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Special Article Series on Signal Processing Education via Hands-On and Design Projects

As professionals in the signal and information processing field, we build on the tools and theories we learned in our undergraduate studies, adding knowledge and skills over the years. For many of us, it has been a while since our undergraduate studies, yet we can probably recall some of these "Ah-ha" moments when a full meaning of some fundamental theory sank in. As educators and mentors, we seize on these moments and our own experiences to implement new successful teaching methods that advance effective learning and skill development.

In an era of unprecedented technology refresh rate, the challenge of providing a high-quality engineering experience is compounded by the required theoretical background, the increasing multidisciplinary applications, and a growing demand from the industry for engineers with "know-how" skills. Schools need to constantly assess and restructure the manner in which they prepare students to meet these growing demands from the engineering workforce. Educators are faced with the greater challenge of preparing their undergraduate students to deal with real-life engineering problems as early as possible in their education while not compromising on the required theoretical knowledge base. Engineering programs need to find an effective way to incorporate application aspects into the teaching of the fundamental concept. At the same time, they are required to develop teamworking skills, research and development experience, and innovative thinking, which is achievable through full-scale engineering design projects. For the latter, students need to collaborate on more complex engineering problems that integrate a larger set of tools and disciplines to solve and work under realistic constraints. The diversity in engineering applications that utilize signal and information processing opens many possibilities when it comes to the choice of experiments and projects that will keep students engaged in learning. The implementation of such practices becomes feasible with the availability of affordable hardware platforms that incorporate significant on-board computation capabilities alongside access to sensors, actuators, and open-source software tools.

There are few opportunities to share progresses and innovation made through undergraduate engineering design projects. An overview of the state-of-the-art methods used in providing students with practical engineering education is of high interest to educators, researchers, and professionals. A discussion on what is done around the world to advance students' hands-on experience will provide valuable tools and practices to educators and will offer professionals in the industry with a clearer image of the efforts made to increase engineering skills during undergraduate studies.

Integrating more hands-on experiences into formal engineering education is mainstream, and significant efforts are being made in this direction. An insight into the implementation challenges of design projects and experimental platforms from students in their freshmen through senior years and solutions adopted to address them are offered in this issue of *IEEE Signal Processing Magazine* (*SPM*) through a series of article contributions from around the world.

Schäck, Muma, and Zoubir's article, "Signal Processing Projects at Technische Universität Darmstadt," details year-by-year practices implemented throughout undergraduate and graduate studies to support students' hands-on experience. The curriculum builds up theoretical knowledge alongside laboratories and engineering projects that advance professional proficiency. Interdisciplinary aspects, laboratories infrastructure, and the role of competitions in this process are discussed. This overview offers the reader an insight into use practices, detailing their advantages and challenges.

Focusing on engineering projects and competitions, Zhuo, Ren, Jiang, and Zhang's, article, "Hands-On Learning Through Racing," on the National Collegiate Intelligent Model Car Competition in China, introduces an education-through-challenge approach. In an annual competition, participating teams need to design and build cars that will be racing against other teams. The students learn a multitude of engineering skills while developing teamwork capabilities and collaboration skills. The article

Digital Object Identifier 10.1109/MSP.2016.2620199
Date of publication: 11 January 2017

offers extensive details on the structure of these competitions and the skill sets developed through it, enabling the adoption of this competition-based approach by others.

A focus on communications-related practices is given in the article, "Teaching the Principles of Massive MIMO" by Larsson, Danev, Olofsson, and Sörman. This contribution details the development of a course targeting students' exposure to cutting-edge technology and emerging concepts. The course is designed around building system-level understanding and expanding the classical curriculum to integrate a project-like approach. A student perspective is given throughout the article along with lessons learned. It demonstrates the students' experience and how students' feedback has been used to further develop the course impact.

Complementing this issue

Complementing these three feature articles are two articles published in *SPM*'s "SP Education" columns in the July and November 2016 issues, which paved the way for us to introduce the readers to this effort of sharing best practices on hands-on training in signal processing. In *SPM*'s July issue, Simoni and Aburdene [1] shared their eight-year experience and lessons learned in developing application-oriented activities to help students better understand signal processing theory and connect the theory to real-world applications.

In the November 2016 "SP Education" column, Richter and Nehorai introduced the incorporation of undergraduate research projects as a key component in the Electrical and Systems Engineering program at Washington University, St. Louis, Missouri [2]. Thanks to the active involvement of signal processing faculty members, many of the successful projects were related to signal processing, and these experiences substantially boosted the undergraduate enrollment and retention rate and attracted students to pursue a career in engineering.

Undergraduate engineering design projects, commonly introduced in a students' junior and senior years, allow them to work on real-life problems while applying their acquired knowledge and creativity. Some of these projects provide an opportunity to work in collaboration with others on more complex tasks, training students to learn teamwork skills and project management. These collaborations frequently entail a multidisciplinary effort. Signal and information processing plays an important role in many of these engineering projects.

While there are some channels in which students can share and publish their engineering projects, there is a need for a more focused review on engineering projects that offer great opportunities for the implementation of signal and information processing techniques. With the rapid advancement in technology and platforms available for project development, there is high value is sharing the knowledge and results stemming from these efforts to advance the general community. An overview of practical educational tools, application challenges, and keys to successful implementation of these programs is of high interest to both academia and the industry.

To address this need, as part of this article series, *SPM* has opened a SigPort-based submission and archival platform for sharing students' projects contributions. This issue's "SP Education" column is the first to detail these highlighted projects. Through the SigPort repository, a number of undergraduate students and their advisors shared information on relevant engineering projects. Overall, the submitted projects had more than 400 downloads within a two-month period, showcasing the keen interest in the community for such information. Contributions from around the world cover diverse fields and projects reflecting signal and information processing opportunities and applications range.

It is encouraging to learn that *SPM* and its monthly eNewsletter will be working with the IEEE Signal Processing Society's Education Committee and SigPort Committee to continue accepting student project submissions and theses in the broad areas of signal and information processing to archive through the SigPort platform. Summaries of the projects selected from these submissions will be periodically highlighted in *Inside Signal Processing eNewsletter*; and, if space allows, some of these projects may be showcased in *SPM*'s "SP Education" column.

We hope that the introduction of this series of articles dedicated to signal and information processing in engineering projects will promote communication and discussion on undergraduate studies, capabilities development, and increase interest and involvement from the engineering community. We look forward to bringing you the next set of informative articles in upcoming issues of the magazine.

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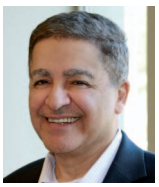

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Digital Object Identifier 10.1109/MSP.2016.2643718