ME news Summer 2015

Stanford | ENGINEERING
Mechanical Engineering

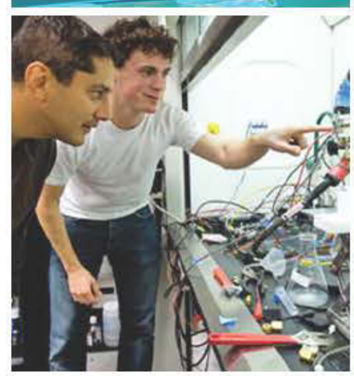
DEPARTMENT OF MECHANICAL ENGINEERING | STANFORD UNIVERSITY

FLOW PHYSICS & COMPUTATIONAL ENGINEERING

BIOMECHANICAL ENGINEERING

DESIGN

THERMOSCIENCES



MECHANICS & COMPUTATION

Dear Alumni and Friends,

Greetings! I am pleased to have this opportunity to share with you the latest exciting developments in the Mechanical Engineering Department here at Stanford. We have had a great year with research breakthroughs and a sustained commitment to teaching excellence. The big news related to our teaching is the surging interest in mechanical engineering among the Stanford undergraduates, which has caused our enrollments to grow steadily over the past 5 years. We have responded with a major ongoing effort on improving and extending our core offerings in design and in the thermal and mechanical sciences. The planning phase launched last Fall and there are concrete changes on track starting in AY 15-16.

We are investing heavily in our leadership in research by supporting the early careers of the many faculty we have recently hired into the department. Among our most recent recruits is Professor John Dabiri, who will formally start this summer and bring his work on wind turbine technology and bio fluid mechanics to campus. Professor Dabiri's research interests are highlighted in an article on page 2 of this newsletter. We have also recently recruited two faculty in the product design area, Professors Erin MacDonald and Sean Follmer. Professor Follmer is a specialist in human-computer interactions and will join us at the end of the summer. You can read more about Professor Follmer's interests on page 3, and Professor MacDonald joined us last Fall and will be featured in a future issue of this newsletter.

Our department is home to a vibrant group of mid-career specialists working on solid mechanics. Their interests are primarily in advanced simulations of materials and biological structures and range from predictions of wear and degradation of automobile engine materials to the mechanical functionality of human organs like the heart and the brain. This is a particularly creative group of young scholars, and not all of their contributions lie strictly within the traditional areas of mechanics. The article on page 6 highlights a highly innovative contribution — an iPad Brailler — that emerged from the efforts of Professor Adrian Lew and his team.

Last year, the department went through an important strategic planning exercise, which occurs approximately once every 5 years. The committee included all of the associate professors in the department, who happened to span nearly all of the diverse disciplinary specialties of the department. The committee put forward a number of important recommendations that we are considering and implementing as a department. One of these recommendations was to develop a student-oriented annual ME research conference. The first offering of this conference occurred this past May and was a tremendous success. Please refer to pages 4 and 5 for more details.

As always, we invite you to visit our website at http://me.stanford.edu to learn about more of our research and teaching activities.

Kenneth E. Goodson
Davies Family Provostial Professor
and Robert Bosch Chairman

Fluid Mechanics — From Biological Inspiration to Real-World Impact

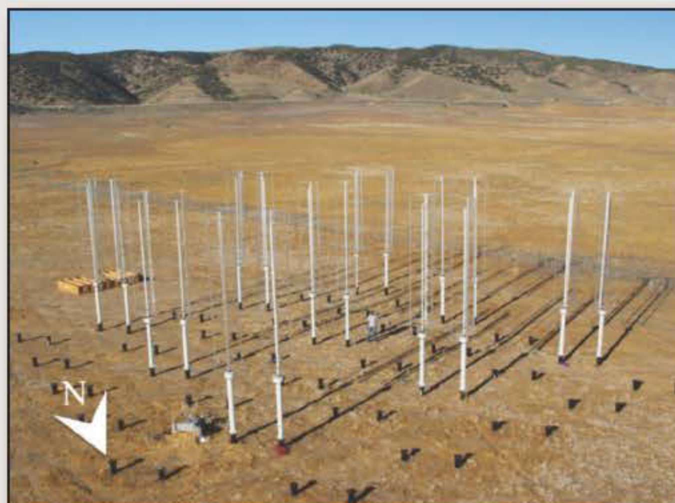
John O. Dabiri

One and a half billion people around the world have no access to electricity. For hundreds of millions more, access comes at a heavy price, both economically and environmentally. Yet in most of these cases, renewable energy in the form of air and water currents is literally within reach. Our challenge is to harvest that energy reliably and at a reasonable cost, often in the absence of a modern electrical infrastructure.

My lab is pursuing fundamental research in fluid mechanics that can be brought to bear on the issue of global energy poverty. Renewable energy sources are more diffuse than conventional fuels, so we must think creatively about how to harness sufficient energy to meet the demands of developing countries and to complement the existing generation in developed nations, while avoiding unintended impacts on land and water use. Over the past several years, we have focused our efforts on distributed wind energy generation. In contrast to the monolithic structures that have become icons of modern wind energy technology, distributed deployment of smaller wind turbines with blades that spin on a vertical axis (known as vertical-axis wind turbines) has shown potential to facilitate access to wind energy where cost, size, and environmental constraints have been showstoppers for traditional horizontal-axis wind turbines.

Optimization of wind farms for maximum power generation and minimum environmental signatures is a multi-scale, multi-disciplinary problem with innumerable design possibilities. Our guiding philosophy has been to take inspiration from engineering solutions found in nature, such as the hydrodynamics of fish schooling and gas exchange in plant canopies. By elucidating and then exploiting the governing fluid mechanics principles underlying natural flow-structure interactions, we have been able to demonstrate that order-of-magnitude increases in the footprint power density of wind farms are achievable. Large-scale field tests, such as the one in southern California shown here, have been an important tool for bridging the gap between laboratory models and commercial implementation, while also providing key data to ground-truth numerical simulations.

At Stanford, we're pursuing exciting initiatives that will enable real-world testing of distributed wind energy technologies in the Altamont Pass and of tidal and wave energy technologies in collaboration with Stanford's Hopkins Marine Station. Both thrusts will provide students with essential hands-on experiences to complement their classroom learning. The combination of engineering science and design thinking in Mechanical Engineering provides an ideal incubator for this activity and for our other projects in the broader field of fluid mechanics. These include research aimed at understanding the role of fluid dynamic forces in the function, evolution, and ecology of marine organisms; diagnostics of cardiac function based on blood flow; and, biological oceanography from local to global scales. In each case, we are motivated by the opportunity to create altogether new areas of academic inquiry, to invent biology-inspired technologies, and to translate ideas into real-world impact.



Field test of an array of vertical-axis wind turbines in southern California. Scale is indicated by the author, standing in the center of the array.

Designing Shape-Changing User Interfaces

Sean Follmer

Product design today is at a crossroads. The Internet of Things is upon us and devices are becoming interconnected, including more functions due to the low cost of microcontrollers and wireless connectivity. Digital convergence has become a reality; a mobile phone acts as a communications device, web browser, game player, camera, and thousands of other uses, but has the same static physical form for all of these applications. Designers often lack the tools to support all of these new computational features gracefully. Instead, they rely on complex on-screen menus, embracing the ease of graphical display while ignoring physical affordances. My belief is that the physical form of products and devices must better reflect their interactivity. We must embrace the dexterity of the hand, and find new ways to represent digital information through physical form and to interact in richer ways through our hands and bodies.

My research looks at how we can apply tactile and shape-changing displays and interfaces to address the lack of physical affordances in today's interactive products. This involves the creation of tangible interfaces that use their form to adapt to the functions and ways users want to interact with them, so users can directly manipulate physically embodied information. In order to prototype these interactions, technologies are developed to alter material properties (stiffness, shape, color, etc.), taking inspiration from fields like haptics, soft robotics, and materials science.

Tactile displays, which allow users to interpret information not only through visual display but also directly through form, can be used to provide physical affordances on demand. With my colleagues at the MIT Media Lab, I developed inFORM, a fast, large scale tactile display, which can render physical forms in 2.5D, by moving 900 physical pins up and down 100mm at 30fps (Figure 1). An array of 900 actuators controls the height

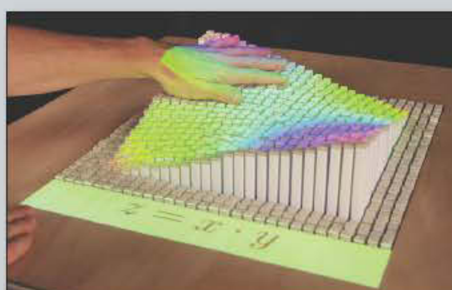


Figure 1. Representing 3D surface equations physically on inFORM, a large-scale tactile display.

of physical pixels arranged in a 30 x 30 grid, in a 38cm x 38cm space. The inFORM display can change shape to fit the context of different applications – a physical model is rendered allowing direct physical manipulation of a computer-aided design, physical bar charts rise out of the surface, or a 3D map is displayed allowing urban planners to physically visualize and modify a city design. Physical user interface elements such as buttons, or sliders, can be positioned around content and repositioned easily. The form becomes the function. But we cannot only render digital

Figure 2. Physical Telepresence provides physical embodiment, remote manipulation and new capabilities through computer-mediated teleoperation. Here, local and remote users physically interact with a 3D car model.

information, we can also represent remote user's arms through the display — enabling physical telepresence (Figure 2). Here, users can effectively reach out of the screen and manipulate objects at a distance, creating a much stronger sense of presence and allowing for gestural communication found in co-located interaction. In addition, two remote users can modify a shared physical 3D model, with changes synchronized in real time.

My research also incorporates the exploration of how tactile display and larger shape change can be used in mobile devices to create rich interaction possibilities. In

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Mechanical Engineering Students Showcase Imaginative Research at First MECON

Could we create 3D models of the brain so accurate that surgeons could use them to plan operations? Build space probes that hop over the surfaces of low-gravity comets and asteroids? Or develop micro-devices that would train lab-grown muscle cells to patch damaged hearts?

These were just three among the more than one hundred projects that were showcased at a recent conference designed to give students and faculty a chance to get a sense of the broad range of interdisciplinary initiatives being pursued by members of the Stanford Mechanical Engineering community.

"We all spend so much time focused on our own areas that we thought it would be valuable to create an opportunity for everyone to see all the other interesting work that is going on," said Ellen Kuhl, an associate professor of mechanical engineering and one of the organizers of the first Mechanical Engineering Conference (MECON).

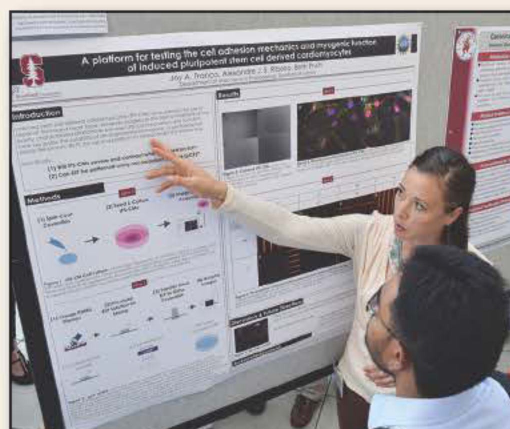
MECON organizers (left to right): Martin Winterkorn, Alexander Zollner, Professor Ellen Kuhl, Charbel Eid. Not pictured: Professor Xiaolin Zheng.

This inaugural MECON, held on May 1, featured 18 research talks and 92 poster presentations. Associate Professor Xiaolin Zheng and graduate students Alexander Zollner, Charbel Eid and Martin Winterkorn worked with Kuhl and Department Chair Kenneth Goodson to organize a daylong series of events that culminated with an awards presentation by Stanford Engineering Dean Persis Drell.

Department Chairman, Professor Kenneth Goodson, welcoming the ME Community to the inaugural Mechanical Engineering Conference (MECON).

A midday poster session and luncheon was a social high point of the day as the entire department turned out to eat wrapped sandwiches, sip soft drinks and walk down the rows of students eager to brief colleagues on their projects.

At one poster, graduate student Joy Ann Franco explained how mechanical engineers are researching ways to develop a type of repair kit for failing hearts. Our hearts beat thanks to specialized muscle cells known as cardiomyocytes. In heart failure, these cardiomyocytes stop working properly or die altogether. Unfortunately, the heart does not heal itself and so the damaged cells cannot be repaired. Biomedical researchers would like to use cardiomyocytes derived from stem cells in the lab to patch damaged heart tissue. But so far there's been a hitch. Researchers have not yet learned how to coax their stem cell-derived cardiomyocytes to look and behave like working heart cells. Franco is



Joy Ann Franco, a first year mechanical engineering student from Professor Beth Pruitt's group presenting her research on engineering cardiac heart muscle cells as a potential treatment for heart failure.

collaborating with postdoctoral scholar Alexandre Ribeiro and Associate Professor Beth Pruitt on

Mechanical Engineering Students Showcase Imaginative Research at First MECON (cont.)

the following approach: creating microdevices that would train lab-grown cardiomyocytes the way a gardener might train ivy to grow up a lattice.

Professor Xiaolin Zheng and Department Chairman, Professor Kenneth Goodson, judging the podium presentations.

Further down the row of presenters graduate student Caitlin Ploch held a three-dimensional replica of a brain as she explained her poster. CT scans and similar technologies can image the brain with great precision. Marrying such scans with 3D printing technology makes it possible to create accurate models of a patient's brain injury. Ploch is working with business school graduate student Chris Mansi and Professor Kuhl to use these realistic models as preoperative training tools to help neurosurgeons plan and practice complex procedures.

Dean Drell presenting the 1st place student poster award to Georgios Katsikis from Professor Manu Prakash's research group. He also wins training with a professional race car driver on the Audi racing track.

Turning to space exploration, PhD student Ben Hockman let visitors hold the cube-shaped prototype described in his poster. Hockman is working with Assistant Professor of Aeronautics and Astronautics Marco Pavone to solve a problem: how to explore asteroids, comets and small moons whose low gravity make their surfaces ill-suited for rover-type explorers. The possible solution, embodied in the cube that visitors got to hold, was a satellite engineered to hop lightly from point to point like a tumbleweed, yet sturdy enough so that its instrumentation could survive repeated shocks.

"Mechanical engineering is an incredibly broad discipline, and the talks and posters at this first MECON demonstrate how our students and faculty are collaborating across the entire campus," said Goodson, who is the Bosch Chairman of Mechanical Engineering and the Davies Family Provostial Professor at Stanford.

Goodson introduced Dean Drell, who closed this successful first conference by presenting awards to some of the notable speakers and posters.

Three undergraduates were among those honored by the Dean: Pedro Milani, Will Roderick and Andrea Stein. Four graduate poster presenters received special mention: Yanli Wang, Tany Liu, Erica Castillo and Georgios Katsikis. Three graduate podium awards went to Hardik Kanaria, Michael Barako and Mona Eskandari.

Dean Persis Drell presenting the student poster and podium presentation awards.

"I am delighted at the way this first MECON turned out," Goodson said. "We owe so much to the student and faculty organizers, and to all the members of the ME community who took part."

— Tom Abate

A Brailler on a Flat Screen

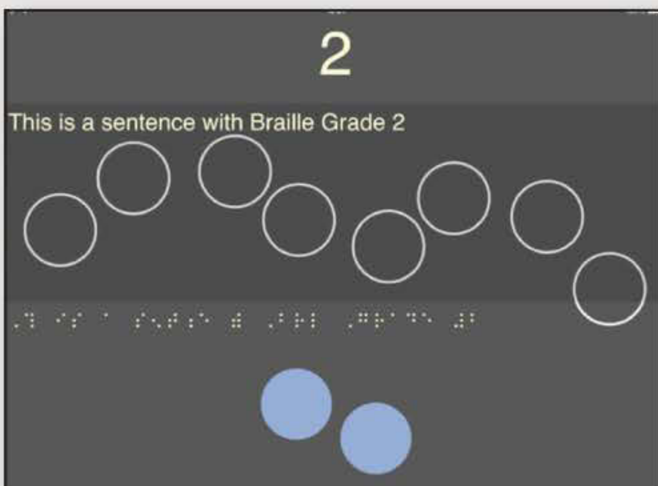
Adrian Lew

Do you have an iPhone or an iPad? If so, then skip to the end of the article to learn how a blind or visually impaired person would type in it before you continue reading, and time how long it takes you to type your name. The five minutes or so I once spent waiting for a blind friend to type a password on an iPad cauterized my impression of how much a blind-friendly way to type on a touchscreen device was needed.

This was the state of affairs back in May 2011, when Dr. Sohan Dharmaraja (who was then an engineering doctoral candidate) and I sat down in a campus coffee shop to choose a project for an intern to the summer program of the Army High-Performance Computing Research Center. The labyrinthian pathways of a brainstorming session took us to the Office of Accessible Education at Stanford, where we were introduced to a Brailler: a device with ten keys to type Braille. At that time, there was no Brailler available on a touchscreen device.

For people who learned to read and write Braille as children, less than 10% of all visually impaired people in the U.S., typing on a Brailler is second nature, attaining typing speeds that are often faster than on standard keyboards. Similar to a typewriter, a Brailler indents a page to form up to six raised dots per Braille cell, which can then be "read" by sensing them with the fingers.

An electronic Brailler stores the sequence of Braille cells, which can then be sent to an embosser or "Brailler printer." Alternatively, the Braille cells can be translated to text. For example, Braille cells "⠯" and "⠿" indicate the words "and" and "for" in contracted Braille. The translation of the same cells is different under other Braille codes, such as for Spanish or mathematics.



A screenshot of iBrailler Notes: the circles are the locations where the fingers have been placed, and the keyboard calibrated. For sighted friends and for partially sighted users, the Braille cells and their translation are also shown. The typing screen is devoid of buttons. Instead, functionality is accessed through gestures.

"How do they find the keys?" This is the question most frequently asked about a Brailler on an iPad; it's a flat screen after all… For us, the answer was evident: let's put the keys under the fingertips of the users, so they do not need to search for them. Users simply hold their fingertips anywhere on the glass surface of an iPad and the software then draws the keys around them. If the user loses track of the keys, the hands can be lifted and then replaced on the glass to reset the keys to the fingertips. This idea received an Honorable Mention in the 2012 Chairman's Awards for Advancement in Accessibility of the Federal Communication Commission, and was echoed by the press around the world. Since the introduction of iOS 8, it is now offered in every iPad and iPhone as a feature called "Braille Input."

Typing long texts requires additional functionality, like navigating around the text, and utilizing copy, cut, paste, undo and redo. Blending these functionalities in a way that is friendly to a visually impaired user requires designing an app with such users in mind. Recently, we did this with "iBrailler Notes," combining the adaptive keyboard with text editing functionalities, and it can now be found in the App Store. Over time, we expect iBrailler Notes will incorporate all of the functionalities found in traditional Brailler devices. For now, we are pleased that the basic

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Design Shape-Changing User Interfaces *(continued from pg. 3)*

this situation, the challenge is not only to design actuation techniques that require low power in a small form factor, but also to achieve large-scale changes in form. These mobile devices might change shape to provide subtle haptic notifications, or to adapt to different applications. I advised a team of researchers to create PneUI, shape-changing interfaces powered by pneumatic composites that integrate sensing and actuation. Our design is a mobile device that can change form to accommodate different functions: a curved shape for talking on the phone, a stiff bar for touch interactions, and a wrist worn device while on the go. The device also uses motion to convey information.

In addition to computationally controlled shape change, users should be able to define the form of their own device on demand by interacting with deformable UIs. Here, a user can customize the form of the device to match the current task. This approach requires devices that are stiff when users apply them to an existing task, and soft when users are changing their shape to suit another purpose. To accomplish this, particle jamming, a variable stiffness technology, is applied to user interface design. I developed a number of novel embedded sensing techniques to acquire the 3D shape of the device, either through optical sensing with index matched jamming media and hydraulic fluid or capacitive sensing. When a user shapes the device into a given form, the system identifies it and locks the shape using particle jamming. The system switches the mode to match the form, for example a game controller (Figure 3).

Figure 3. Shape-changing devices, such as Shapephone, can lock into different shapes using particle jamming.

My vision is to create a future in which interactivity is not limited to pixels on the screen, but rather considers dynamic physical form acting in concert with hands. Robots are entering the home, but their functions right now are limited to cleaning and domestic roles. I see a much broader application for actuated products that use dynamic form to speak and interact with us, driven by design. At Stanford, my new research group will explore new designs and technology for this new type of ubiquitous robotics. We will also integrate user centered design principles to understand how people interact with such devices and work to uncover new opportunities for interaction. Computation and interaction, undoubtedly, will serve an increasing role in design but, at the same time, it is imperative that design serve a fundamental role in these communities.

A Brailler on a Flat Screen

(continued from pg. 6)

version of iBrailler Notes is available to potentially millions of sight impaired people.

How to type with Apple's VoiceOver: From Settings, select "General," then "Accessibility," scroll to the bottom and choose "Accessibility Shortcut." Choose "VoiceOver" among the options present. Hereafter, triple clicking the home button will activate/deactivate "VoiceOver," Apple's main technology to make touchscreen devices and computers accessible to people that are visually impaired. To get a feel for how to use it, open, for example, the "Notes" app and choose to create a new note. This will bring up a keyboard for you to type. Make sure that your device is not muted, and then triple click the home button: you should hear the device saying "VoiceOver On." Now touch any of the keys in the keyboard. This will select the key and you will hear the letter's name, but it will not be typed. To type, make sure the letter is selected, and then double tap the screen. Now, close your eyes, type your name, and time how long it takes you to do it. When you are done, triple click the home button to deactivate "VoiceOver."

ME *faculty achievements*

Mark A. Cappelli
Best Poster Award, National Nuclear Security Administration Annual Symposium, 2015.

Ovijit Chaudhuri
DARPA Young Faculty Award, 2014.

John O. Dabiri
Schweppe Endowed Lecture, University of Texas, 2015.
Fellow, American Physical Society, 2014.
Best Paper (Wind Energy), ASME Turbo Expo, 2014.

Charbel Farhat
Den Hartog Lecture in Mechanics, MIT, 2015.
Designated Primary Key-Influencer, U.S. Navy, 2014.

J. Christian Gerdes
Best Paper Award, 12th International Symposium on Advanced Vehicle Control (with N. Kapania), 2014.

Kenneth E. Goodson
Hawkins Memorial Lectureship, Purdue School of Mechanical Engineering, 2015.
Rohsenow Lectureship, MIT, 2015.
Fellow, American Physical Society, 2014.
Donald Kern Heat Transfer Award (AIChE), 2015.
Yunchuan Aisinjioro-Soo Distinguished Lectureship, University of Illinois Urbana Champaign (2015).

Ronald K. Hanson
Goodwin Memorial Lecture, California Institute of Technology, 2015.
Honorary Professor, University of Duisburg-Essen, Germany, 2014.
Honorary Professor, Northwest Polytechnic University, China, 2014.
Milton van Dyke Award in Gallery of Fluid Motion, 2014.

Thomas W. Kenny
Senior Associate Dean of Engineering for Student Affairs at Stanford, September 2015.
Richard W. Weiland Professorship in Mechanical Engineering at Stanford, 2014.
Senior Member, IEEE, 2014.
Fellow, ASME, 2014.

Ellen Kuhl
Fellow, American Institute for Medical and Biological Engineering, 2014.
Midwest Mechanics Seminar Speaker, 2014.

Sanjiva Lele
Best Paper Award, AIAA Aviation and Aeronautics Forum and Exposition (with D. Dawson), 2015.

Ali Mani
ONR Young Investigator Award, 2015.

Arun Majumdar
Fellow, Indian National Academy of Engineering, 2014.
Honorary Member, ASME, 2014.

Beth L. Pruitt
Fellow, ASME, 2015.
Best Poster Award, NanoEngineering in Medicine and Biology Conference, 2014.

Juan G. Santiago
VIII Editor's Choice Author, *Journal of Chromatography A*, 2014.

Sheri D. Sheppard
U.S. Professor of the Year for doctoral and research universities, Carnegie Foundation for the Advancement of Teaching and CASE, 2014.
Best Paper Award, ASEE Annual Conference (with S. Giersch, F. McMartin, E. Nissen and P. Weilerstein), 2014.

Sindy K. Y. Tang
NSF CAREER Award, 2015.

Hai Wang
Distinguished Paper Award, 35th International Symposium on Combustion (with Y. Tao and J. Camacho), 2014.

Xiaolin Zheng
Young Investigator Lectureship, *Nano Letters*, 2015.

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