

✓ 4A9 526 0652

Statistically Sound Machine Learning for Algorithmic Trading of Financial Instruments

Developing Predictive-Model-Based Trading Systems
Using *TSSB*

David Aronson

with

Timothy Masters, Ph.D.
Technical Advisor

Edition 1.20

Table of Contents

Introduction	1
Two Approaches to Automated Trading	1
Predictive Modeling	2
Indicators and Targets	3
Converting Predictions to Trade Decisions	4
Testing the Trading System	5
Walkforward Testing	7
Cross Validation	9
Overlap Considerations	10
Performance Criteria	11
Model Performance Versus Financial Performance	12
Financial Relevance and Generalizability	12
Performance Statistics in <i>TSSB</i>	13
Desirable Program Features	16
A Simple Standalone Trading System	19
The Script File	19
The Audit Log	23
A Walkforward Fold	26
Out-of-Sample Results for This Fold	31
The Walkforward Summary	33
A Simple Filter System	35
The Trade File	35
The Script File	37
The Audit Log	41
Out-of-Sample Results for This Fold	43
The Walkforward Summary	45
Common Initial Commands	47
Market Price Histories and Variables	47
Quick Reference to Initial Commands	48
Detailed Descriptions	50
INTRADAY BY MINUTE	50
INTRADAY BY SECOND	50
MARKET DATE FORMAT YYMMDD	51

MARKET DATE FORMAT M_D_YYYY	51
MARKET DATE FORMAT AUTOMATIC	51
REMOVE ZERO VOLUME	52
READ MARKET LIST	52
READ MARKET HISTORIES	53
MARKET SCAN	54
RETAIN YEARS	55
RETAIN MOD	56
CLEAN RAW DATA	59
INDEX	59
READ VARIABLE LIST	60
OUTLIER SCAN	61
DESCRIBE	62
CROSS MARKET AD	63
CROSS MARKET KL	63
CROSS MARKET IQ	64
STATIONARITY	65
A Final Example	68
Reading and Writing Databases	73
Quick Reference to Database Commands	73
Detailed Descriptions	74
RETAIN MARKET LIST	74
VARIABLE IS TEXT	75
WRITE DATABASE	75
READ DATABASE	76
READ UNORDERED DATABASE	77
APPEND DATABASE	78
IS PROFIT	79
A Saving/Restoring Example	80
Creating Variables	83
Overview and Basic Syntax	83
Index Markets and Derived Variables	84
An Example of IS INDEX and MINUS INDEX	85
Multiple Indices	86
Historical Adjustment to Improve Stationarity	87
Centering	87
Scaling	88
Normalization	89
An Example of Centering, Scaling, and Normalization	89

Cross-Market Normalization	92
Pooled Variables	93
MEDIAN pooling	94
CLUMP60 Pooling	94
Mahalanobis Distance	96
Absorption Ratio	97
Trend Indicators	99
MA DIFFERENCE ShortLength LongLength Lag	99
LINEAR PER ATR HistLength ATRlength	99
QUADRATIC PER ATR HistLength ATRlength	100
CUBIC PER ATR HistLength ATRlength	100
RSI HistLength	101
STOCHASTIC K HistLength	101
STOCHASTIC D HistLength	101
PRICE MOMENTUM HistLength StdDevLength	101
ADX HistLength	102
MIN ADX HistLength MinLength	102
RESIDUAL MIN ADX HistLength MinLength	102
MAX ADX HistLength MaxLength	103
RESIDUAL MAX ADX HistLength MaxLength	103
DELTA ADX HistLength DeltaLength	103
ACCEL ADX HistLength DeltaLength	104
INTRADAY INTENSITY HistLength	104
DELTA INTRADAY INTENSITY HistLength DeltaLength	104
REACTIVITY HistLength	105
DELTA REACTIVITY HistLength DeltaDist	107
MIN REACTIVITY HistLength Dist	107
MAX REACTIVITY HistLength Dist	107
Trend-Like Indicators	108
CLOSE TO CLOSE	108
N DAY HIGH HistLength	108
N DAY LOW HistLength	109
Deviations from Trend	110
CLOSE MINUS MOVING AVERAGE HistLen ATRlen ...	110
LINEAR DEVIATION HistLength	110
QUADRATIC DEVIATION HistLength	111
CUBIC DEVIATION HistLength	111
DETRENDED RSI DetrendedLength DetrenderLength Lookback	112

Volatility Indicators	113
ABS PRICE CHANGE OSCILLATOR ShortLen Multiplier ..	113
PRICE VARIANCE RATIO HistLength Multiplier	114
MIN PRICE VARIANCE RATIO HistLen Mult Mlength	114
CHANGE VARIANCE RATIO HistLength Multiplier	114
MIN CHANGE VARIANCE RATIO HistLen Mult Mlen	115
ATR RATIO HistLength Multiplier	115
DELTA PRICE VARIANCE RATIO HistLength Multiplier	115
DELTA CHANGE VARIANCE RATIO HistLength Multiplier	116
DELTA ATR RATIO HistLength Multiplier	116
BOLLINGER WIDTH HistLength	116
DELTA BOLLINGER WIDTH HistLength DeltaLength ..	117
N DAY NARROWER HistLength	117
N DAY WIDER HistLength	118
Indicators Involving Indices	119
INDEX CORRELATION HistLength	119
DELTA INDEX CORRELATION HistLength DeltaLength ..	119
DEVIATION FROM INDEX FIT HistLength MovAvgLength	120
PURIFIED INDEX Norm HistLen Npred Nfam Nlooks Look1	121
Basic Price Distribution Statistics	123
PRICE SKEWNESS HistLength Multiplier	123
CHANGE SKEWNESS HistLength Multiplier	123
PRICE KURTOSIS HistLength Multiplier	123
CHANGE KURTOSIS HistLength Multiplier	124
DELTA PRICE SKEWNESS HistLen Multiplier DeltaLen ..	124
DELTA CHANGE SKEWNESS HistLen Multiplier DeltaLen	124
DELTA PRICE KURTOSIS HistLen Multiplier DeltaLen	124
DELTA CHANGE KURTOSIS HistLen Multiplier DeltaLen ..	124
Indicators That Significantly Involve Volume	125
VOLUME MOMENTUM HistLength Multiplier	125
DELTA VOLUME MOMENTUM HistLen Multiplier DeltaLen	125
VOLUME WEIGHTED MA OVER MA HistLength	126
DIFF VOLUME WEIGHTED MA OVER MA ShortDist LongDist	126
PRICE VOLUME FIT HistLength	127

DIFF PRICE VOLUME FIT ShortDist LongDist	127
DELTA PRICE VOLUME FIT HistLength DeltaDist	127
ON BALANCE VOLUME HistLength	128
DELTA ON BALANCE VOLUME HistLength DeltaDist ..	128
POSITIVE VOLUME INDICATOR HistLength	129
DELTA POSITIVE VOLUME INDICATOR HistLen DeltaDist	
.....	129
NEGATIVE VOLUME INDICATOR HistLength	129
DELTA NEGATIVE VOLUME INDICATOR HistLen DeltaDist	
.....	129
PRODUCT PRICE VOLUME HistLength	130
SUM PRICE VOLUME HistLength	131
DELTA PRODUCT PRICE VOLUME HistLen DeltaDist ..	131
DELTA SUM PRICE VOLUME HistLen DeltaDist	131
Entropy and Mutual Information Indicators	132
PRICE ENTROPY WordLength	133
VOLUME ENTROPY WordLength	133
PRICE MUTUAL INFORMATION WordLength	133
VOLUME MUTUAL INFORMATION WordLength	134
Indicators Based on Wavelets	135
REAL MORLET Period	137
REAL DIFF MORLET Period	138
REAL PRODUCT MORLET Period	138
IMAG MORLET Period	139
IMAG DIFF MORLET Period	139
IMAG PRODUCT MORLET Period	140
PHASE MORLET Period	140
DAUB MEAN HistLength Level	141
DAUB MIN HistLength Level	141
DAUB MAX HistLength Level	141
DAUB STD HistLength Level	141
DAUB ENERGY HistLength Level	141
DAUB NL ENERGY HistLength Level	142
DAUB CURVE HistLength Level	142
Follow-Through-Index (FTI) Indicators	143
Low-Pass Filtering and FTI Computation	144
Block Size and Channels	144
Essential Parameters for FTI calculation	144
Computing FTI	147
Automated Choice of Filter Period	148
Trends Within Trends	148

FTI Indicators Available in <i>TSSB</i>	150
FTI LOWPASS BlockSize HalfLength Period	150
FTI MINOR LOWPASS BlockSize HalfLength LowPeriod HighPeriod	151
FTI MAJOR LOWPASS BlockSize HalfLength LowPeriod HighPeriod	151
FTI FTI BlockSize HalfLength Period	151
FTI LARGEST FTI BlockSize HalfLength LowPeriod HighPeriod	152
FTI MINOR FTI BlockSize HalfLength LowPeriod HighPeriod	152
FTI MAJOR FTI BlockSize HalfLength LowPeriod HighPeriod	152
FTI LARGEST PERIOD BlockSize HalfLength LowPeriod HighPeriod	153
FTI MINOR PERIOD BlockSize HalfLength LowPeriod HighPeriod	153
FTI MAJOR PERIOD BlockSize HalfLength LowPeriod HighPeriod	153
FTI CRAT BlockSize HalfLength LowPeriod HighPeriod ..	154
FTI MINOR BEST CRAT BlockSize HalfLength LowPeriod HighPeriod	154
FTI MAJOR BEST CRAT BlockSize HalfLength LowPeriod HighPeriod	155
FTI BOTH BEST CRAT BlockSize HalfLength LowPeriod HighPeriod	155
Target Variables	156
NEXT DAY LOG RATIO	156
NEXT DAY ATR RETURN Distance	157
SUBSEQUENT DAY ATR RETURN Lead Distance	157
NEXT MONTH ATR RETURN Distance	157
HIT OR MISS Up Down Cutoff ATRdist	158
FUTURE SLOPE Ahead ATRdist	158
RSQ FUTURE SLOPE Ahead ATRdist	159
Screening Variables	161
Chi-Square Tests	162
Options for the Chi-Square Test	163
Output of the Chi-Square Test	164
Running Chi-Square Tests from the Menu	165
Nonredundant Predictor Screening	167

Options for Nonredundant Predictor Screening	170
Running Nonredundant Predictor Screening from the Menu . .	171
Examples of Nonredundant Predictor Screening	173
Models 1: Fundamentals	179
Overview and Basic Syntax	181
Mandatory Specifications Common to All Models	183
The INPUT list	183
The OUTPUT Specifier	184
Number of Inputs Chosen by Stepwise Selection	184
The Criterion to be Optimized in Indicator Selection	185
A Lower Limit on the Number or Fraction of Trades	189
Summary of Mandatory Specifications for All Models	190
Optional Specifications Common to All Models	191
Mitigating Outliers	191
Testing Multiple Stepwise Indicator Sets	192
Stepwise Indicator Selection With Cross Validation	193
When the Target Does Not Measure Profit	194
Multiple-Market Trades Based on Ranked Predictions	195
Restricting Models to Long or Short Trades	196
Prescreening For Specialist Models	196
Building a Committee with Exclusion Groups	197
Building a Committee with Resampling and Subsampling	199
Avoiding Overlap Bias	200
A Popularity Contest for Indicators	202
Bootstrap Statistical Significance Tests for Performance	204
Monte-Carlo Permutation Tests	206
An Example Using Most Model Specifications	207
Sequential Prediction	208
Models 2: The Models	213
Linear Regression	213
The MODEL CRITERION Specification for LINREG Models	213
The Identity Model	215
Quadratic Regression	216
The General Regression Neural Network	219
The Multiple-Layer Feedforward Network	220
The Number of Neurons in the First Hidden Layer	220
The Number of Neurons in the Second Hidden Layer	221
Functional Form of the Output Neuron	221

The Domain of the Neurons	222
A Basic MLFN Suitable for Most Applications	223
A Complex-Domain MLFN	224
The Basic Tree Model	225
A Forest of Trees	227
Boosted Trees	229
Operation String Models	231
Use of Constants in Operation Strings	233
Split Linear Models for Regime Regression	236
An Ordinary SPLIT LINEAR Model	238
The NOISE Version of the SPLIT LINEAR Model	239
Committees	241
Model Specifications Used by Committees	242
The AVERAGE Committee	244
The LINREG (Linear Regression) Committee	245
Constrained Linear Regression Committee	246
Models as Committees	247
Creating Component Models for Committees	248
Exclusion Groups	249
Explicit Specification of Different Indicators	250
Using Different Selection Criteria	250
Varying the Training Set by Subsampling	251
Varying the Training Set by Resampling	252
Oracles	253
Model Specifications Used by Oracles	254
Traditional Operation of the Oracle	255
Prescreen Operation of the Oracle	257
The HONOR PRESSCREEN Option	257
The PRESSCREEN ONLY Option	257
An Example of Prescreen Operation	259
More Complex Oracles	260
Testing Methods	263
Performance for the Entire Dataset	264
Walkforward Testing	265
Cross Validation by Time Period	266
Cross Validation using a Control Variable	267
Cross Validation by Random Blocks	269
Preserving Predictions for Trade Simulation	270

Market States as Trade Triggers	271
An Example of Simple Triggering	272
Triggering Based on State Change	275
Triggering Versus Prescreening	277
Commands Common to All Four Examples	278
Example 1: Model Specialization via PRESCREEN	280
Example 2: Unguided Specialization	285
Example 3: Triggering on High Volatility	290
Example 4: Triggering on Low Volatility	295
 Permutation Training	 299
The Components of Performance	302
Permutation Training and Selection Bias	306
Multiple-Market Considerations	311
 Transforms	 313
Expression Transforms	315
Quantities That May Be Referenced	316
Vector Operations in Expression Transforms	320
Vector-to-Scalar Functions	321
An Example with the @SIGN_AGE Function	321
Logical Evaluation in Expression Transforms	323
An Example with Logical Expressions	324
A More Complex Example	325
Principal Component Transforms	326
Invoking the Principal Components Transform	327
Tables Printed	328
An Example	329
Linear and Quadratic Regression Transforms	332
A Regression Transform Example	333
The Nominal Mapping Transform	336
Inputs and the Target	336
Gates	337
Focusing on Extreme Targets	338
Declaring the Transform and its Options	338
A Nominal Mapping Example	341
The ARMA Transform	345
The PURIFY Transform	353
Defining the Purified and Purifier Series	353
Specifying the Predictor Functions	355
Miscellaneous Specifications	356

Usage Considerations	357
A Simple Example	359
Complex Prediction Systems	363
Stacking Models and Committees	365
Graphics	371
Series Plot	372
Series + Market	374
Histogram	375
Thresholded Histogram	377
Density Map	380
Bivariate and Trivariate Plots	386
Trivariate Plots	391
Equity	393
Prediction Map	397
Indicator-Target Relationship	400
Isolating Predictability of Direction Versus Magnitude	405
Finding Independent Predictors	407
A FIND GROUPS Demonstration	410
Market Regression Classes	417
REGRESSION CLASS Demonstrations	419
The Hierarchical Method	419
The Sequential Method	423
The Leung Method	427
Developing a Stand-Alone System	431
Choosing Predictor Candidates and the Target	431
Choosing the Target	431
Quality Does Not Equal Quantity for Predictors	434
Predictor and Target Selection for this Study	436
Stationarity	439
The Problem of Outliers	440
Cross-Market Compatibility	442
Data Snooping: Friend or Foe?	444
Checking Stability with Subsampling	445
How Long Does the Model Hold Up?	449
Finding Models for a Committee	451
The Trading System	453

The Final Test	456
Trade Simulation and Portfolios	459
Writing Equity Curves	461
Performance Measures	465
Portfolios (File-Based Version)	466
A Portfolio Example	470
Integrated Portfolios	479
A FIXED Portfolio Example	482
An OOS Portfolio Example	483