

# Contents

Preface . . . . .	v
Figures . . . . .	xvii
Tables . . . . .	xxi
<b>1 Introduction</b>	<b>1</b>
1.1 The History of S and S-PLUS . . . . .	2
1.2 S-PLUS on Different Operating Systems . . . . .	4
1.3 Notational Conventions . . . . .	6
<b>2 Graphical User Interface</b>	<b>9</b>
2.1 Introduction . . . . .	9
2.2 System Overview . . . . .	10
2.2.1 Using a Mouse . . . . .	11
2.2.2 Object Explorer . . . . .	11
2.2.3 Commands Window . . . . .	11
2.2.4 Toolbars . . . . .	12
2.2.5 Graph Sheets . . . . .	12
2.2.6 Script Window . . . . .	12
2.3 Getting Started with the Interface . . . . .	13
2.3.1 Importing Data . . . . .	13
2.3.2 Graphs . . . . .	13
2.3.3 Data and Statistics . . . . .	15
2.3.4 Customizing the Toolbars . . . . .	15
2.3.5 Chapters . . . . .	16
2.4 Detailed Use of the GUI Interface . . . . .	18

2.5	Object Explorer . . . . .	18
2.6	Help . . . . .	19
2.7	Data Export . . . . .	21
2.8	Working Directory . . . . .	23
2.9	Data Import . . . . .	24
2.10	Data Summaries . . . . .	27
2.11	Graphs . . . . .	29
2.12	Trellis Graphs . . . . .	36
2.13	Linear Regression . . . . .	38
2.14	PowerPoint (Windows Only) . . . . .	42
2.15	Excel (Windows Only) . . . . .	44
2.16	Script Window . . . . .	45
2.17	UNIX/Linux GUI . . . . .	47
2.18	Summary . . . . .	56
2.19	Exercises . . . . .	57
2.20	Solutions . . . . .	58
<b>3</b>	<b>A First Session</b>	<b>73</b>
3.1	General Information . . . . .	73
3.1.1	Starting and Quitting . . . . .	74
3.1.2	The Help System . . . . .	75
3.1.3	Before Beginning . . . . .	75
3.2	Simple Structures . . . . .	76
3.2.1	Arithmetic Operators . . . . .	76
3.2.2	Assignments . . . . .	77
3.2.3	The Concatenate Command: <code>c</code> . . . . .	79
3.2.4	The Sequence Command: <code>seq</code> . . . . .	80
3.2.5	The Replicate Command: <code>rep</code> . . . . .	81
3.3	Mathematical Operations . . . . .	82
3.4	Use of Brackets . . . . .	84
3.5	Logical Values . . . . .	85
3.6	Review . . . . .	88
3.7	Exercises . . . . .	91
3.8	Solutions . . . . .	92
<b>4</b>	<b>A Second Session</b>	<b>95</b>
4.1	Constructing and Manipulating Data . . . . .	95
4.1.1	Matrices . . . . .	96
4.1.2	Arrays . . . . .	101
4.1.3	Data Frames . . . . .	104
4.1.4	Lists . . . . .	107
4.2	Introduction to Functions . . . . .	108
4.3	Introduction to Missing Values . . . . .	109
4.4	Merging Data . . . . .	110
4.5	Putting It All Together . . . . .	111

4.6	Exercises . . . . .	114
4.7	Solutions . . . . .	116
<b>5</b>	<b>Graphics</b>	<b>125</b>
5.1	Basic Graphics Commands . . . . .	125
5.2	Graphics Devices . . . . .	126
5.2.1	Working with Multiple Graphics Devices . . . . .	128
5.3	Plotting Data . . . . .	128
5.3.1	The <code>plot</code> Command . . . . .	129
5.3.2	Modifying the Data Display . . . . .	130
5.3.3	Modifying Figure Elements . . . . .	131
5.4	Adding Elements to Existing Plots . . . . .	133
5.4.1	Functions to Add Elements to Graphs . . . . .	133
5.4.2	More About <code>abline</code> . . . . .	135
5.4.3	More on Adding Axes . . . . .	135
5.4.4	Adding Text to Graphs . . . . .	137
5.5	Setting Options . . . . .	138
5.6	Figure Layouts . . . . .	140
5.6.1	Layouts Using Trellis Graphs . . . . .	140
5.6.2	Matrices of Graphs . . . . .	140
5.6.3	Multiple-Screen Graphs . . . . .	141
5.6.4	Figures of Specified Size . . . . .	142
5.7	Exercises . . . . .	145
5.8	Solutions . . . . .	146
<b>6</b>	<b>Trellis Graphics</b>	<b>153</b>
6.1	An Example . . . . .	154
6.2	Trellis Basics . . . . .	156
6.2.1	Trellis Syntax . . . . .	156
6.2.2	Trellis Functions . . . . .	157
6.2.3	Displaying and Storing Graphs . . . . .	157
6.3	Output Devices . . . . .	158
6.4	Customizing Trellis Graphs . . . . .	160
6.4.1	Setting Options . . . . .	160
6.4.2	Arranging the Layout of a Trellis Graph . . . . .	161
6.4.3	Ordering of Graphs . . . . .	163
6.4.4	Axis Customization . . . . .	164
6.4.5	Modifying Panel Strips . . . . .	165
6.4.6	Arranging Several Graphs on a Single Page . . . . .	165
6.4.7	Updating Existing Trellis Graphs . . . . .	167
6.4.8	Writing Panel Functions . . . . .	168
6.5	Further Trellis Hints . . . . .	171
6.5.1	Useful General Trellis Settings . . . . .	172
6.5.2	Graphing Individual Profiles . . . . .	173
6.5.3	Preparing Data to Use for Trellis . . . . .	174

6.5.4	The subset Option . . . . .	175
6.5.5	Adding a Key . . . . .	175
6.5.6	The subscripts Option in Panel Functions . . . . .	177
6.6	Exercises . . . . .	181
6.7	Solutions . . . . .	183
<b>7</b>	<b>Exploring Data</b>	<b>193</b>
7.1	Descriptive Data Exploration . . . . .	193
7.2	Graphical Exploration . . . . .	204
7.2.1	Interactive Dynamic Graphics . . . . .	219
7.2.2	Old-Style Graphics . . . . .	219
7.3	Distributions and Related Functions . . . . .	220
7.4	Confirmatory Statistics and Hypothesis Testing . . . . .	225
7.5	Missing and Infinite Values . . . . .	231
7.5.1	Testing for Missing Values . . . . .	232
7.5.2	Supplying Data with Missing Values to Functions . . . . .	232
7.5.3	Missing Values in Graphs . . . . .	233
7.5.4	Infinite Values . . . . .	233
7.6	Exercises . . . . .	235
7.7	Solutions . . . . .	238
<b>8</b>	<b>Statistical Modeling</b>	<b>251</b>
8.1	Introductory Examples . . . . .	251
8.1.1	Regression . . . . .	251
8.1.2	Regression Diagnostics . . . . .	253
8.2	Statistical Models . . . . .	255
8.3	Model Syntax . . . . .	256
8.4	Regression . . . . .	257
8.4.1	Linear Regression and Modeling Techniques . . . . .	258
8.4.2	ANOVA . . . . .	261
8.4.3	Logistic Regression . . . . .	263
8.4.4	Survival Data Analysis . . . . .	265
8.4.5	Endnote . . . . .	267
8.5	Exercises . . . . .	268
8.6	Solutions . . . . .	271
<b>9</b>	<b>Programming</b>	<b>285</b>
9.1	Lists . . . . .	285
9.1.1	Adding and Deleting List Elements . . . . .	287
9.1.2	Naming List Elements . . . . .	288
9.1.3	Applying the Same Function to List Elements . . . . .	290
9.1.4	Unlisting a List . . . . .	294
9.1.5	Generating a List by Using <code>split</code> . . . . .	294
9.2	Writing Functions . . . . .	294
9.2.1	Documenting Functions . . . . .	297

9.2.2	Scope of Variables . . . . .	297
9.2.3	Parameters and Defaults . . . . .	298
9.2.4	Passing an Unspecified Number of Parameters to a Function . . . . .	300
9.2.5	Testing for Existence of an Argument . . . . .	301
9.2.6	Returning Warnings and Errors . . . . .	301
9.2.7	Using Function Arguments in Graphics Labels . .	302
9.3	Iteration . . . . .	303
9.3.1	The <code>for</code> Loop . . . . .	303
9.3.2	The <code>while</code> Loop . . . . .	304
9.3.3	The <code>repeat</code> Loop . . . . .	305
9.3.4	Vectorizing a Loop . . . . .	305
9.3.5	Large Loops . . . . .	307
9.4	Debugging: Searching for Errors . . . . .	308
9.4.1	Syntax Errors . . . . .	309
9.4.2	Invalid Arguments . . . . .	310
9.4.3	Execution or Run-Time Errors . . . . .	310
9.4.4	Logical Errors . . . . .	311
9.5	Output Using the <code>cat</code> Function . . . . .	314
9.6	The <code>paste</code> Function . . . . .	316
9.7	Exercises . . . . .	318
9.8	Solutions . . . . .	319
<b>10</b>	<b>Object-Oriented Programming</b>	<b>323</b>
10.1	Creating Classes and Objects . . . . .	325
10.2	Creating Methods . . . . .	328
10.3	Debugging . . . . .	333
10.4	Help . . . . .	334
10.5	Summary and Overview . . . . .	334
10.6	Exercises . . . . .	335
10.7	Solutions . . . . .	336
<b>11</b>	<b>Input and Output</b>	<b>349</b>
11.1	Reading S-PLUS Commands from a File: The <code>source</code> Function . . . . .	349
11.2	Data Import/Export: Easiest Method . . . . .	350
11.3	Data Import/Export: General Method . . . . .	352
11.4	Data Import/Export: Basic Method . . . . .	353
11.5	Reading Data from the Terminal . . . . .	354
11.6	Editing Data . . . . .	355
11.7	Transferring Data . . . . .	356
11.8	Recording a Session . . . . .	356
11.9	Exercises . . . . .	358
11.10	Solutions . . . . .	359

<b>12 Tips and Tricks</b>	<b>363</b>
12.1 Useful Techniques . . . . .	363
12.1.1 Housekeeping: Cleaning Up Directories . . . . .	363
12.1.2 Storing and Restoring Graphical Parameters . . . . .	364
12.1.3 Naming of Objects . . . . .	364
12.1.4 Repeating Commands . . . . .	365
12.2 Programming Environment and Techniques . . . . .	366
12.2.1 The Process of Developing a Function . . . . .	366
12.2.2 Setting up an Editor and Running the Code in S-PLUS . . . . .	366
12.2.3 Treating Data Frames as Lists . . . . .	368
12.2.4 Working with Graph Sheets . . . . .	369
12.2.5 Incorporating and Accessing C and Fortran Pro- grams . . . . .	371
12.2.6 Batch Jobs . . . . .	374
12.2.7 Libraries . . . . .	376
12.3 Factors . . . . .	378
12.3.1 Creating Factors and Ordered Factors . . . . .	378
12.3.2 Internal Representation of Factors . . . . .	380
12.3.3 Where Levels Play a Role . . . . .	381
12.3.4 Where Factors Can Lead Their Own Lives . . . . .	382
12.3.5 How Factors Come Into Life . . . . .	384
12.3.6 Adding and Dropping Factor Levels . . . . .	385
12.4 Including Graphs in Text Processors . . . . .	386
12.4.1 Generating Graphs for Windows Applications . . . . .	387
12.4.2 Generating PostScript Graphs . . . . .	388
12.4.3 PostScript Graphs in L <sup>A</sup> T <sub>E</sub> X . . . . .	389
12.4.4 If You Don't Have a PostScript Printer . . . . .	390
12.4.5 Greek Letters in Graphs . . . . .	390
12.5 Exercises . . . . .	392
12.6 Solutions . . . . .	394
<b>13 S-Plus Internals</b>	<b>401</b>
13.1 How S-PLUS Works Under UNIX . . . . .	401
13.1.1 The Working Chapter . . . . .	402
13.1.2 Customization on Start-Up and Exit . . . . .	402
13.2 How S-PLUS Works Under Windows . . . . .	404
13.2.1 Command Line Options . . . . .	404
13.2.2 Start-up and Exit Functions . . . . .	405
13.2.3 How the Script Window works . . . . .	406
13.3 Storing Mechanism . . . . .	407
13.4 Levels of Calls . . . . .	408
13.5 Exercises . . . . .	410
13.6 Solutions . . . . .	411

<b>14 Information Sources on and Around S-Plus</b>	<b>413</b>
14.1 Insightful . . . . .	413
14.2 S-News: Exchanging Information with Other Users . . .	414
14.3 The StatLib Server . . . . .	414
14.4 What Next? . . . . .	415
<b>15 R</b>	<b>417</b>
15.1 Development . . . . .	418
15.2 Some Similarities Between R and S . . . . .	418
15.3 Some Differences Between R and S . . . . .	418
15.3.1 Language . . . . .	419
15.3.2 Libraries . . . . .	420
15.3.3 Trellis-Type Graphs . . . . .	420
15.3.4 Colors and Lines . . . . .	421
15.3.5 Data Import and Export Formats . . . . .	421
15.3.6 Memory Handling . . . . .	421
15.3.7 Mathematical Formulae in Graphs . . . . .	421
15.3.8 Graphical User Interfaces . . . . .	421
15.3.9 Start-Up Mechanism . . . . .	422
15.3.10 Windows Integration . . . . .	422
15.3.11 Support . . . . .	422
15.4 Summary . . . . .	423
<b>16 Bibliography</b>	<b>425</b>
16.1 Print Bibliography . . . . .	425
16.2 On-Line Bibliography . . . . .	427
16.2.1 S-PLUS Related Sources . . . . .	427
16.2.2 T <sub>E</sub> X-Related Sources . . . . .	429
16.2.3 Other Sources . . . . .	429
<b>Index</b>	<b>431</b>