GPU Accelerated Backtesting and ML for Quant Trading Strategies

GTC 2015 | San José | California

Dr. Daniel Egloff
daniel.egloff@quantalea.net
March 18, 2015

Motivation

QuantAlea

- Goals
  - Execute automated algorithmic trading strategies
  - Optimize risk return
- Procedure
  - Extract signals and build price forecasting indicators from market data
  - Transform indicators into buy / sell decisions
  - Apply portfolio risk management
- Challenges
  - Find relevant signals and indicators
  - Engineer and parameterize trading decision
  - Find optimal parameters
- Approach
  - Exploit parallelism in the computations
  - Accelerate calculations by using a GPU cluster

Algo Trading Strategies

QuantAlea

Market data

Rules

Trading decision

Symbol	Pct	Last	Change	Prev	Bid	Ask	High	Low	EVol	Volume
ES #F	+0.11%	136400	+150	136250	136400	136425	136625	134250	1084656	2076198
SP #F	+0.13%	136430	+180	136250			136620	134210	2111	10585
$SPX	-0.05%	1368.39	-0.71	1369.10			1370.08	1363.94		
NQ #F	+0.25%	263200	+650	262550	263175	263200	264150	258650	160303	320105
$NDX D	+0.01%	2638.09	+ 0.17	2637.92			2644.37	2620.96		
$COMPID	-0.04%	2955.09	-1.25	2956.34			2960.67	2939.21		
YM #F	-0.08%	1294600	-1100	1295700	129450	129460	1296200	1277900	78269	139189
DJ M2	-0.02%	1295500	-200	1295700	129500		1296000	1291000	0	131
DJ #F	-0.02%	1295500	-200	1295700	129500		1296000	1291000	0	131
ES U2	+0.17%	135825	+225	135600	135750	135800	135875	133750	908	1679
$INDU D	-0.27%	13003.04	-35.23	13038.27			13036.15	12970.00		43960296
TF #F	+0.23%	78840	+180	78660	78830	78840	79140	77280	66434	153710
$RUT D	-0.06%	791.34	-0.50	791.84			792.67	788.07		
MC #F	+0.29%	96330	+280	96050	96320	96340	96630	94660	15015	26228
NK #F	-1.13%	9155	-105	9260			9155	9155	0	3315
$TRAN D	+0.57%	5257.48	+29.84	5227.64			5257.62	5198.00		4747289
ZB #F	+0.04%	14324	+2	14322	14324	14325	14419	14321	142139	323844
US M2	+0.07%	14325	+3	14322			14325	14325	0	323844
$TYX	-0.20%	3.065	-0.006	3.071			3.070	3.052		
ZN M2	+0.01%	132210	+5	132205	132210	132215	133020	132195	484043	1299349
TY M2	+0.34%	132205	+145	132060			132210	132210	0	1299349
$TNX	-0.37%	1.873	-0.007	1.880			1.880	1.859		
ZF M2	+0.02%	123307	+7	123300	123307	123310	124032	123297	170942	405572
ZT M2	-0.01%	110087	-2	110090	110087	110090	110092	110082	59470	122419
6E M2	-0.28%	13052	-37	13089	13051	13052	13062	12957	190719	237586
6S M2	-0.39%	10868	-43	10901	10867	10868	10877	10778	35792	39567
6B M2	+0.26%	16183	+42	16141	16182	16184	16193	16110	64892	99435
6J M2	+0.01%	12526	+1	12525	12525	12526	12564	12504	48836	78999
6A M2	+0.20%	10160	+20	10140	10159	10160	10165	10065	83072	160266
6C M2	+0.10%	10048	+10	10038	10047	10048	10060	10002	60345	103796
6N M2	+0.05%	7934	+4	7930	7934	7936	7945	7886	11427	18113
DX M2	+0.15%	79705	+118	79587	79705	79710	80135	79660	17688	24757

Mathematical operations

Input

Configurations

Output

Example

Buy signal

Sell signal

Markets

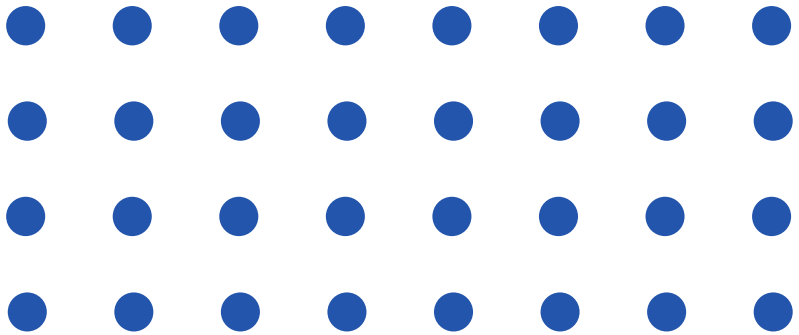
QuantAlea

- Futures market
  - CME 50 liquid futures
  - Other exchanges
- Equity markets
  - World stock indices
- FX markets
  - 10 major currency pairs
  - 30 alternative currency pairs
- Options markets
  - Options on futures
  - Options on indices

Strategy Universe

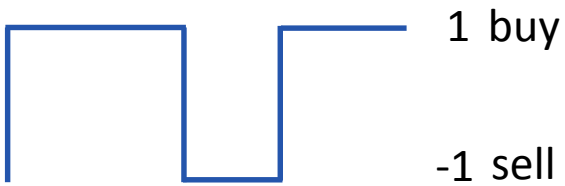
QuantAlea

Strategy configurations



Configuration c

Trading decision s(c)



Utility U(s(c))

P&L / drawdown

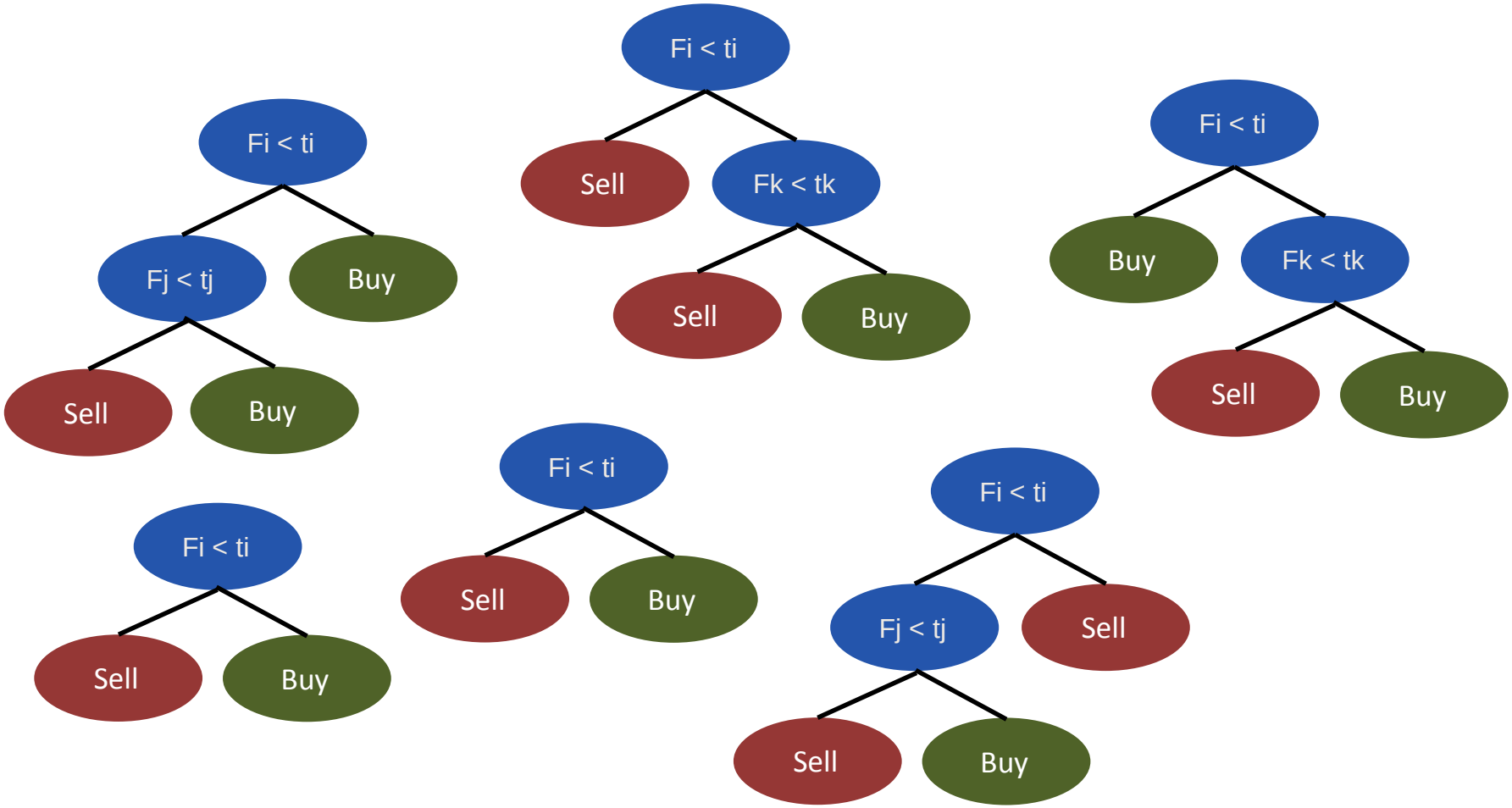
Strategy Engineering

QuantAlea

Challenge 1: How can we engineer a strategy producing buy / sell decisions ?

Random Forests

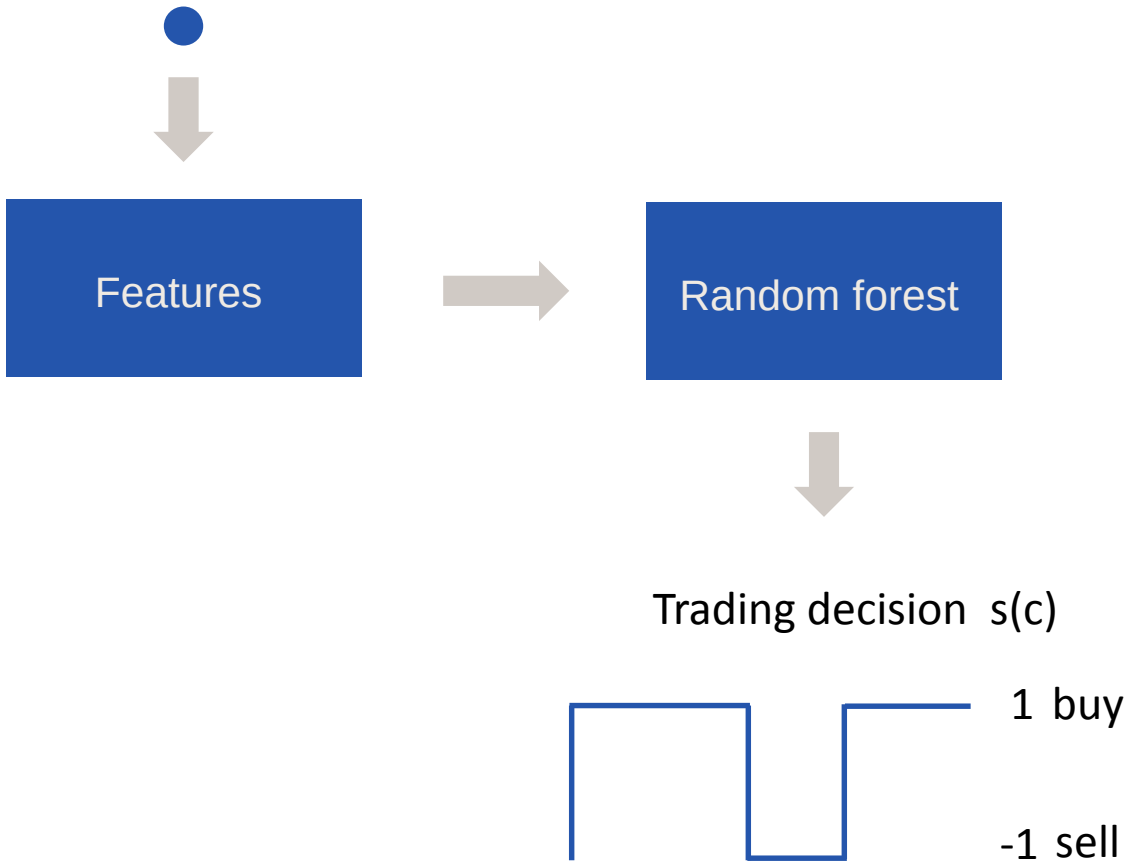
QuantAlea



Random Forests

QuantAlea

Strategy configuration c



Training Random Forests

QuantAlea

Bootstrapping to create training sets

C 4.5 algorithm for individual tree construction

- Selecting subset of features for tree construction
- Each node is associated with a subset of training samples
- Recursive, starting at the root node
- At each node execute divide and conquer algorithm to find locally optimal choice
  - If samples are in same class (or few class) node is a leaf associated with that class
  - If samples are in two or more classes
    - Calculate information gain for each feature
    - Select feature if largest information gain for splitting

Entropy

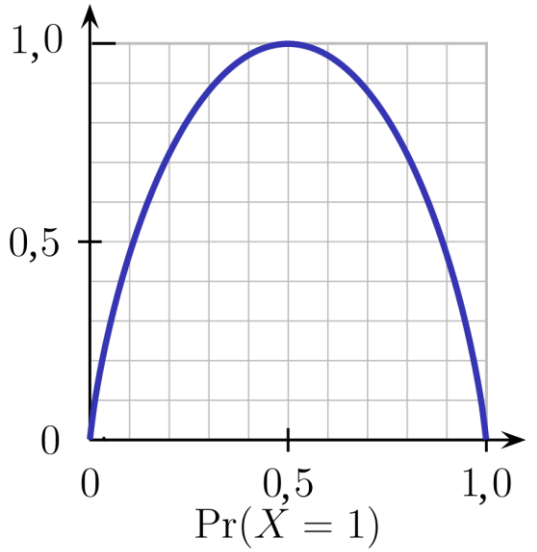
T = set of samples associated with node

$C_1, \ldots, C_n$ = classes of samples

Entropy

$$Ent(T) = -\sum_{i=1}^{n} \frac{freq(C_i,T)}{|T|} \; log_2 \left(\frac{freq(C_i,T)}{|T|} \right)$$

- Characterizes impurity of samples
- Measure of uncertainty
- Additive: impurity of several subsets is sum of impurities



Information Gain

QuantAlea

$T_1, \ldots, T_s$ = subsets of T generated by splitting on selected attribute

Information gain discrete feature

$$gain(T_1, \ldots, T_s) = Ent(T) - \sum_{i=1}^{s} \frac{|T_i|}{|T|} Ent(T_i)$$

Information gain continuous feature with optimal splitting threshold

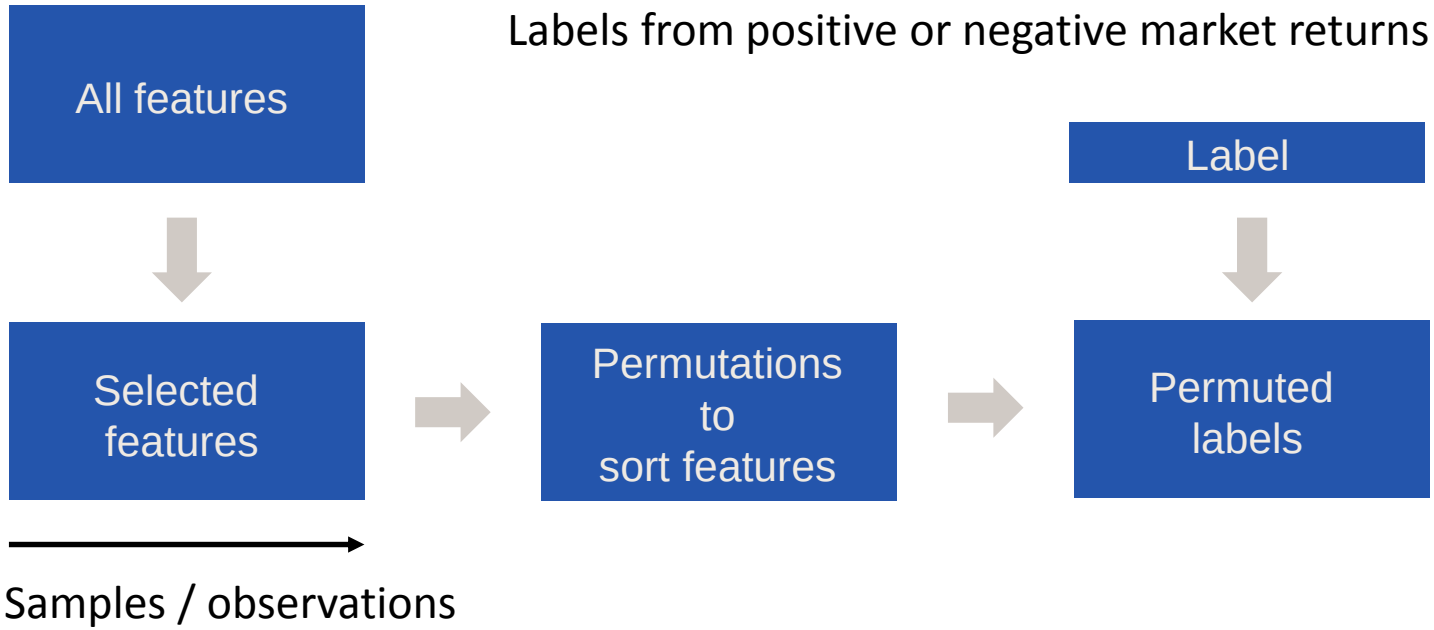
$$gain(t) = gain(T_{\leq t}, T_{>t})$$

$$t_* = argmax\ gain(t)$$

Actual implementation uses ratio information gain over split ratio

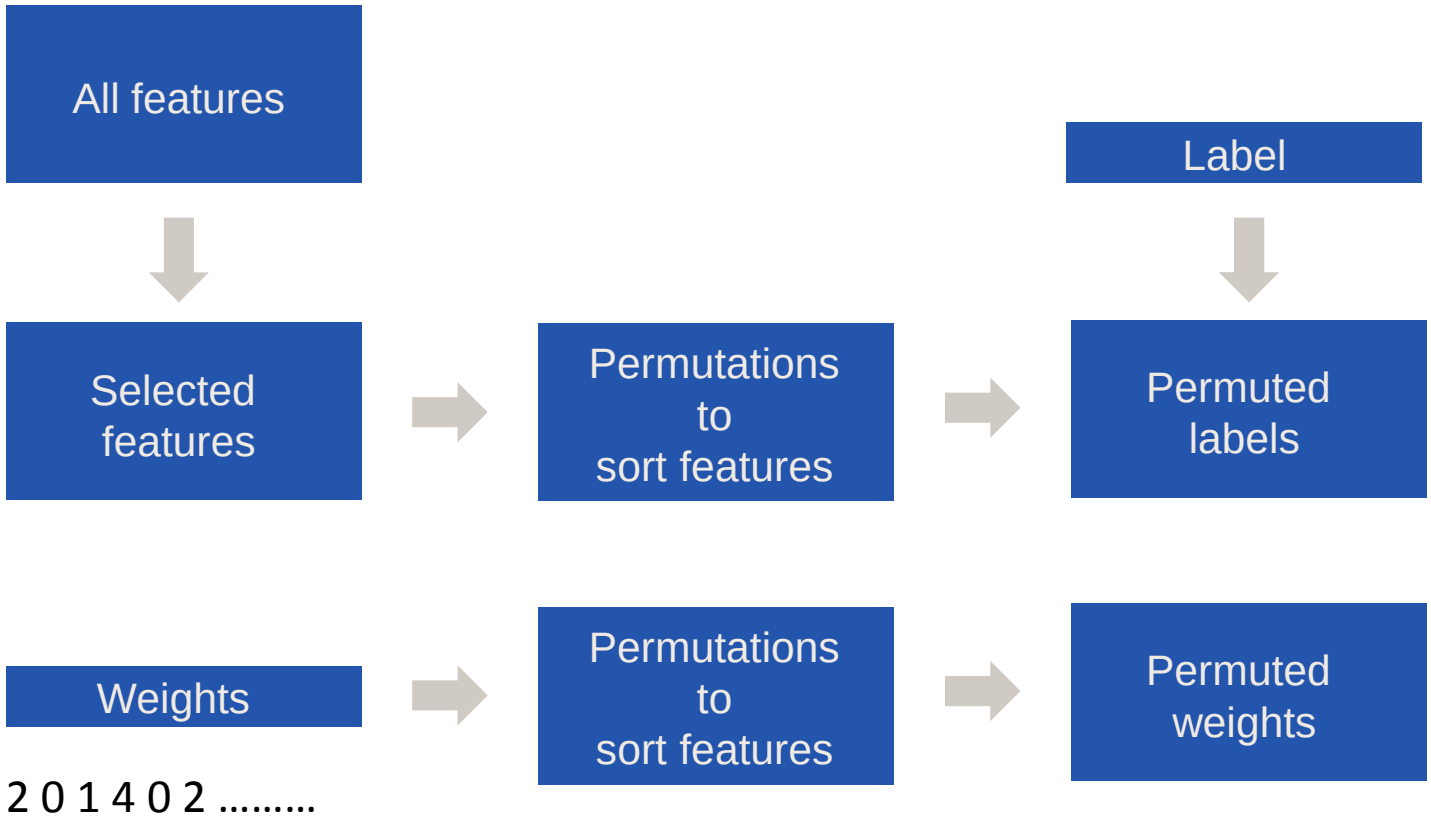
Training Individual Trees

QuantAlea



Training Individual Trees

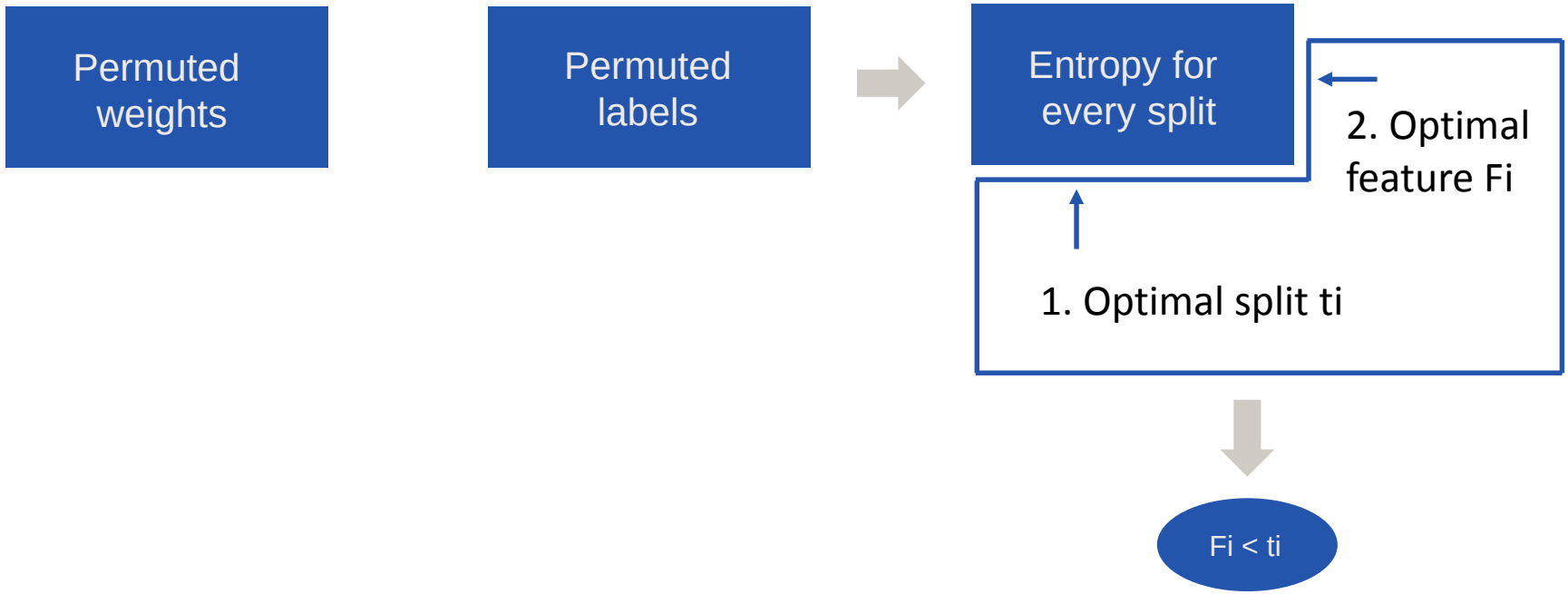
QuantAlea



Training Individual Trees

QuantAlea

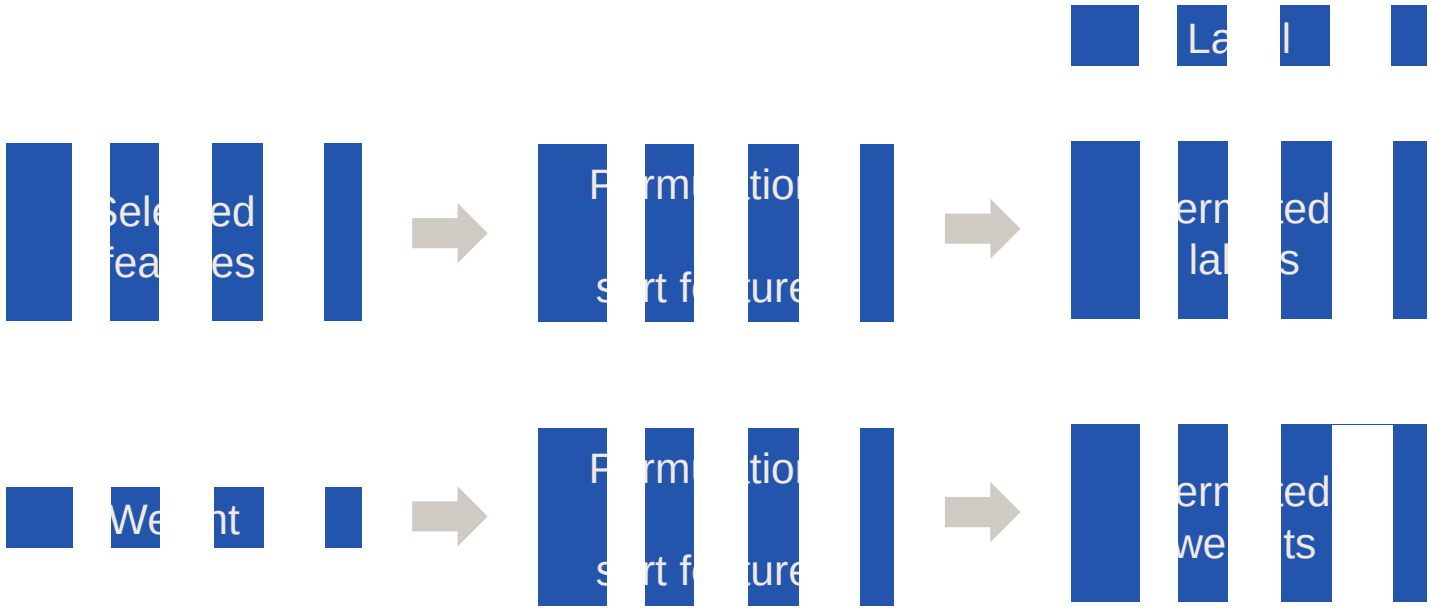
Entropy criterion for
best feature and split



Training Individual Trees

QuantAlea

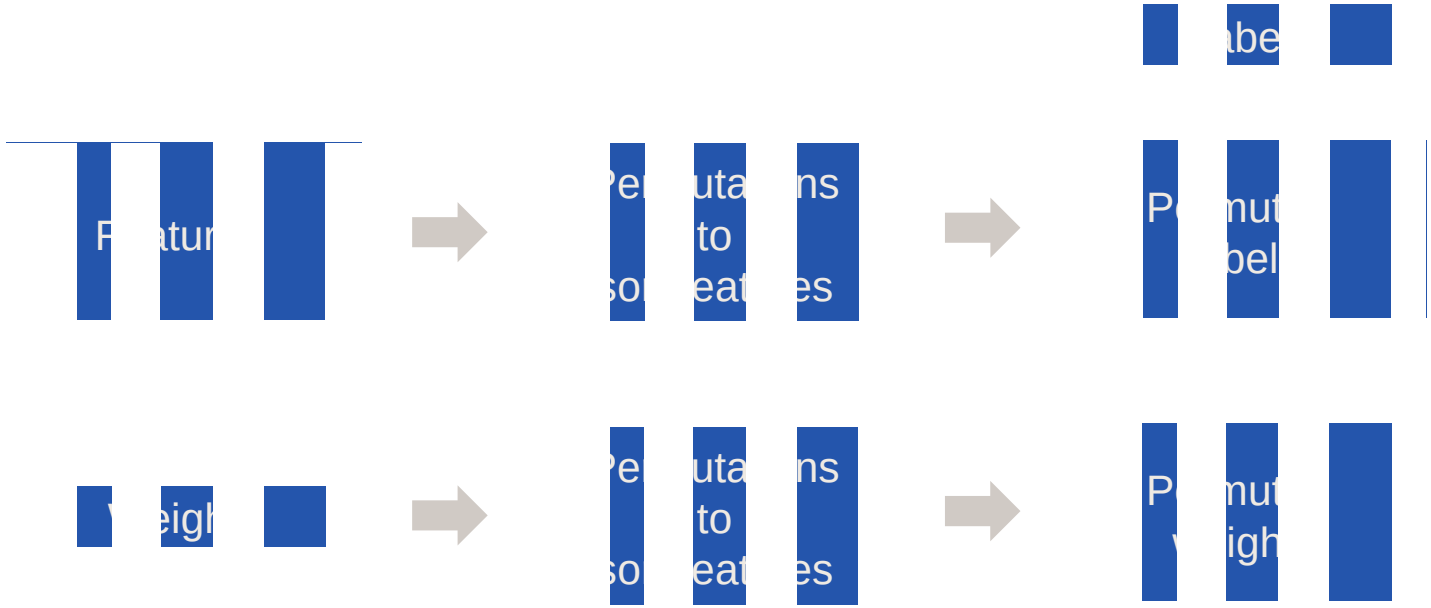
Recursively refine classification: mask data according to classification



Training Individual Trees

QuantAlea

Recursively refine classification: mask data according to classification



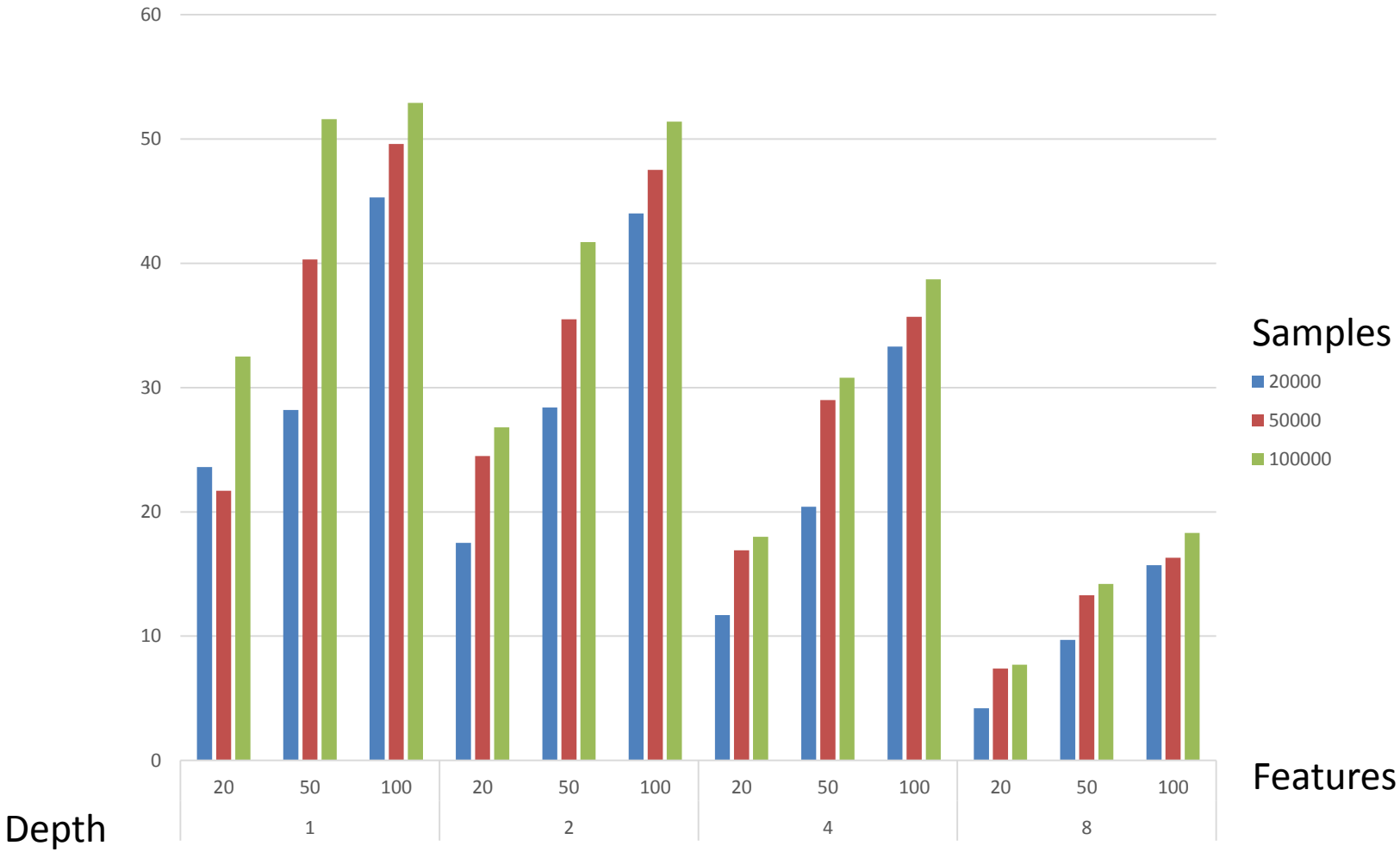
GPU Implementation

QuantAlea

- Parallelism at multiple levels
  - Multiple trees, one for each set of weights
  - Independent features
  - Independent split points
  - Multiple nodes further down the tree
- GPU kernels can be implemented with standard primitives
  - Random number generation for weights
  - Parallel scan (cumulative sum)
  - Parallel map
  - Parallel reduction to find optimal feature and split

Speedup

QuantAlea



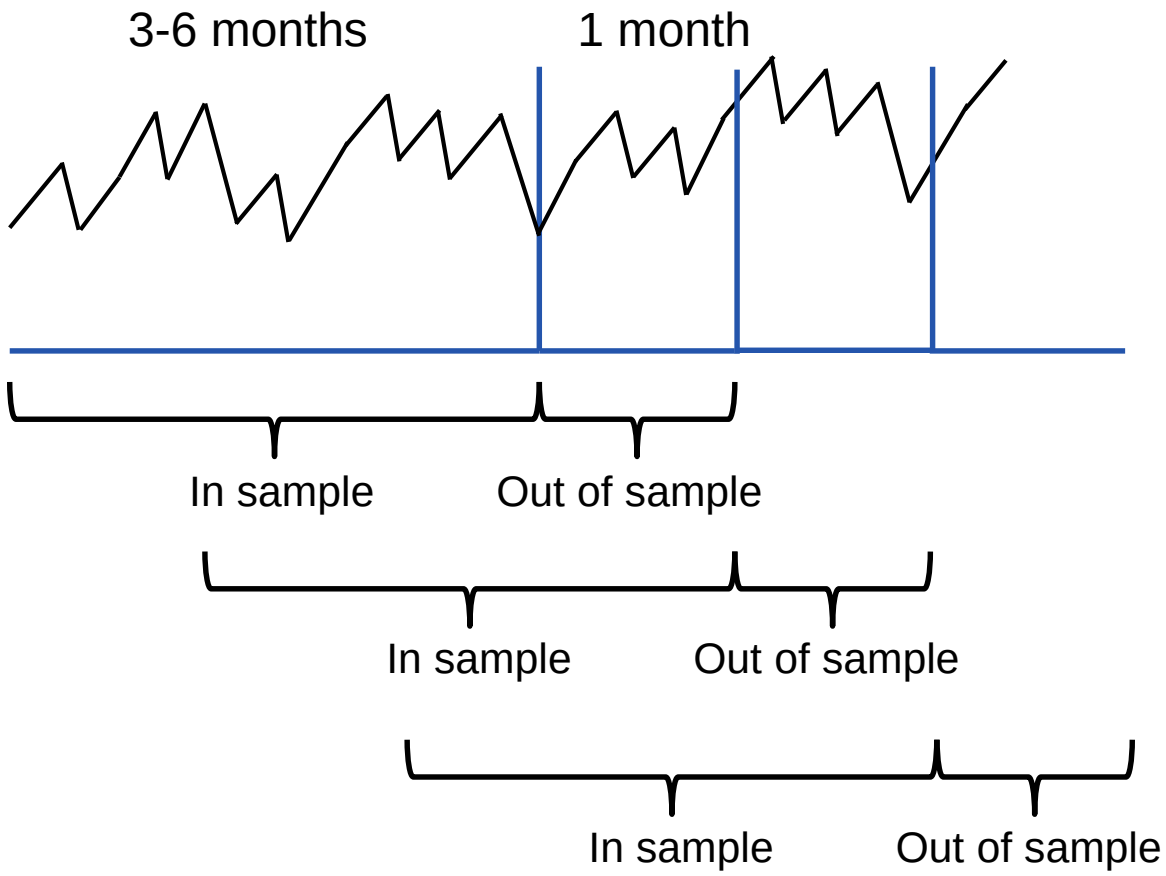
Strategy Backtesting

QuantAlea

Challenge2: How to choose best trading strategy ?

Walk Forward Optimization

QuantAlea

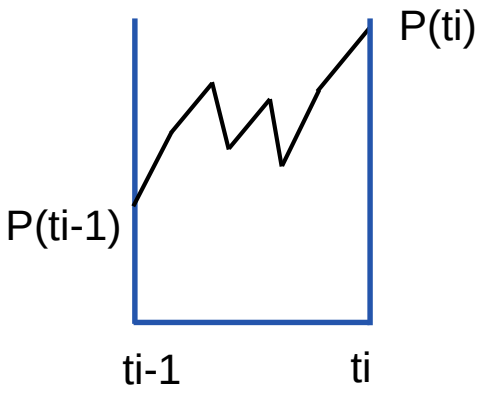


Trading P&L

QuantAlea

Market prices

Market returns



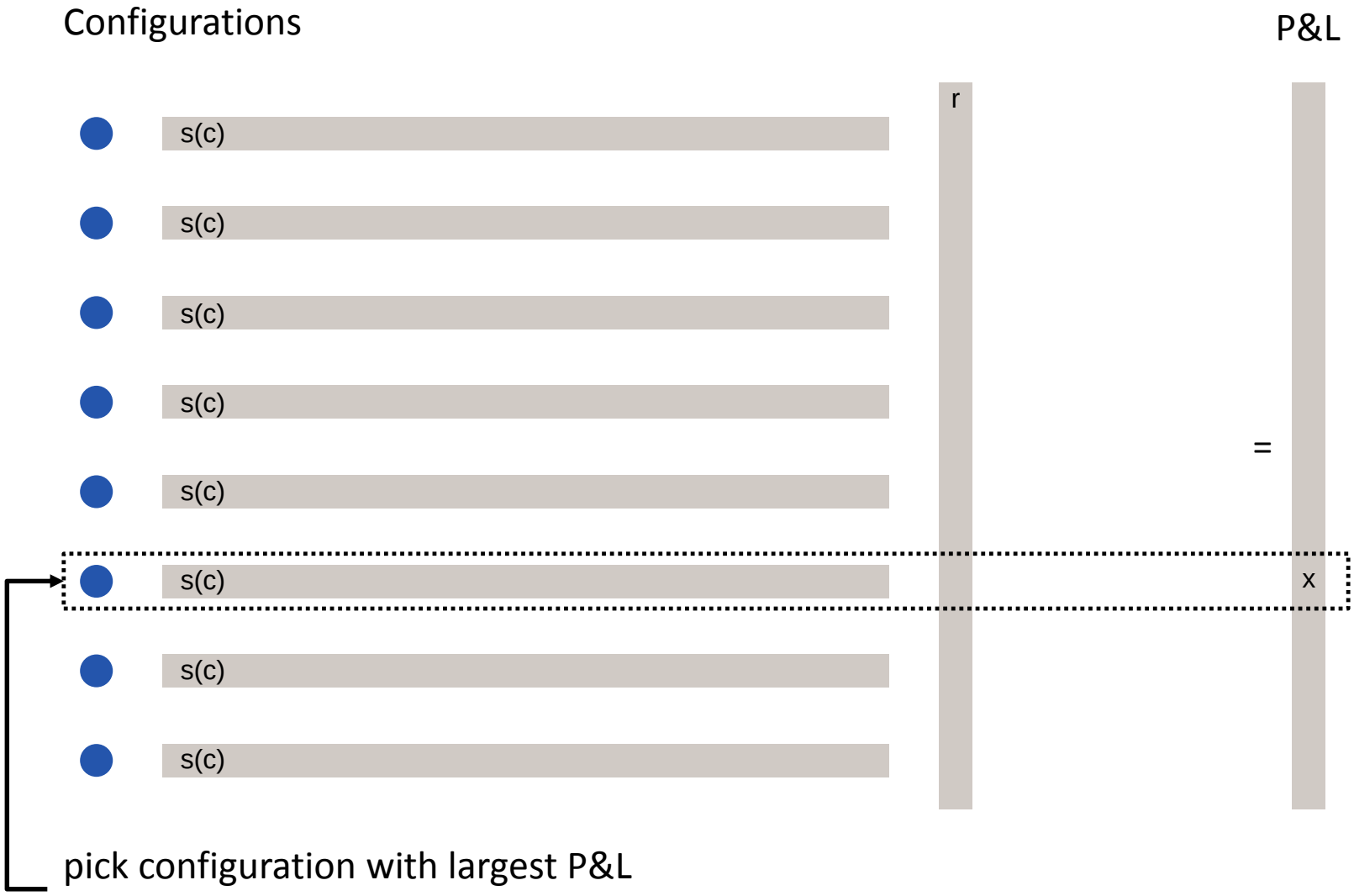
$$r(t_i) = \log(P(t_i) / P(t_{i-1}))$$

Market returns r(ti)	.....	r	r	r	r	r	.....
Trading decision s(c)	.....	1	-1	1	1	-1	.....

time

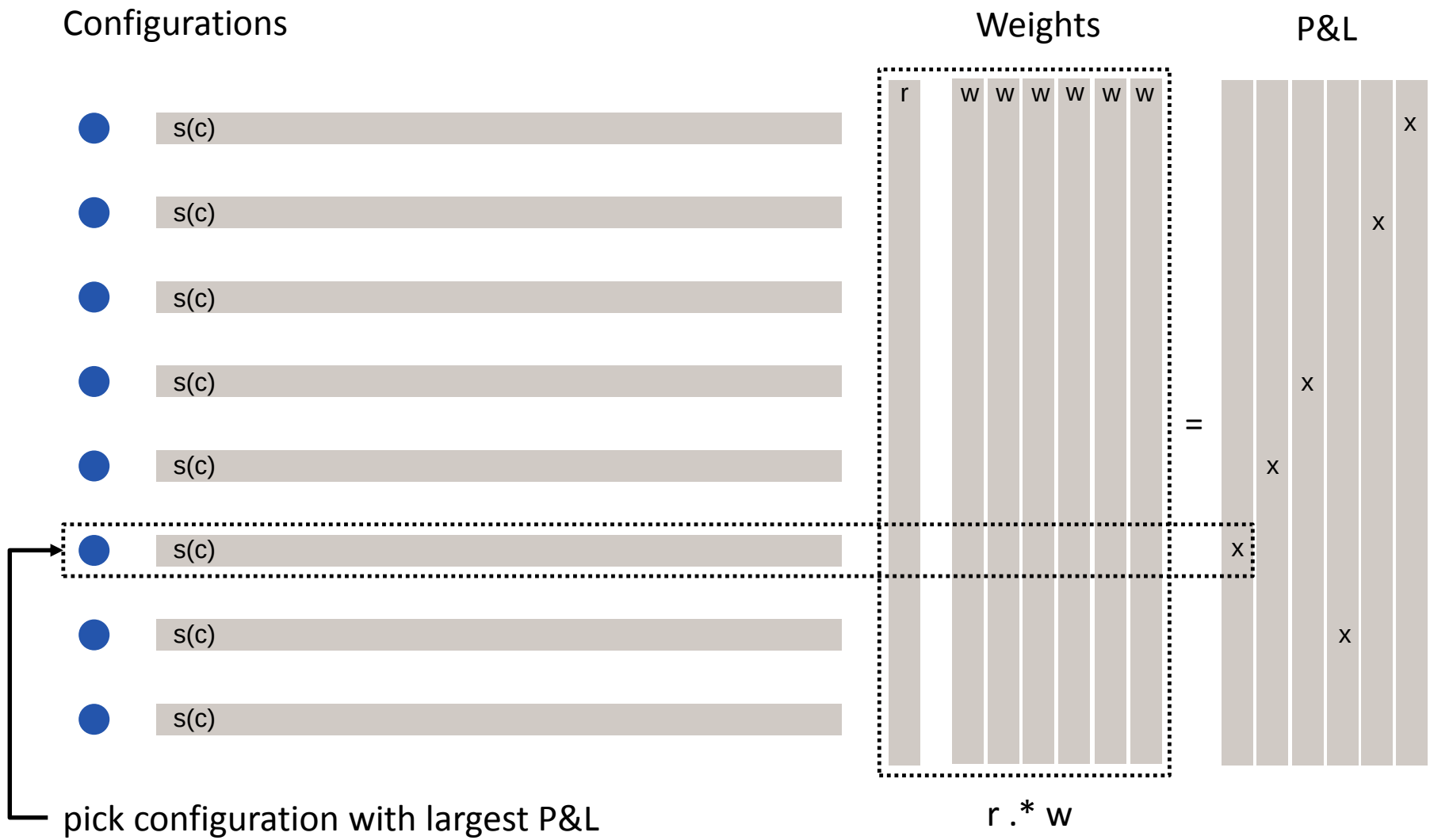
$$P\&L(c) = \langle s(c), r \rangle$$

Optimal Configuration



Bootstrapping Trading P&L

QuantAlea



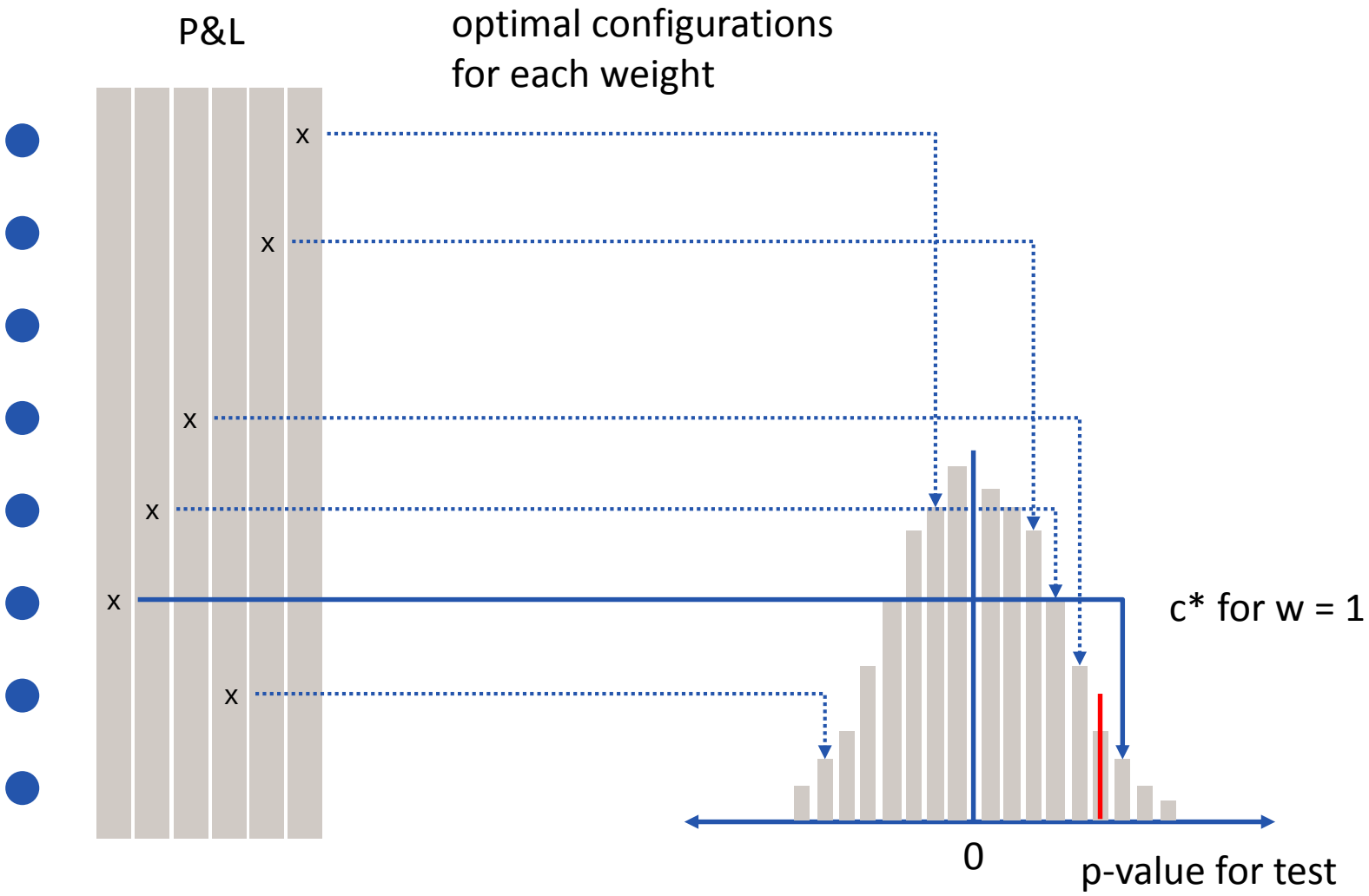
Hypothesis Tests

QuantAlea

Null Hypothesis	Alternative Hypothesis
Trading P&L<= 0	Trading P&L > 0

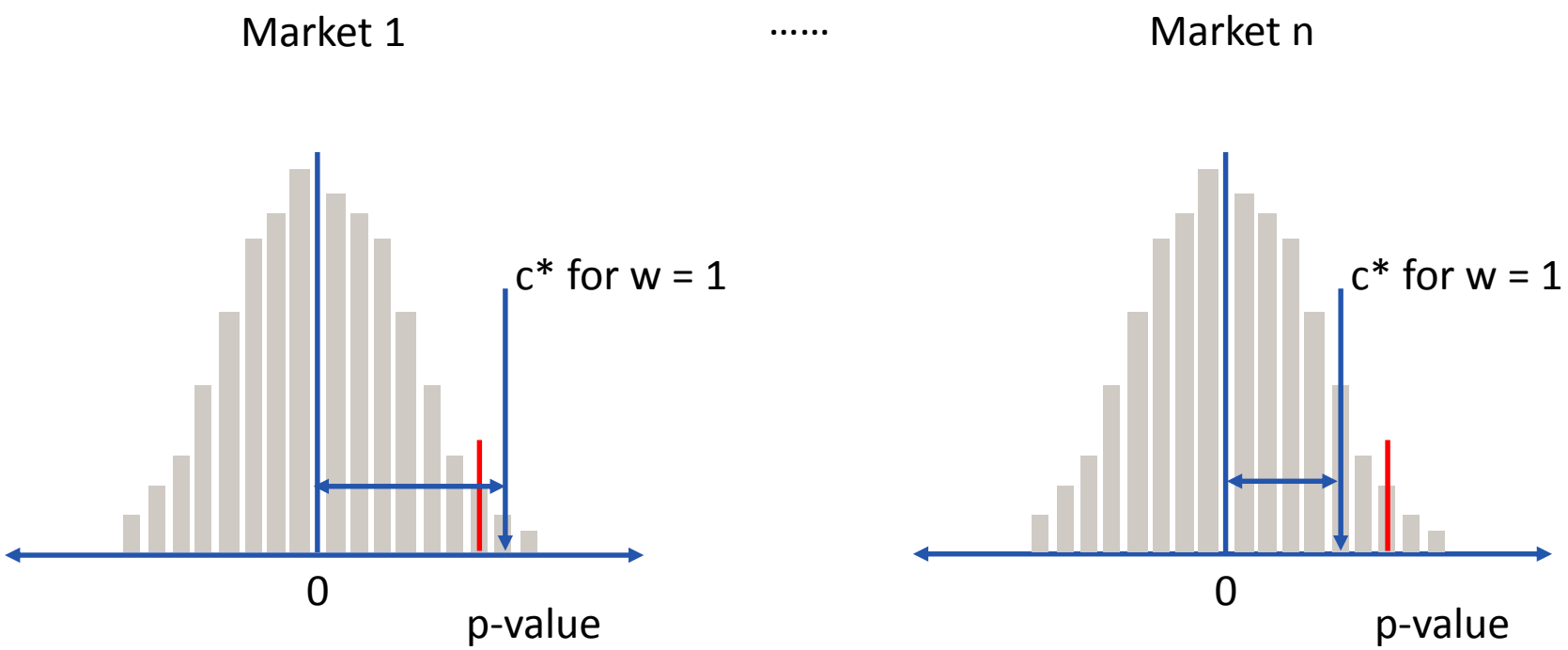
Trading P&L Distribution

QuantAlea



White Reality Check

QuantAlea



- Scale exposure according to distance from 0
- Do not trade if negative returns

GPU Implementation

QuantAlea

- Parallelism at multiple levels
  - Multiple markets
  - Independent in-sample / out-of-sample windows
  - Independent strategy configurations
  - Independent time steps for utility functions such as mean return
- GPU kernels can be implemented with standard primitives
  - Random number generation
  - Matrix multiplication (almost, up to return vector scaling the weights)
  - Parallel reduction

GPU Implementation

QuantAlea

- GPU grid
  - Multiple markets
  - Independent in-sample / out-of-sample windows
- Per GPU
  - Independent strategy configurations
  - Independent time steps for utility functions such as mean return

Questions ?

Dr. Daniel Egloff
daniel.egloff@quantalea.net
March 18, 2015