Judges' Commentary: The Bitcoin and Gold Portfolio Problem

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Introduction and Overview

This is the seventh year that the MCM has offered a Problem C, which focuses on mathematical modeling based on real-world data. As mentioned in the 2018 Problem C commentary [Oliveras et al. 2018], the problems continue to be of two types: those developed from a large data set, and those applied to a data set. This year's problem was mostly of the first type, requiring the development of forecasting models from two time-series data sets, and then applying those models to a subsequent optimization under uncertainty challenge.

The authors and judges for Problem C continue to expect students to include an analysis of the uncertainties of their results. Again, this year, the papers that did this well were markedly more successful than those that did not.

The Problem

Price data in US dollars were provided for five years for Bitcoin and for gold. Teams were given an initial balance of $1,000 US and asked by a trader to develop a model that uses only the past stream of daily prices to date to determine each day if the trader should buy, hold, or sell their assets in their portfolio. Commissions costs for transactions were set.

Teams were given the following tasks:

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- Develop a model that gives the best daily trading strategy based only on price data up to that day. How much is the initial $1,000 investment worth on 9/10/2021 using your model and strategy?
- Present evidence that your model provides the best strategy.
- Determine how sensitive the strategy is to transaction costs. How do transaction costs affect the results and the strategy?
- Communicate your strategy, model, and results to the trader in a memorandum of at most two pages.

Overview and Triage

The judging process relies heavily on a triage phase. Each paper is read by two experienced judges. Those judges give an initial assessment, and those assessments are combined to determine which papers move further in the judging process. It is very important for student teams to understand what the judges weigh in this triage process.

Judges first assess whether the paper addresses the required elements of the modeling process, and whether a team has answered the questions posed in the problem statement. Most judges begin by reading the abstract and the memorandum to get an overall sense of the paper before reviewing the main body. It is critical that both of these components be well-written crisp summaries of the results. The burden is on the team to explain what they are doing and to summarize results for a nontechnical audience, with recommendations and justifications in their letter to the marketing director. If a judge cannot follow what they say they have done in the letter, then the marketing director will not be able to understand, either.

Judges then use a rubric to assess how well teams addressed each of the required elements. Teams that omit a required element usually score no higher than Successful Participant.

What Was the Goal of the Model?

The problem explicitly stated that the goal was to maximize total return. Many teams modified that goal to consider risk. For example, Team 2200688 from the South China University of Technology modified its approach to "balance the return and risk." The judges accepted such modifications.

In the next sections, we discuss the most common shortfalls observed by judges.

Missing Required Elements

As in previous years, many student teams omitted required elements. This year, the requirement most frequently omitted was the one to present evidence that a team's model provides the best strategy. This, of course, is likely the most difficult element of the problem.

A proof of optimality is difficult. Many teams addressed "best" by saying they had used an optimal method to estimate parameters for their selected model. That, of course, is not the same as showing that they have selected the best model.

One approach, by Team 2218931 from Northwest University (China), was to construct a portfolio of possible models and show that their selected model had the best results in that portfolio (see **Table 1**).

Table 1. Asset value comparison of strategies by Team 2218931 from Northwest University (China).

Classification	Strategy	Asset Value ($)	Ranking
Quantitative Trading	our model	270836.00	1
Long-Term Trading	Control Group 2	73097.98	2
Long-Term Trading	Control Group 3	37219.59	3
Actual Trading	Control Group 4	3712.93	4
Short-term trading	Control Group 5	3117.20	5
Long-Term Trading	Control Group 1	1341.28	6

Handling Uncertainty

Forecasts for the future are inherently uncertain. Only the very best papers incorporated this uncertainty into their models and action plans. For example, Team 2200688 from South China University of Technology included confidence bounds in their forecasts (see **Figure 1**). This was one of the factors in their selection as an Outstanding paper.

Very few papers addressed the uncertainty of their predictions for future prices, and even fewer incorporated that uncertainty into describing their results. For future contests, papers that do this well will continue to earn the higher designations and awards.

Transaction Costs and Number of Trades

As day traders know, commissions can become quite expensive if one trades frequently. We required sensitivity analysis of the commission rates.

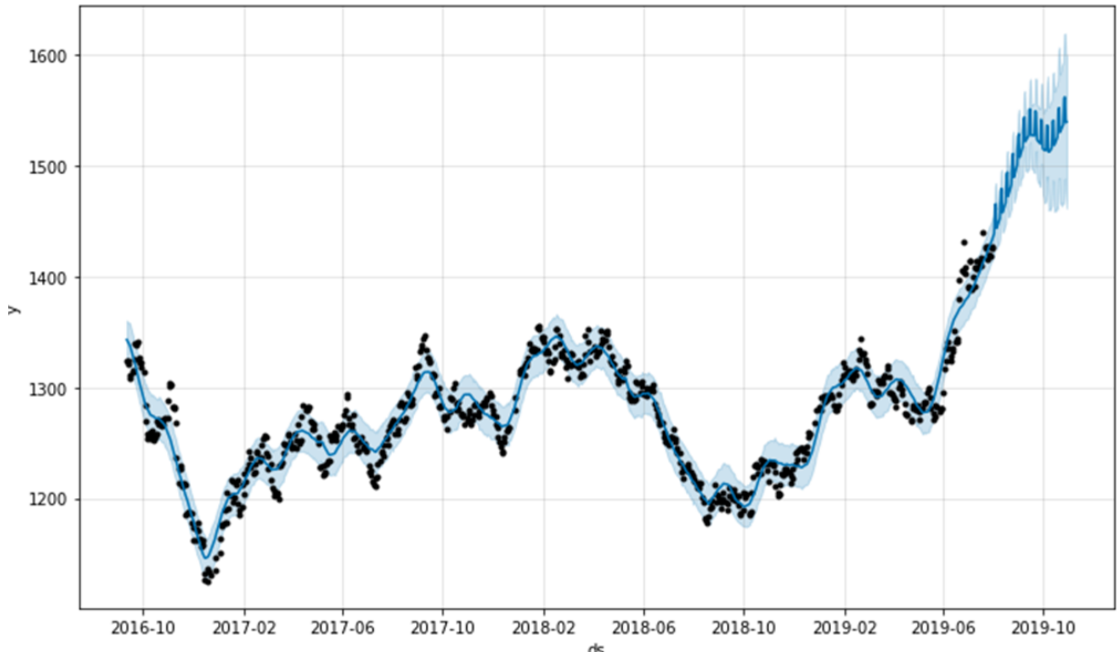

Figure 1. Confidence bands for a price forecast, by Team 2200688 from South China University of Technology.

The very best papers summarized for the reader the number of trades made in their strategy and the costs of those trades.

Many of the less-successful papers traded too frequently, and the commission costs made their overall results significantly lower.

One team, 2229059 from Columbia University, tried to address this by requiring a holding period for each asset before it could be sold again. They used a discrete search to select the holding period that they felt performed best.

Returns under Perfect Knowledge

Many papers calculated how much profit could be used using perfect information. This is a useful benchmark for how successful a team's strategy could be. It is also a useful check against error: If a model exceeds what can be done with perfect information, it likely contains a mistake.

Differing assumptions can result in different amounts for this calculation. One example is shown in **Figure 2**.

Other teams, using other assumptions, produced a wide range of results under perfect information.

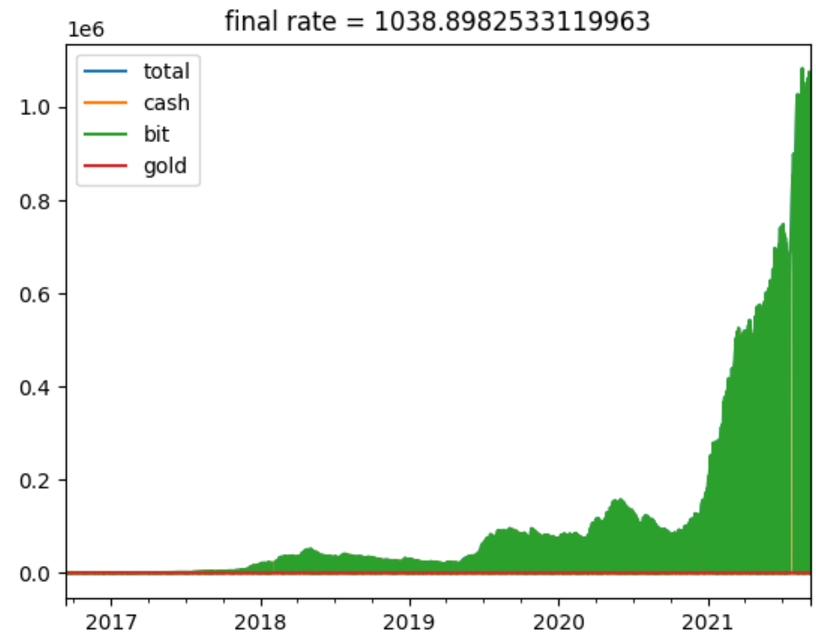

Figure 2. Rate of return under perfect information, by Team 2200401 from Shanghai Tech University. Units on the vertical axis are in millions of US dollars.

Writing Crisp Recommendations

The best papers were well-written. Their recommendations to the traders were clear and easily understood. Those recommendations also explicitly stated the results obtained by the team from their models. The memorandum summarizing results could be read independently of the main paper: It included adequate detail and explanations.

Over the last few years, the judges have noted significant improvement in the quality of writing for the abstracts, main body, and recommendations of the papers.

What Made Papers Outstanding?

The Outstanding papers shared several attributes:

- They answered all the required elements.
- They included good graphical summaries, such as the one in **Figure 3**.
- They included their results in the summary and in the abstract.
- Their analysis of strengths and weaknesses was very strong.
- Their results were plausible.

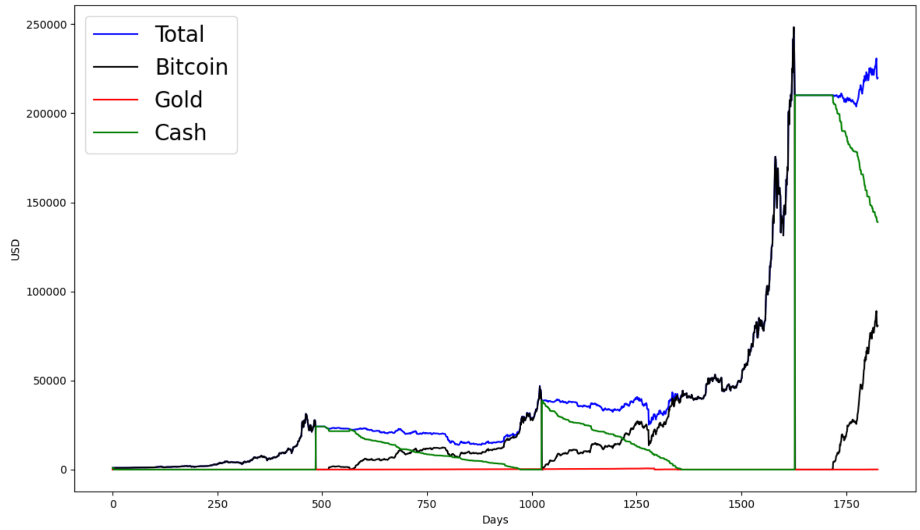

Figure 3. Portfolio value and strategy, by Team 2229059 from Columbia University.

Conclusion

Problem C continues to be wildly popular among contestants because the problems are accessible and can be approached using a wide range of methods.

What characterizes Problem C is that it *requires teams to deal with uncertainty*, due to underlying randomness in the data, statistical imprecision in forecasts, or uncertainty in the estimation of model parameters. Teams that address these issues well in future contests will continue to be ranked high by the judges.

Reference

Oliveras, Katie, Stacey Hancock, and David H. Olwell. 2018. Judges' commentary: The Southwest states' energy compact. *The UMAP Journal* 39 (3): 343–350.

About the Author

David H. Olwell is Professor and Dean at the Hal and Inge Marcus School of Engineering of Saint Martin's University. He earned a B.S. at the US Military Academy, where he studied mathematics, and an M.S. in Mathematics, an M.S. in Statistics, and a Ph.D. in Statistics from the University of Minnesota. He was previously on the faculties of the US Military Academy and of the Naval Postgraduate School. Dr. Olwell has been a problem author for both the MCM and HiMCM, an MCM judge for two decades, and was the Head Judge for Problem C.