

FORMAL MODELING CAN IMPROVE SMART TRANSPORTATION
ALGORITHM DEVELOPMENT

by

WATHUGALA GAMAGE DULAN MANUJINDA WATHUGALA

A THESIS

Presented to the Department of Computer and Information Science
and the Graduate School of the University of Oregon
in partial fulfillment of the requirements
for the degree of
Master of Science

June 2017

THESIS APPROVAL PAGE

Student: Wathugala Gamage Dulan Manujinda Wathugala

Title: Formal Modeling Can Improve Smart Transportation Algorithm Development

This thesis has been accepted and approved in partial fulfillment of the requirements for the Master of Science degree in the Department of Computer and Information Science by:

Stephen Fickas

Chair

and

Scott L. Pratt

Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

Degree awarded June 2017

© 2017 Wathugala Gamage Dulan Manujinda Wathugala

THESIS ABSTRACT

Wathugala Gamage Dulan Manujinda Wathugala

Master of Science

Department of Computer and Information Science

June 2017

Title: Formal Modeling Can Improve Smart Transportation Algorithm Development

Ensuring algorithms work accurately is crucial, especially when they drive safety critical systems like self-driving cars.

We formally model a published distributed algorithm for autonomous vehicles to collaborate and pass thorough an intersection. Models are built and validated using the “Labelled Transition System Analyser” (LTSA). Our models reveal situations leading to deadlocks and crashes in the algorithm.

We demonstrate two approaches to gain insight about a large and complex system without modeling the entire system: *Modeling a sub system* - If the sub system has issues, the super system too. *Modeling a fast-forwarded state* - Reveals problems that can arise later in a process.

Some productivity tools developed for distributed system development are also presented. *Manulator*, our distributed system simulator, enables quick prototyping and debugging on a single workstation. *LTSA-O*, extension to LTSA, listens to messages exchanged in an execution of a distributed system and validates it against a model.

CURRICULUM VITAE

NAME OF AUTHOR: Wathugala Gamage Dulan Manujinda Wathugala

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon, Eugene
University of Colombo, Colombo

DEGREES AWARDED:

Master of Science, Computer and Information Science, 2017, University of Oregon
Bachelor of Science, Computer Science, 2002, University of Colombo

AREAS OF SPECIAL INTEREST:

Algorithm Modeling & Simulation
Distributed Systems
Autonomous Vehicles
Machine Learning

PROFESSIONAL EXPERIENCE:

Graduate Teaching Fellow, University of Oregon, 2015 – 2017.

Graduate Research Fellow, University of Oregon, 2016.

Lecturer, University of Colombo, 2002 – 2013.

GRANTS, AWARDS AND HONORS:

Felice Proctor Award (Non-theater major who has made a significant contribution to the theater production program in 2005), Virginia Polytechnic Institute and State University, 2005.

Fulbright Scholarship, US-SL Fulbright Commission & United States Government, 2004.

Mohan Munasinghe Award (Best Computer Science student), University of Colombo, 2002.

CINTEC Award (Best Computer Science senior thesis), University of Colombo, 2002.

Justin Samarasekara Award (Most outstanding science student), University of Colombo, 2002.

Joseph Nalliah Arumugam Memorial Award (Student having the highest average marks), University of Colombo, 2002.

Physical Science Award (Best undergraduate research project in Physics, Computer Science, Mathematics or Statistics), Sri Lanka Association for the Advancement of Science, 2002.

The Scholarship (Best results, B.Sc. 1st year examination), University of Colombo, 1998.

Prof. J.E. Jayasuriya Prize for Mathematics, University of Colombo, 1998.

PUBLICATIONS:

Weliwitigoda, P. & Weerasinghe, A. R. & Wathugala, W. G. D. M. & Dharmaratne, A. T. (2004). Music Score Recognition with Waves, Purnima Weliwitigoda, Ruwan Weerasinghe. *International Information Technology Conference*.

Yogendirakumar, K. & Weerasinghe, A. R. & Wathugala, W. G. D. M. & Dharmaratne, A. T. (2004). Music Score Recognition with Waves, Purnima Weliwitigoda, Ruwan Weerasinghe. *International Information Technology Conference*.

Wathugala, W. G. D. M. & Kodikara, N. D. (2002). A Sinhala Finger Spelling Interpretation System Using Nearest Neighbor Classification. *International Information Technology Conference*.

ACKNOWLEDGEMENTS

Professional

We thank Weigang Wu, Jiebin Zhang, Aoxue Luo and Jiannong Cao, the authors of the paper we build our work on. We picked their work not because it is easy to pick on but because they have done excellent work and we thought that their work is worthy of carrying forward.

We extend our special thanks to Weigang Wu, for corresponding with us via email and helping us acquire a copy of the supplement that accompanies the main paper, which we were unable to locate on-line.

We thank Jeff Magee, Jeff Kramer, Robert Chatley, Sebastian Uchitel and Howard Foster, the developers of the “Labelled Transition System Analyser” (LTSA) tool for sharing their code-base with us. Without their generosity, our extension to LTSA, LTSA-O, would have been impossible.

Jeff Magee is put on a separate spotlight for a big thank you. Despite being a very busy person, he promptly responded in details for our clarifications regarding LTSA and our models.

I thank Stephen Fickas, my thesis advisor, for everything. Without the numerous discussions I had with him, ideas he contributed, time he spent on reading my thesis and providing constructive feedback, and caring he extended toward me as his student, this work would have been infeasible.

I thank C. W. W. Kannangara (13 October 1884 - 23 September 1969), the first Minister of Education and the *Father of Free Education* in Sri Lanka for establishing free education. I further thank all the governments and the general public of Sri Lanka for keeping free education alive for the generations to come

and funding my education till I graduated from college. Without this funding, the chances of I coming this far is mere.

Personal

I thank Deepa Wathugala, my aunt. During my first term, when I did not get a Graduate Employee position and considering going home without even beginning this journey, she lent me money to pay for my tuition.

My mother, Indrani Wathugala, gave birth to me and raised me to be a good person. She gave me all the psychological support from the other side of the globe. Thank you for everything.

I greatly appreciate my wife, Sharmila Iroshmi Thenuwara. She took all the responsibilities of managing our home on to her shoulder and allowed me to focus fully on my work. She even helped me in my work in various regards such as proof reading and finding articles on the web. She is the best wife a man could ever have. I love you more each day.

My father, Wimal Wathugla, is the “Higgs Boson” that glue all the dots together. He was the role model of my life and he taught me to be a good man. In 1957, when he was just 21 years old, he won the second price of a lottery worth Rs. 14,660. Instead of thinking of building a luxurious life for himself, he spent the money for the betterment of his family and to provide a better education to all his siblings including his youngest brother, Wije Wathugala. While my uncle is pursuing his Ph.D., he met my aunt Deepa Wathugala. This connects the dots and that made me survive my first term at the University of Oregon. Dear father, you are getting the returns of your investment in multiple orders and thank you for having a great vision.

Dots in the past are starting to connected well. I am glad about that.

I dedicate my thesis to the future generations to come.
I hope my work will aid in some way to make a better universe for them.

TABLE OF CONTENTS

Chapter		Page
I.	INTRODUCTION	1
	1.1. Chapter One Section One	1
	1.1.1. Chapter one seciton one sub-section one	1
	1.1.1.1. Chapter one seciton one sub-section one sub-sub-section one	1
II.	METHODOLOGY	3
	2.1. Chapter Two Section One	3
III.	RESULTS	5
	3.1. Chapter Three Section One	5
	3.1.1. Chapter three seciton one sub-section one	5
	3.1.1.1. Chapter three seciton one sub-section one sub-sub-section one	5
IV.	CONCLUSION	6
	4.1. Chapter Four Section One	6
	4.1.1. Chapter four seciton one sub-section one	6
	.1.1.1. Chapter four seciton one sub-section one sub-sub-section one	6
APPENDICES		
A.	THE FIRST APPENDIX	7

Chapter	Page
A.1. Appendix One Section One	7
A.1.1. Chapter four seciton one sub-section one	7
B. THE SECOND APPENDIX	8
B.1. Appendix Two Section One	8
B.1.1. Chapter two seciton one sub-section one	9

LIST OF FIGURES

Figure	Page
1. A figure with a long long caption to demonstrate how that behaves in the list of figures when caption breaks into multiple lines.	2
2. A figure with a long long caption to demonstrate how that behaves in the list of figures when caption breaks into multiple lines.	4

LIST OF TABLES

Table	Page
1. A demo table to send to the List of tables to show how it appear in the list of tables. Need to be long to see how line spacing works.	1
2. A demo table to send to the List of tables to show how it appear in the list of tables. Need to be long to see how line spacing works.	3

LIST OF ALGORITHMS

Algorithm	Page
1. A very long algorithm caption so that it goes into two lines in the caption to see the line spacing between them.	1
2. A very long algorithm caption so that it goes into two lines in the caption to see the line spacing between them.	3

LIST OF LISTINGS

Listing	Page
1. Python listing to demonstrate how it behaves in the list of listings. Note that under the title List of Listings, there are no subtitles Listing.....	Page 1
2. Python listing to demonstrate how it behaves in the list of listings. Note that under the title List of Listings, there are no subtitles Listing.....	Page 3

CHAPTER I

INTRODUCTION

1.1 Chapter One Section One

Table 1. A demo table to send to the List of tables to show how it appear in the list of tables. Need to be long to see how line spacing works.

one	two
one	two
one	two

Algorithm 1 A very long algorithm caption so that it goes into two lines in the caption to see the line spacing between them.

```
1: if I get these problems solved then
2:     I will be happy).
3: end if
```

1.1.1 Chapter one section one sub-section one.

1.1.1.1 Chapter one section one sub-section one sub-sub-section one.

Listing 1 Python listing to demonstrate how it behaves in the list of listings. Note that under the title List of Listings, there are no subtitles Listing..... Page

```
1 print 'hello world'
```




Figure 1. A figure with a long long caption to demonstrate how that behaves in the list of figures when caption breaks into multiple lines.

CHAPTER II

METHODOLOGY

2.1 Chapter Two Section One

Table 2. A demo table to send to the List of tables to show how it appear in the list of tables. Need to be long to see how line spacing works.

one	two
one	two
one	two

Algorithm 2 A very long algorithm caption so that it goes into two lines in the caption to see the line spacing between them.

```
1: if I get these problems solved then  
2:   I will be happy).  
3: end if
```

Listing 2 Python listing to demonstrate how it behaves in the list of listings. Note that under the title List of Listings, there are no subtitles Listing..... Page

```
1 print 'hello world'
```



Figure 2. A figure with a long long caption to demonstrate how that behaves in the list of figures when caption breaks into multiple lines.

CHAPTER III

RESULTS

3.1 Chapter Three Section One

3.1.1 Chapter three seciton one sub-section one.

3.1.1.1 Chapter three seciton one sub-section one sub-sub-section one.

CHAPTER IV

CONCLUSION

4.1 Chapter Four Section One

4.1.1 Chapter four seciton one sub-section one.

4.1.1.1 Chapter four seciton one sub-section one sub-sub-section one.

APPENDIX A

THE FIRST APPENDIX

A.1 Appendix One Section One

A.1.1 Chapter four seciton one sub-section one.

APPENDIX B

THE SECOND APPENDIX

B.1 Appendix Two Section One

B.1.1 Chapter two seciton one sub-section one.