Academic Corner

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In this issue, we interview IEEE SMC member Sarah Power. Sarah is an associate professor in the Department of Electrical and Computer Engineering and the Division of Population Health and Applied Health Sciences at Memorial University of Newfoundland in St. John's, Canada. Dr. Power completed B.Eng. (Memorial University, 2006) and M.A.Sc. (University of Toronto, 2008) degrees in electrical engineering, followed by a PhD in biomedical engineering (University of Toronto, 2012). In 2015, she became an assistant professor at Memorial University and was promoted to associate professor in 2022. Her research interests lie primarily in the area of non-invasive brain-computer interfaces.

(1) What inspired you to merge engineering with biomedical applications?

My path into biomedical engineering was shaped by a combination of curiosity, family influences, and a desire to make a meaningful impact on people's lives. In high school, I was fascinated by health and human physiology and imagined that I would eventually go to medical school. I just needed to decide on the best program to get me there. At the time, I honestly didn't fully understand what engineering was, but I knew I enjoyed and excelled at physics and math, and I looked up to my two older brothers, who had both pursued engineering in university. It seemed like a practical and promising path, offering strong job prospects and a solid foundation for my future plans. After enjoying the foundational first-year courses in programming and electric circuits over those related to statics and dynamics, I decided to enter the electrical engineering program.

This turned out to be the right choice. I was drawn to the logical elegance of electrical engineering, with its focus on problem-solving and innovation. My experience at Memorial University in St. John's, Canada, further solidified this passion, as the school's excellent cooperative education program gave me the opportunity to complete six internships in a variety of industries and work environments. These experiences broadened my perspective and allowed me to gain valuable hands-on skills, but they also reaffirmed that my true interest still lay in human health-related areas. By the time I finished my degree, I realized I didn't want to abandon engineering for medical school; instead, I wanted to find a way to merge my two passions. Pursuing graduate studies in biomedical engineering became the perfect solution.

It honestly felt like fate when Dr. Tom Chau from the PRISM Lab at the University of Toronto reached out to me after seeing my application. His work, which focused on creating innovative solutions to allow children with profound disabilities to communicate, could not have aligned more perfectly with my interests and aspirations. I consider myself extremely fortunate to have had the opportunity to work with an incredible mentor like Dr. Chau, who is a pioneer in childhood disability research and an overall wonderful person. I was able to immerse myself in groundbreaking research that has had a positive impact on the lives of children and their families.

During my time in Dr. Chau's lab, throughout my M.A.Sc. and PhD, I delved into the world of brain-computer interfaces (BCIs) and we were among the first groups to explore functional near-infrared spectroscopy (fNIRS) for this purpose. Since finishing my PhD, I have continued to pursue BCI research in my own lab at Memorial University. Looking back, my journey feels like a natural evolution—a blend of early interests, new opportunities, and a desire to do meaningful work. Biomedical engineering has given me the perfect platform to merge my skills and passions in engineering and in human health and physiology, with my desire to make a difference in people's lives.

(2) How do you see brain-computer interfaces (BCIs) evolving?

Brain-computer interfaces (BCIs) were initially developed to help individuals with severe motor impairments communicate and control external devices. While non-invasive BCIs based on EEG (electroencephalography) and fNIRS (functional near-infrared spectroscopy) have made significant strides, particularly with advancements in signal processing and machine learning for neural decoding, they still face limitations. The quality of the acquired brain signals is insufficient to achieve the speed and accuracy required for effective device control. Challenges such as long user training times, fatigue, and signal interference also hinder widespread adoption. Invasive BCIs, which involve direct implantation of sensors onto or into the brain, offer much better signal quality and precise control. While they come with higher risks and other complexities, ongoing advancements in sensor technology—such as wireless implantation and improved long-term stability—are making these systems safer, less invasive, and more viable for real-world application. As this technology advances, invasive BCIs hold the most promise for allowing individuals with motor impairments to control devices like wheelchairs, prosthetics, and computers.

Despite the limitations of non-invasive BCIs for device control, there are still many promising applications for these systems, particularly in neurorehabilitation. One key area is neurofeedback-based training for stroke recovery, which has shown success in helping patients regain motor function by promoting neuroplasticity. Through this process, the brain recruits unaffected areas to compensate for damaged regions, and with repetition, new neural pathways controlling movement are established. As BCI technology continues to improve, these systems could become an essential tool in the recovery of individuals with brain injuries or neurological disorders.

Another exciting research area involves the development of “passive” BCIs, which monitor mental states like fatigue, stress, or cognitive workload based on EEG or fNIRS. These systems have the potential to enhance human-computer interaction and optimize performance in various fields, such as healthcare, education, entertainment, and workplace safety. For instance, real-time monitoring of cognitive workload could help prevent errors in high-stakes environments like aviation, surgery, or industrial settings. In education, passive BCIs could provide personalized feedback to help students optimize their learning and focus during tasks. In mental health, these systems could be used to monitor emotional states, such as detecting early signs of depression or anxiety, and provide real-time interventions, such as relaxation exercises or mood tracking. While challenges remain in making these systems reliable, low-cost, and adaptable to real-world environments, research is actively addressing these issues to enable broader adoption.

While invasive BCIs are likely to drive the future of device control, non-invasive BCIs still offer valuable applications, especially in rehabilitation and mental state monitoring. With continued advancements in both non-invasive and invasive technologies, BCIs have the potential to revolutionize healthcare, enhance productivity, and optimize human-computer interaction across a range of industries.

(3) What role does signal processing play in advancing healthcare technologies?

Signal processing plays a crucial role in advancing healthcare technologies by enabling the extraction of meaningful information from complex physiological data, such as EEG, ECG, EMG, or fNIRS signals. These signals are often noisy and nonlinear, so advanced signal processing techniques are essential for detecting patterns and insights that were previously inaccessible. This capability is key not only to brain-computer interfaces, but also to driving innovations in other areas of health monitoring, diagnosis, and therapy.

One notable application is in early detection and intervention. For example, research is ongoing to develop EEG-based seizure detection systems for patients with epilepsy. Signal processing algorithms analyze the data in real-time to identify subtle changes in brain patterns that could precede a seizure, allowing for potential early intervention, such as medication adjustments or alert systems. While still in development, this approach holds promise for improving patient outcomes.

Signal processing is also showing potential for the early detection of neurodegenerative conditions like dementia. Through EEG analysis, researchers are investigating specific brain wave patterns and changes in neural activity that could signal the onset of dementia before noticeable symptoms appear. This early detection could allow for timely interventions that might slow disease progression and improve the quality of life for patients.

Signal processing is also critical for remote monitoring and chronic disease management, which are essential for improving patient outcomes and reducing healthcare costs, particularly in rural areas with limited access to healthcare facilities. Advancements in wearable devices integrating biomedical sensors, combined with advanced processing algorithms to extract metrics like heart rate, blood pressure, and glucose levels, could expand continuous health monitoring and enable earlier detection of issues such as arrhythmias, heart failure, or diabetes complications.

The integration of machine learning with signal processing is also accelerating innovation with seemingly limitless possibilities. For instance, machine learning models could be trained on large datasets to identify patterns that clinicians may miss. Applied to ECG data, machine learning could predict the likelihood of cardiovascular events, such as heart attacks, offering preventive insights.
In addition, signal processing is being explored to improve sleep disorders, where techniques such as polysomnography (PSG) and EEG analysis help monitor sleep patterns and detect disturbances like sleep apnea or restless leg syndrome. These methods could help optimize treatment plans and improve sleep quality for patients, leading to better overall health outcomes.

These are but a few examples. Ultimately, signal processing has the potential to transform healthcare by turning raw physiological data into actionable insights. As these technologies continue to evolve, they could lead to significant improvements in quality of life and health outcomes, from neurological and cardiovascular diseases to chronic disease management

(4) What advice would you give to researchers interested in interdisciplinary fields?
Interdisciplinary research is both challenging and rewarding, requiring a blend of curiosity, adaptability, and collaboration. For researchers venturing into interdisciplinary fields, it’s important to develop a strong foundation in your core discipline. A deep understanding of your primary field provides the expertise, credibility, and confidence needed to contribute meaningfully to interdisciplinary projects and helps you identify where your skills can intersect with other domains.

Be open to learning about new fields. While you don’t have to be an expert in all areas, developing a working knowledge of the key concepts, methods, and terminology of other disciplines will help you communicate effectively with collaborators and understand the broader context of the work.

Seek out diverse collaborators, as they are the backbone of interdisciplinary research. Build relationships with researchers from other fields through networking events, interdisciplinary conferences, or institutional initiatives, and look for collaborators who are open-minded, communicative, and value diverse perspectives.

Focusing on real-world challenges is critical in interdisciplinary research, especially in fields like biomedical engineering. Letting real-world problems guide your efforts ensures that your work addresses genuine needs, and doesn't just develop technologies that are impressive within one discipline but lack practical application in the intended domain. For example, a researcher might design a cutting-edge biomedical sensor that performs well in a lab but is too expensive, fragile, or complex to actually use in clinical or remote settings. By addressing tangible and realistic healthcare challenges, you can integrate insights from medicine, engineering, and other fields to create feasible, impactful solutions that improve patient care and outcomes.

Interdisciplinary research offers the chance to tackle complex problems and drive innovation by combining the strengths of multiple fields. By staying curious, adaptable, and collaborative, researchers can make meaningful contributions in these exciting and dynamic areas.

(5) What role has IEEE played in your career?

Like most electrical engineers, IEEE has played an important role in my career, both as a researcher and a professional engineer. From the beginning, IEEE has served as an invaluable resource, offering access to high-quality technical literature and cutting-edge research through its extensive library. Serving as a reviewer for IEEE publications and events has provided valuable insight into the publication process and sharpened my ability to critically evaluate research. Attending IEEE conferences and workshops has provided opportunities to present my work, receive constructive feedback, and engage with a global network of researchers and practitioners. Involvement with my local IEEE chapter – particulary as a member of the organizing committee for our local Newfoundland Electrical and Computer Engineering Conference for several years - has allowed me to connect with peers and contribute to initiatives that promote knowledge sharing and innovation within my community. Since 2020, I have particularly enjoyed serving as co-chair of the technical program committee for the Brain-Machine Interface (BMI) Workshop at the IEEE SMC Conference. This experience has broadened my perspective and fostered lasting professional relationships.