Wiley Trading Series

EUGENE A. DURENARD

PROFESSIONAL AUTOMATED TRADING

THEORY AND PRACTICE

WILEY

Praise for

Professional Automated Trading

"*Professional Automated Trading* is a unique insight into the highly secretive world of automated trading. Eugene Durenard is uniquely qualified as its author—he not only has the direct experience of cutting-edge technology and the highly technical expertise to push it to its limits, but he also has a unique gift for communicating highly complex ideas in a manner that even a layman can easily understand. All of the techniques actively used in the field are discussed in detail in this book—even highly experienced automated traders will benefit from Eugene's insights. I don't think there is a more comprehensive guide available than this—it covers all aspects of automated trading, from database construction to management of a quantitative hedge fund. Many of the topics covered here are 'inside secrets' that practitioners rarely reveal."

—BUFORD SCOTT, Global Head of Alternative Asset Group, Standard Chartered Bank, London

"*Professional Automated Trading: Theory and Practice* is a most welcome reference book on the subject of systematic trading. This book by Eugene Durenard covers the theory, practices, and technologies of the field. Systematic trading is undoubtedly a growing part of the financial markets in large institutions as well as in privately run hedge funds, and Eugene's book gives a transparent and solid analysis of a subject that appears mysterious to many people."

—BERNARD SAINT-DONAT, top mathematician, former academic, and active investor running a large family office in New York City

Cover Design: Paul McCarthy
Cover Illustration: © iStockphoto.com / ideiadois

Subscribe to our free Trading eNewsletter at wiley.com/enewsletters

Visit wileyfinance.com

WILEY

Also available as an e-book

$95.00 USA / $105.00 CAN

ISBN 978-1-118-12985-2

59500

9 781118 129852

Trading is a science based on a variety of fields, from mathematics to physics. It is also an art based on knowing and respecting the markets and, equally important, knowing oneself. But most of all, trading is a business that hinges on a carefully understood discipline and process of seeking reward in the face of risk.

No one is more familiar with this than author Eugene Durenard. A recognized expert in automated trading—who has long incorporated aspects of artificial life and robotics systems research into his trading—he knows what it takes to create systematic trading strategies that are adaptive and opportunistic. Now, with this new book, he shares those valuable insights with you. Whether you're part of a professional prop trading desk or an ambitious individual trader, this practical guide will put you in a better position to successfully navigate today's competitive markets.

Divided into four comprehensive parts, *Professional Automated Trading: Theory and Practice* opens with an introductory chapter that sets the stage for modern systematic trading. It critically examines the merits of systematic trading from a philosophical and psychological perspective, as well as focuses on it as a business activity.

With this information in hand, Durenard moves on to skillfully cover the theory, practice, and technologies needed to excel at this endeavor.

- **Part I** introduces the basic conceptual and programmatic framework for the design of trading strategies as trading agents—exploring data representation, indicators, basic model types, and techniques to test them

[CONTINUED ON BACK FLAP]

[CONTINUED FROM FRONT FLAP]

- **Part II** introduces innovative concepts designed to tackle adaptation of trading strategies to changing market conditions. Those include Swarm Systems that help navigate the higher complexity of the markets at lower timescales
- **Part III** focuses on the important aspect of trading costs and slippage—discussing the analysis of the intraday bid-offer and volume seasonality in major markets and detailing several algorithmic execution strategies designed to help reduce market impact
- **Part IV** presents the practical implementation of a real-time, low-latency automated trading infrastructure designed to support a Swarm of Trading Agents operating on a collection of Electronic Commerce Networks (ECNs)

Engaging and accessible, *Professional Automated Trading* contains the information you need to make the most of automated trading in free markets.

EUGENE A. DURENARD is CEO of DTC Ltd in Bermuda, a firm that specializes in applying systematic techniques to leveraged and real money trading across a wide variety of asset classes. DTC has been acting over the years as investment advisor and manager for a range of institutions including banks, hedge funds, and proprietary trading groups. DTC is currently advising Capital G, the largest private bank in Bermuda, where Eugene acts as Head of Research and Product Development. Eugene is a partner and CIO of ERA Capital Partners, a Chicago-based quantitative systematic Proprietary Trading Group.

l system, or transmitted in any form or
inning, or otherwise, except as permitted
, without either the prior written
he appropriate per-copy fee to the
MA 01923, (978) 750-8400,
its to the Publisher for permission should
nc., 111 River Street, Hoboken,
//www.wiley.com/go/permissions.

author have used their best efforts in
ith respect to the accuracy or
any implied warranties of
ay be created or extended by sales
contained herein may not be suitable
ppropriate. Neither the publisher nor
l damages, including but not limited to

echnical support, please contact our
2974, outside the United States at

print-on-demand. Some material
ided in e-books or in print-on-demand.
led in the version you purchased, you
nore information about Wiley products,

Contents

Preface xv

CHAPTER 1
Introduction to Systematic Trading 1
1.1 Definition of Systematic Trading 2
1.2 Philosophy of Trading 3
1.2.1 Lessons from the Market 3
1.2.2 Mechanism vs. Organism 5
1.2.3 The Edge of Complexity 5
1.2.4 Is Systematic Trading Reductionistic? 6
1.2.5 Reaction vs. Proaction 6
1.2.6 Arbitrage? 7
1.2.7 Two Viable Paths 7
1.3 The Business of Trading 7
1.3.1 Profitability and Track Record 8
1.3.2 The Product and Its Design 10
1.3.3 The Trading Factory 12
1.3.4 Marketing and Distribution 15
1.3.5 Capital, Costs, and Critical Mass 16
1.4 Psychology and Emotions 19
1.4.1 Ups and Downs 19
1.4.2 Peer Pressure and the Blame Game 20
1.4.3 Trust: Continuity of Quality 20
1.4.4 Learning from Each Other 21
1.5 From Candlesticks in Kyoto to FPGAs in Chicago 22

PART ONE
Strategy Design and Testing

CHAPTER 2
A New Socioeconomic Paradigm 33
2.1 Financial Theory vs. Market Reality 33
2.1.1 Adaptive Reactions vs. Rigid Anticipations 33

2.1.2 Accumulation vs. Divestment Games 37
2.1.3 Phase Transitions under Leverage 38
2.1.4 Derivatives: New Risks Do Not Project onto Old Hedges 40
2.1.5 Socio-Political Dynamics and Feedbacks 41
2.2 The Market Is a Complex Adaptive System 42
2.2.1 Emergence 43
2.2.2 Intelligence Is Not Always Necessary 44
2.2.3 The Need to Adapt 45
2.3 Origins of Robotics and Artificial Life 45

CHAPTER 3
Analogies between Systematic Trading and Robotics **49**
3.1 Models and Robots 49
3.2 The Trading Robot 50
3.3 Finite-State-Machine Representation of the Control System 52

CHAPTER 4
Implementation of Strategies as Distributed Agents **57**
4.1 Trading Agent 57
4.2 Events 60
4.3 Consuming Events 60
4.4 Updating Agents 61
4.5 Defining FSM Agents 63
4.6 Implementing a Strategy 66

CHAPTER 5
Inter-Agent Communications **73**
5.1 Handling Communication Events 73
5.2 Emitting Messages and Running Simulations 75
5.3 Implementation Example 76

CHAPTER 6
Data Representation Techniques **83**
6.1 Data Relevance and Filtering of Information 83
6.2 Price and Order Book Updates 84
6.2.1 Elementary Price Events 85
6.2.2 Order Book Data 85
6.2.3 Tick Data: The Finest Grain 88
6.3 Sampling: Clock Time vs. Event Time 89

[CONTINUED ON BACK FLAP]

6.4 Compression
6.4.1 Slicing Tim
6.4.2 Slicing Pric
6.4.3 Market Di
6.5 Representation
6.5.1 Charts and
6.5.2 Translating
6.5.3 Translating
6.5.4 Psychology

CHAPTER 7
Basic Trading Strategies
7.1 Trend-Following
7.1.1 Channel Br
7.1.2 Moving Av
7.1.3 Swing Brea
7.2 Acceleration
7.2.1 Trend Asyr
7.2.2 The Shado
7.2.3 Trading Ac
7.3 Mean-Reversion
7.3.1 Swing Reve
7.3.2 Range Proj
7.4 Intraday Patterns
7.4.1 Openings
7.4.2 Seasonality
7.5 News-Driven Strat
7.5.1 Expectatio
7.5.2 Ontology-I

CHAPTER 8
Architecture for Market-I
8.1 Traditional Marke
8.2 Conditional Mark
8.3 Electronic Market-
8.4 Mixed Market-Ma
8.5 An Architecture fo

CHAPTER 9
Combining Strategies into
9.1 Aggregate Agents
9.2 Optimal Portfolic
9.3 Risk-Managemen

Games 37
ge 38
t Project onto
40
eedbacks 41
stem 42
43
essary 44
45
45

otics 49
49
50
f the
52

nts 57
57
60
60
61
63
66

73
73

75
76

83
nation 83
84
85
85
88
89

6.4 Compression 90
6.4.1 Slicing Time into Bars and Candles 90
6.4.2 Slicing Price into Boxes 96
6.4.3 Market Distributions 97
6.5 Representation 97
6.5.1 Charts and Technical Analysis 99
6.5.2 Translating Patterns into Symbols 101
6.5.3 Translating News into Numbers 102
6.5.4 Psychology of Data and Alerts 104

CHAPTER 7
Basic Trading Strategies **105**
7.1 Trend-Following 105
7.1.1 Channel Breakout 106
7.1.2 Moving Averages 106
7.1.3 Swing Breakout 112
7.2 Acceleration 114
7.2.1 Trend Asymmetry 115
7.2.2 The Shadow Index 116
7.2.3 Trading Acceleration 117
7.3 Mean-Reversion 118
7.3.1 Swing Reversal 118
7.3.2 Range Projection 120
7.4 Intraday Patterns 122
7.4.1 Openings 122
7.4.2 Seasonality of Volatility 122
7.5 News-Driven Strategies 124
7.5.1 Expectations vs. Reality 124
7.5.2 Ontology-Driven Strategies 125

CHAPTER 8
Architecture for Market-Making **127**
8.1 Traditional Market-Making: The Specialists 127
8.2 Conditional Market-Making: Open Outcry 128
8.3 Electronic Market-Making 129
8.4 Mixed Market-Making Model 131
8.5 An Architecture for a Market-Making Desk 134

CHAPTER 9
Combining Strategies into Portfolios **139**
9.1 Aggregate Agents 139
9.2 Optimal Portfolios 141
9.3 Risk-Management of a Portfolio of Models 142

CHAPTER 10
Simulating Agent-Based Strategies 145
10.1 The Simulation Problem 146
10.2 Modeling the Order Management System 147
10.2.1 Orders and Algorithms 148
10.2.2 Simulating Slippage 149
10.2.3 Simulating Order Placement 151
10.2.4 Simulating Order Execution 153
10.2.5 A Model for the OMS 155
10.2.6 Operating the OMS 156
10.3 Running Simulations 158
10.3.1 Setting Up a Back Test 158
10.3.2 Setting Up a Forward Test 160
10.4 Analysis of Results 162
10.4.1 Continuous Statistics 163
10.4.2 Per-Trade Statistics 164
10.4.3 Parameter Search and Optimization 165
10.5 Degrees of Over-Fitting 167

PART TWO
Evolving Strategies

CHAPTER 11
Strategies for Adaptation 173
11.1 Avenues for Adaptations 173
11.2 The Cybernetics of Trading 175

CHAPTER 12
Feedback and Control 179
12.1 Looking at Markets through Models 179
12.1.1 Internal World 179
12.1.2 Strategies as Generalized Filters 180
12.1.3 Implicit Market Regimes 181
12.1.4 Persistence of Regimes 183
12.2 Fitness Feedback Control 184
12.2.1 Measures of Fitness 186
12.3 Robustness of Strategies 192
12.4 Efficiency of Control 193
12.4.1 Triggering Control 193
12.4.2 Measuring Efficiency of Control 194

12.4.3 Test Re
12.4.4 Optimiz

CHAPTER 13
Simple Swarm Systems
13.1 Switching Strateg
13.1.1 Switchi
13.1.2 Switchi
13.1.3 Mechan
13.2 Strategy Neighbo
13.3 Choice of a Simp
13.4 Additive Swarm S
13.4.1 Exampl
13.5 Maximizing Swa
13.5.1 Exampl
13.6 Global Performar

CHAPTER 14
Implementing Swarm Syst
14.1 Setting Up the Sw
14.2 Running the Swa

CHAPTER 15
Swarm Systems with Lear
15.1 Reinforcement Le
15.2 Swarm Efficiency
15.3 Behavior Exploita
15.4 Exploring New B
15.5 Lamark among th

PART THREE
Optimizing Execution

CHAPTER 16
Analysis of Trading Costs
16.1 No Free Lunch
16.2 Slippage
16.3 Intraday Seasonali
16.4 Models of Market
16.4.1 Reaction
16.4.2 Limits to

145
146
stem 147
148
149
: 151
153
155
156
158
158
160
162
163
164
nization 165
167

173
173
175

179
179
179
lters 180
181
183
184
186
192
193
193
ntrol 194

12.4.3 Test Results 196
12.4.4 Optimizing Control Parameters 197

CHAPTER 13
Simple Swarm Systems **199**
13.1 Switching Strategies 199
13.1.1 Switching between Regimes 200
13.1.2 Switching within the Same Regime 200
13.1.3 Mechanics of Switching and Transaction Costs 205
13.2 Strategy Neighborhoods 206
13.3 Choice of a Simple Individual from a Population 208
13.4 Additive Swarm System 210
13.4.1 Example of an Additive Swarm 211
13.5 Maximizing Swarm System 214
13.5.1 Example of a Maximizing Swarm 215
13.6 Global Performance Feedback Control 216

CHAPTER 14
Implementing Swarm Systems **219**
14.1 Setting Up the Swarm Strategy Set 220
14.2 Running the Swarm 220

CHAPTER 15
Swarm Systems with Learning **223**
15.1 Reinforcement Learning 224
15.2 Swarm Efficiency 224
15.3 Behavior Exploitation by the Swarm 225
15.4 Exploring New Behaviors 227
15.5 Lamark among the Machines 227

PART THREE
Optimizing Execution

CHAPTER 16
Analysis of Trading Costs **231**
16.1 No Free Lunch 231
16.2 Slippage 232
16.3 Intraday Seasonality of Liquidity 233
16.4 Models of Market Impact 234
16.4.1 Reaction to Aggression 235
16.4.2 Limits to Openness 235

CHAPTER 17
Estimating Algorithmic Execution Tools 237
17.1 Basic Algorithmic Execution Tools 237
17.2 Estimation of Algorithmic Execution Methodologies 240
17.2.1 A Simulation Engine for Algos 240
17.2.2 Using Execution Algo Results in Model Estimation 241
17.2.3 Joint Testing of Models and Algos 242

PART FOUR
Practical Implementation

CHAPTER 18
Overview of a Scalable Architecture 247
18.1 ECNs and Translation 247
18.2 Aggregation and Disaggregation 249
18.3 Order Management 250
18.4 Controls 250
18.5 Decisions 251
18.6 Middle and Back Office 251
18.7 Recovery 252

CHAPTER 19
Principal Design Patterns 253
19.1 Language-Agnostic Domain Model 253
19.2 Solving Tasks in Adapted Languages 254
19.3 Communicating between Components 257
19.3.1 Messaging Bus 258
19.3.2 Remote Procedure Calls 259
19.4 Distributed Computing and Modularity 260
19.5 Parallel Processing 262
19.6 Garbage Collection and Memory Control 263

CHAPTER 20
Data Persistence 265
20.1 Business-Critical Data 265
20.2 Object Persistence and Cached Memory 267
20.3 Databases and Their Usage 269

CHAPTER 21
Fault Tolerance and Recove
21.1 Situations of Stres
21.1.1 Commun
21.1.2 External
21.1.3 Trades Bu
21.1.4 Give-Up
21.1.5 Internal S
21.1.6 Planned M
21.2 A Jam of Logs Is B
21.3 Virtual Machine ar

CHAPTER 22
Computational Efficiency
22.1 CPU Spikes
22.2 Recursive Comput and Performance
22.3 Numeric Efficiency

CHAPTER 23
Connectivity to Electronic C
23.1 Adaptors
23.2 The Translation La
23.2.1 Orders: F
23.2.2 Specific E
23.2.3 Price Sou
23.3 Dealing with Later
23.3.1 External
23.3.2 Avoid Bei
23.3.3 Synchroni
23.3.4 Improving

CHAPTER 24
The Aggregation and Disaggr
24.1 Quotes Filtering an
24.1.1 Filtering
24.1.2 Synthetic
24.2 Orders Aggregatio
24.2.1 Aggregati
24.2.2 Fills Disag
24.2.3 Book Trar

237
237
ı
240
gos 240
ılts in Model
241
d Algos 242

247
247
249
250
250
251
251
252

253
253
s 254
ıts 257
258
259
ırity 260
262
ontrol 263

265
265
ıory 267
269

CHAPTER 21
Fault Tolerance and Recovery Mechanisms **273**
21.1 Situations of Stress 273
21.1.1 Communication Breakdown 273
21.1.2 External Systems Breakdown 274
21.1.3 Trades Busted at the ECN Level 275
21.1.4 Give-Up Errors Causing Credit Line Problems 276
21.1.5 Internal Systems Breakdown 277
21.1.6 Planned Maintenance and Upgrades 277
21.2 A Jam of Logs Is Better Than a Logjam of Errors 277
21.3 Virtual Machine and Network Monitoring 278

CHAPTER 22
Computational Efficiency **281**
22.1 CPU Spikes 281
22.2 Recursive Computation of Model Signals and Performance 282
22.3 Numeric Efficiency 285

CHAPTER 23
Connectivity to Electronic Commerce Networks **291**
23.1 Adaptors 291
23.2 The Translation Layer 292
23.2.1 Orders: FIX 292
23.2.2 Specific ECNs 293
23.2.3 Price Sources: FAST 293
23.3 Dealing with Latency 294
23.3.1 External Constraints and Co-Location 294
23.3.2 Avoid Being Short the Latency Option 295
23.3.3 Synchronization under Constraints 296
23.3.4 Improving Internal Latency 297

CHAPTER 24
The Aggregation and Disaggregation Layer **299**
24.1 Quotes Filtering and Book Aggregation 300
24.1.1 Filtering Quotes 300
24.1.2 Synthetic Order Book 301
24.2 Orders Aggregation and Fills Disaggregation 301
24.2.1 Aggregating Positions and Orders 301
24.2.2 Fills Disaggregation 303
24.2.3 Book Transfers and Middle Office 303

CHAPTER 25
The OMS Layer **305**
25.1 Order Management as a Recursive Controller 305
25.1.1 Management of Positions 307
25.1.2 Management of Resting Orders 307
25.1.3 Algorithmic Orders 308
25.2 Control under Stress 309
25.3 Designing a Flexible OMS 310

CHAPTER 26
The Human Control Layer **311**
26.1 Dashboard and Smart Scheduler 311
26.1.1 Parameter Control 311
26.1.2 Scheduled Flattening of Exposure 312
26.2 Manual Orders Aggregator 313
26.2.1 Representing a Trader by an Agent 313
26.2.2 Writing a Trading Screen 314
26.2.3 Monitoring Aggregated Streams 314
26.3 Position and P & L Monitor 314
26.3.1 Real-Time Exposure Monitor 315
26.3.2 Displaying Equity Curves 315
26.3.3 Online Trade Statistics and Fitnesses 315
26.3.4 Trades Visualization Module 317

CHAPTER 27
The Risk Management Layer **319**
27.1 Risky Business 319
27.2 Automated Risk Management 320
27.3 Manual Risk Control and the Panic Button 320

CHAPTER 28
The Core Engine Layer **323**
28.1 Architecture 323
28.2 Simulation and Recovery 325

CHAPTER 29
Some Practical Implementation Aspects **327**
29.1 Architecture for Build and Patch Releases 327
29.1.1 Testing of Code before a Release 327
29.1.2 Versioning of Code and Builds 328
29.1.3 Persistence of State during Version Releases 328

29.2 Hardware Consi
29.2.1 Bottlene
29.2.2 The Edg

Appendix
Auxiliary LISP Functions

Bibliography

Index

305
Controller 305
307
Orders 307
308
309
310

311
311
311
xposure 312
313
an Agent 313
314
treams 314
314
itor 315
315
d Fitnesses 315
lule 317

319
319
320
c Button 320

323
323
325

327
eleases 327
Release 327
uilds 328
g Version Releases 328

29.2 Hardware Considerations 329
29.2.1 Bottleneck Analysis 329
29.2.2 The Edge of Technology 330

Appendix
Auxiliary LISP Functions **333**

Bibliography **341**

Index **351**