Judges' Commentary: The Outstanding HIV/AIDS Papers

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Introduction

The final judging for the 2006 Interdisciplinary Contest in Modeling took place at the United States Military Academy on Saturday, February 25, 2006. The seven judges spent a full and enjoyable day reading and comparing a fine set of creative and enjoyable papers.

The Problem

This year's problem charged our teams with advising the United Nations on how best to allocate financial resources in the global fight against HIV/AIDS. Teams were provided a common set of historical and projected data in a variety of categories for various areas, regions, and countries around the world over time. This data included the global incidence of AIDS, the geographic distribution of HIV/AIDS subtypes, populations, fertility rates, age data, birth rates, and life expectancies. Teams were then charged with several related interdisciplinary tasks:

- Build a model to estimate the change in the number of HIV/AIDS cases in a variety of selected countries over time.

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- Estimate the level of financial resources realistically available from foreign donors. Estimate the expected rate of change in the number of HIV/AIDS cases in the selected countries under realistic assumptions if these resources were used to fund antiretroviral (ARV) drug therapy, if they were used to fund the development of a preventive HIV/AIDS vaccine, and if funding were split to fund both at a lower level of effort for each.
- Reformulate the above three models, but now taking into account the assumption that persons receiving ARV treatment (but at a less than 90% adherence rate) have a 5% chance of producing vaccine-drug-resistant strains.
- Write a white paper to the United Nations recommending how the projected available financial resources should be allocated between ARV treatments and a preventive vaccine, what level of emphasis to give HIV/AIDS relative to other foreign policy priorities, and recommendations for how to coordinate donor involvement for HIV/AIDS.

Analysis of Papers

The judges chose to organize their thoughts in the following areas as they studied student responses. We summarized what we saw and gave feedback on our perspectives along these same lines.

Executive Summary

Every team demonstrated that they knew that it was essential to provide a good executive summary, both in content and in clarity. Moderately successful efforts summarized what the requirements were and made statements like "In our analysis we project the decrease in HIV/AIDS cases if ARV treatments and/or preventive vaccines are developed." The more successful efforts recognized that this section should serve as a "bottom line up front" and actually summarized their most important conclusions here, making statements like "We find that the cost of ARV treatment is prohibitive in poorer countries and that wealthier countries have their own financial assets for the more costly ARV development, and therefore the UN effort should be exclusively toward development of a preventive vaccine that can then be distributed to all countries." *The most effective papers summarized the conclusions, not just the problem.*

Science

Many papers demonstrated knowledge of the science of HIV/AIDS with separate sections devoted to the biology of the disease, the mechanisms of transmission, the epidemiological spread, the efficacy of current ARV therapy and the potential value of a preventive vaccine. As an infectious disease, HIV/AIDS is certainly one of the most problematic diseases in our current history due to its global spread, ease of transmission, its high mutation rate in terms of noncompliant ARV therapy, and its failure to induce preventive immunity in the many vaccine trials to date.

Add to this equation the widely differing global issues of governance, public health infrastructure, education, culture, and socioeconomics, and you have our current global state of infection with an estimated 40 million people living with HIV, according to the World Health Organization.

Although many papers addressed the basics of the HIV/AIDS epidemic, some papers certainly addressed this capacious issue better than others.

The least successful papers supported their science simply by dumping Internet data into this section of the paper, including more science than necessary to address the problem, not focusing on the correct areas of science for the problem, and/or failing to document their information—this type of paper was quickly eliminated from consideration for a high-level award.

The moderately successful papers clearly had the science section written by one member of the team and the subsequent modeling sections written by other teammates. Although each section was individually well-written, the sections were very self-contained and hardly connected with each other.

The most effective papers incorporated most if not all of the science background that was presented as a basis for their following models. For example, if the team talked about how ARV treatment prolonged the lifespan of the infected person but did nothing to prevent the transmission of the virus, then the model reiterated this fact when it assumed that the level of spending on ARV had no effect on the rate of spread of HIV/AIDS. The most effective papers presented the science that was essential to the model but very little science that was just gratuitous.

Modeling

The most effective papers made their assumptions explicit as they built or presented their model. They were explicit in tying assumptions to the science when appropriate. The two predominant types of models presented were differential (differential-equation based and/or difference-equation based) and stochastic (probabilistic, based on transition probabilities). Neither was favored over the other by the judges; we saw both mediocre and excellent examples of both types of models and made no value judgments based on the type of model used.

In both cases, the features that typified the mediocre models were:

- developing more model details than were required,
- refusing to make simplifying assumptions and instead attempting to capture details in the model that were too fine for the questions being asked,

- presenting reams of output without highlighting a few of the more pertinent numbers and explaining what they meant, and
- making no attempt to make an argument as to why the model output seems reasonable and why it is reasonable to proceed to use the model in analysis.

In some papers, the model selected seemed like an awkward fit for the scenario, such as an awkward selection of partitions in a differential equation model, giving the feeling that the model had been selected mostly because it was the one that had been "pre-positioned" before the competition or was first off the shelf rather than because it was the most appropriate model. As one judge reflected, some models appeared to be hammers looking for nails within the scenario.

The most effective models

- gave rationale for the hypotheses,
- made appropriate assumptions to make the model more tractable,
- showed just the output necessary for later analysis,
- explained what the output meant with a few specific cases, and
- made an argument why the model seemed to be working reasonably well and merited use in further analysis.

Teams demonstrated their ability to make appropriate model refinements in the third requirement, when the assumption of vaccine-drug-resistant strains was introduced; here, clarity in showing exactly what was being changed and in highlighting the change in output was most important.

In most contests, all of the models selected by teams tend to fall in a few fairly homogeneous groups, but occasionally a team adopts a truly novel technique of analysis. This year that occurred with a team that simulated the spread of HIV/AIDS with a cellular automata simulation. This team simulated the population with a representative group of 10,000 individuals with six characteristics (age, sex, level of connection in society, social status, health, and cliquishness). At each time step of the simulation, each cell is determined to change value (from not infected to infected) or not (remain uninfected or remain infected), depending on the values of the surrounding eight cells, according to a set of rules which are developed from the parameters of the problem. Statistics are gathered from many runs of the simulation and then applied to answer the questions at hand. Several of the judges found this to be an intriguing approach that would have required more set-up and tuning to get it running properly but that offers a unique level of customizability and analysis. While this report was not one of the Outstanding papers, it was definitely innovative and commendable interdisciplinary modeling.

Analysis/Reflection

The more effective papers took time to reflect on and discuss the ways in which their model appeared to be strong and the ways in which it appeared to be weak in addressing the problem. They also took time to demonstrate the sensitivity and robustness of their model, either by actually changing a few parameter values and demonstrating the change in output, or at least through a short discussion (such as "a 10% change in any coefficient in this system of linear ODEs is likely to only have a corresponding change in the output because the eigenvalues appearing in our solution are so far separated").

This problem asks a lot, and even a long weekend is not much time; even in the Outstanding papers, we found that the financial piece of the scenario received very thin treatment by way of analysis and reflection. That was disappointing for the judges, because it was intended to be a major part of the interdisciplinary modeling.

Implementation

Moderately successful papers often looked as if a member of the team wrote this section who had not been very involved in the modeling and analysis. Those recommendations for implementation relied more on insight and background research than they did on the results obtained from analyzing the model. Often the implementation recommendations made no distinctions between country, region, or class.

The most effective papers recommended "policy through analysis": The policies that they recommended were justified by the model analysis that they had just been completed. It was not always necessary to quote numbers, but these papers made reference to their analysis when they presented their recommendations. These papers also were the ones that often made recommendations on resources and policy based on country wealth or demographics. They were also explicit in the assumptions that led to their recommendations; e.g., whether they recommended that certain countries be given priority access to ARV therapy because they have the highest incidence of disease and the objective is to minimize suffering; or to give priority to vaccine therapy in different countries because the objective is to prevent HIV spread in other less-infected areas of the world.

Communication

All teams demonstrated that they understood that the clarity and style of writing were very important to an effective product. We were generally pleased with most papers; very few teams were not clear and effective in their prose, and therefore, many papers earned congratulatory comments by the judges.

The most effective papers ensured that all of the sections were connected to one another—not just by adding a few sentences, but by articulating the logical connection between subsequent sections, in particular on Modeling, Analysis, and Recommendation, and those preceding. They also understood that well-selected graphics could be very effective in making a point, but that gratuitous graphics that were easy to make but which did not make an important point were distracting. Teams are reminded that proper documentation is always necessary to an effective paper. Judges saw some undocumented material for which they were sure they knew the source, and for which they felt it necessary to run checks.

As to length, short and succinct with adequate explanation is always preferred. Long, rambling papers were eliminated because of the frustration in reading too much detail or repetition.

Conclusion

The judges extend their thanks and congratulations to all of the teams. We truly enjoyed reading and studying your work and have come to have quite a bit of confidence in your abilities. We are interested and excited to see what problems you will attack as experienced interdisciplinary modelers when your studies are completed.

About the Authors

Kari Murad is an Associate Professor at the College of Saint Rose in Albany, NY. Her teaching interests include immunology, microbiology, virology and science education. She is actively involved in the National Science Foundation-supported SENCER-project (Science Education for New Civic Engagements and Responsibilities), service learning and problem-based science education initiatives on her campus. Additionally, she is currently the editor of *Science Teachers Bulletin*, a magazine for K–12 science teachers in New York State, and is the director of the Albany city middle school science fair (Joseph Henry Science Fair).

Joe Myers has served for two decades in the Dept. of Mathematical Sciences at the United States Military Academy. He holds degrees in Applied Mathematics and other disciplines and is a licensed Professional Engineer. He currently serves as a Professor, having directed freshman calculus, sophomore multivariable calculus, the electives program, and the research program. He has been involved in several major initiatives to improve teaching and learning, including building interdisciplinary activities and programs under the NSF-sponsored Project Intermath; integrating technology and student laptop computers into the classroom; and weaving modeling, history, and writing threads into the mathematics curriculum. He enjoys modeling and problem solving, has posed and guided the research of dozens of math majors, and has been involved in several research projects with the Army Research Laboratory.