Judges' Commentary: The Outstanding Sweet Spot Papers

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Introduction

Apparently the march of technology in Major League Baseball (MLB) is more of a crawl. The basic tools of baseball have not changed or been substantially modified for a long time. It would seem that the business goals of MLB are being adequately met with tools that are decades—if not centuries—old.

In particular, the baseball bat is pretty much the same implement that it was when Abner Doubleday walked the earth. It is not often that a tool persists basically unchanged without some improvement being brought to bear. Some began to wonder what the properties of such a remarkable tool might possess.

A Few Words About the Problem

Like most problems in the Mathematical Contest in Modeling (MCM)®, this problem was deliberately designed to be open-ended. In particular, the key phrase "sweet spot" in the statement of the problem was not defined. This was fortunate because teams brought many definitions forward and this produced a richer experience not only for the teams but also for the judges. Some of the useful interpretations of "sweet spot" included:

- the spot where a batted ball would travel farthest,
- the spot where the sensation of vibration in the batter's hands is minimized,
- the center of percussion,
- the location that produces the greatest batted ball speed, and
- the location where maximum energy is transferred to the ball.

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Several other definitions or interpretations are easily found through even a cursory literature search. Teams that did not discover this were generally eliminated in triage.

This observation compels us to consider also the relationships among problem statements, the Internet, and competing teams. It is extremely difficult, if not impossible, to imagine a problem that would be suitable for the MCM and for which there has been no prior art. Truly original problems, ones at which the MCM teams are the first to have a go, must be rare. Sometimes, we see a situation in which the proposed problem—while in its most general form is familiar—may be novel as an application to a particular situation which has received scant prior attention.

An example of this kind of problem is the Tollbooth Problem of the 2005 MCM.[1] While it would have been nearly impossible to find prior art applied specifically to the situation presented (namely, to barrier tolls on the Garden State Parkway in New Jersey), standard methods of queueing theory and dimensional analysis could be brought to bear.

In general, the Internet provides teams with a powerful resource to help find what, if anything, has been done on a topic before. This is a recent development that was not in play even a decade ago. Teams, coaches, and judges need to find a fair way of coping with this changed situation:

- On one end of the spectrum, it is not reasonable for a team to simply copy what they find on the Internet and submit this as their solution. No one learns any modeling from this.
- At the other end of the spectrum, teams may develop entirely new models that do not resemble anything found online. While this may be desirable, it is probably unusual.

Most submitted papers will fall somewhere between these extremes. The challenge for everyone is to make the MCM a learning experience for the teams and an enriching one for the judges in the face of this new technology. A general discussion of this issue is beyond the scope of this article; so suffice it to say that for this particular problem, the presence on the Internet of substantial material on solving the problem was appropriately treated by the winning teams. Teams who simply copied material from sources without adding any value of their own were not considered winning teams.

Interpretation Is Important

As always, interpretation is a key to success in modeling problems. Teams must recognize that in addition to their usual semantic or prose usage, key words in the problem statement must also be given a mathematical meaning in

[1] Editor's Note: Dr. Tortorella was the author of both the Tollbooth Problem, as well as the Sweet Spot Problem that he comments on here as a contest judge.

the context of a model. Successful papers began by providing definitions of at least two possible interpretations of "sweet spot." Once that is accomplished, it begins to be possible to talk in quantitative terms about how to determine such a sweet spot (or spots).

Modeling

Whatever model is chosen, it is necessary to produce an expression relating the sweet spot (SS) to physical parameters of the batter–bat–ball system. For instance, the Zhejiang University team investigated the SS as the location on the bat where the batted ball speed is greatest upon leaving the bat. Then the team developed a relationship between this definition and

- impact location,
- ball mass,
- ball initial speed,
- the moment of inertia of bat,
- the swinging bat speed, and
- the coefficient of restitution (COR) of the ball.

This team made good use of clear illustrations to help the reader grasp the work involved.

The Huazhong University of Science and Technology team made use of a weighted average of two SS criteria and found, not surprisingly, that the resulting location of SS is a compromise between batter comfort and batted-ball departure speed. This is a nice example of how a team amplified results available on the Internet to generate new insights. The Princeton University team defined SS as the location on the bat that imparts maximum outgoing velocity to the batted ball.

An interesting comment on the choice of SS criteria is that most teams did not explicitly connect their choice to the strategy of the game. That is, the criteria for the SS should be related in some explicit way to the result that the batter is trying to achieve, namely, to score runs. From this point of view, criteria such as "maximum batter comfort" are perhaps secondary desirable features but are probably not the most important ones in the short term. It may be more suitable to choose criteria such as maximum batted-ball departure velocity, maximum location controllability, or something that is directly related to producing runs. Most teams accepted their criteria as being implicitly connected with results of the game, but few if any discussed this point—clearly a key point!—at all.

The Outstanding teams were able to develop clear equations, based on the dynamics of the batter–bat–ball system, for the location of the SS. Most teams followed this approach, but the Outstanding papers were especially clearly reasoned and made good use of illustrations to help clarify points for the reader.

The contest weekend is a busy weekend; but those papers that took the time to pay attention to helping the reader with good organization, clear writing, and attractive presentation in their report received more favorable reviews. Of course, these desirable features cannot make up for a weak solution; but lack of such features can easily cover up a good solution and make it harder to discern. This is not a trivial concern, because triage reads are very fast and it would be distressing if a triage judge were to pass over a worthwhile paper because its presentation made it hard for the judge to discern its solution quality.

Some teams, including the Huazhong University of Science and Technology team, expressed their results very precisely (for example, the SS is 20.15 cm from the end of the bat). This may be more than is required, partly because of the limited precision of real-world measuring instruments, but also because teams should be aware that stating a result in such a fashion compels a sensitivity analysis for this quantity. The Outstanding teams determined that even though a location for the SS could be calculated, the point of impact of the ball with the bat could vary somewhat from the SS without too much change in the value of the objective function (e.g., the batted-ball departure velocity). The Huazhong University of Science and Technology team, as well as several other teams, defined a "Sweet Zone" to capture the notions that

- different SS criteria lead to different locations on the bat, and
- most of the objective functions employed are not very sensitive to the specific location of the bat-ball impact.

Conclusion

Studying these Outstanding papers offers good lessons in preparing entries for the MCM. Here are a few:

- **Make your paper easy to read.** That means at the very least:
  - number the pages and the equations,
  - check your spelling and grammar,
  - provide a table of contents, and
  - double-space the text (or at least use a font size large enough for easy readability).

  All four Outstanding papers did a good job with this.
- **Good organization will not make up for poor results, but poor organization can easily overwhelm good results**—and make them hard to dig out. It can help to organize the paper into sections corresponding to the requirements in the problem statement and into subsections corresponding to parts of the problem. The teams from the U.S. Military Academy and Princeton University did an especially good job with this.

- **Define all terms that a reader might find ambiguous.** In particular, any term used in the model that also has a common prose meaning should be carefully considered.
- **Complete all the requirements of the problem.** If the problem statement says that certain broad topics are required, begin by making an outline based on those requirements. Typical examples are statement and discussion of assumptions, strengths and weaknesses of model, and sensitivity analysis.
- **Read the problem statement carefully, looking for key words implying actions:** "design," "analyze," "compare," and other imperative verbs. These are keys to the work that you need to do and to the sections that your paper ought to contain.
- **When you do "strengths and weaknesses" or sensitivity analysis, go back to your list of assumptions and make sure that each one is addressed.** This is your own built-in checklist aiding completeness; use it.
- **Your summary should state the results that you obtained, not just what you did.** Keeping the reader in suspense is a good technique in a novel, but it simply frustrates judges who typically read dozens of papers in a weekend. The Princeton University paper has an excellent summary: crisp, concise, and thorough.
- **Use high-quality references.** Papers in peer-reviewed journals, books, and government Websites are preferred to individuals' Websites. Note also that it is not sufficient to copy, summarize, or otherwise recast existing literature; judges want to see *your* ideas. It's okay to build on the literature, but there must be an obvious contribution from the team.
- **Verify as much as you can.** For example, the physical characteristics of baseballs and baseball bats are readily verifiable. Make whatever sanity checks are possible: Is your answer for the departing ball's speed faster than the speed of light? If so, should it be?
- **Finally, an Outstanding paper usually does more than is asked.** For example, the team from the U.S. Military Academy (and many other teams that lacked other qualities needed to be Outstanding) studied two different models for the problem and compared the results from each approach; the reasonably good agreement that they obtained showed that either
  - they were on the right track; or
  - they were victims of very bad luck, in that both of the methods gave nearly the same bad answers!

About the Author

Mike Tortorella is Visiting Professor at RUTCOR, the Rutgers Center for Operations Research at Rutgers, the State University of New Jersey, and Managing Director of Assured Networks, LLC. He retired from Bell Laboratories as a Distinguished Member of the Technical Staff after 26 years of service. He holds the Ph.D. degree in mathematics from Purdue University. His current interests include stochastic flow networks, network resiliency and critical infrastructure protection, and stochastic processes in reliability and performance modeling. Mike has been a judge at the MCM since 1993 and particularly enjoys the MCM problems that have a practical flavor of mathematical analysis of social policy. Mike enjoys amateur radio, playing the piano, and cycling.