IEFT (COMSM0101) Coursework Assessment 2022

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***Abstract*—This document tells you about the coursework assessment for *Internet Economics and Financial Technology (IEFT)* in academic year 2022-23. 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 (BSE) to run a series of experiments to evaluate a new adaptive trading strategy called PRDE which stands for *Parameterised Response Differential Evolution*. After you have evaluated PRDE, we invite you to improve upon it, either by adapting/extending PRDE itself or by doing something entirely different. In your evaluation of PRDE, 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 novel zero-intelligence 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 kth 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 in $\mathcal{K}$, and so on.

In a paper [7][2] to be presented at the *IEEE Symposium Series on Computational Intelligence*, in Singapore in December 2022, a better adaptive version of PRZI is introduced: this is known as *Parameterized Response Differential Evolution* (PRDE, pronounced "purdie"). PRDE uses a very basic form of a widely-used optimization technique called *Differential Evolution* (DE), first introduced by Storn & Price [8], which has been found to often be a top-performing method in comparative studies and in various machine-learning competitions: see e.g. [9] for a review of work on DE.

DE is a form of evolutionary computation, a genetic algorithm, that maintains and updates a population of candidate solutions – in that sense, it is similar to the stochastic hill-climber: whereas the number of different candidate solutions in PRSH was referred to above as k, in the DE literature the number of candidate solutions is very often instead referred to as NP – for "Number in Population". The first and simplest form of DE, which is what is used in PRDE, requires that $NP \geq 4$. For ease of comparison with PRSH, we'll continue to refer here to k rather than NP in PRDE.

If you read about DE, you will find that it is intended to optimise candidate solutions that can be represented as strings or vectors of real numbers – the string or vector is the "genome" in the genetic algorithm – but in PRDE, as in PRSH, what is being optimized is a single strategy, a single real value $s \in [-1, +1]$, and so the string is of length one, or the vector is one-dimensional. This makes the implementation of DE in PRDE simpler than what you will find described in general papers on DE, because there is no place for a *crossover* operator in PRDE, and so the DE parameter CR (the *crossover probability*) is undefined for PRDE.

As explained in detail in [8], there is one more parameter of major significance in DE, the *differential weight*, which is conventionally denoted by F: this is a coefficient which controls the extent to which the difference between two candidate solution vectors is mixed in with a *base vector*

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

[2] See: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4153519.

(which is essentially just another candidate solution randomly drawn from the population).

The implementation of PRDE on GitHub has a particular choice of values for k and F, but it is entirely possible that a better choice of those two values exists, i.e. a (k, F) pair that gives much better performance. That is something we ask you to explore in this coursework assessment.

In this coursework we want you to design and execute a set of experiments on BSE that evaluate PRDE, to gain some understanding of how the choice of k and F 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,[3] 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 then 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*.[4]

If you choose to, your report can simply describe and discuss the explorations of k and F in PRDE that you conducted: if you do only this, and you do a really good job, then you can get a very good grade (≥60%), but not a first-class mark (i.e., your final mark will be less than 70%). To get into the ≥70% zone, you need to do something more: we ask you to improve upon PRDE either by editing/extending PRDE, or by using some other form of adaptive algorithm, e.g. some form of machine learning, to create a trading strategy that hopefully can be demonstrated to outperform PRDE. 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 whether your trader-agent is more profitable than the original PRDE or not.

II. Further Details

A. 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 [10]–[12] 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).

B. Extending PRDE

If you decide to extend PRDE, 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 different s-values in PRDE 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 [13] and [14], and for a more detailed technical treatment see [15]. 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 – it's up to you. For instance, there is a revised/extended form of DE known as JADE [16] that might offer an improvement on the very simple/basic DE process used in PRDE.

C. 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.

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

[4] See: www.overleaf.com

Good luck!

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