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An Exciting Juncture for Signal Processing Research: On Building Bridges, Challenges, and Opportunities

A warm greeting to the signal processing community as I start my term as the editor-in-chief of *IEEE Signal Processing Magazine* (*SPM*). I hope to be worthy of the confidence invested in me and to be able to follow successfully in Christian Jutten's footsteps. He led our magazine for three years with dedication and brought timely topics like green signal processing, ethics, and reproducibility to the attention of our community. I certainly have big shoes to fill!

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SPM is the flagship publication of the IEEE Signal Processing Society (SPS) and as such, serves as a melting pot of multiple technical areas represented by the 12 SPS technical committees (TCs) and associated technical entities. There is natural overlap among the areas under the wings of these TCs, and our technical working groups and initiatives are two ways of cultivating these overlaps. In my first editorial, I would like to concentrate on these overlaps and building bridges across areas to foster cross fertilization. I will start my discussion with a focus on technical areas within the SPS and then move onto IEEE, where we have different areas represented through 39 technical Societies, and will conclude with a discussion on building bridges across disciplines, going beyond IEEE and its electrical and computer engineering umbrella. This also gives me a chance to tell a little bit about my background and my involvements within the SPS.

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Interdisciplinary research, from the early 2000s to today

Many research problems facing us today require coordinated efforts from multiple disciplines to enable cross fertilization. Thus, the need for interdisciplinarity naturally arises from these research questions. Although most areas of science (both the physical and social sciences) and engineering have been moving in that direction, there are still considerable barriers to interdisciplinary, or cross-disciplinary, research.

A report published by the National Academies Press back in 2000 [1] clearly identifies the major obstacles to interdisciplinarity and offers a number of solid recommendations to overcome them, together with mechanisms to evaluate and measure success. The report was drafted by a committee formed to enable building bridges across the brain, behavioral, and clinical sciences. This was also when the National Institute of Biomedical Imaging and Bioengineering (NIBIB) was founded within the National Institutes of Health (NIH), the main sponsor of biomedical research in the United States. The NIBIB was envisioned as, and still is, the major sponsor of method-based research within the NIH, and hence, by its nature, it is interdisciplinary. It is likely that the institute's creation was prompted by discussions that led to this report.

More importantly, the findings and recommendations of this sizeable (130-page) report are highly relevant for other types of multidisciplinary efforts as well. When we take a close look at those, we observe that almost all the obstacles identified back in 2000 are still pervasive within our research landscape, which unfortunately prefers to build silos with hard-to-penetrate walls between disciplines. The value system and accountability for each discipline are defined within those boundaries. This simplifies important tasks, such as evaluation. For example, in academia,

within promotion and tenure committees, the questions always center around contributions to the discipline. Obviously, contributions to multiple disciplines, or to the general body of knowledge in general, are much harder to assess. Hence, as [1] emphasizes, one should start with removing the obstacles that discourage interdisciplinary efforts and find ways to facilitate interdisciplinary research. The support and collaboration of universities, funding agencies, and research organizations are expected to make the biggest difference.

When we examine the change within the last 20 years, it is easy to note progress in certain aspects, e.g., increasing availability of funding opportunities that span disciplines and the growing acknowledgment of the importance of interdisciplinary work, but overall, what we observe are, sadly, just baby steps. Going through the list of barriers identified in the report, many are still highly pervasive, with little to no change. Two such barriers are "disciplinary jargon" and cultural differences. In this editorial, I will concentrate on the first one, but obviously, language and culture are intimately related. As noted in [1], "Scientists trained in a discipline learn to speak a specific language and adopt the analytical and methodological constructs that have accumulated in that discipline." A positive aspect is that this helps with building the community and effective communication within the discipline, yet it persists as an impediment to building bridges with other disciplines. In addition, it has been cited as the main reason "different disciplines are continually rediscovering one another's discoveries" [1].

Unified editors information classification schemes—Bridges across our TCs

I served as the SPS vice president-technical directions (VP-TD) during the period January 1, 2019–December 31, 2021, a rewarding experience for multiple reasons. Most importantly, it helped me gain a thorough understanding of the areas represented within the SPS as well as their interrelationships. An intense but very useful exercise played a key role: the definition of a unified set of Editors Information Classification Schemes (EDICSs) for the SPS. The goal was to come up with a core set of EDICSs for the SPS that would be used in the SPS-owned transactions as well as in our two major conferences, the ICASSP and ICIP. I worked closely with the Publications Board as well as all the TCs. The exercise meant long discussions and bargaining with the editors-in-chief of the transactions; the VP-publications at the time, Sergios Theodoridis; and the TCs.

Reflecting back, I see that this was a great way to start my term as VP-TD because the entire exercise demonstrated the strengths and weaknesses of all the TCs and their relationships with our publications. Luckily, a major part of the work was done at ICASSP 2019, prior to the COVID-19 lockdown, when we could still interact face-to-face, as negotiations at times were intense. Contentious debates included learning versus adaptivity; multimodal versus multisensor, or multiview; matrix/tensor decompositions versus blind source separation; sparse versus sparsity-aware learning; and so on. It was most challenging for areas that are inherently interdisciplinary, like those represented by the Bio Imaging and Signal Processing (BISP) TC, where even which subtopics would be kept became a big discussion item. In the end, we did converge to a set, we managed to negotiate, and we were reminded of the classic line from William Shakespeare's play *Romeo and Juliet*, "A rose by any other name would smell as sweet." After all, like a rose, our research topics are just as dear to us.

In the end, sometimes happily, sometimes less so, we finally acknowledged that seemingly different terms did, in fact, describe similar concepts and converged to a unifying list across our TCs and our transactions (https://signalprocessingsociety.org/publications-resources/unified-edics). The final list had a much better signal-to-noise ratio (SNR) than the one with which we had started.

There are multiple benefits to a unified set of EDICSs. Unnecessary repetition of very similar areas is eliminated, decreasing the overall noise and improving the SNR. Overlaps across TCs are clarified, as now a selected EDICS could be used by more than one TC. For updates to EDICSs, TCs can no longer act as islands but instead need to communicate with other TCs and publications, factoring in the relevance of a topic for others. At the Society level, a unified set of EDICSs offers advantages, such as explaining submission trends in our conferences and publications, describing which topics are well represented in our conferences and which ones in publications, and revealing whether some of those are going to venues outside the SPS. With a simple and straightforward update procedure, we can also be more proactive and easily introduce new topics. It is natural for conferences to take the lead in such introductions, as by their very nature they are more agile. However, because the relevant publications are made aware during the process, they can adopt the newly introduced EDICSs, making them more adaptable as well.

The process was not an easy one, as is often the case when building bridges. The way matters have been handled over the years represents a comfortable steady state, and while small iterations around this local optimum are easy, the bigger ones require much effort. There is also the temptation to roll back to the previous state. I understand that in the last few years, the unified list has not been fully implemented; however, there are current efforts to improve the process, which I hope will lead to a final unified set that will also be fully implemented by our main conferences and all transactions.

Bridges across societies within IEEE

The IEEE Future Directions Committee (FDC), working with Societies, Councils, and other IEEE operating units (henceforth, "Societies"), is responsible for determining the direction of existing or emerging areas of growth and establishing initiatives in these areas. These initiatives typically span multiple Societies' fields of interest, and when they graduate and leave the FDC, usually after three years, the initiatives are

typically absorbed by one Society but have partner Societies that are also involved. There are a handful of those for which all involved parties feel strongly and hence do not want to give leadership to one Society. These entities end up being independent and usually function through a memorandum of understanding across involved Societies, initially as Technical Communities. IEEE Brain is one such example, starting its existence as an initiative in 2015 and transitioning to a Technical Community in 2021. The chair position for IEEE Brain rotates among its core members, and last year, I served as its chair, representing one of its three core members, the SPS. (At the time, there were three, and starting in 2024, IEEE Brain has four core members: the SPS; IEEE Engineering and Medicine in Biology Society; IEEE Systems, Man, and Cybernetics Society; and IEEE Standards Association.)

The attraction of building bridges across the relevant areas was clear to all members. Within IEEE Brain, we could address all aspects of the "brain"—arguably the most complex entity on our planet—and work together for brain discovery and bring reliable and ethical neurotechnology to the marketplace. Still, we ended up spending considerable time discussing the name of our flagship event, an annual workshop that last took place on 9–10 November 2023, in Washington, DC, USA, in conjunction with the Society for Neuroimaging Conference. It was a fully in-person event and had a fee structure, a first for IEEE Brain since it had transitioned into a Technical Community and was very well received. We ended up with "IEEE Brain Discovery and Neurotechnology Workshop" as the name, and the workshop included three tracks: "Emerging Neurotechnologies," "Machine Learning for Brain Discovery," and "Clinical Applications and Impact." The most widely appreciated characteristic of the gathering was having these three aspects under one roof. For those on the computational side like me, it was eye-opening seeing that clinical impact was not a distant goal and that there were already multiple methods for intervention and therapy. In addition, I learned of emerging neurotechnologies that could enable high-resolution in vivo (or active) imaging in a more accessible way compared with modalities such as magnetic resonance imaging and even electroencephalograms. Having all three groups of researchers in one room also resulted in lively panel discussions. I am looking forward to the next installment of the workshop this fall.

Bridges across disciplines

Obviously, across different disciplines, the language barrier is an even bigger obstacle. I will share a personal anecdote, an old one but one I still remember vividly. It convinced me that having good personal communication did not guarantee that we could easily communicate on scientific matters as well.

Shortly after my sister, Sibel Adali, started her academic career as a computer science professor, she and I started bouncing around ideas for a joint project that ended up being a proposal submitted to the U.S. National Science Foundation. Her expertise in databases and mine in statistical signal processing nicely complemented each other in framing the statistical analysis of scientific data of different types and modalities to facilitate complex decision making. It was after at least a month-long intense discussion that we finally recognized a big gap in our communication: when we talked about "data," we were at very different levels. For me, it was the physical data, while for my sister, with her focus on information integration for novel data types, "data" referred to an abstract construction that can be incorporated into a logical framework for reasoning under uncertainty. This was in the late 1990s; today, with the pervasiveness of so-called artificial intelligence (AI) solutions in every domain, "data" is now more broadly used for the physical entity. After we acknowledged the communication gap, matters went much smoother, as we were listening more carefully, trying to better understand each other's point of view and the presented ideas.

Building bridges for the SPM

Building a common vocabulary is hard. My recent experiences—the unified EDICSs project, and convergence to a name for the IEEE Brain workshop—are both simple reminders for me. A common vocabulary provides important benefits when it can be accomplished, but sometimes, rather than building a common vocabulary, simply acknowledging the existence of a communication gap might be sufficient. Then, we realize the need to listen to one another more carefully. After all, the key ingredient in most interdisciplinary work is an open mind and willingness to communicate and understand one another.

Last year, we celebrated the 75th anniversary of the SPS, devoting two special issues of *SPM* to our major accomplishments and our path forward. In this first issue of 2024, we have two "Perspectives" articles that emphasize the current excitement within the signal processing research landscape. Ana Pérez-Neira underlines the growing number of paper submissions in our conferences, most notably at the ICASSP, and discusses the sustainability of our conferences [A1]. José Moura revisits a lively discussion at a panel during last year's ICASSP that examined the relationship of AI and signal processing [A2] and underlines that our field is more dynamic and pervasive than ever.

The growing array of challenges we see today, which involve making intelligent inferences from (usually large and heterogeneous) data, are right up our alley. After all, we are the ones who know how to integrate prior information into our solutions, how to balance the model and data-driven aspects of a problem and build that into our solutions. We also know how to make our solutions respond to practical considerations, such as robustness, while also paying attention to theoretical guarantees. The important concept of model match—including within a data-driven setting—is embedded in the basic results of estimation theory, and explainability organically becomes part of our solutions rather than an afterthought, as in black-box solutions [2]. We have been doing all this in signal processing, and this is what the AI world is now

realizing! Also, all these "grand challenges," as Moura notes, involve an interdisciplinary component.

Hence, this is an exciting period for signal processing research. Signal processing by its very nature has been building bridges, as we typically start with understanding the problem domain, its constraints and demands, and drawing from reliable prior information. If we are more open to communication with other disciplines, then we will be even more relevant, and discussions, such as whether it is AI versus signal processing or how we place ourselves with respect to the AI world, will become largely irrelevant.

I will finish by reiterating my opening thought that as the flagship publication of the SPS, our magazine is a melting pot of different areas and a forum for new directions. I would like it to transform into an even bigger melting pot, one that is welcoming to building bridges with many other communities. This will mean more open minds, clear acknowledgment of potential communication gaps, and a sincere willingness to understand, communicate, and connect. We will also have other challenges to address, such as the review of such articles as opposed to referring them to other venues when they are not exactly what we have been used to seeing. If we are, instead, more welcoming and ready to be more inclusive, we will expand our horizons even further and become even more relevant. I am hopeful that we can rise up to the challenge.

Acknowledgment

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Appendix: Related articles

[A1] A. I. Pérez-Neira, "Going for sustainable conferences," *IEEE Signal Process. Mag.*, vol. 41, no. 1, pp. 25–30, Jan. 2024, doi: 10.1109/MSP.2024.3360955.

[A2] J. M. F. Moura, "Signal processing at 75: More dynamic and pervasive than ever," *IEEE Signal Process. Mag.*, vol. 41, no. 1, pp. 22–24, Jan. 2024, doi: 10.1109/MSP.2024.3367229.

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[1] T. C. Pellmar and L. Eisenberg, Eds., *Bridging Disciplines in the Brain, Behavioral, and Clinical Sciences*. Washington, DC, USA: Institute of Medicine, 2000, p. 144. [Online]. Available: http://www.nap.edu/catalog/9942.html

[2] T. Adalı, R. Capobianco Guido, T.-K. Ho, K.-R. Müller, and S. Strother, "Interpretability, reproducibility, and replicability [From the Guest Editors]," *IEEE Signal Process. Mag.*, vol. 39, no. 4, pp. 5–7, Jul. 2022, doi: 10.1109/MSP.2022.3170665.

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