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FHDW Fachhochschule der Wirtschaft

LEADERS IN IDEAS AND SOLUTIONS

Automating Robustness Analysis of Trading Strategy Development Processes

DBA research by Edwin Stang

May 2021: Work in Progress

Supervisors:

Hans-Wolfgang Loidl, Boulis Ibrahim

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Agenda

1. Idea
2. Development Progress
3. Expression Language
4. Possible uses
5. Signal vs Breakout Strategies

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1. Idea

- Automate Trading Strategy Development
- Formalise Decision Points
  - Strategy (When to Buy/Sell)
  - Risk & Money Management (Scaling Profit vs Loss)
  - Portfolio & Higher Level (Handling Multiple Strategies)
- Simulate a Team of Random Developers
  - Automated Strategy Generation (Evolutionary Machine Learning)
- Automated Longitudinal Study
  - Walk-Forward-Analysis (here 16 Years in 1 Market)
- Measure Robustness of the Process
  - Monte Carlo Significance Test

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2. Development Progress

- Working on Trading Platform since 2009
  - Modular Architecture, designed for Reuse and Flexibility; Ideal Basis for Research
- Extend with ML Features in DBA
  - Explainable AI
    (Debuggable in Code & UI)
  - Expression Language for Decision Points
    (Domain Specific Language)
  - High Performance Backtesting Engine

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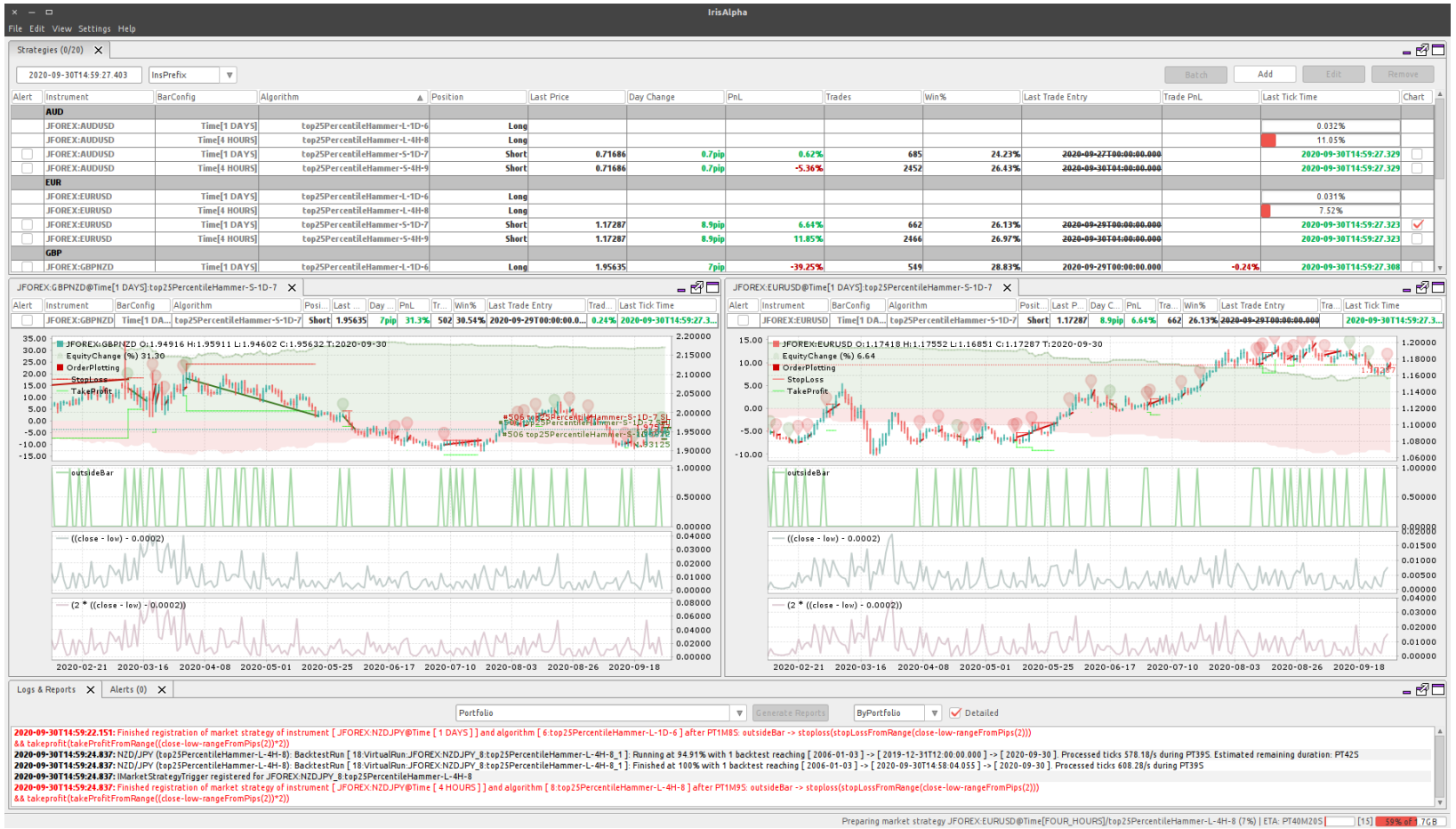
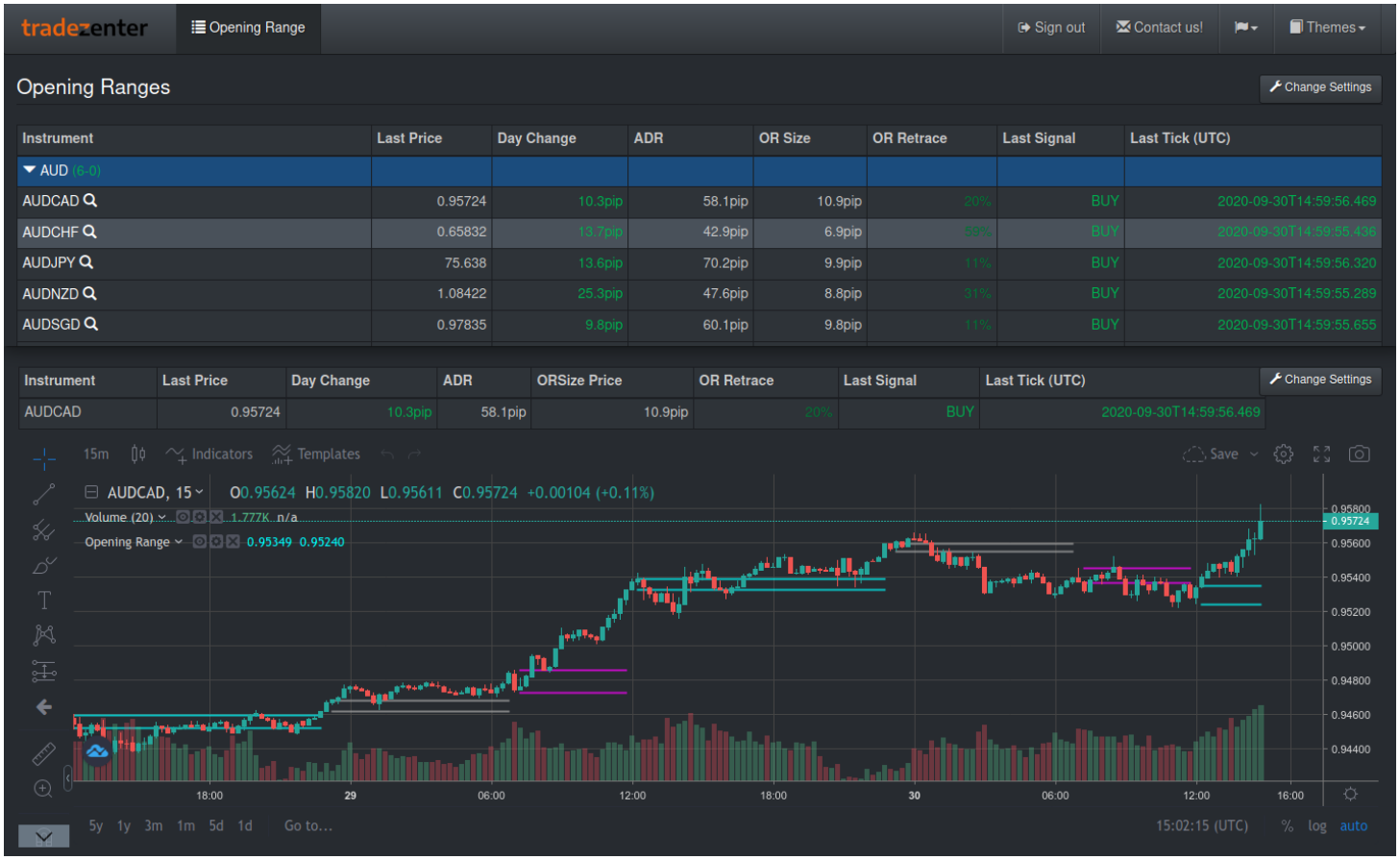
2.1. Frontends: Desktop Apps



2.2. Frontends: Web Apps



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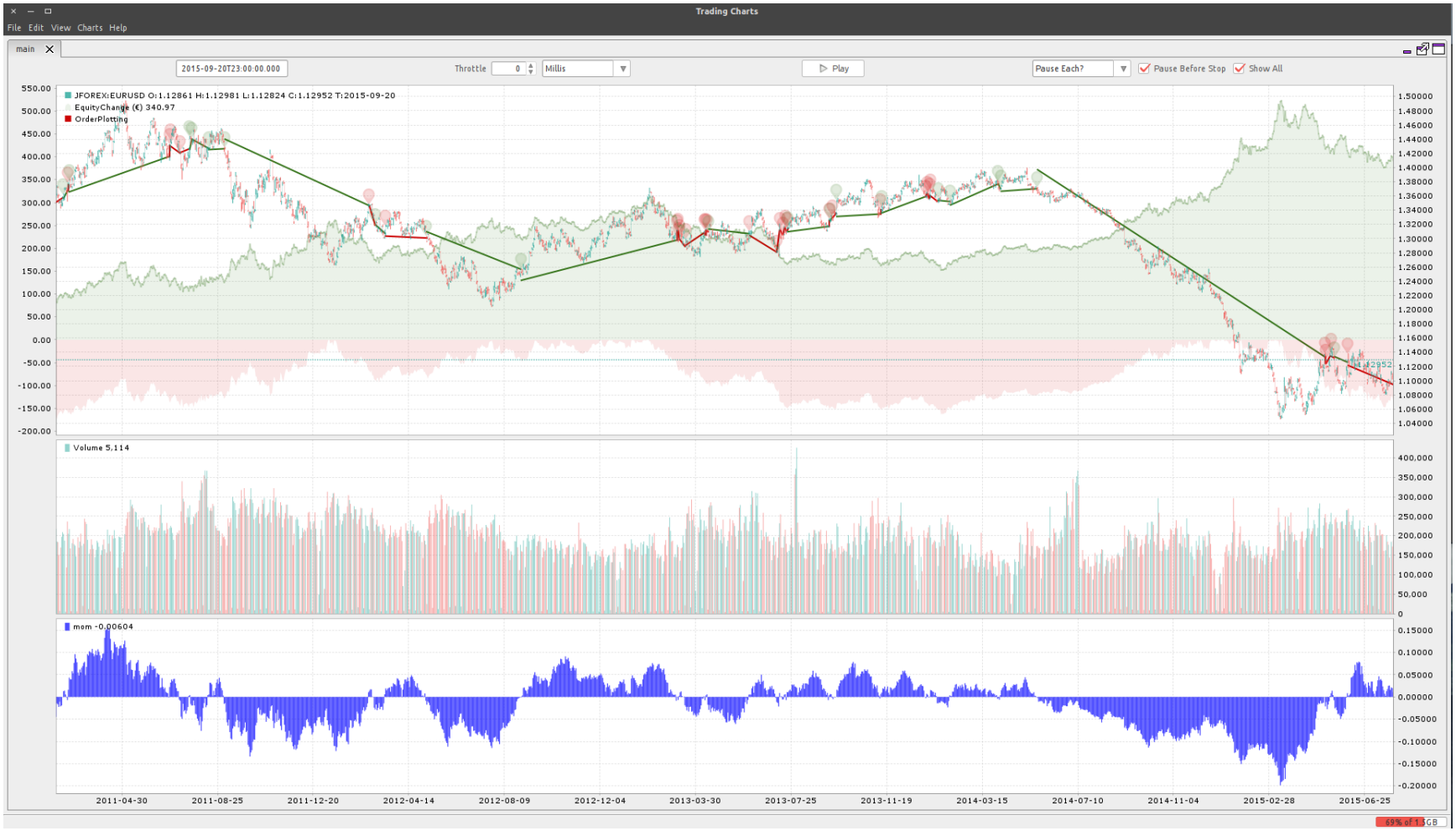
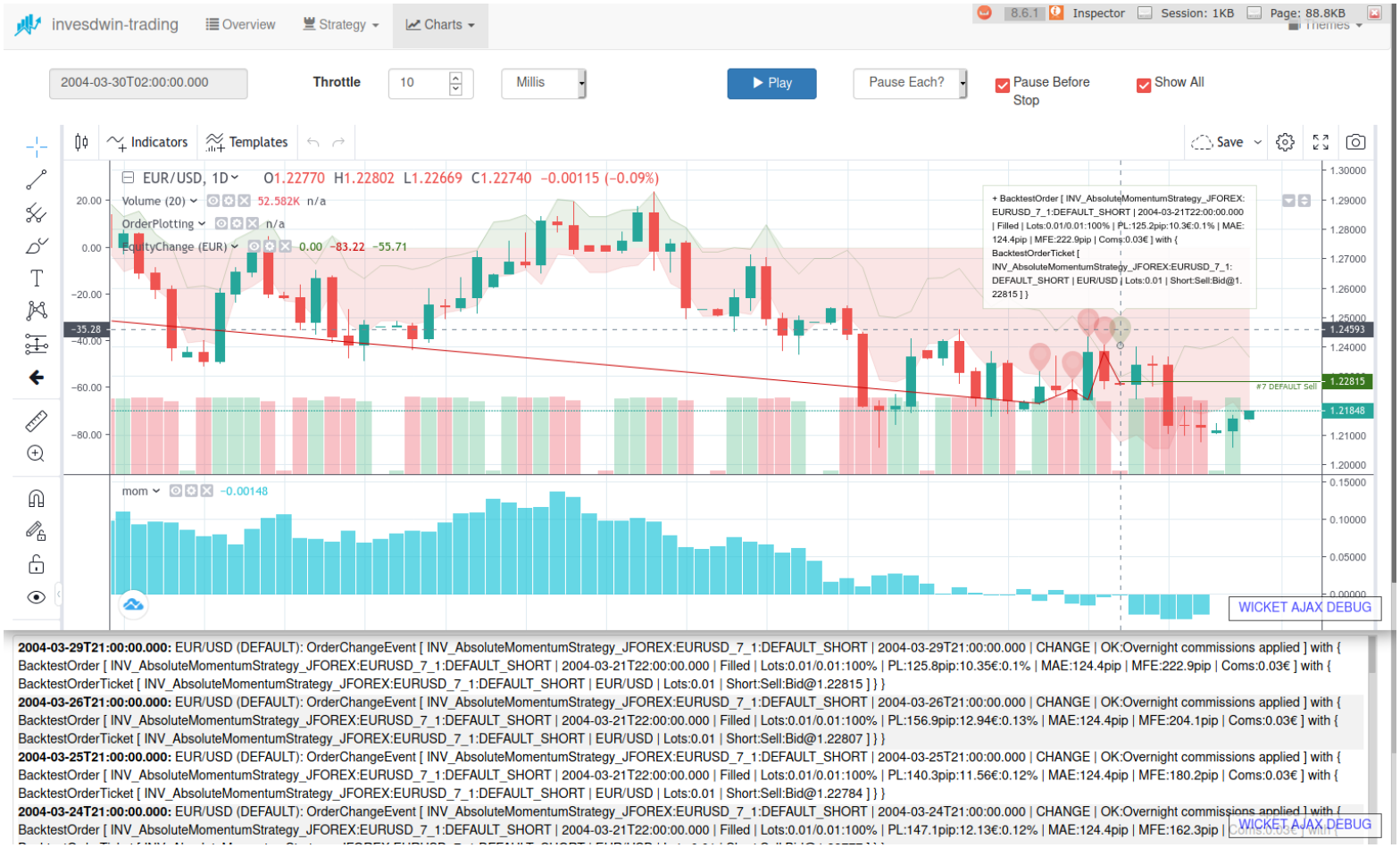
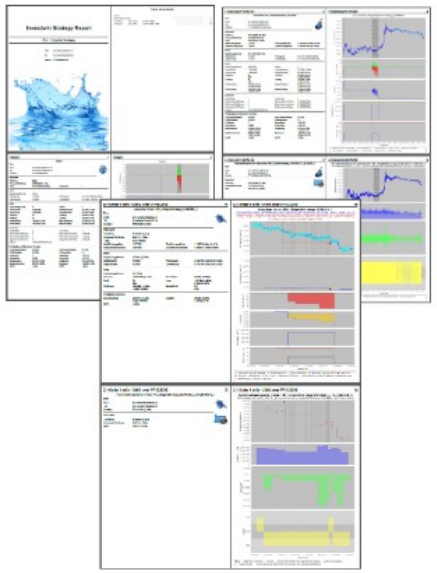
2.3. Visual Backtesting: Desktop



2.4. Live Monitoring: Web



2.5. Reports

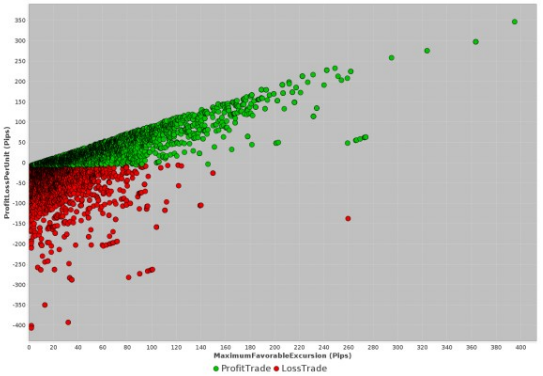


ProfitFactor:

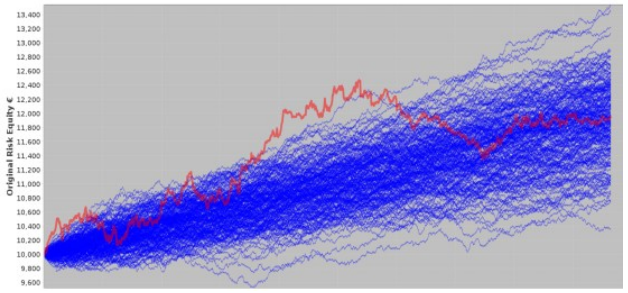
P1:sAtrBarsCount	P2	P3	sAtrMultiplier_2	sAtrMultiplier_2.8	sAtrMultiplier_3.6	sAtrMultiplier_4.4	sAtrMultiplier_5.2	sAtrMultiplier_6	sAtrMultiplier_6.8	sAtrMultiplier_7.6	sAtrMultiplier_8.4	sAtrMultiplier_9.2	sAtrMultiplier_10	x
sAtrBarsCount_50	**JFOREX:EURUSD**	**400:TRND**	1.80	2.01	2.62	2.46	2.31	2.28	2.34	2.25	2.21	2.21	2.37	2.26
sAtrBarsCount_75	JFOREX:EURUSD	400:TRND	1.79	2.03	2.48	2.49	2.34	2.26	2.32	2.36	2.25	2.45	2.42	2.29
sAtrBarsCount_100	JFOREX:EURUSD	400:TRND	1.92	2.16	2.55	2.50	2.37	2.36	2.26	2.38	2.27	2.47	2.44	2.33
sAtrBarsCount_125	JFOREX:EURUSD	400:TRND	1.92	2.14	2.53	2.50	2.37	2.36	2.26	2.38	2.27	2.54	2.44	2.34
sAtrBarsCount_150	JFOREX:EURUSD	400:TRND	1.83	2.14	2.52	2.50	2.34	2.35	2.26	2.29	2.51	2.45	2.43	2.33
sAtrBarsCount_175	JFOREX:EURUSD	400:TRND	1.83	2.14	2.48	2.41	2.43	2.34	2.31	2.24	2.54	2.43	2.41	2.32
sAtrBarsCount_200	JFOREX:EURUSD	400:TRND	1.96	2.14	2.48	2.41	2.43	2.33	2.31	2.23	2.49	2.50	2.41	2.34
sAtrBarsCount_225	JFOREX:EURUSD	400:TRND	1.96	2.05	2.47	2.41	2.38	2.33	2.30	2.23	2.53	2.50	2.40	2.32
sAtrBarsCount_250	JFOREX:EURUSD	400:TRND	1.98	2.05	2.47	2.40	2.37	2.33	2.30	2.23	2.39	2.49	2.39	2.31
sAtrBarsCount_275	JFOREX:EURUSD	400:TRND	1.96	2.04	2.46	2.44	2.37	2.37	2.30	2.22	2.43	2.49	2.42	2.32
sAtrBarsCount_300	JFOREX:EURUSD	400:TRND	2.04	2.03	2.44	2.39	2.36	2.32	2.30	2.22	2.43	2.48	2.42	2.31
		x	1.91	2.08	2.50	2.45	2.37	2.33	2.30	2.28	2.39	2.46	2.41	

ProfitLossRatio:

P1:sAtrBarsCount	P2	P3	sAtrMultiplier_2	sAtrMultiplier_2.8	sAtrMultiplier_3.6	sAtrMultiplier_4.4	sAtrMultiplier_5.2	sAtrMultiplier_6	sAtrMultiplier_6.8	sAtrMultiplier_7.6	sAtrMultiplier_8.4	sAtrMultiplier_9.2	sAtrMultiplier_10	x
sAtrBarsCount_50	**JFOREX:EURUSD**	**400:TRND**	8.97	8.55	10.02	9.10	8.35	7.61	7.66	7.34	7.03	6.96	7.27	8.08
sAtrBarsCount_75	JFOREX:EURUSD	400:TRND	9.16	8.66	9.81	9.22	8.44	7.75	7.63	7.49	7.15	7.56	7.43	8.21
sAtrBarsCount_100	JFOREX:EURUSD	400:TRND	9.57	9.08	9.79	9.28	8.37	7.99	7.48	7.56	7.21	7.63	7.49	8.31
sAtrBarsCount_125	JFOREX:EURUSD	400:TRND	9.55	9.00	9.70	9.26	8.37	7.99	7.49	7.55	7.20	7.78	7.49	8.31
sAtrBarsCount_150	JFOREX:EURUSD	400:TRND	9.10	9.01	9.68	9.26	8.46	7.97	7.48	7.31	7.80	7.57	7.45	8.28
sAtrBarsCount_175	JFOREX:EURUSD	400:TRND	9.09	9.00	9.58	9.00	8.48	7.92	7.46	7.39	7.83	7.52	7.39	8.22
sAtrBarsCount_200	JFOREX:EURUSD	400:TRND	9.49	9.04	9.57	8.98	8.47	7.91	7.46	7.18	7.73	7.68	7.39	8.26
sAtrBarsCount_225	JFOREX:EURUSD	400:TRND	9.46	8.71	9.52	8.96	8.34	7.89	7.44	7.17	7.81	7.66	7.36	8.21
sAtrBarsCount_250	JFOREX:EURUSD	400:TRND	9.33	8.70	9.52	8.95	8.33	7.88	7.43	7.15	7.48	7.63	7.33	8.16
sAtrBarsCount_275	JFOREX:EURUSD	400:TRND	9.33	8.69	9.50	8.86	8.31	7.83	7.44	7.15	7.56	7.63	7.57	8.17
sAtrBarsCount_300	JFOREX:EURUSD	400:TRND	9.33	8.68	9.43	8.92	8.30	7.87	7.43	7.15	7.56	7.62	7.57	8.17
		x	9.31	8.83	9.65	9.07	8.38	7.87	7.49	7.29	7.49	7.57	7.43	



1.5 Monte Carlo Simuation



1.4 Walk Forward Analysis: geneticCombination 16

Walk Forward Analysis

for Optimization Parameter Set: geneticCombination

WalkForwardEfficiency:	53.17%	SymmetricalEfficiency:	82.27%

Out of Sample Optimization Steps (Symmetrical:PreOptimization)

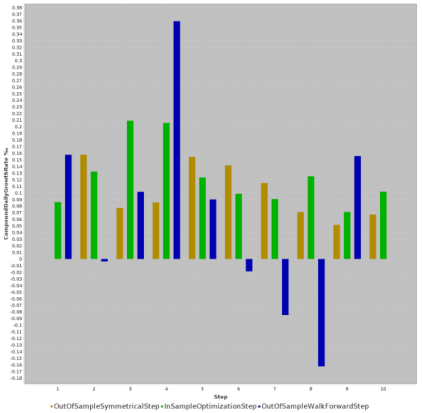
AvgPeriod:	P4Y4M3W3DT16H26M	AvgCDGR:	0.1%

In Sample Optimization Steps

AvgPeriod:	P6Y4M3W6DT9H3M	AvgCDGR:	0.12%

Out of Sample Walk Forward Steps (Asymmetrical:PostOptimization)

AvgPeriod:	P11M2W6DT11H4M	AvgCDGR:	0.068%



1.3 Biased White's Reality Check 7

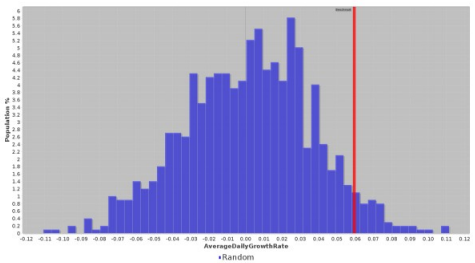
Biased White's Reality Check: AverageDailyGrowthRate

by doing a statistical significance test on 996 random strategies based on pure luck

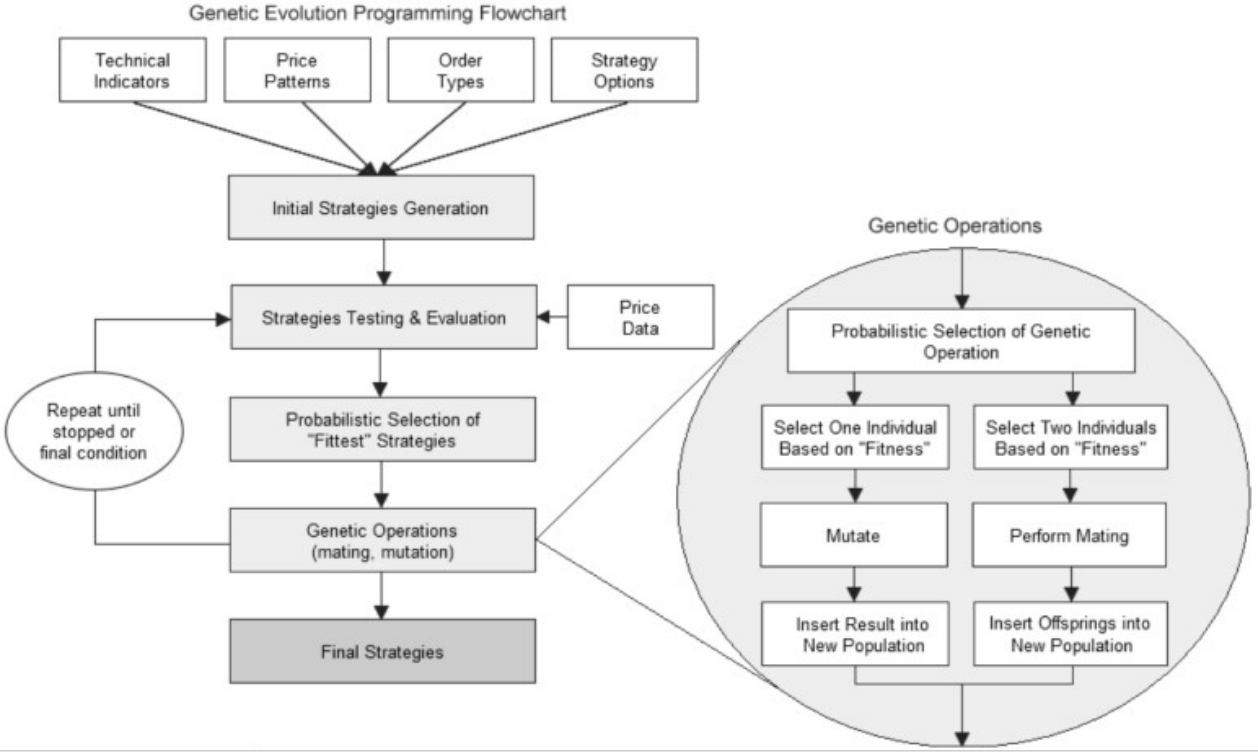
without modeling against data mining bias because only considering the current detrended simulation

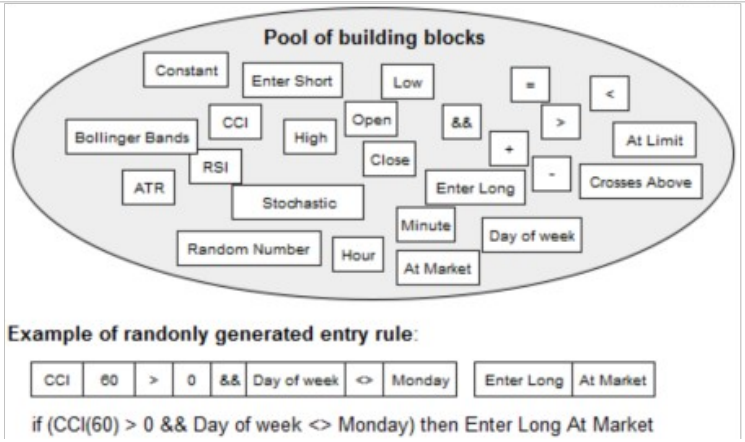
BenchmarkADGR::	0.05952%	MedianRandomADGR:	0.003306%
ProbabilityOfLuck:	4.82%	ProbabilityOfNonLuck:	95.18%
DataMiningBias:	55.54%		

Probability	as Confidence Level	as Confidence Interval
1%	0.08239%	0.002954% -> 0.003802%
2%	0.07339%	0.002688% -> 0.004122%
5%	0.05764%	0.001422% -> 0.005440%
25%	0.02618%	-0.00911% -> 0.01486%
50%	0.00349%	-0.02229% -> 0.02618%
75%	-0.02229%	-0.03954% -> 0.04029%
95%	-0.05887%	-0.06851% -> 0.06911%
98%	-0.07118%	-0.07708% -> 0.08239%
99%	-0.07708%	-0.08744% -> 0.09085%



2.6. Genetic Programming





Source: https://www.strategyquant.com/licenses/d?code=sqxug

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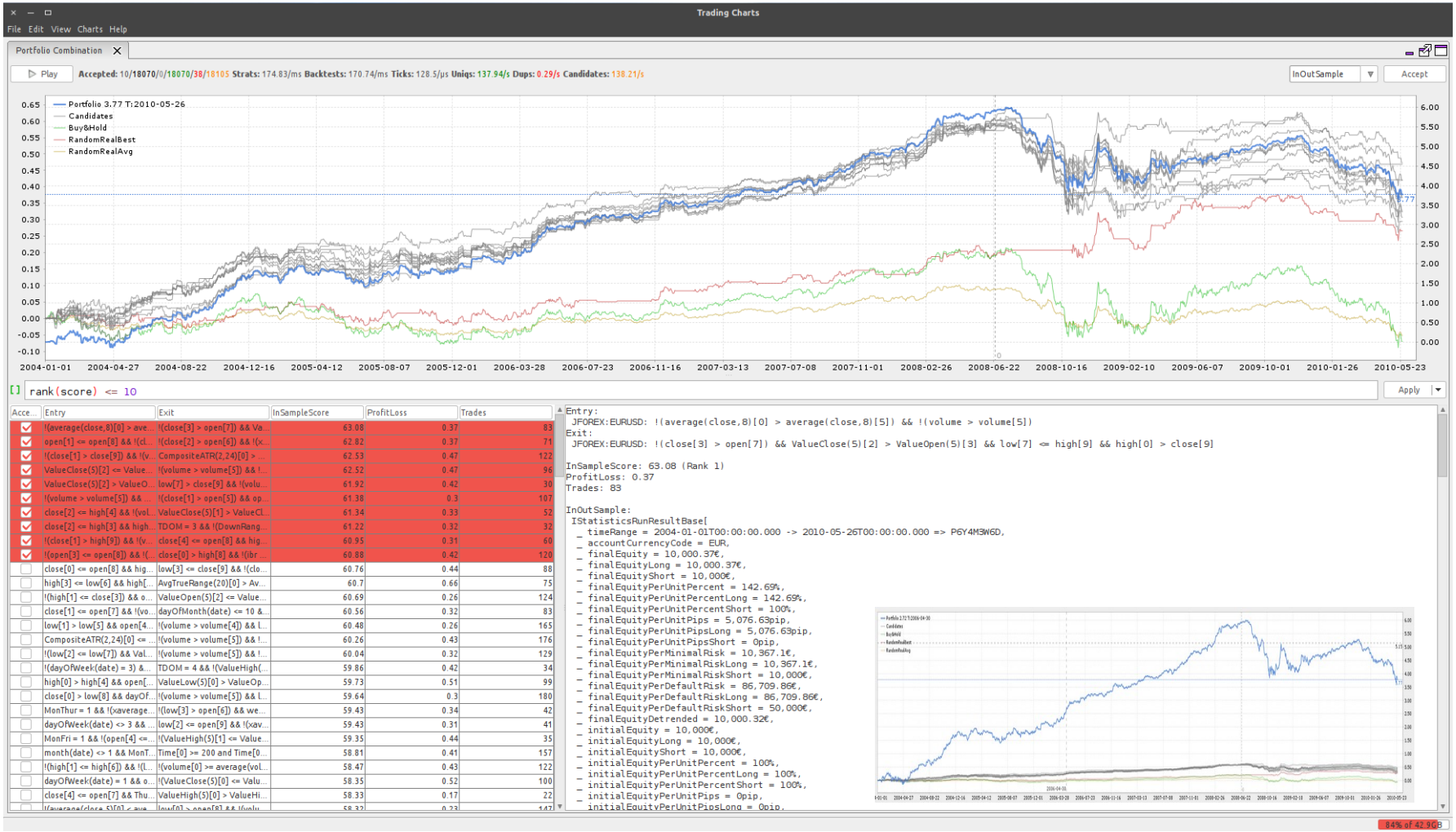
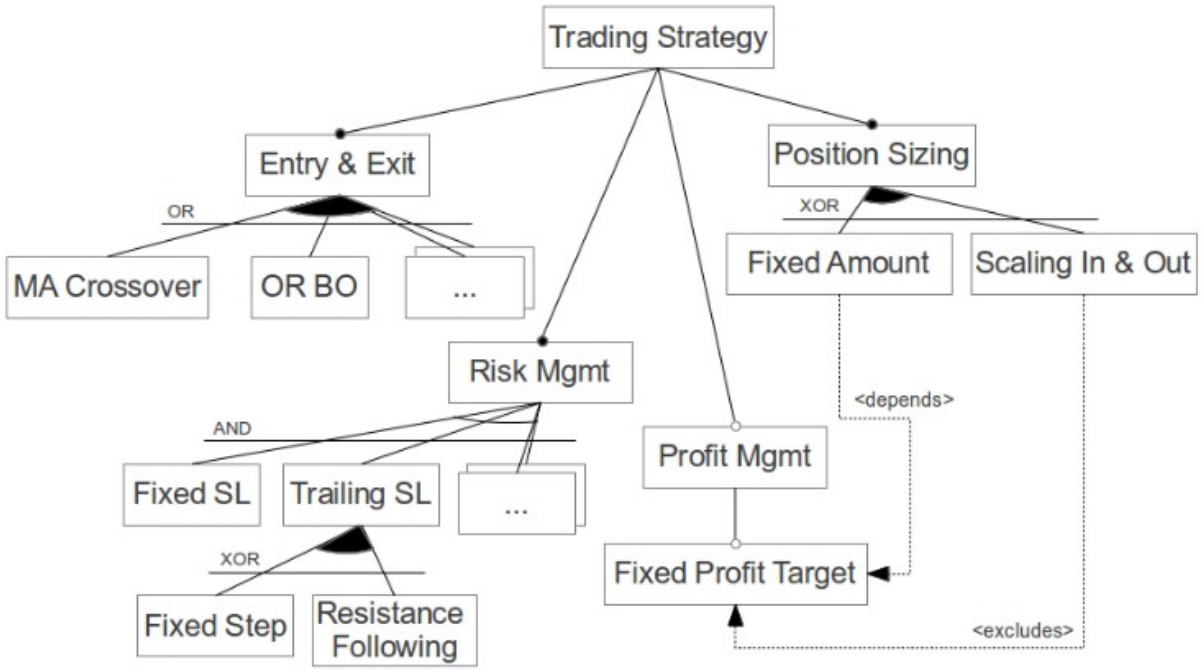
2.7. Portfolio Selector



3. Expression Language

- Extract Decision Points from Trading Strategies
- Formalise them into Expressions



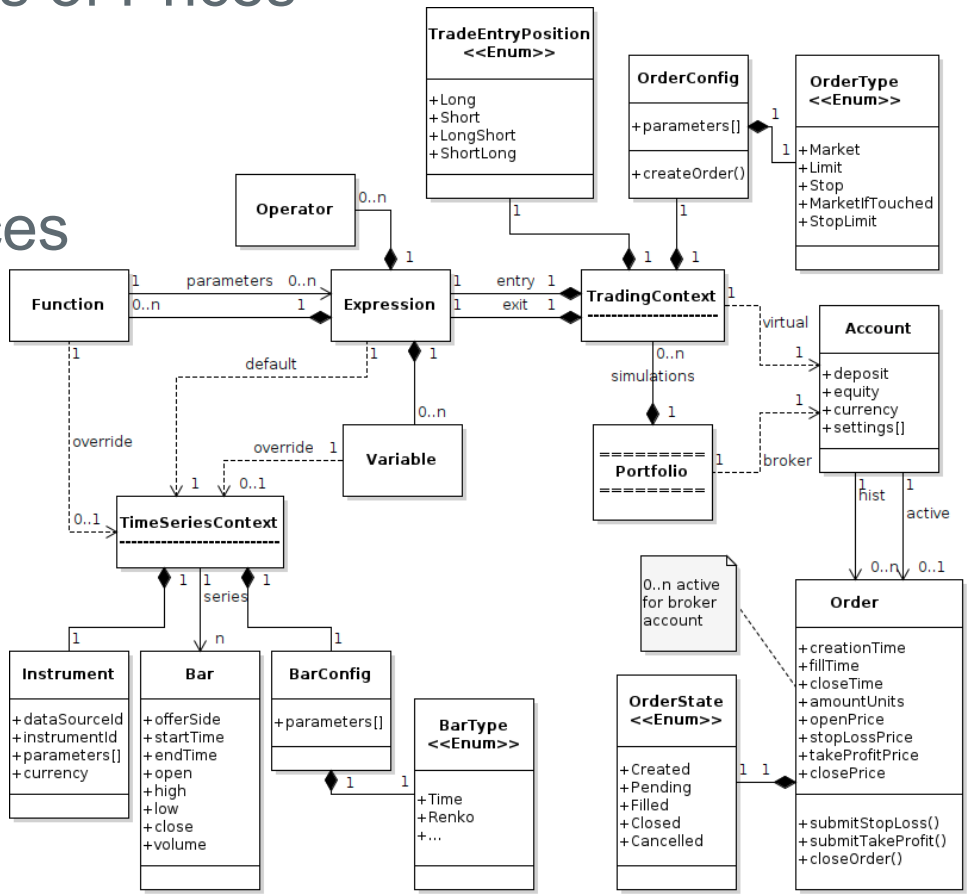
3.1. Expression Context

- **Instrument**: Market to Trade
  (S&P500, EUR/USD, Corn, Oil, Bitcoin)
- **Bar**: Aggregated Timeseries of Prices
- **Indicator**:

  Function to Transform Prices
- **Order**:

  Execute Buy/Sell
- **Broker**:

  Tracks Profit/Loss



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Action (Decision Point) :=

Guard (Constraint) + [Side Effect (Context Attribute Modifier)]

3.2. Decision Points: Strategy

- **Bar Preprocessors**:
  - Time[1 DAY|UTC-7] - Timeshift, Detrend
  - PriceRange[volatility(20)*0.5] - Session, SkipFlat
  - Oversampling, Random - OrnsteinUhlenbeck
- **Entry**: avg(25) > avg(5) && indicator(2) > 20
  - Variants: Long, Short, LongShort, ShortLong
- **Exit**: !entry || stopLoss(volatility(14)*2)

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3.2. Decision Points: Risk

- **Order Type**: Market, Limit[volatility(14)*2], Stop[fixed(20)]
  - Embed: <entry> && enterLongAtLimit(volatility(14)*2)
- **Money Management / Position Sizing**:
  - Fixed Amount, Weighted, Markowitz, OptimalF, ...
- **Equity Curve Trading**:
  - lossTradesToday < 3 && equityRiskPercent < 30

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3.2. Decision Points: Higher Level

- **Strategy/Portfolio Selection**:
  - rank(os_profitLoss) <= 10 && profitLoss > 0
- **Nested Optimisation**:
  - avg(optimise(start=20, min=5, max=50, step=5)) > avg(5)
- **Robustness Checking**:
  - whitesRealityCheckProbabilityOfLuckPercent < 5
  - walkForwardEfficiencyPercent > 50
  - monteCarloDrawdownPercent(confidence=0.95) < 15

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3.3. Language Design I

- Domain Specific Language
- Functional Style with Selected Side Effects
  - no vars (yet), single statement, no exceptions
- No Collections/Lists/Types
  - Everything can be interpretet as double series
  - Optimised Storage: double/int/boolean/bitset
- Functions/Variables interchangeable
  - omit optional arguments (default applies)
  - omit parentheses for nullary function calls

    function() vs function

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3.3. Language Design II

- Case Insensitive: function vs FuNcTiOn
- Nesting Allowed: “function1(function2)” for arguments
- Metadata: Functions/Variables defined in Platform Context
  (used for Code Completion and Documentation Assist)
- Indexing: Date, int
  - close[2]; open[indexOf(addDays(today(),-3)]
- Non-Strict: Gracefully handle NaN/Null as Neutral/Missing
  - NaN && true → true
- Aggregate Functions: if, occurs, stable, once, vote, select

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3.4. Implementation

- Java, Object-Oriented, High-Performance
- Final, Immutable
- Zero-Copy, Zero-Allocation
- Based on Parsii
  - Extend Language Features
  - Improve Performance
  - Trading Platform Context
- Combining Expressions without String Parsing
  - optional working with objects => less overhead

Source: http://andreas.haufler.info/2013/12/how-to-write-one-of-fastest-expression.html

- **PARSII:** 28.3 ms
- **EXPR:** 37.2 ms
- **MathEval:** 7748.5 ms
- **JEP:** 647.0 ms
- **MESP:** 220.8 ms
- **JFEP:** 274.3 ms

3.5. Expression Performance

Entry:

```
close() > 3.14 && (2 + (7 - 5) * 3.14159 * pow(close(),
   (12-10)) + sin(-3.141)) > 1000
```

Strategies: Iterations through Series

Variation	Invesdwin	Parsii	Janino	Groovy	Spring
Parsing, 1 Thread	22.51/ms	3.70/ms	2.00/ms	0.18/ms	0.59/ms
Parsing, 12 Threads	122.50/ms	21.25/ms	7.61/ms	0.83/ms	2.40/ms
Caching, 1 Thread	60.94/ms	4.35/ms	15.30/ms	12.80/ms	0.63/ms
Caching, 12 Threads	432.73/ms	24.79/ms	71.20/ms	44.31/ms	2.39/ms

Bars: Evaluations of Data Points

Variation	Invesdwin	Parsii	Janino	Groovy	Spring
Parsing, 1 Thread	119.41/µs	19.43/µs	9.76/µs	0.92/µs	3.03/µs
Parsing, 12 Threads	649.74/µs	112.71/µs	40.40/µs	3.36/µs	12.73/µs
Caching, 1 Thread	323.23/µs	22.56/µs	81.15/µs	67.93/µs	3.22/µs
Caching, 12 Threads	2295.19/µs	131.50/µs	377.70/µs	235.06/µs	12.65/µs

- with BitSet:

Variation	Strategies	Bars
Caching, 1 Thread	223.31/ms	1202.55/µs
Caching, 12 Threads	1488.04/ms	8013.07/µs

Intel I9 9900K 5 GHz

20 years daily bars

RAM irrelevant in this test (<1MB)

“Caching” reuses parsed Expression

BitSets provide maximum performance indifferent to expression complexity!

4. Possible Uses

- Compare Strategy Types against each other:
  - Trend Following vs Mean Reversion
  - Signal vs Breakout
- Compare Machine Learning Techniques:
  - Evolutionary: Differential Evolution, Harmony Search, Symbiotic Organisms, Extreme Learning
  - Other: Support Vector Machines, (Deep) Neural Networks, etc
- Compare Robustness Techniques:
  - Whites Reality Check, Monte Carlo, Cross Validation, Walk Forward Analysis

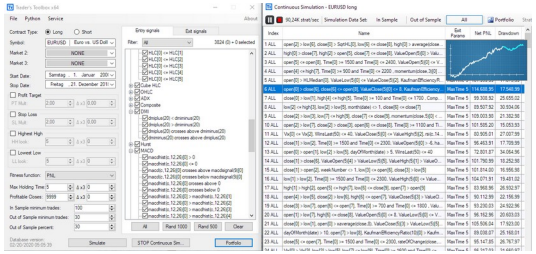
4.1. Generator Performance

- Daily Data with Signal Strategies
  - 140k to 1.6 million Backtests per Second
  - with 12 Cores
- Speed and RAM usage Depending on
  - Time Range
  - how many Simulated Trades happen (Breakout slower)
  - Granularity: Ticks, PriceRange, Volume, 5 Mins, Daily, ...
- **Allows Testing Processes, not just Strategies**
  - 4-8 Times Faster than Fastest Alternative
  - Alternatives offer only Entry/Exit Decision Points in Cross Sectional Studies without Significance Test

5. Signal vs Breakout Strategies

- Signal Strategies: Filter only
  - Entry: enterLongAtMarket(Signal1 && Signal2 && Signal3 && Signal4)
  - Exit: exit(Signal5 && Signal6 && Signal7 && Signal8)
  - Inspired by BuildAlpha

    (Source: https://www.buildalpha.com/)



- Breakout Strategies: Price Target
  - Entry: FilterLong && enterLongAtStop(LongPriceLevel + Volatility * Factor)
    || FilterShort && enterShortAtStop(ShortPriceLevel - Volatility * Factor)
  - Exit: exitOnClose
  - Inspired by BetterTraderAcademy

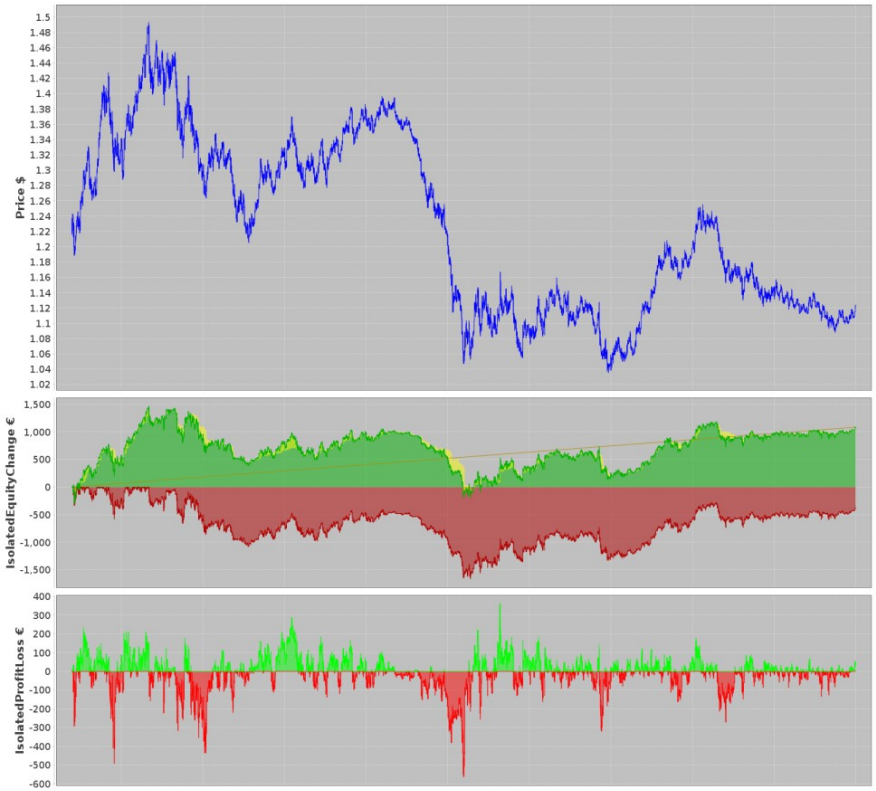
    (Source: https://www.bettertraderacademy.com/)

5.1. Test Setup

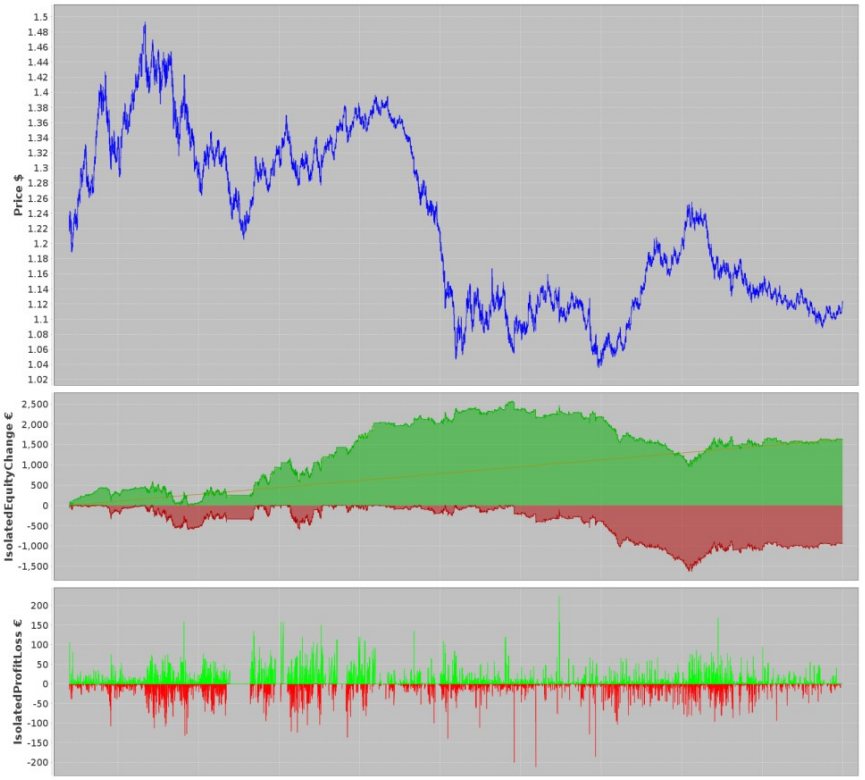
- **Foreign Exchange Market**: EURUSD
- **Commission:** Dukascopy Broker
  (Source: https://www.dukascopy.com/swiss/english/about/fee-schedule/)
- **Bars**: Daily → Time[1 DAY|UTC]
- **Order Types**: [Market] vs [Stop, Limit, StopLimit, MarketIfTouched]
- **Positions**: [Long] vs [Long || Short]
- **Money Management**: FixedAmount(minLot)
- **Strategy Filter**: rank(inSampleProfitLoss) <= 10
- **Walk Forward Analysis**:
  - 6 Years IN Samples; 1 Year OUT Samples
  - 10 Steps from 2010 to 2020

5.2. Test Results: ProfitLoss

Signal

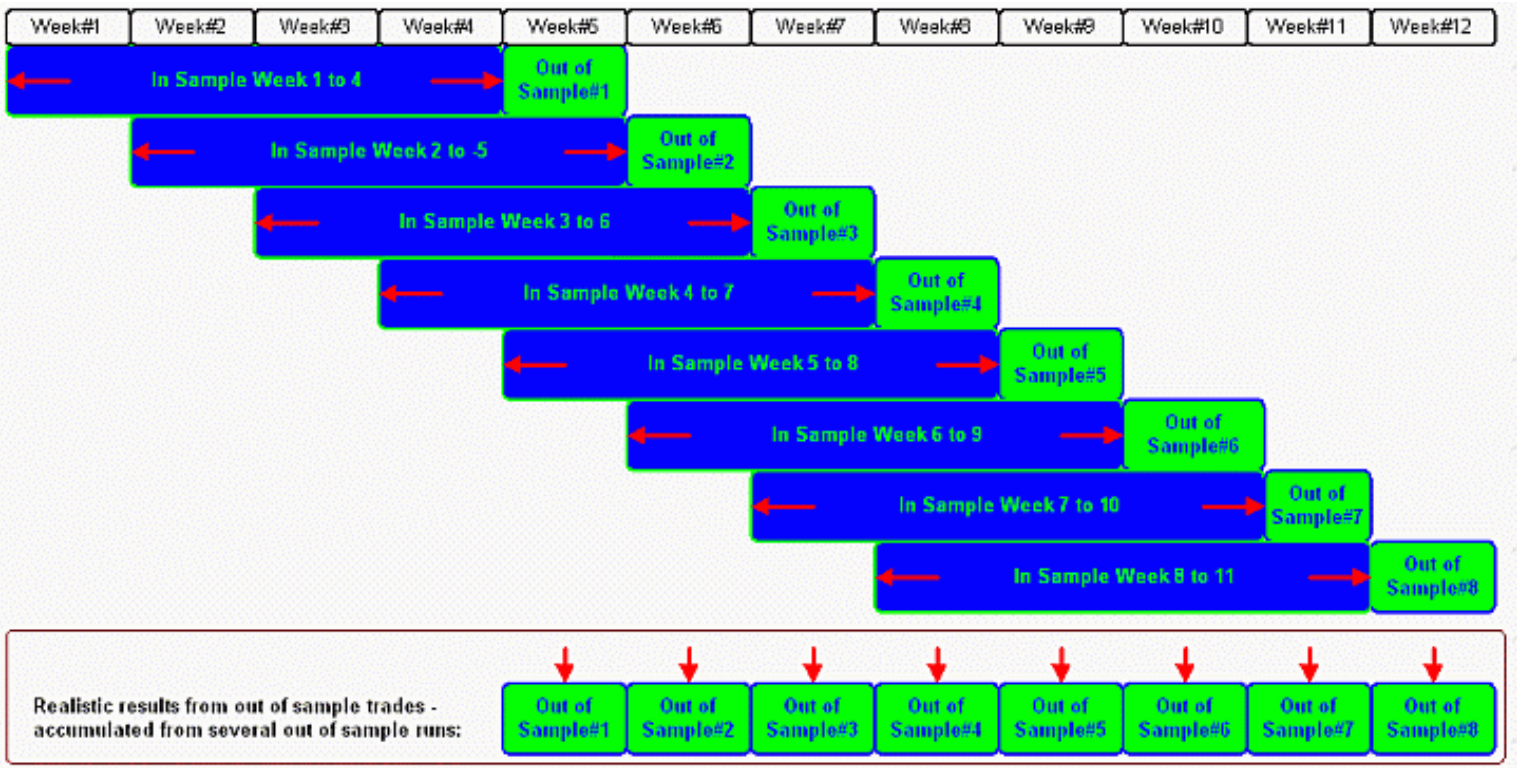


Breakout



5.3. Walk Forward Analysis

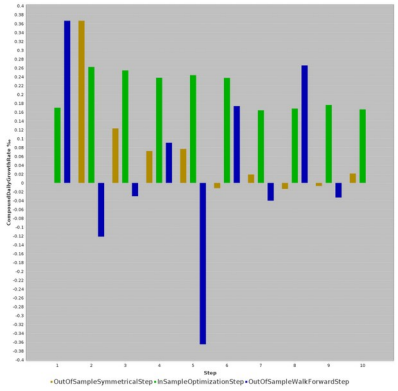
- Automated through Optimisation Workflows
- Alternative: Cross-Validation Variations



Source: https://blackwellglobal.com/mt4-walk-forward-optimisation/

5.4. Test Results: Walk Forward

Signal



InSample vs OutOfSample

WalkForwardEfficiency:	16.42%	SymmetricalEfficiency:	34.55%

Out of Sample Optimization Steps (Symmetrical/PreOptimization)

AvgPeriod:	P4Y4M2W3DT16H20M	AvgCDGR:	0.072‰

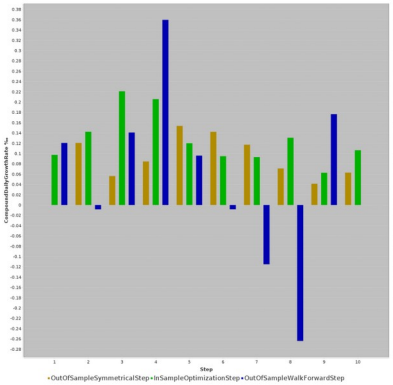
In Sample Optimization Steps

AvgPeriod:	P6Y4M3W6DT9H30M	AvgCDGR:	0.21‰

Out of Sample Walk Forward Steps (Asymmetrical/PostOptimization)

AvgPeriod:	P11M2W6DT19H40M	AvgCDGR:	0.034‰

Breakout



WalkForwardEfficiency:	43.4%	SymmetricalEfficiency:	74.11%

Out of Sample Optimization Steps (Symmetrical/PreOptimization)

AvgPeriod:	P4Y4M2W3DT16H20M	AvgCDGR:	0.094‰

In Sample Optimization Steps

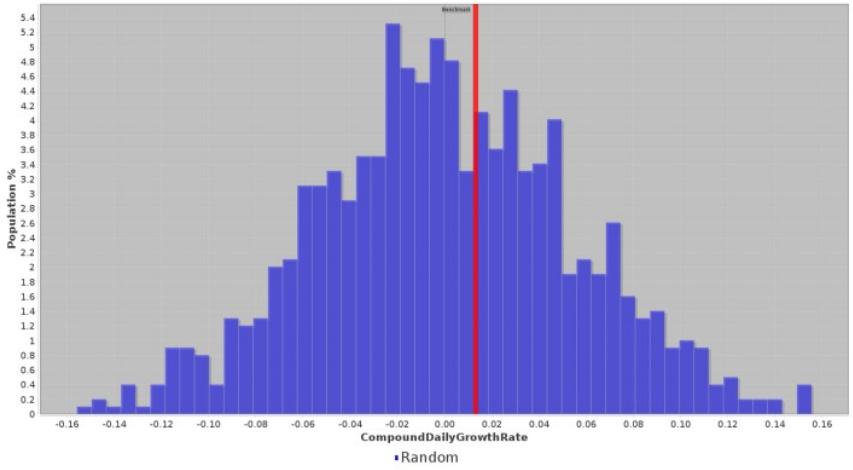
AvgPeriod:	P6Y4M3W6DT9H30M	AvgCDGR:	0.13‰

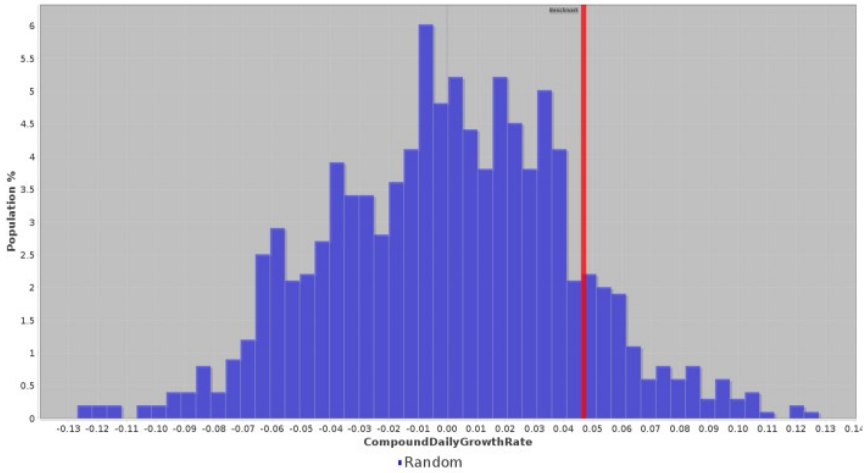
Out of Sample Walk Forward Steps (Asymmetrical/PostOptimization)

AvgPeriod:	P11M2W6DT19H40M	AvgCDGR:	0.055‰

5.5. Test Results: Whites Reality

Signal		Breakout	
Detrended & Random Benchmark			
BenchmarkCDGR::	0.01318‰	BenchmarkCDGR::	0.04696‰
ProbabilityOfLuck:	39.86%	ProbabilityOfLuck:	11.65%
DataMiningBias:	16.58%	DataMiningBias:	16.94‰
MedianRandomCDGR::	0.002185‰	MedianRandomCDGR::	0.0007953‰
ProbabilityOfNonLuck:	60.14%	ProbabilityOfNonLuck:	88.35%





5.6. Monte Carlo Simulation

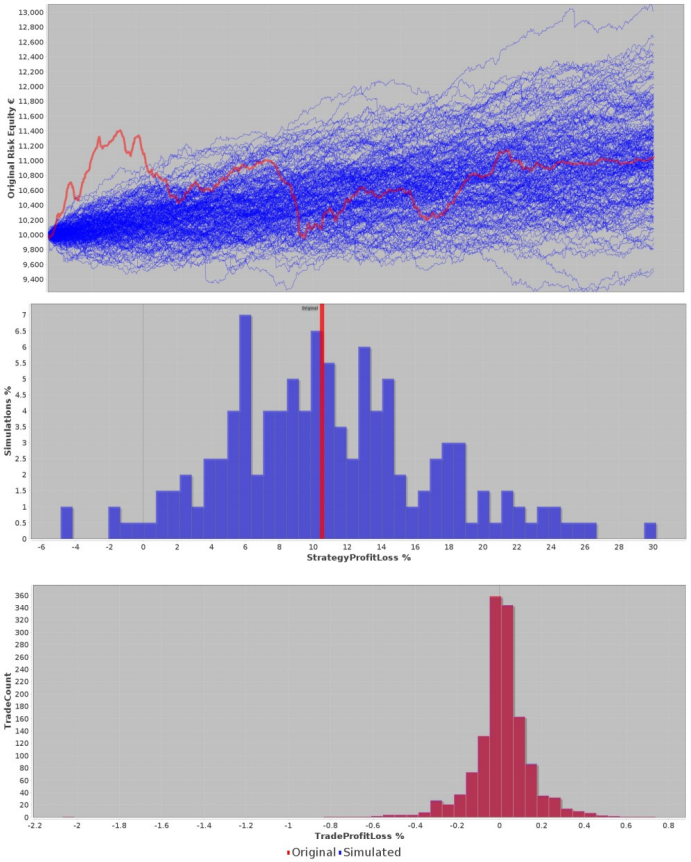
- Repeat Walk Forward Analysis ‘x’ Times
- Confidence Levels for Significance Test
- Does the **Process** mitigate **Randomness**?

Monte Carlo Simulation

with randomized and recurring orders in 200 simulations, showing each with Original Risk Equity and Minima

OriginalMaxDrawdown:	1,456.37€ (-12.76%) 1,515.6€ (-12.92%)	NewMaxDrawdownAvg:	435.23€ (- 437.32€ (-
OriginalProfitLossSum:	1,052.05€ (+10.52%) 1,391.6€ (+13.92%)	NewProfitLossSumAvg:	1,090.66€ 1,427.35€
OriginalAPPT:	0.77€ (+0.0077%) 1.01€ (+0.01%)	NewAPPTAvg:	0.79€ (+0. 1.04€ (+0.

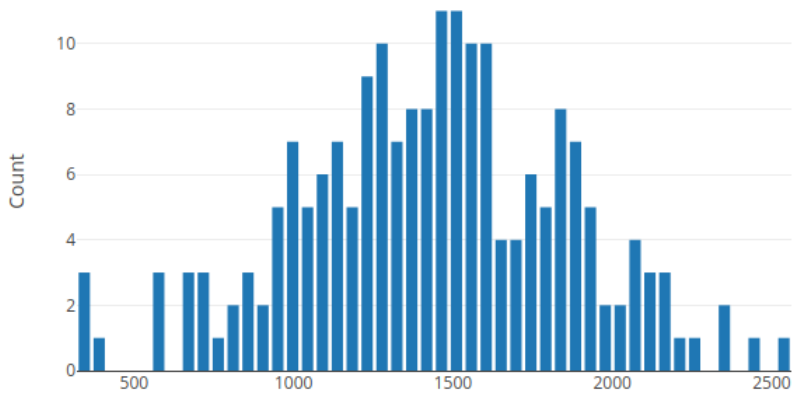
Confidence Level	MaxDrawdown	ProfitLossSum	Expect
1%	189.23€ (1.77%) 196.51€ (1.79%)	2,666.35€ (+26.66%) 3,257.88€ (+32.58%)	1.94€ 2.37€
2%	193.95€ (1.9%) 204.76€ (1.88%)	2,459.3€ (+24.59%) 2,937.1€ (+29.37%)	1.79€ 2.14€
5%	225.97€ (2.14%) 231.62€ (2.22%)	2,203.26€ (+22.03%) 2,630.04€ (+26.3%)	1.6€ (+ 1.91€
25%	301.44€ (2.83%) 350.42€ (2.99%)	1,447.03€ (+14.47%) 1,845.28€ (+18.45%)	1.05€ 1.34€
50%	383.03€ (3.79%) 432.21€ (3.74%)	1,043.13€ (+10.43%) 1,373.65€ (+13.74%)	0.76€ 1€ (+0
75%	502.25€ (4.88%) 493.08€ (4.83%)	620.84€ (+6.21%) 970.72€ (+9.71%)	0.45€ 0.71€
95%	706.32€ (6.72%) 723.01€ (6.53%)	155.33€ (+1.55%) 355.87€ (+3.56%)	0.11€ 0.26€
98%	870.41€ (8.34%) 878.36€ (7.92%)	-111.74€ (-1.12%) 137.97€ (+1.38%)	-0.08€ 0.1€ (+
99%	1,022.21€ (9.04%) 879.57€ (8.38%)	-199.03€ (-1.99%) -61.53€ (-0.62%)	-0.14€ -0.04€



5.7. Test Results: Stability

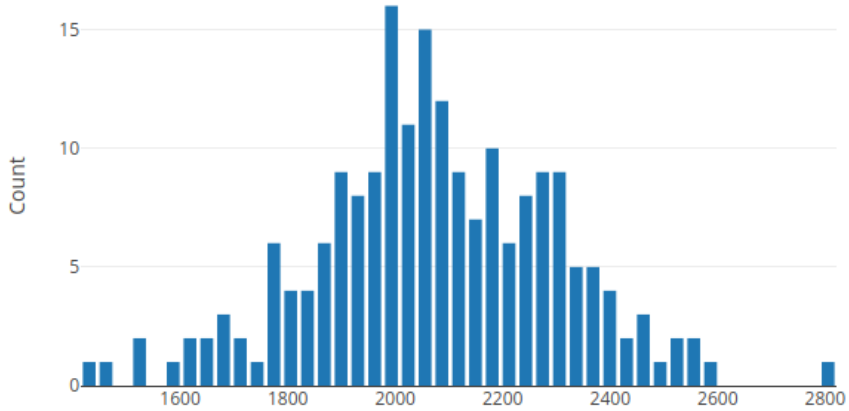
200 Runs

Signal



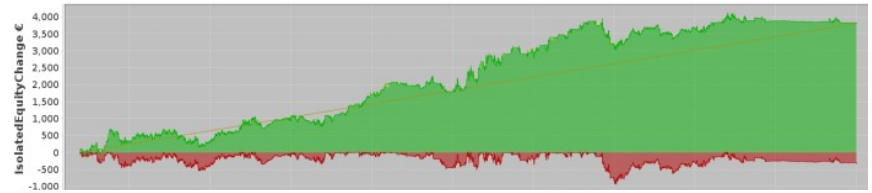
Confidence Level	66.ProfitLoss
1%	2528.84000
2%	2343.97000
5%	2173.51000
25%	1739.11000
50%	1452.83000
75%	1159.93000
95%	714.87000
98%	568.97000
99%	362.11000
Avg	1439.32300
Range	2335.25000
IQ-Range	579.18000

Breakout



Confidence Level	66.ProfitLoss
1%	2811.01000
2%	2550.84000
5%	2466.10000
25%	2249.46000
50%	2062.98000
75%	1942.70000
95%	1684.96000
98%	1576.65000
99%	1513.90000
Avg	2078.13455
Range	1562.26000
IQ-Range	306.76000

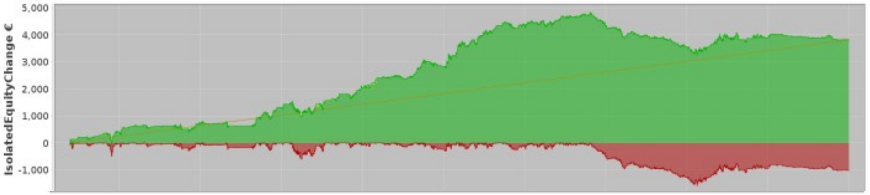
5.8. Breakout Order Types



[Stop]

WalkForwardEfficiency: 119.1%

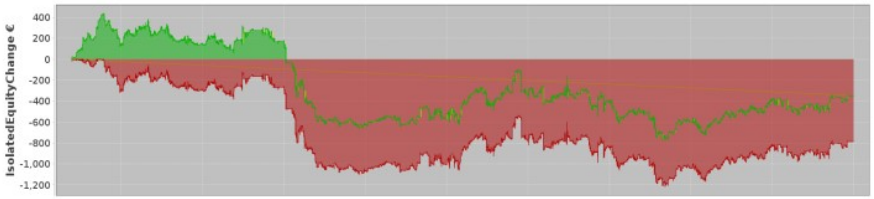
SymmetricalEfficiency: 131.14%



[Limit]

WalkForwardEfficiency: 93.08%

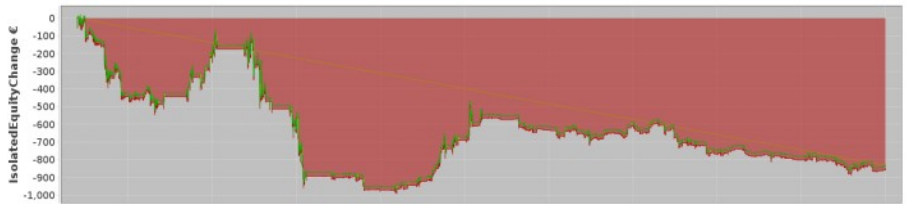
SymmetricalEfficiency: 117.81%



[StopLimit]

WalkForwardEfficiency: -16.82%

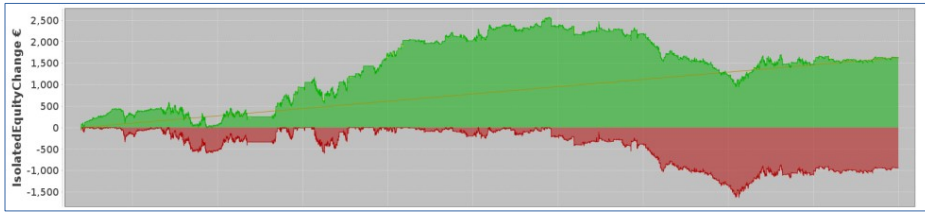
SymmetricalEfficiency: -18.06%



[MarketIfTouched]

WalkForwardEfficiency: -60.76%

SymmetricalEfficiency: -113.29%



[Stop, Limit, StopLimit, MarketIfTouched]

WalkForwardEfficiency: 43.4%

SymmetricalEfficiency: 74.11%

Next Research Question:

Which process can reduce false positives without human bias?

HERIOT WATT UNIVERSITY

FHDW Fachhochschule der Wirtschaft

Thank You for Your Attention!

Further Questions?

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