Proceedings of the 2014 Winter Simulation Conference
A. Tolk, S. Y. Diallo, I. O. Ryzhov, L. Yilmaz, S. Buckley, and J. A. Miller, eds.

COMPUTATIONAL INTELLIGENCE IN FINANCIAL ENGINEERING TRADING COMPETITION: A SYSTEM FOR PROJECT-BASED LEARNING

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ABSTRACT

This paper discusses the implementation of the Trading Competition held at the 2014 IEEE Computational Intelligence in Financial Engineering conference (CIFEr 2014). Participants in the competition were asked to hedge a simulated portfolio of assets, worth approximately $54 million. The winner was the individual whose portfolio most closely generated a 1% annualized return based on daily tracking. The goal of the competition was to provide participants with the opportunity to learn portfolio management and hedging skill. Self-assessments indicate that contestants improved their portfolio management skills and enjoyed their experience. This paper discusses methods used to generate the simulated stock and option prices and to construct the trading platform. All of the software used in the competition is being made open source in the hope that students, professors, and practitioners improve on the idea of the competition, thereby facilitating project-based learning for the future practitioners of economics, finance, and financial engineering.

1 INTRODUCTION

Today's volatile markets have made hedge funds an attractive investment option. While hedge funds may sometimes underperform the market, the industry as a whole has grown from $100 billion to $2.5 trillion in 16 years (Amin and Kat 2003). This growth has increased competition, as well as the need for better hedging methods.

Like many strategies used in the financial industry, hedging techniques remain trade secrets. Unlike simple stock trading, running a hedge fund may require greater capital and therefore may incur a greater risk of losses. These observations suggest there is a need for a simulation environment in which students and other future practitioners can practice hedging skills. The Trading Competition of the 2014 IEEE Computational Intelligence in Financial Engineering (CIFEr 2014) conference had the goal of providing such an environment for student participants in the conference. This competition was modeled on the McIntire Hedge Fund Tournament, designed by Dr. Stefano Grazioli, held annually as part of undergraduate coursework in the McIntire School of Commerce at the University of Virginia.

The McIntire Hedge Fund Tournament was started in 2003 and is currently in its 15th edition. It is held in conjunction with a formal class that teaches both hedging strategy and trading algorithm development. Recent classes have been as large as 70 students, divided into teams of approximately 3 students. This has led to a database of trading strategies that is of academic interest to researchers attempting to develop methodologies for reverse engineering trading strategies (Hayes, Beling, and Scherer 2013).

A number of simulated trading environments exist, and trading competitions are common in finance degree programs and other venues. In many such simulations and competitions, the goal is to generate the highest return. The difficulty with return as an objective is that it tends to bias participants to high-risk strategies. We feel that that what is needed instead is a structure that induces participants to balance risk and returns simultaneously.

The goal of the CIFEr 2014 Trading Competition was to allow participants to learn portfolio management and hedging skill, while managing a simulated portfolio. The competition presented participants with a challenging problem, hedging under uncertainty, which required them to gather the necessary information and resources to develop a viable strategy. In other words, the competition invokes project-based learning, which has been shown to improve students' ability to learn and retain information (Gallagher et al. 1995, Thomas 2000).

This paper describes the implementation of the CIFEr 2014 Trading Competition. Both the simulated price generation software and trading platform software are available for download (CIFEr 2014). Section 2 provides a brief review of the education literature as it pertains to simulation-based education and project-based learning. Section 3 describes the design and implementation of the competition. Section 4 briefly summarizes the competition results and the feedback that was provided to participants. Finally, Section 5 offers concluding remarks and thoughts on future competitions based in part on surveys of the CIFEr 2014 participants.

2 OVERVIEW OF EDUCATION

2.1 Simulation-Based Financial Education

Computer web-based simulations for educational purposes have been used for many years (Lawrence 1997). Simulations expand traditional case studies, allowing students to actively influence the outcomes of a case. Keys et al. stated "A [business simulation] game, in a nutshell, is a dynamic, live case which provides not just a snapshot of realistic business problems but includes a moving picture of many interrelated business problems (Keys, Wells, and Edge 1993)." This sentiment can be expanded to finance; simulations allow students to experience the consequences of their action. According to Kincaid et al. (2003) simulation provides the following benefits in an educational environment:

- helps students see complex relationship that are impractical otherwise,
- allows technical skills to be taught in an applied manner,
- provides students with new methods of problem solving,
- provides realistic training and skills, and
- is cost effective.

To access the previously mentioned benefits of simulation education many schools have set up a finance lab, also known as a trading room. A trading room is usually equipped with hardware systems related to finance, such as a stock ticker and Bloomberg terminals. Additionally, many of these financial labs are equipped with stock trading simulations that allow students to trade financial assets. These simulation packages can be expensive, a license can cost as much as $7,500 annually (Duggal and Meyer 2011).

The efficacy of trading simulations as a teaching tool remains in doubt. Duggal and Meyer (2011) utilized a bond trading simulation in a Business Finance class. Students were first taught bond valuation in a traditional lecture class. After which, half of the students in the class participated in the bond trading simulation, the rest did not participate and were treated as the control group. The students that took part in the trading simulation were given both simulated bonds and cash, which they could use to buy or sell additional bonds. After the simulation exercise both the control group and the simulation participants took a bond valuation exam. The exam found no statistical difference between students that participated in the simulation exercise and the control group.

Using an equity simulation, Moffit, Stull, and McKinney (2010) found that students' investment knowledge statistically improved after performing simulated equity trades over a nine-week period. Students were given an assessment before and after the nine-week simulation exercise. It is important to note that students were not given any instruction on investment information. However, the students had access to on-line resources where they could learn investment information on their own. This study leveraged project-based learning because the students were expected to learn and develop a solution on their own. The next section will discuss project-based learning in more detail.

Although the efficacy of simulations on student outcomes is unclear, schools are moving towards adopting them. There is a need for a low cost trading simulation that will allow students to benefit from a simulation-based education. To facilitate this goal the authors' have developed a hedge fund trading competition. The code has been made available to researchers, teachers, students, and practitioners to use and expand.

2.2 Review of Project-Based and Competition Learning

Project-based learning (PBL) is defined as a complex tasks that challenge students and culminate in a realistic product (Thomas 2000). Researchers have found that student learning is maximized when the task they are completing resembles the real life scenarios they will face (Brown, Collins, and Duguid 1989). Under this paradigm, then, any problem that is given to the student should be grounded in reality.

There is a lack of research into the effectiveness of PBL in university settings. At the pre-university level, by contrast, there has been research highlighting the benefits of presenting students with "ill-structured" problems. In Gallagher et al. (1995), Thomas (2000), for example, high school seniors were presented with raw data about people dying of a disease with flu-like symptoms in local hospitals. The students were asked to perform several tasks, including

- determine if a problem existed,
- define the problem,
- identify relevant information,
- identify needed resources,
- generate and analyze possible solutions, and
- present the preferred solution.

Students that participated in the PBL coursed showed significant improvement in problem solving skills, when compared to their peers that did not participate. Subsequent studies have demonstrated that PBL can improve students' ability to learn and retain information (Stepien and Gallagher 1993; Boaler 1998; Olfat et al. 2013). Researchers have formed a consensus that students participating in project-based learning do as well or better than their peers who participate in traditional rote learning.

The motivation for the CIFEr 2014 Trading Competition was a desire to provide students in economics, finance, and financial engineering with a system facilitating PBL. Participants in the competition were given price series a month prior to the start of trading, which they are encouraged to leverage in developing a successful hedging strategy. The competitors were told the price series will be similar to the price series seen during the competition. This allowed students to investigate a complex task, hedging under uncertainty, and present a realistic strategy at the competition. Competitors are not told how to hedge a portfolio, rather they were left to determine the resource and the information needed to accomplished the desired task, as well as develop a viable solution.

A core component of the CIFEr 2014 event was the competitive spirit it generated. The use of competition as a pedagogical aid has been record as early as the 1st century BCE (Verhoeff 1997). There are competing arguments on the efficacy of competition, with some claiming that, as competition is part of every culture, it should be incorporated into education and others stating that competition is contradictory to collaboration and thus is detrimental to the education process (Verhoeff 1997). Although, the CIFEr Trading Competition was a strictly individual competition, future iterations of the competition will be structured around team play in an effort to meld cooperation and competition.

3 TRADING COMPETITION

3.1 Description

Any registered conference attendee could participate in the trading competition. Participants were given a basket of stocks and options, which had to be held for the full duration of the competition. Contestants were provided cash which they could use to hedge their positions. Their initial total portfolio value was \$54,000,000. Portfolio value is the amount of cash plus the value of all stocks and options in a participants portfolio. The CIFEr 2014 Trading Competition was held over a 6 week period, with a simulated bid and ask price being presented for each asset every week day. At the beginning of every day, the tracking error TE was calculated for each team. Tracking error was defined to be:

$$TE_t = \begin{cases} \frac{PV_t - T_t}{2} & \text{if } PV_t \geq T_t \\ T_t - PV_t & \text{else} \end{cases} \tag{1}$$

where PV is the portfolio value and T is the target value, equal to initial portfolio value plus a 1% annualized return to date. To minimize tracking errors, teams entered long or short positions in stocks or options to offset the illiquid position. Participants were apprised of the following restrictions on entering or maintaining positions:

- The value of the margin account must not exceed \$22 million.
- Contestants must have at least 30% of the margin account value in cash at all times.
- Contestants may not trade any asset more than once a day.
- For a trade to be initiated, the required amount of cash must be present in the portfolio.
- Contestants may not trade any asset that has a value of zero dollars.
- Contestants cannot trade assets in their initial portfolio.
- Contestants must pay 1% transaction cost for short trading and 0.4% transaction cost for all other trading.
- Each day Contestants receive 1% annualized interest on their cash holdings.
- Trades are limited to assets derived from thirty stocks: AA, AAPL, ABX, AU, BAC, BBT, BP,C, CISCO, CVX, DUK, ED, EXC FCX, GOOG, IBM, JPM, MSFT, NEE, POT, PXD, RF, RIG, SBS, SLB, SO, VALE, WFC, XOM, and YHOO.

The above abbreviations are stock ticker symbol for each asset. The thirty assets were selected from five sectors, six stocks were choose from each sector. The sectors were Base Materials, Energy, Finance, Technology, and Utilities. Assets within the same sector are highly correlated, which allows participants to hedge one asset with another. The team with the lowest cumulative tracking error was crowned winner.

3.2 Price Series

The price series in the competition were based on an historical S&P 500 price series. The first step in estimating the price series was to estimate the Beta of each equity (stock) asset, the benchmark being the S&P 500. Beta measures the relation between S&P 500 returns and that of a specific stock. Using the Beta a price series can be generated that closely follows the real price series. To increase the difficulty of the competition a $N(0,\sigma)$ was added to generate a layer of noise, where σ is the implied volatility of the stock. The noise adds a layer of randomness to the price series, as well as obscuring the historical time period.

Generating the option prices seen in the competition required several additional steps. Firstly, the historical volatility for each stock was found. Volatility was measured as the standard deviation of log returns. Additionally, an expiration date of the options needed to be selected. To limit the difficulty of the competition the expiration date was chosen to be outside the competition time window. This means teams did not have to worry about exercising the options. Furthermore, stocks were assumed not to pay a dividend, as dividend would have increased the difficulty of constructing an appropriate portfolio. The last assumption the authors made was that all options were European styled options. This meant that the options could not be exercised prior to the expiration date. Again this was to limit the difficulty in the competition, allowing it to be accessible to people of different skill levels and finance backgrounds.

Using the simulated price series of each stock and the Black-Scholes formula a simulated option price series was generated. Similar to the stock price series a U(-2%,2%) was added to generate a layer of noise. Five puts and five call options were calculated for each stock. All options were created to be in the money at the start of the competition, but the future price path was not controlled in any fashion. The strike price of the options incremented by $0.50 or $1.00, depending on if the underlying stock value started below or above $15 respectively. A diagram of the price generation process can be seen in Figure 1.

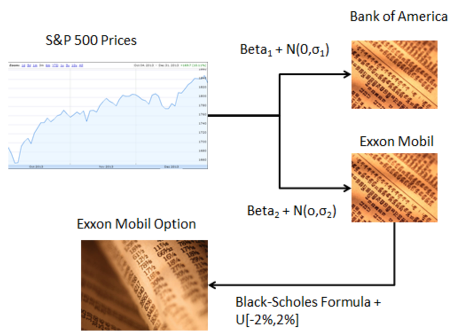

Figure 1: Price series generation diagram.

3.3 Implementation

The web application, which the competitors interfaced with, was developed in Flask. Flask is a web development framework that is written in Python. It was choose because it provides a simple but extensible framework, which will allow future iterations of the competition to easily extend their predecessors. Additionally, Flask is capable of running on multiple types of operating system and is relatively easy to learn.

The web interface has two pages, one for login/registration and the main page where contestants can see the current equity prices and make trades. The main page also displays the contestants' tracking error history as a graph. This allows for participants to keep track of their performance as the competition progresses. The competition was hosted on Heroku, a cloud service provider. Heroku allows for dynamic allocation of resources, allowing the system to automatically scale as more users register. Figure 2 illustrates how a user interfaces with the system.

Participants could login into the system at any time and view their cumulative tracking error, as well as the available stocks and options. Competitors could then perform a trade, which is checked against the aforementioned rules. If a rule was violated the competitor would be informed of the violation and the trade was prevented from occurring. The system would update new prices and calculate tracking error at 00:00 GMT. GMT was chosen because this was an international competition associated with a conference held in London.

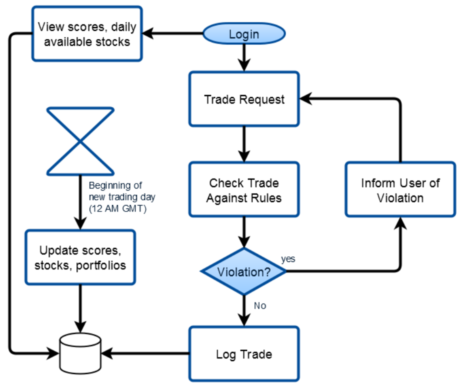

Figure 2: System flow diagram.

4 RESULTS

The competition did not have a large number of participants. Only 15 participants competed in the competition, with about a third never making a trade. With such few participants, the contingent of non-active traders placed 3rd. That is to say, all but two traders that actively trade made their portfolio worse. Although, this was discouraging to competitors it provided a learning opportunity, which was addressed during a competition panel held at CIFEr.

At the panel, contestants were given an opportunity to discuss their strategies. It turns out that most of the participants did not have formal training in hedging portfolios. Additionally, the contestants that were applying economic hedging strategies did not understand the underlying assumptions of the models they were using. Specifically, participants did not take into account that options converge to a price as they near their expiration date. One does not need to adjust holdings as much because the relationship between the stock and option prices becomes less volatile. Some participants were consistently adjusting their holding even though they were receiving diminishing returns from these adjustments. These participants' tracking errors were increased as a result of losing money to transaction costs. The participants that attended the panel discussion learned through hands on experience why it is paramount to understand the underlying assumptions of any model. Figure 3 illustrates the cumulative error of each contestant throughout the competition. The non-active traders are marked with an asterisk.

In Figure 3, a delta hedging strategy performed by the authors' is presented for comparison. For more information on delta hedging please see Hull (1999). The strategy developed by the authors' outperformed the winning competitor by 10%. This result indicates that every participant can benefit from formal hedging education. Future competitions will provide participants with more guidance in hedging techniques.

5 CONCLUSION

Overall the competition is seen as a success, as students were given an opportunity to learn hedging strategies first hand. Participants were asked to fill-out a self-assessment once the competition ended, below is a summary of the responses. It should be noted that only four participants completed the self-assessment.

1. What was the main reason you entered this competition? The majority of the competitors stated they either wanted to learn portfolio management skills or test skills that they already had. This reinforces the idea of project-based learning, as a tool for students to develop and synthesize skills in a real-world setting. As stated previously, the goal of the competition was to allow students to learn portfolio management skills in a competitive but risk-free environment.

2. What did you like about this competition? The responses to this question varied, with students highlighting the opportunity to test hedging strategies and the trading environment mimicking real-world investment constraints.

3. What did you dislike about this competition the most? One student mentioned that there were several

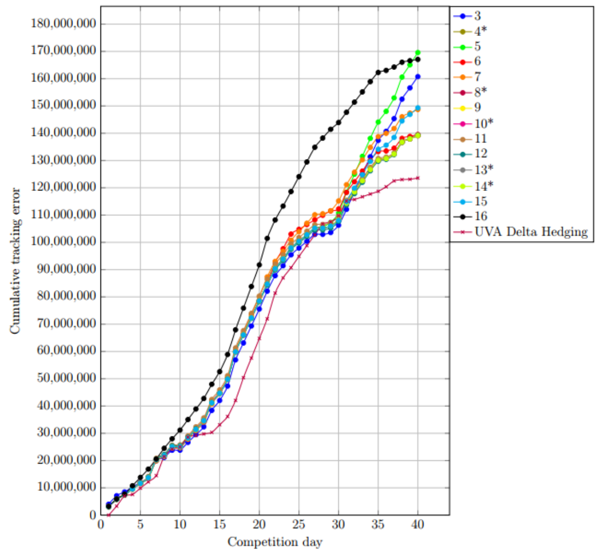

Figure 3: Competition results.

technical errors experienced during the competition. Although, these errors were quickly resolved, they lowered his overall experience in the competition. The errors have been fixed in the released competition software cited above. Other participants would have liked access to historical data and a larger portfolio of assets to trade. The portfolio of possible assets was originally limited to make the competition easier. However, future iterations of the competition can be easily extended to a larger number of assets.

4. How effective do you feel that this competition improved your skills in hedging (1-5)? The median response was a 4, with the lowest response being a 2. The participant that responded with a 2 had formal training in portfolio hedging, which may have resulted in him feeling that he did not learn a significant amount. However, the other participants stated the competition improved their skills.

5. How did you enjoy the competition (1-5)? The responses ranged from 3 to 5, with the median response being a 4. This shows that not only did the competition help improve participants hedging skills, they also enjoyed the process of learning.

6. How can this competition be improved? Participants would like an algorithmic version of the competition. That is to say, they would prefer to design an algorithm and allow it to interface via an API with the competition system. The authors originally considered this option but rejected it because it increased the barrier to entry. In other words, contestants would be required to know how to program software, interface via web connection, and error test their software code. In a formal classroom Dr. Grazioli has successfully integrated the design and implementation of algorithms into the competition held at the University of Virginia. However, due to the constraints of hosting an international competition, with students of varying software skill level, the authors felt this added unnecessary complexity.

The responses to the self-assessment and the competition panel discussion highlighted the benefits of the competition, while providing an opportunity to suggest improvements. Overall students enjoyed their experience and improved their skills through hands on project-based learning. Future iterations of the competition will allow for team based competition, providing students the opportunity to improve their collaboration skills. Additionally, the price series will be made more realistic by allowing stocks to pay dividends, American style options, and better option strike price placement. Furthermore, students will be provided access to historical data during the competition, as well as a news feed that will provide information on why prices moved in a specific direction. An algorithmic version of the competition may be developed to allow students the opportunity to implement a portfolio hedging algorithm. The IEEE

Computational Intelligence in Financial Engineering Technical Committee has agreed to host competitions at future conferences, providing students the opportunity to solve real world problems.

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