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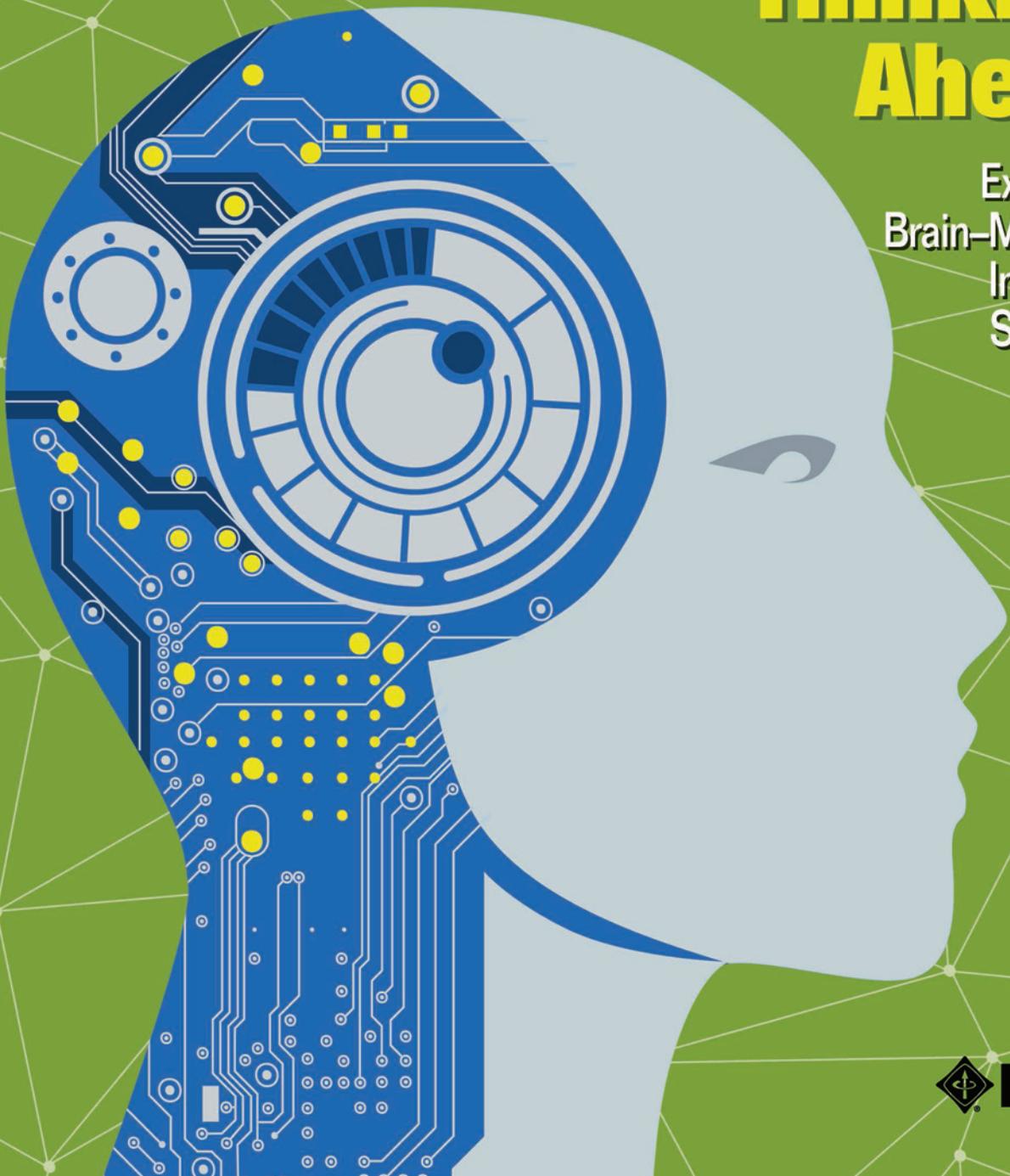
Systems, Man, & Cybernetics

Volume 6, Number 3 ■ July 2020

Magazine

Thinking Ahead

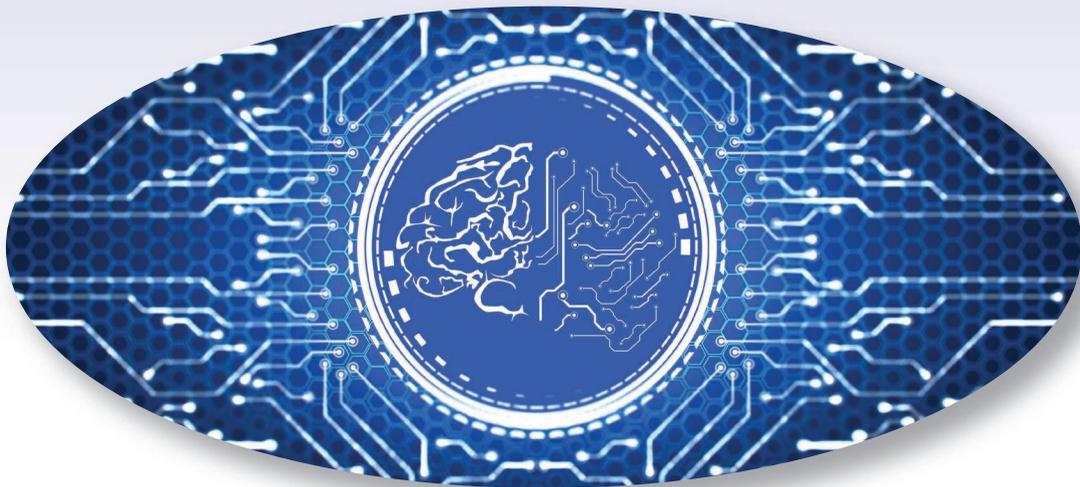
Exploring
Brain–Machine
Interface
Systems



 IEEE

Brain–Machine Interface Systems

by Ljiljana Trajkovic



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This special section of *IEEE Systems, Man, and Cybernetics Magazine* contains contributions on a timely research topic: brain–machine interface (BMI) systems. The section was solicited by the late Mo El-Hawary, past editor-in-chief of the magazine. It includes a pictorial view of BMI activities sponsored by the IEEE Systems, Man, and Cybernetics (SMC) Society as well as technical articles. Also included in this section is an interesting reprint from *Communications of the ACM* where SMC Society members José del R. Millán, Michael H. Smith, and 2019 SMC BMI Workshop panelist Al Emondi discuss brain–computer interfaces (BCIs). A collection of testimonials was also solicited to honor Michael H. Smith, the driving force behind the Society’s BMI efforts and activities. (See “Testimonials”.) Finally, I very much appreciate contributions by Tiago H. Falk, Christoph Guger, Ricardo Chavarriaga, Joel Libove, the authors of testimonials and technical articles submitted to this special section, and the valuable and extensive efforts of the reviewers. I also thank the IEEE Brain Initiative, IEEE Standards Association,

IEEE Societies and Councils, and numerous supporters and contributors to SMC BMI Workshops over the years.

Since 2009, the IEEE SMC Society has been organizing and supporting BMI Workshops as part of the annual IEEE SMC flagship conferences (Figures 1–12). Furthermore,



Figure 1. IEEE President James A. Jefferies opening the Global Brain Initiatives meeting at the 2018 SMC BMI Workshop.



Figure 2. The Global Brain Initiatives meeting chaired by SMC BMI Workshop General Chair Michael H. Smith.



Figure 3. The audience is fascinated by a presentation at an SMC BMI Workshop.



Figure 4. A distinguished industry panel at an SMC BMI Workshop.

Testimonials

Prof. Jack L. Gallant

University of California at Berkeley

It would be difficult to overstate Dr. Smith's contributions to the SMC, the IEEE, and the advancement of neurotechnology within the IEEE. Dr. Smith's involvement in the SMC Society over the past decade has been critical for the success, modernization, and expansion of the Society. Although Dr. Smith does not currently hold a formal position in the SMC Society, he continues to play a critical role in the Society as an advisor, recruiter for senior service positions, long-range planner, and a repository of institutional memory. He initially spearheaded and has continued to push the Society to play a key role in the development of the field of BMI devices. He created the first of many SMC Society BMI Workshops in 2009.

An important contribution of Dr. Smith was that he immediately started inviting members of the U.S. Brain Initiative to participate in these workshops, helping to build an early relationship between the U.S. Brain Initiative and the IEEE. Another contribution was his inviting representatives of the world's Global Brain Initiatives to one of his workshops, again helping to build a relationship between them and the IEEE. Also, a significant contribution of Dr. Smith has been the development and promotion of the IEEE Brain Initiative. As a senior advisor of the IEEE Brain Initiative, he promoted the idea of an IEEE Brain Initiative through the SMC and then lobbied other IEEE Societies and the IEEE leadership to come on board. He recruited a leading neuroengineer, Prof. Jose Carmena, to become involved in SMC's BMI Workshop and later serve as the Society's representative to the IEEE Brain Initiative (where he is now a cochair). Throughout the several years that it took to bring this effort to fruition, Dr. Smith was doggedly persistent but always unfailingly polite and politically astute. He was happy for others to get the credit for his hard work as long as the end result was positive. I suspect that few members of the IEEE have been as generous with their time and so effective in the outcome.

Prof. Larry O. Hall

University of South Florida

Mike Smith has provided important service to the IEEE SMC Society, with his first major above-and-beyond service coming before he was president. He helped out President Pierre Borne by attending IEEE Technical Activity Board meetings when President Borne could not. This was a big-time commitment. He made the effort to understand the issues and how the president wanted to vote on them. Understanding how another will want something done is time consuming, and Mike did it seamlessly.

Mike also did a great job stabilizing SMC Society finances just before and while he was the Society president. The Society ran into a brief rough spot, where it was in an operational fiscal deficit. Mike was able to quickly spot a couple of places for improvement that

immediately swung the finances into the positive with a solid surplus. His extensive experience in business was instrumental in enabling a quick turnaround.

One of the ways that Mike helped out the Society was by growing the size of the annual conference by making it a great event for attendees from a social as well as scientific perspective. He pioneered the use of quality special sessions to build attendance. Mike motivated people to put together the special sessions and, in particular, utilized the unflagging help of Prof. Hideuki Takagi. He was and continues to be the force behind SMC's BMI Workshops. Mike also experimented with novel ways to add members, such as providing conference attendees a one-year membership in the SMC Society. He increased member value through the publications received (electronically) while keeping the membership fee affordable. In general, Mike proved himself to be a tireless motivator, worker, and ambassador for the SMC Society.

Mike Smith always has ideas about how to make things bigger and better. He is always very generous in sharing his ideas, and when someone is interested in an idea, he helps create a path to realize it. Mike is also good at modifying any approaches that can be improved after having been ideated. He has worked hard both as a leader and behind the scenes to make the Society a more modern, sustainable entity, which all members appreciate.

Prof. José del R. Millán

Ecole Polytechnique Fédérale de Lausanne

My first encounter with Mike Smith was in 2009, on the occasion of the annual IEEE SMC conference in San Antonio, Texas. In fact, Mike had the early vision to make the field of BMI (or brain-computer interface) an integral part of the research program of the SMC Society, and he invited Dr. Jose Carmena from the University of California, Berkeley and me to give a tutorial on this topic during the conference. Soon after, Mike convinced the two of us to join the SMC Society and establish the Technical Committee on BMI Systems. The three of us started the organization of the annual BMI Workshop as part of the flagship annual IEEE SMC conference, whose scientific prestige grew rapidly. The SMC BMI Systems Workshop is now attracting an increasing number of submissions over the years, especially from researchers initially outside the IEEE.

Mike's relentless and fervent efforts have made the BMI Workshop a key element of the annual IEEE SMC conference, placing the SMC Society at the heart of the IEEE Brain Initiative and BMI activities. We can certainly state that Mike has played (and continues to play) a pivotal role in making the SMC Society a reference in the field of BMI. This is far from a trivial achievement because, due to its multidisciplinary nature, BMI is a growing research field that is attracting significant interest in many domains and conferences.

a number of IEEE Societies, IEEE Councils, and the IEEE Brain Initiative have technically cosponsored these Workshops for a number of years. The IEEE SMC BMI Workshops have included regular technical program sessions, special sessions, interesting and engaging panels, prominent invited speakers, tutorials, and IEEE Standards Association meetings. Since 2016, highlights of the BMI workshop programs have also included BR41N. IO BCI Hackathons.

The 2018 IEEE SMC BMI Workshop, held in Miyazaki, Japan, was the venue of a meeting of the Global Current and Emerging Brain Initiatives, with representatives from 10 countries and other stakeholders. The 2020 IEEE SMC BMI Workshop will be held in Toronto, Canada, 11–14 October 2020 (http://musaelab.ca/bmi20/smc2020_bmi.html). We hope to see many of you in Toronto this year!

Special Section Articles

The topics of the three technical articles in this special section address machine learning schemes in BMIs, machine learning algorithms for electroencephalography signals, and body/BMI.

- ◆ “Brain–Machine Interfaces: A Tale of Two Learners,” by S. Perdikis and J. del R. Millán, addresses the need



Figure 5. A lively poster discussion with SMC BMI Workshop General Cochair Tiago Falk (foreground) and Cochair Ricardo Chavarriaga (background).



Figure 6. The preparation of a Unicorn BCI at an SMC BMI Workshop Hackathon.



Figure 7. A Hackathon participant working on a smart home controller with a BCI system.



Figure 8. The judges listening to SMC BMI Workshop Hackathon presentations.



Figure 9. The judges, including (seated, second left) IEEE President Barry L. Shoop; (standing, left) SMC BMI Workshop General Chair Michael H. Smith; (seated, third left) SMC BMI Workshop Speaker Jack Gallant; and (seated, center) IEEE Brain Initiative Cochair Paul Sajda, discuss Hackathon presentations.



Figure 10. Happy Hackathon winners. (Far left): SMC BMI Workshop Hackathon Chair and organizer Christoph Guger.



Figure 11. The SMC BMI Workshop was a true success, and what a better way to finish it off than having the IEEE SMC Society President (2018–2019) Eddie Tunstel (third from bottom right) hosting a traditional Japanese sukiyaki dinner, followed by roasted marshmallows for dessert enjoyed by all including the author (bottom left).



Figure 12. SMC BMI Workshop General Chair Michael H. Smith celebrates the conclusion of a successful SMC BMI Workshop.

for subjects to learn how to modulate their brain activity and to more effectively combine machine and subject learning.

- ◆ “Neural Interface Instrumented Virtual Reality Headsets: Toward Next-Generation Immersive Applications,” by R. Cassani, M.-A. Moïnnereau, L. Ivănescu, O. Rosanne, and T. H. Falk, describes a portable, wireless body/BMI prototype that integrates a number of sensors into a virtual-reality head-mounted display.
- ◆ A. Appriou, A. Cichocki, and F. Lotte offer a formal study of recent machine learning algorithms and convolutional neural networks used for designing calibration-free BCI systems in “Modern Machine-Learning Algorithms: For Classifying Cognitive and Affective States From Electroencephalography Signals.”

About the Author

Ljiljana Trajkovic (ljilja@cs.sfu.ca) is a professor in the School of Engineering Science, Simon Fraser University, Burnaby, British Columbia, Canada. Her research interests include communication networks and dynamical systems. She is the IEEE Division X delegate/director (2019–2020) and past president of the IEEE Systems, Man, and Cybernetics Society and IEEE Circuits and Systems Society. She is the general cochair of SMC 2020 and SMC 2020 BMI Workshop. She served as the general cochair of SMC 2019 and SMC 2018 BMI Workshops and as the technical program chair of SMC 2017 and SMC 2016 BMI Workshops. She is a Distinguished Lecturer (2020–2021) of the IEEE Systems, Man, and Cybernetics Society and a Fellow of the IEEE.

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