Judge's Commentary: The Outstanding Submarine Detection Papers

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Introduction

The problem of locating, classifying, and tracking objects under the ocean's surface is extremely important and has stimulated a great deal of significant oceanographic research. Despite the collapse of the Soviet Union and the end of the Cold War a few years ago, a number of countries possess submarine fleets that represent a very real strategic threat to other nations. Therefore, this kind of modeling problem will retain its importance for many decades.

Modeling

The fundamental approach to mathematical modeling can be summed in these three steps:

- Formulate a scientific problem in mathematical terms.
- Solve the underlying mathematical problem, perhaps inventing new mathematical methods in the process.
- Interpret the mathematical results in light of the original problem.

During the last step, the accuracy of the model's predictions are considered. If they are not good enough, then they can be used to highlight weaknesses in the model. Refinements are made and the three-step process is repeated as appropriate.

The Outstanding papers excelled in their application of both the first and third steps. For example, a critical factor noted by the judges was whether teams considered the environmental effect that the ocean has on sound propagation. Another factor weighed by the judges involved accounting for the properties of the ambient noise field itself. The literature contains extensive discussions of both ideas, and too many teams did little or nothing in this area. A great number of papers made absolutely no attempt to do any true acoustic modeling. Instead, they looked like homework sets for a signal-processing course, rolling out page after page of theory without ever making a clear linkage to the problem posed. While the judges did not doubt the mathematical prowess present in some of those papers, those papers contained very little modeling—and modeling, after all, is what the contest was all about. Papers with simple models that were well conceived and whose shortcomings were clearly noted tended to fair much better that papers with extremely elaborate calculations and little connection with the real world.

Novel Approaches

Several papers stood out for the novel ideas that they incorporated into their problem analysis. This usually involved clever schemes for designing receivers so that they would work well under the conditions specified in the problem. Even though the mathematical analysis may have been a bit short, evidence of creative thinking generally gave teams that tried something new a substantial boost in the judges' eyes.

Literature Searching

Many teams made little or no effort to search the literature to discover relevant references. Between the time that the problem was chosen for the MCM and the contest date, *Scientific American* published an article that treated aspects of this subject shortly before the competition began [Buckingham et al. 1996]. Very few teams mentioned this paper among their references.

Conclusion

The very best papers displayed a healthy balance among the three modeling steps. Lots of powerhouse mathematics was certainly not sufficient for a paper to be competitive; teams in future years should bear this point in mind as they organize their write-ups. *Mathematical modeling is as much about modeling as it is about mathematical detail.*

Reference

Buckingham, M.L., John R. Potter, and Chad L. Epifanio. 1996. Seeing underwater with background noise. *Scientific American* 274 (2) (February 1996): 86–90.

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About the Author

John S. Robertson is Chair of the Dept. of Mathematics and Computer Science at Georgia College and State University. He received his Ph.D. from Rensselaer Polytechnic Institute in 1986. He studied under Mel Jacobson and Bill Siegmann, two applied mathematicians who have made substantial contributions to the understanding of underwater sound propagation. Dr. Robertson subsequently became interested in problems related to atmospheric sound propagation and has written a number of research papers in both ocean and atmospheric acoustic propagation. He is passionately interested in applied mathematics and loves to teach students with all kinds of backgrounds. He enjoys living as a Yankee transplant in Georgia, where he no longer needs to shovel snow.