

# Table of Contents

## To the Reader

<b>1</b>	<b>The Basics of Interpretation</b>	<b>1</b>
1.1	Evaluation . . . . .	2
1.2	Basic Evaluator . . . . .	3
1.3	Evaluating Atoms . . . . .	4
1.4	Evaluating Forms . . . . .	6
1.4.1	Quoting . . . . .	7
1.4.2	Alternatives . . . . .	8
1.4.3	Sequence . . . . .	9
1.4.4	Assignment . . . . .	11
1.4.5	Abstraction . . . . .	11
1.4.6	Functional Application . . . . .	11
1.5	Representing the Environment . . . . .	12
1.6	Representing Functions . . . . .	15
1.6.1	Dynamic and Lexical Binding . . . . .	19
1.6.2	Deep or Shallow Implementation . . . . .	23
1.7	Global Environment . . . . .	25
1.8	Starting the Interpreter . . . . .	27
1.9	Conclusions . . . . .	28
1.10	Exercises . . . . .	28
<b>2</b>	<b>Lisp, 1, 2, ... ω</b>	<b>31</b>
2.1	Lisp <sub>1</sub> . . . . .	32
2.2	Lisp <sub>2</sub> . . . . .	32
2.2.1	Evaluating a Function Term . . . . .	35
2.2.2	Duality of the Two Worlds . . . . .	36
2.2.3	Using Lisp <sub>2</sub> . . . . .	38
2.2.4	Enriching the Function Environment . . . . .	38
2.3	Other Extensions . . . . .	39
2.4	Comparing Lisp <sub>1</sub> and Lisp <sub>2</sub> . . . . .	40
2.5	Name Spaces . . . . .	43
2.5.1	Dynamic Variables . . . . .	44
2.5.2	Dynamic Variables in COMMON LISP . . . . .	48
2.5.3	Dynamic Variables without a Special Form . . . . .	50
2.5.4	Conclusions about Name Spaces . . . . .	52

2.6	Recursion . . . . .	53
2.6.1	Simple Recursion . . . . .	54
2.6.2	Mutual Recursion . . . . .	55
2.6.3	Local Recursion in Lisp <sub>2</sub> . . . . .	56
2.6.4	Local Recursion in Lisp <sub>1</sub> . . . . .	57
2.6.5	Creating Uninitialized Bindings . . . . .	60
2.6.6	Recursion without Assignment . . . . .	62
2.7	Conclusions . . . . .	67
2.8	Exercises . . . . .	68
<b>3</b>	<b>Escape &amp; Return: Continuations</b>	<b>71</b>
3.1	Forms for Handling Continuations . . . . .	74
3.1.1	The Pair <code>catch/throw</code> . . . . .	74
3.1.2	The Pair <code>block/return-from</code> . . . . .	76
3.1.3	Escapes with a Dynamic Extent . . . . .	77
3.1.4	Comparing <code>catch</code> and <code>block</code> . . . . .	79
3.1.5	Escapes with Indefinite Extent . . . . .	81
3.1.6	Protection . . . . .	84
3.2	Actors in a Computation . . . . .	87
3.2.1	A Brief Review about Objects . . . . .	87
3.2.2	The Interpreter for Continuations . . . . .	89
3.2.3	Quoting . . . . .	90
3.2.4	Alternatives . . . . .	90
3.2.5	Sequence . . . . .	90
3.2.6	Variable Environment . . . . .	91
3.2.7	Functions . . . . .	92
3.3	Initializing the Interpreter . . . . .	94
3.4	Implementing Control Forms . . . . .	95
3.4.1	Implementation of <code>call/cc</code> . . . . .	95
3.4.2	Implementation of <code>catch</code> . . . . .	96
3.4.3	Implementation of <code>block</code> . . . . .	97
3.4.4	Implementation of <code>unwind-protect</code> . . . . .	99
3.5	Comparing <code>call/cc</code> to <code>catch</code> . . . . .	100
3.6	Programming by Continuations . . . . .	102
3.6.1	Multiple Values . . . . .	103
3.6.2	Tail Recursion . . . . .	104
3.7	Partial Continuations . . . . .	106
3.8	Conclusions . . . . .	107
3.9	Exercises . . . . .	108
<b>4</b>	<b>Assignment and Side Effects</b>	<b>111</b>
4.1	Assignment . . . . .	111
4.1.1	Boxes . . . . .	114
4.1.2	Assignment of Free Variables . . . . .	116
4.1.3	Assignment of a Predefined Variable . . . . .	121
4.2	Side Effects . . . . .	121
4.2.1	Equality . . . . .	122

2.6	Recursion . . . . .	53
2.6.1	Simple Recursion . . . . .	54
2.6.2	Mutual Recursion . . . . .	55
2.6.3	Local Recursion in Lisp <sub>2</sub> . . . . .	56
2.6.4	Local Recursion in Lisp <sub>1</sub> . . . . .	57
2.6.5	Creating Uninitialized Bindings . . . . .	60
2.6.6	Recursion without Assignment . . . . .	62
2.7	Conclusions . . . . .	67
2.8	Exercises . . . . .	68
<b>3</b>	<b>Escape &amp; Return: Continuations</b>	<b>71</b>
3.1	Forms for Handling Continuations . . . . .	74
3.1.1	The Pair <code>catch/throw</code> . . . . .	74
3.1.2	The Pair <code>block/return-from</code> . . . . .	76
3.1.3	Escapes with a Dynamic Extent . . . . .	77
3.1.4	Comparing <code>catch</code> and <code>block</code> . . . . .	79
3.1.5	Escapes with Indefinite Extent . . . . .	81
3.1.6	Protection . . . . .	84
3.2	Actors in a Computation . . . . .	87
3.2.1	A Brief Review about Objects . . . . .	87
3.2.2	The Interpreter for Continuations . . . . .	89
3.2.3	Quoting . . . . .	90
3.2.4	Alternatives . . . . .	90
3.2.5	Sequence . . . . .	90
3.2.6	Variable Environment . . . . .	91
3.2.7	Functions . . . . .	92
3.3	Initializing the Interpreter . . . . .	94
3.4	Implementing Control Forms . . . . .	95
3.4.1	Implementation of <code>call/cc</code> . . . . .	95
3.4.2	Implementation of <code>catch</code> . . . . .	96
3.4.3	Implementation of <code>block</code> . . . . .	97
3.4.4	Implementation of <code>unwind-protect</code> . . . . .	99
3.5	Comparing <code>call/cc</code> to <code>catch</code> . . . . .	100
3.6	Programming by Continuations . . . . .	102
3.6.1	Multiple Values . . . . .	103
3.6.2	Tail Recursion . . . . .	104
3.7	Partial Continuations . . . . .	106
3.8	Conclusions . . . . .	107
3.9	Exercises . . . . .	108
<b>4</b>	<b>Assignment and Side Effects</b>	<b>111</b>
4.1	Assignment . . . . .	111
4.1.1	Boxes . . . . .	114
4.1.2	Assignment of Free Variables . . . . .	116
4.1.3	Assignment of a Predefined Variable . . . . .	121
4.2	Side Effects . . . . .	121
4.2.1	Equality . . . . .	122

7.5	Instructions . . . . .	238
7.5.1	Local Variables . . . . .	239
7.5.2	Global Variables . . . . .	240
7.5.3	Jumps . . . . .	242
7.5.4	Invocations . . . . .	243
7.5.5	Miscellaneous . . . . .	244
7.5.6	Starting the Compiler-Interpreter . . . . .	245
7.5.7	Catching Our Breath . . . . .	247
7.6	Continuations . . . . .	247
7.7	Escapes . . . . .	249
7.8	Dynamic Variables . . . . .	252
7.9	Exceptions . . . . .	255
7.10	Compiling Separately . . . . .	260
7.10.1	Compiling a File . . . . .	260
7.10.2	Building an Application . . . . .	262
7.10.3	Executing an Application . . . . .	266
7.11	Conclusions . . . . .	267
7.12	Exercises . . . . .	268
<b>8</b>	<b>Evaluation &amp; Reflection</b>	<b>271</b>
8.1	Programs and Values . . . . .	271
8.2	<b>eval</b> as a Special Form . . . . .	277
8.3	Creating Global Variables . . . . .	279
8.4	<b>eval</b> as a Function . . . . .	280
8.5	The Cost of <b>eval</b> . . . . .	281
8.6	Interpreted <b>eval</b> . . . . .	282
8.6.1	Can Representations Be Interchanged? . . . . .	282
8.6.2	Global Environment . . . . .	283
8.7	Reifying Environments . . . . .	286
8.7.1	Special Form <b>export</b> . . . . .	286
8.7.2	The Function <b>eval/b</b> . . . . .	289
8.7.3	Enriching Environments . . . . .	290
8.7.4	Reifying a Closed Environment . . . . .	292
8.7.5	Special Form <b>import</b> . . . . .	296
8.7.6	Simplified Access to Environments . . . . .	301
8.8	Reflective Interpreter . . . . .	302
8.9	Conclusions . . . . .	308
8.10	Exercises . . . . .	309
<b>9</b>	<b>Macros: Their Use &amp; Abuse</b>	<b>311</b>
9.1	Preparation for Macros . . . . .	312
9.1.1	Multiple Worlds . . . . .	313
9.1.2	Unique World . . . . .	313
9.2	Macro Expansion . . . . .	314
9.2.1	Exogenous Mode . . . . .	314
9.2.2	Endogenous Mode . . . . .	316
9.3	Calling Macros . . . . .	317

9.4	Expanders . . . . .	318
9.5	Acceptability of an Expanded Macro . . . . .	320
9.6	Defining Macros . . . . .	321
	9.6.1 Multiple Worlds . . . . .	322
	9.6.2 Unique World . . . . .	325
	9.6.3 Simultaneous Evaluation . . . . .	331
	9.6.4 Redefining Macros . . . . .	331
	9.6.5 Comparisons . . . . .	332
9.7	Scope of Macros . . . . .	333
9.8	Evaluation and Expansion . . . . .	336
9.9	Using Macros . . . . .	338
	9.9.1 Other Characteristics . . . . .	339
	9.9.2 Code Walking . . . . .	340
9.10	Unexpected Captures . . . . .	341
9.11	A Macro System . . . . .	344
	9.11.1 Objectification—Making Objects . . . . .	344
	9.11.2 Special Forms . . . . .	350
	9.11.3 Evaluation Levels . . . . .	351
	9.11.4 The Macros . . . . .	352
	9.11.5 Limits . . . . .	355
9.12	Conclusions . . . . .	356
9.13	Exercises . . . . .	356
<b>10</b>	<b>Compiling into C</b>	<b>359</b>
10.1	Objectification . . . . .	360
10.2	Code Walking . . . . .	360
10.3	Introducing Boxes . . . . .	362
10.4	Eliminating Nested Functions . . . . .	363
10.5	Collecting Quotations and Functions . . . . .	367
10.6	Collecting Temporary Variables . . . . .	370
10.7	Taking a Pause . . . . .	371
10.8	Generating C . . . . .	372
	10.8.1 Global Environment . . . . .	373
	10.8.2 Quotations . . . . .	375
	10.8.3 Declaring Data . . . . .	378
	10.8.4 Compiling Expressions . . . . .	379
	10.8.5 Compiling Functional Applications . . . . .	382
	10.8.6 Predefined Environment . . . . .	384
	10.8.7 Compiling Functions . . . . .	385
	10.8.8 Initializing the Program . . . . .	387
10.9	Representing Data . . . . .	390
	10.9.1 Declaring Values . . . . .	393
	10.9.2 Global Variables . . . . .	395
	10.9.3 Defining Functions . . . . .	396
10.10	Execution Library . . . . .	397
	10.10.1 Allocation . . . . .	397
	10.10.2 Functions on Pairs . . . . .	398

10.10.3 Invocation . . . . .	399
10.11 call/cc: To Have and Have Not . . . . .	402
10.11.1 The Function call/ep . . . . .	403
10.11.2 The Function call/cc . . . . .	404
10.12 Interface with C . . . . .	413
10.13 Conclusions . . . . .	414
10.14 Exercises . . . . .	414
<b>11 Essence of an Object System</b>	<b>417</b>
11.1 Foundations . . . . .	419
11.2 Representing Objects . . . . .	420
11.3 Defining Classes . . . . .	422
11.4 Other Problems . . . . .	425
11.5 Representing Classes . . . . .	426
11.6 Accompanying Functions . . . . .	429
11.6.1 Predicates . . . . .	430
11.6.2 Allocator without Initialization . . . . .	431
11.6.3 Allocator with Initialization . . . . .	433
11.6.4 Accessing Fields . . . . .	435
11.6.5 Accessors for Reading Fields . . . . .	436
11.6.6 Accessors for Writing Fields . . . . .	437
11.6.7 Accessors for Length of Fields . . . . .	438
11.7 Creating Classes . . . . .	439
11.8 Predefined Accompanying Functions . . . . .	440
11.9 Generic Functions . . . . .	441
11.10 Method . . . . .	446
11.11 Conclusions . . . . .	448
11.12 Exercises . . . . .	448
<b>Answers to Exercises</b>	<b>451</b>
<b>Bibliography</b>	<b>481</b>
<b>Index</b>	<b>495</b>