effort set forth by President Daniels that will culminate in a near 30% expansion of our entire department. Part of this expansion will include hiring 20 new faculty members, who will help us build on a tremendous legacy set forth by the pioneers of computer science who founded our first department.

The future holds great promise, as we look back with great pride, moving forward with great excitement!

COMPUTER SCIENCE 50TH ANNIVERSARY

The Department of Computer Science at Purdue University celebrated its 50th year anniversary from the fall of 2012 to the spring of 2013. The year marked a variety of celebrations, as the department welcomed back alumni, friends, and their families. The celebration kicked off in the fall with a day chock-full of events, including a CS camp for K-12 students, tours of the Lawson building, robotics demonstrations, and a tribute performance by the Purdue "All-American" Marching Band. CS faculty provided history of the department and three lectures by Kevin Grazier, Purdue alumnus and scientific advisor for Hollywood film and television, Dan Reed, Vice President of Research and Economic Development of the University of Iowa, and Mike Stoppelman, Vice President of Engineering, Yelp. The closing celebration was held in the spring, culminating with presentations by Professor Deborah Estrin of Cornell Tech; Dr. Farnam Jahanian, Assistant Director for Computer and Information Science and Engineering Directorate at the National Science Foundation; Professor Fran Berman of Rensselaer Polytechnic Institute, and Dr. Vint Cerf, commonly referred to as the *Father of the Internet*. The Harris Corporation, Google, and the Nielsen Company provided support for the events.

YEAR IN REVIEW

SEPTEMBER 1, 2012 — AUGUST 31, 2013

CS SELECTS THREE OUTSTANDING ALUMNI

The Department of Computer Science and the College of Science recognized three individuals for the 2012 Computer Science Outstanding Alumni distinction. Robert Balog (BS '87), Ronald Boisvert (MS '77 and PhD '79), and Marc Shinbrood (BS '72) were honored by faculty, staff, and students during an awards ceremony.

QI's RESEARCH FEATURED IN DRUG DEVELOPMENT & DISCOVERY

An article in the August 2012 issue of *Drug Development & Discovery* magazine, "Bringing Stem Cells to the Forefront" prominently features the research of Yuan (Alan) Qi, assistant professor of computer science, statistics, and by (courtesy) Biology. The article focuses on combating cancer by identifying and isolating cancer stem cells. Dr. Qi's research of cytometry coupled with supercomputing may provide the necessary tools for this.

WAGSTAFF SETS TWO WORLD RECORDS IN FACTORIZATION

Samuel Wagstaff, professor of computer science and CERIAS fellow, has set two new world records in computer-based mathematics. One of these records was achieved years before experts had predicted. Wagstaff announced record factorizations by the Elliptic Curve Integer Factoring Algorithm, primes of 79 and 75 decimal digits.

ALIAGA PROJECT RECEIVES NSF GRANT

Associate Professor, Daniel Aliaga and his co-investigator, Professor Dev Niyogi, earth and atmospheric sciences, received a $552,000 research granted from the National Science Foundation for their project "STRONG Cities: Simulation Technologies for the Realization of Next Generation Cities." The award will be used to create a computational framework for producing next-generation new city designs or modifications to existing cities and, in doing so, will address what has been called the "ultimate design challenge": urbanization.

BERTINO SELECTED NEW DIRECTOR OF DISCOVERY PARK'S CYBER CENTER

Professor Bertino, who joined the Purdue faculty in January 2004, has served as interim director of the Cyber Center since July 2010, succeeding Professor Ahmed Elmagarmid.

CS UNDERGRADUATE NAMED "LEGACY MAKER"

Samantha Feulner, a junior in computer science was named one of Purdue University's "5 Students Who Are Legacy Makers" in October 2012.

GRACE HOPPER ATTENDANCE CONTINUES TO GROW FOR CS WOMEN

Ten women from Purdue Computer Science (two more than the previous year) attended the annual Grace Hopper Celebration in Baltimore, Maryland. The celebration is host to conferences that feature the research and career interests of women in computing.

ALUMNUS GIVES CERIAS SEMINAR

Former Purdue Computer Science undergraduate, Chris Kanich returned to his alma mater in October to present a Security Seminar for the Center for Education and Research in Information Assurance and Security (CERIAS). Kanich's seminar, "Understanding Spam Economics", explored the mechanisms and effectiveness of spam and other Internet scams, providing an understanding of which is necessary for counteracting cybercrime.

LAWSON SHOWCASES NEW ART INSTALLATIONS

During the fifty-year celebration, the building featured projects of several artists whose work celebrates the intersections of computer science and artistic expression. On the second floor, Petrônio Bendito's "Experience Color" exhibition portrays color as an optical, psychological, and cultural presence. Bendito is an associate professor of art and design at Purdue, and his art and research in computational color design methods has been presented internationally. In addition, Professor Greg Frederickson's work also appears on the second floor. His collection, "A Parade of Algorithmic Mathematical Art", is a series of computer-generated images that illustrate geometric dissections of increasing sophistication. David Spellmeyer contributed a series of striking photographs of cityscapes titled "Urban Geometry" which were displayed on Lawson's third floor.

PURDUE CS STUDENTS TRIUMPHANT, GARNERING TOP PRIZES AT HACKERRANK

Three Purdue CS undergraduates, sophomore Nathaniel Cherry, senior Derek Li, and senior Brent Woodhouse took top honors in HackerRank, a competitive intercollegiate hacking league. This year's event drew twenty schools with more than 1,500 competitors vying for a portion of the $10,000 prize money. Woodhouse tied for first place with a student from Tufts University, splitting the top prize of $5000. Li and Cherry also emerged victorious in the overall competition, splitting the remaining $5,000 among those who cracked the final challenge.

LUCIER NAMED FELLOW OF THE AMERICAN MATHEMATICAL SOCIETY (AMS)

Bradley Lucier, professor of computer science and mathematics, has been named a Fellow of the American Mathematical Society (AMS). The Fellows of the AMS program recognizes members who have made outstanding contributions to the creation, exposition, advancement, communication, and utilization of mathematics.

NEVILLE TO RECEIVE FUNDS FROM CENTER FOR SCIENCE OF INFORMATION

Assistant Professor Jennifer Neville advises two of the four project teams selected for student collaborative seed grants by the Center for Science of Information (CSoI). Neville supervises graduate student, Pablo Robles-Granda on the project "Investigation of Metabolic Phenomena Using Information Theory" and graduate student Suvidha Kancharla, on the project "Graph Inference based on Random Walks".

IN MEMORIAM: SHREERAM ABHYANKAR

Shreeram Abhyankar, Marshall Distinguished Professor of Mathematics since 1988, died on Friday, November 2, 2012. He was 82 years old. Born in Ujjain, India in 1930, Abhyankar earned his PhD from Harvard University in 1955. Before joining the faculty of Purdue University as a full professor in 1963, he was an associate professor of mathematics at Cornell University and Johns Hopkins University. He was named a Marshall Distinguished Professor in 1967, and he was also a professor of industrial engineering by courtesy. His numerous honors include being recently named a Fellow of the American Mathematical Society.

ABET AWARDS CS ALUMNUS DISTINGUISHED SERVICE AWARD

Professor Stuart H. Zweben (MS '71, PhD '74) received the highest honor that ABET, the recognized accreditor for college and university programs in applied science, bestows. Zweben accepted the award during the 2012 ABET Annual Awards Banquet in Baltimore on October 26.

ACM NAMES THREE CS FACULTY DISTINGUISHED SCIENTISTS

Professor Ahmed K. Elmagarmid, Associate Professor Tony Hosking, and Associate Professor Ninghui Li were named Distinguished Scientists by the Association for Computing Machinery (ACM). This honor was in recognition of their significant research accomplishments and contributions in computing. The ACM Distinguished Member designation is the second highest level of distinction (between Fellow and Senior) for ACM members. Less than 10% of ACM members may ever hold a Distinguished Member designation.

CS ALUMNUS PUBLISHES IT NOVEL

Gene Kim, (BS '93) co-authored *The Phoenix Project: A Novel About IT, DevOps, and Helping Your Business Win* with Kevin Behr and George Spafford. The department named Kim an Outstanding Alumnus in Spring 2007. He also co-authored *Tripwire* (1992) with Eugene Spafford, while still an undergraduate at Purdue.

CS ALUMNA NAMED DISTINGUISHED WOMAN SCHOLAR

Distinguished Professor in the Department of Defense Analysis at the Naval Postgraduate School, Dorothy E. Denning was selected as one of the Distinguished Women Scholars of Purdue University's Susan Buckley Butler Center for Leadership Excellence. This recognition celebrates alumnae who have made significant contributions in their academic and professional communities. Professor Denning received her PhD from the department in 1975, was hired after graduation as an assistant professor, then promoted to associate professor in 1981.

EUGSTER EARNS GOOGLE RESEARCH AWARD

Associate Professor Patrick Eugster earned the sponsored research award from Google. Google Research awards are structured as unrestricted gifts to universities to support the work of world-class, full-time faculty members at top universities around the world. The project, Geo-Distributed Big Data Processing is joint work with PhD students Chamikara Jayalath and Julian Stephen and postdoctoral research assistant Kirill Kogan. Eugster's award provides $59,000 for one year.

ATALLAH RECEIVES THE OUTSTANDING COMMERCIALIZATION AWARD

Distinguished Professor Mikhail Atallah received the Outstanding Commercialization Award for Purdue University Faculty. This award is presented by Purdue Research Foundation's Office of Technology Commercialization, which supports the economic development initiatives of the university.

KIHARA NETS NEARLY $500K GRANT FROM NSF

Daisuke Kihara, associate professor of biological sciences and computer science received a research grant from the National Science Foundation with an estimated total of $480,195 through May 2016. The project that earned this NSF grant is titled "ABI Innovation: Protein Functional Sites Identification Using Sequence Variation." Kihara is the single principal investigator.

LI EARNS RESEARCH GRANT FROM IBM

Associate Professor Ninghui Li and Assistant Professor Yuan (Alan) Qi received a grant from IBM for their project, "Analytics for Insider Threat Detection and Prevention" for which they are both co-principal investigators.

QUALCOMM SPONSOR'S HOSKING'S RESEARCH OF CS ASSOCIATE PROFESSOR

Associate Professor, Antony Hosking is the recipient of a sponsored research award from Qualcomm, Inc. for his project titled "Memory Management for Dalvik on Mobile Device Platforms." The award of $200,000 is divided into a two-year period. The lead graduate student working with Hosking, Ahmed Hussein, interned with Qualcomm the summers of 2012 and 2013.

2012 PhD GRAD WINS BALLOUS-PAZER IQ DISSERTATION AWARD

Recent graduate, Mohamed Yakout won the prestigious Ballous-Pazer IQ Dissertation Award for his thesis. The award is given to a recipient whose thesis demonstrates the most significant contribution to the information quality field and also has been completed within the two calendar years prior to the International Conference on Information Quality.

CS SELECTS LANDWEBER AS 2012 DISTINGUISHED ALUMNUS

Lawrence Landweber (MS '66, PhD '67) is the John P. Morgridge Professor Emeritus of Computer Science at the University of Wisconsin – Madison, where he was on the faculty from 1967 to 2000. In addition to being honored in a formal ceremony for his achievements, Landweber also presented a colloquium earlier that day.

NEVILLE RECOGNIZED BY ALMA MATER

Assistant Professor Jennifer Neville has been honored for Outstanding Achievement by a Young Alum by her alma mater, University of Massachusetts, Amherst. Neville earned her bachelor's, master's and PhD degrees from the university sequentially in 2000, 2004, and 2006.

SPAFFORD MAKES EPIC ACHIEVEMENT

Professor Eugene Spafford was named a 2013 member of the Electronic Privacy Information Center (EPIC) Advisory Board. EPIC is a public interest research center (established in Washington, D.C.) to focus on public attention about emerging civil liberty issues, meanwhile protecting privacy, the First Amendment, and constitutional values. The board comprises a distinguished group of experts in law, technology, and public policy.

FASTEST CAMPUS SUPERCOMPUTER NAMED AFTER FOUNDING DEPARTMENT HEAD

Purdue confirms ownership of the nation's fastest university-owned supercomputer, developed in collaboration with HP, Intel, and Mellanox. The 2013 supercomputer is named for Samuel Conte, who helped establish the nation's first computer science program at Purdue in 1962 and served as department head for 17 years. Conte can process a problem 15,000 times faster than a 15-inch Apple MacBook Pro, a high-end consumer laptop.

CISCO SUPPORTS COMPUTER SCIENCE PROJECT - A FOG ARCHITECTURE

Associate Professor Patrick Eugster, Dr. Kirill Kogan, and graduate students, Chamikara Jayalath and Julian Stephen, received a gift of $98,987 from Cisco to support the "A Fog Architecture" project. The project strives for a seamless landscape between end hosts and cloud data centers, as the fog paradigm has the potential to more efficiently deliver existing cloud-based services and enable new presently infeasible services.

On Saturday, January 28, 2012, the first annual Windward International Collegiate Programming Finals were held. Seven teams (17 students total) competed in Purdue University's Code War competition in the Lawson Computer Science Building. Three teams advanced to the semifinals of the national code war: Atom (Shakthidhar Reddy Gopavaram and Bharath Guntur), Team Rocket (Ben Goosman and Brent Woodhouse), and BotBebop (Nathaniel Cherry). Nathaniel Cherry, a junior in computer science, placed third in the national finals with BotBebop.

CENTER FOR SCIENCE OF INFORMATION

A recent development in information sciences has been the establishment of The Center for Science of Information (CSoI) as one of NSF's Science and Technology Centers. The center seeks to develop the fundamental principles underlying various aspects of information, along with their application to diverse scientific, engineering, social, and economic domains. Its mission is to advance science and technology through new paradigms in the quantitative understanding of the representation, communication, and processing of information in biological, physical, social and engineering systems. It aims to use information theory and its tools as a basis for extending the scope of information science, beyond Claude Shannon's original objective of laying the foundation for communication theory for reliably reproducing data. Led by Purdue, center member institutions include UIUC, UCSD, UC-Berkeley, Princeton, Howard, Bryn Mawr, MIT, Stanford, and Texas A&M University.

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CENTER ACCOMPLISHMENTS:

250 CONFERENCE PROCEEDINGS AND **176** INVITED TALKS

500 PAPERS PUBLISHED IN PEER REVIEWED JOURNALS AND CONFERENCES

$1 MILLION IN SUPPORT FROM INDUSTRY RESEARCH COLLABORATIONS

17,254 WEBSITE VISITS: WWW.SOIHUB.ORG

20+ EDUCATION VIDEO MODULES AVAILABLE ONLINE

IEEE IT SOCIETY SUMMER SCHOOL **CO-HOST**

FOUR MULTI-INSTITUTIONAL, INTERDISCIPLINARY STUDENT RESEARCH TEAMS REPRESENTING **SEVEN** UNIVERSITIES

FIVE CENTER-WIDE POSTDOCS/FELLOWS WORK ACROSS DISCIPLINES AND INSTITUTIONS

ONE-THIRD OF CSOI STUDENTS ARE FEMALE

SPOTLIGHT ON DIVERSITY

I can see myself in all things and all people around me — Ancient Sanskrit Phrase

WOMEN THINK BIG AT GRACE HOPPER CONFERENCE FOR WOMEN

Purdue women in computer science had the third highest attendance this year at the Grace Hopper Conference (GHC), the world's largest technical conference for women in computing. More than 4000 women attended the sold-out symposium aptly titled, Think Big, where presenters with backgrounds in industry, academia, research and government gathered for special sessions focusing on the role of women in today's technology fields. Anali Sakhala, a senior in computer science, attended the conference and came back to campus inspired, "When I entered the hall where the keynote was going to be held, my jaw dropped. I had never seen something so grand, so huge—I had certainly never seen 4800 women under one roof. When Sheryl Sandberg, Maria Klawe and Telle Whitney (featured speakers) started conversing, they set the stage on fire."

The conference recognizes and promotes the research and career interests of women in computing, in addition to providing academic institutions and corporations with an outlet for recruitment. Social events abound during the conference, as women network with peers, mentors, academics, and industry leaders. Professor of Computer Science, Elena Grigorescu accompanied the students to the conference and noted GHC provides a great opportunity for students to network, finding out about graduate schools, internships and jobs. "With more than 4000 women attending, one gets a dramatic change of perspective compared to what we're used to in CS classes. This effort will certainly succeed in encouraging the presence of women in computational fields," said Grigorescu.

BUILDING THE BRIDGE TO COMPUTER SCIENCE

In anticipation of the expected need and anticipated growth of computer science, the CS Department has taken steps to ensure the success of all students admitted to the program. With that in mind, the Bridge Program was established to help students with a high potential for computer science, but with little or no programming experience. Students learn basic computer science and programming concepts at a comfortable pace in a fun and informal environment. The Bridge Program helps incoming students be successful in the first CS class – CS 18000. Class topics include Java Basics, Input and Output, Primitive Types, Selection, Repetition, Arrays, Methods, Classes, Inheritance, Graphical User Interfaces, and Dynamic Data Structures. During the two-week program, students get to experience college life and reside in campus residence halls. This experience helps students develop a network of peers and make lasting friendships that are vital to their academic success.

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.

Progress in structural biology and molecular biophysics requires 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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DAISUKE KIHARA

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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.

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DAVID GLEICH

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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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WALID AREF

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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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DONGYAN XU

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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.

Simulation. 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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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, and 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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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 share 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 design 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 Microsoft Breakthrough research award (one out of ten nationally) for Professor Qi.

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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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SONIA FAHMY

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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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PATRICK EUGSTER

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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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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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Xiangyu Zhang, *CAREER: Scalable Dynamic Program Reasoning*, National Science Foundation, 02/15/2009 - 01/31/2015.

Patrick T. Eugster and Xiangyu Zhang, *CSR-DMSS, SM: A Holistic Approach to Reliable Pervasive Systems*, National Science Foundation, 09/01/2008 - 08/31/2012.

STRONG CITIES LAB: SIMULATION TECHNOLOGY FOR THE REALIZATION OF NEXT GENERATION CITIES

DANIEL G. ALIAGA

We are in the first century of the urban civilization. In the year 1900, about 14 percent of the world's population of 1.6 billion people lived in cities. According to the United Nations State of World Population in 2007: for the first time in history, starting in the year 2008, more than half of the world population of 7 billion people lives in cities. Cities are highly complex ecosystems of socio-economic entities which provide concentrated living, working, education, and entertainment options to its inhabitants. Further urbanization is inevitable. Although cities embody environmental damage, the potential benefits of urbanization far outweigh the disadvantages – the challenge is in learning how to exploit its possibilities. Harvard economist and author of "The Triumph of the City" Edward Glaeser affirms: "cities magnify humanity's strengths ... and spur innovation". TED, the non-profit foundation that organizes conferences worldwide disseminating "ideas worth spreading", has recently awarded its annual prize to the idea of "The City 2.0", which seeks to connect people around the globe to share ideas about urbanization as the ultimate design challenge. Properly managing the growth of existing cities and the design and functioning of future cities is a vital issue that will only continue to increase in importance during the 21st century.

The research group seeks creating algorithms, visualizations, and IT infrastructure to implement decision support system tools for sustainable urban ecosystem planning. Such tools assists urban stakeholders (e.g., urban planners, engineers, environmentalists, politicians, and concerned citizens) in trying "what if" scenarios of design decisions for obtaining an increased level of sustainability. Our framework builds upon our current work in progress for a) acquiring (or obtaining) a 3D procedural model approximation of an existing (or desired) urban area – the urban area can range from a neighborhood to an entire city, and b) performing an inverse modeling computation (e.g., semi-supervised learning, Hidden Markov Models, etc.) so as to propose altered 3D city models satisfying a desired behavior. The bulk of the work is to create an initial set of sustainability decision support tools including, altering the city layout so as to produce better urban weather, to the reduce heating and cooling energy consumption and to change traffic flow to one of less congestion and of less energy consumption/emissions.

This proposed work exploits our previously and currently funded and deployed systems of urban modeling and simulation (http://www.cs.purdue.edu/cgvlab/urban) funded by NSF, California Metropolitan Transportation Commission, Google, Adobe, and in collaboration with Purdue's CyberCenter. Our work also brings together researchers spanning many fields and performs cross-disciplinary research projects focused on the idea of designing and simulating the functioning of existing and future cities. In particular, we have been very active in bridging the gap between visualization/computer graphics, and urban planning and simulation, earth and atmospheric sciences, and civil engineering. To date, we have published numerous papers addressing 3D building reconstruction and modeling, integrating urban simulation and urban visualization, combining urban modeling with meteorological simulation, joining urban and vegetation ecosystem modeling, merging traffic micro-simulations with fast 3D visualization, and deploying large-scale IT infrastructures for urban planning.

Figure 1. Inverse Cities. A user is given a satellite view (c) of Pacific Grove, CA, and is asked to draw the terrain and highways, click on downtown, provide population/jobs count, and highlight the parks. Our preliminary inverse modeling system generates all city geometry (f) (colors are manually adjusted for comparison). Zoomed areas of the original (a, b) and synthetic (d, e) show qualitative similarity.

FEDERATED BIG DATA PROCESSING

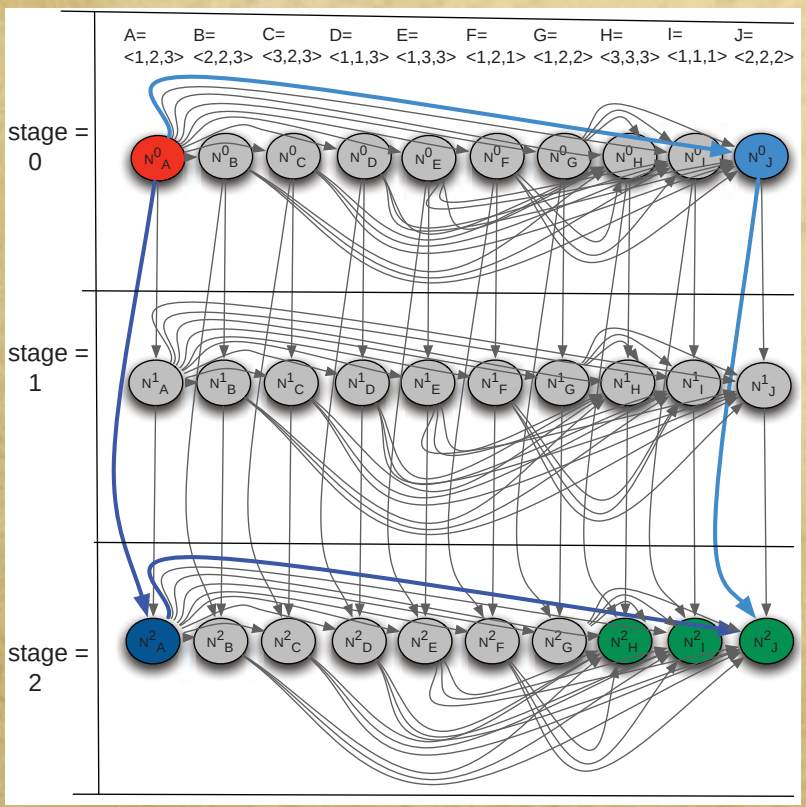
PATRICK EUGSTER

Dealing with big data is a major challenge for our society. The "cloud" intuitively offers a possible response to many needs of big data processing. However, the cloud abstraction offers the illusion of ubiquitous resources which can mislead clients to believe that "details" of cloud implementation such as location of users with respect to cloud datacenters do not matter. Such location-agnosticism can have a strongly adverse effect on performance when computing on datasets that are "geo-distributed", that is, distributed or partitioned across datacenters. Such scenarios are increasingly frequent because of globalization or natural internal breakdowns into departments and units of larger corporations or also governments: different units collect data and erect datacenters to house those datasets and operate on them, whilst many analysis tasks need to gain intelligence across units.

The common approach of copying first all data to one datacenter before computing on it can lead to prohibitively high latency and costs. This is especially the case with many big data analysis tasks where the response sought is very small compared to the inputs to the analysis, thus leading to large amounts of data being transferred over inter-datacenter connections that are an order of magnitude slower than communication inside datacenters, and usually charged for by cloud providers in contrast to inter-datacenter communication which is free. In addition, many analysts execute big data tasks in a more iterative manner, by adjusting constraints for filtering or matching data in response to earlier computation results. This leads to repetitively copying the same datasets. A better approach is thus to move computation towards the data as much as possible, rather than inversely copying all data to one place (e.g., local to the client) where computation occurs.

G-MR [1] is a variant of the popular Hadoop MapReduce engine that enables efficient computation on datasets distributed across datacenters. The principles underlying G-MR are independent of MapReduce in that they consider a notion of sequences of transducers (roughly functions) being applied to a dataset partitioned across datacenters. Data transformation graphs (DTGs) represent different interleavings of sub-computations of such a sequence across data partitions (or their derivations) with respect to copying of the data. That is, by the end of an analysis task all data must be consolidated in one place to achieve a correct response to a query, but such consolidation can happen at different points during the computation and in different orders among the (derivations of) data partitions. DTGs thus enumerate different ''execution paths'', with nodes in such graphs representing a given distribution of data across datacenters at a given stage of the computation, and edges representing either computation or copying actitivies. Weights are assigned to edges in a way corresponding to the measure to be optimized, e.g., time, cost, a combination, and the cheapest execution path is subsequently selected. Weights are obtained via sampling on a single execution path, by inferring complexities of steps.

Figure X depicts an example DTG for a single MapReduce task being applied to a dataset distributed across three datacenters, with one partition in each. Nodes in tier 0 represent different distributions of these input partitions prior to computing. Tier 1 nodes represent the state of computation after the mapping phase, and tier 2 nodes after the reduction phase. Edges within tiers represent copying operations and edges across tiers (downwards) represent progress of computation.



In follow-up work, G-MR has been extended to support more generic "data-flow'' computations on multiple geo-distributed datasets. Rout [2] is a corresponding extension of Yahoo's popular PigLatin language for big data analysis.

[1] C. Jayalath, J. Stephen, and P. Eugster. From the Cloud to the Atmosphere: Running MapReduce across Datacenters. IEEE Transactions on Computers (TC), 63(1): 74–87, 2014.

[2] C. Jayalath and P. Eugster. Efficient Geo-Distributed Data Processing with Rout. In 33rd International Conference on Distributed Computing Systems (ICDCS 2013), pages 470-480, July 2013.

K-12 OUTREACH

Purdue Computer Science K-12 Outreach program is committed to improving access to high quality computer science education for Indiana students, educators and communities. Under the guidance of the program's coordinator, Phil Sands, 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, work with the Indiana Hoosier Heartland chapter of the Computer Science Teachers Association (CSTA), and site visits. For students, the focus is on engagement opportunities both on-site and at Purdue's campus in order to increase the scope of their initiatives.

One of the key areas of the outreach program is the enhanced effort to encourage underrepresented minority groups within the field of computer science. Traditionally, computer science has been overwhelmingly homogeneous with regards to its participants. In order to affect change in this area, K-12 Outreach will begin a new high school program to mentor young women in computer science. This program will engage 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 the eighteenth year, Purdue will host a summer camp for middle school aged 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. Expanding on the middle school camp, Purdue will also offer a computer security camp for high school students for the first time this year.

Purdue's Reaching Out for Computer Science (ROCS) student group continues to provide assistance to K-12 Outreach activities through their volunteer efforts. The group earns Purdue students university credit for offering time from their busy schedules to work with the youth of Indiana on computer science activities. This year, ROCS participated in events with 4H, the Girl Scouts of America, Operation Military Kids, and several elementary and middle school students throughout the state.

EDUCATION

PHD RECIPIENTS

DECEMBER 2012

Suleyman Cetintas
Effective and Efficient User and Content Modeling for Intelligent Tutoring Systems
Advisor: Lou Si
Employer: Yahoo

Jayaram Kallapalayam Radhakrishnan
Engineering Efficient Event-Based Distribution Systems
Advisor: Patrick T. Eugster
Employer: Hewlett Packard

Ahmet Erhan Nergiz
Private Data Outsourcing Using Anonymization
Advisor: Christopher W. Clifton
Employer: Google

Rongjing Xiang
Statistical Relational Learning for Single Network Domains
Advisor: Jennifer L. Neville
Employer: Foursquare

Feng Yan
Efficient Learning Algorithms for Gaussian Processes
Advisor: Yuan Qi
Employer: Facebook

Dan Zhang
Dealing with Ambiguous and Partial Supervision in Complex Information Retrieval Applications
Advisor: Lou Si
Employer: Facebook

MAY 2013

Meghana Chitale
Functional Profiling of Protein Sequences and Application of Functional Associations for Missing Enzyme Prediction
Advisor: Daisuke Kihara
Employer: Epic Systems

Nan Ding
Statistical Machine Learning in T-Exponential Family of Distributions
Advisor: S.V.N Vishwanathan
Employer: Google

Despoina Perouli
Methods for Safe, Flexible and Secure Policy Based Routing
Advisor: Elisa Bertino, Sonia Fahmy
Employer: Purdue University

Wahbeh Qardaji
Differentially Private Data Publishing: From Histograms to Transaction Sets
Advisor: Ninghui Li
Employer: Google

Dasarath Weeratunge
Dynamic Program Analyses for Debugging Concurrency Bugs in Large Multi-threads Programs
Advisor: Xiangyu Zhang, Suresh Jagannathan, Zhiyuan Li
Employer: Intel

Di Xie
Time Varying Network Reservation for Cloud Data Centers
Advisor: Ramana Kompella Y. Charlie Hu
Microsoft, WA
Employer: Microsoft

AUGUST 2013

Samer Samir Barakat
High Performance Structure Extraction for Visualization
Advisor: Xavier Tricoche Wojciech Szpankowski

Vasil S. Denchev
Binary Classification with Adiabatic Quantum Optimization
Advisor: S.V.N. Vishwanathan & Zhiyuan Li
Employer: Google

Sriharsha Gangam
High Accuracy, Lightweight Methods for Network Measurement Services
Advisor: Sonia Fahmy, Ramana Kompella

Wei-Min Yao
Enhancing Scalability in Network Simulation and Testbed Experiments
Advisor: Sonia Fahmy, Kihong Park

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Wei-Yen Day
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Xiaoyu Ding
Youhan Fang
Robert Fruchtman
Joshua Fuerst
Venkata Gandikota
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ENGAGEMENT

SPOTLIGHT ON ALUMNI

DISTINGUISHED ALUMNI

Lawrence H. Landweber (MS '66, PhD '67) is the John P. Morgridge Professor Emeritus of Computer Science at the University of Wisconsin – Madison, where he was on the faculty from 1967 to 2000. Landweber is a Fellow of the ACM and in 2005 received the IEEE Award on International Communication. In 2009, the Internet Society awarded him with the Jonathan B. Postel Service Award for his contributions to CSNET. In 2012, he was inducted into the first class of the Internet Hall of Fame. In 1995, Newsweek Magazine called him the "Guardian of the Internet" and included him among their "Net 50." Additionally, Landweber presented a colloquium for the Department of Computer Science, titled "Past Is Prologue" prior to receiving his award.

OUTSTANDING ALUMNI

Robert Balog earned his bachelor's degree in computer science from Purdue University in 1987. He assumed the role of senior vice president of engineering for KVH Industries, overseeing all of KVH's satellite, guidance, and stabilization engineering efforts, in October 2008. Previously, he served as KVH's vice president of engineering (satellite products). Before joining KVH in February 2005, Robert served as president of Automation Services, an engineering contract services company, and as vice president of engineering at ADE Corporation in Massachusetts. He also held a number of positions, including general manager and vice president of R&D, during ten years at Speedline Technologies in Franklin, Massachusetts. He's been a member and served as chairman of the Surface Mount Equipment Manufacturers Association Board of Directors, along with other positions. Additionally, he's received U.S. patents.

Ronald Boisvert earned his master's degree in computer science from Purdue in 1977 and his doctorate in 1979. He leads the Applied and Computational Mathematics Division of the Information Technology Laboratory at the National Institute of Standards and Technology (NIST). During his thirty-three year career with NIST, he helped develop the original ELLPACK system for elliptic boundary value problems, the NBS Core Math Library, VFFTPACK (for vectorized FFTs), VFNLIB (for vectorized Bessel functions), the Guide to Available Mathematical Software, and the Matrix Market. He is one of the principal editors for the NIST Digital Library of Mathematical Functions. He has served as Editor-in-Chief of the ACM Transactions on Mathematical Software (1992-2005), Co-Chair of the Numerics Working Group of the Java Grande Forum (1998-2003), and Chair of the International Federation for Information Processing (IFIP) Working Group 2.5 on Numerical Software (2000-2012). He is currently Co-Chair of the Publications Board of the Association for Computing Machinery (ACM). He received the U.S. Department of Commerce Silver Medal for Meritorious Federal Service (1992) and Gold Medal for Distinguished Achievement (2011).

Marc Shinbrood earned his bachelor's degree in computer science from Purdue in 1972 – a member of the first computer science graduating class. He is vice president of the Web Application Firewall business unit at Trustwave Holdings Inc. He has been in the vendor software and appliance business environment for more than thirty-five years, and for the last fifteen years, he's focused on enterprise-level software and appliance security solutions. Prior to Trustwave, Marc was CEO and Chairman of Breach Security. Currently, he is responsible for the Trustwave WebDefend Web application firewall business and more than 400 customers. He has held many positions for the computer software company, including serving as CEO five various times. He is the author of numerous articles and videos, a frequent speaker at industry events and conferences, and associate technical editor for Midrange Computing magazine.

From left: Department Head Sunil Prabhakar, Marc Shinbrood (B.S. '72), Ronald Boisvert (M.S. '77 and Ph.D. '79), and Robert Balog (B.S. '87)

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The All American Marching Band pays tribute to the CS 50th anniversary celebration, during the Purdue vs. Michigan half-time show.

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, meanwhile 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.

PREMIER PARTNERS

Cisco
Eli Lilly and Company
Google, Inc.
Harris Corporation
IBM
Intel Corporation
Interactive Intelligence
Lockheed Martin
Microsoft Corporation
Motorola
Northrop Gruman
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PARTNERS

Allston Trading
Amazon
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Hewlett-Packard
Hulu
Land O'Lakes
Lutron Electronics
Microsemi Corporation
Nielsen
Sandia National Labs
Sonoma Partners
State Farm
Teradata
Twitter, Inc.
VMware, Inc.
Walmart
Yelp
Zynga

GUEST SPEAKERS

VINT CERF

Widely known as a "Father of the Internet," Dr. Cerf is the co-designer of the TCP/IP protocols and the architecture of the Internet. In December 1997, President Bill Clinton presented the U.S. National Medal of Technology to Cerf and his colleague, Robert E. Kahn, for founding and developing the Internet. In 2004, he was the recipient of the ACM Alan M. Turing award (sometimes called the "Nobel Prize of Computer Science") and in 2005 he was given the Presidential Medal of Freedom by President George Bush.

See more at:
http://internethalloffame.org/inductees/vint-cerf#sthash.i8HVGIRe.dpuf

KEVIN GRAZIER

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. 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.

DEBORAH ESTRIN

Dr. Deborah Estrin of Cornell Tech provided an introductory keynote lecture, "Embedding Mobile Computing and Research in Everyday Life." Deborah Estrin is a Professor of Computer Science at Cornell Tech in New York City and a Professor of Public Health at Weill Cornell Medical College. She is co-founder of the non-profit startup, Open mHealth. Estrin's Small Data Lab @ CornellTech develops new personal data APIs and applications for individuals to harvest the small data traces they generate daily.

MOIRA GUNN

Host of the public radio program Tech Nation and BioTech Nation on National Public Radio, she earned her MS in computer science from Purdue in 1972, studying systems and programming. She was invited back to campus to join the 50th celebration festivities.

DATE	SPEAKER/AFFILIATION	TALK TITLE
9/11/2012	Christopher Vick, Qualcomm Research	Architectural Musings: Rethinking Mobile Computer Systems Architecture
9/21/2012	Prof. John Hopcroft, Cornell University	**CONTE SPEAKER** ~ New Directions in Computer Science
10/24/2012	Dr. Nick Duffield, AT&T Labs Research	Two Sampling Problems for Measurement in Networks and Beyond
11/1/2012	Dr. Ian Duff, Rutherford Appleton Laboratory & CERFACS	**CONTE SPEAKER** ~ Solving Large Sparse Linear Systems: The Exascale Challenge
11/28/2012	Prof. Tom Mitchell, Carnegie Mellon University	**CONTE SPEAKER** ~ Never Ending Learning
12/3/2012	Dr. Hakim Weatherspoon, Cornell University	SoNIC: Precise Relatime Software Access and Control of Wired Networks
1/17/2013	Dr. Leszek Lilien, Western Michigan University	Active Bundles for Protecting Privacy During Sensitive Data Dissemination
2/14/2013	Dr. Allison Lewko, Microsoft Research New England	Expanding Capabilities for Functional Encryption
2/18/2013	Dr. Domagoj Babic, Facebook	Malware Analysis with Tree Automata Inference
2/20/2013	Ganesh Ananthanarayanan, University of California, Berkeley	Big Data Analytics with All-or-Nothing Parallel Jobs
2/21/2013	Dr. Yisong Yue, Carnegie Mellon University	Interactive Machine Learning with Humans in the Loop
2/26/2013	Dr. Barzan Mozafari, Massachusetts Institute of Technology	Building the Next Generation of Data-Intensive Systems: From Complex Event Processing to Large-Scale Analytics
3/4/2013	Dr. Stefano Tessaro, Massachusetts Institute of Technology	Theoretical Foundations for Applied Cryptography
3/15/2013	Dr. Trent Jaeger, Pennsylvania State University	Adversary Accessibility: Key to Finding and Preventing Vulnerabilities
3/18/2013	Ryan Stutsman, Stanford University	Durability and Crash Recovery for Distributed In-Memory Storage
3/21/2013	Dr. Prateek Mittal, University of California, Berkeley	Trustworthy Communications Using Network Science
3/21/2013	Prof. Barbara Liskov , Massachusetts Institute of Technology	**CONTE SPEAKER** ~ The Power of Abstraction
3/25/2013	Dr. Jacob Abernethy, University of Pennsylvania	Learning in an Adversarial World, with Connections to Pricing, Hedging, and Routing
3/28/2013	Prof. Prasad Tetali, Georgia Institute of Technology	Phase Transitions in the Square Lattice Gas Model
4/1/2013	Dr. Zhichun Li, NEC Research Labs	Towards Scalable Vulnerability Detection and Mitigation
4/3/2013	Dr. Ceren Budak, University of California, Santa Barbara	Understanding and Managing the Diffusion of Information in Online Social Networks
4/11/2013	Prof. Andrew Brown, University of Southampton	Computing Beyond a Million Processors: Biologically-Inspired Massively – Parallel Architectures
4/12/2013	Prof. Lawrence Landweber, University of Wisconsin - Madison	Past Is Prologue
4/29/2013	Dr. Michael Bond, Ohio State University	Practical Language and System Support for Reliable Concurrent Software
5/16/2013	Prof. George C. Polyzos, University of California, San Diego	Clean –Slate Information-Centric Publish/Subscribe Internetworking
2/3/2013	Prof. Veljko Milutinovic, University of Belgrade, Serbia	DataFlow SuperComputing

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, 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 (CS 110). 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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DEPARTMENTAL

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Christoph Hoffmann, Associate Head
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John T. Korb, Assistant Head
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Lauren Terruso, Advisor
Sean Winningham, Advisor


MOVES THE WORLD FORWARD

1960's

Programing Languages
- o FORTRAN IV
- o COBOL
- o LISP
- o ALGOL 60
- o SNOBOL
- o BASIC
- o BCPL
- o Smalltalk

• Achievements in space First commerical communications Satellite, Telstar I, goes into orbit. Neil Armstrong and Buzz Aldrin are the first humans to walk on the moon.

1962

IBM installs a 1401 and a 7090 at Purdue University.

• Samuel D. Conte beomes the first Head of the Computer Science Department at Purdue. October 1962.

• The Department of Computer Science at Purdue University is the first Computer Science Department in the United States. Felix Haas hires Samuel Conte to be the founding head.

• The Engineering Administration Building is the first home of the Computer Science Department.

1963

The student chapter of the Association for Computing Machinery (ACM) is started at Purdue.

• The American Standard Code for Information Interchange (ASCII) is developed to standardize data exchange among computers.

• The first master's degree in Computer Science is awarded at Purdue.

1964

IBM introduces the System/360, which used microcode to implement the basic instruction set.

1965

Ted Nelson coins the term "hypertext" to refer to linked content.

• Gordon Moore makes an observation: Over the history of computing hardware, the number of transistors on integrated circuits doubles approximately every two years. This observation later becomes known as Moore's Law.

1966

The first PhD degree in Computer Science at Purdue is awarded to Kenneth M. Brown.

• Pong is released, becoming the first commercial computer game.

1967

The Computer Science Department at Purdue moves to the Mathematical Sciences Building.

• The first bachelor's degree in Computer Science is awarded.

• IBM creates the first floppy disk.

1969

The world's first laser printer is invented at Xerox.

• The Advanced Research Projects Agency Network (ARPANET) is the world's first operational packet switching network and the progenitor of what becomes the global Internet.

• The first U.S. bank ATM goes into service in Rockville Centre, N.Y.

1970's

Programing Languages
- o Pascal
- o Modula
- o C
- o ML
- o Scheme

• Digital Equipment Corporation introduces the VAX with "Virtual Address eXtension".

1970

Xerox Palo Alto Research Center (PARC) is established to perform basic computing and electronic research.

1971

Intel introduces the first microprocessor. The Intel 4004 is a 4-bit central processing unit (CPU).

1973

Ethernet is developed at Xerox PARC. Early commercial versions run at 3 megabits per second.

1974

Intel introduces the 8086 CPU, launching a series of x86 microprocessor instruction set architectures.

1975

Bill Gates and Paul Allen form Microsoft.

• MITS ships one of the first PCs, the Altair 880, with one KB of memory, as a mail-order kit for $397.00.

1976

Steve Jobs and Steve Wozniak demonstrate the first Apple computer at the Home Brew Computer Club.

• Shugart Associates develops the 5.25" floppy disk.

1977

MOUSE4, a very fast version of the popular Ratfor Fortran pre-processor, is released.

• The Grader program for managing and summarizing student grade data is developed and distributed.

1978

The department installs a VAX 11/780 computer system running UNIX, the first at a university. ASCII terminals go into faculty offices and email is sent via uucp to ihnp4.

1979

VisiCalc, developed by Software Arts for the Apple II, becomes the first electronic spreadsheet.

• Peter J. Denning becomes the second Head of the Computer Science Department at Purdue.

• Usenet, a worldwide, distributed discussion system, is developed at Duke University.

1980's

The Computer Science Computing Facilities group is created to meet the explosion of students.

• Programing Languages
- o C++
- o Objective-C
- o Tcl
- o Perl

• Growth in research funding increases from $447K in 1980 to $3.6M in 1989 bringing a substantial increase in PhD students.

1980-82

Peter J. Denning serves as President of the Association for Computing Machinery (ACM).

1981

IBM introduces the first "personal computer", the IBM PC.

• Over 500 new freshmen enter the program, resulting in greatly increased class size and corresponding shortage of faculty, space, and computing facilities.

• The Purdue Computer Science Department is part of the original consortium of universities that create CSNET.

1982

The Xinu operating system is developed and used for instruction and research.

• Sun Microsystems introduces the first workstation to support the Unix operating system.

• The RCS Revision Control System is developed.

• Tron is the first movie to use computer-generated special effects.

1983

The migration of the ARPANET from NCP to the TCP/IP protocol suite is completed and the Internet is established.

• John R. Rice becomes the third Head of the Department of Computer Science at Purdue.

• Microsoft introduces the Windows operating system.

1984

Apple introduces the Macintosh.

• The Domain Name System (DNS) is deployed to replace the file-based host tables for finding IP addresses.

1985

The Computer Science Department introduces the first supervised computing and teaching laboratories at Purdue.

• The ELLPACK system for solving elliptical partial differential equations is developed and published at Purdue.

• The Computer Science Department moves its headquarters to the newly renovated Memorial Gymnasium, retaining space in the Math, Physics, and Recitation buildings.

• The Software Engineering Research Center (SERC), part of the National Science Foundation's Industry-University Cooperative Research Program, is established at Purdue with connections to other universities.

1986

CSIM, a C-based process-oriented simulation language is released.

• DeTeX, a program for removing TeX constructs from input files, is released and distributed.

1988

The Morris Internet worm is one of the first computer worms to hit the Internet and the first to gain significant mainstream media attention.

1989

The Computer Science K-12 Outreach Program is started.

1990's

Programming Languages
- o Python
- o Java
- o Ruby

1990

Electronic Frontier Foundation (EFF) is founded.

• Hubble telescope goes into space.

• The Internet Movie Database (IMDb) is launched. Domain imdb.com comes online in 1996.

1991

The National Science Foundation (NSF) opens the Internet to commercial use.

• The World Wide Web is launched to the public. By 1993, there are 50 WWW servers known to exist.

• PGP, a public key used for encryption, is released as Freeware.

1992

Tripwire, Inc., is founded by Purdue alumnus Gene Kim, based on a paper co-authored with Eugene Spafford while a student at Purdue.

• Purdue establishes a Chapter of Upsilon Pi Epsilon (UPE), the International Honor Society for the Computing Sciences.

1993

Purdue Computer Science student, Ian Murdock, starts the Debian Project, a Linux distribution.

1994

The "Good Time Virus", an Email hoax, is first sent out in e-mail and spread on the Internet.

1995

The Computer Science Department starts the Corporate Partners Program and forms the Corporate Partners Council.

• The "Dot-Com" boom starts.

• The first wiki, a website that allows simplified content editing, is created.

• The USB 1.0 standard is released.

• The ParaSol discrete event simulation system is released.

1996

More e-mail than postal mail is sent in the U.S.

• Google is founded.

1997

Facebook.com comes online.

• Ahmed Sameh becomes fourth Head of the Computer Science Department at Purdue.

• On July 8, 1997, Internet traffic records are broken as the NASA website broadcasts images taken by Pathfinder on Mars. The broadcast generates 46 million hits in one day.

• The IBM Deep Blue defeats world champion chess player Kasparov.

• Digital Video Discs (DVDs) first go on sale.

1998

The Center for Education and Research in Information Assurance and Security (CERIAS) is formed at Purdue from the COAST lab and is one of world's leading centers for research and education in areas of information security.

• The first Computer Science Department Job Fair is held.

1999

The Undergraduate Student Board (USB) is founded.

2000's

Programming Languages
- o C#

2000

Fear of what might happen because of the year 2000 bug fail to materials. Computers continue to work.

• NASDAQ hits record high (5132.52) and marks the turning point of the dot-com boom.

• Domain twitter.com comes online.

2001

Wikipedia is founded.

• BitTorrent, the first peer-to-peer file sharing protocol, is introduced on a public message board.

• The Computer Science Women's Network (CSWN) is created.

• Apple introduces the iPod.

• Segway is unveiled.

2002

The Graduate Student Board (GSB) is created.

• Purdue faculty and students create a simulation of the 9/11 attack on the

• Computer Science faculty create software security company Arxan Technologies.

• Susanne Hambrusch becomes fifth Head of the Computer Science Department at Purdue.

2004

The new Computer Science Building is named for Richard and Patricia Lawson.

• Facebook is launched.

2006

The Computer Science Department moves to the Lawson Computer Science Building.

• The DaCapo suite for Java benchmarking is released.

2007

Amazon releases the first Kindle.

• Aditya Mathur becomes the sixth Head of the Computer Science Department at Purdue.

2008

Hulu website is release.

• A Cisco TelePresence conferencing system is installed in the Lawson Building.

2009

Analog TV is moved to high-definition.

2010

Sunil Prabhakar serves as Interim Head for the Computer Science Department at Purdue.

• Harris Corporation donates a 16' x 9' tiled video wall for the Lawson Commons.

• The Center for the Science of Information is established at Purdue as an NSF Science and Technology Center.

• The first all-robotic surgery is performed.

2012

Sunil Prabhakar becomes the seventh Head of the Computer Science Department at Purdue.

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