



Universiteit
Leiden
The Netherlands

Reasoning about object-oriented programs: from classes to interfaces

Bian, J.

Citation

Bian, J. (2024, May 21). *Reasoning about object-oriented programs: from classes to interfaces*. Retrieved from <https://hdl.handle.net/1887/3754248>

Version: Publisher's Version

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/3754248>

Note: To cite this publication please use the final published version (if applicable).

Reasoning about object-oriented programs: from classes to interfaces

Jinting Bian

Copyright © 2024 Jinting Bian, All Rights Reserved

ISBN 978-94-6496-122-5

Cover design: Zhiyu Gu

Reasoning about object-oriented programs: from classes to interfaces

Proefschrift

ter verkrijging van

de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties

te verdedigen op dinsdag 21 mei 2024

klokke 11:15 uur

door Jinting Bian

geboren te Taiyuan, China

in 1994

Promotores: Prof. dr. F.S. de Boer
Prof. dr. M.M. Bonsangue

Promotiecommissie: Prof. dr. R.V. van Nieuwpoort
Prof. dr. H.C.M. Kleijn
Prof. dr. M.-C. Jakobs (Ludwig-Maximilians Universität)
Prof. dr. M. Sirjani (Malardalen University)
Dr. E. Poll (Radboud Universiteit)
Dr. A.W. Laarman



Jinting Bian was financially supported through the China Scholarship Council (CSC) to participate in the PhD programme of Leiden University. Grant number 202007720094.

The research in this thesis was performed at the Center for Mathematics and Computer Science (CWI) in Amsterdam and Leiden Institute of Advanced Computer Science at Leiden University, under the auspices of the research school IPA (Institute for Programming research and Algorithmics).

Copyright © 2024 Jinting Bian.

Contents

1	Introduction	1
1.1	Background	1
1.2	Thesis outline	4
1.3	Main challenges and contributions	5
2	Preliminaries	11
2.1	Object-oriented programming	11
2.2	Java Collection Framework	12
2.3	Theorem prover overview	14
2.3.1	KeY theorem prover	14
2.3.2	Isabelle/HOL theorem prover	17
3	Class specification and verification: a step-by-step guide	21
3.1	Introduction	22
3.2	Preliminaries	23
3.3	Structure and behavior of <code>java.util.LinkedList</code>	25
3.3.1	Expected and unexpected method behavior	28
3.3.2	Integer overflow bug	29
3.3.3	Verification goal	30
3.4	Formulating a class invariant	32
3.5	The acyclicity property	35
3.6	The <code>add</code> method	35
3.7	The <code>remove</code> method	38
3.8	Summary	44
4	History-based reasoning about interfaces	47
4.1	Introduction	48
4.2	Background	49
4.3	Specification and verification challenges for the <code>Collection</code> interface	50
4.4	History-based reasoning approach	54
4.4.1	The executable history-based approach	54
4.4.2	The logical history-based approach	55
4.4.3	Comparative analysis	56
4.5	Summary	58

5	Executable history-based reasoning: a case study	59
5.1	Introduction	60
5.2	History-based specification in KeY	60
5.2.1	The <code>History</code> class for <code>Collection</code>	60
5.2.2	Attributes of <code>History</code>	62
5.2.3	The <code>Collection</code> interface	65
5.2.4	History-based refinement	66
5.3	History-based verification of <code>Collection</code>	67
5.4	Summary	71
6	Logical history-based reasoning: an advanced case study	73
6.1	Introduction	74
6.2	Intergrating Abstract Data Types in KeY	74
6.3	History-based specification	79
6.3.1	History abstractions	82
6.3.2	Method contracts of <code>Collection</code>	85
6.4	History-based client-side verification	90
6.4.1	Significant improvement in proof effort	91
6.4.2	Reasoning about <code>Iterator</code>	93
6.4.3	Reasoning about binary methods	95
6.4.4	Proof statistics	98
6.5	Summary	99
7	History-based reasoning about behavioral subtyping	101
7.1	Introduction	102
7.2	Methodology	103
7.2.1	History-based refinement theory	105
7.2.2	Verifying method call and method implementation	106
7.3	Case study	107
7.3.1	History-based reasoning	108
7.3.2	History-based specification	111
7.3.3	Behavioral subtyping	113
7.3.4	Example of method call and implementation	116
7.4	Summary	117
8	Conclusion	119
8.1	Summary of contributions	119
8.2	Future work	121
	Bibliography	125
	English summary	131
	Nederlandse samenvatting	133
	Acknowledgements	135

Curriculum Vitae	137
Publication List	139

