Judges' Commentary: The Outstanding Geographic Profiling Papers

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Introduction

The stated problem this year dealt with the issue of geographical profiling in the investigation of serial criminals. International interest in this topic has led to numerous publications, many of which present mathematical models for analyzing the problems involved. Although it was entirely appropriate and expected that teams working on this problem would review the literature on the subject and learn from their review, teams that simply presented published schemes as their mathematical models fell far short of what was expected. The judges looked for sparks of creativity and carefully explained mathematical model building with sensitivity analysis that went beyond what is found in the literature. This factor is what added value to a paper.

Documentation and Graphs

We observed a noticeable improvement in how references were identified and in the specific precision in documenting them within the papers. Considering the numerous online resources available, proper documentation was an especially important factor in this year's problem.

Despite the improvement, many papers contained charts and graphs from Web sources with no documentation. All graphs and tables need labels and/or legends, and they should provide information about what is referred to in the paper. The best papers used graphs to help clarify their results and documented trustworthy resources whenever used.

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Assumptions

In many cases, teams made tacit assumptions about the criminals being considered but did not state or justify critical mathematical assumptions that were later used implicitly. Assumptions concerning probability distributions, anchor points, distances, units, mathematical procedures, and how to measure results were generally not discussed or justified.

Since this is a modeling contest, a lot of weight is put on whether or not the model could be used, with modification, in the real world. Also, clear writing and exposition is essential to motivate and explain assumptions and to derive and test models based on those assumptions.

Summary

The summary is of critical importance, especially in early judging. It should motivate the reader and be polished with a good synopsis of key results. For this problem, teams were asked to add to their one-page summary (which can have some technical details) also a two-page executive summary appropriate for the Chief of Police. Many teams seemed to assume that the Chief of Police would have impressive mathematical credentials.

The Problem and Its Analysis

Teams were asked to develop at least two different schemes for generating geographical profiles and then to develop a technique for combining the results of the different schemes in such a way as to generate a useful prediction for law enforcement officers. Although the papers designated as Meritorious generally developed interesting schemes, very few papers did an adequate job of testing their results and doing sensitivity analysis.

Most papers dealt with issues associated with the serial criminal's home base, usually referred to as the anchor point, and the buffer zone around that point within which the criminal is unlikely to commit crimes. Locations were identified using latitude and longitude and sometimes a time factor. Weights were frequently assigned to data points, sometimes taking more recent crimes into account more heavily and sometimes incorporating qualitative factors into the scheme. Teams used various metrics in describing "distances" between the anchor point and crime locations. Papers that rose to the top used well-defined metrics that were clearly explained. One cannot measure the reliability or validity of a model without clearly defined metrics.

Many teams mentioned that there was not a lot of data with which they could validate their model, although they did find some specific location information that included from 13 to 20 crimes in a given series. Some teams used as their only example the Sutcliffe case cited in the problem. In almost all cases, teams

used their model to predict the location of the final crime based on all of the previous locations for that criminal. They could easily have had many more data points with which to validate their models. For example, if 13 crime locations were available, they could have used the first n locations to predict the location of crime $n+1$, for each $n = 7, \ldots, 12$. The judges agreed that this problem did not lend itself to validation by simulation, as many other problems do.

In describing the reliability of predicted results for proposed models, it was sometimes difficult to determine precisely how teams had arrived at their results. Since the literature is full of models and even computer models, it would have been worthy if teams had solved a problem via one of these methods and used that as a baseline to compare the results of original models that they proposed. Not a single team did this to the judge's satisfaction. Judges do not generally look for computer code, but they definitely look for precise algorithms that produce results based on a given model.

Concluding Remarks

Mathematical modeling is an art. It is an art that requires considerable skill and practice in order to develop proficiency. The big problems that we face now and in the future will be solved in large part by those with the talent, the insight, and the will to model these real-world problems and continuously refine those models. Surely the issue of solving crimes involving serial killers is an important challenge that we face.

The judges are very proud of all participants in this Mathematical Contest in Modeling and we commend you for your hard work and dedication.

About the Author

Marie Vanisko is a Mathematics Professor Emerita from Carroll College in Helena, Montana, where she taught for more than 30 years. She was also a Visiting Professor at the U.S. Military Academy at West Point and taught for five years at California State University Stanislaus. In both California and Montana, she directed MAA Tensor Foundation grants on mathematical modeling for high school girls. She also directs a mathematical modeling project for Montana high school and college mathematics and science teachers through the Montana Learning Center at Canyon Ferry, where she chairs the Board of Directors. She has served as a judge for both the MCM and HiMCM.