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# redefining robotics

## Yosi Bar-Cohen brings biomimetics within arm's reach.

**By Erin M. Schadt**

Imagine sitting down to an arm-wrestling match. You place your elbow on the table and reach across to grab your opponent's hand. You grasp a hand, but it's not human. Instead, the arm is powered by artificial muscles.

This scene may not be too far off due to efforts by SPIE Fellow Yoseph Bar-Cohen, a senior research scientist and group leader at the Jet Propulsion Laboratory (JPL; Pasadena, CA) responsible for Nondestructive Evaluation and Advanced Actuators (NDEAA) Technologies.

## EAP in action

Bar-Cohen first pitched the idea to develop artificial muscles to NASA's TeleRobotic Inter- center Working Group in 1995. From this sprang a four-year project called LoMMAs (Low Mass Muscle Actuators) involving a team of scientists from NASA, the Langley Research Center (Hampton, VA), and the University of New Mexico (Albuquerque, NM).

This project was supported by the NDEAA lab, which Bar-Cohen formed in 1991. This lab not only focuses on actuators and robotics, but also on NDE methods, transducers, and sensors. In 1999, NASA spotlighted Bar-Cohen and his team's creation of a four-fingered gripping device and a dust-wiper EAP actuator for space applications.

Also that year, Bar-Cohen initiated the first SPIE conference "Electroactive Polymer Actuators and Devices (EAPAD)" as a part of the Smart Structures and Materials Symposium, and has chaired the conference each year ever since. "To make this field more exciting, I came up with a challenge to the world science and engineering community to develop a robotic arm that would arm wrestle a human opponent and win," he says. "Furthermore, I initiated a session called 'EAP-in-Action' at the EAPAD conference where developed materials and devices are presented, and my hope is to have the arm-wrestling match as part of this session."

But his passion for EAP doesn't stop there. He edited the book *Electroactive Polymer (EAP) Actuators as Artificial Muscles—Reality, Potential, and Challenges,* published in 2001 by SPIE Press. In addition, he and co-editor Cynthia Breazeal took the field of artificial muscles to the next level—biomimetic robots—in their book *Biologically Inspired Intelligent Robots,* out soon from SPIE Press.

## more than muscle

Bar-Cohen isn't just about muscle, though. During childhood, he says, "I enjoyed reading books about chemistry tricks, and, of course, liked to impress the neighborhood kids with the expertise that I gained."

*Yoseph and Denny Bar-Cohen with their Shih-Tzu, Bamba.*

During high school, Bar-Cohen was drawn to physics, finding that it provides the foundation to understanding nature and chemistry. He went on to earn his undergraduate degree in physics from the Hebrew University (Jerusalem, Israel). "Right around the time that I finished my undergraduate studies, the university opened a new master's program in applied science and technology. It had what I sought—a materials science department—and I was the first student to graduate from this program," he says.

In 1971, while a co-op student at the Israel Aircraft Industry, he discovered the interdisciplinary field of nondestructive evaluation (NDE), and earned a PhD at the Hebrew University with the thesis topic of ultrasonic visualization of defects using the analogy to optics.

Shortly thereafter, Bar-Cohen moved to the United States with his wife, Denny, and young fraternal twins, Limor and Yaniv, to work at the NDE branch of the Air Force Materials Laboratory, Wright Patterson Air Force Base (Dayton, OH). During his first year there, he discovered the polarization backscattering (PBS) phenomenon, and later discovered the leaky lamb waves (LLW) in composite materials.

"Actually, I was looking through a Schlieren system to see if I could detect leaky surface waves, which was a phenomenon that was widely studied in metals in the early

'80s," Bar-Cohen explains. "To my surprise, I was getting similar patterns even though I was using a relatively low-precision system, and the phenomenon appeared in many angles as opposed to the case of the surface waves. Out of concern that this was an artifact, I conducted many experiments over a period of three months before mentioning it to anyone."

Thankfully, he did share his work on PBS and LLW; the resulting studies by NDE engineers are used around the world to detect defects in composite structures. Because of this innovation in the field of NDE, Bar-Cohen was awarded SPIE's NDE Lifetime Achievement Award in 2001. He is also a fellow of the American Society for Nondestructive Testing.

Since forming the NDEAA in 1991, "most of my time is dedicated to research and development related to harnessing the capabilities of electroactive materials for planetary and other applications," he says. Mechanisms resulting from work at JPL include the ultrasonic/sonic driller/corer (which won the 2000 *R&D Magazine* award as one of the 100 most innovative instruments of that year), piezopumps, the haptic interface MEMICA, multi-radiation ferrosource, medical treatment tools, biomimetics, and robotics. These innovations and initiatives earned him the 2001 NASA Honor Award: NASA Exceptional Engineering Achievement Medal.

"I attribute my success to my imagination, creativity, and hard work; but above all, it comes from good collaboration with top experts worldwide," Bar-Cohen says. "My idea of cooperative research with interdisciplinary experts was adapted from the world of the ants who collectively are capable of performing impressive tasks that are far beyond what they are expected to be able to do as individuals."

## beyond robotics

"My daughter, Limor, lives in Los Angeles," Bar-Cohen says, "and is a social-science researcher at UCLA's Center for Healthier Children, Families, and Communities. My son, Yaniv, lives with his wife Dorin in Boston, and he is a Fellow at the Harvard children's hospital, specializing in pediatric cardiology." Denny is just as busy. She went back to school, earned an MS in psychology, and is nearing completion on a PhD in organizational psychology at the California School of Professional Psychology, part of Alliant University.

Bar-Cohen and Denny find time to ride their tandem bicycle on weekends, with their Shih-Tzu dog, Bamba, along for the ride in the front basket. Bar-Cohen says one of his favorite hobbies is telling jokes; he has even drafted a manuscript for a joke book. And perhaps, sometime soon, he will be able to add robotic arm-wrestling to his list of hobbies.

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