PURDUE UNIVERSITY

Math **PUrview**

IN THIS ISSUE

Distinguished Mathematics Professors Named

Three Mathematics faculty were appointed Distinguished Professors during the 2004-05 academic year by the Purdue University Board of Trustees.

Laszlo Lempert's appointment as Distinguished Professor of Mathematics became effective in December. Lempert is an expert in complex geometry and complex analysis in infinite dimensional spaces. His research interests include complex analysis, partial differential equations, and differential geometry.

He is a member of the Hungarian Mathematical Society, American Mathematical Society, and is an external member of the Hungarian Academy of Sciences. His honors include the Grunwald Prize from the Hungarian Mathematical Society, the Alexits Prize from the Hungarian Academy of Sciences, and the American Mathematical Society's Bergman Prize.

Laszlo Lempert

The most recent of his more than 50 publications uncover fundamental properties of functions that have infinitely many independent variables. These results are expected to be of relevance outside of mathematics, to physical theories that deal with systems with infinitely many degrees of freedom, such as field theories.

Lempert received his undergraduate and doctorate degrees from the University of Budapest in 1975 and 1979, respectively, and was a candidate of sciences at the Hungarian Academy of Sciences in 1984. Before coming to Purdue, Lempert was a visiting lecturer at Princeton University from 1984 to 1985, taught at the University of Budapest from 1975 to 1992, and was a visiting research fellow at the University of Paris from 1979 to 1980.
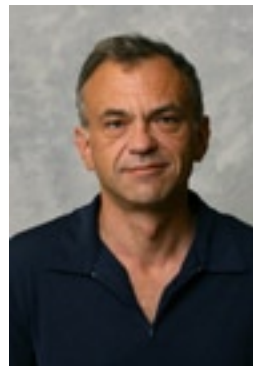
The Board of Trustees appointed Alexandre Eremenko a Distinguished Professor of Mathematics in February. Eremenko has been at Purdue since 1991 and is a world leader in complex function theory. He has made contributions in several areas of mathematics, including complex dynamics, ordinary differential equations, real analytic geometry, Fourier analysis, and control theory.

He has received Purdue's H.N. McCoy Award, an Alexander von Humboldt Award, and is a member of the presidium of the Kharkov Mathematical Society.

Born in the former Soviet Union, Eremenko earned his

Alexandre Eremenko

doctorate from Rostov State University, Rostov-on-Don, Russia. He received his doctor of science degree from the Institute of Mathematics in Novosibirsk, Russia.

Leonard Lipshitz

Once again we've reached the end of a very busy academic year. To give you an idea of our level of activity, the Mathematics Department teaches about 24,500 Purdue students per year. During the fall 2004 semester, our departmental teaching was distributed as follows: 14,784 precalculus student-hours, 23,422 calculus student-hours, 6,379 post-calculus undergraduate student-hours, and 2,539 graduate level student-hours. During 2004-05, roughly 117 bachelor, 23 master, and 13 doctoral degrees in mathematics were awarded. Our efforts to provide mathematics instruction to all Purdue students and to train future mathematicians is accomplished by dedicated and talented faculty, graduate TAs and lecturers, who are aided by an efficient staff that works effectively to support our teaching mission.

At the same time, our level of research activity has never been stronger. Approximately 15 different research seminars met last year on a regular (usually weekly) basis. Experts in various fields of mathematics from around the world are routinely invited to give seminar talks here, which gives our faculty and graduate students many opportunities to exchange ideas with other leading mathematicians.

Owing to the strength and reputation of our current faculty, efforts to recruit new faculty were quite successful this year. Hires were made at both the junior and senior levels. Joining us next fall as assistant professors are Monica Torres (Ph.D. 2002, University Texas at Austin; postdoc at Northwestern; pde, calculus of variations) and Dongbin Xiu (Ph.D. 2003, Brown University; postdoc at Princeton, Brown, Los Alamos; stochastic modeling, multi-scale simulation). New full professors will include Minhyong Kim from the University of Arizona (arithmetic algebraic geometry) and Michael Röckner of the University of Bielefeld (stochastic analysis and its applications). Seven new Research Assistant Professors will join the faculty, along with several visitors.

In addition, Maarten de Hoop will join the Department as Professor and Director of our Center for Computational and Applied Mathematics. Maarten comes to Purdue from the Colorado School of Mining in Golden. He has applied sophisticated methods from pure mathematics to develop new numerical methods for the analysis of seismic data. He has successfully collaborated with geophysicists and interacted with a wide range of scientists and engineers. Maarten previously worked in the oil extraction industry and has a track record of successful interaction with industry as an academic. We look forward to his arrival.

I will take a break from administration to work on mathematical research during my sabbatical in the fall, but the Department's efforts to excel and innovate in both teaching and research will continue. Rodrigo Bañuelos has agreed to step in and keep the department running. I am confident he will get AY 2005-06 off to a good start and will continue the momentum.

— Leonard Lipshitz, Head

Actuarial Science Alumni
Join us as we celebrate the
20th anniversary of our actuarial
science program!

What: **Purdue Actuarial Alumni Banquet**
When: **Friday, September 9**
Where: **Purdue Memorial Union**

Watch your mailbox for information about the banquet and
tickets to Saturday's Purdue vs. Akron football game.
Or, contact T. J. Cornwell: tcornwel@purdue.edu

Bañuelos Appointed Interim Head

Rodrigo Bañuelos will serve as Interim Head of the Department while Leonard Lipshitz takes sabbatical leave during the fall 2005 semester.

Bañuelos earned his Ph.D. from the University of California, Los Angeles in 1984. He spent two years as a Bantrell Resarch Fellow at the California Institute of Technology and one year as an NSF Postdoctoral Fellow at the University of Illinois at Urbana before coming to Purdue in 1987. He was promoted to Associate Professor in 1989 and to Professor in 1992.

His research interests are in probability and its connections to harmonic analysis and partial differential equations. Bañuelos was an NSF Presidential Young Investigator from 1989 to 1994. He was elected a Fellow of the Institute of Mathematical Statistics in 2003 and received the Blackwell-Tapia Prize in Mathematics in 2004 (see page 8). From 1998 to 2002, he served on the Scientific Advisory Council of the Mathematical Science Research Institute at Berkeley. He was a member of the United States National Committee on Mathematics from 1998-2001.

Rodrigo Bañuelos

Bañuelos is a current Board of Trustees member for the Institute for Pure and Applied Mathematics at UCLA. His other memberships include the American Mathematical Society, the Institute of Mathematical Statistics, the Society for Advancement of Chicanos and Native Americans in Sciences (SACNAS), and the Human Relations Commission for the City of West Lafayette.

2005 Distinguished Mathematics Alumnus

Lawrence D. Stone
B.S. 1964; M.S. 1966, Ph.D. 1967

Ten alumni were honored by the College of Science in a program held at Purdue on April 15, 2005.

Dr. Larry Stone is President and CEO of Metron, Inc. He began his career in 1967 at Daniel H. Wagner, Associates, where he rose to the rank of Senior Vice President before leaving in 1986 to join Metron.

Stone's technical work has included modeling the operational Anti-Submarine Warfare (ASW) effectiveness of nonacoustic sensors, developing tactical decision aids for ASW search and localization, and participat-

Lawrence D. Stone

ing in a National Science Foundation project to apply search theory to oil exploration. He was the technical and project manager for the development of a multiple-target, nonlinear, correlator-tracker, NodeStar, designed for use in the Navy's Integrated Underwater Surveillance System. He co-authored the book *Bayesian Multiple Target Tracking* and continues to work on a number of tracking and discrimination systems for the Navy Missile Defense Agency and Defense Advance Research Projects Agency.

In 1999, Stone was elected to the National Academy of Engineering for his contributions to optimal search theory and practice. The Operations Research Society of America awarded its Lanchester Prize to his text, *Theory of Optimal Search*, as the best work in operations research published in English in 1975. He was codirector of the 1979 NATO Advance Research Institute on Search Theory and Applications in Faro, Portugal, and coeditor of the conference proceedings, *Search Theory and Applications*. He has published numerous papers in search theory, taught the subject at the Naval Postgraduate School, and has participated in many search operations. He has also published papers in probability theory, optimization, and data fusion.

He rendered on-scene assistance to the U.S. Navy in the 1974 search for unexploded ordnance in the Suez Canal, and he participated in the development of the Coast Guard's computerized search and rescue planning program, CASP. During the 1968 search for the remains of the submarine *Scorpion*, Dr. Stone provided on-scene analysis assistance for six weeks near the Azores. Based on this experience, he coauthored a fleet manual for use in deep ocean search.

In 1986, Stone produced the probability maps used by the Columbus America Discovery Group to locate the *S.S. Central America*, which sank in 1857, taking an estimated $400 million of gold coins and bars to the ocean bottom one and a half miles below.

In recent years, Stone has renewed his relationship with the Purdue Mathematics Department by returning to campus to give career talks and serve on an advisory committee, and by providing summer internships for Purdue mathematics undergraduates.

Research in Cardiac Modeling
by Greg Buzzard

A summer 2003 research experience with a cardiac modeling team at Gene Network Sciences (GNS) in Ithaca, NY led Professor Greg Buzzard to expand his research to include the computational modeling of biological systems.
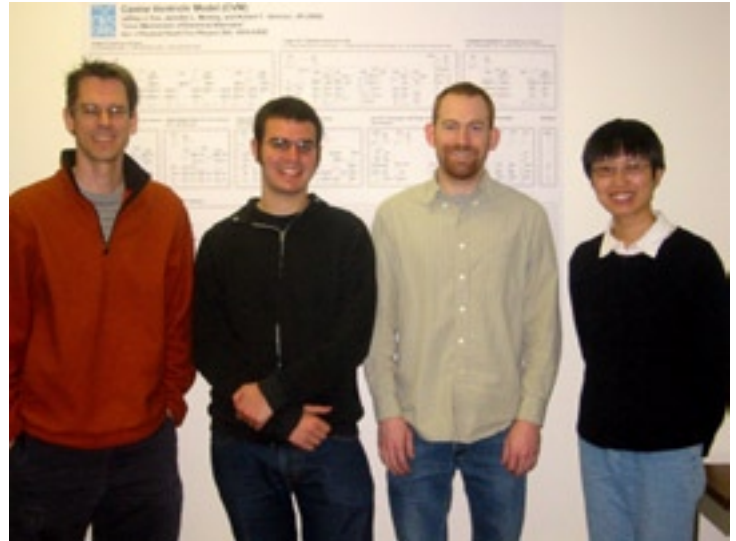
Heart rhythm disturbances such as ventricular tachycardia (VT) and ventricular fibrillation (VF) are a significant cause of morbidity and mortality in the United States. Great efforts have been devoted toward understanding the causes of these disorders, but these efforts have been hampered for at least two reasons. First, there is no effective way to measure electrical activity throughout the heart during VT and VF, and second, there is no effective way to modify specific ionic currents to determine the effect of these currents on such arrhythmias.

One approach to overcoming these obstacles is to create a detailed computer model of cardiac electrical activity. Several such models have been developed in recent years. Typically, such a model consists of a system of ordinary differential equations that are used to model the ionic currents in a single cardiac cell. In addition, there may be some means to model electrical wave propagation throughout a collection of cells via a discretized partial differential equation. However, there are several difficulties in using such models to understand large-scale phenomena such as VT and VF. As such models become more detailed, the data needed to determine the precise values for parameters such as rate constants becomes at least proportionately greater. Moreover, the computational power needed to simulate more detailed models increases greatly, particularly in the case of simulating 3-dimensional cardiac tissue, in which the number of cells can easily be in the millions. Finally, it is generally very difficult to understand the relationship between parameters in the model of a single cell and global phenomena such as wave propagation.

In addition to my work as a research mathematician focusing on dynamical systems, I also have a bachelor's degree in computer science and experience teaching in the computer science department at Cornell University. While I've found research in pure math to be very engaging and

The cardiac modeling team at GNS: Greg Buzzard, Dave Rand, Jeff Fox, and Qinlian Zhou.

have been successful at it, I've had a desire to use my skills in computer science to a greater extent. I've also wanted to work on interdisciplinary problems that have a direct bearing on the well-being of others, yet which have a strong mathematical component and have the potential to lead to important advances in mathematics.

These desires led me to spend the summer of 2003 working at Gene Network Sciences (GNS), a company in Ithaca, New York devoted to computational modeling of biological systems. Prior to that summer, GNS had focused almost exclusively on modeling signal transduction and gene expression in colon cancer cells. GNS was quite successful in that endeavor; they constructed perhaps the most detailed model of a cancer cell currently in existence.

During summer 2003, I worked with Jeff Fox, a founding scientist at GNS with a background in computational modeling of heart function. Dr. Fox was in the process of expanding the

modeling effort at GNS to include detailed models of heart cells and electrical activity in the heart. We worked in close consultation with two Cornell University professors, Robert Gilmour of the School of Veterinary Medicine and John Guckenheimer of the Department of Mathematics, to implement a computational model of a single canine heart cell and a prototype model of electrical propagation in cardiac tissue.

In response to both the importance and the difficulty of understanding heart arrhythmias, in spring 2004 GNS embarked on a multiyear project to develop a flexible and efficient software package to explore complex models of heart function, combining its expertise in the computational modeling of cell biology with the expertise of Gilmour and Guckenheimer. This project includes the creation of a detailed model of heart cell function using experimental data collected through Gilmour's lab to refine the computer model and vice versa; development and

incorporation of fast and efficient numerical techniques in conjunction with Guckenheimer; and exploration of the dependence of global features, such as wave propagation, on model parameters.

With support from the National Science Foundation's "Interdisciplinary Grants in the Mathematical Sciences" program, I joined the cardiac modeling team at GNS for the period September 2004 to August 2005 to develop computational models of heart cells and heart tissue. Our focus was to implement and refine a model of a single heart cell using experimental data collected at Cornell, to couple models of single cells in order to model heart tissue, to use this model of heart tissue to study the mechanisms underlying ventricular fibrillation, and to explore possible new approaches to the numerical simulation of these models.

My own goals for participation in this larger project were 1) implementation and refinement of one or more ionic models of a single cardiac cell and comparison with experimental data, 2) implementation of a 3-dimensional model of electrically coupled cardiac cells and identification of global properties such as conduction block, 3) investigation of numerical methods for improving speed and accuracy of simulation.

While I might have been able to expand my research focus in a different setting, the opportunity to work on the initial phases of a well-defined project with key players already identified has made the shift easier and quicker.
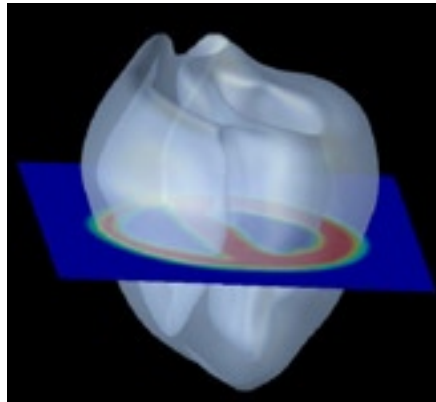
Three-dimensional computer model of the rabbit ventricular anatomy (anatomical data courtesy W. J. Rappel, UCSD). The cross-section corresponds to the simulation shown below.
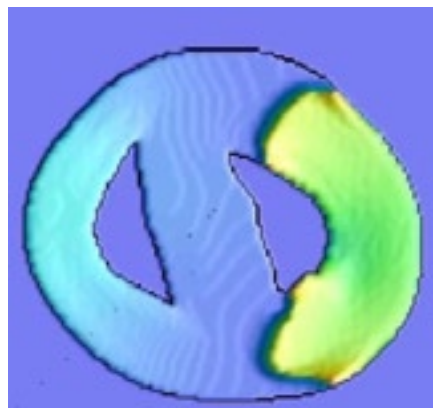
Computer simulation of electrical wave propagation in a two-dimensional ventricular cross-section. The electrical wave was initiated in the left ventricle and is spreading to the right ventricle. Yellow corresponds to activated cardiac tissue.

Spending a year at GNS has prepared me to establish additional collaborations in related areas, such as with neuroscientists at Purdue, and to teach and mentor graduate and undergraduate students wishing to do research in computational biology.

Moreover, the modeling of cardiac cells and tissue has much in common with other areas of computational modeling of biological systems. In particular, the electrical firing properties of cardiac cells have many similarities to the firing properties of neurons. Even some of the global phenomena, such as wave propagation and conduction block, are similar in these two systems. Thus I will have a natural opportunity to expand the range of my research in collaboration with others working in computational biology at Purdue.

After I return to Purdue, I plan to teach a course on computational biology, with an emphasis on heart modeling, for upper level undergraduates or beginning graduate students. As interest grows, I hope to develop a continuation class devoted to more sophisticated methods or to collaborate with researchers in Biomedical Engineering on a course more suited for other aspects of modeling, as well as mentor graduate and undergraduate students with an interest in computational biology.

For additional information about Greg Buzzard's research, refer to http://www.math.purdue.edu/~buzzard/ .

John Cushman

John Cushman was appointed a University Distinguished Professor of Earth and Atmospheric Sciences by the Board of Trustees on April 8.

Cushman came to Purdue in 1978 as Assistant Professor of Agronomy. In 1995 he joined the Department of Mathematics with a courtesy appointment as Professor, and earlier this year he accepted a joint appointment in the Departments of Earth & Atmospheric Sciences and Mathematics.

Cushman is an expert in microporous systems and nanofilms, porous media physics, applied mathematics, statistical mechanics, stochastic modeling, multiphase transport in swelling polymers, fate and transport of chemicals in the environment, and genetic evolution in microbial populations.

He is a member of the Society for Industrial and Applied Mathematics, the Society of Engineering Science, the American Association for the Advancement of Science, and the Materials Research Society. Cushman is a Fellow of the American Geophysical Union and the Soil Science Society of America. In 1995, he received Purdue's Herbert Newby McCoy Award, given to the faculty member who made the most significant contribution to science during the previous year. He serves on the editorial boards of numerous professional journals.

Cushman has authored four books, one novel, more than 170 papers and book chapters, and has given 120 invited presentations. He has served as a reviewer for programs at Oak Ridge National Lab, Los Alamos National Lab, Pacific Northwest National Lab, and Argonne National Lab.

MATHEMATICS AWARDS

|	
Eugene V. Schenkman Memorial Award	Sarah Shoup
Glen E. Baxter Memorial Award	Bess Walker
Michael Golomb Mathematics Award	Jason Anema
	Damir Dzhafarov
Meyer Jerison Memorial Award in Analysis	Kyle Riggs
Gerald R. MacLane Memorial Award	Andrea Rubiano
Merrill E. Shanks Memorial Award	Sally Diekelman
	Nicole Irving
Mathematics Faculty Award	Daniel Bryant
	Joshua Robinson
	Bradley Rodgers
Senior Achievement Award	Christopher Scheper
	Kenneth Wakeland
MAA Math Competition Team (1st place)	Kyle Riggs
	Bradley Rodgers
	Christopher Wilmore
Putnam Exam Recognition	Bradley Rodgers
Problem of the Week Recognition	
First Prize Award	Yuandong Tian
	Alan Bernstein
Certificates of Merit	Jason Anema
	Thomas Engelsman
	Miguel Hurtado
	Niru Kumari
	Ashish Rao
	Amit Sirsat
	Justin Woo, Jr.

2005 Student Awards Program

Graduate student and MacLane Award winner Andrea Rubiano (center) with Mrs. Gerald R. MacLane and graduate committee chair, Professor Johnny Brown.

To the left are award winners Bradley Rodgers, Jason Anema, Daniel Bryant, Damir Dzhafarov, Sally Diekelman, Sarah Shoup, Kyle Riggs, and Joshua Robinson.

Mathematics advisor Cara Wetzel presents undergraduate chair, Professor Kenji Matsuki, with the "Advisors Award — in appreciation of his wisdom." Looking on are advisors Janice Thomaz and Meredith Graham.
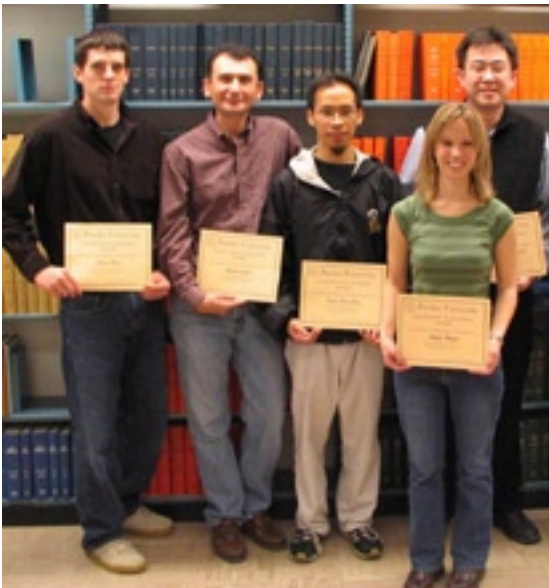
Five graduate teaching assistants were reconized for outstanding teaching: left to right James Price, Yalcin Sarol, Kuan-Hua Chen, Angela Hodge, Withit Chatlatanagulchai.

Scholarship recipients Kyle Riggs, Kari Cripe, Kenneth Wakeland, Amanda Brown, Shauna McClure, Deborah Simon, and Margaret Brown.

Award-winning students and scholarship recipients were recognized at the annual Mathematics Department awards program on April 28.

MATHEMATICS SCHOLARSHIPS

Alton D. and Juanita S. Andrews Memorial Scholarship
> Bess Walker

Thomas Arai Scholarship
> Michael Eusebio

Leonard D. and Anna W. Berkovitz Scholarship
> Matthew Barrett

Meyer Jerison Scholarship
> Kari Cripe

Virginia Mashin Scholarship
> Ashwin Adhikari
> Jennifer Hicks

Arthur Rosenthal Scholarship
> Lance Aschilman
> Megan Barr
> Lisa Bramer
> Margaret Brown
> James Martindale
> Kevin Query
> Kyle Riggs
> Clinton Walden
> Sarah Wilson

Jean E. Rubin Scholarship
> Ashwin Adhikari
> Lee Ballard
> Malik Haddadin

Helen Clark Wight Scholarship
> Shauna McClure
> Deborah Simon

ACTUARIAL SCIENCE AWARDS

Towers-Perrin Scholarship
> Amanda Brown
> Kevin Query
> Rahul Jyoti
> Jennifer Miller

CIGNA Exam Awards
> Jason Anema
> T. J. Cornwell
> Christopher Porter
> Ching Fong Sin

Accolades

Rodrigo Bañuelos was the second recipient of the Blackwell-Tapia Prize, established by Cornell University and MSRI, Berkeley, in honor of David Blackwell and Richard Tapia, two distinguished mathematical scientists who have inspired generations of young ethnic minority students and professionals to enter mathematics careers. Bañuelos was honored at the Blackwell-Tapia Prize and Conference Program on November 12-13, 2004, at UCLA's Institute for Pure and Applied Mathematics. The prize goes to mathematical scientists who have contributed significantly to their fields of expertise and who have served as role models for mathematical scientists and students from underrepresented minority groups or who have addressed in significant ways the problem of the underrepresentation of minorities in mathematics.

F. Shahidi

Freydoon Shahidi, Distinguished Professor of Mathematics, delivered the annual Joseph Fels Ritt Lectures at Columbia University on April 21-22, 2005. He spoke on "Functoriality Principle and the Spectral Theory of Automorphic Functions." Recent Ritt Lecturers have been Don Zagier, Karen Uhlenbeck, Edward Witten, Nigel Hitchin, Mike Hopkins, and Tom Mrowka.

Graduate student **Aaron Zerhusen** was awarded a 2005-06 Bilsland Dissertation Fellowship by the Graduate School. He received his masters degree at Purdue in December 2002 and is working under Laszlo Lempert in complex analysis in Banach spaces. Zerhusen's dissertation topic is an embedding theorem for pseudoconvex domains in certain Banach spaces.

A. Zerhusen

Two mathematics faculty received 2004-05 Joel Spira Teaching Awards: Professor **Steve Bell** for undergraduate service teaching and Associate Professor **Aaron Yip** for graduate service teaching. Recipients are selected on the basis of student votes. The awardees received a cash prize of $500 made possible by Purdue physics alumnus, Joel Spira, founder and operator of Lutron, a large manufacturer of switches and lighting controls.

S. Bell
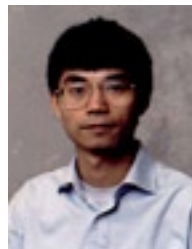
A. Yip

C. Neugebauer

Professor **Christoph Neugebauer** celebrated 50 years of math instruction in the department. His daughter, Jacqueline Klinker, organized a surprise party in the department, and the the occasion was featured in the August 30, 2004 edition of the *Purdue Exponent*. Neugebauer began his career at Purdue in 1954 after completing his Ph.D. at Ohio State University. He is known for his clear lecturing style, his profound knowledge, and his excitement for mathematics, which he still shares with colleagues and students alike.

University Faculty Scholar

Jiu-Kang Yu has been appointed a University Faculty Scholar. The honor recognizes outstanding accomplishments by Purdue faculty mid-way through their academic careers. The five-year, non-renewable appointment provides $10,000 per year of discretionary funding for the recipient's research program.

Jiu-Kang Yu

Yu has distinguished himself in the field of number theory, one of the oldest subjects in mathematics (dating back to Euclid), which is about patterns and structures of numbers. He has made fundamental contributions to the Langlands program in number theory with his work on the representation theory of p-adic groups, one of the building blocks of the Langlands program.

Yu's work on construction of supercuspidal representations is the major contribution to the subject. His paper "Construction of tame supercuspidal representations" (*Journal of Amer. Math. Soc.*, 14, 579-622, 2001) is considered one of the most important in the last ten years in the field; this work settles one of the major problems in representation theory of p-adic groups. The heavy geometric use of Bruhat-Tits buildings initiated by Yu may be the most effective tool in completing the construction in full generality.

Yu received the Chern Prize in 2001 for his contribution to Bruhat-Tits theory and supercuspidal representations, and in 2004 he was invited to give a series of lectures on the topic at the Fields Institute in Toronto.

In addition to representation theory, Yu has broad interests in fields related to number theory, exemplified by his joint work with Chai (*Annals of Mathematics* 2001) on congruences of Néron models and by his paper on Sato-Tate equi-distribution law for Drinfeld modules (*Compositio* 2003).

Dr. Leslie L. Martin, son of Eudoxia Martin, presented Nancy Eberle with a staff award that he and his family established in 2001. To Dr. Martin's right are his nieces, Linda Bryant and Diane Martin Frey. Nancy's husband, Jim, and graduate chair Johnny Brown are to Nancy's right.

Nancy Eberle, graduate office coordinator for the Department of Mathematics, received the Eudoxia Girard Martin Memorial Staff Recognition Award on December 9. The annual award recognizes a staff member who, in service to the University community, demonstrates those qualities of heart, mind, and spirit that evince a love for and helpfulness to students, faculty, and staff. The award was established in 2001 through an endowment funded by the sons of Eudoxia Martin, who served as executive secretary to several Purdue deans of engineering during the period 1920-1955.

Nancy began working in the Mathematics Department graduate office in 1969. According to Steve Bell, a former graduate chair, "Nancy is extremely sensitive to the needs and worries of our students; her intuition about what needs to be done for whom and when is uncanny. Furthermore, she has gently and competently trained every faculty graduate chair in the department to do their jobs, and she has helped them learn to put on a more humane and sympathetic face. She calmly and deftly handles the deluge of application materials and the incessant queries that come from applicants all over the world."

"The one thing that stands out to me is the kindness of our students," Nancy says. "They are so appreciative of all the routine parts of the job I do for them."

The students return that sentiment. According to Meike Niederhausen, "Nancy is the glue that holds the graduate program together. . . She is the perfect example of a true Boilermaker."

Nancy received a medallion, a framed description of the life of Eudoxia Girard Martin, and a $1,000 honorarium.

Faculty Notes

The 55th Midwest Partial Differential Equations Seminar was hosted at Purdue on April 9-10. Faculty organizers were P. Bauman, M. Chen, D. Danielli, N. Garofalo, A. Petrosyan, D. Phillips, A. Sa Barreto, P. Stefanov, and A. Yip.

Speakers included Andrea Bertozzi, UCLA; Jerry Bona, University of Illinois at Chicago; James Colliander, University of Toronto; Georg Dolzmann, University of Maryland; Marius Mitrea, University of Missouri-Columbia; Daniel Spirn, University of Minnesota; Konstantina Trivisa, University of Maryland; and Gunther Uhlmann, University of Washington.

The meeting was funded by the National Science Foundation and the Purdue Mathematics Department.

Three faculty promotions were announced in April.

Zhilan Feng (epidemiological and ecological modeling) and David Goldberg (representation of p-adic groups, with application to automorphic forms and number theory) were promoted to Professor.

Associate professor Gregery Buzzard (complex geometry, complex dynamics, applications to systems biology) was awarded tenure.

Professor James McClure was given a courtesy appointment as Professor in the College of Education.

Your Gifts are Important to Us!

As we continually strive to improve the quality of our programs, our goal is to increase funding for departmental student activities and scholarships. We thank those who currently support our work and hope that others will consider designating the Mathematics Department for gifts in future campaigns.

http://www.purdue.edu/udo/giving/give.shtml

Innovation in Learning

SAGE: a Homework on the Web System*
by Brad Lucier

*SAGE = Student Assignments Graded Electronically

A desire to help students succeed in their math courses resulted in the development of a unique system for doing homework on the web.

Each year, the Department of Mathematics teaches precalculus (algebra and trigonometry) to thousands of students. While most of these students have studied these subjects in high school, very few can claim mastery of the material upon entering Purdue. Their backgrounds vary: for some, high school algebra was their terminal math course, while for others, trigonometry was studied as a prerequisite for calculus.

In many cases, an adverse experience in a previous math class, and/or a general lack of motivation to "re-learn" material previously studied in high school, hinders our precalculus students. As a result, the fraction who either withdraw from algebra and trig or who earn a grade of D or F—a number called the W/D/F rate—is frequently high. For example, prior to the year 2000, the W/D/F rate for MA 154 (trigonometry) was at times over 60%.

Brad Lucier

In fall 2000, the Mathematics Department decided to investigate whether homework-on-the-web systems could improve the experience of our precalculus students. An examination of the offerings of several textbook publishers and independent software developers revealed that none of the systems available at the time was suitable for general use. Realizing the department would have to develop its own homework system, we decided to begin with trigonometry course material, and I undertook the development of a system based on the following principles:

(1) the system should be correct: it should accept all correct answers and reject all incorrect answers.

(2) the system should be flexible: all possible questions should be posable and checkable within the system.

To anyone not familiar with the field, the two principles seem self-evident—how could any system be developed that did *not* satisfy these principles? Nevertheless, here are some problems found in commercial systems in 2000.

(1) A problem in one publisher's system was posed as follows:

The value of $\sin(\pi/4)$ is:

(A) .707107   (B) 1.414214   (C) .5   (D) 2

Here the choices do not include the true answer $\sqrt{2}/2$, which can be input as sqrt (2)2, although (A) is an approximation to the answer. This can be corrected by simply changing the problem to "the value of $\sin(\pi/4)$ to six decimal places is …"

(2) Often systems will accept correct answers in one form but not in an equivalent form. For example, one might find that sqrt (2)/2 is accepted as the value of $\sin(\pi/4)$, but sqrt (1/2) is *not*. This *particular* example is often caught, but there are sometimes an *infinite* number of correct answers. For example one may ask: For which values of x is $\sin^2(x) = 1/2$? Use n to indicate an integer.

While the natural answer to this problem is Pi/4+(Pi/2)∗n, infinitely many other answers, including, e.g., Pi/4-(Pi/2)∗n and 3∗Pi/4+Pi∗n/2, are *also* correct. So an attempt at *pattern-matching* certain answers is not enough; some level of symbolic manipulation is necessary in the system.

(3) One commercial system we tested accepted sqrt(1-(cos(x))^2) as an answer to a question where the true answer was sin(x). A moment's reflection shows that this answer could not possibly be correct—sin(x) is positive half the time and negative the other half, yet sqrt(1-(cos(x))^2) is always positive.

How could this system say that these two functions were equal? It tests two functions for equality by evaluating them at a number of random points in an interval, and the default interval is [0,1]. For $x \in [0,1]$, both sin(x) and sqrt(1-(cos(x))^2) take the same values. This makes the mistake understandable, perhaps, but it is still an error.

Thus, a successful system needs to use floating-point arithmetic for testing whether answers are within a certain tolerance, rational arithmetic for other answers ($\tan^2(\pi/6) = 1/3$, *not* .333333333), and symbolic processing for other answers. Furthermore, the students are used to treating decimal numbers as *exact*—in most programming languages, for example, .1 is automatically transformed into the floating-point number nearest to .1, which is

$$3602879701896397/36028797018963968 = .10000000000000000555111512312 5\ldots$$

Students expect it to be treated as 1/10 *exactly*.

So much for correctness. To maintain flexibility, I decided to use a general-purpose programming language both to describe the problems and to check the correctness of the answers. This would give the maximum power and flexibility in designing problems, at the cost of extra complexity. In particular, it would not be reasonable to expect the lecturers teaching the courses to write code to define or check the answers to problems.

A further decision was to use the system mainly as an aid to understanding rather than as a way to assign grades. Students are offered unlimited attempts to answer each question. A student's score on a question is recorded on the due date for that question, but a student can go back later in the semester and attempt questions that were not completed earlier. The parameters of each problem are chosen randomly, sometimes from a small list (there are only so many "nice" multiples of π), sometimes from a larger set. So each form of a specific problem is given to a number of students,

but each student has a unique homework assignment for the course as a whole.

These design considerations led to the decision to use the programming language Scheme, a dialect of Lisp, to implement the main part of the system and to use Maple as a back end to provide the symbolic manipulations capabilities that were needed. Scheme has exact rational arithmetic, as well as floating-point arithmetic, and the system can be programmed so that, e.g., .1 is interpreted as 1/10 exactly.

Of course, building the system was a bigger task than first anticipated. I first collaborated with graduate student Jeremy TerBush for several years to build the main part of the system and later worked with another graduate student, Francisco Blanco-Silva, to finish it. Others involved in the project included Rita Saerens, supervisor of all teaching assistants; Fabio Milner, chair of the elementary services committee; Devi Nichols, coordinator of elementary services courses; and Tim Delworth, coordinator and main lecturer for MA 154.

Delworth showed an incredible amount of enthusiasm, support, and patience while the system was being developed. Each year a new group of students has to be taught that, yes, the answer the system expects is the *right* answer, since any deviance for correctness is treated as a design flaw and is fixed as it is uncovered. At first Delworth answered all questions about the homework system himself, a tremendous undertaking when 800 students are using it each spring semester. Later, a bulletin board system was established, and an undergraduate "answer person" hired, so that common questions could be answered by other students or by the undergraduate "expert".

The results have been good, even surprisingly good. The immediate effect was to halve the W/D/F rate to about 30%. Students

Tim Delworth

get immediate feedback on the correctness of their homework answers, and most students who make any attempt at all to do the homework answer nearly all problems correctly in the end.

After two semesters of such success, the W/D/F rate started climbing again, and the number of students in the class stayed roughly the same. Normally, a higher success rate would lead to fewer students repeating the class, which would lead to lower enrollment. Since the enrollment has stayed the same, however, it appears that more students are being placed in the course by academic advisors. One suspects, therefore, that the greater success rate has led advisors to assign more marginally prepared students to the course. Even so, the W/D/F has remained significantly below the pre-2000 rate of 60%.

Homework-on-the-web systems offered by publishers have improved since 2000. Perhaps a commercial system now exists that would satisfy our requirements. Recent attempts to extend the system to high school algebra have not met with success—we have not found a rigorous definition of the requirement to "simplify" an answer in algebra. But some attempts are still being made in this area, and perhaps a commercial system or a locally developed system will eventually be adopted for algebra courses.

In Memorium

Professor Y.L. Lawrence (Larry) Tong passed away on May 2, 2005 after a brief illness. He was 60.

Larry Tong received his Ph.D. in 1970 at Johns Hopkins University and worked there for one year as an instructor. He began his professional career at Purdue in 1971, joining the faculty as an assistant professor. He was promoted through the ranks, becoming a full professor in 1984.

Over the years Tong held visiting appointments at the Institute for Advanced Study in Princeton, the University of Sidney, the Max Planck Institute in Bonn, and National Taiwan University.

Tong's main research focus was on complex differential geometry, though he also branched out in other directions. His work is very highly regarded for addressing fundamental questions and for the depth and subtlety of the arguments.

He was a successful teacher at all levels from large calculus lectures to advanced graduate courses. He served on numerous committees, often as chair, and was associate head of the department for three years. His loss will be felt throughout the Department.

Yue-Lin Lawrence Tong

Professor Tong is survived by his wife, Hsaio-Ming, of West Lafayette; a son, Charles, in Ohio; and a daughter, Joann, in California.

A memorial fund has been established to assist tenure track assistant professors early in their careers. For information on how to make a contribution on-line or by mail, consult http://www.purdue.edu/udo/giving/give.shtml .
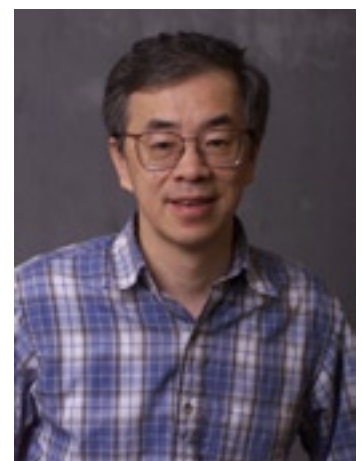
— Leonard Lipshitz

Math Club News

Left to right: Brad Rodgers, Kyle Riggs, Dominic Naughton, Jamie Weigandt, Chris Wilmore, and Jared Laughlin at Purdue's Fort Wayne campus.

Two student teams competed in the Indiana Colleges Math Competition (ICMC) held at the MAA Indiana Sectional Conference in Fort Wayne on April 2-3. The first team (Chris Willmore, Kyle Riggs, Brad Rodgers) won the competition and the second team (Jared Laughlin, Jamie Weigandt) finished 22nd out of 36 teams (a good performance considering there were just two students on that team).

The winning team's performance was very good. They scored 69 points out of 80. The second and third teams were from Rose-Hulman and scored 63 points and 48 points.

Math Club members worked with their advisor, Dr. Dominic Naughton, on some undergraduate research projects this past year. Jared Laughlin presented his project (Equal Area Functions) as a talk at the MAA conference. It attracted many students and was well received.

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