
The Greatest Thesis in the World



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Doctor of Philosophy

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Statement of Originality

I hereby certify that the work embodied in this thesis is the result of original research, is free of plagiarised materials, and has not been submitted for a higher degree to any other University or Institution.

Feb. 2026

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Date _____

Signature

Signature

Xiufeng Xu

Supervisor Declaration Statement

I have reviewed the content and presentation style of this thesis and declare it is free of plagiarism and of sufficient grammatical clarity to be examined. To the best of my knowledge, the research and writing are those of the candidate except as acknowledged in the Author Attribution Statement. I confirm that the investigations were conducted in accord with the ethics policies and integrity standards of Nanyang Technological University and that the research data are presented honestly and without prejudice.

Mar. 2026
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Prof. Yi Li

Authorship Attribution Statement

This thesis contains material from two published peer-reviewed conference papers and one completed manuscript under review, all of which I am listed as an author.

Chapter 4 is published as [Xiufeng Xu, Chenguang Zhu, and Yi Li. Compsuite: A dataset of java library upgrade incompatibility issues. In International Conference on Automated Software Engineering. 2023. DOI: 10.1109/ASE56229.2023.00127.](#)

The contributions of the co-authors are as follows:

- Prof. Yi Li and Dr. Chenguang Zhu proposed the topic and provided insightful comments on the methodology and experiment design.
- I constructed the dataset, designed and implemented the tool, performed the experiments, analyzed the data and drafted the manuscript.

Chapter 5 is published as [Xiufeng Xu, Fuman Xie, Chenguang Zhu, Guangdong Bai, Sarfraz Khurshid, and Yi Li. Identifying Multi-parameter Constraint Errors in Python Data Science Library API Documentation. In Proceedings of the ACM on Software Engineering. 2025. DOI: 10.1145/3728945.](#)

The contributions of the co-authors are as follows:

- Prof. Yi Li and Dr. Chenguang Zhu proposed the topic and revised the manuscript.
- I co-designed the methodology, implemented and evaluated the approach, and drafted the manuscript.
- Fuman Xie contributed to the implementation of the tool, assisted in conducting the evaluation, and refined the manuscript.
- Prof. Sarfraz Khurshid and Prof. Guangdong Bai provided insightful comments on the methodology design.

Chapter 6 is from a completed paper under review.

The contributions of the co-authors are as follows:

- Prof. Yi Li proposed the topic, supported the research, provided guidance to the methodology design, and revised the manuscript.
- I co-designed the methodology, implemented the tool, conducted the experiments, analyzed the data, and drafted the manuscript.
- Dr. Xiuheng Wu contributed to the implementation of the tool and assisted in conducting the experiments.

- Dr. Zejun Zhang provided insightful comments and helped to write the related works section.

Feb. 2026

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Date

Signature

Xiufeng Xu

Acknowledgements

I wish to express my greatest gratitude to my advisor.

“If I had one hour to save the world, I would spend 55 minutes defining the problem and only five minutes finding the solution.”

—Einstein, Albert

To my dear family

Abstract

My abstracts

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3.1 My Table. 5

Symbols and Acronyms

Symbols

\mathcal{R}^n	the n -dimensional Euclidean space
\mathcal{H}	the Euclidean space
$\ \cdot\ $	the 2-norm of a vector or matrix in Euclidean space
$\ \cdot\ _G$	the induced norm of a vector in G-space
$\ \cdot\ _E$	the induced norm of a vector or matrix in probabilistic space
\odot	the Hadamard (component-wise) product
\otimes	the Kronecker product
$\langle \cdot, \cdot \rangle$	the inner product of two vectors
\circ	the composition of functions
∇f	the gradient vector
\mathcal{C}^k	the function with continuous partial derivatives up to k orders
$x_{i,k}$	the i -th component of a vector x at time k
\bar{x}	the vector with the average of all components of x as each element
$\mathbf{1}$	all-ones column vector with proper dimension
\mathcal{C}	the average space, i.e., $\text{span}\{\mathbf{1}\}$
\mathcal{C}^\perp	the disagreement space, i.e., $\text{span}^\perp\{\mathbf{1}\}$
Π_\parallel	the projection matrix to the average space \mathcal{C}
Π_\perp	the projection matrix to the disagreement space \mathcal{C}^\perp
$O(\cdot)$	order of magnitude or ergodic convergence rate (running average)
$o(\cdot)$	non-ergodic convergence rate
\mathcal{N}_i	the index set of the neighbors of agent i

Acronyms

DOP	Distributed Optimization Problem
EDOP	Equivalent Distributed Optimization Problem
SDOP	Stochastic Distributed Optimization Problem
OEP	Optimal Exchange Problem
OCF	Optimal Consensus Problem
DOCP	Dynamic Optimal Consensus Problem
AugDGM	Augmented Distributed Gradient Methods
AsynDGM	Asynchronous Distributed Gradient Methods
D-ESC	Distributed Extremum Seeking Control
D-SPA	Distributed Simultaneous Perturbation Approach
D-FBBS	Distributed Forward-Backward Bregman Splitting
ADMM	Alternating Direction Method of Multipliers
DSM	Distributed (Sub)gradient Method
GAS	Globally Asymptotically Stable
UGAS	Uniformly Globally Asymptotically Stable
SPAS	Semi-globally Practically Asymptotically Stable
USPAS	Uniformly Semi-globally Practically Asymptotically Stable
HoS	Heterogeneity of Stepsize
FPR	Fixed Point Residual
OBE	Objective Error
i.i.d.	independent and identically distributed
<i>a.s.</i>	almost sure convergence of a random sequence

Chapter 1

Introduction

1.1 Some useful hints

My figure citation: Figure [1.1](#). (command: `fref`)

My section citation: Section [1.2](#). (command: `sref`)

My Chapter citation: Chapter [1](#). (command: `cref`)

My Paper citation: [\[1\]](#). (notice back reference to page from bibliograph)

My equation citation: [\(1.1\)](#). (command: `eqref`), or cite equation by tag: [\(DOP\)](#).

$$F(\theta) = \sum_{i=1}^m f_i(\theta) \tag{DOP}$$

$$F(\theta) = \sum_{i=1}^m f_i(\theta) \tag{1.1}$$

1.2 Major Contributions

Our main contributions can be stated as follows:

- *First part*: My first contributions, several lines



FIGURE 1.1: An illustration.

- *Second*: Second contributions, several lines
- *Third name*: Third contributions, several lines

1.3 Outline of the Thesis

Chapter [1](#) introduces ...

Chapter [2](#) reviews ...

More chapters

....

Chapter 2

Literature Review

2.1 Part 1

When you cite a paper [1], the back reference from bibgraph will apper as page number.

You can also cite paper with author name using the command ‘citet’: such as: Bauschke and Combettes [1].

2.2 Part 2

cite another paper [2].

Lemma 2.1 (My lemma). *A great lemma.*

$$c^2 = a^2 + b^2 \tag{2.1}$$

Theorem 2.2 (My theorem). *A great theorem.*

$$c^2 = a^2 + b^2 \tag{2.2}$$

Proof. The proof is intuitive.

□

Corollary 2.3 (My corollary). *A great corollary.*

$$c^2 = a^2 + b^2 \tag{2.3}$$

Proposition 2.1 (My proposition). *A great proposition.*

$$c^2 = a^2 + b^2 \tag{2.4}$$

Example 2.1 (My example). A great example.

$$c^2 = a^2 + b^2 \tag{2.5}$$

Definition 2.1 (My definition). A great definition.

$$c^2 = a^2 + b^2 \tag{2.6}$$

Assumption 2.1 (My assumption). A great assumption.

$$c^2 = a^2 + b^2 \tag{2.7}$$

Remark 2.1 (My remark). A great remark.

$$c^2 = a^2 + b^2 \tag{2.8}$$

Chapter 3

Chapter3 Name

3.1 Section1

See Figure [3.1](#)



FIGURE 3.1: Another illustration.

Let's cite out first table: Table [3.1](#).

Table	Group 1		Group 2	
	Col 1	Col 2	Col 1	Col 2
Row 1	14.37	5.76	2.65	2.84
Row 2	5.43	7.36	2.22	2.49
Row 3	5.54	5.68	4.42	2.92

TABLE 3.1: My Table.

Chapter 4

Chapter4 Name

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

4.1 Section 1

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

4.2 Section 2

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

Chapter 5

Chapter5 Name

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

5.1 Section 1

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

5.2 Section 2

Quisque facilisis auctor sapien. Pellentesque gravida hendrerit lectus. Mauris rutrum sodales sapien. Fusce hendrerit sem vel lorem. Integer pellentesque massa vel augue. Integer elit tortor, feugiat quis, sagittis et, ornare non, lacus. Vestibulum posuere pellentesque eros. Quisque venenatis ipsum dictum nulla. Aliquam quis quam non metus eleifend interdum. Nam eget sapien ac mauris malesuada adipiscing. Etiam eleifend neque sed quam. Nulla facilisi. Proin a ligula. Sed id dui eu nibh egestas tincidunt. Suspendisse arcu.

Appendix A

Proofs for Part I or Chapter 3

A.1 Proof of Lemma

$$\psi^{av}(\theta) = \frac{1}{T} \int_0^T [\psi(\theta + \mu(\tau)) + C] \otimes \frac{\mu(\tau)}{a} d\tau$$

A.2 Proof of another Lemma

$$\begin{aligned} \gamma_1(\|x\|) &\leq W(t, x) \leq \gamma_2(\|x\|) \\ \frac{\partial W}{\partial t} + \frac{\partial W}{\partial x} \phi(t, x, 0) &\leq -\gamma_3(\|x\|) \end{aligned} \tag{A.1}$$

List of Author's Awards, Patents, and Publications¹

Awards

- Best Paper Awards, “A Great System,” *Nature*.

Patents

- A Great System, “A Great System,” *Nature*.

Journal Articles

- My name and My colleague, “A Great System,” *Nature*.

Conference Proceedings

- My name, My colleague 1, My colleague 3 and My colleague 3, “Greater System,” in *Conference of Vision, 2018*.

¹The superscript * indicates joint first authors

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- [1] Heinz H Bauschke and Patrick L Combettes. *Convex analysis and monotone operator theory in Hilbert spaces*. Springer Science & Business Media, 2011. [1](#), [3](#)
- [2] J. B. Rawlings and B. T. Stewart. Coordinating multiple optimization-based controllers: New opportunities and challenges. *Journal of Process Control*, 18: 839–845, 2008. [3](#)