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FACULTY newsletter

CPMS Physical and Mathematical Sciences

ABOVE Dr. Paul Farnsworth

Finding Proteins With Laser Vision

Finding and studying important proteins has become more efficient and more accurate using laser technology newly developed in the Department of Chemistry and Biochemistry at Brigham Young University.

Because proteins are involved in almost every function within the human body, scientists are extremely interested in understanding how they work. During the last two years Dr. Paul Farnsworth and graduate student Matt Heywood have been fine-tuning a new method for detecting and studying proteins.

"Sometimes there's an interest in finding a particular protein that may be a disease marker or something like that," Farnsworth said. "We wanted a general purpose detector that could detect very small quantities of [these kinds of] proteins."

To study proteins scientists shine a laser on them as they flow through a thin tube, causing them to fluoresce. In order to make them more visible, protein molecules have typically been altered through a chemical reaction that adds fluorescent tags. While the added fluorescence is helpful in studying the proteins, it creates changes in the molecular structure that can confuse the results.

Farnsworth's method employs an ultraviolet laser that causes the proteins to fluoresce without having to chemically mark them first. Using this method, scientists could potentially detect and identify proteins without changing their structure or function.

One of the difficulties with this new technique is even though the proteins do fluoresce on their own, they will lose their fluorescent properties if they are exposed to too much ultraviolet light.

"You're kind of caught between a rock and a hard place," Farnsworth said. "In order to get the best results, you have to be careful about how much light you expose the proteins to and for how long, and then [figure out] how best to detect the light that comes out."

To find the ideal settings for detecting the proteins, Farnsworth developed a mathematical model that predicts how much light the proteins are exposed to as they flow through the thin tubes. He and Heywood then spent the rest of their time verifying the results of the mathematical model.

Using this new method, it may be possible in the future to detect proteins associated with certain diseases or medical conditions accurately, quickly, and inexpensively.

by: Erik Westesen

ABOVE Student presentations in the Showcase session

The SRC Experience: Student Presentations

The 25th annual Student Research Conference (SRC) was held March 19 giving hundreds of students the opportunity to present and learn about mentored research at BYU.

During the conference both undergraduate and graduate students from the College of Physical and Mathematical Sciences (CPMS) were given the chance to explain the research that they are conducting as part of their education. Students from other majors and from local high schools also attended the conference's Showcase session, in addition to some of the more technical sessions.

One of the major benefits of SRC is that it gives students valuable experience in presenting in a professional atmosphere. Professor Gus Hart, of the Department of Physics and Astronomy, said he encourages his students to present at SRC. While many schools only offer a poster session for students, BYU allows them to speak on their research, which he said is a far better experience.

"I think other schools do things similarly, but I think BYU tends to do it a little bigger, and a little better," Hart said.

Students are only given 12 minutes for their presentation. Andrew Misseldine, a student in the Department of

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ABOVE Dr. David Allred

Exploring the Red Dirt Closer to Home

Rovers speed across a vast expanse of red dirt, gathering samples to study back at the Mars Research Station — the Mars Desert Research Station (MDRS), that is. No, these are not robots on the red planet: they are the products of students from all over the world gathered to compete at the annual University Rover Challenge in Hanksville, Utah.

MDRS is a project of the Mars Society, a group committed to exploring the potential of establishing a permanent settlement on Mars. To test the feasibility of such a settlement, they select research sites on Earth that resemble this extra-terrestrial body. With its miles of barren red dirt, occasional volcanic boulders and lumpy landscape, Hanksville neatly fits the criteria.

The rover challenge allows students, including those from BYU, to take advantage of an opportunity to test their instruments on "Mars" and perhaps develop tools that will make future discoveries possible. Teams are pushed to "design and build the next generation of Mars rovers that will one day work alongside human explorers in the field," according to the official MDRS website. Each rover must successfully complete a list of tasks designed to test its range of skills, including precise movements when dealing with tiny objects and powerful acceleration across rough, bumpy terrain.

Brigham Young University has created its own student-run program, the BYU Mars Rover, which focuses on preparing a machine especially for this competition. The group is funded by the Departments of Physics and Astronomy, Mechanical Engineering, and Electrical and Computer Engineering. Dr. David Allred, a faculty member of the Department of Physics and Astronomy, currently serves as the program director.

This year's challenge will be held June 2-4, and includes nine registered teams from three countries: the United States, Canada, and Poland. In addition to bragging rights for an entire year, the winners will receive cash prizes and have the opportunity to present their work at the Mars Society Convention in Dallas, Texas.

by: Natalie Wilson

ABOVE Dr. David Kung

Photo: Luke Hansen/ Daily Universe

Making Fine Music, Mathematically Speaking

At a keynote speech given on March 18 at the 2011 Center for Undergraduate Research in Mathematics (CURM) Conference sponsored by the Department of Mathematics, Dr. David Kung taught students all about math, from the multiplication of fractions to calculus, and entertained them with music from Bach and even "The Simpsons."

Kung, a concert violinist and professor of mathematics at St. Mary's College, has focused a large portion of his research on harmonic analysis. In his lecture, he spoke about the math that explains how a string vibrates, what the human ear actually hears, and how music has changed during the last few hundred years.

After plucking a string on his violin, Kung explained that a string oscillates in multiple spatial patterns at once, creating a combination of sine waves. Each of these sine waves has a number of nodes, or stationary points, associated with its pattern. The number of nodes in the lowest frequency wave is related to the pitch of the note. To demonstrate what nodes look like, a student from the audience held one end of a jump rope while Kung swung the rope in a manner to create a wave response with a point in the middle that was stationary (a node).

"When I pluck my instrument, you think of this as a single note," Kung said. "In the single note, you're actually hearing a whole symphony of different sounds."

The length of a string and its tension determine the pitch of the note that we hear. However, the note consists of many sine waves, all of which are mathematically related to the lowest frequency sine wave that determines the pitch. The concept underlying the tuning of instruments is that these higher frequency sine waves may or may not sound "good" in combination with other notes that are played on the instrument.

Understanding the math behind a vibrating string changes how an instrument may be tuned. Because the strings extend beyond the bridge and the nut, creating non-ideal terminations of the string, the locations of the nodes are actually not at locations on the string that can be represented by a rational number fraction of the string. Rather, they end up being at irrational fractions of the string. This effect leads to the multiple sine waves on the string being potentially "out of tune."

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ABOVE Dr. Jay McCarthy

Simplifying Cyberspace & Programming

A building as large as a football stadium stacked with three stories of computers—sound crazy? Actually, it's facilities like these that make the Internet possible. Maintaining them, however, can be very costly. This is where Jay McCarthy, a faculty member in the Department of Computer Science, comes in.

McCarthy has developed a technique for programming web applications like Gmail, Blackboard, Amazon, Ebay, etc., enabling companies to perform the same tasks with fewer machines.

Computer programming has been around for a while, but Web programming is a comparatively new field of twenty years. Despite the similarities between these two disciplines, Web programming presents new complex problems that cannot be directly solved with traditional programming approaches.

"The way that computers talk online is such that a lot of the techniques that developed over the sixty years of programming history are not obviously usable online," McCarthy said.

Some of the online solutions that have been developed are roundabout and inefficient. However, with McCarthy's technique, Web programmers can use the simpler, traditional techniques. This cuts human labor and frees up computer space as well.

The Internet is based on a network of computers that must store vast amounts of information in order to satisfy the millions of Internet search requests daily. The same indirect methods that bogged down Web programmers can also clutter this network. But, again thanks to McCarthy, a more straightforward approach of computer programming simplifies computer interactions, enabling fewer machines to do the same job.

Twenty companies, including the medicine and dentistry school of Queen Mary, University of London, are already benefiting from McCarthy's work, resulting in a more efficient use of their time, space, and machines. Perhaps in the future, even more organizations will use his technique to generate Internet data.

by: Natalie Wilson

ABOVE Dr. Tony DeRose

Behind-the-scenes Look at Pixar Mathematics

Tony DeRose, winner of a Scientific and Technical Academy Award in 2006, took students to the digital backstage of Pixar Animation during his keynote lecture at the Center for Undergraduate Research in Mathematics (CURM) Conference sponsored by the Department of Mathematics on March 18.

As the leader of Pixar's research group, DeRose has extensive experience in using math to create art, tell stories, and visit unseen worlds. During a lecture on BYU's campus, he gave students a small preview of how mathematics makes it all possible.

DeRose, who has a doctorate degree in computer science and a bachelor's degree in physics, explained how Pixar characters are animated. The explanation involved some math that is more complex than what's taught in the average high school class, but visually it was fairly easy to understand. Controlling each of the 10,000 points in a character's body would be extremely difficult for animators. DeRose explained how, through math, they are able to turn the characters into digital puppets — only needing to control about 300 points on the puppet.

"One of our jobs as technologists at Pixar is to build really cool and powerful mathematics underneath, and then build artist's tools on top of them that let the artists focus on the creative and artistic task," DeRose said. "The mathematics is just a power tool that turns their high-level artistic input into whatever motion or shape or color variation is desired."

Pixar movies all start out with story telling. Once the writers have a story idea put together, they create a set of sketches and recordings that explains what the movie will be like. Then, concept artists further sketch out what the world and its characters will look like.

DeRose said that only after all this preliminary work has been done do the animators start. They then begin to work with the mathematicians to digitally create the setting and characters.

Because the majority of their software is created within Pixar, DeRose indicated that there are many interesting job opportunities with a company like Pixar. He said if mathematics majors are interested in this field, they should take as much applied math and linear algebra as they can, learn C++, and take a basic graphics animation class.

At the end of his lecture, DeRose also revealed that his favorite Pixar film is The Incredibles. He said he would love to see a sequel, but that there are currently no plans for a second movie.

by: Erik Westesen

ABOVE Statistics student, Michelle Withers, presents her research

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Mathematics, said that the short time is challenging because so much goes into a research project. Presenting at SRC helped him hone his skills as a presenter.

"You have to balance how much background you give, but still present your results with enough [information] that it makes sense to your audience," Misseldine said. "[SRC] definitely helps me focus on the important things; oftentimes you only get a small window to pitch your research."

SRC also helps educate the BYU community on the research being done at the university. Hart said it was fun to learn more about the research of colleagues in his department and to see what students are doing.

Students from colleges outside CPMS also found value in the conference. Jennifer Kironde, a senior in public health, said it was important to her to learn how physics and science apply to the real world. She said she felt that people often get lost in numbers and math, and forget about the application and good that science can do.

"I think becoming a well-rounded person means getting out of your comfort zone, giving people a chance to teach you something you don't know," Kironde said. "I'm a senior now, but if I could do it again I think I would inquire into studying physics and astronomy."

Many students who attended found that SRC helped them better solidify what they wanted to study at BYU. One freshman, Natacia Snow, is currently a math education major, but she had been thinking about switching to English. After attending the conference, she said she wants to stay with math education.

"I think it's a good opportunity, especially for freshmen if they're dabbling in some math and physics, to go to some technical [presentations]," Anthony said. "They could find out, 'Oh I really like quantum physics,' or 'I really like relativity.'"

The Showcase session was organized to help people who feel less math-and-science-minded to better understand what CPMS is involved in. The students who presented talked about how they did their research, and what it meant to "normal people."

A group of high school students also attended the session, and afterwards went to a physics demonstration. Hannah Waddel, a high school sophomore, said she is very interested in a career in science. She said she especially liked the physics demonstration, and it helped her consider a career in that field.

"[SRC] is a great opportunity to learn about future careers and how people can apply [science] to problems," Waddel said. "Sometimes it seems like it's all really abstract, like I'll never use it – SRC shows that it is useful."

by: Erik Westesen

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Early musicians tuned their instruments using intervals – for example, they would make sure every fifth note in the scale was in tune. Using intervals to tune an instrument will work in one key, but if playing in another key, the relationship between notes changes so that they are not in tune.

For that reason, modern tunings don't just tune every fifth note. They try to equalize discrepancies in the "proper" tunings over all notes so that every key sounds in tune; this is called equal tempered tuning. Such a tuning allows musicians to play music that will sound right to our ears in any key, even though mathematically the instruments are not quite in tune.

The equal tempered tuning has only begun to be used in the last century. Changes in tuning methods help to explain changes in music. When Bach was composing his pieces, there were certain chords that did not sound right in certain keys. Bach had to write his music with this in mind, in order to avoid those chords. When he changed keys, he had to change to a key that he knew would still sound good for the chords he wanted to play.

"Both Bach and [modern composers] are using all 12 notes that are available to them; they're just using them in different ways . . . [partially] because of the underlying mathematics," said Kung.

Kung finished his lecture by playing Bach's Chaconne, Partita No. 2 for violin. As Bach's music filled the hall, Kung left listeners wondering how Bach's music might have been different if he had composed his music with an equal tempered scale.

by: Erik Westesen

Dates to Remember

University Commencement
Thursday April 21, 4 p.m.
Marriott Center

Line Up for Commencement
3:15 p.m.
North ASB Parking Lot

College Convocation
Friday April 22, 8 a.m.
WSC Ballroom

Line Up for Convocation
7:30 a.m.
WSC Garden Court

COLLEGE GRANTS

Physics & Astronomy

Lawrence Rees
Sponsor: University of Michigan
Title: New Detectors, Electronics and Algorithms for Fast Neutron Spectroscopy

COLLEGE PUBLICATIONS

Chemistry and Biochemistry

J. Song, D. Jensen, D. Hutchison, B. Turner, T. Wood, A. Dadson, M. Vail, M. Linford, R. Vanfleet, R. Davis, "Carbon-Nanotube-Templated Microfabrication of Porous Silicon-Carbon Materials with Application to Chemical Separations", Advanced Functional Materials, 2011, volume 21/issue 6, pp. 1132-1139

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Geology

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Mathematics

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R. J. Draper, M. Adair, P. Broomhead, S. Gray, S. Grierson, S. Hendrickson, A. Jeppsen, J.D. Nokes, S. Shumway, D. Siebert, G. Wright, "Seeking Renewal, Finding Community: Participatory Action Research in Teacher Education", Teacher Development, 2011, volume 15/issue 1, pp. 1-18

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Statistics

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S. Guthrie, J. Michner, B. Wilson, D. Eggett, "Effects of Environmental Factors on Construction of Soil-Cement Pavement Layers", Portland Cement Association, Skokie, IL, 2011

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J. Lawson, P. Aggarwal, T. Leininger, K. Fairchild, "Characterizing Variability in Smestad and Gratzel's Nanocrystalline Solar Cells: A Collaborative Learning Experience in Experimental Design", Journal of Statistics Education, 2011, volume 19/issue 1, pp. 1-23

T. Parker, O. Hoopes, D. Eggett, "The Effect of Seat Location and Movement or Permanence on Student-Initiated Participation", College Teaching, 2011, volume 59/issue 2, pp. 79-84

P. Ranjan, W. Lu, D. Bingham, C. S. Reese, B. Williams, C. Chou, F. Doss, M. Grosskopf, J. Holloway, "Follow-up Experimental Designs for Computer Models and Physical Processes", Journal of Statistical Theory and Practice, 2011, volume 5/issue 1, pp. 119-136

C. S. Reese, A. Wilson, J. Guo, M. Hamada, V. Johnson, "A Bayesian Model for Integrating Multiple Sources of Lifetime Information in System-Reliability Assessments", Journal of Quality Technology, 2011, volume 43/issue 2

G. Schaalje, M. Roper, G. Snow, "Extended Nearest Shrunken Centroid Classification: A New Method for Open-set Authorship Attribution of Texts of Varying Sizes", Literary and Linguistic Computing, 2011, volume 26/issue 1, pp. 71-88

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B. Wilson, W. Guthrie, D. Eggett, "Analysis of Fly Ash as a Partial Substitute for Portland Cement to Minimize Freeze-Thaw Damage in Cement-Treated Base", Transportation Research Board 90th Annual Meeting Compendium of Papers, Transportation Research Board of the National Academies, Washington, D.C., January 2011

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