In this issue of *IEEE Control Systems Magazine (CSM)* we speak with Dorothée Normand-Cyrot, who has 30 years of experience as a control theorist at the French Centre National de la Recherche Scientifique (CNRS). She joined CNRS in 1980 as a researcher and has been directeur de recherche since 1991. She works at the Laboratoire des Signaux et Systèmes, a research laboratory under the aegis of CNRS, University Paris Sud-11, and Supélec, an engineering educational institution, at Gif-sur-Yvette. Dorothée works on a wide range of nonlinear control problems in automation, largely from a discrete-time perspective. She became an IEEE Fellow in 2005.

We also speak with Tarek Sobh, vice president for graduate studies and research and dean of the School of Engineering at the University of Bridgeport, Connecticut. Tarek has worked on diverse applications in robotics, automation, manufacturing, and sensing, and he is the founder of the Interdisciplinary Robotics, Intelligent Sensing, and Control (RISC) Laboratory at the University of Bridgeport.

DOROTHÉE NORMAND-CYROT

Q. You're an IEEE Fellow "for contributions to digital and discrete-time control systems." Congratulations!

Dorothée: This award makes me very proud to belong to the IEEE Control Systems Society, and I am grateful to my colleagues and friends who supported my nomination.

Q. What motivates your interest in discrete-time systems?

Dorothée: My interest in control theory is the natural output of many circumstances. To better explain such a choice, I would like to go back to a period with some flashes on my professional life. In the year 1971, post 1968 (we are in Paris!), 17 years old with a scientific high school degree, I wondered about my scientific future in a context where the "Grandes Ecoles"—jewel of French scientific training—were still closed to women! Only "ad hoc" scientific training was offered to women. Passion or rebellion, I elected to study pure mathematics in a coeducational university.

My first interest was in algebra: a high-level course in category theory, encounter with Andrée Bastiani-Ehresmann, the priestess of morphisms, functors, and cofunctors and of doctorate studies in stochastic automata theory. This was my way to enter the world of abstraction, formal analogies, proving conjectures through combinatoric calculus. Research in mathematics became rapidly a self-evident choice.

Dorothée Normand-Cyrot in Paris.

We are now in 1975, the golden age of nonlinear systems theory. In an apprenticeship with Michel Fliess, promotor of formal series in control theory, I was faced with the equivalence in the generating series language between rationality and finite-dimensional state-space realizations as a nonlinear extension of the famous Kalman result. My first work was to adapt these formal methods to the discrete-time context, a domain treated by very few researchers (Sontag's polynomial response maps). Sketch of experience, wish of originality, defy, my choice will soon be fixed.

Two years at the Electricité de France, the national company managing electrical resources, I dealt with power plant modeling for hydraulic, thermal even nuclear plants. This period was characterized by a strong engagement involving academics and representatives of industry definitively and set my research activity in the area of nonlinear systems and control theory.

My thèse d'etat, obtained in 1983, enabled me to travel in the rich universe of nonlinear control theory. My first experience abroad as professore a contratto was at the University of Rome "La Sapienza," where differential geometry in control was leveraging; it was the beginning of an active collaboration with Salvatore Monaco. A successful example of a fruitful interdisciplinary connivance: algebra and geometry serve discrete-time systems.

After around 30 years of activity, my interest in discrete-time systems is still alive. Nonlinear discrete-time theory is a stimulating research area—several different approaches compete

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to set the more adequate framework to attack its pathologies. To quote a few, let us say that discrete-time evolutions are governed by jumps, that the composition of functions, a nonlinear operation, takes the place of derivatives, that nonlinearities in the control variable make the design a difficult task. However, the discrete-time domain inherits a tremendous advantage because of its own incredibly fertile applied field, by which I mean the sampled-data domain. Such a cross fertilization between continuous time and discrete time through sampled data is an inexhaustible source of interesting problems. In a permanent interplay, consolidated results available in continuous time are advising steps to discrete time, as well as difficulties to be faced in discrete time that are helpful to solve intricate unsolved continuous-time problems.

Q. What problems are you focusing on now? What problems would you really like to solve?

Dorothée: The second part of your question is ambitious and borders on the philosophy of life! What else than to contribute to human society welfare?

I will address a number of topics we are working on in collaboration with Salvatore and past Ph.D. students who are now confirmed researchers and always concerned with the topic, Jean Pierre Barbot, Stefano Di Gennaro, Vincent Fromion, Paolo Di Giamberardino, Mohamed Djemai, and Claudia Califano.

From 2000, nonlinear discrete-time or sampled-data systems are definitively out of the shade, we can even say in fashion, joining trends in control. An example is the popular hybrid domain. What are hybrid systems if not heterogeneous ones mixing up continuous-time and discrete-time behaviors with discrete events inducing jumps, resets, and discontinuities? I believe that our work provides tools that should be efficient in such a framework.

Another challenge resides in the duality between analytical and numerical approaches for control. Sampled-data and digital systems are at the heart of research, hand in hand with computer scientists; faster calculus or functional calculus? Deduction from statistics or structural analysis? Optimization or design with optimality? These questions appeal to different perceptions that need to be understood before they can be solved with mutual respect.

With a little more detail, we are working on the following problems: nonlinear discrete-time modeling revisited through the setup that we proposed to represent discrete-time or sampled-data dynamics as two coupled differential/difference equations. The difference equation models the free evolution as a jump. The differential equation models the effect over the dynamics of control variations. The efficiency of such a representation is shown with reference to various analysis and control problems, a direct modeling in these terms should renew the discrete-time context.

A second topic regards passivity, Lyapunov-like methods, and Hamiltonian structures, in discrete-time. What does passivity mean in discrete-time? What is the discrete-time or sampled-data equivalent to Hamiltonian dynamics? Following an approach inherited from Poincaré, mathematical structures endorsing nice properties as well as the ways to find them back are developed to serve complexity. Then, in practice, approximate solutions are implemented. Finally, let me quote my favorite sampled-data or redesign control. Our wish should be to change the gears, as I said before. I mean to take advantage of the methodologies and tools developed in discrete time or sampled-data domains to face difficult or even unsolved continuous-time problems. Examples do exist regarding moving through controllability directions, evolving over Lie groups, motion planning under nonholonomic constraints. This is an exciting area too.

Dorothée Normand-Cyrot of CNRS at the French coast.

Q. Which conferences do you normally attend?

Dorothée: To attend conferences is essential as it gives one the opportunity for exchanges and collaborations. I shall say, without flattery, that the IEEE CDC is my favorite; it is the "Control Theory Festival," an event that must be attended, where to feel tendencies, to meet leaders. Even if I don't participate as often as I would like, I enjoy the CDC. I remember my first one in San Diego, 1981, Athens in 1986, where everyone wore the tee shirt "We are in Control," 2004 celebrating both the 50th anniversary of the IEEE Control Systems society and mine (!), the joint venture IEEE-CDC-EUCA-ECC in Sevilla 2005 with my Fellow awardees. Other conferences like the IFAC World Congress play a similar role. I am, of course, used to participating in the European Control Conference, and I enjoy ACC because it brings me to the United States. A particular mention for the CIFA "Conférence Internationale Francophone en Automatique," which I helped to launch in 2000, it takes place every two years in French (sorry for some chauvinism). Medium-sized

conferences dedicated to specific topics as well as national meetings are emulating meeting places for fruitful exchanges opening the mind. I deplore the decline of such opportunities.

Research, fed by the desire of understanding, realizes an immaterial process of creation.

Q. Please talk a little about CNRS.

Dorothée: In France, research activity grows up in many different organisms such as research institutions, universities, high educational schools, and public or private companies. Among other research institutions such as INRIA, INSERM, INRA, CNES, and ONERA, dedicated to a specific area or some aggregation of them, CNRS appears in pole position for the plurality of its disciplines. Such a richness makes the CNRS a fantastic research apparatus to increase knowledge through fundamental research. Interactions between people having in mind the same goal but in different domains is a source of innovation in its first theoretical meaning.

At present, in the new panorama dominated by economic rules, research institutions are urged to prove their efficiency and demonstrate their productivity through visible projects and new evaluation procedures. Finalized projects with identified objectives and profits to industry or economics with large partnerships are the most favorite ones. Structures and superstructures networking many different contributors to maximize visibility are built according to different logics. Various new committees are set up to perform valuation. All these matters develop a sensitive debate between politicians, leaders, and the community, resulting in bad criticisms making every researcher sad. It appears that the reason could be some nebulous perception of research activity. In this context, I am convinced that one could take benefit from recalling a perhaps romantic way of looking at research.

Research, fed by the desire of understanding, realizes an immaterial process of creation. Freedom is a basic requirement for it. Too many rules compel the mind and are brakes to innovation. That's why to "search" cannot be decreed. That's why research does not develop well in a rigid structure and why we must have trust in researchers. Abstraction, which consists of revealing identical structures in many different contexts is an extraordinary supply for this process of creation; properties that these structures endorse reveal new understanding. Research is also carried out by dream in a quest of harmony. I am used to state that after many hours of graffiti, when calculus ends with an expression embedding properties and given characteristics, we recognize a true result from its harmony, in terms of recursivity, homogeneity, balance … dream, abstraction, freedom, do not have to eclipse perseverance, tenacity, we could say fidelity to an idea, to an approach, without verging on obsession, always a risk in looking for a proof, the settlement of a conjecture. Roughly speaking, I should say that research borders art in its creative achievement and freedom of desire. Even if it is a professional activity, it grows up with passion. To be convinced about that should allow one to better understand its requirements and needs to build a privileged environment.

Coming back to CNRS, I think that a public research institution such as CNRS should promote knowledge and excellence through fundamental research regardless of applicable impacts. Finalized projects involving pluridisciplinary partnership promote technological innovation but do not satisfactorily act for fundamental research. Worse, it might hide it, being the performances set on applicable aspects, being unusual the come back to source. As soon as applications benefits or possible profits are identified within a specified domain, research merges with development and might be confined to the sector dedicated to institutions or companies.

To fix the ways of fundamental research diverts from creativity. I should recommend to select carefully researchers, as CNRS does, and to be faithful afterwards. Even more, I should recommend allocating regular funds to support Ph.D. students and post-docs to attend conferences and further mobility. Looking perpetually for financial support diverts from research activity and, as I said before, should lead to mask fundamental aspects into more appealing headlines in accordance with funding agencies dictates. Some down to top attitude should be preferable I think.

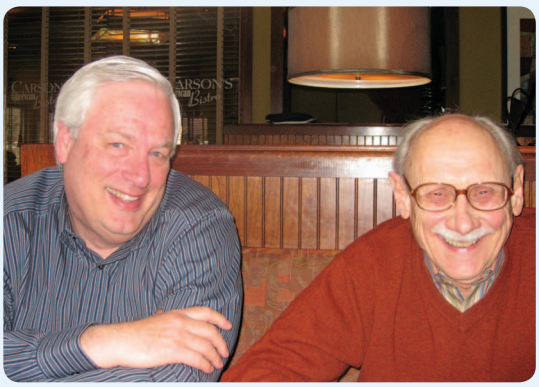
About valuation, which is heavily present at the CNRS, my impression is that there is low coherency between objectives, measures, and feedback in evaluating procedures. It is clear that depending on its goals, fundamental or applied research productivity cannot be examined accordingly to the same parameters. The confusion in the assignments of research organizations as well as the super-structures putting together many different forces in different contexts with different constraints and status do not help.

Q. How do you see the future of control research in Europe in general, and the role of CNRS in particular?

Dorothée: Control research in Europe has an enormous potential within its variety funded on an ancient and strong tradition. I am very much on behalf of recognizing and supporting national abilities or experience among European nations. I believe that standardization on behalf of increasing average level does not promote excellence.

The comments I made regarding fundamental research at large within CNRS generalize to national

Birthday



Harris McClamroch (left) and Elmer Gilbert celebrating the ninth anniversary of Elmer's 70th birthday. Elmer is emeritus professor at the University of Michigan. Harris is a former editor of *IEEE Transactions on Automatic Control* and former president of the IEEE Control Systems Society.

and European levels. Control should overpass controversy between applied or fundamental objectives being its proper methodologies set to supply automation at large. It is why control is at the heart of technological innovation in many different domains from traditional aeronautical, mechanical, electrical engineering, up to biology or human society services. However, such a wealth is also a risk for its recognition as a discipline, *Control—The Hidden Technology*, by K.J. Aström, and William G. Dow distinguished lecture. The result is that control theory develops within applied mathematics, or theoretical computer sciences up to applied sectors with which it interacts or more trendy headings such as robotics, artificial intelligence, embedded or networked technology to quote a few in relation with research trends fixed by funding agencies.

My claim is that control should be recognized as a discipline, and we might do what can be done to support theoretical research and training of "control theorists" at any formation or university level. Let us picture industries, public, or private companies hiring a control theorist adviser as they use to do for economics, human resources, or psychology!

As we know, typical abilities like observation, analysis, control, and feedback might serve in the fields of health, policy, and economics without reminding high finance also, a very sensitive subject just now.

Following the logic of the market and giving up the national funding on behalf of European agencies confines fundamental research to large international projects oriented toward research and development. As I said before, control theory, the hidden technology, cannot take pole position in such a context. My opinion is that European as well as national funding agencies should support networking around methodological objectives trusting in recognized experts in the community, to consolidate theoretical competencies, to promote methodological innovation, and to prevent researchers from solitary confinement.

Regarding the expected role of CNRS in control and relying on community agreement, CNRS as well as any other organizations interested in control theory should activate these goals adopting a down to top attitude. As a public research organization, CNRS should develop fundamental research in close relation with university. As soon as privileged applied sectors are identified, as soon as developments are feasible and tangible, we can speak about customization of methodologies, research might be (at least partially) supported by the entities to which it brings benefits, industry, private society, or organism in close relation with the engineering educational institutions.

Regarding the urge to build besides research institutions, and even though the number of researchers declines, structures with uncertain frontiers is confusing and the time spent in planning them is to the detriment of scientific production. This determines a general tendency to the standardization of trainings, jobs, and assignments, which, in my view, does not suit the excellence of scientific research.

To conclude, I would like to note the enjoyment I got when animating the GDR, a CNRS network federating control theory in France, when participating to launch ECC and CIFA as well as a binational educational network in control. I am convinced that the control community at each national level and in Europe still needs to be networked, to promote exchanges of ideas and human resources. I will be glad to continue to act in these directions.

Q. Do you have any advice for young researchers?

Dorothée: To the young researchers I would quote Susanna Tamaro: "go where passion brings you" but also "look for excellence in yourself," and "listen to your peers." My opinion is that everybody carries excellence in them. The difficulty is to find it and the right professional environment; being senior in the field, we should help them, it is our job.

I would also recommend them mobility "to leave it is to feed," curiosity, and reactivity, especially in the future world, control theory might be helpful. Having met the opportunity of an almost binational professional activity, I can manifest that this is the source of intellectual progress. Research can isolate, the activity is rather individualistic, and collaboration and exchange of experience is essential. This is even more crucial in a European context where broad campuses are rare. Splendid opportunities are given today to support mobility. Students should profit from this with our help again to determine their scientific objectives.

Q. What are some of your interests outside of professional activities?

Dorothée: Oh! Too many! Time will miss.

Research, you know, is time consuming and mind invasive, whenever she knocks at the door, by day or night, during weekend or vacations, this is the price to pay. For me, besides research, the most efficient outlet should be a sport obliging to different efforts and so liberating the mind. I try to swim, to sail, and to ski. I am looking forward to practice gymnastics but just to stay fit!

Without a specific hobby, I am used to cultivating creativeness in other topics than research as cooking, customizing objects, home furniture or dressing, all that without any pretension, just for fun. All of this is so simple!

Q. Thank you for speaking with *CSM*!

Dorothée: You're most welcome. It was my pleasure.

TAREK SOBH

Q. Do you have a vision for the future of robotics and automation? How does control technology play a role?

Tarek: My feeling about the future of robotics and automation is probably partially driven by the global economic problem, and I think that the issue is where and what robotics and automation applications are deployable. I personally think service robotics and service-oriented automation applications are key to our future development, both as a nation and in general in the world. I think the principle behind interdisciplinary education and the applicability of areas and fields like robotics or automation are relevant when it comes to new emerging interdisciplinary areas that can change the face of the economy whether in health care, biomedical, sustainable development, energy engineering, or environmental sustainability. For example, in environmental sustainability, it is probably prudent of us to think of control applications, strategies, or machinery that can help in areas such as environmental cleanup that can contribute, from a systems point of view, to efficient alternative fuels technologies and developing them. When it comes to biomedical applications, biotechnology and health care, in terms of service robotics it is probably prudent for us to think of applications in telesurgery, maintenance of health care facilities, drug delivery, and other venues to which we can contribute.

Q. What do you feel are the real technological challenges in this field?

Tarek: I think that robotics, automation, or control are areas that are highly interdisciplinary, so from the point of view, for example, of education, it takes a lot for someone to be able to be functional and productive within that area and make a difference from an applications point of view. For an engineer to be proficient or for a scientist to get to the point of being productive in robotics, automation, or control, there is a need for that person to be capable of understanding and be proficient in circuit theory, electrical engineering, control, mathematics, or mechanical engineering Thus, as an educator, I think some of the technological challenges are related to being able to educate the next generation of scientists; excite, entice, and make sure that they are proficient in different areas. From a technological point of view, such as hardware and software, things are changing rapidly. From a computational perspective, I think we are not utilizing the capabilities that exist right now. When you talk about applications in computer vision, for example, we do have enough software, and we have been producing hardware that is capable of processing very significant amounts of data in real time. However, when it comes to applications within the new UAV area, applications within hybrid projectiles, or applications within computer vision or machine perception, or even in the area of security, I do not think we have caught up with the sensory processing part yet, meaning there are not enough applications out there that utilize the available hardware capabilities. I feel the technological challenges are, at least partially, within the area of real-time processing of significant amounts of data, varying from applications in biomedical engineering, to weather forecasting, to security, to ID recognition of human beings or other objects, and we are not yet seeing the dispersal of these technologies that enable sensory processing at a very high level in real time while utilizing the capabilities of hardware in our everyday life applications. Thus, whether it is a robot roaming a building providing services, an airplane that is unmanned, or sensors inside the body to check things like tumors, there is a significant need to be able to process information, react to the analysis after gathering the data, and to react in real time to make control and actuation decisions as to what to do next. I think this would be one of the significant technological challenges, namely, real-time significant sensory processing.

Tarek Sobh, dean of the School of Engineering at the University of Bridgeport.

Q. In looking back, what components of your education do you see as most valuable to you today? Do you use that perspective to guide your students?

Tarek: I think the most important aspect of my education is the variety of courses and research that I have accomplished across many different disciplines. As an undergraduate in Egypt, I studied courses over a five-year period in areas such as

operations research, mathematics, electrical and mechanical engineering, computer science, engineering, theory, and programming. Coming to the United States and being a graduate student at the University of Pennsylvania, I have also had the pleasure and the advantage of studying courses across so many different disciplines as a graduate student. Having the opportunity to study and do projects at an interdisciplinary level has been key to my capability of working. In my opinion, to work in this area and be productive from an outcomes point of view there is really a significant need for engineers to be more rounded. When you think about areas, for example, biomedical engineering, alternative energy, energy engineering, or sustainable development, one of the biggest problems that we face is not only that students need to have a solid base of courses across so many different disciplines, but they also need to know about the applications of these technologies. Furthermore, a well-rounded engineer needs to have wonderful communication skills. They need to be good writers, they need to know how to work in teams, they need to be able to give good presentations, they need to have the basics of engineering economy at least, and they need to have a background on the societal impact of engineering, computing, automation, and robotics and control in general.

Q. Speaking modestly, of course, what technological accomplishment are you most proud of?

Tarek: Speaking modestly, I guess the technological accomplishment I am most proud of is to "laugh." I think in my own case, when you track my career, I began as an assistant professor, actually in my case as a research assistant professor, at the University of Utah and then I joined the University of Bridgeport and helped establish the RISC lab—the Robotics Intelligence Sensing and Control lab—at the University of Bridgeport. I think one of the major things that I am personally proud of is the concept of being able to do hybrid control, hybrid integration, and control of machinery and design. The other area in which I had some modest contributions, I think, is that of engineering education. Furthermore, the idea of being able to integrate systems for many different purposes, prototyping, design, and integration is an area that I am happy to have worked in.

Q. Which conferences do you normally attend to present your work?

Tarek: The IEEE Robots and Automation Conference is a typical meeting for research in this area. I attended many different types of conferences across the years varying from ICAR to the American Control Conference, to various IEEE workshops and symposia on vision and image processing, control, and many other areas. Recently, I have also been attending conferences that have to do with engineering education, given my current job description, from various IEEE to American Society for Engineering Education conferences, workshops, and symposia that address contemporary issues in engineering education. I would say that some other conferences that I enjoyed attending include the International Symposium on Intelligent Control, conferences that are organized by the International Federation of Automatic Control, IASTED, and other automation conferences including the International Conference on Control Application and conferences on industrial electronics.

Q. What subjects do you enjoy—or not enjoy—teaching?

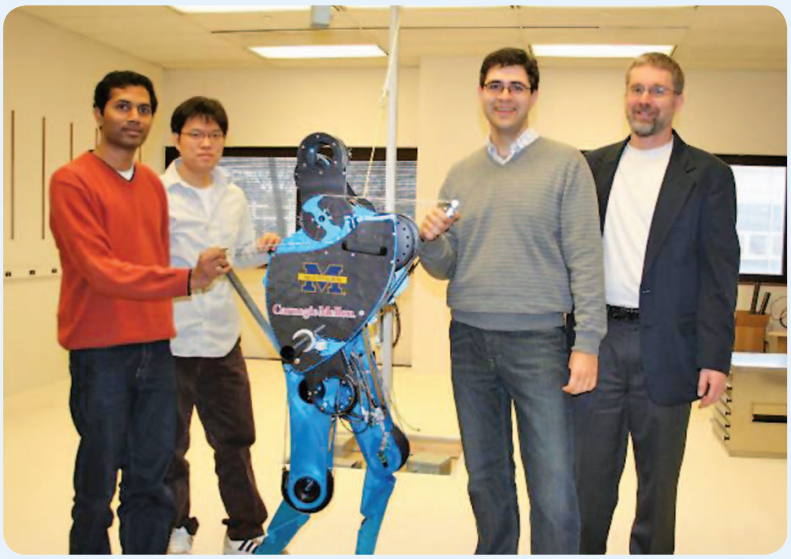
Tarek: I have taught so many different classes across the years from electrical engineering, to computer science, to computer engineering, and of course automation and robotics. Personally, my favorite subject to teach is introduction to robotics and automation, because it is a course that really makes everything else fall together for the students, especially when they take it at their senior year. By that time they would have typically finished taking the required prerequisites and background in basic control, circuits, mathematics. When they are introduced to the feel of robotics and automation and play with equipment, mobile platforms, and articulated manipulators it is real fun because they finally get to understand at least one application area in which all of the education that they have been receiving over the years actually falls together. When they start designing control strategies, doing certain tasks with a mobile manipulator, integrating simple vision processing and other algorithms into whatever projects that they are working on near the end of the course, it becomes enjoyable. That would be my preferred course. I love teaching computer vision, image processing, and pattern recognition because these are courses within my own area. I have taught many courses in data structures, algorithms, and basic programming, operating systems, and in some cases control and electrical engineering courses, and I enjoy teaching most of these with the exception of the very theory-oriented courses. The courses that I do not enjoy teaching are in the area of theoretical computer science, although it can be made to be real fun and actually it is an interesting subject, but very basic theory-type courses are a little bit tough for the students to grasp the usefulness of, especially when it is an introductory level course in theoretical computer science or theory of computation.

Q. Please talk a little about the University of Bridgeport and what you see as similar or different from the education you received as an undergraduate.

Tarek: Well, the University of Bridgeport is a very interesting place. I am sure some of the readers of this article might know Bridgeport

has been classically known as the manufacturing city of the United States. The company Bridgeport Machines (milling machines) came to life here. The University of Bridgeport has been known historically to be the premier school for students who are interested in professional careers. Thus, we have been well known for many years in the state of Connecticut and New England for our excellence at the graduate and professional levels; professional, pre-professional, graduate, pre-graduate education, whether in engineering, education, business, or health sciences. The University of Bridgeport is oriented toward professional graduate programs. As a matter of fact, when you take a look at the school that I am dean of, the School of Engineering, we are heavily centered toward the graduate program. We have approximately 1,600 students total in the School of Engineering, and I think more than 1,200 of these are graduate students, mostly in the masters and of course several in the PhD. programs. I like to think that I have had a role in shaping the School of Engineering because I have been in this position for close to ten years now, and of course, as of recently, I think I have also had a role in shaping graduate education at the University of Bridgeport because I am the vice president of graduate studies and research. We are very interdisciplinary by design, thus, we encourage our students from the School of Engineering to actually cross the aisle and take a few courses from the School of Business at the graduate level, for example. Projects between the health sciences division, engineering, and business are very common. Projects in K–12 education are also common between engineering and the School of Education. We have several dual degree programs available. We encourage students within the School of Engineering in one department such as electrical engineering, mechanical engineering, or computer engineering to take classes in other departments to round out their education. We have a unique technology management program that is interdisciplinary between the School of Engineering and the School of Business. I think we have a total of close to 60% of our student in graduate programs, again in particular, engineering, business, education, and health sciences. Interdisciplinary funding is common for most of our externally funded projects, especially in recent years.

Ready to Run



From left: Koushil Sreenath, Hae-Won Park, MABEL, Ioannis Poulakakis, and Jessy Grizzle, all from the University of Michigan's EECS Department. MABEL represents the next generation of bipedal robots, following in the footsteps of RABBIT, which was featured on the cover of the October 2003 issue of *IEEE Control Systems Magazine*.

Q. What are your interests outside of professional activities?

Tarek: I like to read a lot—history, biographies, novels, politics, or whatever. Reading is my sanctuary in many cases, regardless of whether I am on a plane because, as you would imagine, I travel a lot, especially in the last seven or eight years; or before I go to sleep or I am resting. For me reading is really a way of relaxing. I also am a soccer and squash player. I love playing squash and have been playing for the last 30 plus years, and in the earlier years I played squash competitively. I have been playing soccer for a long time. We are blessed at the University of Bridgeport because we are a seaside campus, and we have both an amazing soccer field and a seaside park that overlook the Long Island Sound. Typically we try to organize soccer games in the seaside park and given that the University of Bridgeport is an international school, we have students, faculty, and staff who are very avid soccer players. It is an amazing experience having two 11-player teams with 15 nationalities represented. It is really very cool. Traveling used to be one of the things that I enjoyed a lot, but not as much lately because I have been doing too much for my job.

Q. Thank you for speaking with *CSM*!

Tarek: You're most welcome.