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Brain–Computer Interface Research

A State-of-the-Art Summary 8



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Kai Miller
Editors

Brain–Computer Interface Research

A State-of-the-Art Summary 8

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Introduction



Christoph Guger, Kai Miller, and Brendan Z. Allison

Abstract Facebook, Elon Musk, and others are pursuing large-scale research and development projects involving brain-computer interface (BCI) systems. Each year, we have organized a BCI Research Award devoted to the best projects in BCI research. This year's book begins with a chapter that introduces BCIs, the Research Awards, and this book series. Most chapters present projects from the Eighth Annual BCI Research Award written by the scientists, doctors, and engineers behind each project. This book concludes with a chapter containing interviews with the winners, highlights from the BCI Research Awards Ceremony at the Seventh International BCI Meeting, and discussion of emerging BCI activities such as BCI Hackathons and Cybathlons.

Welcome to our eighth book! As we write or edit these chapters, we are currently preparing for the Tenth Annual Brain-Computer Interface (BCI) Research Award ceremony. Many of our earlier books have said the same thing that we often say at the awards ceremonies: we want to recognize and encourage top projects in the field. Each year, we still receive numerous award submissions, and the projects that have been nominated and their corresponding book chapters have been very interesting. We are grateful to readers like you for helping our books succeed, and hope you enjoy this year's book.

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1 What Is a BCI?

Brain-computer interfaces (BCIs) translate information from the brain directly to output signals like messages or commands. While most authors (including us) do not typically use a hyphen after “brain,” we included it here to emphasize that BCIs read information from the brain, not write to it. BCIs provide a way to communicate without moving, and have primarily sought to help people with severe disabilities who cannot communicate any other way.

However, in the past several years, new BCI approaches for new types of patients have been developed and often validated with patients. The chapters in this book include BCIs that could potentially help patients hear more effectively, relearn how to move after a stroke, or use devices like exoskeletons or prostheses based on imagined movements. Another chapter from Bolu Ajiboye and colleagues shows a different BCI for prosthetic control using electrodes inside the skull, while Christian Herff and his team wrote a chapter about work toward BCIs that directly translate imagined speech into words.

Along with the many people working on BCIs, more people seem to be learning about BCIs. Universities offer new classes that include BCI research, with more faculty and other staff who can teach courses, mentor students, and support hands-on BCI activities and projects. Major public activities like BCI hackathons, Cybathlons, and demonstrations are also increasing.

2 The Annual BCI Research Award

The Annual BCI Research Award is organized through the non-profit BCI Award Foundation. Jury members may not submit projects, but otherwise, the award is open to any research group, regardless of their location, equipment used, etc. The awards procedure this year followed a procedure similar to prior years:

- A Chairperson of the Jury is chosen from a top BCI research institute.
- This Chairperson forms a jury of well-known BCI experts to judge the Award submissions.
- We post the submission instructions, scoring criteria, and the deadline for the Award.
- The jury scores each submission based on the scoring criteria below. The jury then chooses twelve nominees and the first, second, and third place winners.
- The nominees are announced online, asked to contribute a chapter to this annual book series, and invited to a Award Ceremony that is attached to a major conference (such as an International BCI Meeting or Conference).
- The Gala Awards Ceremony is a major part of each conference. Each of the twelve nominees are announced and come onstage to receive a certificate. Next, the winners are announced. The winner earns \$3000 USD and the prestigious trophy. The 2nd and 3rd place winners get \$2000 USD and \$1000 USD, respectively.

This year, for the first time, the third-place prize was generously donated by the BCI Society. The BCI Society is a non-profit organization that organizes the BCI Meeting series (bcisociety.org), and has kindly made our Gala Awards Ceremony part of their meetings. The other cash prizes were provided by an Austrian company called g.tec medical engineering (author CG is the CEO), which manufactures equipment and software for BCIs and other applications.

The 2018 jury was:

Kai Miller (Chair of the Jury)

Natalie Mrachacz-Kersting (2017 Winner)

Vivek Prabhakaran

Yijun Wang

Milena Korostenskaja

Sharlene Flesher

This year's jury had an unusually high number of members who were nominated for BCI Research Awards in prior years. Like earlier juries, the 2018 jury included the preceding year's winner, Natalie Mrachacz-Kersting. The Chair of the jury, Kai Miller, was nominated in 2011 and 2014, and Milena Korostenskaja was nominated in 2017. Sharlene Flesher's team won second place in the 2016 BCI Research Awards for their work with an intracortical microstimulator as a feedback source for BCI users. Having a jury with alumni from previous awards should help the jury members appreciate the projects that they have to review.

The scoring criteria that the jury used to select the nominees and winners were the same as all previous BCI Research Awards:

- Does the project include a novel application of the BCI?
- Is there any new methodological approach used compared to earlier projects?
- Is there any new benefit for potential users of a BCI?
- Is there any improvement in terms of speed of the system (e.g. bit/min)?
- Is there any improvement in terms of accuracy of the system?
- Does the project include any results obtained from real patients or other potential users?
- Is the used approach working online/in real-time?
- Is there any improvement in terms of usability?
- Does the project include any novel hardware or software developments?

The jury then tallies the resulting scores, and the nominees are posted online. The nominees are invited to a Gala Awards Ceremony for that year's awards. For several years, this ceremony has been part of the biggest BCI conference for that year, which has had one of two organizers. The BCI Society organizes a BCI Meeting every even-numbered year, while the Technical University of Graz hosts a BCI Conference every odd-numbered year.

This year's ceremony was part of the 2018 BCI Meeting in Asilomar, CA. We held the ceremony outside, expecting a warm and dry evening, and the California weather did not disappoint anyone. Everyone enjoyed a pleasant beach breeze throughout the ceremony. We reviewed the BCI Awards process, asked the at least one nominee from each team to come receive a certificate and other prizes. Then, we announced



Fig. 1 The Chair of the Jury, Kai Miller, announces the projects nominated for the BCI Award at the BCI Meeting 2018. Christoph Guger is in the foreground on the right side of the picture, and Brendan Allison is behind him

the three winners and presented their prizes (Figs. 1 and 2). After the ceremony, many of us walked west to celebrate on the beach.

3 The BCI Research Award Book Series

The BCI Research Award Books have always been part of the BCI Research Awards. Since the first BCI Research Award in 2010, we published a book each year that presents the projects that were nominated this year. We encourage the authors of those chapters to add other material such as discussion and future directions.

Over the course of several years, we have decided to allow more time for authors to develop their contributions. This allows them time to publish underlying material and present new and more detailed information in their chapters, including additional results or discussion. For example, the next chapter from Mikhail Lebedev



Fig. 2 Christoph Guger (organizer), Kai Miller (Chair of Jury), Sharlene Flesher (jury), Josef Fallner (nominee), Vivek Prabhakaran (jury), Brendan Allison (emcee)

and colleagues includes discussion about future directions to help patients with hand-writing. In another example, the penultimate chapter from Chen Yang and colleagues presents details about how their BCI system works and how it was implemented with healthy persons and a patient.

After we receive the chapters from the authors, we review them, and sometimes request changes from the authors. After the chapters are ready, we send them to the publisher. The publisher sends back final proofs for review, and then the book goes into production.

Each year's book also begins with an introduction chapter like this one and ends with a chapter summarizing the highlights. Some books have included other material such as commentaries or, as is the case this year, interviews with authors. We've often noticed that the awards both track and anticipate changes in BCI research, and many chapters present emerging directions. The chapters introduce ideas, methods, and results that are relevant to readers who are interested in developing and building BCIs, as well as readers curious about basic scientific questions about how the brain works. Before these chapters from the nominees, the next section presents the nominated projects.

4 Projects Nominated for the BCI Award 2018

The jury scored all of the submissions using the scoring criteria (see Sect. 2 of this chapter), then tallied the scores to determine the twelve nominated for the BCI Research Award 2018. The nominees, including their affiliations and project names, were:

Alexei E. Ossadtchi^{1*}, Elizaveta Okorokova², Joseph S. Erlichman³, Valery I. Rupasov⁴, Mikhail A. Lebedev^{1,5}, and Michael Linderman⁴

Generating Handwriting from Multichannel EMG

- 1 National Research University Higher School of Economics.
- 2 University of Chicago.
- 3 St. Lawrence University.
- 4 Norconnect Inc.
- 5 Duke University.

Martin Burns, Dingyi Pei, Ramana Vinjamuri

Real-time EEG Control of a Dexterous Hand Exoskeleton embedded with Synergies

Department of Biomedical Engineering, Stevens Institute of Technology, NJ, USA.

James O'Sullivan², Zhuo Chen¹, Jose Herrero⁴, Guy M McKhann³, Sameer A Sheth³, Ashesh D Mehta⁴, Nima Mesgarani^{1,2,5}

Neural decoding of attentional selection in multi-speaker environments without access to clean sources

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- 2 Mortimer B Zuckerman Mind Brain Behavior Institute, Columbia University, New York, USA.
- 3 Department of Neurological Surgery, The Neurological Institute, 710 West 168 Street, New York, USA.
- 4 Department of Neurosurgery, Hofstra-Northwell School of Medicine and Feinstein Institute for Medical Research, Manhasset, NY, USA.

J. Faller¹, J. Cummings¹, S. Saproo¹, P. Sajda^{1,2}

BCI-based regulation of arousal improves human performance in a demanding sensory-motor task

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- 2 Data Science Institute, Columbia University, New York, USA.