Tülay Adali | Editor-in-Chief | adali@umbc.edu

Today's Rapidly Evolving Education Landscape: Challenges and Opportunities

For reasons beyond our control, the issues of *IEEE Signal Processing Magazine* arrive to you with delays this year. As you receive the current March issue, we are back from another edition of our flagship conference, the IEEE International Conference on Acoustic, Speech, and Signal Processing (ICASSP), which took place in Seoul, Korea, 14–19 April 2024. It was successful and vibrant, and, with 4,432 attendees and 2,826 accepted papers (out of 5,896 submitted), it was bigger than ever. At the risk of being labeled a grumpy Muppet, I will note that ICASSPs are now a tad too big for me, as I often found myself at a loss trying to choose among a seemingly endless number of attractive sessions and events at any given time. Of course, we still have our workshops, which are intimate and focused, and a number of them are even single track.

ICASSP 2024

Putting this minor quibble aside, ICASSP 2024 was rich, including not only an array of exciting technical sessions and invited talks but also events such as panels, forums, demos, short courses, and exhibitions. Our active discussion topic—the relationship of artificial intelligence (AI) and/or machine learning (ML) to signal processing (SP)—was ever present in many of these events. The AI/ML panel series was one of those, and this edition had a focus on the impact of recent AI/ML advancements in SP education. It was organized by Andres Kwasinski, with Martin Haardt, José Moura, Danilo Mandic, and Gene Cheung as panelists. Moura, reflecting on the evolution of statistical SP, noted how we have successfully balanced the model and data-driven approaches over the years. He thus placed the new set of AI/ML tools carefully into context as part of data-driven solutions to both our old and new SP problems. He further underlined that we cannot ignore the new AI/ML tools that are now available because they actually promise to make our area much more interesting by presenting new opportunities for us. These and other ideas led to interesting discussions and exchanges of opinions.

This year's ICASSP, like previous editions, included the presentation of the Society awards, among them the Regional Distinguished Teaching Award, presented this year to Rich Radke from Rensselaer Polytechnical Institute for "bringing new technology and pedagogy into the classroom and tying academic concepts to real-world practice." This was an attractive opportunity to bring examples to our discussion, and, already familiar with Radke's exciting course offering, I reached out to him. Following a brief discussion with the magazine editorial team, we converged on having him tell us about his experience teaching his new course, "Computational Creativity," where he introduced and made use of the most recent generative modeling tools and discussed their impact on art, education, law, and ethics. In our current issue of *IEEE Signal Processing Magazine*, Radke [A1] shares his experiences teaching the course, but, more importantly, he comes up with a broad set of questions on the role of educators in the age of generative AI.

Graduate training in AI/ML/SP for sustained career growth

The questions in Radke's article [A1] reminded me of some of the discussions at a panel I had moderated last year. This was part of the IEEE and National Science Foundation joint workshop "Toward Explainable, Reliable, and Sustainable ML in Signal and Data Science," which took place on 20–21 March 2023 at the University of Maryland, College Park campus. The panelists, Aylin Yener, May Wang, Anthony Vetro, Eric Xing, Xiao-Ping Zhang, and Bhuvana Ramabhadran, represented a diverse background: SP, computer science, information theory, biomedicine, biology, and ML. They also represented a mix of members from both academia and industry.

Our topic was graduate training in ML and the related disciplines for sustained career growth. It was an animated discussion with active audience participation, making it clear that this is a topic we all care a great deal about. Two points

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met with a clear consensus, and we kept coming back to them: the need to teach fundamentals rather than recipes to our students and the need to equip our students with critical thinking (CT).

Teaching the "fundamentals"

Many panelists underlined the need to teach—or, rather, continue to teach—the "fundamentals." In my institution, like many others, there is a proliferation of AI-themed courses that, to a large degree, respond to market demands. While a number of these courses primarily focus on the available tools and their use, important theoretical concepts appear to be part of the discussion as well, judging from their syllabi. However, when presented as a potpourri, it might be questionable what the students actually acquire in terms of these fundamentals. Another questionable aspect is the additional perspective presented by each of these courses, all offered within the same institution, as usually they have significant overlaps.

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Apart from a "Data Fusion" course, I have been mostly teaching two traditional courses: "Probability and Random Processes" and "Detection and Estimation Theory," both at the graduate level. I do enjoy the material, and, while what I cover in these courses has not changed much over the years, how I present the material has. I like emphasizing that these courses provide the key background for ML and, especially when discussing estimation theory, I discuss how some of our new "data-driven solutions" can also be discussed under the classical estimation theory umbrella. I note that we now have a spectrum of solutions, from model based to model driven and, finally, to data driven. Assignments that deal with some of today's familiar problems, like prediction in social networks and classification in computer vision, also help me make the connections to ML and relevance of these courses clear.

Critical thinking

Another topic our panel underscored was the need to teach our students CT. Given the frequency with which we keep hearing about "AI hallucination," this is certainly important, but its importance transcends this troubling aspect of generative AI tools like ChatGPT. While CT has always been an essential component of education at any level, with so many tools available and rapidly evolving as well as increasing in number, distilling the information for meaningful and useful inference has now become ever more challenging.

When I started looking at how one could actually teach CT, it quickly became clear that it was far from straightforward, starting with the simple fact that there was not even a consensus on what it means [1]. Among multiple references, an early work [2] listed a few concrete elements one should teach, which resonated with me as elements I have been emphasizing in my teaching and mentorship. Included in this list were the following: value reason and truth, respect others during discussion, be open-minded, and be willing to see things from another's perspective. These points were echoed in other reports, such as [3], which noted, "From early childhood, people should be taught, for example, to reason, to seek relevant facts, to consider options, and to understand the views of others." While I might not have labeled those as elements of CT, these were points I would frequently emphasize. They also relate to an important challenge I keep coming back to—how one can teach "common sense" or, at least, try to sharpen common sense reasoning skills, as they play a key role in how students interact with the outside world.

As noted in an old saying, "Two of the most common things are rare: common sense and common courtesy." Perhaps these are not entirely rare, but, in certain populations, representation might be poor; e.g., somewhat surprisingly, students with good analytical skills might not be terribly gifted in terms of common sense. An example that I still find amazing is when we are responding to reviewer comments—well, criticisms—on our paper submissions. It still baffles me when one of my students comes with a draft of responses that are mostly constructed to do little more than hint at the reviewers' ignorance. When explaining why we might want to restate the responses, encouraging a change in point of view usually helps, as does a discussion on simple checks and balances, questioning what the students might have to gain by educating the reviewers in all the ways they have erred.

For teaching CT, besides a change of perspective, collaborative work is also noted as being helpful, as is giving open-ended questions in our courses. Such questions are harder to grade—and they require CT on the part of the instructor as well—but they are much more useful. Coding and coming up with the right solution to a given assignment might be getting easier thanks to generative AI. What is more difficult is constructing a simulation study that will enable a meaningful comparison across methods or help highlight important aspects of a given solution.

Back to Radke's column and the ICASSP 2024 AI/ML panel

Radke's final points in [A1] as well as the ICASSP 2024 panel echo the points that were raised at our discussion a year earlier. Radke notes that the ease with which students would learn and could be familiar with complex software tools for generative modeling did not really translate into understanding the underlying methodology. He then notes the important role educators still have in teaching the key concepts. On the other hand, the ICASSP 2024 panel discussed various ways new tools are being integrated into curricula, as in [4]. Haardt underlined the important role SP has to play in those and noted the need to teach students to think more fundamentally about different aspects of data, e.g., where they come from and what the samples represent as well as how to model, sample, represent, and visualize

such information robustly while making sure that the resulting algorithms are insensitive to various sources and types of noise for different applications and tasks. Another point is the need for students to be aware of the privacy issues and sources of bias in collecting the data as well as the implications future techniques and developments might impose on society and humanity. These are also reasons why ethics courses are now becoming a familiar component of any ML/AI/SP curricula.

It is a rapidly evolving research and education landscape thanks to the developments in AI/ML, to which SP is intimately linked. There are many success stories; grand promises; and, of course, big challenges. The questions raised in our panel discussions and in [A1] are just the beginning. The hope is that they will contribute to convergence to a meaningful steady state, which itself is dynamic, but then we can decrease the noise in the system—e.g., in terms of too many course offerings—and can more reliably track this highly dynamic wave of change.

The discussion in Radke's article [A1] is one that we will continue in future issues of our magazine. Incidentally, his is the first article where we started acknowledging the associate editors who manage the review. This common practice was not previously adopted in our magazine, and, from now on, it will be implemented for our column and forum as well as feature articles. We acknowledge the whole guest editorial team for our special issues, as we do in this issue, dedicated to part one of the special issue on hypercomplex signal and image processing. Part one includes seven articles addressing current advances in this feature-rich mathematical framework offering powerful solutions. As always, I am looking forward to hearing from you on the content of our magazine as well as suggestions as to what you would like to see in future issues.

Acknowledgment

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Appendix: Related articles

[A1] R. Radke, "A signal processor teaches generative artificial intelligence," *IEEE Signal Process. Mag.*, vol. 41, no. 2, pp. 6–10, Mar. 2024, doi: 10.1109/MSP.2024.3388166.

References

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[2] S. Bailin, R. Case, J. R. Coombs, and L. B. Daniels, "Conceptualizing critical thinking," *J. Curriculum Stud.*, vol. 31, no. 3, pp. 285–302, 1999, doi: 10.1080/002202799183133.

[3] P. A. Facione, *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction*. Millbrae, CA, USA: The California Academic Press, 1990.

[4] S. Gannot et al., "Data science education: The signal processing perspective [SP education]," *IEEE Signal Process. Mag.*, vol. 40, no. 7, pp. 89–93, Nov. 2023, doi: 10.1109/MSP.2023.3294709.