Judges' Commentary: The Fusaro Award for the Geographic Profiling Problem

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Introduction

MCM Founding Director Fusaro attributes the competition's popularity in part to the challenge of working on practical problems. "Students generally like a challenge and probably are attracted by the opportunity, for perhaps the first time in their mathematical lives, to work as a team on a realistic applied problem," he says. The most important aspect of the MCM is the impact that it has on its participants and, as Fusaro puts it, "the confidence that this experience engenders."

The Ben Fusaro Award for the 2010 Geographic Profiling Problem went to a team from Duke University in Durham, NC. This solution paper was among the top Meritorious papers that this year received the designation of Finalist. It exemplified some outstanding characteristics:

- It presented a high-quality application of the complete modeling process.
- It demonstrated noteworthy originality and creativity in the modeling effort to solve the problem as given.
- It was well-written, in a clear expository style, making it a pleasure to read.

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Criminology and Geographic Profiling

Each team was asked to develop a method to aid in the investigations of serial criminals. The team was to develop an approach that makes use of at least two different schemes and then combine those schemes to generate a geographic profile that would be a useful prediction for law enforcement officers. The prediction was to provide some kind of estimate or guidance about possible locations of the next crime. based on the time and locations of the past crimes. In addition to the required one-page summary, teams had to write a two-page less-technical executive summary for the Chief of Police.

In doing Web searches on this topic, teams found many publications and many proposed models. While it was important to review the literature, to receive an Outstanding or Meritorious designation, teams had to address all the issues raised and come up with a solution that demonstrated their own creativity.

The Duke University Paper

Abstract (One-Page Summary)

The Duke team did an excellent job with their abstract. In one page, they motivated the reader and provided the reader with a good sense of what the team had accomplished. It gave an overview of everything from the assumptions, to the modeling and how it was done, to the testing of their models, and finally, to the analysis of the accuracy of their results and limitations of their models. It was well-written and a great example of what an abstract should be.

Executive Summary (for the Police Chief)

The executive summary too was well-written and gave an overview of the team's approach, acknowledging limitations of their models. However, it was a little too vague in providing a precise idea of exactly what information would need to be collected and how to go about implementing the proposed models. Because the executive summary is a critical part of the requirements, this was part of what kept the Duke paper from being designated as Outstanding.

Assumptions

The team began with a brief survey of previous research on geographic profiling and used the information that they had gathered to decide what assumptions seemed appropriate. As a result, their list of assumptions was well-founded. The team exemplified one of the most important aspects in mathematical modeling by demonstrating precisely how their assumptions were used in the development of their models and how the assumptions enabled them to determine parameters in their models.

The Models

The team's first model involved a geographic method that took into account not only the location of crimes but also population densities, crime rates, and selected psychological characteristics. They used a bivariate Gaussian probability function and numerous parameters associated with previous crime locations. They did a very good job of showing how their assumptions and previous crime scenes led to the computation of these parameters and then using these parameters to estimate the probability function to be used in their model.

The team's second model involved a risk-intensity method and made use of the geographic method but extended it to make different projections with different probabilities associated with each of those projections.

Testing the Models

The Duke team was among the top papers, not only because of their well-based models, but because they tested their models—not with just one serial crime case, but with many cases. Their parameters allowed them to consider crimes other than murder, and they were able to examine how good their models were in several real-life situations. By analyzing their results, they were able to comment on the sensitivity and robustness of their models. This was something that very few papers were able to do, and a very important step in the modeling process.

Recognizing Limitations of the Model

Recognizing the limitations of a model is an important last step in the completion of the modeling process. The teams recognized that their models would fail if their assumptions did not hold—for example, if the criminal did not have a predictable pattern of movement.

References and Bibliography

The list of references consulted and used was sufficient, but specific documentation of where those references were used appeared only for a few at the start of the paper. Precise documentation of references used is important throughout the paper.

Conclusion

The careful exposition in the development of the mathematical models made this paper one that the judges felt was worthy of the Finalist designation. The team members are to be congratulated on their analysis, their clarity, and for using the mathematics that they knew to create and justify their own model for the problem.

About the Authors

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.

Peter Anspach was born and raised in the Chicago area. He graduated from Amherst College, then went on to get a Ph.D. in Mathematics from the University of Chicago. After a post-doc at the University of Oklahoma, he joined the National Security Agency to work as a mathematician.