Dissertation Type: Research

DEPARTMENT OF COMPUTER SCIENCE

Some Structural Guidelines for CS MEng Dissertations

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A dissertation submitted to the University of Bristol in accordance with the requirements of the degree of Master of Engineering in the Faculty of Engineering.

Wednesday 21st April, 2021

Declaration

This dissertation is submitted to the University of Bristol in accordance with the requirements of the degree of MEng in the Faculty of Engineering. It has not been submitted for any other degree or diploma of any examining body. Except where specifically acknowledged, it is all the work of the Author.

Angus Parsonson, Wednesday 21st April, 2021

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Executive Summary

A compulsory section, of at most 1 **page**

This section should précis the project context, aims and objectives, and main contributions (e.g., deliverables) and achievements; the same section may be called an abstract elsewhere. The goal is to ensure the reader is clear about what the topic is, what you have done within this topic, *and* what your view of the outcome is.

The former aspects should be guided by your specification: essentially this section is a (very) short version of what is typically the first chapter. Note that for research-type projects, this **must** include a clear research hypothesis. This will obviously differ significantly for each project, but an example might be as follows:

> My research hypothesis is that a suitable genetic algorithm will yield more accurate results (when applied to the standard ACME data set) than the algorithm proposed by Jones and Smith, while also executing in less time.

The latter aspects should (ideally) be presented as a concise, factual bullet point list. Again the points will differ for each project, but an might be as follows:

- I spent 120 hours collecting material on and learning about the Java garbage-collection sub-system.
- I wrote a total of 5000 lines of source code, comprising a Linux device driver for a robot (in C) and a GUI (in Java) that is used to control it.
- I designed a new algorithm for computing the non-linear mapping from A-space to B-space using a genetic algorithm, see page 17.
- I implemented a version of the algorithm proposed by Jones and Smith in [6], see page 12, corrected a mistake in it, and compared the results with several alternatives.

Summary of Changes

A conditional section, of at most 1 page

Iff. the dissertation represents a resubmission (e.g., as the result of a resit), this section is compulsory: the content should summarise all non-trivial changes made to the initial submission. Otherwise you can omit it, since a summary of this type is clearly nonsensical.

When included, the section will ideally be used to highlight additional work completed, and address criticism raised in any associated feedback. Clearly it is difficult to give generic advice about how to do so, but an example might be as follows:

- Feedback from the initial submission criticised the design and implementation of my genetic algorithm, stating "there seems to have been no attention to computational complexity during the design, and obvious methods of optimisation are missing within the resulting implementation". Chapter 3 now includes a comprehensive analysis of the algorithm, in terms of both time and space. While I have not altered the algorithm itself, I have included a cache mechanism (also detailed in Chapter 3) that provides a significant improvement in average run-time.
- I added a feature in my implementation to allow automatic rather than manual selection of various parameters; the experimental results in Chapter 4 have been updated to reflect this.
- Questions after the presentation highlighted a range of related work that I had not considered: I have make a number of updates to Chapter 2, resolving this issue.

Supporting Technologies

A compulsory section, of at most 1 page

This section should present a detailed summary, in bullet point form, of any third-party resources (e.g., hardware and software components) used during the project. Use of such resources is always perfectly acceptable: the goal of this section is simply to be clear about how and where they are used, so that a clear assessment of your work can result. The content can focus on the project topic itself (rather, for example, than including "I used LaTeX to prepare my dissertation"); an example is as follows:

- I used the Java `BigInteger` class to support my implementation of RSA.
- I used a parts of the OpenCV computer vision library to capture images from a camera, and for various standard operations (e.g., threshold, edge detection).
- I used an FPGA device supplied by the Department, and altered it to support an open-source UART core obtained from http://opencores.org/.
- The web-interface component of my system was implemented by extending the open-source WordPress software available from http://wordpress.org/.

Notation and Acronyms

An optional section, of roughly 1 or 2 pages

Any well written document will introduce notation and acronyms before their use, *even if* they are standard in some way: this ensures any reader can understand the resulting self-contained content.

Said introduction can exist within the dissertation itself, wherever that is appropriate. For an acronym, this is typically achieved at the first point of use via "Advanced Encryption Standard (AES)" or similar, noting the capitalisation of relevant letters. However, it can be useful to include an additional, dedicated list at the start of the dissertation; the advantage of doing so is that you cannot mistakenly use an acronym before defining it. A limited example is as follows:

AES	:	Advanced Encryption Standard
DES	:	Data Encryption Standard
	⋮	
$\mathcal{H}(x)$	:	the Hamming weight of x
$\mathbb{F}_q$	:	a finite field with q elements
x_i	:	the i-th bit of some binary sequence x, st. $x_i \in \{0, 1\}$

Acknowledgements

An optional section, of at most 1 **page**

It is common practice (although totally optional) to acknowledge any third-party advice, contribution or influence you have found useful during your work. Examples include support from friends or family, the input of your Supervisor and/or Advisor, external organisations or persons who have supplied resources of some kind (e.g., funding, advice or time), and so on.

Chapter 1

Contextual Background

A compulsory chapter, of roughly 5 pages

1.1 Introduction

1.2 Motivation

1.3 High-Frequency Trading

1.4 Previous Work

1.5 Project Approach

This chapter should describe the project context, and motivate each of the proposed aims and objectives. Ideally, it is written at a fairly high-level, and easily understood by a reader who is technically competent but not an expert in the topic itself.

In short, the goal is to answer three questions for the reader. First, what is the project topic, or problem being investigated? Second, why is the topic important, or rather why should the reader care about it? For example, why there is a need for this project (e.g., lack of similar software or deficiency in existing software), who will benefit from the project and in what way (e.g., end-users, or software developers) what work does the project build on and why is the selected approach either important and/or interesting (e.g., fills a gap in literature, applies results from another field to a new problem). Finally, what are the central challenges involved and why are they significant?

The chapter should conclude with a concise bullet point list that summarises the aims and objectives. For example:

> The high-level objective of this project is to reduce the performance gap between hardware and software implementations of modular arithmetic. More specifically, the concrete aims are:
>
> 1. Research and survey literature on public-key cryptography and identify the state of the art in exponentiation algorithms.
> 2. Improve the state of the art algorithm so that it can be used in an effective and flexible way on constrained devices.
> 3. Implement a framework for describing exponentiation algorithms and populate it with suitable examples from the literature on an ARM7 platform.
> 4. Use the framework to perform a study of algorithm performance in terms of time and space, and show the proposed improvements are worthwhile.

Chapter 2

Technical Background

A compulsory chapter, of roughly 10 **pages**

2.1 The Limit Order Book

2.2 Deep Learning

2.2.1 Long-Short-Term-Memory Networks

2.2.2 LSTM ODE Networks

This chapter is intended to describe the technical basis on which execution of the project depends. The goal is to provide a detailed explanation of the specific problem at hand, and existing work that is relevant (e.g., an existing algorithm that you use, alternative solutions proposed, supporting technologies).

Per the same advice in the handbook, note there is a subtly difference from this and a full-blown literature review (or survey). The latter might try to capture and organise (e.g., categorise somehow) *all* related work, potentially offering meta-analysis, whereas here the goal is simple to ensure the dissertation is self-contained. Put another way, after reading this chapter a non-expert reader should have obtained enough background to understand what *you* have done (by reading subsequent sections), then accurately assess your work. You might view an additional goal as giving the reader confidence that you are able to absorb, understand and clearly communicate highly technical material.

Chapter 3

Project Execution

3.1 Data Selection

My initial requirements were for the data to be:

- Cheap/free
- Timestamped (necessary to realise the benefits of the ODE)
- High quality (millisecond level with a large number of ticks per day)
- Multilevel
- Available over a number of trading days
- Real-world

There are several limit order book data solutions available. To choose the right option, it was important to consider the various tradeoffs of each one with respect to my requirements. Table 3.1 illustrates this.

The Bristol Stock Exchange (BSE) (insert reference here) is a minimal simulation of a limit order book financial exchange, thus synthetic data of very high quality can be easily generated. However, given that BSE data is not real - arguably it will not provide the best indication as to whether LSTM-ODEs can be utilised for high-frequency trading.

The Nasdaq benchmark dataset from (insert paper reference here) contains normalised, labelled and high-quality data taken over ten trading days. Ntakaris et al. also provide benchmark prediction accuracies of other techniques with which I could compare my model. However, when I contacted the authors to obtain timestamps, they informed me that Nasdaq had requested these be irretrievable (to prevent full reconstruction of the LOB).

Lobster and TrueFX both provide very high-quality limit order book data, however; their subscription prices are beyond my bankroll. TrueFX offers live market streaming of level 3 data, meaning it would be possible to execute orders. Therefore, TrueFX premium will be a good solution to use my LSTM-ODE in production.

Dukascopy Bank is a Swiss company providing online/mobile trading, banking and financial services. One of the services they provide is the Swiss FX Market (SWFX), which is an electronic communication network trading platform built and operated by them. Dukascopy offer top of book SWFX data to the public. The inclusion of the bid/ask volumes, and the ability to download more than just Forex data led me to choose Dukascopy over TrueFX freemium.

Although the Dukascopy data is only level 1, according to (insert paper here), level 1 data provides the most useful features for machine learning. Therefore I should be able to obtain some degree of accuracy. In addition to this, if my model is able to perform well on level 1 data, it is reasonable to assume it will be able to perform even better with access to the full order book.

3.2 Data Peprocessing

Normalisation, sequencing of data for LSTMs, train/test split.

Dataset	Price	Unit	Period	Timestamped	Ticks per day	Level
Dukascopy	Free	ms	Up to date	Yes	>100,000	1
TrueFX (freemium)	Free	ms	Up to date	Yes	>100,000	1
Nasdaq benchmark	Free	ms	01-14/06/10	No	400,000	2
Lobster	£4.1k pa	ms/ns	Up to date	Yes	>400,000	2
TrueFX (premium)	£5.3k pm	ms	Up to date	Yes	>400,000	3
BSE	Free	ns	Unlimited	Yes	All	2

Table 3.1: This is an example table.

foo

Figure 3.1: This is an example figure.

3.2.1 Labelling

3.2.2 Feature Selection

3.3 Network Architecture

3.4 Training

Talk about Google Colab, BluePebble, lack of optimisation for ODE solvers leading to lack of time.

3.5 Testing

Talk about testing and metrics. If simple trading experiments are done, talk about those.

3.6 Summary

This is an example sub-section; the following content is auto-generated dummy text. Notice the examples in Figure 3.1, Table 3.1, Algorithm 3.1 and Listing 3.1. Lorem ipsum dolor sit amet, consectetuer adipiscing elit. Ut purus elit, vestibulum ut, placerat ac, adipiscing vitae, felis. Curabitur dictum gravida mauris. Nam arcu libero, nonummy eget, consectetuer id, vulputate a, magna. Donec vehicula augue eu neque. Pellentesque habitant morbi tristique senectus et netus et malesuada fames ac turpis egestas. Mauris ut leo. Cras viverra metus rhoncus sem. Nulla et lectus vestibulum urna fringilla ultrices. Phasellus eu tellus sit amet tortor gravida placerat. Integer sapien est, iaculis in, pretium quis, viverra ac, nunc. Praesent eget sem vel leo ultrices bibendum. Aenean faucibus. Morbi dolor nulla, malesuada eu, pulvinar at, mollis ac, nulla. Curabitur auctor semper nulla. Donec varius orci eget risus. Duis nibh mi, congue eu, accumsan eleifend, sagittis quis, diam. Duis eget orci sit amet orci dignissim rutrum.

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for $i = 0$ **upto** n **do**
  $t_i \leftarrow 0$
end

Algorithm 3.1: This is an example algorithm.

```
for( i = 0; i < n; i++ ) {
  t[ i ] = 0;
}
```

Listing 3.1: This is an example listing.

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Example paragraph. This is an example paragraph; note the trailing full-stop in the title, which is intended to ensure it does not run into the text.

Chapter 4

Critical Evaluation

A topic-specific chapter, of roughly 15 **pages**

This chapter is intended to evaluate what you did. The content is highly topic-specific, but for many projects will have flavours of the following:

1. functional testing, including analysis and explanation of failure cases,
2. behavioural testing, often including analysis of any results that draw some form of conclusion wrt. the aims and objectives, and
3. evaluation of options and decisions within the project, and/or a comparison with alternatives.

This chapter often acts to differentiate project quality: even if the work completed is of a high technical quality, critical yet objective evaluation and comparison of the outcomes is crucial. In essence, the reader wants to learn something, so the worst examples amount to simple statements of fact (e.g., "graph X shows the result is Y"); the best examples are analytical and exploratory (e.g., "graph X shows the result is Y, which means Z; this contradicts [1], which may be because I use a different assumption"). As such, both positive *and* negative outcomes are valid *if* presented in a suitable manner.

Chapter 5

Conclusion

A compulsory chapter, of roughly 5 pages

The concluding chapter of a dissertation is often underutilised because it is too often left too close to the deadline: it is important to allocation enough attention. Ideally, the chapter will consist of three parts:

1. (Re)summarise the main contributions and achievements, in essence summing up the content.
2. Clearly state the current project status (e.g., "X is working, Y is not") and evaluate what has been achieved with respect to the initial aims and objectives (e.g., "I completed aim X outlined previously, the evidence for this is within Chapter Y"). There is no problem including aims which were not completed, but it is important to evaluate and/or justify why this is the case.
3. Outline any open problems or future plans. Rather than treat this only as an exercise in what you *could* have done given more time, try to focus on any unexplored options or interesting outcomes (e.g., "my experiment for X gave counter-intuitive results, this could be because Y and would form an interesting area for further study" or "users found feature Z of my software difficult to use, which is obvious in hindsight but not during at design stage; to resolve this, I could clearly apply the technique of Smith [7]").

Bibliography

Appendix A

An Example Appendix

Content which is not central to, but may enhance the dissertation can be included in one or more appendices; examples include, but are not limited to

- lengthy mathematical proofs, numerical or graphical results which are summarised in the main body,
- sample or example calculations, and
- results of user studies or questionnaires.

Note that in line with most research conferences, the marking panel is not obliged to read such appendices.