Mapping the Future of Closed-Loop Brain-Machine Neurotechnology
Development of next generation closed-loop brain-machine interfaces requires input on overcoming key technology challenges in order to realize full potential

Brain-machine interfaces (BMIs) are designed to establish communication between the brain and external devices (e.g., a computer or prosthetic), using recorded signals to control the devices. Closed-loop BMIs extend this cycle further by continuously recording signals from the brain and nervous system, decoding this information, and then encoding information and sending it back to the brain and/or nervous system, usually in the form of localized stimulation. Research and development of closed-loop technologies for control of neural activity has increased steadily over the last decade due in part to the potentialities that both reading and writing into the nervous system may offer for both the advancement of neuroscience as a field as well as for therapeutic interventions and associated consumer applications.

Recently, closed-loop neurotechnologies have shown promise for providing therapeutic and rehabilitative options for patients, as well as the potential for delivering augmentative capabilities. These efforts range from restoring movement function, providing functional cures for neurological diseases such as epilepsy and Parkinson's disease, treating memory disorders and neuropsychiatric disorders, increasing learning speed and ability, and devices that can both sense and stimulate activity in our sensory motor system.

Although still in its infancy, development of closed-loop BMI neurotechnologies is in part driven by the prevalence of neurological and psychiatric disorders, many of which do not respond well to pharmacological treatments or do not have other viable treatment options. The potential to provide proven therapeutic devices that address chronic depression, post-traumatic stress disorder (PTSD), and diseases such as epilepsy and Parkinson's disease will guide technology development in the near future. Closing the loop on such devices will offer more precision and personalization, as therapeutic stimulation becomes better designed to respond more directly to the patient's own neural physiology. Ultimately, next generation closed-loop devices will reimagine the partnership between the brain and body's nervous systems, with the potential to provide effective precision electronic medicine and drive new consumer applications in areas of wellness, gaming, and training.

Given current development trajectories, next generation closed-loop neurotechnologies that decode and encode neural activity from multiple nervous system sites, e.g., the central nervous system, peripheral nervous system, and autonomic nervous system (CNS/PNS/ANS), will likely occur within the next ten to twenty years. To that end, the IEEE Brain Initiative has issued a white paper identifying key challenges and advances required to successfully develop and translate these next generation closed-loop neurotechnologies.

"This white paper will be a valuable resource for neuroscientists, clinicians, and entrepreneurs on the state of the art in neurotechnology and brain-machine interface systems, from the perspective of closed-loop control of neural activity," says IEEE Brain Co-Chair Jose M. Carmena, Chancellor's Professor of Electrical Engineering and Neuroscience and Co-Director of the Center for Neural Engineering and Prostheses (CNEP) at the University of California, Berkeley.

The paper is the first step in the formation of a technology roadmap illustrating short- and long-range goals of the closed-loop technology development cycle. "The roadmap that will follow from this white paper will guide the development of these technologies for basic science and clinical translation, with a strong emphasis on neuroethics and the impact of this technology in society," adds Carmena.

Feedback on the development trajectory of next generation closed-loop BMI technology is vital for ensuring that all stakeholders have a voice in this process, and input from the greater neuroscience community, including neuroscientists, engineers, neuroethicists, and clinicians, is requested. The white paper can be found here, and comments and concerns can be sent to brain-clwp@ieee.org.

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The mission of the IEEE Brain Initiative is to facilitate cross-disciplinary collaboration and coordination to advance research, standardization, and development of technologies in neuroscience to help transform our understanding of the brain to treat diseases and to improve lives. Learn more about the program and activities at brain.ieee.org.

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