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EDITOR-IN-CHIEF John Mecklin
john.mecklin@miller-mccune.com

ONLINE EDITOR Michael Todd
michael.todd@miller-mccune.com

ART DIRECTOR Albert Chiang
albert.chiang@miller-mccune.com

DEPUTY ONLINE EDITOR William Yelles
william.yelles@miller-mccune.com

STAFF WRITERS
Tom Jacobs
tom.jacobs@miller-mccune.com
Matt Palmquist
matt.palmquist@miller-mccune.com

COPY EDITORS
Melinda Masson, Mike Traphagen

CONTRIBUTORS
Valerie Brown, Arnie Cooper, Peter Friederici, James L. Gibson, Mark L. Haas, Lindsey McCormack, Mark Obbie, Bernice Yeung

FELLOW
Amy Ramos

INTERN
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EDITORIAL ADVISORY COMMITTEE
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THE MILLER-McCUNE CENTER FOR RESEARCH, MEDIA AND PUBLIC POLICY

FOUNDER AND PRESIDENT
Sara Miller McCune

MILLER-MCCUNE
MILLER-MCCUNE.COM
804 Anacapa St.
Santa Barbara, CA 93101
(805) 899-8620

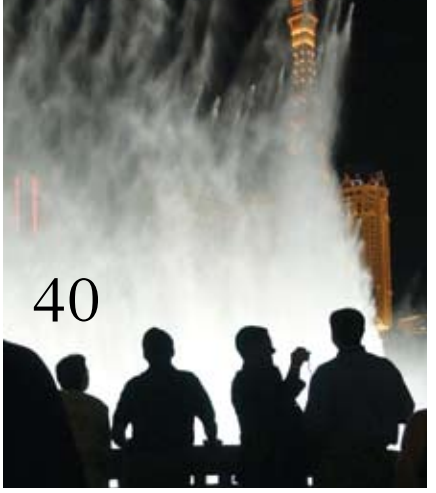
LETTERS TO THE EDITOR
theeditor@miller-mccune.com

ADVERTISING AND MARKETING INQUIRIES
Geane DeLima (805) 899-8620
geane.delima@miller-mccune.com

PERMISSIONS AND SYNDICATION
theeditor@miller-mccune.com

SUBSCRIPTIONS AND SUBSCRIBER SERVICES
Miller-McCune
PO Box 698
Santa Barbara, CA 93102

On the cover: Illustration by Brian Ajhar; this page top: Zumaphotos/Newscom; robot at bottom: Jupiter Images/Newscom



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The Complete Book of Robots

A comprehensive new robotics handbook raises the question: Will we take these machines into our everyday lives?

A Miller-McCune *interview of the University of Naples' Bruno Siciliano.* BY MATT PALMQUIST

Three toy robots by Jupiter Images/Newscom; NASA robot courtesy Johnson Space Center/DARPA; Bruno Siciliano courtesy Springer Publishers

BRUNO SICILIANO is a professor of control and robotics at the University of Naples, Italy, and the president of the IEEE Robotics and Automation Society, the world's leading robot research association. He is also the co-editor, with Stanford's Oussama Khatib, of the new *Springer Handbook of Robotics*, unveiled in May at the International Conference on Robotics and Automation in Pasadena, Calif. The 1,611-page handbook is a weighty tome, providing a comprehensive roundup of international accomplishments in the field and presenting the very latest research in robotics. Half technical manual, half encyclopedia, the handbook is stuffed with complex equations and diagrams describing how to build and manipulate robots and also contains thoughtful essays on the social and ethical implications of robotics. Siciliano and Khatib defined the scope and subject matter of the project and were supported by editors for the seven sections in the book: robotics foundations; robot structures; sensing and perception; manipulation and interfaces; mobile and distributed robotics; field and service robotics; and human-centered and lifelike robotics.

As those last couple of section titles indicate, robots are becoming more and more a part of everyday life for millions of humans around the world; the handbook is intended for scholars working in disciplines as far-ranging as biomechanics, neuroscience, virtual simulation, animation, surgery and sensor networks. *Miller-McCune* caught up with Siciliano the day after the reception for the book's public release in Pasadena.

M-M: How did this project get started?
Siciliano: Springer had started a series of handbooks in engineering and physics. It was their intention to choose several hot, solid research fields in which to write handbooks. This is a nice approach because it's not a stand-alone volume but part of a series. For all of the libraries, they can just buy the series. The handbook has something like 500 copies pre-sold through Amazon,

Robonaut B, a humanoid robot designed by NASA's Robotic Systems Technology Branch in collaboration with the Defense Advanced Research Projects Agency, tries to attach a tether to a handrail. Below: University of Naples professor Bruno Siciliano.

so it indicated there was a need.

We had started, a year or two years earlier, on a series of monographs, which is called STAR, which stands for Springer Tracts in Advanced Robotics. The editors are myself, Oussama Khatib from Stanford and Frans Groen from the Netherlands. We have also formed EURON, which stands for the European Robotics Research Network, going on eight years now. This is a very successful project in which 200 research groups in Europe have networked and exchanged information regularly every year. EURON has become identifiable as a leader in spanning robotics communities and dissemination.

But because this was an excellent opportunity to publish the most recent results about robotics, we didn't want to make this handbook a European series. Oussama is one of the stars in robotics worldwide, a big name in the field, and we have an international board of 15 distinguished colleagues from America, Europe and Asia/Oceania. This was a project nurtured in Europe but conceived internationally.

M-M: Why was it particularly important in the field of robotics to have a comprehensive handbook like this?

Siciliano: In our community, we found that there had been wonderful results achieved in various areas of robotics in recent years. Robotics spans across many fields. You can say robotics is mechanics; you can say robotics is artificial intelligence; you can say robotics is sensing and perception. The robotics world is a strongly interdisciplinary community. And there is research coming from completely different backgrounds: computer science, mechanical engineering — I am an electronic engineer myself. But to work in robotics, I had to understand other fields: mechanics, dynamics, perception, computer architecture, software, hardware. To become a roboticist, you must blend all these skills. In robotics, there were several good books and several textbooks, but there was no book spanning the whole field of robotics from its foundation to the most advanced applications. It was extremely challenging and extremely rewarding to start working on this project.

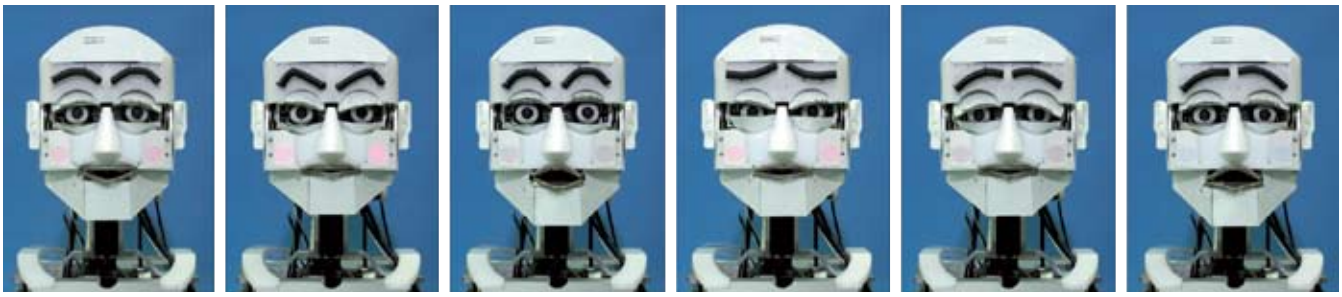
In fact, I have to say, I am, of course, proud to have written a textbook that has been adopted in classrooms worldwide. But even though I myself have not written a chapter in this textbook except for the introductory chapter, I am much more happy, more satisfied, to have achieved this. We put together 165 authors from all over the world. As a rule, we required that every chapter would have multiple authorship. We identified the topics and tried to recruit the best authors, and, in several cases, the authors came from different geographical backgrounds and different schools of thought. But we wanted to make it as broad and open and least biased as possible.

M-M: So you played the role of organizer and referee?

Siciliano: Yes, exactly. We worked for a year, year and a half on how to structure the project. We identified some macro areas. Part A is the foundation of robotics. Then come four parts that could be considered the core knowledge of robotics, the methodologies and technologies of our field. We have part B about mechanical structures; part C about sensing and perception; part D about manipulation and interfaces; and part E about mobile and sophisticated robotics. It's the core knowledge of the field. Every part could be a textbook in itself.

M-M: For this project, how did you begin to define robotics?

Siciliano: I have to say that, in the imagination of people, robotics could be anything — anything dealing with



The seven basic facial expressions — happiness, anger, surprise, disgust, sadness and fear — of the robot known as WE-4RII. Below: The humanoid robot Justin has arms and hands that approximate the freedom of movement of a human's.

artificial intelligence. The book refers to the modernization of robotics, which is the intelligent connection of perception to action. This is scientific robotics. Robots, of course, can be toys — which, in a way, help promote and disseminate the knowledge in the field. But from a scientific viewpoint, these are a little bit more than toys.

M-M: Is there a danger, when you're spending several years compiling this kind of comprehensive handbook, that it could become . . .

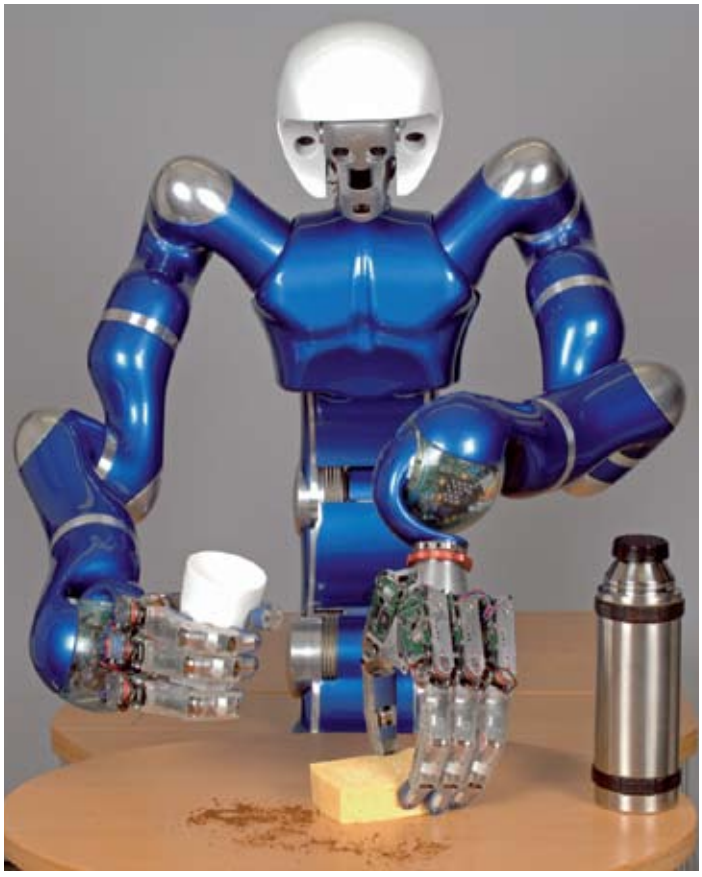
Siciliano: Outdated?

M-M: Wow, you're good. You've heard that question a time or two, I take it. So how do you sleep at night, knowing that this project you've been working on for years, in such a rapidly moving field, could be considered obsolete by next week?

Siciliano: I think not. The foundations are the foundations. These will be the same in five to 10 years. For the core methodologies and technologies, the material has been very well assessed, so I don't think this will be a problem. But in terms of updating it, we are already talking about a second edition.

M-M: So what is the next frontier in robotics?

Siciliano: I make an example of sensor technology. Sensor technology is very well advanced, so we have a lot of very sophisticated and powerful sensors available that you can use for allowing a robot to interact, say, with a stretcher in an environment cohabitated with human beings. This is clearly the challenge now, and what is missing is the merging of different information, some kind of intelligent algorithms that can use the sensory feedback and give different weight and relativity to what the robots are experiencing.



We continually use touch, vision, tactile, all the different senses in the human brain, and we carry out data fusion and the merging of sensory information. We don't realize it, but we do this subconsciously and in an intelligent fashion by giving more relativity to certain things. So if I want to grasp an object on the table, first I look at the object, using vision; then I direct my hand to grasp the object. But once in contact with the object, I could manipulate the object even with my eyes closed — and I could perform some kind of identification of the object through its shape or texture. I do some kind of fusion of different sensory information. In that direction with robots, there could be more progress.

M-M: When you survey all the different fields in which robots are becoming more and more useful — from eradicating land mines to shearing sheep to exploring Mars — what is the most exciting area to you?

Siciliano: The most exciting, and the most challenging, is the final part of the handbook, on field and service robots. And to a larger extent, human-centered and lifelike robotics represents the challenge: robots interacting with humans. We refer to it as HRI, human-robot interaction. This is the natural evolution of MMI, man-machine interaction.

M-M: In 1942, Isaac Asimov came up with the Three Laws of Robotics for his science fiction books: A robot should not injure a human being, must obey all orders given by humans and must protect its existence unless that means conflicting with the first or second law. If human-robot interaction is the major focus in the field, it sounds like we actually might need Asimov's laws soon — and not just in military fields, where we already know that unmanned aircraft have had a huge impact in Iraq and Afghanistan. Should humans be scared?

Siciliano: To some extent, yes. On one hand, robots have been working outside of factories since the late '80s, and you have field robots, which are robots exploring space, the sea, contaminated fields, working in mines. Now we are approaching the decade of robots in the home and in our social environment. This means assisting disabled people, using robots for surgery. Then the question comes: Are we ready to accept these machines in our homes, in our schools, in our hospitals? That's a big question.

M-M: What do you think? Are we ready?

Siciliano: You can approach it on two levels. The first is cognitive human interaction, and the other is physical. The interaction is social, in terms of intelligence, but hopefully you can have physical interaction, too. Take the Asimov law: When you have a robot interacting with a human, then it becomes about safety and dependability. We have a project in Europe right now, and this is the so-called PHRIENDS project (which stands for Physical Human-Robot Interaction: DepENDability and Safety). The goal of PHRIENDS is to make robots and humans friends with each other. Before, the robots were used in secluded and segmented areas — behind fences — because they were thought of as potentially dangerous to humans. Now we can have a robot that you can cooperate with as a farmworker, say, or even a robot that an amputee can wear. If you interact that closely with the robot, from the physical point of view, the issues are safety and dependability. We want to make robots that are inspired by humans but won't hurt them.

M-M: Cultural issues must also play a huge role around the world in determining research directions, especially research on humans' interaction with robots.

Siciliano: Absolutely. The Japanese are already building humanoids. In the U.S. and Europe, it's a different approach. In the western cultures, not as much work and research is done in building android machines, so-called anthropomorphic robots, because, actually, if a machine has the aspect of an android, that might be scary, whereas, in Japan, they intentionally build machines that are human or animal-inspired because it's part of the religion, the culture. They believe that the machine should have the same aspect as a human or animal to be acceptable in a social environment. When the Sony dog, the AIBO, came out, in Japan it sold out in a few hours. It took six months to sell the same amount of pieces in the U.S. and Europe.

M-M: And how could those cultural issues impact research on robotics?

Siciliano: Take the example of the personal computer, the laptop. Anywhere you go now, you don't pay particular attention if you see one. In a home, there is a computer. It has become pervasive and, as such, has become ubiquitous. Computers are everywhere — not only computers but networks, wireless connections. Will it happen that 20 years from now, robotics will become so ubiquitous, so basic, that we won't pay attention to the fact that maybe there is a little cart, or a little machine, walking around in a home? Would you pay attention to a robot vacuum cleaner? That's the big challenge for robotics, to get to that point. The main difference between a computer and a robot is that a robot involves motion — a computer doesn't move, doesn't interact.

M-M: So progress in research is going to have as much to do with humans' ability to deal with and accept these robots?

Siciliano: That's right. Like unmanned vehicles — like cars, like aircraft, like submarines — you will have autonomously operated vehicle robots, which will become more and more intelligent, with the capability of interacting with the environment in an intelligent and reactive fashion. The big challenge is that those machines are ready to make decisions and to *adapt* their behavior. For instance, take the example of the South African athlete who can now run the 400 meters at the Olympic Games on prosthetic legs — that's kind of on the edge, on the threshold.

If you interact closely with a robot, from a physical point of view, the issues are safety and dependability. We want to make robots that are inspired by humans but won't hurt them.

You can also think about building a sort of superhuman. There's a project in the U.S. at Berkeley, which we discuss in the book, about a machine that is an exoskeleton — a robot that you wear. The main idea behind it is you can wear a backpack as heavy as 150 kilos, and you don't feel the weight, because the robot, the machine, is connected to the nerves and to the muscles of the man. He might be a soldier, carrying a very heavy backpack in a military field. Thanks to virtual reality, you can have the person feeling a much lighter weight. You can build a superhuman. And that is … scary.

M-M: Be careful.

Siciliano: Exactly. M2