Defect Detect

DUmps Binaries Logs INternals School of Security

Rust Memory Thinking Version 2

Dmitry Vostokov Software Diagnostics Services

Memory Thinking for Rust

Slides with Descriptions and Source Code Illustrations

Second Editon

Dmitry Vostokov Software Diagnostics Services

OpenTask

Memory Thinking for Rust: Slides with Descriptions and Source Code Illustrations, Second Editon

Published by OpenTask, Republic of Ireland

Copyright © 2025 by OpenTask

Copyright © 2025 by Dmitry Vostokov

Copyright © 2025 by Software Diagnostics Services

Copyright © 2025 by Dublin School of Security

All rights reserved. No part of this book may be reproduced, stored in a retrieval system, transmitted in any form or by any means, or used for training artificial intelligence systems without the prior written permission of the publisher.

OpenTask books are available through booksellers and distributors worldwide. For further information or comments, send requests to <u>press@opentask.com</u>.

Product and company names mentioned in this book may be trademarks of their owners.

A CIP catalog record for this book is available from the British Library.

ISBN-13: 978-1912636488 (Paperback)

Revision 2.00 (April 2025)

able of Contents		Pointer Dereference	
Table of Contents	3	One to Many	
Preface	9	Many to One	
About the Author	10	Many to One Dereference	
Introduction	11	Invalid Pointer	
Prerequisites	11	Invalid Pointer Dereference	
Training Goals	12	Wild (Dangling) Pointer	
Warning	12	Pointer to Pointer	
Training Principles	13	Pointer to Pointer Dereference	
Schedule	13	Naming Pointers and Entities	
Training Idea	14	Names as Pointer Content	
General Rust Aspects	14	Pointers as Entities	
What We Do Not Cover	15	Unsafe Rust Code Examples	
Linux Rust Aspects	16	Pointer	
Windows Rust Aspects	16	Unsafe Pointer Dereference	
Why Rust?	17	One to Many	
My Genealogy of Rust	18	Memory Leak	
Rust Mastery Process	18	Many to One	
Thought Process	19	Unsafe Many to One Dereference	
Philosophy of Unsafe Pointers		Invalid Pointer	
	20	Unsafe Invalid Pointer Dereference (Al	ign
A General Pointer Concept	20		-
Pointer	21		

Unsafe Invalid Pointer Dereference (Access Violation)	40
Unsafe Wild (Dangling) Pointer	41
Pointer to Pointer	42
Unsafe Pointer to Pointer Dereference	43
Philosophy of Values	45
Values and Owners	46
Moving Values	47
Copying Values	49
Dropping Values	50
Ownership Tree	52
Ownership Tree and Drops	53
Partial Drops	54
Ownership Tree and Moves	56
Multiple Owners (not in Rust)	57
Multiple Owners and Drops	58
Owners vs. Pointers	58
Rust: A Copernican Revolution	59
Values Revolve Around Pointers	59
Owners Revolve Around Values	60
Rust Philosophy of Values	61
Restricted Ownership	62

ccess		Value Lifetime	63
	40	Owner Lifetime	65
	41		05
	42	Rust Philosophy of Pointers	68
		Types of Pointers	69
2	43	Mut Pointers vs. Pointers to Mut	69
	45		70
	46	References as Pointer Types	70
	47	Mut Refs vs. Refs to Mut	72
	47	References as Addresses	73
	49	Borrowing References	75
	50		
	52	Reference Lifetime	77
	50	x64 Disassembly Review (WinDbg)	79
	53	x64 CPU Registers	79
	54	Instructions and Registers	80
	56	instructions and Registers	80
	57	Memory and Stack Addressing	80
		Memory Cell Sizes	81
	58	Memory Load Instructions	81
	58	Memory Store Instructions	82
	59	wemory store instructions	02
	59	Flow Instructions	82
		Function Parameters	83
	60	Struct Function Parameters	83
	61		
	62	x64 Disassembly Review (GDB AT&T Flavor)	84
		x64 CPU Registers	84

x64 Instructions and Registers	85	Rust Static Memory References	97
Memory and Stack Addressing	85	Stack Memory	102
x64 Memory Load Instructions	86	Thread Stack Frames	102
x64 Memory Store Instructions	86	Local Value Lifecycle	103
x64 Flow Instructions	87	Scope	103
x64 Function Parameters	87	Rust Stack Memory Values	104
x64 Struct Function Parameters	88	Rust Stack Memory References	104
ARM64 Disassembly Review	89	Heap Memory	107
A64 CPU Registers	89	Rust Heap Memory Values	108
A64 Instructions and Registers	90	Rust Const Values	110
Memory and Stack Addressing	90	Useful WinDbg Commands	112
A64 Memory Load Instructions	91	Useful GDB Commands	112
A64 Memory Store Instructions	91	Memory and Pointers	113
A64 Flow Instructions	92	Mental Exercise	114
A64 Function Parameters	92	Debugger Memory Layout	114
A64 Struct Function Parameters	93	Memory Dereference Layout	115
Memory Storage	94	Names as Addresses	115
Memory Regions	95	Addresses and Entities	116
Dynamic Virtual Memory	95	Addresses and Structures	116
Static Memory	96	Pointers to Structures	117
Rust Static Memory Values	96	Arrays	117
Global vs. Local Static	97	Arrays and Pointers to Arrays	118

Fat Pointers	118	Tuples	157
Array Slices	119	Structs	159
String Literals (UTF-8)	122	Tuple-like Structs	160
Byte Strings	124	Newtypes	163
Vectors	125	Newtypes (Binary Compatible)	165
Vector Slices	126	Named-field Structs	166
Strings	129	Reference/Pointer to Struct	169
String Slices	130	Ref/Ptr to Struct Dereference	170
C-Strings	132	Dereference with Replacement	171
C-String Slices	133	One Ref/Ptr to Many Structs	173
Basic Types	135	Memory Leak	173
Bytes, Pointers, and References	136	Many Ref/Ptr to One Struct	174
u32, Pointers, and References	138	Many to One Dereference	174
Little-Endian System	140	Ref/Ptr to Ref/Ptr to Struct	175
u64 and Pointers	141	Ref/Ptr to Ref/Ptr Dereference	175
Size	143	Memory and Structs	179
Alignment	147	Addresses and Structs	180
Entity Conversion	149	Struct Field Addresses	180
Conversion through Pointers	150	Ref/Ptr to Structs	183
Safe Conversion (Explicit Cast)	151	Ref/Ptr to Struct and Fields	184
Safe Conversion (Coercion)	153	External Struct Alignment	187
Forcing	155	Internal Struct Alignment (WinDbg)	187

Internal Struct Alignment (GDB)	188	Boxed Trait Object Layout	225
Enums	191	Struct Constructors	228
Simple Enums	192	Struct Destructor	230
Enums with Structs	195	Struct Clone	234
Enum Null Pointer Optimization	199	Struct Copy	235
Source Code and Symbols	201	Parameters by Value	237
Conceptual Layer (Modules)	202	Parameters by Ref/Ptr	240
Logical Layer (Crates)	202	self	242
Physical Layer (Source Files)	203	Trait Objects as Parameters	243
Name Isolation	203	Struct as Return Value	244
Functions	206	Closures and Captures	246
Pointers to Functions	207	Closure Struct	247
Pointers to Functions References to Functions	207 209	Closure Struct A64 Closure Struct Example	247 248
References to Functions	209	A64 Closure Struct Example	248
References to Functions Function Pointer Types	209 211	A64 Closure Struct Example Captures (Borrowing)	248 248
References to Functions Function Pointer Types Struct Function Fields	209 211 212	A64 Closure Struct Example Captures (Borrowing) Captures (Borrowing) x64 Linux	248 248 249
References to Functions Function Pointer Types Struct Function Fields Associated Functions	209 211 212 213	A64 Closure Struct Example Captures (Borrowing) Captures (Borrowing) x64 Linux Captures (Move)	248 248 249 250
References to Functions Function Pointer Types Struct Function Fields Associated Functions Pointers to Associated Functions	209 211 212 213 215	A64 Closure Struct Example Captures (Borrowing) Captures (Borrowing) x64 Linux Captures (Move) Captures (Move) x64 Linux	248 248 249 250 251
References to Functions Function Pointer Types Struct Function Fields Associated Functions Pointers to Associated Functions Type-associated Functions	209 211 212 213 215 217	A64 Closure Struct Example Captures (Borrowing) Captures (Borrowing) x64 Linux Captures (Move) Captures (Move) x64 Linux Smart Pointers	248 248 249 250 251 253
References to Functions Function Pointer Types Struct Function Fields Associated Functions Pointers to Associated Functions Type-associated Functions Trait Functions	209 211 212 213 215 217 219	A64 Closure Struct Example Captures (Borrowing) Captures (Borrowing) x64 Linux Captures (Move) Captures (Move) x64 Linux Smart Pointers Why Smart Pointers?	248 248 249 250 251 253 254

Shared Ownership	261	Rust Books	272
Pinning	266		
Use Cases	267		