Sound Perspectives

TECHNICAL COMMITTEE REPORT

Signal Processing

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Signal Processing Technical Committee members advance and disseminate improved methods for drawing inferences from acoustic measurements.

The Technical Committee (TC) on Signal Processing (SP) in Acoustics (TCSP) has the purpose of advancing and disseminating improved methods for drawing inferences from an ever-increasing volume of acoustic measurements. The TCSP seeks to take maximal advantage of the increasing available computational resources in order to explore and exploit the great volumes of acoustic observations that are presently available. The members of the TCSP develop flexible and accurate modeling schemes that permit the seamless modeling of such acoustic measurements across significant spatial and temporal domains.

The TCSP continues to expand its reach to a wider range of problems in acoustics and to more adaptable and varied modeling regimens. The TCSP develops methods so that these more flexible models can capture realistic dependencies and can be applied to large and varied acoustic observation sets. TCSP members are interested in extracting the maximal amount of information from these datasets, and we therefore strive for improved statistical efficiency leading to a sharper resolution of the problem at hand. By developing efficient computational schemes, the TCSP makes available the testing of hypotheses that were previously out of reach just a few decades ago. In doing this, TCSP members not only address questions that are highly germane to SP itself, but they also reach out across many other TCs to collaborate on a diverse range of problems that benefit from SP expertise.

The TCSP has its origins well over 30 years ago as scientists and researchers from the diverse Acoustical Society of America (ASA) communities began to share their statistical models, inference methodologies, and acoustic SP algorithms. This group grew into the Interdisciplinary Technical Group on Signal Processing (ITG-SP) in 1994, and as the demands for greater accuracy in inference over a wider range of acoustic hypotheses expanded, the ITG-SP flowered into the TCSP in 2000. Since this time, the TCSP has grown and continues to expand its reach into challenging inference problems where complex acoustical processes shape observations. The methods of describing model regimens and parameters as well as linking models to the observations have matured and continue to increase in relevance to acoustic sensing.

Topics addressed in the TCSP are diverse and varied. These include, but are in no ways limited to, detection of objects by either their acoustic signature or their scattered acoustic field from an active acoustic source; estimation of the location or direction of motion of an acoustic source; tracking of acoustic sources in multipath reverberant environments; acoustic nondestructive testing of material; and acoustic inverse problems both underwater and in air as well as optimal processing of acoustic observations recorded from unconventional configurations of acoustic sensors. The TCSP has a strong interest in drawing inferences regarding the acoustic media, acoustic tomography, and boundary interrogation for detection or estimation. Although human voiced acoustic communication is not a central focus of the TCSP, acoustic transmission of modulated data through spatially complex and temporally dynamic media has been an enduring interest within the SP community.

More broadly, the TCSP provides methodologies of analysis for inference problems in an open environment where diverse disciplines can come together to sharpen their approaches and permit the cross-fertilization of methods. The TCSP is a place where the individual researcher can find an approach to analysis that best fits his/her observational assets and his/her inference needs. From the most fundamental epistemological questions regarding probabilistic reasoning to the seemingly mundane and yet essential ones regarding computational efficiency, the TCSP community is an open- and generous-minded group. For these reasons, there is a very strong appreciation of the multidisciplinary nature of acoustics within the TCSP, and this reverence holds the TCSP in close proximity to other TCs. We have members with strong ties to TCs in underwater acoustics, noise, acoustical oceanography, architectural acoustics, and animal bioacoustics as well as others with ties to the number of jointly sponsored special sessions reflecting this deep and enduring synergy. Within the TCSP, it is not uncommon to see lively and productive interactions on fundamental issues between architectural acousticians and underwater acousticians. The TCSP takes great satisfaction in the broad dissemination of methodologies that enhance and improve the accuracy of acoustic inferences across the diverse disciplines within acoustics. Because of this, it is a natural organic aim of the TCSP that our members enrich and enliven the various TCs with which they interact.

The TCSP is devoted to the development of a full range of statistical inference methods as necessary in acoustic inference. The SP community continues to be an environment where acoustic modeling issues are addressed from the perspective of model efficacy as supported by observations. This aspect of the TCSP takes many instances, from practical risk-minimizing parameter point estimation (Gendron, 2016; Michaloupolou and Pole, 2016) to full posterior inference (Dosso, 2002; Michaloupolou and Gerstoft, 2016) to the development of a framework for a fair comparison of disparate models from acoustic measurements (Dettmer et al., 2010; Xiang and Fackler, 2015).

Providing Practical Solutions

We continue to see the TCSP contribute solutions to important and useful problems in acoustics. For instance, the vital need for determining the location of the discharge of a firearm with a ballistic model-based method (Lo and Ferguson, 2015) directly addresses the problem of ranging small-arms fire to save lives. The approach operates with no more than a single acoustic sensor node collocated with the vital target and is accomplished without a priori knowledge of the muzzle speed and ballistic constant of the bullet. The method requires the extraction of the differential time of arrival and angle of arrival of the muzzle blast and ballistic shock wave at the sensor node.

Another practical example of the reach of the TCSP is the nondestructive testing of critical containers by acoustically exploring for cracks (Anderson et al., 2017). The method focuses high-frequency elastic energy to a point to probe for an anomalous fissure. The approach has been demonstrated to save time and resources in the necessary task of helping determine the strength and endurance of vital stainless steel canisters whose failure and breach could pose a significant risk to human life.

Recently, there has been much interest in the optimal use of extremely sparse acoustic arrays, with the methods employed being termed "compressive sensing" (CS). Acoustic CS is the processing of sparse configurations of acoustic sensors for the purpose of drawing inferences regarding some acoustically relevant feature. CS asserts that such underdetermined problems can be solved provided the feature is likewise sparse. An example is the estimation of an ocean acoustic sound-speed profile (SSP) from the inversion of acoustic fields measured on sparse arrays (Bianco and Gerstoft, 2016). CS has been demonstrated to estimate SSPs in a range-independent shallow ocean by inverting a nonlinear acoustic propagation model. The demerits of sparse configurations are of practical interest because sensor elements can and do fail and are not often able to be quickly replaced. CS methods have been compared with conventional beamforming using at-sea horizontal towed arrays for the discerning of an acoustic target bearing with comparisons in terms of a signal-to-interference ratio by Edelmann and Gaumond (2011). Sparse configurations of sensors can also take on purposeful and highly structured forms for reducing the computational burden of beamforming with coprime arrays (e.g., Adhikari et al., 2014; Xiang et al., 2015).

The localization of an acoustic source in a reverberant ocean waveguide continues to be an area of active interest within the TCSP. Recent advances to this problem include the inclusion of realistic sparse constraints on the solution (e.g., Ferero and Baxley, 2014) in order to capture the relatively small number of acoustic sources that typically occupy an observed volume in an ocean waveguide. This example typifies many TCSP contributions because it illustrates the incorporation of accurate prior model information to a large acoustic dataset inference problem while judiciously exploiting computational resources.

Acoustic communication through complex and dynamic acoustic media continues to be an exciting area for the TCSP, with the shallow-water acoustic environment remaining an important focus of attention for our researchers. We continue to explore the ability of an acoustic receiver to estimate the space- and time-varying acoustic response as this can often be critical for optimal performance of a communication link. The essential properties of the shallow-water acoustic channel continue to be illuminated (Yang, 2012), and useful statistical models for capturing its dynamics coherently at the receiver are actively being pursued and developed for a range of applications from the very low signal-to-noise ratio and the low-throughput rate communication link (e.g. Gendron, 2016) to the very high frequency, short-range, high-throughput rate links (Song et al., 2009).

An Environment for Peer-to-Peer Enrichment

The TCSP is also an environment within the ASA with a rich heritage in probabilistic modeling and inductive reasoning (Xiang and Fackler, 2015). For analysts who are excited about the foundational underpinnings of inductive reasoning that form the basis of modern statistical SP methods, the TCSP is a welcoming community where a free exchange of ideas takes place in an open and generous atmosphere. Experimental observations of acoustic phenomena are vital for our scientists and researchers both to better understand underlying theories in acoustics and to solve tangible and practical inference problems. We see observation as the foundation of our research and, just as important, essential to our peer scientific interaction. Because scientific progress comes about by consensus, the TCSP seeks to advance the language of this process and provide a common framework for scientists to reach a common understanding of the driving mechanisms of diverse acoustic phenomena.

Conclusion

It is a genuinely exciting time for us within the TCSP where we see interaction and exchanges of ideas blossoming into more accurate methods for ever more challenging models and increasingly large datasets. As we look forward, we are inspired and motivated by our recent past and the standards of our ASA Silver Medalists Edmund Sullivan, Ted Birdsall, and Brian Ferguson. Their breadth of contribution and generosity of spirit to SP in acoustics gives us confidence that this same spirit of enrichment will continue. The wide scope of problems that are presently being addressed provides both challenge and motivation. We are excited to advance methods and models that take advantage of improved computational resources in the hopes that the large acoustic datasets will be more completely heard and produce more accurate results. Ultimately, the goal of the TCSP is for these developments to provide a more exact understanding of acoustic phenomena, leading to the betterment and enrichment of human life and well-being. In so doing, we hope to advance and provide an indispensable service to civil society. We hope you will join us.

Biosketch

Paul Gendron received his BS from the University of Massachusetts Amherst, MS from Virginia Tech, and PhD from the Worcester Polytechnic Institute, all in electrical engineering. He served as a staff scientist at the Naval Research Laboratory and the Space and Naval Warfare Center Pacific and was an Office of Naval Research (ONR) visiting scientist to the Defence Research and Development Canada (DRDC)-Atlantic Research Centre in 2007. He is presently with the University of Massachusetts Dartmouth. His interests include statistical signal processing for underwater surveillance and communications.

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