Summer Research Program in Industrial and Applied Mathematics

SEOUL NATIONAL UNIVERSITY

Sponsor

⟨**Magnum Research Limited**⟩

Final Report

⟨Portfolio Management using Reinforcement Learning⟩

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Abstract

This sample report serves two purposes. First, it introduces the RIPS "house style"—preferences for how copy is set and laid out on a page.* Second, by comparing this document with the LaTeX source, it illustrates the effects of LaTeX code on the resulting typeset.†

(The Abstract should succinctly summarize the purpose and results of the RIPS project. Usually, it will be one paragraph of no more than half a page to one page in length. The Abstract is often the last major component to be written, since it is almost impossible to know what to say until you have essentially completed the project.

The Abstract is self-contained. For example, unfamiliar acronyms should be used sparingly, and if used, should also be spelled out. References to the literature should be specified completely, not cited for look-up in the Bibliography.)‡

*R. M. Ritter, *New Hart's Rules: The Handbook of Style for Writers and Editors*, Oxford University Press, 2005.

†Location of the source code is provided in Appendix B.

‡Note that in front matter the footnote reference can be a symbol, but in the body it is usually a number.

Acknowledgments

It is appropriate in the Acknowledgments to thank individuals or organizations who made especially noteworthy contributions to your project. Elsewhere, within the body of the report, you can acknowledge more specific contributions where appropriate. These are matters of courtesy and professional ethics. As an example:

> The RIPS LaTeX report template has been developed by Mike Raugh with advice and assistance from Oleg Alexandrov and Shawn Cokus in the early stage of development and general support of IPAM and the System Administration staff. The first RIPS template was based on an early version of the Math Clinic's report template at Harvey Mudd College; there the original template has been improved and is managed by Claire Connelly, the HMC Math Department's system administrator. Claire and her co-authors offer coding advice, a wealth of references, and a note about the origin of the template in their current edition, the `sample-clinic-report.pdf` accessible at `http://www.math.hmc.edu/computing/support/tex/sample-report`. Claire copyedited the third edition of Grätzer's *Math into LaTeX*, most of which work seems to have survived into the fourth edition: *More Math into LaTeX* [**?**].

When acknowledging individuals in this section, it is OK to use the names by which you know and speak to them. Here it is OK to write "Oleg Alexandrov." But you must be formal on the Title page and elsewhere within the report, where it is proper to specify honorifics, e.g., Dr. or Prof. On the Title page you would write "Dr. Oleg Alexandrov," and likewise within the body of the report if you were acknowledging him for a specific contribution, Claire Connelly uses no honorific, so you would use just her name on the title page. When in doubt, check the person's business card or follow usage on the person's web page.

As a result of suggestions from users, this Sample Report and its source are under continual improvement. Please contact the RIPS program director for your suggestions. An up-to-date list of changes is recorded in the "Revisions" folder for the Master Template Folder.

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Chapter 1

Introduction

The investors ultimate goal is to optimize profit or risk-adjusted return in trading system. Investors construct a portfolio for hands-off or passive investment. A portfolio, a collection of multiple financial assets such as stocks, bonds and bills is usually characterized by its constituents(assets included in a portfolio), weights(the ratio of the total budget invested into each asset), and expected return. Portfolio management is the art and science of making decisions about investment mix and policy, matching investments to objectives, and balancing risk against performance. In this research, we are using reinforcement learning methodologies to optimize portfolios.

Our research is supported by Magnum Research Limited. It is a fintech company aiming to use advanced AI techniques to help different types of investor to build up a personalised portfolio to optimize their profit in the financial market.

In this project, we are using reinforcement learning to develop an automated trading strategy. The performance of the algorithm is indicated by comparing to the benchmark. For simplifying our situation we just consider the 2-stock portfolio. We also assume that we can buy and sell the stocks at the open and closed price and our behaviour does not affect the stock market. To solve the problem in Reinforcement learning setting the main methodology we used in the report is Q-learning and Deep Q-network.

Reinforcement learning is a learning strategy that can let agent to learn without knowing the rule from the environment beforehand but only the reward of actions it make. The objective is to optimize the total reward it gets, and through the process of exploration and exploitation, the agent will learn gradually.

Reinforcement learning has been applied to many situations. The most famous one should be a modified version of well known AlphaGo[1], AlphaGo Zero. It involves the technique deep reinforcement learning. Another example is that using deep reinforcement learning, we can train the computer to play atari game[2].[1] With wide application of reinforcement learning, someone proposed to apply reinforcement learning in financial sector especially for portfolio management. Some of the previous works attempted to tackle this problem. (Related work and previous work summary)

[1]AlphaGo is a copmuter program that able to win the world class Go player. On 23,25,27 May 2017 AlphaGo win the first ranked Go player Ke Jie

[2]Google DeepMind is able to do this in 2013

Chapter 2

Methodology for Q-learning and Deep Q Network

The main methodologies we are using for the research are Q-Learning and Deep Q Network(DQN). Here are some explanations about those methodologies.

2.1 Q-learning

Q-Learning is one of the Reinforcement Learning algorithms that attempts to learn the value of being in a given state, and taking a specific action there. Q-table is a table of values for every state(row) and action(column) possible in the environment. Within each cell of the table, we learn a value for how good it is to take a given action within a given state. We start by initializing the table to be all zeros, and then as we observe the rewards we obtain by taking various actions, we update the table accordingly.

When updating the Q-table, Bellman equation is used. Bellman equations concept is that the expected long-term reward for a given action in a given state is equal to the immediate reward gained from the current action plus the expected reward from the best future action taken at the following state. Q-table is used to estimate the long-term reward. As shown below, Q-value for a given state(s) and action(a) should equal to the current reward(r) plus the maximum discounted(γ) future reward expected according to Q-table for the next state(s) we would end up in.

$$Q(s, a) = r + \gamma(\max(Q(s, a))$$

In Q-learning, for every training process, we first check whether the state already exists in the q-learning table, if it exists, we choose the action with the largest Q-value. If it doesnt exist, we build a new empty line of this state and random choose action. Then we update the value in the q-learning table by Q-TABLE learning formula .

As we use q-learning model, we need to discretize the states and actions. For actions, we discretize it by choosing actions as the weight of stock A of the total portfolio value and only keep one decimal. So we define the action vector as $(0, 0.1, 0.2, , 0.9, 1)$. For the states, we tried two models. We first use the pair of stocks close price, but it is not general enough to be used as states in q-learning model. Then we generalize

the states by using the pair of stocks close price change, and only keep two decimals. After that, we generalize our states by using another method. We using the slopes of the linear regression functions of the stocks each fixed period(3 days, 10 days).

For the reward function, at the first we simply used portfolio value change as a reward. However, as for portfolio management, we should not only consider the profit, but the risk. Thus we use sharpe ratio as the models reward function. Sharpe ratio formula

2.1.1 Q-learning Algorithm

Initialising $Q(s, a)$ arbitrarily
Repeat (for each episode):
Initialise s
Repeat (for each step of a episode):
Choose a from s using policy derived from Q (e.g. ϵ greedy)
Take action a, observe r, s

$$Q(s,a) \leftarrow Q(s,a) + \alpha(r + \gamma \max_{a'} Q(s',a') - Q(s,a)) \tag{2.1}$$

$$s \leftarrow s' \tag{2.2}$$

Equation (2.1) and (2.2) are the update equations.

2.2 Deep Q Network (DQN)

Deep Q Network uses the techniques from deep learning to approximates Q-score, since in Q-Learning both state and action state need to be discrete and calculating and optimizing Q-score is both time and memory consuming. The key is that we apply the deep neural network to approximate the Q-function. We know that neural network is used to find out the right weights by the back propagation process so it can be used to map all state-action pairs to rewards. One standard example for neural network is using the convolutional neural network (CNN).

Due to the problem of correlation between states and non-stationary targets, when we train the neural network, we store transition in memory M, and randomly sample mini-batch from M and replay to solve the problem. Plus, we separate the target network and copy the network regularly to solve non-stationary targets problem.

Initialise replay memory D to capacity N
Initialise action-value function Q with random weights θ
Initialise target action-value function $\hat{Q}$ with weights $\theta^- = \theta$
For episode =1, M do
  Initialise sequence $s_1 = \{x_1\}$ and preprocessed sequence $\phi_1 = \phi(s_1)$
  For $t = 1,T$ do
    With probability ϵ select a random action a_t
    otherwise select $a_t = argmax_a Q(\phi(s_t), a\ \theta)$
    Execute action a_t in emulator and observe reward r_t and image x_{t+1}
    Set $s_{t+1} = s_t, a_t, x_{t+1}$ and preprocess $\phi_{t+1} = \phi(s_{t+1})$
    Store transition $(\phi_t, a_t, r_t, \phi_{t+1})$ in D
    Sample random minibath of transitions $(\phi_j, a_j, r_j, \phi_{j+1})$ from D

$$Set\ y_j = \begin{cases} r_j, & \text{if episode terminates at step j+1} \\ r_j + \gamma max_{a'} \hat{Q}(\phi_{j+1}, a'; \theta^-)) & \text{otherwise} \end{cases}$$

    Perform a gradient descent step on $(y_j - Q(\phi_j, a_j; \theta))^2$ with respect to network parameter θ
    Every C steps reset $\hat{Q} = Q$
  End For
End for

Chapter 3

Data Description

The algorithms will be tested on stock market data or cryptocurrency data. For stock data, we will collect stock history of each days open price and close price by using Python library Pandas.DataReader. The stock history that we will use for training algorithm is from 2006.6.29 to 2018.6.29 which includes the financial crisis to train the model on non-occasional circumstances.

Stocks are chosen among S & P 500, considering the beta index, duration, and whether they contain some meaningful abrupt price change history. Samples we have chosen are from the top 10 stocks with the highest weight in S & P 500s high-beta index fund .

Constituent	Symbol	Sector
Align Technology Inc	BALGN	Health Care
Micron Technology Inc	MU	Semiconductor
Nvidia Corp	NVDA	Semiconductor
Lam Research Corp	LRCX	Semiconductor
Advanced Micro Devices	AMD	Semiconductor
NetFlix Inc	NFLX	Consumer Discretionary
Applied Materials Inc	AMAT	Semiconductor
KLA-Tencor Corporation	KLAC	Semiconductor / Material
Freeport-McMoRan Inc	FCX	Mining and Metal
Incyte Corp	INCY	Health Care / Pharmaceutical

Table 3.1: Stock Data we used

We chose one stock from 10 high-beta stocks shown above, and another from low-beta stocks to make up our portfolio. In later steps, we choose K number of stocks considering the sectors, plus other foreign companies such as Lotte from South Korea to make the impact of exchange rate into consideration.

Chapter 4

Mathematical Description of the Project

For an automated trading robot with reinforcement learning, investment decisions and actions are made periodically. We allocate fixed amount of budget into two stocks, aiming to maximize return while controlling the volatility and considering the transaction cost. These are the mathematical setting of the portfolio management problem.

4.1 Mathematical Formalism

We define $p_1, p_2, p_3, ..., p_t, ...$ as the close price of an stock sequences of each day released from the exchange center. Then for another stock, its close price sequence is $q_1, q_2, q_3, ..., q_t, ...$ Let price vector to be (p_t, q_t). We use price price change vector $(\frac{p_t - p_{t-1}}{p_{t-1}}, \frac{q_t - q_t - 1}{q_{t-1}})$ to define the state later. pv_t is the portfolio value at time period t, which is calculated based on the market value of two stocks and two stocks' weight. We define a_t as weight of stock1 at the time period t in the portfolio value. It is calculated as the proportion of stock1's market value in the total portfolio value.We define the initial portfolio as $ 10,000 which is called budget from now on.

For n days close price $p_1, p_2, p_3, ..., p_n$, if a line is $F(x)$, the error $\epsilon = (F(i) - p_i)^2, i = 1, 2, 3, ..., n$. We can find a line $f(x) = a_n x + b_n$ that minimize the sum of error $min \sum_{i=1}^{n} (f(i) - p_i)^2$, then the line $f(x)$ is the simple linear regression function of these n days close price. And for another stock, the simple linear regression function is $g(x) = k_n x + h_n$

4.2 Transaction Cost

In a real world, buying or selling stocks is not free. The cost includes commission fee, tax, etc. Assuming a transaction cost proportional to the stock market values exchanged in the market, we set the rate to be 0.2%. We used the preceding study by Angelos to determine the rate. Since we assumed the stock share to be float type,

we used formula below to calculate transaction cost.

$$\frac{T}{2} = |\frac{pv_t}{p_t}a_{t-1} - \frac{pv_{t+1} - T}{p_t + 1}a_t| * p_t * rate$$

4.3 Benchmark

The models test data performance was compared against two benchmarks. We used the preceding study by Oliver and Hamza to determine the benchmarks. The first, the do-nothing benchmark, allocates half of its starting budget to each stock half-half and then does nothing. This benchmark acted as a very crude approximation of the market since it represents the raw performance of the two stocks.

The second, the rebalance benchmark, re-evaluates its holdings at the end of every market days, and buys or sells stock to ensure the total portfolio value is split into 50-50 between the two stocks. It is important to note that it maintains a proportion of stock values, not stock shares.

4.4 Dataset and Features

We trained our Q-table and neural network using historical stock data gathered from Yahoo finance using the Python library Pandas.DataReader to automatically download the stock histories.

Stock riskiness is quantified by beta index. Beta bigger than 1 indicates that a stock is more volatile than the market, while less volatile stock has a beta smaller than 1. We chose ten stocks from S & P 500s high-beta index fund, and five low-beta stocks from 2000/05/01 to 2001/05/01. Then we random choose two high-beta stock from those ten, and one low-beta stock from those five to make up two stock pairs for test. For the other thirty two possible combination made up by the remained stocks, we randomly chose ten pairs to train our model.

For testing, we also chose two stocks combination based on beta index. We tested on two combinations in order to reduce the impact of the unique behavior of the data. We used AMAT(1.29) and CAJ(0.78), and FCX(2.53) and CAJ(0.78) as test sets.

4.5 Assumption

While building model for portfolio management, we took some assumptions. First, we buy and sell the stock at the close price. Second, our behavior of buying and selling does not affect the stock market. Third, we can discretize the stock price and the stock unit to be bought and sell can be non-integer. Lastly, transaction rate occurred by buying and selling are same, and proportional to the exchanged market value.

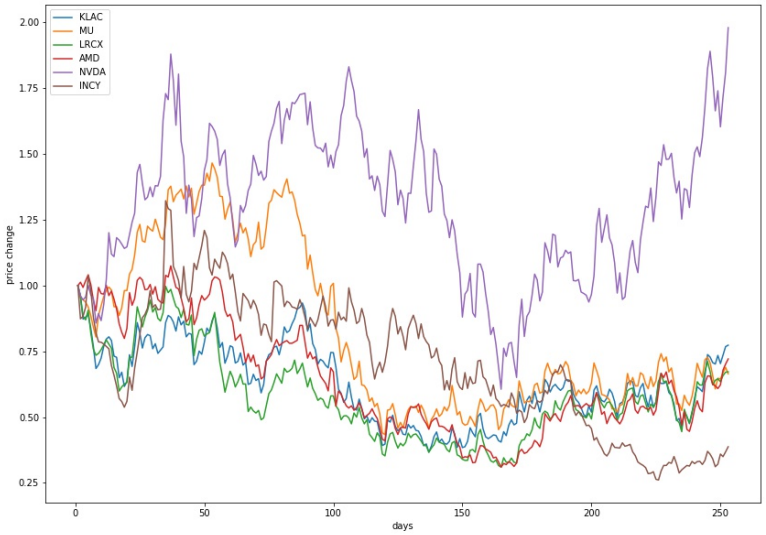


Figure 4.1: High Beta Stock

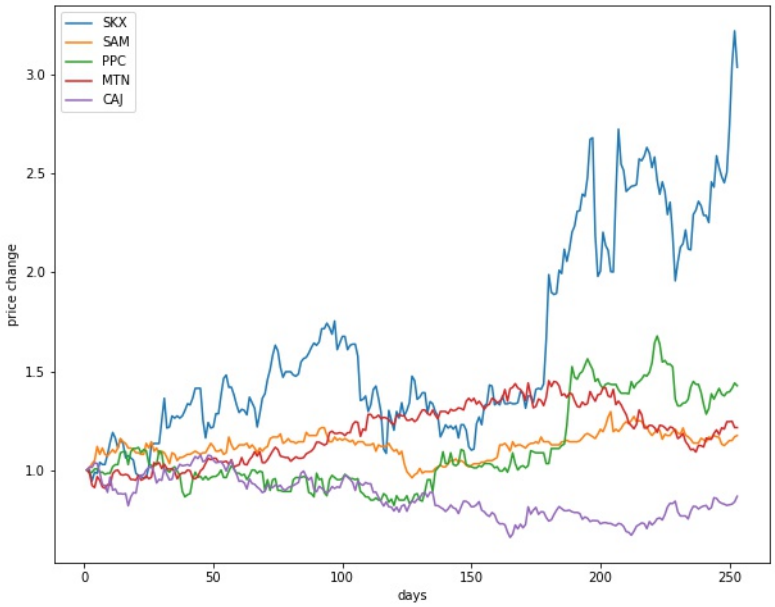


Figure 4.2: Low Beta Stock

Chapter 5

Results and Discussion

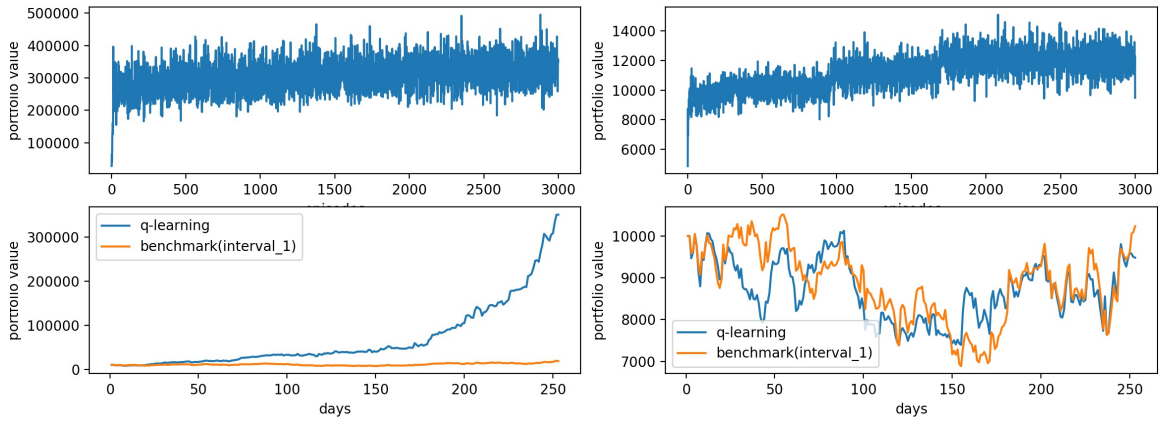
5.1 Q-Learning

5.1.1 Basic Model

To build basic model, we used portfolio value change as a reward function, which means the agent will choose the action that will increase the expected portfolio value the most. We used two decimal of price change pair as a state.

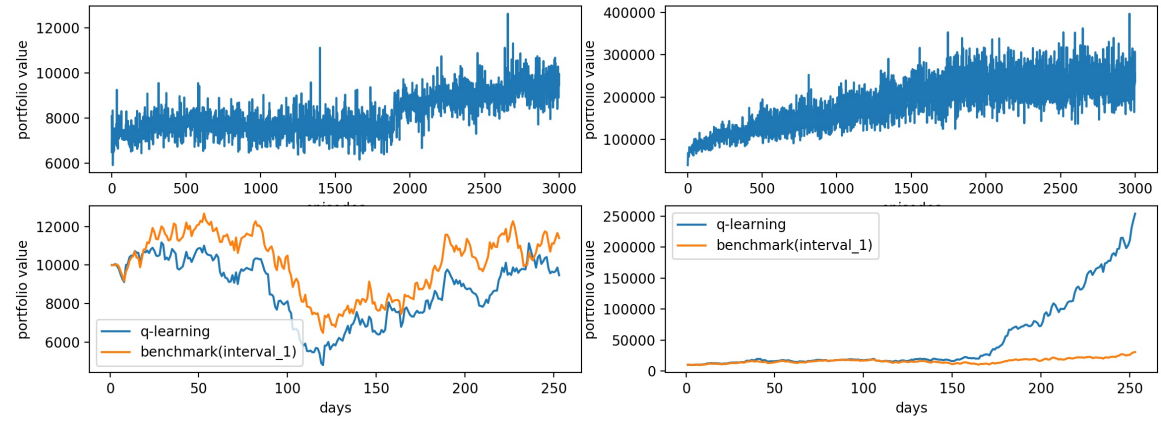
We adjusted the parameters to give better performance. The learning rate(α), which decides the impact of new data on the existing Q-table, was set as 0.0001 based on experiment. The discount factor(γ), which discounts the sum of future reward was set as 0.9. The epsilon(ϵ) was set as 0.9 and for every time period it is decreased 1% until it reaches 0.01. It is in order to let the actions be chosen more randomly for exploration in the earlier times, since Q-table doesnt contain much information. However later times actions are more likely to be chosen based on Q-table with smaller epsilon value. With those parameters, we trained the Q-table for each dataset 3000 episodes each.

As we trained on 10 training datasets, the performances of the basic model on each dataset didnt have distinct patterns. Usually, the portfolio gains by the model were way better(3 4 times final portfolio value) than benchmark, but training results from 4th, 7th, 8th, 9th training set were similar or even below the benchmark gains. Each plot below has two subplots. The upper plot shows how the final portfolio value changes over every episode, and using the last episodes data we drew bottom plot which shows the portfolio value change over days. Compared to those of training 1 with KLAC and SKX data and training 10 with NVDA and SKX data, the results of training 4 and training 9 are not good. We didnt find any clear reason behind this. The dimension of Q-table is steadily increased with more training as shown in below plot.



(a) Training 1 (KLAC & SKX)

(b) Training 4 (AMD & MTN)



(c) Training 9 (MU & PPC)

(d) Training 10 (NVDA & SKX)

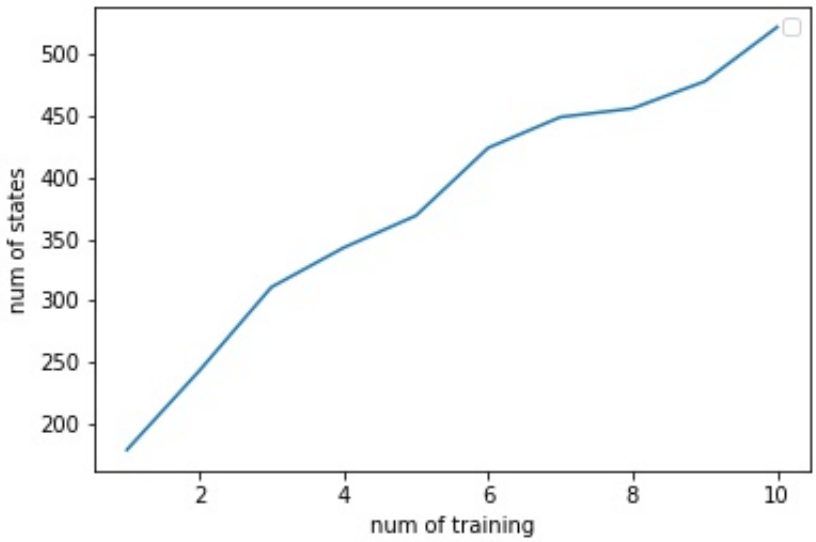


Figure 5.2: Dimension change over training

Using the Q-table we trained, we tested on two test datasets(AMAT & CAJ, FCX & CAJ). Test results using FCX & CAJ dataset usually showed better results. However more training didnt guarantee better test results. For AMAT & CAJ, the best test result was using the Q-table trained with 1 dataset, and further training tables made the test results portfolio value be decreased. On the other hand, for FCX & CAJ, the best test result was with 8 times training Q-table, and before and after that the final portfolio value is below benchmarks. To check the reason why test results keep changing, we analyzed the actions taken in each result. Even the actions taken in the test using 9 times training, and using 10 times training differed a lot. The last plot which has 3 subplots is drawn using the FCX & CAJ data. The first subplot is comparing the actions taken with 5 and 8 times training, while the second is comparing 8 times and 10 times, and the last is comparing 10 times and 9 times.

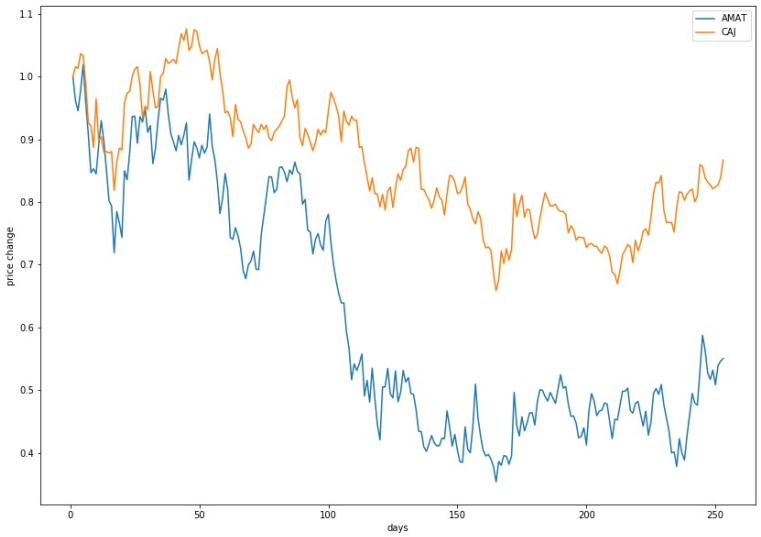
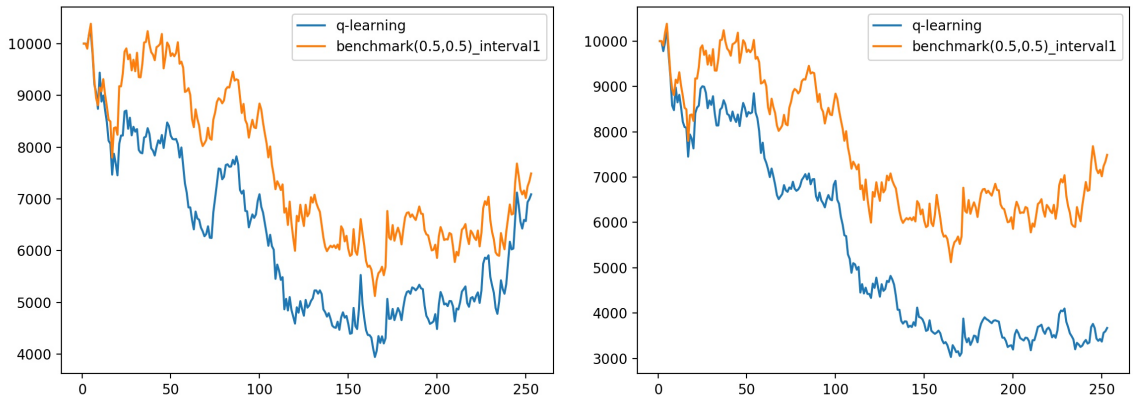


Figure 5.3: TEST SET1 (AMAT & CAJ) :PRICE CHANGE



(a) TEST SET1 (AMAT & CAJ):1 training (b) TEST SET1 (AMAT & CAJ):3 training

5.1.2 Linear Regression

5.2 Deep Q-Network

Q-learning has some obvious problems in our problem setting. Firstly, to implement Q-learning we have to discretize the state, which is the stock price. However, if we discretize the stock price, the result we get will be inaccurate, which implies that the profit we get may not be optimized. Thus, it is necessary to find an alternative way that can handle the continuous state situation.

Secondly, the action state can also be continuous . It is impossible to find all the Q-value corresponding to each actions for a state. Computer should be able to find action that fits our goal the most even when it runs into entirely new situation, but if Q-table values that computer finds are not enough computer will choose the action randomly. Thus, it is necessary to find another way that helps the computer find the right action without having to find out every single Q-table value directly.

To solve these two big problems, Deep Q Network is an appropriate method to solve them.

In our Deep Q Network algorithm, computer chooses action randomly with predetermined probability, which is called epsilon exploration. It is mainly used in stochastic process like this situation where stock price changes randomly, because if without this epsilon exploration after one certain state happens computer choose the action depending on this specific state solely even though there are high probabilities the other states can happen as well. When neural networks are trained, we use mini-batch which picks items randomly in the memories which consists of plenty of pairs of state, action, reward, and next-state. In Q-learning, Q-table is updated with time and it is affected by time correlation. Unlike Q-learning, in Deep Q Network this algorithm called Experience Replay is used to avoid correlation between each memory, especially with this kind of situation where time is related with, and it makes results better.

In this project, fully connected layers, whose inputs are vectors, are used instead of convolutional neural networks, whose inputs are matrixes, because states in this

project are price changes, which can be expressed more easily as vectors than matrixes.

Relu and linear function are used as an activation function, Mean Squared Error function as a loss function, and Adam function as an optimizer. In terms of hyperparameters, we chose figures similar to those that are mainly used.

5.2.1 Including Exchange Ratio

In the later state of the project, we try to include the exchange ratio into our consideration. The application is that you can include two different countries' stock into the portfolio and settle at the end of the date with one of the stocks' currency in the portfolio. Since sometime due to the difference of public holiday and time-zone in different countries, we may face the situation that one country's stock market is working while the other one is not. When we face such situation, we will just skip that date in our training model.

The way we calculate the portfolio value is as follows

$$pv_t = pv_{t-1} * [(p_t/p_{t-1}) * w_1 + (q_t/q_{t-1}) * w_2 * cv_t/cv_{t-1})]$$

the portfolio value will be in the currency you have chosen.

Chapter 6

Conclusion

Chapter 7

Some extra advice for starting up with LaTeX

The following is a small collection of answers to questions RIPS students have asked.

1. **How do I open and modify LaTeX files, as well as view the results?**

   Several LaTeX typesetters are available on the IPAM network. The default options are activated by clicking on the main page for the report template,

   `z-Report-Master-2015.tex`

   The present version of the template is being maintained using the TeXworks typesetter "pdfLaTeX." For more information about other options, see the README file listed among the files used in construction this report.

   The template is divided into several chapters, appendixes and other files with functions identifiable by their names coded in LaTeX (files ending in ".tex") along with some graphics files coded as Encapsulate Postscript (".eps"). If you modify any one of these source files, you will need to run the typesetter on the main `z-Report-Master-2015.tex` file. See Chapter **??** for tips handling bibliographic references. And see Appendix B for location of the LaTeX sources relating to this sample report.

2. **Should I use a single-sided or double-sided format for my report?**

   Clearly, double-sided printing saves paper. But this is not as simple as it seems. Best to explain this in vocabulary used by publishers: *opening*, *recto*, and *verso*: An *opening* is the pair of pages you see when you open a book at random; the recto is the page on the right-hand side, and the verso is the page on the left-hand side — or, on a single leaf, recto is the front side and verso is the opposite side. When you open almost any book at the start of a new chapter, the first page of the chapter will appear on the right-hand page—*recto*. This is true whether or not the left-hand page of the opening—*verso*—is blank. That's the way it should be in your report. Each major section of your report, not just chapters, should begin on a recto.

Rectos are always odd-numbered. Very likely, you will not get these results if you submit your single-sided report for double-sided copying on a printer. There are some LaTeX acrobatics you must specify to make your double-sided report turn out with proper recto-verso pagination, the code for which is built into `z-Report-Master-2014.tex`; you will see which document class to use—and which to comment out—at the top of the file.

3. **What format should I use for my report for the editing process, and for the final copies?**

   See Chapter 8.

4. **How do I convert images (for example, in JPG, GIF, BMP, or PNG formats) to EPS?**

   There is a simple procedure using a "Terminal" on an iMac: just invoke the "`convert`" command and specify the source and target file and coding. Other methods can be complicated.

   Another possibility is to read them in MATLAB and export them to EPS from there. Here's a sample code:

```
A=imread('MyFigure.jpg');            % read the image
imshow(A);                           % show it on the screen
saveas(gcf, 'MyFigure.eps', 'psc2'); % export to color eps
```

   Note that this can create large EPS files. Simple diagrams are better recreated in INKSCAPE or MATLAB and then exported to EPS.

5. **What if a figure caption is too long to fit nicely in the list of figures?**

   Chapter 3 discusses figures in general; there you can see an example of how a figure caption is created. Ordinarily, the figure caption provides the text for the title for the figure in the report's List of Figures.

   But what if the figure caption is too long or otherwise inappropriate for using in the List of Figures? The solution is to include an alternative title in square brackets (before the curly brackets—braces) in the caption declaration:

```
\caption[Alternative title for List of Figures]{The caption
that appears under your figure; it can be more complex than
is appropriate for a title in the List of Figures.}
```

   The same technique is used for providing alternative titles for tables—and for running heads as well, although these are not used in your RIPS report.

6. **A useful little thing to know about fractions:** When you compose an inline fraction, sometimes it looks too small: $\frac{x}{y}$. Instead of using the LaTeX "`frac`" function, try "`dfrac`" to increase the size: $\dfrac{x}{y}$.

7. **Where can I find more information on LaTeX?**

   The internet is a great resource. Search and ye shall find! See, for example,

   `http://latex-project.org/`

   Or you may want to get one of the books listed in the Bibliography, for example, *More Math Into LaTeX* [**?**], or the *LaTeXCompanion* [**?**]. Your mentor most likely knows a lot of LaTeX too, so don't hesitate to ask for help.

8. **Where can I find standard references to resolve finer points of style?**

   There are many good references, but the RIPS director uses the 16^{th} edition of *The Chicago Manual of Style* [**?**] and its companion *A Manual for Writers of Research Papers, Theses, and Dissertations: Chicago Style for Students and Researchers* [**?**] as references of first resort, followed by the handy compact reference *Hart's New Rules* [**?**]. Other highly developed style guides are the *MLA Handbook for Writers of Research Papers* [**?**] and the *Publication Manual of the American Psychological Association* [**?**].

   The examples in Grätzer's *More Math into LaTeX* [**?**] can also be used to resolve some style questions as well as questions about LaTeX coding. See the bibliography pages for other good resources.

9. **How should I punctuate itemized and enumerated lists?**

   Here's a rule that gets broken easily because the items in a list are sometimes not just a single phrase or sentence. Usually you will introduce your list with a sentence or phrase that ends with a colon. In that case:

   - begin each item with a lower-case initial letter;
   - terminate all but the last sentence with a semicolon or a phrase with a comma;
   - end the last sentence or phrase with a period.

   Here's an example that shows how any rule starts to get tricky:

   - begin each item with a lower-case initial letter;
   - terminate the last sentence with a semicolon or a phrase with a comma,
   - but end the last sentence or phrase with a period.

   I think the comma at the end of the second item is correct, but you may be tempted to place a semicolon there to be consistent. And in case you have more than one sentence, or a mixture of a sentence and a phrase on a single line, What then? I'd prefer to avoid the latter complication if possible by make each item a simple sentence or phrase, and use only sentences or only phrases in a single list.

10. **Are there standard fonts for representing filenames, file extensions, URLs?**

    In this document we have used `teletype` for filenames and SMALL CAPS for file extensions, program names, and the names of software packages. For URLs, we use `teletype`.

11. **How do I write the `tilde` symbol?**

    Just hitting the tilde key on the keyboard won't work, as that character is special to LaTeX. Instead, use the `\sim` command, which gives $\sim$. The reason the plain keyboard tilde character is special is that it is used for a non-breaking space, e.g., by writing

    ```
    Dr.~Jones
    ```

    instead of simply

    ```
    Dr. Jones
    ```

    This is how to tell LaTeX never to break a line after `'Dr.'` with `'Jones'` starting at the beginning of the next line.

12. **LaTeX and BibTeX reserved characters**

    These characters are interpreted in special ways by LaTeX typesetters:

    $$\# \ \$ \ \% \ \hat{} \ \& \ \_ \ \{ \ \} \ \tilde{} \ \backslash$$

    You may print them in your text by "escaping" them with the backslash (\), e.g., use \# in your LaTeX code. If not properly escaped, these characters can cause mysterious errors, especially in BibTeX files because the source of the error can be inadequately-referenced by LaTeX.

13. **Why do BibTeX `bib` files so often fail to compile?**

    If you have not used BibTeX before, you may find it a bit difficult getting used to it. It's not a part of LaTeX, so it requires some special handling. Most LaTeX users find it to be worth the effort, since it allows them to keep their references in a separate file (or files) that can easily be re-used. BibTeX makes it easy to reference items and to present them in a consistent format.

    No doubt about it, BibTeX does have some fussy features. For example, your reference list will crash if it contains reserved characters, e.g., in URLs. The point of confusion is that some characters reserved by BibTeX are not reserved elsewhere or the normal methods of escape don't work, so these characters can be pesky and catch you unawares. Here are some character encodings that are useful as alternatives in your bib file:

    - use {`\&`} for *ampersand*;
    - use {`\_`} for *underbar*;
    - use {`\sim`} for *tilde*.

The curly brackets are not strictly necessary, but they are used to avoid needing a space before a character that follows the symbol.

Which bibliographic style should I use?

There are many options. For example, the *siam* and *ieeetr* styles produce good results for RIPS reports.

Your bibliography should distinguish book titles by printing them in *italic* font. But titles of written materials that appear within a collection such as journal articles are distinguished by surrounding them with double quote and are preferably printed in *roman* font, and preferably the title of the *collection* is italicized.

Both the "siam" and "ieeetr" italicize book titles. However they treat article and collection titles, and multiple entries by the same author, differently.

The advantage of the "siam" style is that it aggregates books or articles by the same author in reverse-chronological order under a single author entry. A disadvantage is that it also italicizes article titles and does not quote them, and it prints collection titles in roman font. The quotation problem is easily solved by your supplying them in your `bib` file by surrounding the title with two back quotes on the left and two apostrophes on the right, but you cannot switch the italic and roman fonts, which is unfortunate but acceptable.

An article is cited here as an example using the "siam" bibiliographic style: "A Set of Postulates for Plane Geometry (Based on Scale and Protractors)" by G. D. Birkhoff [**?**]. Take a look at the `bib` file to see how it was necessary to surround the title of the article with quotes; moreover, curly braces were used to prevent BibTeX from reducingl the capital letters in the title to lowercase.

The "ieeetr" style differentiates book and article titles, and titles for articles in collections, correctly. However, if there are multiple books or articles by an author, "ieeetr" awkwardly tosses additonal entries to the end.

Check the available options to make sure you can get a good result.

14. **Where do inline citations go within the "body text"?**

The *body text* or *running text* is the main text in a book or report; it excludes chapter and section heads, front matter, back matter and sometimes, depending on context, footnotes and captions. Generally, it's what the author wrote and not the text supplied by the publisher. For the purpose here, I include footnotes and captions.

The Chicago Manual of Style [**?**] is silent on where to place inline citations, whether within a sentence or after the period, but Turabian gives examples of citations within sentences and none after the period [**?**]. According to *The Chicago Manual of Style* you can do something like this for a block quotation — note that there are no quotation marks, and authorship (or citation) is dropped in parentheses below the quotation:

> O for a Muse of fire, that would ascend
> The brightest heaven of invention,

A kingdom for a stage, princes to act
And monarchs to behold the swelling scene!
(Prologue to "Henry V" by William Shakespeare)

15. **How do I control the page placement of figures and tables?**

The placement algorithms in LaTeX are complicated. The GRAPHICX package used by the RIPS Master Template is discussed in extensive detail in the athoritative "Using Imported Graphics in LATEX and pdfLATEX" by Keith Reckdahl at

`http://ctan.math.washington.edu/tex-archive/info/epslatex/english/epslatex.pdf`

For a start, see Sections 18 and 19: "Customizing Float Placement" and "Customizing the Figure Environment." Note especially Section 21, "Non-Floating Figures:"

> Since non-floating figures can produce large sections of vertical whitespace, non- floating figures are generally considered poor typesetting style. Instead, users are strongly encouraged to use the figure environments `[!ht]` optional argument which moves the figure only if there is not enough room for it on the current page.

See the internet for other solutions, e.g., for fixing gross placement errors using commands like: `\raggedbottom, \baselinestretch, \parskip`.

16. **How long should my report be?**

Depending on how formal you choose to make your midterm report, it can evolve into the final report, so the latter will usually be longer than the midterm report but not necessarily. The dissertation of at least one Nobel Laureate was under thirty pages in length, so it is possible to report winning results succinctly. Here's a rule of thumb:

Just decide what points you want to make, and then make all your points in clear language, using figures and tables wherever they facilitate understanding. It's hard to be succinct when you don't have a lot of time to prune your text. But try to be as brief as possible without injuring clarity.

After you have done that, check to see whether your report has all the major ingredients described in this Sample Report, especially in Chapters 1 & 2. Considered as a draft on its way to becoming the final report, the midterm report may be written a little more loosely and contain things that you may decide to prune later.

If everything is there, including the extra pages created by LaTex, such as table of contents, list of figures, list of tables, as necessitated by your text, then that's how long your report should be.

Chapter 8

Final comments about polishing your report for publication

Writing a good report is a serious challenge, requiring time and attention to details that are easily and often greatly underestimated by inexperienced writers. So how does a good report acquire its final polish?

Your academic mentor will help guide your writing throughout your project. He or she will be the first to review your report draft and edit it not only for style but also for technical correctness. After you have satisfied your academic mentor with your draft, you will submit it to the RIPS program director for *copy editing*, who will attend to matters of readability, grammar, and style. After you submit your drafts for their review, it is likely they will return it to you with corrections, crossed out text, and possibly even suggestions for overhauling whole parts of it. That is normal editing practice, and it is an expected part of the process of writing a professional-quality document.

Since your report is sponsored work, your sponsoring liaison should be given an opportunity to review it before its release. But here's an important caution: Don't submit a draft to your sponsor until *after* it has been revised in compliance with suggestions from your academic mentor and the RIPS director. It's good practice to give sponsors your most professional efforts—not your first drafts. After you have satisfied the editing requirements of your academic mentor and the RIPS director, you should send your sponsor a `pdf` of a copy by email for review. Your sponsor may suggest further changes.

You will facilitate the process of editing your report by submitting a single-sided printed copy for editing. Double-sided is too hard to work with. Although it is typical for copy editing to use double spacing of a manuscript to allow for editorial comments between lines, it is unnecessary for a RIPS report. A table of *proofreader's marks* used by copy editors for mark-up, and used sometimes here at IPAM, is referenced in Appendix B.

After you have completed all the edits required by your academic mentor and the RIPS director, you can prepare final copies in two formats, respectively: (1) a single-sided `pdf` as an electronic copy, which you can email to your sponsor, and (2) a slim double-sided copy for the final print version — you can print this in the fatter

single-sided format if your figures or text bleed through to the flip side of the page. See Chapter 7 for a discussion of the special pagination requirements for double-sided copying.

Note that when you use ADOBE READER for printing your `pdf`, you are presented with options for *page scaling*. You may have to play with this to get the margins right.

Appendix A

BibTeX Sample Records, Record Types and Fields

```
@BOOK{gM68,
   author = "George A. Menuhin",
   title = "Universal Algebra",
   publisher = "D.~van Nostrand",
   address = "Princeton",
   year = 1968,
}

@BOOK{fR82,
   author = "Ferenc R. Richardson",
   title = "General Lattice Theory",
   edition = "Expanded and Revised",
   language = "Russian",
   publisher = "Mir",
   address = "Moscow",
   year = 1982,
}

@ARTICLE{eM57,
   author = "Ernest T. Moynahan",
   title = "On a Problem of {M. Stone}",
   journal = "Acta Math. Acad. Sci. Hungar.",
   pages = "455--460",
   volume = 8,
   year = 1957,
}

@ARTICLE{eM57a,
   author = "Ernest T. Moynahan",
   title = "Ideals and Congruence Relations in
      Lattices.~\textup{II}",
   journal = "Magyar Tud. Akad. Mat. Fiz. Oszt. K{\"{o}}zl.",
   language = "Hungarian",
   pages = "417--434",
   volume = 7,
   year = 1957,
}

@PHDTHESIS{sF90,
   author = "Soo-Key Foo",
   title = "Lattice Constructions",
   school = "University of Winnebago",
   address = "Winnebago, MN",
   year = 1990,
   month = dec,
}
```

Figure A.1: Examples of BibTeX records for a `.bib` file (*The LaTeX Companion*, 2^{nd} ed, 2004, 384–385)

article	An article from a journal or magazine. *Required*: author, title, journal, year. *Optional*: volume, number, pages, month, note.
book	A book with an explicit publisher. *Required*: author or editor, title, publisher, year. *Optional*: volume or number, series, address, edition, month, note.
booklet	A work that is printed and bound, but without a named publisher or sponsoring institution. *Required*: title. *Optional*: author, howpublished, address, month, year, note.
inbook	A part of a book, e.g., a chapter, section, or whatever and/or a range of pages. *Required*: author or editor, title, chapter and/or pages, publisher, year. *Optional*: volume or number, series, type, address, edition, month, note.
incollection	A part of a book having its own title. *Required*: author, title, booktitle, publisher, year. *Optional*: editor, volume or number, series, type, chapter, pages, address, edition, month, note.
inproceedings	An article in a conference proceedings. *Required*: author, title, booktitle, year. *Optional*: editor, volume or number, series, pages, address, month, organization, publisher, note.
manual	Technical documentation. *Required*: title. *Optional*: author, organization, address, edition, month, year, note.
mastersthesis	A master's thesis. *Required*: author, title, school, year. *Optional*: type, address, month, note.
misc	Use this type when nothing else fits. A warning will be issued if all optional fields are empty (i.e., the entire entry is empty or has only ignored fields). *Required*: none. *Optional*: author, title, howpublished, month, year, note.
phdthesis	A Ph.D. thesis. *Required*: author, title, school, year. *Optional*: type, address, month, note.
proceedings	Conference proceedings. *Required*: title, year. *Optional*: editor, volume or number, series, address, publisher, note, month, organization.
techreport	A report published by a school or other institution, usually numbered within a series. *Required*: author, title, institution, year. *Optional*: type, number, address, month, note.
unpublished	A document having an author and title, but not formally published. *Required*: author, title, note. *Optional*: month, year.

Table 13.1: BibTeX's entry types as defined in most styles

Figure A.2: BibTeX entry types, entered on the first line of a BibTeX record (*The LaTeX Companion*, 2^{nd} ed, 2004, 375)

address	Usually the address of the publisher or other institution. For major publishing houses, just give the city. For small publishers, specifying the complete address might help the reader.
annote	An annotation. Not used by the standard bibliography styles, but used by others that produce an annotated bibliography (e.g., annote). The field starts a new sentence and hence the first word should be capitalized.
author	The name(s) of the author(s), in BibTeX name format (Section 13.2.2).
booktitle	Title of a book, part of which is being cited (Section 13.2.2). For book entries use the title field.
chapter	A chapter (or section or whatever) number.
crossref	The database key of the entry being cross-referenced (Section 13.2.5).
edition	The edition of a book (e.g., "Second"). This should be an ordinal, and should have the first letter capitalized, as shown above; the standard styles convert to lowercase when necessary.
editor	Name(s) of editor(s), in BibTeX name format. If there is also an author field, then the editor field gives the editor of the book or collection in which the reference appears.
howpublished	How something strange has been published.
institution	Institution sponsoring a technical report.
journal	Journal name. Abbreviations are provided for many journals (Section 13.2.3).
key	Used for alphabetizing and creating a label when the author and editor information is missing. This field should not be confused with the key that appears in the \cite command and at the beginning of the database entry.
month	The month in which the work was published or, for an unpublished work, in which it was written. For reasons of consistency the standard three-letter abbreviations (jan, feb, mar, etc.) should be used (Section 13.2.3).
note	Any additional information that can help the reader.
number	The number of a journal, magazine, technical report, or work in a series. An issue of a journal or magazine is usually identified by its volume and number; a technical report normally has a number; and sometimes books in a named series carry numbers.
organization	The organization that sponsors a conference or that publishes a manual.
pages	One or more page numbers or range of numbers (e.g., 42-111 or 7,41,73-97 or 43+, where the '+' indicates pages that do not form a simple range).
publisher	The publisher's name.
school	The name of the school where the thesis was written.
series	The name of a series or set of books. When citing an entire book, the title field gives its title and an optional series field gives the name of a series or multivolume set in which the book is published.
title	The work's title, typed as explained in Section 13.2.2.
type	The type of a technical report (e.g., "Research Note"). This name is used instead of the default "Technical Report". For the entry type phdthesis you could use the term "Ph.D. dissertation" by specifying: type = "{Ph.D.} dissertation". Similarly, for the inbook and incollection entry types you can get "section 1.2" instead of the default "chapter 1.2" with chapter = "1.2" and type = "Section".
volume	The volume of a journal or multivolume book.
year	The year of publication or, for an unpublished work, the year it was written. Generally, it should consist of four numerals, such as 1984, although the standard styles can handle any year whose last four nonpunctuation characters are numerals, such as "about 1984".

Table 13.2: BibTeX's standard entry fields

Figure A.3: BibTeX fields, the "catalog" fields for a BibTeX record. ("The LaTeX Companion", 2^{nd} ed, 2004)

Appendix B

Where to find this sample RIPS report?

Read-only LaTeX source code for the RIPS Report Template, sample Beamer slide presentations, and other LaTeX supporting materials are available at,

```
Computer ->  IPAM RIPS FOLDER -> on the R Drive under under "Templates-etc"
```

Your report will be "copyedited", i.e., edited for conformance to the RIPS *House Style*. For reference, a table of proofreader's marks that may be used for markup of your draft is included. It was copied from *The Chicago Manual of Style, 16th ed.* (See original source at: `www.chicagomanualofstyle.org/tools_proof.html`.)

Appendix C

Glossary

Page vs Leaf: In bookbinding, a trimmed sheet of paper bound in a book; each side of a leaf is a **page**.

Opening: The two pages you see when you open a book. The right-hand **page** is the **recto**—and the left-hand page is the **verso**.

Recto: The front side of a **leaf**; in a book or journal, a right-hand page. To **start recto** is to begin on a recto page, as any major section—e.g., title page, table of contents, preface, chapter, appendix, bibliography—normally does. Contrast **verso**.

Verso: The back side of a **leaf**; the **page** on the left-hand side of an **opening**.

Front matter: As applied to this report, the material that appears in the front of the document, including title page, the abstract, acknowledgments, table of contents, list of figures, list of tables, usually numbered with lowercase roman numerals. RIPS reports initiate pagination with 1 in the front matter and proceed throughout with arabic numerals. This variation of usage is allowed because modern typesetting permits easy re-pagination after pages have been added to the front matter, something not easily done—after completion of the main matter—when typesetting was done by hand.

Main matter: The main part of the document, including the appendixes. **Page** numbers start from 1 using arabic numerals if front matter is enumerated using roman numerals.

Back matter: Material that appears at the back of the document, which in our report includes only the Bibliography.

Appendix D

Abbreviations

IPAM. Institute for Pure and Applied Mathematics. An institute of the National Science Foundation, located at UCLA.

RIPS. Research in Industrial Projects for Students. A regular summer program at IPAM, in which teams of undergraduate (or fresh graduate) students participate in sponsored team research projects.

UCLA. The University of California at Los Angeles.

Selected Bibliography Including Cited Works

[1] V. Mnih, K. Kavukcuoglu, D. Silver, A. Graves, I. Antonoglou, D. Wierstra, and M. Riedmiller, *Playing Atari with Deep Reinforcement Learning*, ArXiv e-prints, (2013).