INFT Coursework Assessment 2021

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***Abstract*—This document tells you about the coursework assessment for *Introduction to Financial Technology* (INFT) in academic year 2021-22. The layout of this document also serves as an example of the format that you are required to use for your final submission. The coursework requires you to use the Bristol Stock Exchange to run some experiments to evaluate a new adaptive trading strategy called PRSH which stands for *Parameterised Response Stochastic Hill-climber*. After you have evaluated PRSH, we invite you to improve upon it, either by adapting/extending PRSH or by doing something entirely different. In your evaluation of PRSH, and of your attempted improvement, we expect you to design appropriate evaluation experiments, use informative visualisations of the results, and apply appropriate statistical tests.**

***Index Terms*—Automated Trading, Financial Markets, Adaptive Trader-Agents, Optimization, Multi-Armed Bandits.**

I. Introduction

The Bristol Stock Exchange (BSE: see [1], [2]) is a simple simulation of an electronic financial exchange based on a continuous double auction running via a limit order book, where the market can be populated by a variety of automated trader-agents, and experiments can be run in the style of Smith [3] or Gode & Sunder [4]. BSE includes pre-coded versions of a variety of trader-agent strategies, including the widely-known ZIC [4] and ZIP [5], and two BSE "house strategies" called GVWY and SHVR.

In 2021 two new trader strategies were added to BSE: PRZI and PRSH. PRZI (pronounced "prezzy") stands for *Parameterized-Response Zero-Intelligence*, while PRSH (pronounced "pursh") stands for *Parameterised Response Stochastic Hill-climber*. The behavior of a PRZI trader is governed by a single numeric parameter, the trader's *strategy* value, denoted by s, which is a real number between plus and minus 1 (or, in maths notation, $s \in [-1, +1] \in \mathbb{R}$): full details of PRZI are given in [6].[1] Depending on its specific value of s, a PRZI trader might behave like SHVR, like ZIC, like GVWY, or like some hybrid mix of those strategies, but an individual PRZI trader is defined to keep the same s value for as long as it exists: that is, PRZI is not specified to *adapt* its strategy over time. Extending PRZI so that it is adaptive gave rise to PRSH. An individual PRSH trader adapts its value of s over time via a very simple stochastic hill-climbing method which is easy to understand but very inefficient. PRSH's hill-climber operates on an infinite loop, where in each pass through the loop it evaluates a set $\mathcal{K}$ containing k different values of s by trading in the market using each s value for a specific period of time; then, after the k^{th} s-value has been evaluated, it works out which s-value generated the most profit, denoted by s_0, and then it creates $k-1$ "mutations" of s_0; the loop then repeats, using s_0 and its $k-1$ mutants as the new set of k different values $\mathcal{K}$, and so on.

In this coursework we want you to design and execute a set of experiments on BSE that evaluate PRSH, to gain some understanding of how the choice of k affects its behavior, and how (for any specific value of k) altering the mutation function affects its behavior. We want you to write a report, using the same layout and format as this document, of no more than 8 pages of A4 paper. This document's format is the IEEE standard for conference-papers, and the IEEE make templates and style-files available for download[2], for Microsoft Word and for the technical document preparation system called LaTeX . Many of you may be familiar with Word already, but if you learn to use LaTeX you will probably find that very useful for when you write your masters thesis describing your final individual project. As a UoB student you have free access to a cloud-based LaTeX platform called *Overleaf*[3]. This document was produced in LaTeX using the IEEE templates.

If you choose to, your report can simply describe and discuss the explorations of PRSH that you conducted: if you do only this, and you do a really good job, then you can get a very good grade ($\geq 60\%$), but not a distinction-grade mark (i.e., your final mark will be less than 70%). To get into the $\geq 70\%$ zone, you need to do something more: we ask you to improve upon PRSH either by editing/extending PRSH, or by using some other form of adaptive algorithm, e.g. some form of machine learning, to create a trading strategy that outperforms PRSH. Again, you will need to design and execute a set of experiments in BSE, and again you will need to use appropriate visualisations and statistical tests, to show that your trader-agent is more profitable than the original PRSH.

II. Further Details

A. *Exploring PRSH*

For your evaluation of PRSH, two primary questions have already been introduced in the text above: what is the best value of k, and what is the best style of mutation function.

[1] See: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3823317

[2] See: www.ieee.org/conferences/publishing/templates.html

[3] See: www.overleaf.com

On the topic of the mutation function, as an example, consider when $k = 5$: you could just identify s_0 and create four mutants s_1 to s_5 by repeatedly applying $s_i = s_0 + \mathbb{U}(-0.1, +0.1)$ where $\mathbb{U}(r_{\min}, r_{\max})$ denotes a draw from a uniform distribution over the range $[r_{\min}, r_{\max}] \in \mathbb{R}$. (And note that you'd need to clip the resulting s_i values to ensure that they are all within $[-1, +1]$, because when s_0 is close to ± 1 there is a chance that the mutant s_i values go out of range). Or, you could maybe do something cleverer, such as $s_{1,2} = s_0 + \mathbb{U}(0, 0.1)$ and $s_{3,4} = s_0 - \mathbb{U}(0, 0.1)$ so that half the mutants are exploring the value of increasing s while the other half are exploring the effect of decreasing s. And, taking it a bit further, you could maybe try something like $s_1 = s_0 + \mathbb{U}(0, 0.05)$ and $s_2 = s_0 + \mathbb{U}(0.05, 0.15)$ (and similar for s_3 and s_4) so that two mutants are exploring the effects of small changes to s while the other two are exploring the effects of bigger changes.

B. Experiment Design and Analysis

For any changes to PRSH of this sort, you will need to design an appropriate set of experiments, gather the data produced by those experiments, visualise the data, and conduct a rigorous statistical analysis. In principle, you could find yourself running a *lot* of market sessions, so you may need to make some simplifying assumptions given the limited time available. As we saw in the lectures, when the IBM team [7]–[9] were evaluating and comparing different trader-agent strategies, they introduced the notion of *one-in-many* and *balanced-group* tests: you may wish to take inspiration from the IBM studies. If you are comparing two strategies, let's call them A and B, you need to decide on an appropriate *metric*, i.e., what value(s) will you be comparing: you could use raw profit; or profit per unit time; or profit per trade; or some measure of margin (profit as a percentage of the limit price) – it's up to you to decide an appropriate metric and to justify your decision. And, as the metrics returned by A and B will be at least partially stochastic (i.e., there will be some randomness, some noise, in your sampling of the metrics from A and B) you will need to think about how best to compare A with B if you wish to rigorously claim that one is better than the other.

You'll also need to think about the nature of the supply and demand schedules in your experiments, whether they are static or should vary over time, etc; and you will need to think about how many different strategies to test at any one time (e.g., the IBM team used largely static supply and demand schedules, and spent a lot of time looking at pairwise comparisons, testing A *vs.* B rather than A *vs.* B *vs.* C *vs.* D).

C. Extending PRSH

If you decide to extend PRSH, you may find it useful to read some literature on *multi-armed bandits* (MABs), a long-established field of study in which the fundamental issues are: when you have k alternatives that each offer some stream of rewards or payoffs (just as the set of k s-values in PRSH do), how do you decide which ones to use (and how often to use each) to maximise total payoffs received, and how do you best deal with the possibility that the streams of payoffs available from each alternative might change over time. There is a fundamental tradeoff between *exploring* the payoffs from the k alternatives, and *exploiting* the alternatives that you believe to give good payoffs. For introductions to MABs see [10] and [11], and for a more detailed technical treatment see [12]. This is just one suggestion: we are not *requiring* you to draw inspiration from MAB algorithms: you might want to instead use some contemporary form of machine learning algorithm instead; that would be absolutely fine.

D. Style

Finally, when we say that the maximum length of your report should be eight pages in this IEEE format, we really mean it: if your final PDF has more than eight pages then we will reject it (that is what happens when over-long papers are submitted for peer-review) and the eight pages must include everything: the title, the abstract, the text, all the figures and diagrams, any footnotes or endnotes, all the references, and any appendices. This is absolutely the standard definition of "no more than 8 pages". But it does not have to be exactly eight full pages: if you can say all that you want to say in fewer than eight pages, that is fine.

When you write your report, write it in such a style that it could in principle be submitted, without edits, to a peer-review scientific conference: give it a title that explains what findings you are reporting; give it an abstract that tells the reader what the paper is about; cite appropriate literature; etc. The more your report looks and feels like a publishable (or published) scientific paper, the higher the marks it will get.

Good luck!

References

[1] D. Cliff, *Bristol Stock Exchange: open-source financial exchange simulator*. https://github.com/davecliff/BristolStockExchange, 2012.

[2] ——, "BSE : A Minimal Simulation of a Limit-Order-Book Stock Exchange." in *Proc. 30th Euro. Modeling and Simulation Symposium (EMSS2018)*, F. Bruzzone, Ed., 2018, pp. 194–203.

[3] V. Smith, "An Experimental Study of Competitive Market Behaviour," *Journal of Political Economy*, vol. 70, no. 2, pp. 111–137, 1962.

[4] D. Gode and S. Sunder, "Allocative Efficiency of Markets with Zero-Intelligence Traders: Market as a Partial Substitute for Individual Rationality," *Journal of Political Economy*, vol. 101, no. 1, pp. 119–137, 1993.

[5] D. Cliff, "Minimal-intelligence agents for bargaining behaviours in market-based environments," HP Labs Technical Report, Tech. Rep. HPL-97-91, 1997.

[6] ——, "Parameterized-Response Zero-Intelligence Traders," *SSRN:3823317*, 2021.

[7] G. Tesauro and R. Das, "High-performance bidding agents for the continuous double auction," in *Proc. 3rd ACM Conference on Electronic Commerce*, 2001, pp. 206–209.

[8] R. Das, J. Hanson, J. Kephart, and G. Tesauro, "Agent-human interactions in the continuous double auction," in *Proc. IJCAI-2001*, 2001, pp. 1169–1176.

[9] W. Walsh, R. Das, G. Tesauro, and J. Kephart, "Analyzing complex strategic interactions in multiagent systems," in *Proc. of the AAAI Workshop on Game-Theoretic and Decision-Theoretic Agents*, 2002.

[10] J. Myles White, *Bandit Algorithms for Website Optimization: Developing, Deploying, and Debugging*. O'Reilly, 2012.

[11] A. Slivkins, *Introduction to Multi-Armed Bandits*. Arxiv:1904.07272v6, 2021.

[12] T. Lattimore and C. Szepesvari, *Bandit Algorithms*. Cambridge University Press, 2020.