Judge's Commentary: The Outstanding Air Traffic Control Papers

Patrick J. Driscoll
Department of Mathematical Sciences
U.S. Military Academy
West Point, NY 10996
ap5543@exmail.usma.army.mil

Introduction

The Federal Aviation Administration (FAA) Air Traffic Control problem was an interesting mix of quantitative and qualitative inquiry. Teams used a variety of modeling approaches to resolve the qualitative issue of how to model the complexity of an air traffic controller's job; they apparently discovered that this type of question is often the most challenging, the most interesting, and frankly, the most fun to tackle.

The Approaches of the Top Papers

The top papers in this year's contest did so with a flair of creativity and obvious thoughtful consideration for all dimensions of the modeling process. Many recognized that the number of aircraft in a controller's sector must ultimately be a significant contributing factor to this complexity. A good number of papers further refined this notion to include dimensions such as workload, relative proximity of aircraft, and number of aircraft flight path adjustments required per unit time, among others.

Many papers recognized that aircraft conflict occurs in pairs and proceeded to assess the maximum number of possible conflicts for a given scenario. Some papers chose to divide the overall airspace into vertically separated layers and then developed conflict algorithms for the 2-D problem on a particular layer as opposed to using a 3-D model from the start. However, several papers fell

The UMAP Journal 21 (3) (2000) 301–304.

back on a tacit 3-D model for complexity without realizing that their earlier results did not extend to this case. The most common approach to address the 3-D problem directly was to create an inner collision space (either a sphere or rectangle) around the aircraft and then use a larger alert space (containing this inner collision space) for early warning. The difference in radii between the two spaces was used as a measure for air traffic control conflict reaction time, so that a controller could adjust one of the aircrafts' courses without causing excessive internal forces on the aircraft, its passengers, or its cargo.

There was a wide range of techniques used by teams to represent and identify potential conflicts along aircraft flight paths. Some reduced this problem to a time-parameterized vector-intersection problem in the 2-D plane, and others did the same for the 3-D case as well.

There were several more extensive approaches worth noting:

- One paper assumed that a drift error exists from wind effects, weather, and turbulence along an aircraft flight vector in three-space and applied a probability distribution to this error. This enabled the team to construct a stochastic simulation to test their model design.

- Still another paper incorporated both straight and curved parametric flight paths into their methodology. In both cases, if the flight paths of two aircraft drifted sufficiently close to cause an alert space violation, a controller was presumed to take corrective action to prevent intrusion into the collision space. The number of these alerts occurring for a given aircraft density in traffic then became a component of complexity measurement.

Other Papers

The papers that did not rise to the top possessed glaring omissions or oversights that typically manifest themselves when teams run out of time, fail to properly identify all of the questions being asked, or develop complex mathematical representations and then find themselves lacking the ability to solve them. There seemed to also be a bit of uncertainty in some papers as to what exactly it means to *analyze* a model.

Teams that dismissed portions of the problem based on the claim that "FAA ATC conflict software already exists" missed the point: The FAA knows what they have in their repertoire of tools; they are looking for other ideas and approaches that might facilitate a better solution than they currently have. If the head of the FAA were completely satisfied with the status quo, there would be no problem to be solved.

The Need for Verification

The Model Must Produce Results...

Certain fundamental elements of modeling are consistently present in quality applications of the problem-solving process. Without these, technical reports have noticeable gaps in the information that they provide—gaps that call into question the validity, voracity, credibility, and applicability of the results being presented. This situation is similar to courtroom testimony; judges and juries have a difficult time believing a witness unless sufficient evidence is presented to support the witness's testimony. Consequently, if an MCM team's principal effort is to construct computer code to simulate an air traffic scenario, *they must present results that provide evidence that their code/model actually ran and yielded the information sought*. Analyzing the output of a model provides a basis for determining if the modeling approach chosen was reasonable.

...Which Must Be Presented and Analyzed...

Simply put, after creating an acceptable mathematical representation (system of equations, simulation, differential equations, etc.) of a real-world event, this representation (model) must be tested to verify that the information it produces (solutions, simulation output, graphics, etc.) makes sense in the context of the questions being asked and the assumptions made to create the mathematical representation. *It is insufficient to present such a representation without this additional evidence*. Once a mathematical model is created, symbolic, graphical, and / or numerical methods must be used to produce evidence that the model works. Many of the best papers did so using a combination of these three approaches; some teams wrote C++ code or used spreadsheets, while others used a computer algebra system such as MAPLE or MathCad as their workbench.

...and Compared with Clearly Stated Assumptions

Far and away, papers reaching the final round of judging paid a good deal of attention to stating their assumptions clearly, explaining the impact of each assumption and why they felt it was necessary to include it in their model development. They were also very careful not to assume away the challenging and information-relevant portions of the problem posed. Teams' increased sensitivity to this aspect of the modeling process has consistently improved over the years to the point that it is a hallmark of most modeling efforts today. From a judging perspective, it is far easier to follow the logical construction of these teams' models and to identify what they were attempting to do. However, even a few of the best papers mistakenly placed key pieces of information in appendices rather than in the section of the paper where supporting evidence was desperately needed.

Use of Existing Research

Teams are increasingly adept at using the Internet to find credible, reliable information sources to support their modeling efforts. There is a good deal of room for improvement in team papers as to how best to incorporate this information properly into a technical report, especially for a team that perceives that it has struck the motherlode of reference sources. Incorporating others' work without diluting one's own effort is challenging. However, parroting large portions of technical reports, thereby reducing a team's main contribution to simply interpreting someone else's research, is clearly not the solution.

Three uses of existing research are common to most technical reports:

- To chronicle the events leading to the approach taken in the current paper and to help the reader understand the context or domain of the problem. This action is typically accomplished in an Introduction or Background section.
- To identify and justify technical parameters needed for the new approach. For the FAA problem, some of these parameters could have been the average airspeed of a Boeing 747 or the typical work hours of an air traffic controller.
- To compare the graphical, symbolic, or numerical results generated by the new modeling approach with those previously identified, so as to examine the benefits or drawbacks of the new approach.

Credible existing research used in these ways does not replace or dilute the current effort but directly supports and strengthens it.

Given the time pressure of the MCM, one has to be very cautious not to get trapped into adopting a complicated modeling component from existing research without being able to explain clearly its development, its use and limitations, and its impact on the current model. This remains the classic red herring of the MCM, luring teams into committing to an approach only to discover late in the process that they are ill-equipped to handle it properly. Ultimately, the evidence of this error appears in the MCM entry in such forms as miraculously appearing formulae, unexplained graphics, and tables of data still waiting to be analyzed. Just as in a court of law, the MCM judges consistently find the results of models built on such tenuous foundations difficult to believe.

About the Author

Pat Driscoll is an Academy Professor of Operations Research in the Dept. of Mathematical Sciences at USMA. He received his M.S. in both Operations Research and Engineering Economic Systems from Stanford University, and a Ph.D. in Industrial & Systems Engineering from Virginia Tech. He is currently the program director for math electives at USMA. His research focuses on mathematical programming and optimization. Pat is the INFORMS Head Judge for MCM / ICM contests.