University of
BRISTOL

DEPARTMENT OF COMPUTER SCIENCE

MARMOSET: Multi Agent Routing for Managing Online Smart-cities for E

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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 13$^{\text{th}}$ April, 2016

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.

Alexander Hill, Wednesday 13$^{\text{th}}$ April, 2016

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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.

Supporting Technologies

A compulsory section, of at most 1 page

This project has two parts - a back end engine written in Java, and a front end visualisation part running in the browser using JavaScript.

Back End

- The Open Source routing engine GraphHopper [4] was used for performing basic routing requests and handling storage and processing of the OpenStreetMaps data.
- NanoHttpd [5] was used for a static file server to provide HTML, CSS and images to the front end.
- Java WebSocket [7] was used for communication between the front and back end.
- OpenStreetMaps [3] is used for the raw mapping data. Specific sections of the maps can be downloaded from Geofabrik.

Front End

- The map interface on the front end uses the JavaScript library Leaflet.js [1] for the map and marker APIs.
- Mapbox is used for the image tiles to display the underlying map.

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
$\vdots$		
$\mathcal{H}(x)$	:	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

When MapQuest first launched in 1996, most drivers found their way to new locations using physical paper maps as well as knowledge gained through experience. With the advent of Google Maps and the proliferation of mobile devices, many drivers are now provided with directions that can incorporate large amounts of additional information - including current traffic conditions and road closures. This is particularly important in cities, where the levels of congestion during 'rush hour' can have a drastic impact on travel time.

Looking forwards, we can see two trends that suggest that congestion will become more of an issue in future. Firstly, more and more people are living in cities - even with good public transportation, this will increase the number of vehicles on the road even if it lowers the proportion of households that own cars. Secondly, on-demand transport solutions (such as those provided by Uber) are leading to more vehicles on the road, especially at peak times. One of Uber's key insights is using market techniques to better match supply and demand than existing taxi and minicab services. If there is an increase in riders requesting vehicles in a certain area, Uber activates ̈surge pricing", increasing the cost of the ride by a fixed multiple - for example, 1.5x. This information is sent to their network of drivers, who will move to the location in search of higher paying riders. The net result of this is that high-demand in certain areas will create further congestion, even though on demand transportation is usually more efficient than personal car ownership.

At the same time, we are beginning to witness the rise of self-driving cars, capable of planning and executing routes themselves with no need for human intervention. This raises many questions about the role of personal transportation and the effect this will have on congestion. Will driving become as dated as horseriding is today - or will people's enjoyment of it mean that there'll always be human driven vehicles on the road? More importantly, will self driving cars improve or harm congestion - and how will they decide what routes they should take?

Answers to these questions are important to many people, including individual drivers, companies owning large fleets of vehicles, and city planners. Although it is not possible to provide definitive answers, simulation provides a technique for evaluating how future transportation will look and the impact it may have.

original description bit

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

2.1 Algorithmic Background

2.1.1 Dijkstra's Algorithm

Dijkstra's Algorithm [2], originally designed in 1956, forms the foundation of most modern routing algorithms.

The algorithm operates on a graph consisting of nodes connected to each other by edges. Each edge has a weight - this could be the length of the road in a real world map. Given two nodes S and D, the goal is to return a list of edges that represents the shortest path between the nodes.

At its core, the algorithm picks the edge with the next shortest distance from the source node and updates the distance value for that node. It repeats this process until it finds the source node connected to an edge, then works backwards to construct the shortest path between the two nodes.

Add more in depth english explanation of how/why it works k?

2.1 shows how the algorithm operates in pseudocode.

A* Algorithm

Contraction Heirarchies

2.1.2 Nagel-Schreckenberg Model

The Nagel-Schreckenberg Model [6] is a cellular automaton model for the flow of traffic on roads.

The model splits roads into discrete cells, with each car taking up a single cell at a time. The vehicles then follow 4 rules, in parallel to simulate the flow of traffic. Each car has a fixed 'velocity' v for that step, which represents the number of cells the vehicle will move forward in the final rule. The model does not allow for overtaking, and as a result exhibits realistic behaviour for traffic jams and flow.

Each cell is meant to approximately represent the size of vehicles

1. **Acceleration** - if the vehicle is not at the max speed and there is enough space ahead, increase the velocity by 1.

2. **Slowing down** - if there is a vehicle nearer than the current velocity, reduce velocity to one cell

Function DIJKSTRA*(G,s,d)*
    $Q \leftarrow$ new Priority Queue
    $dist[S] \leftarrow 0$
    for *vertex* $v \in G$ **do**
        $dist[v] = \infty$
        $prev[v] = undefined$
        $Q.\text{add}(v, dist[v])$
    end
    while $Q \neq \emptyset$ **do**
        $u \leftarrow Q.\text{extract\_min}()$
        if $u = d$ **then**
            Return BuildPath(u)
        end
        for *neighbour v of u* **do**
            $d \leftarrow dist[u] + \text{distance}(u, v)$
            if $d < dist[v]$ **then**
                $dist[v] \leftarrow d$
                $prev[v] \leftarrow u$
                $Q.\text{decrease\_priority}(v, d)$
            end
        end
    end

Algorithm 2.1: Dijkstra's Algorithm

less than the distance to the vehicle in front.

3. **Randomization** - reduce the velocity by 1 with probability p

4. **Car movement** -

2.2 Implementation Background

2.2.1 GraphHopper Routing Engine

Chapter 3

Project Execution

A topic-specific chapter, of roughly 15 pages

3.1   Project Setup and Modularisation

3.2   Initial Client Server setup

3.3   Cell Automata Model

3.3.1   Vehicle and Cell Iterators

3.4   Performance Improvements

This chapter is intended to describe what you did: the goal is to explain the main activity or activities, of any type, which constituted your work during the project. The content is highly topic-specific, but for many projects it will make sense to split the chapter into two sections: one will discuss the design of something (e.g., some hardware or software, or an algorithm, or experiment), including any rationale or decisions made, and the other will discuss how this design was realised via some form of implementation.

This is, of course, far from ideal for *many* project topics. Some situations which clearly require a different approach include:

- In a project where asymptotic analysis of some algorithm is the goal, there is no real "design and implementation" in a traditional sense even though the activity of analysis is clearly within the remit of this chapter.

- In a project where analysis of some results is as major, or a more major goal than the implementation that produced them, it might be sensible to merge this chapter with the next one: the main activity is such that discussion of the results cannot be viewed separately.

Note that it is common to include evidence of "best practice" project management (e.g., use of version control, choice of programming language and so on). Rather than simply a rote list, make sure any such content is useful and/or informative in some way: for example, if there was a decision to be made then explain the trade-offs and implications involved.

3.5 Example Section

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foo

Figure 3.1: This is an example figure.

foo	bar	baz
0	0	0
1	1	1
⋮	⋮	⋮
9	9	9

Table 3.1: This is an example table.

3.5.1 Example Sub-section

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for $i = 0$ **upto** n **do**
$\quad | \quad t_i \leftarrow 0$
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]").

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[3] OpenStreetMap Foundation. *OpenStreetMap*. http://openstreetmap.org/.

[4] Peter Karich. *GraphHopper Routing Engine*. http://graphhopper.com.

[5] LordFokas, elonen, and ritchieGitHub. *NanoHttpd*. https://github.com/NanoHttpd/nanohttpd. (GitHub Users).

[6] Kai Nagel and Michael Schreckenberg. A cellular automoaton model for freeway traffic. *Journal de Physique I*, 2, 1992.

[7] David Rohmer and Nathan Rajlich. *Java-WebSocket*. http://java-websocket.org/.

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.