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Innovation Starts With Education

Signal processing (SP) is at the very heart of our digital lives, owing to its role as the pivotal enabling technology for advancement across multiple disciplines. Its prominence in modern data science has created a necessity to supply industry, government labs, and academia with graduates who possess relevant SP expertise and are well equipped to deal with the manifold challenges in current and future applications. To this end, the ways to deliver both educational content and the core SP curriculum need to be revisited and integrated into current electrical engineering and computer science degrees to provide high-quality and hands-on multidisciplinary skills, experience, and inspiration for students at all levels.

SP education in today's universities is largely influenced by three modern trends:

1) the availability of competing and complementary online and multimedia resources
2) the fact that we live in a world in which the amount and diversity of information we generate, process, and analyze are growing
3) the explosive growth of computing power and the rapid development of new technologies for implementing both analog and digital SP.

These trends offer both opportunities and challenges, which we can and must exploit in charting dynamically adjustable courses that attract a high level of student engagement while offering a mix of essential background physics, intuition, mathematical rigor, and practical applicability of the taught material.

With such initiatives underway worldwide, this special issue aims to facilitate both keeping abreast with SP education and exploring innovative and participatory ways to present the educational materials. In effect, we cannot assume that students will be able to appreciate the scope and relevance of their courses without explicitly building a bridge between the material presented in class and cutting-edge research and the societal and practical impact of their education. This includes the convergence of educational material with other disciplines (machine learning, data science, big data, bioengineering, artificial intelligence, finance, and many others).

> **"The role of a magician is to make simple things appear mysterious. The role of a teacher is to make mysterious things appear simple."**
> **—Al Oppenheim**

This special issue of *IEEE Signal Processing Magazine* (*SPM*) therefore revolves around three general and most-pressing aspects of modern SP education:

- *How to educate differently (better)*: This includes the use of available technology, bringing research into the classroom, web resources, experiential learning, and massive open online courses (MOOCs).
- *Student engagement*: This includes ways to enhance student creativity and curiosity, student satisfaction issues, various forms of assessment and metrics, engagement of underrepresented populations, and outreach drives.
- *Promotion of the societal impact of SP*: This includes privacy, ethical and security concerns, wearable devices and eHealth, global interconnections through the Internet of Things (IoT), and impact on climate change, global economy, and finance.

A coherent and comprehensive account of these issues is particularly important and timely, given the increasing exposure to popular technological advancements, such as big data, the IoT, and wearable devices. These also naturally lead to questions about the relevance of some classic subjects in modern, real-world applications.

Apart from the values specific to SP, this special issue aims to help the international community engage in education and the outreach of our discipline (including industry-run courses) to better understand, tackle, and address (through a coherent effort of international contributors) some of the key challenges the global education is facing. Indeed, the inexorable advances

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in sensor technology and the IoT and the increasingly diverse forms of data acquisition have inevitably led to wider and more rapid ways in which we generate, process, and revise the notion of information. This trend is already having a major impact on how we educate and learn. Given the rich history of the SP field and the availability of competing and complementary multimedia educational resources, a common challenge in modern SP education is to produce a dynamically adjustable tradeoff, arising, as it does, from both the diversity in student learning styles and the requirements imposed by the future careers of these students.

To this end, we have identified some of the most pressing challenges the global education is facing, which include

- students communicating in a different way, which requires a rethinking of teaching practices that highlight the importance of real-time demonstrations and hands-on projects in teaching
- how to use emerging technologies to improve instruction and teaching next-generation solutions where possible (that is, educating students for jobs that currently may not even exist but will be prominent in five years or so)
- ways to bring research into the curriculum as a paradigm shift
- educating students about the importance of the completion and execution of their ideas/projects and of expressing themselves concisely and precisely through SP tools and SP ways of thinking
- the implementation of elements of service economy into electrical engineering curricula as many economies are moving away from products and into services
- enhancing awareness about the societal impact of SP education and the role of education as a key to innovation and, thus, the creation of enabling technologies for the solution of issues such as climate change, global IoT-enabled interactions, and space exploration
- the need for the reform of education, both geographically and in terms of widely accessible "global" lecture courses.

To address these challenges, we have centered this special issue of *SPM* around the following topics:

- the mitigation of issues related to the perceived difficulty of traditional SP courses, such as strategies on how to teach SP with less math and how to attract attendees from nonengineering departments
- the use of technologically orientated classrooms and emerging technologies, such as MOOCs and web resources
- metrics for success of education delivery in the after-online technology era
- using the principles of SP to improve teaching and research in related areas, such as machine learning, bioengineering, and artificial intelligence and optimization, and vice versa
- curricular changes to meet contemporary demands from industry, such as using practically relevant problems, exploring feasible extensions and new applications of the taught material, and curiosity-driven learning
- preparing students for lifelong learning and teaching lifelong fundamentals of SP and the relevance of SP with respect to technological advances
- challenges and solutions in industry-run courses—the design of short courses offered by academia for industry, government agencies, and national defense
- the role of mentorship and initiatives to encourage and motivate students in research experiences
- promoting creativity in learning, especially when applying the concepts with opportunity windows to explore entrepreneurship, possible product developments, and cross-disciplinary aspects of our work.

The timing of this special issue has been reinforced by the success of the recent special program "Celebrating Signal Processing Education" at ICASSP 2019 in Brighton, United Kingdom, which had the involvement of all of the guest editors of this special issue. This initiative has highlighted that the SP community can significantly benefit from the dissemination of ideas and practices, especially related to the recent rapid evolution of SP education. These topics are of vital importance for the future of our discipline but have not, until now, been properly addressed in a comprehensive and cohesive way in the open literature. This special issue therefore aims at providing a unifying framework to educate SP educators within the general umbrella of "Innovation Starts With Education." Before moving on to the articles in this special issue, we continue this guest editorial with a more personal "Reflections" column by two colleagues, Al Oppenheim and Tony Constantinides, who have been part of this community for more than five decades. We close with a quote from Al Oppenheim: "The role of a magician is to make simple things appear mysterious. The role of a teacher is to make mysterious things appear simple."

Guest Editors

Mónica F. Bugallo (monica.bugallo@stonybrook.edu) received her Ph.D. degree in computer science and engineering from the University of A Coruña, Spain. She is a professor of electrical and computer engineering and the vice provost for faculty affairs and for diversity, equity, and inclusion at Stony Brook University, New York, 11794, USA. She serves as the current chair of the Signal Processing Theory and Methods Technical Committee of the IEEE Signal Processing Society, senior associate editor of *IEEE Signal Processing Letters*, and associate editor of *IEEE Transactions on Signal Processing*. Her research interests include statistical signal processing, with emphasis on the theory of Monte Carlo methods and their application to different disciplines. She has also focused on science, technology, engineering, and mathematics education and has initiated successful programs to engage students at all academic stages in the excitement of engineering and research, with focus on underrepresented groups. She is a Senior Member of IEEE.

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